Ecological Studies on the Japanese Mitten Crab *Eriocheir japonicus* DE HAAN—III Relative Growth of the Chela and Soft-hair Distribution on the Chela

SATOSHI KOBAYASHI and SHUHEI MATSUURA

Department of Fisheries, Faculty of Agriculture, Kyushu University

モクズガニ *Eriocheir japonicus* DE HAAN の生態学的研究—III
鉗脚にみられる相対成長と軟毛の分布

小 林 哲・松 浦 修 平

Abstract

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The relative growth pattern of the chela and the soft-hair distribution on the chela of the Japanese mitten crab, *Eriocheir japonicus* were investigated. According to the distribution pattern of dots plotted between the chela propodus height (CPH) and carapace width (CW), we distinguished three growth phases for the male and two phases for the female, and we fitted a regression line to each phase. The first and the second phases were distinguishable by an inflection at about $30\text{ mm} \leq \text{CW} \leq 40\text{ mm}$ in both sexes, and the third phase in the male could be noted by a discontinuity from the second phase between $50\text{ mm} \leq \text{CW} \leq 65\text{ mm}$. The slope and/or Y-intercept of the regression line for each phase of the male was significantly higher than that for the same phase of the female. The area occupied by soft hair on the chela increased with the CW in both sexes, with the increase being greater in the male than in the female. In the large male ($60\text{ mm} \leq \text{CW}$), the surface of the chela was almost wholly covered with hair, whereas in the large female, both the outer and inner lateral sides were partially covered.

Introduction

In order to understand the structure of the

population, it is important to know the growth pattern and the maturity size of the population members. In particular, the morphometrical changes according to the body size, the sexual differences in the morphometrical changes, and the

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size range within which maturity is attained are essential information.

In brachyuran crabs, the growth pattern has so far been investigated with reference to the patterns of relative growth. It is known that there is inflection or discontinuity in the relative growth pattern of the chela, especially in the males of many species. In these cases, the chela size grows drastically larger as a secondary sexual character, from which the maturity size can be estimated for each species (HARTNOLL, 1974; 1978; 1982).

We were able to recognize the sexual dimorphism regarding the size of the chela and the growth pattern of the soft hair growing on the chela, when researching into the ecology of the Japanese mitten crab *Eriocheir japonicus*. However, the ecology and morphology of the Japanese mitten crab have so far only been partially recorded, and little is known about morphometrical changes according to growth (MIYAKE, 1983; KOBAYASHI & MATSUURA, 1991).

In this report, we describe the change in chela size and the distribution pattern of soft hair on the chela according to growth, and discuss the relationship of these features with puberty.

Materials and Methods

The specimens of *E. japonicus* were collected using crab baskets and hand-held nets each month between September, 1985 and August, 1986. The collection sites were 6 stations from the upper reaches to the lower reaches of the Kaminokawa River, Kagoshima Prefecture (130° 25'–30'E, 32° 38'–43'N), Japan, as described in our previous paper (KOBAYASHI & MATSUURA, 1991).

The carapace width (CW) and chela propodus height (CPH) of the specimens (259 males and 226 females) indicated in Fig. 1 were measured by vernier calipers to the nearest 0.1 mm.

The distribution of soft hair on the chela was also recorded. When the sizes of the chelae were symmetrical, only the right chela was measured but when they were asymmetrical, the largest chela was measured.

Fig. 1 Positions of measurements: CW, carapace width; CPH, chela propodus height.

Results

1. Relative Growth

The relationship between carapace width (CW) and chela propodus height (CPH) is indicated both in normal and logarithmic scales in Fig. 2. By the distribution pattern of the dots, the existence of three growth phases divided by inflection and discontinuity was suggested in the males. The overlapping of the first and second phases was recognizable around $30 \text{ mm} \leq \text{CW} \leq 40 \text{ mm}$. The third phase was recognizable by discontinuity from the second phase between $50 \text{ mm} \leq \text{CW} \leq 65 \text{ mm}$. As for the females, the existence of two growth phases divided by inflection was suggested. The overlapping of the first and second phases was recognizable, although indistinctly so, around $30 \text{ mm} \leq \text{CW} \leq 40 \text{ mm}$.

The relationship between CW and the ratio of CPH to CW is indicated in Fig. 3. In both sexes, a tendency for the ratio to increase with CW was recognized, this being more remarkable in the male. The ratio for small CW sizes ($5 \text{ mm} \leq \text{CW} \leq 10 \text{ mm}$) showed the mean of 0.26 with the range of 0.22–0.30, but for medium CW sizes ($30 \text{ mm} \leq \text{CW} \leq 35 \text{ mm}$), it showed the mean of 0.30 with the range of 0.29–0.33. Furthermore, when the CW was greater than 35 mm, the range drastically increased. For large CW sizes ($60 \text{ mm} \leq \text{CW}$), all the ratios exceeded 0.35. In particular, when the CW exceeded 50 mm, high-value ratios greater than 0.40, with the maximum of 0.53, were recognized. In the case of females, the ratios increased only slightly. The ratio for small

Fig. 2 The relationship between carapace width and chela propodus height.
Lengths are represented by normal scale and natural logarithmic scale.

CW sizes ($5 \text{ mm} \leq \text{CW} \leq 10 \text{ mm}$) showed the mean of 0.26 with the range of 0.21–0.31, while for medium CW sizes ($30 \text{ mm} \leq \text{CW} \leq 35 \text{ mm}$) it showed the mean of 0.27 with the range of 0.25–0.30, and for large CW sizes ($65 \text{ mm} \leq \text{CW} \leq 70 \text{ mm}$) it showed the mean of 0.31 with the range of 0.29–0.32. When the ratios were compared between the sexes, there was no significant difference in small CW sizes ($5 \text{ mm} \leq \text{CW} \leq 10 \text{ mm}$, t -test, $p > 0.05$), but there was a significant difference in medium CW sizes ($30 \text{ mm} \leq \text{CW} \leq 35 \text{ mm}$, t -test, $p < 0.05$) and large CW sizes ($65 \text{ mm} \leq \text{CW} \leq 70 \text{ mm}$, t -test, $p < 0.001$).

Based on these results, we arbitrarily separated the growth phases into three for the male and two for the female, as follows. The overlapping of the first and second phase was recognizable around $30 \text{ mm} \leq \text{CW} \leq 40 \text{ mm}$ in both sexes, and so the range was arbitrarily set at $\text{CW} < 35 \text{ mm}$ in the first phase, and $35 \text{ mm} \leq \text{CW}$ in the second phase for both sexes. In the male, the third phase was distinguished from the second phase by the ratio of CPH to CW. The second phase was within the range of $\text{CPH}/\text{CW} \leq 0.39$ while the third phase was within the range of $0.40 \leq \text{CPH}/\text{CW}$. The equation and line

Fig. 3 The relationship between carapace width and the ratio of chela propodus height to carapace width.

for each phase are shown in Fig. 4. All the regression lines were significant. To compare the growth pattern between different CW ranges of the same sex and between the sexes of the same CW range, the line of each phase was compared by analysis of covariance (Table 1). There were significant differences among all the regression lines in the Y-intercept and/or slope. In both sexes, there was a significant difference between the first and second phase in both slope and the Y-intercept. In the male, the third phase showed significant increases in the Y-intercept but no significant differences in slope when compared with the first and second

phases. Between the sexes, there were significant differences in the same CW range. In the first phases ($CW < 35$ mm), the male demonstrated significantly larger slope than the female. In the second phases ($35 \text{ mm} \leq CW \leq 65$ mm), the male demonstrated significantly larger slope and showed larger values of the Y-intercept than the female. Between the second phase of the female and the third phase of the male ($50 \text{ mm} \leq CW$). There was a significant difference in the Y-intercept but not in the slope.

2. Distribution of Soft Hair

The distribution of soft hair on the chela differed with sex and CW. Five stages could be distinguished by the hairy area of the chela propodus and dactylus. Soft hair on the chela from the inner lateral side view, the upper side view, and the dorsal side view in each stage is illustrated in Fig. 5. In stage I, the hair is not only sparsely distributed, but also fine. In stage II, the hair is densely distributed, but only on the outer lateral side of the propodus and dactylus. In stages III, IV, and V, the hairy area spreads to the inner lateral side. In stage III, the hair spreads only to the part around the attachment of the dactylus. In stage IV, the hairy area spreads to the central part of the inner lateral side of the propodus. In stage V, the hairy tuft on the outer and inner lateral sides joins on the upper side, with most of the surface area of the propodus and dactylus being covered with hair.

The five stages of hair distribution on the chela in relation to CW and CPH are shown in Fig. 6. In both sexes, the hairy area increased with CW and CPH. In the male, stage I occurred when $CW \leq 10$ mm, stage II between $9 \text{ mm} \leq CW \leq 35$ mm, stage III between $38 \text{ mm} \leq CW \leq 45$ mm, stage IV between $46 \text{ mm} \leq CW \leq 60$ mm, and stage V when $CW \geq 50$ mm. As for the female, stage I occurred when $CW \leq 10$ mm, stage II between $10 \text{ mm} \leq CW \leq 45$ mm, and stage III when $CW \geq 50$ mm.

Discussion

It was clear that there was a sexual dimorphism regarding the growth pattern of the chela of *E. japonicus*. The slopes of the regression lines of

Fig. 4 Regression lines for the chela propodus height relative to carapace width.

Table 1 Results of analysis of covariance between the regression lines

	<i>F</i> -value	<i>p</i>
Male-Male		
phase 1, phase 2		
slope	88.42	< 0.001
Y-intercept	11.46	< 0.001
phase 2, phase 3		
slope	0.74	> 0.05
Y-intercept	194.66	< 0.001
phase 1, phase 3		
slope	0.08	> 0.05
Y-intercept	77.62	< 0.001
Female-Female		
phase 1, phase 2		
slope	14.93	< 0.001
Y-intercept	16.20	< 0.001
Male-Female		
phase 1, phase 1		
slope	22.35	< 0.001
Y-intercept	39.78	< 0.001
phase 2, phase 2		
slope	56.68	< 0.001
Y-intercept	537.09	< 0.001
phase 2, phase 3		
slope	1.73	> 0.05
Y-intercept	541.10	< 0.001

the first and second phases were steeper in the male than in the female. Although there was no significant difference in the relative size of the chela (the ratio of CPH to CW) for small CW size ($5 \text{ mm} \leq \text{CW} \leq 10 \text{ mm}$), a significant difference was recognized for medium and large CW sizes ($30 \text{ mm} \leq \text{CW} \leq 35 \text{ mm}$ and $65 \text{ mm} \leq \text{CW} \leq 70 \text{ mm}$) between the sexes. The remarkable increase of chela size in the male is thought to be useful for mating. In the case of *E. japonicus*, the males demonstrate post-copulatory guarding (MORITA, 1974). However, after copulation, the females which are larger than their mates sometimes escape from guarding and can copulate with other males before laying eggs. So the large chelae of the males are thought to be

useful for grasping the females and driving away other males until laying eggs (KOBAYASHI & MATSUURA, 1992). It is therefore probable that large chelae contribute to the reproductive success of the male.

We could also find a sexual dimorphism regarding the growth of the soft hair on the chela. The hairy area increased with CW and CPH, the increase being greater in the male than in the female. The thick, long soft hair makes the total chela volume appear even larger. It would thus seem that the remarkable growth of the hair helps large males to have even larger chelae.

The inflection or discontinuity in the relative growth of the male chela has been regarded as

Fig. 5 Distribution patterns of soft hair growing on the chela propodus and the dactylus from the inner lateral side view (a), the upper side view (b), and the dorsal side view (c) for five stages. The dotted part shows areas covered with dense hair.

puberty in many brachyuran species, and so a description of the maturity size was investigated with reference to the relative growth pattern (HARTNOLL, 1974). In *E. japonicus*, both inflection and discontinuity were noted in the male. Similarly, regarding the Chinese mitten crab *Eriocheir sinensis*, both inflection and discontinuity were noted, and the discontinuity was regarded as puberty (HOESTLANDT, 1948). In the case of *E. japonicus*, the following information on its reproductive ecology suggests that puberty can be indicated by the inflection. In the brackish water zone of the Kaminokawa River, the female specimens collected between September and January consisted of only adults with matured exoskeletons, including some ovigerous crabs. These crabs were found with $CW \geq 35$ mm. As for the males, crabs

between $30 \text{ mm} \leq CW \leq 50 \text{ mm}$ were collected in a large number (KOBAYASHI & MATSUURA, 1991). All dissected specimens from these males had their vas deferens filled with matured spermatophore (KOBAYASHI & MATSUURA, unpublished). This result indicates that male crabs belonging to the second phase of chela growth may participate in reproduction. It thus seems likely that male crabs participating in reproduction consist of both crabs with comparatively small chelae and with large chelae.

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Fig. 6 Five stages of hair distribution on the chela in relation to carapace width and chela propodus height.

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和文摘要

小林 哲・松浦修平 モクズガニ *Eriocheir japonicus* De HAAN の生態学的研究—III. 鉗脚にみられる相対成長と軟毛の分布.

モクズガニの成長に伴う、鉗脚サイズと鉗脚に密生する軟毛の分布様式の変化を記載した。鉗脚高と甲幅の相対成長により、雄では変曲点と不連続部分により3つの phase, 雌では変曲点により2つの phase を区

別し、それぞれに回帰式をあてはめた。同サイズ域の回帰式ではいずれも雄が雌より傾きおよびY切片が大きく、成長するほど雄の方が大きな鉗脚を持つようになることが明らかになった。軟毛も、成長に伴い鉗脚上の分布域が拡大する傾向が認められた。この傾向は雄で著しく、大型雄(甲幅60cm以上)では鉗脚の大部分が毛で覆われるのに対し、大型雌では鉗脚の外側面と内側面のごく一部が覆われるのみであった。このように、モクズガニの場合雄の二次性徴として鉗脚ならびに軟毛の顕著な発達が見られることが明らかになった。

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- SATOSHI KOBAYASHI
Department of Fisheries,
Faculty of Agriculture,
Kyushu University,
Hakozaki, Higashi-ku, Fukuoka 812,
Japan