

# SOME ASPECTS OF RELATIVE GROWTH IN THE BLUE SWIMMING CRAB *NEPTUNUS PELAGICUS* (LINNAEUS)<sup>1</sup>

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## INTRODUCTION

The Blue Swimming Crab, *Neptunus pelagicus* displays in some of its parts a marked sexual dimorphism (Prasad and Tampi, 1953) and, therefore, the authors felt that a study of the relative growth of such parts might be interesting. Further, as Weymouth and MacKay (1936) pointed out: "This method of analysis makes possible the detection of changes of form which occur at certain physiological epochs, notably that of attaining sexual maturity. In the crab, as in most invertebrates, growth continues although at a decreasing rate throughout life. Accordingly there is no final or definitive size or form as in man. Against this background of constantly changing form it is possible to detect changes in the differential growth-ratios of various parts in response to internal factors such as the maturing of the gonads or their virtual destruction, as shown by G. Smith (1910) in his study of 'parasitic castration'." Information on the size at first maturity is not only of scientific interest but also of practical value in the management of the fisheries.

No analyses on the relative growth have so far been attempted on any Indian crab and in general the study of the relative growth of crustaceans has received little attention here. Alcock (1906) merely pointed out that certain features of sexual dimorphism such as proportionately long rostrum of the female shrimp *Penaeus* represent continued juvenile characters. Tazelaar (1930) made a study of the relative growth of certain parts of *Palaemon carcinus*, a large Indian prawn. The measurements made by Kemp, Henderson and Matthai on *Palaemon malcomsoni*,

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*P. carcinus* and *P. bengalensis* also were analysed by Huxley and others (Huxley, 1927 and 1932).

The present paper deals with the growth of the length of carapace, the chela, the first walking leg and the length and width of the sixth abdominal segment in relation to the width of carapace of *Neptunus pelagicus*. For details regarding the study of relative growth reference may be made to Huxley (1932).

#### MATERIAL AND METHODS

The material, on which the present findings are based, included 479 specimens ranging from 8 mm. to 158 mm., in carapace width collected from the landings of the local nets *randu valai* and *konda valai*. In most cases it was not possible to determine the sex of individuals measuring less than about 35 mm., in carapace width from external features and therefore, the specimens were classified into two groups: (1) unsexed, up to 35 mm., and (2) sexed, males and females above 35 mm.

The following measurements, recorded to the nearest quarter of a millimeter by estimation, were made:

- (1) the maximum width of the carapace (distance between the tips of the spines),
- (2) the length of the carapace along the median line,
- (3) the length of the first walking leg when fully stretched out,
- (4) the length of the chela,
- (5) the length and width of the sixth abdominal segment.

In making these measurements no deformed, soft or regenerating parts were included. Similarly, those crabs infested with rhizocephalan parasite as seen from outside were excluded. Appendages on the right side were usually measured but the left ones were substituted when the others were either missing or deformed because normally there is no asymmetry in the appendages.

The method generally employed in the statistical treatment of the relative growth data is that of Huxley (1932). His formula for allometric growth  $y = \beta x^\alpha$  is widely used and in almost all such cases, one of the regression lines has been fitted to the logarithms of the data. Recently Kermack and Haldane (1950) pointed out: 'In many cases of organic correlation it is found that the distribution of the variates is heteroscedastic and skewed. Often, however, the distribution of the logarithms is homoscedastic and more nearly normal... In addition, it may be found that the fitted straight line does not pass through the origin. This may be due to a significant curvature in the trend of the two variates . . . .' So they suggested that 'considerable advantages are obtained in many cases if the reduced major axis of the logarithms is taken.' Following this method

their formula<sup>1</sup>  $\alpha = \left[ \frac{\log(1+v_y^2)}{\log(1+v_x^2)} \right]^{\frac{1}{2}}$  is used in the present paper for calculating the slope of the reduced major axis.

#### RESULTS

##### (a) Carapace length.

The relationship, carapace length on carapace width as found in five groups: (1) young ones up to 35 mm., in which the sexes are indistinguishable, (2) males up to 80 mm., (3) females up to 80 mm., (4) males over 80 mm., and (5) females over 80 mm., is shown in Figs. 1 and 2. Specimens measuring 35 mm., and below

<sup>1</sup> In this formula  $v_x = \sigma_x/\bar{x}$  and  $v_y = \sigma_y/\bar{y}$ . For full details refer Kermack and Haldane (1950).

in which the determination of sex is generally difficult were grouped together and those over 35 mm., were grouped into the respective sexes. A preliminary examina-

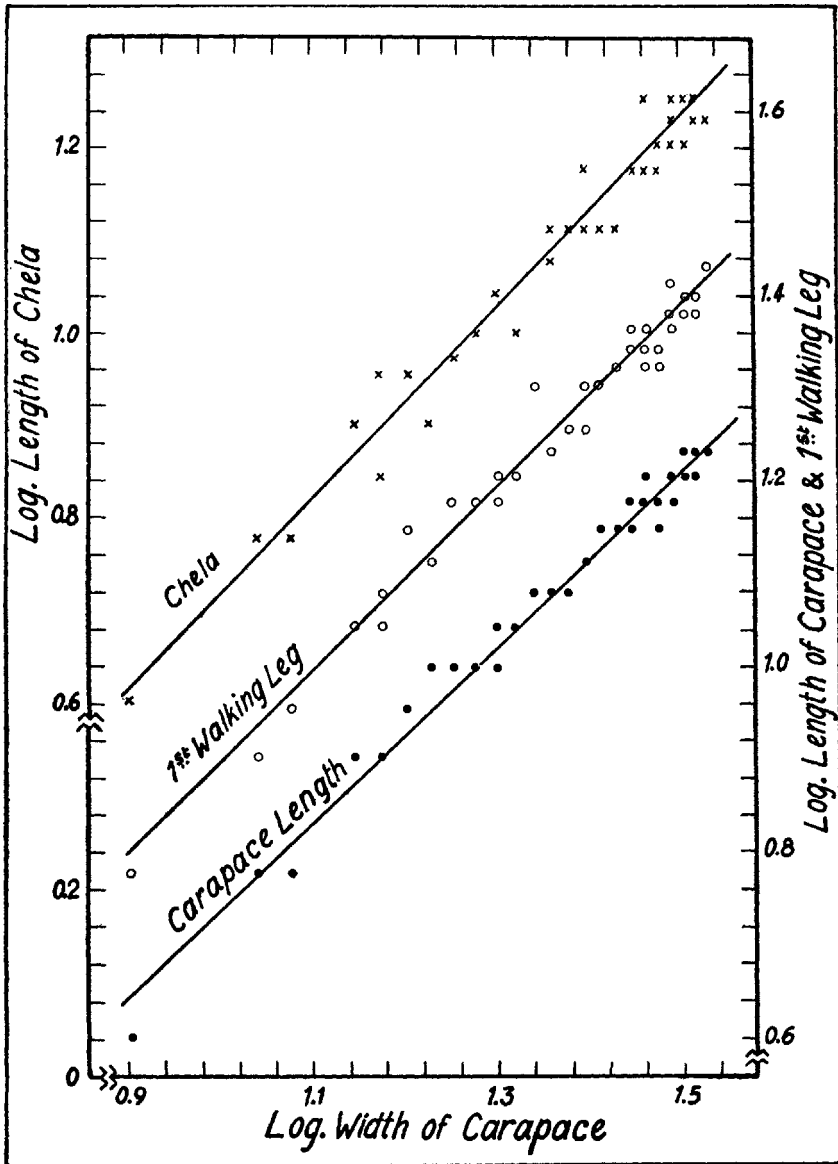


Fig. 1. Logarithmic plot of the length of carapace, first walking leg and the chela on the width of carapace of the unsexed.

tion showed that both males and females exhibit some slight change in relative growth at a carapace width of about 80 mm., and therefore, the growth-coefficients for those from 35-80 mm., and those above 80 mm., were calculated separately. The corresponding values of  $\alpha$  are assembled in Table 1. It will be seen from Figs. 1 and 2 that in all the five different groups mentioned above the character

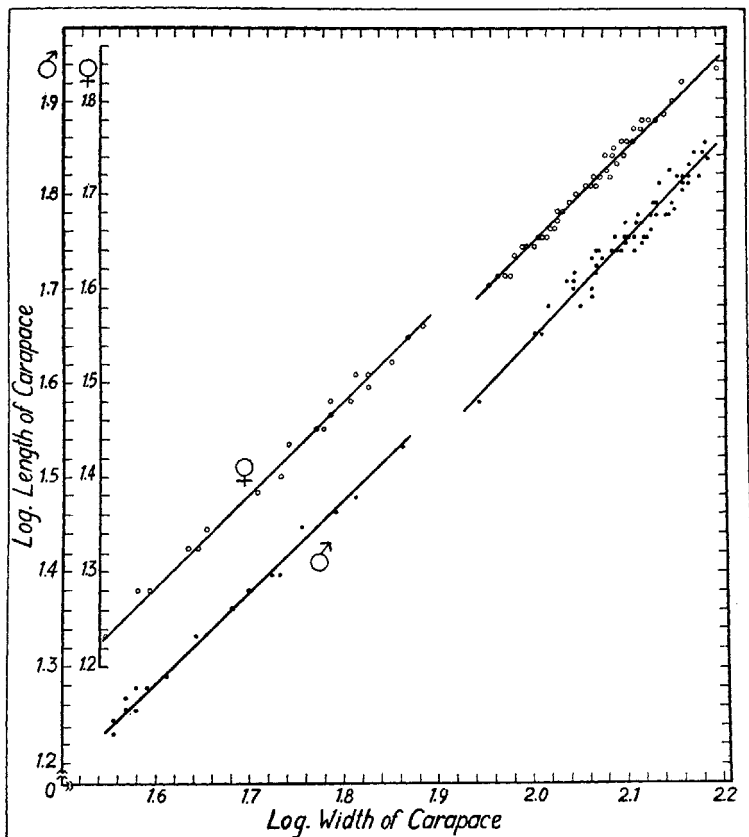


FIG. 2. Logarithmic plot of length of carapace on carapace width in the males and females.

shows simple allometry<sup>1</sup> and the points fall on a straight line on a double logarithmic grid.

TABLE 1  
Carapace length on carapace width:  $\alpha$  values

Size range (mm.)	Sex	$\alpha$	$\sigma_{\alpha}$
Up to 35	Unsexed ..	0.935	$\pm 0.023$
35 to 80	Males ..	0.953	$\pm 0.037$
	Females ..	0.951	$\pm 0.027$
> 80	Males ..	1.051	$\pm 0.028$
	Females ..	1.000	$\pm 0.021$

<sup>1</sup> Needham and Lerner (1940) suggested the terms Heterauxesis, with Isauxesis, Bradyauxesis and Trachyauexesis in place of the earlier terms heterogony, isogony, negative heterogony and positive heterogony respectively. In this paper the terminology suggested by Huxley and Teissier (1936) and Huxley (1950) *i.e.*, allometry with positive allometric growth ( $\alpha > 1$ ), negative allometric growth ( $\alpha < 1$ ) and isometric growth when  $\alpha = 1$  will be used.

The relative growth-rate is lowest in the smallest size range. The growth-ratio varies from 0.935 to 1.051 in the different groups, the minimum being that of the unsexed which may be regarded as slightly negatively allometric and the maximum that of males over 80 mm., where it is isometric or even approaching slight positive allometry. Thus, the length of the carapace relative to width shows a slight decrease in the very small crabs, whereas there is a slight but significant increase in the largest individuals. The value of  $\alpha$  for the smallest size is significantly lower than those of the males and females of the largest size group studied indicating thereby a gradual acceleration in the relative growth-rate as growth advances but the relative growth-ratio of the unsexed is not significantly different from that of the males and females ranging between 35 and 80 mm., in carapace width. Similarly the values show no significant difference either among the males of the two groups or between the sexes of the same size group. The transformation in the general shape of the carapace from the megalopa to the adult is shown in Fig. 3 which demonstrates clearly how as the individual grows the carapace becomes relatively wider.

Figure 3 further shows that there is no marked variation in the carapace length in relation to sex, a fact already indicated by the growth index. In a closely related species, *Callinectes sapidus*, Newcombe, Sandoz and Rogers-Talbert (1949) found that as the crab grows the length of carapace relative to width shows a slower rate of growth. They further noticed: '... a constant differential growth-ratio in the males throughout the mean range of 17.3 to 185.0 mm., and in the females two separate differential rates. From an empirical standpoint of prediction it is of little moment whether the data are fitted to one or two equations. However, sexual maturity provides a reason for recognising the first displacement at a width of about 95 to 100 mm. The second departure is not explainable at this time. It is noticeable that above a width of 100 mm., the males become somewhat longer in proportion to their width than the females...' The growth in *N. pelagicus* is at first nearly negatively allometric gradually increasing to isometry in the females and to a slight positive allometry (though the  $\alpha$  values are not significantly different statistically) in the males above a carapace width of 80 mm. In *Cancer magister*, Weymouth and MacKay (1936) observed a gradual increase in the relative growth-rate of carapace length as in *N. pelagicus* and found no difference between the sexes below a width of approximately 10 cm. They obtained an initial  $k$  value<sup>1</sup> of 0.76 at a width of about 0.5 cm., which gradually increased up to 0.94 at a width of 3.5 cm., and although above 10 cm., females become slightly longer for their width the increase in the value of  $k$ , they noticed, was not readily calculable. An interesting feature noticed in the carapace length of *N. pelagicus* is that as the log/log, graph (Fig. 2) shows between 80 and 88 mm., carapace width there is an actual decrease in the absolute length in both sexes. After this period of length decrease there is a very slight, non-significant increase in the growth index (Table 1). Shaw (1928) observed a similar phenomenon in all except the third pereiopod of the males of *Inachus dorsettensis* but the relative growth-rate in this species following the size decrease does not again reach its previous level.

#### (b) Length of the chela.

In many crustaceans the growth-coefficient of the chela shows distinct variations in regard to sex, some forms having equal positive allometry in both sexes, others exhibiting positive allometry in both sexes but with a lower growth-coefficient in the females and still others showing allometry in males and isometry in females. The growth-coefficients are likely to change also with age and may show sudden

<sup>1</sup> The values of  $\alpha$  given in this paper are not directly comparable to the  $k$  values of other authors as the methods employed in calculating these constants are different.

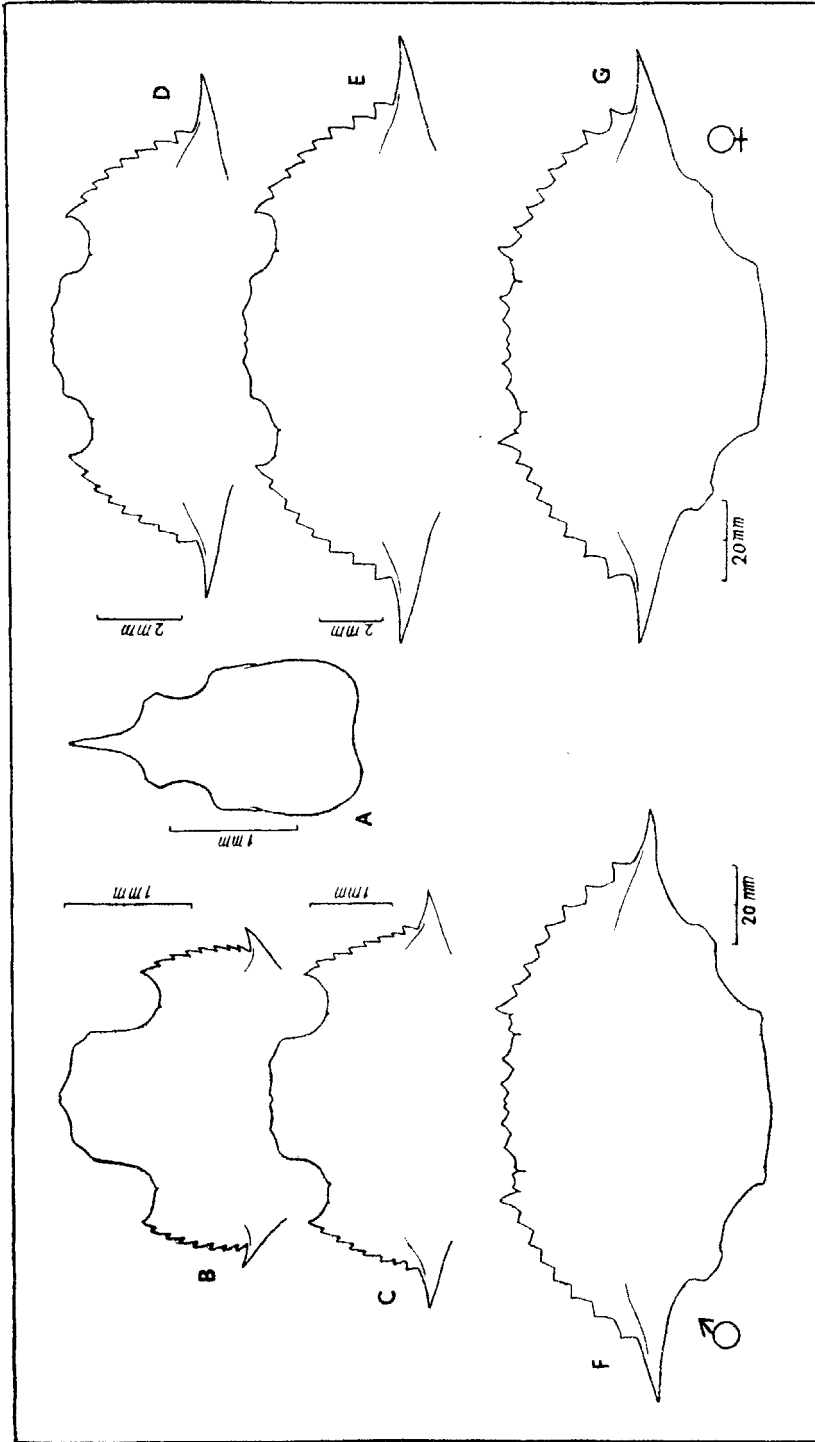


Fig. 3. Changes in the carapace from the megalopa stage A to the adult male F and female G. B, C, D, and E are carapaces of a first instar and three juvenile crabs measuring 5.0 mm., 12.5 mm., and 19.0 mm., width of carapace respectively.

changes associated with such factors as the onset of maturity. One of the best examples of this is probably the large chela of the male Fiddler Crab. The chelae of the adult *N. pelagicus* show distinct sexual dimorphism, being larger in the males than in the females (Prasad and Tampi, 1953).

In Fig. 1 the log. length of chela of the unsexed is plotted against the log. width of carapace and in Fig. 4 the log./log. data for males and females over 35 mm., are given. The group of unsexed crabs has a differential growth-ratio which is

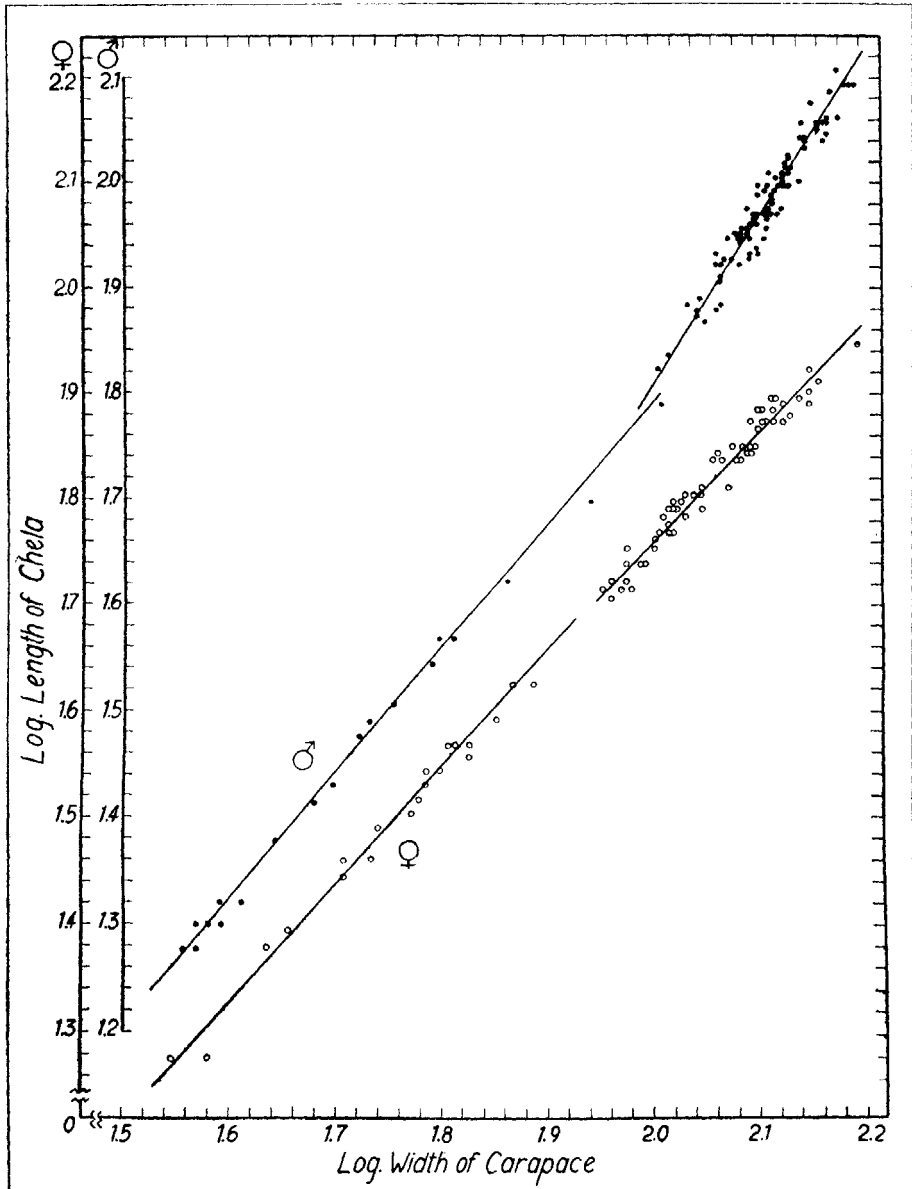


FIG. 4. Logarithmic plot of the length of chela on the width of carapace in the males and females.

only negligibly above unity and therefore, the relative growth may be considered isometric ( $\alpha = 1.031 \pm 0.046$ ). In the case of females over 35 mm., the log. length of chela when plotted against log. width of carapace there is a close approximation to a straight line (Fig. 4) and the value for the size range 35 to 80 mm., is  $1.057 \pm 0.021$  and that for those above 80 mm., is  $1.026 \pm 0.024$  showing a trivial decrease in the relative growth-rate. The growth-ratios of the unsexed and the two groups of females show no significant difference suggesting thereby that the females maintain an almost constant growth-rate. The chela of the males shows somewhat a different condition. The practically isometric growth noticed in the unsexed changes to a slight but non-significant positive allometry in the males up to a carapace width of about 102 mm., when there is a break with an increase in the absolute size followed by a marked change in the growth-coefficient resulting in a distinct positive allometry, the  $\alpha$  value increasing from  $1.162 \pm 0.067$  in the smaller ones to  $1.593 \pm 0.031$  in the largest individuals (Fig. 4). It is also found that the rate of relative growth of the chela in the smaller males does not significantly differ from that of the females but the larger males have longer chelae. A similar change in the growth-rate of the chela of the females in the size range studied has not been noticed indicating thereby that in this character the species under consideration shows sexual dimorphism and that the break followed by an increase in the relative growth-rate of chela in the males may be associated with the commencement of sexual maturity. Thus the size at first maturity in the males seems to be about 102 mm., carapace width.

(c) *Length of the first walking leg.*

A log./log. graph representing the relative growth of the first walking leg of the unsexed is shown in Fig. 1. The relative growth characterising this range is almost negative allometry ( $\alpha = 0.935 \pm 0.028$ ) unlike the length of chela. Among the females of 35 mm. and above, the relative growth-rate is nearly isometric but there appears to be a slight change in the relative growth-rate and the line representing the reduced major axis seems to be formed of two segments, the two component lines intersecting at a carapace width of about 108 mm. (Fig. 5). The  $\alpha$  for the smaller sized female crabs is  $0.988 \pm 0.020$  and that for the larger ones is  $1.063 \pm 0.023$ . While the smaller females do not show a significant difference in their growth-ratio from those of the unsexed the larger ones have a significantly higher rate of growth than the unsexed. In the males there is a break and a sudden increase in the relative growth at a carapace width of about 102 mm., as with the length of chela, and those above 102 mm., show a distinct positive allometry,  $\alpha$  being  $1.433 \pm 0.031$ . The smaller males show a significant difference in the growth-coefficient ( $\alpha = 1.033 \pm 0.028$ ) from that of the unsexed but not from that of the females. According to Huxley (1931) and Sandon (1937) in *Ocypoda aegyptiaca* the walking legs as a whole grow at a slower rate than the carapace showing a negative allometry.

As already mentioned in the case of the chela, the first walking leg too shows definite sexual dimorphism, the larger males having longer walking legs than the females. The sudden increase in the growth-ratio of the first walking leg of the males at a carapace width of about 102 mm., presumably marks the onset of sexual maturity. Huxley (1932) remarked: 'In general, male crustacea appear to have relatively larger pereopods than females'.

(d) *Width of the sixth abdominal segment.*

The abdomen of crabs is another part exhibiting sexual dimorphism and in the female it shows striking allometric growth, for it is always broad in the adult, narrow and of the male type in the juveniles. The gradual transition in the general shape of the abdomen from the megalopa to the adult, both in the males and females,



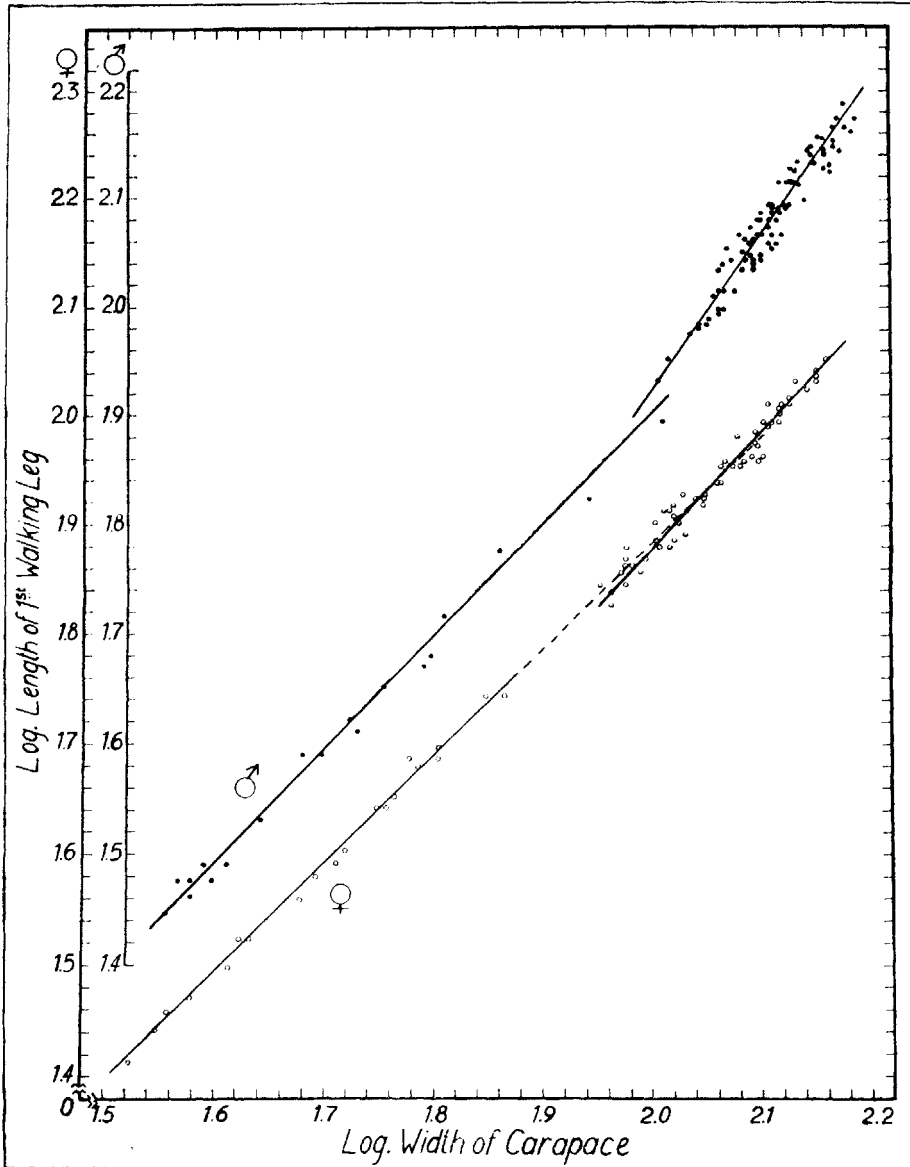


FIG. 5. Relation between the width of carapace and the length of the first walking leg in the males and females. Logarithmic plotting.

is shown in Figure 6. In Figure 7 is plotted the log. width of abdomen of the unsexed against the log. width of carapace. At this stage the growth-coefficient is  $1.121 \pm 0.055$  showing a slight positive allometry. As is to be expected the females show a break in the rate of growth of the width of the sixth abdominal segment in the larger ones (Fig. 8). Up to about 108 mm., the growth-coefficient is  $1.209 \pm 0.026$ , which is not significantly different from that of the unsexed, but following this there is a pronounced acceleration in the growth-ratio, the  $\alpha$  value being  $1.524 \pm 0.057$  and this continues up to the maximum size studied. The males, on the other hand,

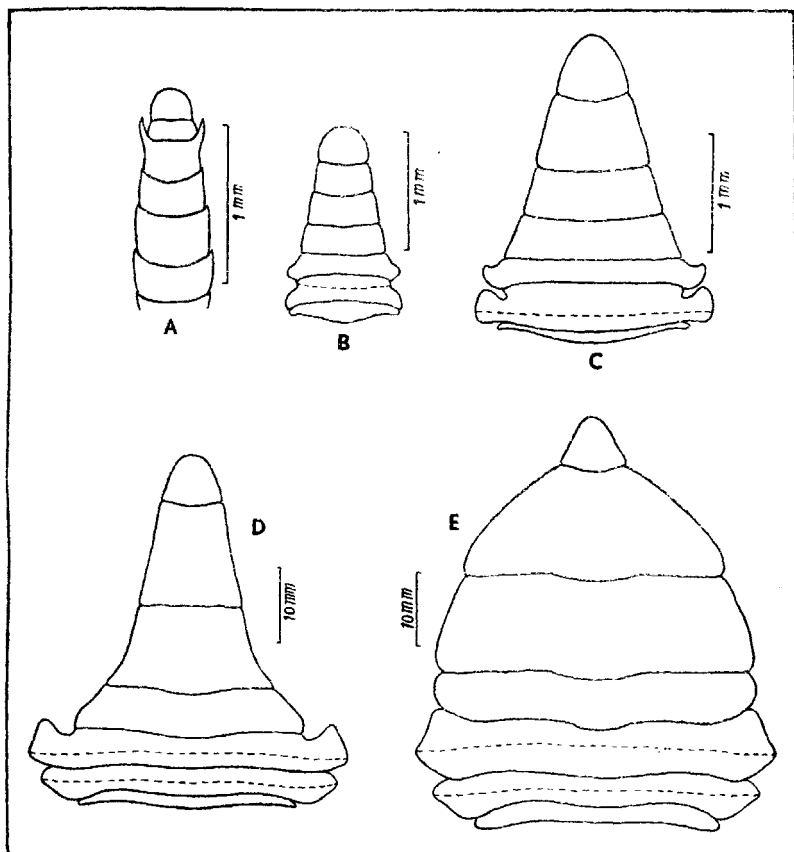


FIG. 6. The abdomen of a megalopa (A), juveniles (B, C, carapace width 2.5 mm. and 7.0 mm., respectively), adult male (D) and adult female (E).

show a constant growth from 35 mm. to the largest size-range included in the present investigation (Fig. 8), but they show a significant difference in the growth-coefficient from those of the unsexed and females of all size ranges (Table 2).

TABLE 2

*Width of the sixth abdominal segment :  $\alpha$  values.*

Size range (mm.)	Sex	$\alpha$	$\sigma_{\alpha}$
Up to 35	Unsexed ..	1.121	$\pm 0.055$
> 35	Males ..	0.997	$\pm 0.016$
35 to 108	Females ..	1.209	$\pm 0.026$
> 108	Females ..	1.524	$\pm 0.057$

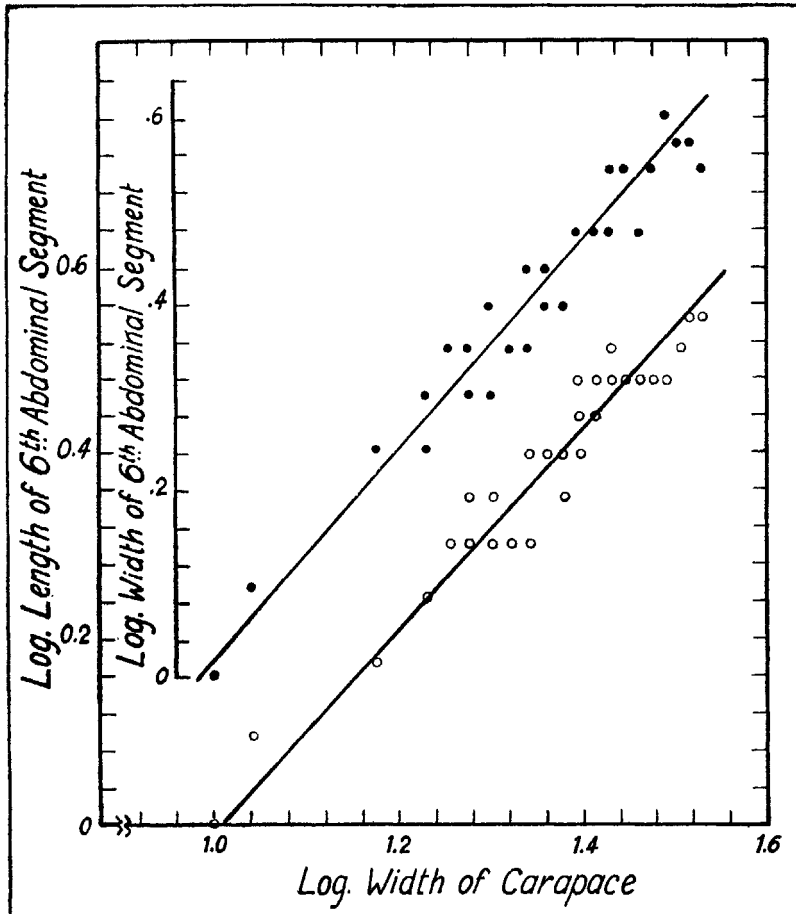


FIG. 7. Logarithmic plot of length and width of the sixth abdominal segment against the width of carapace in the unsexed.

From Table 2 it is further seen that the growth-ratio of the width of the sixth abdominal segment in the males over 35 mm. is nearly isometric and shows a slight but statistically significant decrease from that of the individuals in which sex determination was difficult. The growth index of the females 35 to 108 mm., on the contrary, is not significantly different from that of the unsexed and the change becomes apparent only in the larger females. So it is of interest to note that the rate of growth of the width of the sixth abdominal segment in the smallest *N. pelagicus* is positive allometry, whereas the males all through have a lower relative growth approaching isometry. The females throughout the range of size studied, which includes the largest caught locally, show definite positive allometry in regard to this character. Shaw (1928) noticed in the female *Inachus* 'that the abdomen consists of two long periods, one of slight positive heterogony, the other of isogony, separated by a short period of violent heterogony, which presumably begins directly after a moult, since its effects are shown completely by the next moult.' But in the males of the same species the abdomen is isometric in the young crabs becoming slightly negatively allometric in older crabs. Huxley and Richards (1931) observed in *Carcinus maenas* that the abdomen of the female becomes relatively larger with increased absolute size throughout the whole of its life. As in

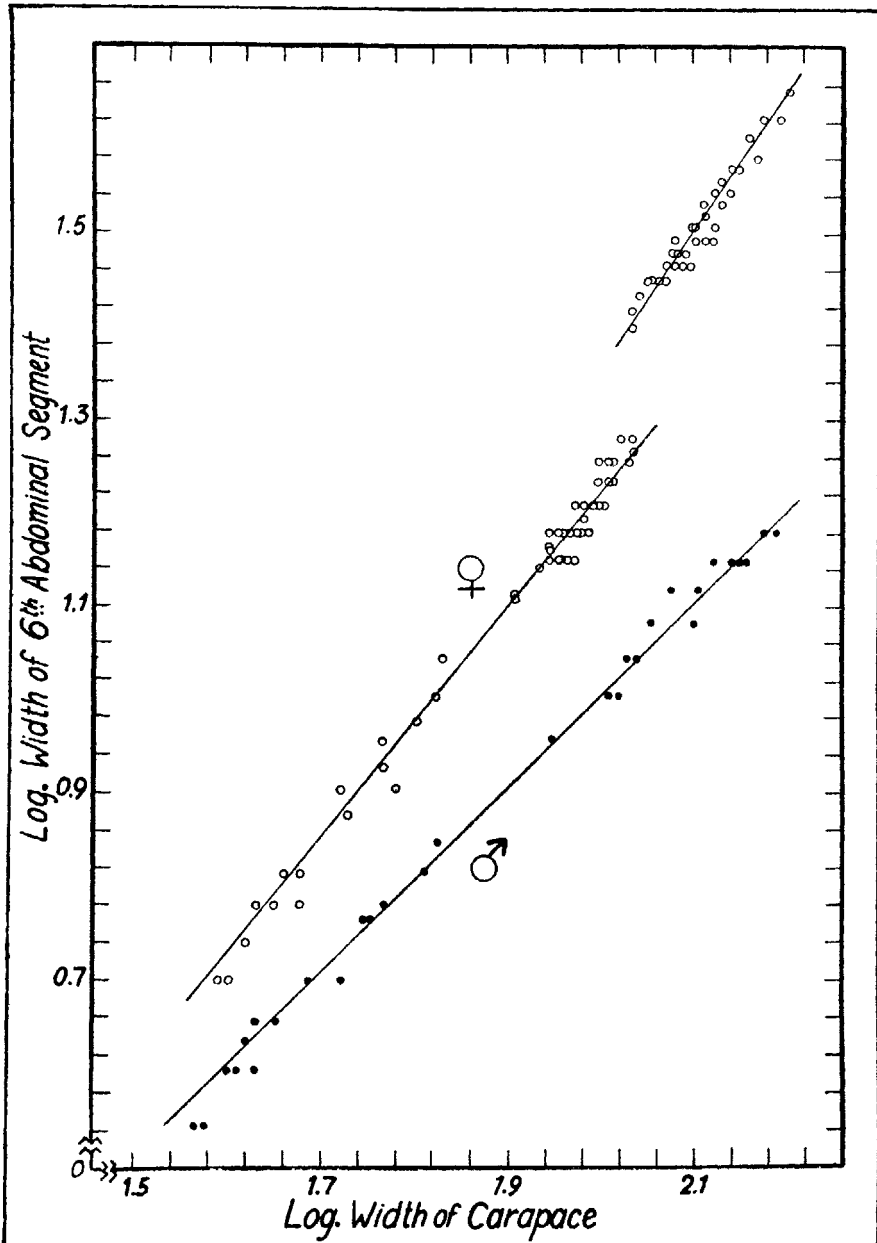


FIG. 8. Logarithmic plot of width of the sixth abdominal segment against the width of carapace in males and females.

*C. maenas* the abdomen in the female *N. pelagicus* also becomes relatively larger with increase in the absolute size all through its life. The investigations of Williams and Needham (1938) on *Pinnotheres pisum* brought out that the relative growth-rate of all abdominal segments in this particular species is lower at the smallest sizes, almost showing negative allometry, but increases in the larger ones to slight

positive allometry, the value of the growth index varying from 0.98 to 1.13. They have, however, pointed out that they did not have sufficient specimens of the smallest sizes to obtain a definite measure of its growth index.

(e) *Length of the sixth abdominal segment.*

The log. length of the sixth abdominal segment of the unsexed plotted against the log. width of its carapace shows that the slope of the line is almost parallel to that of the log. width of the sixth abdominal segment (Fig. 7). There is a close agreement between the values of the growth index of the length and width of the sixth abdominal segment of the unsexed crabs but these are significantly different in the males and females, the males having a slightly higher relative growth-rate

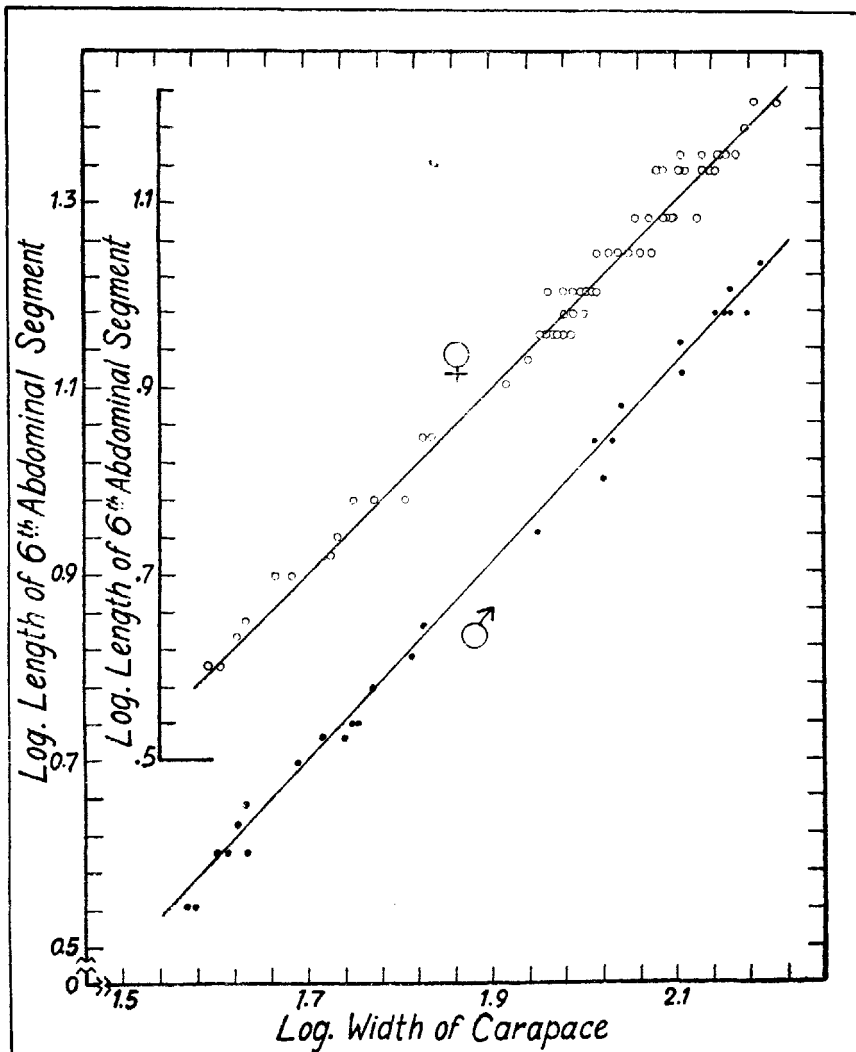


FIG. 9. Logarithmic plot of length of the sixth abdominal segment against the width of carapace in males and females.

in the length while the females show a considerably low  $\alpha$  value in relation to the width (Ref. Tables 2 and 3).

TABLE 3  
*Length of the sixth abdominal segment :  $\alpha$  values.*

Size range (mm.)	Sex	$\alpha$	$\sigma_\alpha$
Up to 35	Unsexed ..	1.091	$\pm 0.054$
	Males ..	1.059	$\pm 0.016$
> 35	Females ..	0.992	$\pm 0.034$

In the males as well as the females over 35 mm., the growth-coefficient is constant throughout and there are no indications of abrupt changes (Fig. 9) and unlike with the width, the growth-ratio of the length of the sixth abdominal segment does not show significant differences between the males and females in the entire size range studied. Although the growth rate in the females falls slightly from that of the unsexed, the difference is not statistically significant. Drach (as cited by Newcombe *et al.*, 1949) studied form changes in the abdomen relative to carapace of *Portunus puber* and found that the data followed three parallel lines. The first discontinuity, according to him, corresponds to the puberty moult and the second due to the moult following the puberty moult. In *Cancer magister* Weymouth and MacKay (*op. cit.*) found that the length of the sixth abdominal segment in the males shows a varying growth-rate, the values of  $k$  ranging from 1.00 to 1.06. The growth-coefficient for the females of the same species becomes markedly different at a carapace width of 10 cm., but the smallest available males and females show isometry. In *N. pelagicus* this growth-ratio does not differ markedly even in the largest males and females studied. Throughout the growth may be regarded as isometric in the females and possibly tending towards slight positive allometry in the unsexed and the males.

#### DISCUSSION

Studies of this nature have usually been undertaken with the main object of mapping out the general pattern of growth intensities and growth centres. Several detailed investigations on many species of crustaceans have established the occurrence of definite growth centres and growth gradients. Evidences have also been given on the effect of the growth-rate of one part on the other, what has been called 'positional effect' where the high positive or negative allometric growth in one appendage influences the rate of growth of the neighbouring appendages. However, in certain species such as *Ocyropoda aegyptiaca* Sandon (1937) observed that 'the positive heterogony of the chela has not apparently had any effect on the growth of the legs adjacent to them, nor has the increased growth of the large chela induced an increased growth-rate in the other appendages on the same side of the body.' But Tazelaar (1930) remarked: 'There is undoubtedly a correlation between marked heterogony in an appendage and the growth-rate of neighbouring appendages. The correlation is of the following nature: that the growth of appendages immediately posterior to the heterogonic organ is increased, that of appendages immediately

anterior is decreased, irrespective of whether they are of the same type as the heterogonic organ (e.g., pereopod and chela) or different type (e.g., maxilliped and chela).'

Needham (1950) stated that the 'growth constant'  $\alpha$  was not constant, even over restricted periods of growth, but was a continuously variable function of carapace size and therefore, he used Medawar's transformation method, with certain modifications, 'to give a single key relation which, within the scope of the data defines abdomen width completely, spatially and temporally.' But according to Huxley (1950) 'This method, however, although providing much the most comprehensive picture or description of the process of form transformation, sheds little light on the possible biological causes or mechanism underlying the process. On the other hand, analysis in terms of allometry does so, since it strongly suggests a graded distribution of some substance or process concerned with the regulation of relative growth-rate.' The analyses in the present investigation have been carried out in terms of allometry.

The aim of this study, as already pointed out in the introduction, is primarily to ascertain whether the species shows any marked changes in the growth-ratio which may be considered as associated with the attainment of sexual maturity as the species shows distinct sexual dimorphism in regard to the chela and the first walking leg, both being relatively longer in the larger males than in the females of the same size range. Similarly, in the case of females the sudden change in the width of the abdomen from the male type to the female type is also a sure sign of the onset of maturity. As Smith (1906) pointed out for *Inachus scorio*, the deviation from a simple straight line series of points in all probability is due to the phenomenon of 'facultative' high and low dimorphism. Such changes may be displayed by different parts in different ways. Thus, Shaw (1928) observed in *I. dorsettensis* that the normal strong allometry of the male chela is replaced by the female isometric type of growth in the non-breeding season and so also in the pereopods. In *Cancer magister* with the onset of sexual maturity there are significant changes in length-width proportions and in the length and width of the seventh abdominal segment. In the males there is a change in the relative growth of the walking leg (Weymouth and MacKay, 1936).

In *N. pelagicus* certain significant changes in the relative growth-rate of parts which can reasonably be attributed to physiological changes associated with the onset of sexual maturity are observed. The authors, during their investigation on the biology of this species (Ref. Prasad and Tampi, *op. cit.*) found that the smallest crab in berry was 106 mm., in carapace width. An analysis of the relative growth of the width of the sixth abdominal segment has shown that there is an abrupt break, increase in width and further accentuation in the rate of growth, an indication of the onset of sexual maturity, at a carapace width of about 108 mm., which is in very close agreement with the observed size of the smallest crab bearing eggs. This sudden change from the 'intermediate type' of abdomen to the typical female type seems to be completed during a single moult preceding the attainment of sexual maturity. No such change is, however, noticed in the length of the sixth abdominal segment which maintains an almost isometric growth throughout. The females, even from a very early stage show a significantly higher rate of relative growth than the males in the width of the sixth abdominal segment (Fig. 8) but sex differentiation based on the shape of the abdomen cannot be depended upon until the crabs have grown to a size of about 35 mm., because the 'intermediate' type of abdomen of the juvenile females cannot always be distinguished with certainty from the male type. The increase in the width of the sixth abdominal segment in the males seems to be gradual and constant throughout without any abrupt change as observed in the larger females. In several instances, such as *Pinnotheres pisum* (Williams and Needham, 1938) and *Carcinus* (Day, 1935) a fall in the relative growth-rate at a particular stage has been observed in the female abdomen. The growth

of the female abdomen in *Pinnotheres* is most rapid before maturity, after which growth is practically isometric. A similar phenomenon of a fall in the growth-rate of the sixth abdominal segment of the female has not been noticed in *N. pelagicus* and with the onset of maturity there is an increase in the relative growth-rate which is maintained throughout.

It was also pointed out earlier in this paper that a slight change in the relative growth-rate of the first walking leg in the females is noticed, the lines representing the reduced major axis of the two phases intersecting at a carapace width of approximately 108 mm. This is probably an additional supporting evidence to the conclusion that the females attain maturity when they are about 108 mm., in carapace width.

The problem of ascertaining the sexual maturity in the males is generally more difficult because many species may not show great external changes at the time of sexual maturity. However, *N. pelagicus* shows easily discernible sexual dimorphism at least in one character, the length of chela. A change in the relative growth-rate of the length of chela in the males is observed at a carapace width of about 102 mm. Similarly, a change in the relative growth-rate of the first walking leg was noticed at the same size. Thus it appears that the onset of sexual maturity may be slightly earlier in the males than in the females. Pearson (1908) recorded a similar condition in *Cancer pagurus* and as for the males of *N. pelagicus* in Australian waters Thomson (1951) stated: 'It is true that the crabs mature at a lesser size which is estimated to be about 4 in., when the secondary sexual characteristics become evident. . . . ' The size of 4 inches given by Thomson is in good agreement with that observed locally. In *Callinectes sapidus* Newcombe *et al.* (1949) found 'little difference in this respect between sexes. The changes in the linear ratios suggest that females mature when about 95-100 mm., in width. The moulting data presented here show that sexual maturity in the males is probably attained at about the same size.'

The abrupt nature of changes in the relative growth-rate of the width of the sixth abdominal segment and the length of the first walking leg in the females at a carapace width of 108 mm., and similar changes in the length of chela and the first walking leg of the males at 102 mm., carapace width suggests that in *N. pelagicus* sexual maturity is usually attained by a single moult. A similar phenomenon has been noticed in *Pugettia producta* by Weymouth (personal communication).

The peculiar phenomenon of decrease in the absolute length of carapace in both sexes is hard to interpret. Shaw (1928) who noticed a similar 'back kink' of the curves for all the pereopods of *Inachus dorsettensis* suggested: 'It may well be that the relative growth-rate of the pereopods decreases at the same time as that of the chelar propus decrease (i.e., there is a similar slowing down of growth in the non-breeding season) and that after this period when the relative growth-rate of the chela rapidly increases, this acts as a drain on the pereopods, so that these never again attain to their former relative size.' In *N. pelagicus* the phenomenon takes place long before the attainment of sexual maturity. Therefore, it does not seem to have any correlation with the breeding activity and the explanation will have to be sought elsewhere. The authors (1953) have mentioned in their report on the biology of this species that there is a certain amount of segregation according to size. Analyses of size-frequencies of crabs landed by two different types of nets, one operated in shallow waters and the other in relatively deeper areas, have shown that the latter composed of crabs above 90 mm., and the former 80 mm., and below. This size range coincides with that when there is a decrease in the carapace length. So it is possible that the observed decrease may be caused by a change in the environment during the migration from shallow to deeper waters. Weymouth (personal communication) has suggested that this retardation of growth may be due to a great increase in the gonadial tissue (which sometimes amounts to a third of the bulk of the tissues) at this moult and the crabs then seek deeper water. However, further detailed work is necessary to ascertain the exact cause.



## SUMMARY

The paper deals with the relative growth (on the basis of carapace width) of (1) the length of carapace, (2) length of the chela, (3) length of the first walking leg and (4) length and width of the sixth abdominal segment in the unsexed, males and females of *N. pelagicus*.

479 crabs ranging from 8 to 158 mm. are included in this study. Huxley's formula for allometric growth has been employed but instead of fitting the conventional regression line to the logarithms of the data, Kermack and Haldane's method of taking the reduced major axis of the logarithms has been used.

Allometric growth has been found in the majority of the parts studied, the  $\alpha$  values ranged from 0.935 to 1.593.

A decrease in the absolute length of the carapace in both males and females has been noticed at a carapace width ranging from 80-88 mm. It is suggested that this is perhaps caused by a change in the environment because there is some evidence of the crabs migrating from shallow to deeper waters at this size.

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