ASPECTS OF THE GENERAL BIOLOGY AND FISHERY OF THE MUD CRAB *SCYLLA SERRATA* (FORSKAL) IN MORETON BAY, QUEENSLAND

by

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DECLARATION OF ORIGINALITY

This thesis reports original work by the author and has not been submitted previously for a degree at any other university. Information derived from other sources is specific ally acknowledged in the text.

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ABSTRACT OF THESIS

Title: Aspects of the general biology and fishery of the mud crab *Scylla serrata* (Forskal) in Moreton Bay, Queensland

by Michael P. Heasman

Growth of post-larval *S. serrata* in Moreton Bay occurs as a progression through 4 allometric growth phases (G.P.I-G.P.IV). These embrace crabs of approximate carapace width ranges 0.36-2.0 cm; 2.0-10.0 cm; 10.0-16.0 cm and 14.0-20.0 cm respectively. Apart from the relative size and form of the abdomen, sexual dimorphism is not overt during G.P.I and G.P.II, i.e. in crabs below approximately 10 cm carapace width. During G.P.III and G.P.IV however, a progressive divergence in the relative size and form of the limbs (the chelae in particular) develops between the 2 sexes. The functional significance of allometric growth in *S. serrata* is discussed as is the use of alternative weight and linear parameters as indices of size and form. Problems associated with the use of morphometric data for taxonomic purposes are also discussed.

The transition from G.P.III to G.P.IV in female *S. serrata* is achieved during the pubertal moult. This moult, which represents the terminal moult of most (≃97%) female *S. serrata* in Moreton Bay, is accompanied by an increase in mean carapace width from 12.85±0.85 cm to 16.65±1.0 cm. The concept of a pubertal moult was found to be irrelevant in reference to male *S. serrata*. Full development of the male genital tract spans at least 2

successive instars and functional maturity, i.e. the ability to successfully inseminate receptive females, is sometimes possessed by penultimate instar males (mean carapace width 14.18±0.82 cm) as well as by G.P.IV terminal instar (mean carapace width 16.45±1.00 cm) males.

Real growth, i.e. the accumulation of organic matter, in *S. serrata* is an essentially continuous process which is interrupted only briefly around times of moulting. Full mineralization of the integument occurs during the first 26% of the moult cycle. Accumulation of organic matter is most rapid during this period. Relatively large losses of organic matter and soluble mineral salts associated with ecdysis are offset by the crab's predilection to moult in seclusion and to consume its own exuvia.

Feeding rate follows a sigmoidal relationship with temperature over the approximate range 16°-27°C. Food consumption falls below maintenance requirements at temperatures below approximately 20°C and to almost insignificant levels at temperatures below 16°C. Preferred feeding areas of *S. serrata* vary considerably with size/age/growth phase, sex and moult condition of individual crabs.

Of the 2 growth components, moult increment and intermoult duration, the latter is far more sensitive to temperature. Moult increments are significantly depressed by protracted exposure to low temperatures. Lowest moult increments occur in early spring rather than during the coldest winter months.

Intermoult duration increases progressively with size. Under near ideal temperatures ($27^{o}\pm0.5^{o}C$), the relationship between carapace width and intermoult duration is adequately described by the equation $Y = 2.996 + 2.747X + 0.254X^{2}$ where Y = intermoult duration (days) and X = carapace width (cm). Least squares linear regressions have been fitted to premoult vs. postmoult carapace width data spanning the entire size range of post-larval *S. serrata* from Moreton Bay.

S. serrata from tropical regions generally appear to grow at a lower rate and to a smaller definitive size than counterparts from sub-tropical and warm temperate regions under comparable conditions. Two possible explanations of these phenomena based on alternative genetic and physiological considerations are presented.

Mating *S. serrata* were captured in all months except July (mid-winter). Peaks in the mating activity of Moreton Bay *S. serrata* occur in mid-spring and late summer. Spawning begins in spring, reaches a peak in early summer and ends during autumn. Incubation period varies in accordance with the rate/temperature equation $D = 17936(T - 4.8)^{-2.33}$ where D = incubation duration (days) and T = temperature (^{o}C). The resistance of developing ova to bacterial and/or fungal infection appears to be markedly reduced at temperatures below $20^{o}C$.

S. serrata were successfully reared through all larval stages. Food density and temperature were found to greatly influence feeding efficiency and hence the ultimate survival of larvae, zoeal instars in particular.

Post-larval recruitment in Moreton Bay begins in late spring or early summer and ends in mid- to late autumn. The exact pattern of recruitment may however vary considerably from year to year.

The seasonal nature of reproduction and growth imposes a distinct year class structure on populations of *S. serrata* in Moreton Bay. The form and progressive development of successive 1 + year old and 2 + year old classes were clearly illustrated in analyses of commercial catch data. Underlying year class structures appear typical of most if not all populations of *S. serrata*. Evidence that few Moreton Bay *S. serrata* survive more than 12 months beyond the terminal moult, i.e. to more than 3-4 years of age, is presented.

Findings of the present study are discussed in relation to the management of *S. serrata* stocks in Queensland.

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GENERAL INTRODUCTION

The natural range of the portunid crab *Scylla serrata* (Forskal)[1] extends through the Indo-Pacific region from Mossel Bay in South Africa along the east African coast including Mauritius and Madagascar to the Red Sea. It continues eastward to India and Sri Lanka and throughout Indonesia, the Philippines and Malaysia. Northward the crab occurs in Thailand, China and Taiwan. The northern limit of its range is the mouth of the Tone River in Japan (Lat 36°N). Southward its range includes Papua New Guinea, Australia and the north island of New Zealand. It occurs on many Pacific islands including the Carolines and Marianas, Samoa and Tuamotus. It was also successfully introduced into Hawaii from Samoa between 1926 and 1935 (Dickinson 1977).

Within Australia, *S. serrata* occurs from Broome Western Australia (Lat 18 °S) north and east to the Northern Territory and Queensland coasts of the Gulf of Carpentaria. Along the east coast of Australia its range extends from the Torres Strait in the north to Port Jackson (Sydney) in the south (lat 34 °S)

Recent reviews of the literature on *S. serrata* have been provided by Dickinson (1977) and Perrine (1978). A comprehensive synopsis of published plus known and available unpublished literature on *S. serrata* is currently being prepared by Drs. B.J. Hill and M.J. Williams of the Queensland Fisheries Service (pers. comm.)

S. serrata is the only large crab to have successfully invaded estuaries in the Indo-Pacific region. In southern Queensland male and female crabs exceeding 2 kg. liveweight or at least 20 and 23 cm

1 Accepted names of portunid crabs referred to in this thesis are listed in appendix three.

carapace width respectively are occasionally captured.

Traditional fisheries based on *S. serrata* occur throughout its distribution. Populations of the crab along the densely settled coastline of central and northern New South Wales and of southern Queensland are subjected to intense fishing pressure by both commercial and amateur (sports and recreational) fishermen.

Queensland Fish Board (Q.F.B.) figures indicate that of the States' annual commercial catch which varied between 72,561 and 164,835 crabs [1] in the period 1951 - 1976 approximately 90% is taken from mangrove estuaries south of Yeppoon i.e. south-east Queensland.

Q.F.B. intake figures for Moreton Bay in the period 1951 - 1976 indicate that following a peak production of 110,980 crabs in 1956 annual commercial catches declined progressively to 19,556 crabs in 1970. Whilst partial recoveries occurred between 1970 and 1974 and again in 1977, the long term trend appears to be one of a progressive decline. There seems little doubt that increasing amateur and to a lesser extent unofficial commercial catches are responsible for this apparent decline of the Moreton Bay fishery. Private motor boat registrations in the region which more than doubled between 1970 and 1976 currently exceed 35,000. Queensland Department of Harbours and Marine (pers. comm.).

Demand for *S. serrata* in Queensland (as indicated by prices adjusted for inflation and varying level of supply) Heasman and Fielder (1977) exceeded supply in the period 1956 - 1976. As the mean wholesale price per crab increased from $1.80 in 1976 to $8.30 in 1979, M. Williams (pers. comm) this situation appears to persist.

[1] Only male crabs of at least 15.0 cm. carapace width may be legally taken under current Queensland fisheries regulations. (Queensland Fisheries Act 1976 - No. 80)

The present study was prompted by 3 principal factors; an intense public interest in and consumer demand for the crab; poor knowledge of the biology of Moreton Bay populations and the crab's apparently high suitability for capital intensive aquaculture in Australia.

Veerannan (1972) found that respiratory metabolic rates of juvenile *S. serrata* acclimated at 27° C were 50 - 60% lower at a test temperature of 16°C than at a test temperature of 27° C.

Du Plessis (1971) ascertained that spawning activity was confined to the warmest half of the year (late spring to mid-autumn) in South Africa. Hill (1975) found that mating activity in 2 South African populations of the crab begins in spring, reaches a peak in early summer and ends in late autumn. On the basis of seasonal changes in the size frequency distribution of these crabs he concluded that post-larval recruitment is an essentially summer phenomenon. Hill also concluded that a distinct seasonal catch cycle in which catches decreased in autumn and recovered in spring reflected reduced feeding in winter. This conclusion was supported by earlier growth and feeding experiments of Du Plessis (1971) who found that feeding rate decreased from late autumn to mid-winter and then recovered progressively through spring. This seasonal feeding cycle followed that of growth, in particular intermoult duration. Durations of ecdyses in crabs reared by Du Plessis varied from 3 to 11 hours over an approximate temperature range of 20 - 30°C.

The above findings provided clear evidence that the seasonal temperature variations in Moreton Bay (16 - 27°C) are likely to exert a profound influence on resident populations of the crab.

The central aim of the present study was to gain a basic understanding of the structure and dynamics of *S.serrata* populations in Moreton Bay. In pursuit of this objective, the influence of temperature on mating, spawning incubation, larval development, feeding and growth were investigated in a series of laboratory experiments. The results of these experiments greatly facilitated interpretation of the results of complementary field investigations.

SECTION ONE

1.0 RELATIVE GROWTH AND FORM OF POST-LARVAL *SCYLLA SERRATA*

1.1 Introduction:

Mauchline (1973) was able to demonstrate that a limited increase in the length of the decapod shrimp *Crangon crangon* and several species of mysids, could occur through stretching of the membranous articulation of abdominal segments between successive moults. Overt growth in the size of most crustaceans is however an essentially discontinuous process, achieved in steps at successive moults. In the *Brachyura*, morphology and hence inter-relationships between various linear dimensions, often change through successive instars with the differential development (allometry) of certain body and limb segments. Single linear reference dimensions *per sé* therefore contain inherent limitations as indices of size and growth over successive instars and, moreover, indicate nothing of the growth occurring within each instar.

The total wet weight of a crustacean also has inherent limitations as a parameter of size and growth in that it practically stabilizes in the relatively short period of water absorption during and immediately following ecdysis. Water absorption of *Scylla serrata* during this period was found to constitute 80-90% of the total weight increase from moult to moult by Du Plessis (1971). According to Lockwood (1968), real growth, the progressive accumulation of tissues and organic reserves, which can only be monitored by biochemical assay, accounts for the replacement of approximately

25% of this water during the ensuing intermoult period. In spite of the limitations of linear dimensions and total wet weight as indices of real size and growth, their use has been unavoidable in this and similar studies. This is particularly true of *in situ* field sampling where measurements have to be simple, fast and preferably non-destructive.

A basic understanding of the morphometry of post-larval *S. serrata* as pursued in this study was particularly prompted by the relative paucity of such data from alternative populations throughout its wide geographical distribution. Single relationships linking total weight and carapace widths for male and female crabs throughout post-larval life were established by Varikul *et al* (1970) in Thailand and Du Plessis (1971) in South Africa. Du Plessis also provided graphical data which indicated that a single relationship of carapace width and carapace length was common to both sexes and maintained throughout post-larval life. Ong Kah Sin (1966) claimed that a carapace length to width ratio of 0.81 in first instar post-larval crabs was reduced through the 2 following instars to 0.67, a value which persisted throughout the remaining growth to maturity of both sexes.

Some morphometric data have also been utilized in taxonomic studies of *Scylla*. Estampador (1949A) proposed that the proportionately larger chelae of *S. tranquebarica* was a supplementary character which distinguished it from 3 alternative 'varieties' of *Scylla* in the Philippines. Although Serene (1952) failed to confirm Estampador's proposition that adult male *S. tranquebarica* alone possessed

chelae of an overall extended length of more than twice their carapace length, he did not employ sufficient quantitative data to deny it. Indeed, only 3 males and 1 female of each variety of *Scylla* from Vietnamese waters were measured and compared. Serene was careful to note however, that sexual dimorphism of the chelae, together with the variability of their form and relative size with age, were factors which were apparently overlooked by Estampador, as was the assymetry of left and right chelae of individual crabs of both sexes.

Changes in the chelae are one example of secondary sexual characteristics which have long been utilized as indirect indices of maturity. This is of particular interest in relation to male brachyurans. The alternative means of positively confirming the maturity of males are the detection of active spermatogenesis or their proven ability to copulate with, and impregnate receptive females. (Ryan, 1967C).

In contrast to males, onset of sexual maturity is explicit in female crabs. The attainment of maturity by female crabs is accompanied by gross morphological changes, particularly of the abdomen and accessory reproductive structures. (Ryan, 1967C). The prominence of these changes led to the concept of the 'pubertal moult' by Perez (1929). As enumerated in Section 4.15, there is a marked discrepancy in the recorded size of mature females from tropical and warm temperate populations of *S. serrata*. It was therefore envisaged that the detection of morphometric parameters which are symptomatic of the onset of sexual maturity of both sexes of *S. serrata* from Moreton Bay would be of

scientific interest, as well as of practical value in the management of the local fishery.

Huxley (1932) first demonstrated that the growth of appendages and other body dimensions is usually a close approximation to the allometric growth (or relative growth) equation: $Y=bX^{\alpha}$ where b and α are constants. On logarithmic axes these power curves become straight lines of the form: Log Y = Log b + α.Log X where the slope is α, the 'equilibrium constant' and b, the size of variant Y when X = 1, termed the 'initial growth index'.

Allometry, defined by Gould (1966) as "the study of variables exhibiting differential growth", facilitates comparisons between animals of greatly varying size (Aldrich, 1974) such as early and late post-larval instar crabs.

Carapace width is the most common reference parameter (X) adopted in brachyuran studies. When α is significantly less than unity ($\alpha<1$) the alternate parameter (Y), for example carapace length, is increasing at a slower rate than carapace width and is exhibiting negative allometry. When α is not significantly different from unity ($\alpha\simeq1$), the 2 parameters are growing isometrically (at the same rate). If α is significantly greater than unity ($\alpha>1$), then carapace length (Y) is increasing at a greater rate than carapace width and is exhibiting positive allometry.

The values of α and b may not be constant over the entire growth range for a measured parameter. Each ontogenetic phase or stanza (Miller and Hoy, 1939) of growth may have its own discrete values which are marked by inflections or

even complete discontinuities (such as often occurs in the pubertal moult) in the graph of relative growth. (Tessier, 1960).

In a review of data published over a wide range of brachyuran species, Hartnoll (1974) was able to demonstrate characteristic patterns in the linear growth of the chelae, abdomens and first (copulatory) pleopods in relation to carapace width. He did so by comparing the interspecific values of α in both juvenile and adult phases of growth and further, discussed the possible functional significance of the differential growth of these structures both within and between sexes. Hartnoll also noted that additional subdivisions of juvenile and adult phases of growth have been detected in some species. Such subdivisions have been demonstrated in a number of portunid crabs including *Callinectes sapidus* (Newcombe *et al*, 1949) and *Portunus puber* (Drach, 1933).

Criteria for the selection of morphological parameters in this study therefore included a consideration of their potential as indicators of juvenile and adult phases of growth and possible subdivisions thereof. The apparent functional significance of the differential development of body and limb parameters, with particular reference to the ecology and behaviour of *S. serrata*, were also considered.

In recent years the increasing use of statistical tools, such as discriminant analysis coupled with the digital computer, have facilitated the choice of single or multiples of linear reference dimensions which give the most precise definitions of size and growth. By virtue of the

segmentation of both the body and appendages of crustaceans, they are naturally and easily divisible into component parts. In the course of this study, parameters of weight corresponding to linear measurements were recorded wherever practicable. It was anticipated that these weight equivalents would serve both as secondary references in the interpretation of growth and form in *S. serrata* and in the formulation of standard limb weight to carapace width relationships. These relationships have found immediate application in the sampling of natural populations as total weight correction factors for crabs having autotomized 1 or more limbs. (See Section 6.21).

1.2 Materials and Methods:

1.21 Collection of crabs

Crabs representative of all post-larval instars were obtained from 4 complementary sources. Laboratory rearing of *S. serrata* larvae in October and November 1975 (see Section 5.5) yielded 1st to 5th post-larval instars. Intertidal collections of crabs from Deception Bay between December 1975 and August 1977 (see Section 5.6), provided small juveniles in the range 1.05 to 8.32 cm carapace width. Crabs larger than 8.0 cm carapace width were taken from the catch of a commercial fisherman in southern Moreton Bay from December 1973 to March 1975 (see Section 6.21) and from a number of collections of crabs entering the intertidal zone on nocturnal flood tides at Coomera Island during, 1975, 1976 and 1977 (see Section 6.22).

All crabs collected in the field were placed amongst fresh mangrove (*Ceriops tagal* and *Avicennia marina*) leaves in enclosed plastic containers to minimize physical damage and evaporative losses during transport to the laboratory.

1.22 Criteria for the selection of crabs

Sampling error was minimized by exercising a number of exclusion criteria. Only crabs of moult cycle stages $C_4 \rightarrow D_2$ (Drach, 1939) were utilized in order to reduce weight variability associated with different stages of the moult cycle. Intermoult to early premoult crabs were also discarded if 1 or more of their limbs were overtly stunted, malformed, damaged or lost and if their chelae were not of a 'standard configuration'. Standard chelae comprise a fully developed right-hand 'crusher' chela and a left-hand 'cutter' chela. Crabs displaying obvious cephalothoracic damage (including erosion or fracture of the 9th anterolateral spines) or malformation were also discarded.

1.23 Determination of sex and sexual maturity

The differential shape of the male and female abdomen enabled the sexing of crabs above 3.0 cm carapace width on casual inspection. The sex of crabs below this size could not however be confidently determined by this method. These small juveniles were therefore examined at 30 x by means of a binocular microscope. Females were recognised by the presence of 4 pairs of biramous pleopods and of oviduct depressions on the sternites of the 6th thoracic segment. Males were recognised by the presence of copulatory pleopods and the absence of oviduct depressions (after Ryan, 1967c).

Sexually mature female *S. serrata* were recognized on casual inspection by the presence of a semicircular and heavily pigmented abdomen and highly setose pleopods. Sexual maturity in male *S. serrata* which is not accompanied by overt or definitive changes in secondary sexual characteristics (see Section 4.2) was not determined.

1.24 Selection and measurement of weight and linear dimensions

Parameters chosen, the rationale for their selection and methods of their measurement were as follows:

a) Total weight

Total wet weight was found to be essentially static at and beyond the 'true intermoult' C_4 stage of the moult cycle (see Section 2.6). Its utility as an indicator of gross size is therefore obvious. Live weights of crabs above 10.0 cm carapace width were read to the nearest 0.1 g on a *Mettler* P.2000 top-loading balance. As the weights of strings used to tie crabs were trivial (less than 0.019 g), they were ignored. Smaller crabs, which were much more active and which could not be physically restrained by tying, could not be accurately weighed alive. These crabs were therefore wrapped in damp paper towelling and anaesthetized by exposure to low temperature ($-7^{o}C$) for 1-2 hours. Freezing of tissues was however avoided wherever possible. In all cases crabs were carefully washed under a stream of tap water, shaken vigorously to remove surface and interstitial gill water and then thoroughly blot-dried prior to weighing. All anaesthetized crabs were laid, carapace downwards, under damp absorbent paper towelling to avoid evaporative and

stomach content losses while equilibrating to ambient temperature. They were then thoroughly blot-dried and weighed to the nearest 0.001 g on a *Mettler* HT6 balance.

b) Cephalothoracic (body) dimensions

Linear dimensions:

The following linear dimensions of all crabs were measured:

• Carapace width (Fig.1.1b)- the minimum distance between the tips of the 9th anterolateral spines.

• Carapace length (Fig.1.1b)- the minimum distance along the mid-line between the posterior margin of the carapace and the nadir of the notch between the central pair of frontal spines. This notch is present in the 1st post-larval instar although the frontal spines are absent. (Ong Kah Sin, 1966).

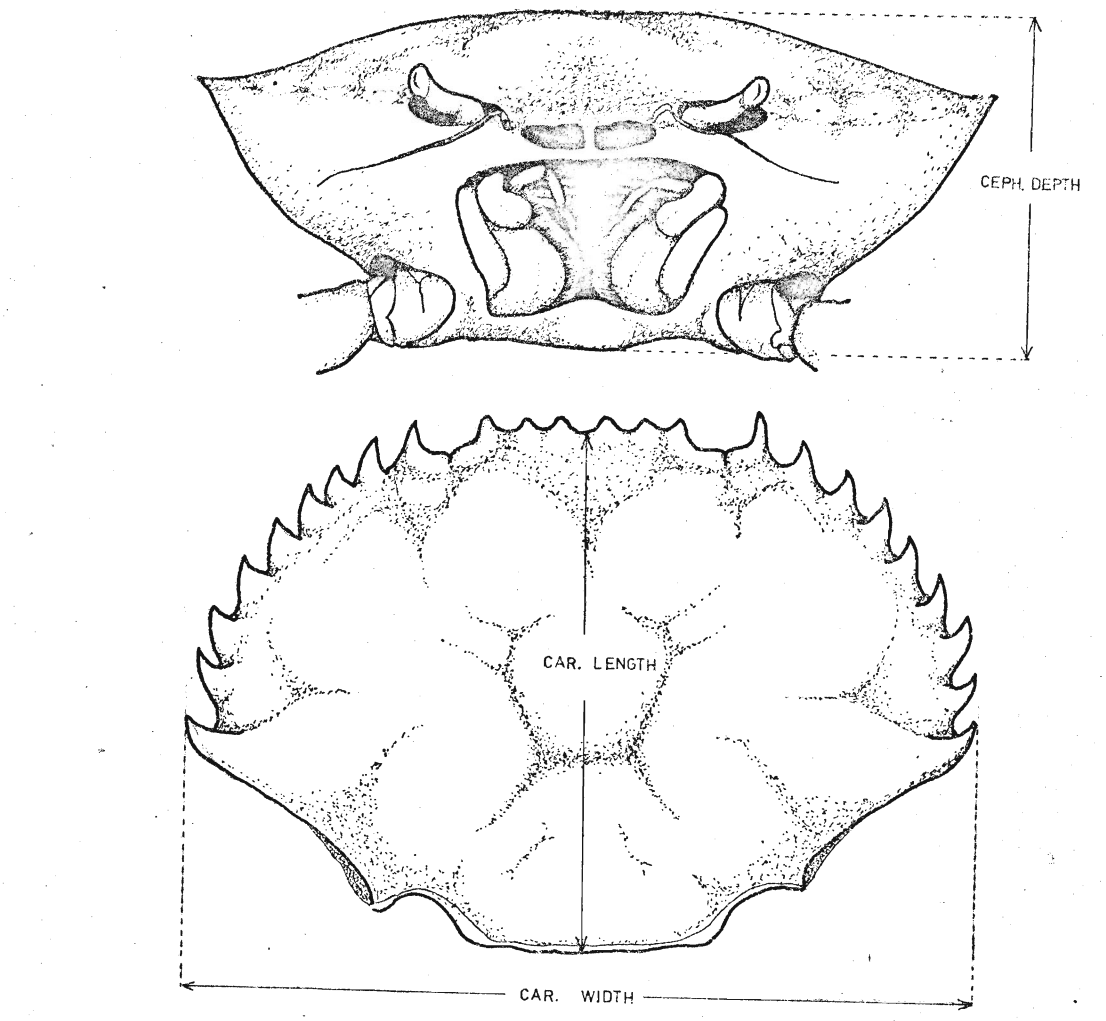
• Body depth (Fig.1.1a)- the maximum dorsoventral distance measured in the saggital plane.

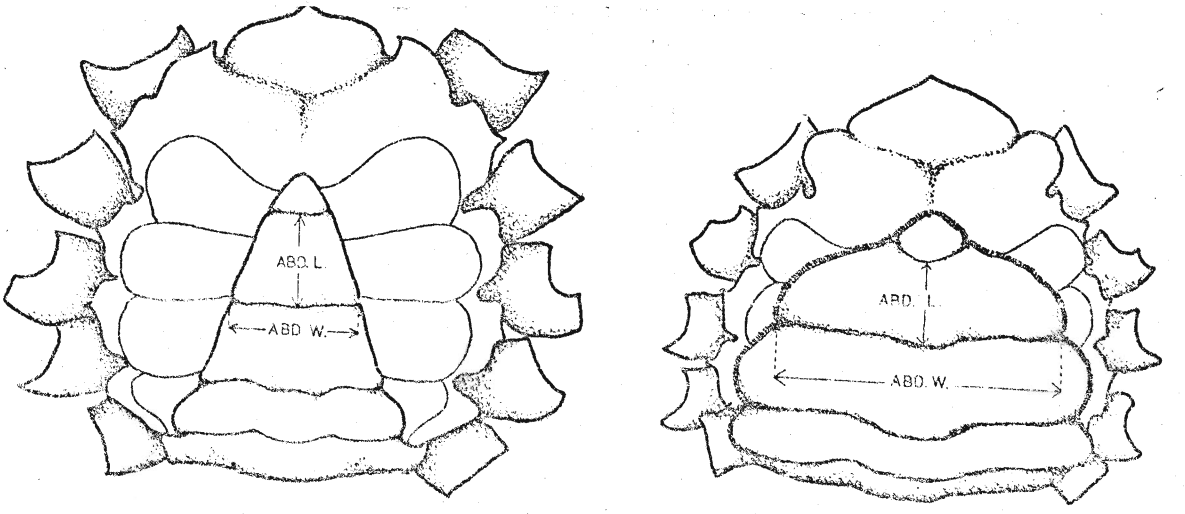
These and all other linear dimensions of crabs above 1.0 cm carapace width were measured with a pair of dial calipers. The linear dimensions of crabs below 1.0 cm carapace width were measured at 30 x by means of a binocular microscope equipped with a graduated eyepiece which had been previously calibrated. All lengths below 5.0 cm were measured to the nearest 0.001 cm while greater lengths were measured to the nearest 0.01 cm.

Carapace width and length, commonly adopted as reference dimensions, were also adopted here. Body depth was chosen to detect possible ontogenetic changes in the three dimensional conformation of the 'body' within and between sexes.

FIG. 1.1

SELECTED LINEAR DIMENSIONS OF THE CEPHALOTHORAX AND ABDOMEN OF POST-LARVAL *S. SERRATA*





Weight parameters:

The employment of weight parameters in defining relative proportions of the body and limbs and possible changes thereof throughout post-larval development, was a major objective of this study. The parameter, limbless weight (cephalothorax and abdomen), was chosen as a direct indicator of body size. Crabs larger than 10.0 cm carapace width, which had been weighed live, were anaesthetized by exposure to low temperature (-7°C), as previously described for small crabs, prior to limb amputation. Exposure times of 2-6 hours, depending upon the overall size of individual crabs, were required. Longer exposure resulted in the freezing of tissues and was again avoided.

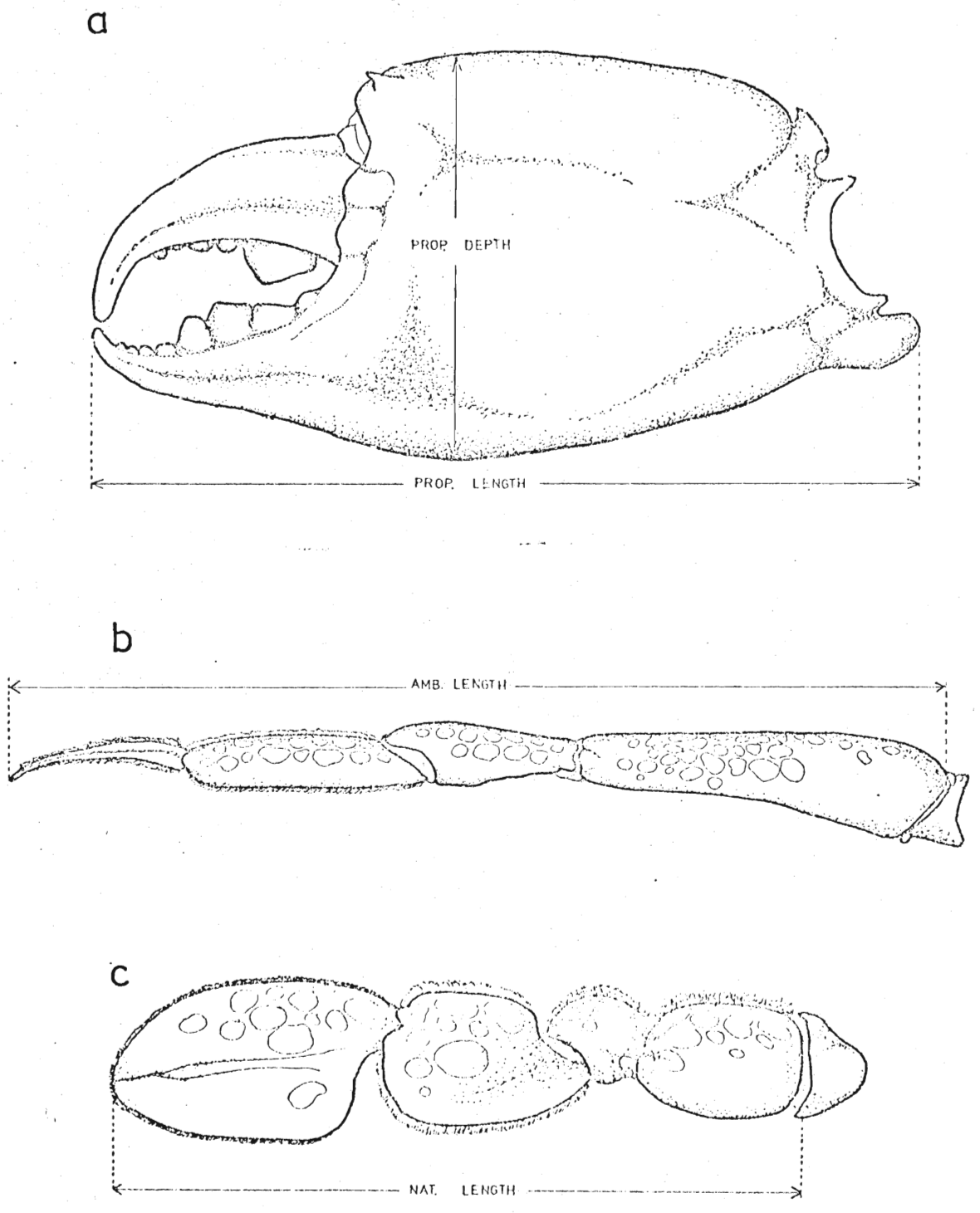
The same preparatory procedures described for the smaller crabs were applied prior to the amputation of limbs and weighing. The limbs of all crabs were severed at the basal ischial joint as close as possible but distal to the autotomy fracture plane so that haemolymph losses were minimized. Amputations were performed on small crabs with a pair of surgical scissors while the limbs of larger crabs were severed with a pair of bone forceps. While small (a few drops in larger specimens), volumes of haemolymph were spilt in the process, such losses were considered negligible.

c) The limbs

• The chelae: Total weight, propodus length and propodus depth of both the right-hand 'crusher' and left-hand 'cutter' chelae, depicted in Fig.1.2a,were measured as previously described. The propodus weights of both

FIG. 1.2

SELECTED LINEAR DIMENSIONS OF THE CHELA (a), AMBULATORY (b) (WALKING) AND NATATORY (c) (SWIMMING) LEGS OF POST-LARVAL *S. SERRATA*



chelae were then determined after the more proximal segments had been removed by a simple twisting action in small crabs or with the aid of bone forceps and surgical scissors in larger crabs. Again very small volumes of blood spilt in the process were considered negligible.

Particular attention was paid to chela parameters as the chelae generally display striking morphological allometry in male crabs (Aldrich, 1974) and are a major component of sexual dimorphism.

• The ambulatory and natatory limbs (the 2nd to 5th periopods): The fully extended lengths (Figs. 1.2b & 1.2c) and weights of these locomotory limbs were determined. Both right and left-hand sets of limbs were measured but only the longest and heaviest of each pair was recorded. This procedure was adopted as limbs in various stages of regeneration were often difficult to recognize on casual inspection.

d) The abdomen

Progressive and marked changes in the shape of the female abdomen, which occur through post-larval growth, prompted the selection of an abdominal dimension. The width of the 6th abdominal segment (Figs. 1.1c & 1.1d), a dimension utilized by Prasad and Tampi (1954) in a morphometric study of *Portunus pelagicus*, was also adopted here.

1.3 Treatment of Data:

1.31 Preliminary treatment

Before detailed analysis of data could be undertaken, it was necessary to detect and delineate the post-larval growth phases of *S. serrata*. This was achieved by selecting from 22 Log_{10} x Log_{10} scattergram plots relating 'selected' and 'reference' dimensions, those which displayed most clearly, changes in differential growth patterns through post-larval development. A series of straight (simple allometry) regression lines which conformed most closely with the distribution of data points were then fitted by eye to these scattergrams.

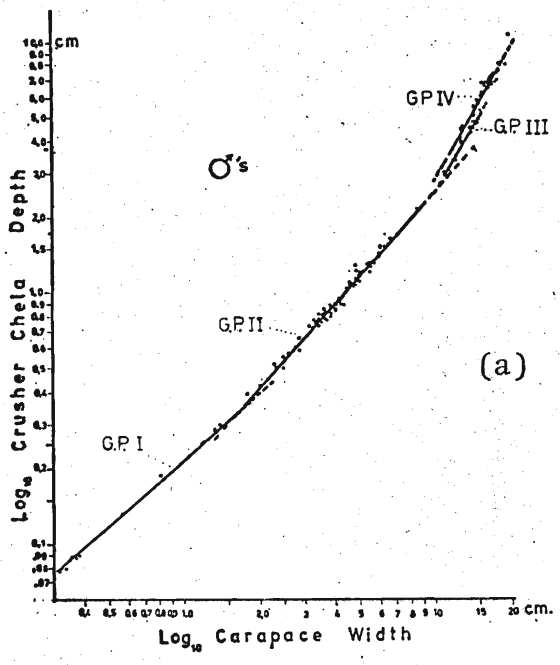
From this exercise it was apparent that the growth of post-larval *S. serrata* occurs as a progression through 4 successive growth phases, within each of which relationships between all linear and weight dimensions are adequately described by simple allometry equations.

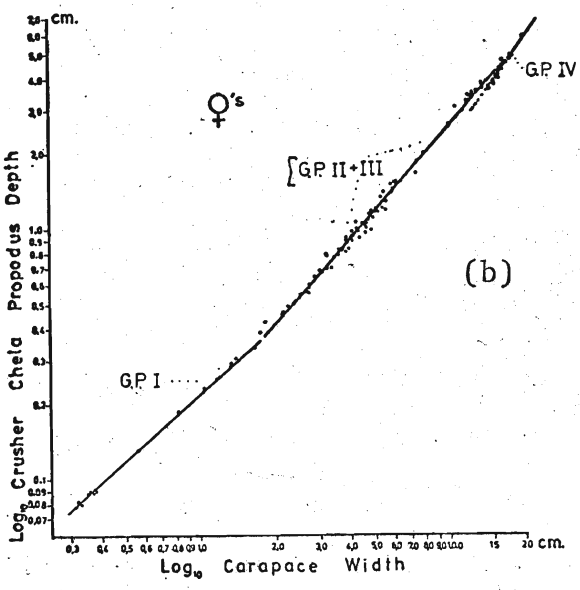
The existence of 4 post-larval growth phases was, in the case of males, most clearly indicated by Log_{10} x Log_{10} scattergrams relating carapace width and linear dimensions of the chelae, in particular depth of the 'crusher' chela propodus (Fig. 1.3a). In females these same 4 growth phases were most clearly indicated in a combination of 2 Log_{10} x Log_{10} scattergrams relating carapace width to the width of the 6th abdominal segment (Fig.1.4) and to the depth of the 'crusher' chela propodus (Fig. 1.3b).

On the basis of these criteria, individual crabs were allocated to 1 of 4 post-larval growth phases which were defined as follows:-

FIG. 1.3

LOG_{10} x LOG_{10} SCATTERGRAMS OF CARAPACE WIDTH VS. DEPTH OF THE 'CRUSHER' CHELA PROPODUS OF MALE (a) AND FEMALE (b) *S. SERRATA* FROM MORETON BAY

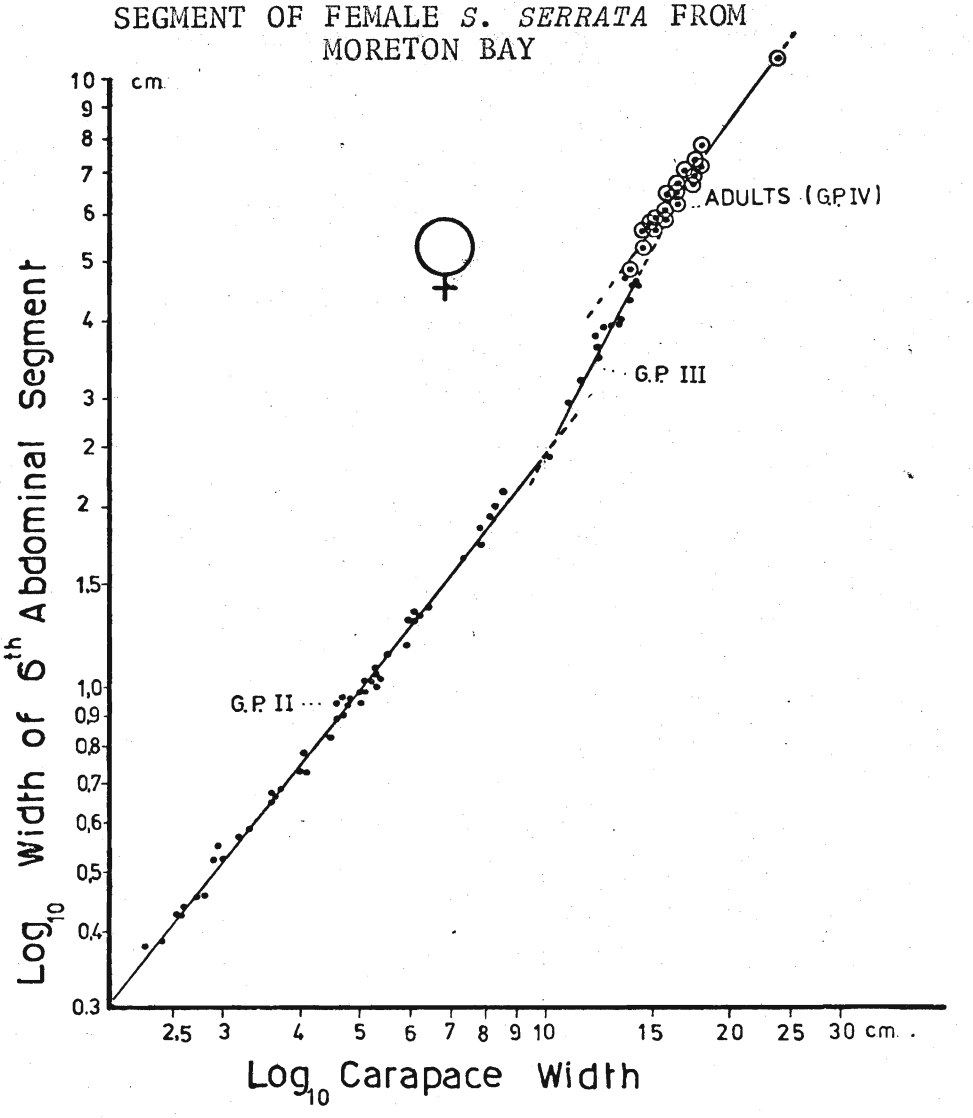




N.B. Four distinct growth phases embracing approximate carapace width ranges of ≤2 cm (G.P.I); 2→10 cm (G.P.II); 10→16 cm (G.P.III) and 14→19 cm (G.P.IV) are evident for males. Data of females do not however provide any distinction between females above and below 10 cm carapace width, i.e. only 3 distinct growth phases are evident.

FIG. 1.4

LOG_{10} x LOG_{10} SCATTERGRAMS OF CARAPACE WIDTH VS. WIDTH OF THE 6th ABDOMINAL SEGMENT OF FEMALE *S. SERRATA* FROM MORETON BAY



N.B. A clear distinction between juvenile female crabs above and below 10 cm carapace width, i.e. between G.P.III and G.P.IV, is provided by these data (compare Fig. 1.3b).

Growth phase one (G.P.I) - crabs of a carapace width less than 2.0 cm. Data of the linear dimensions of the 2 sexes were treated separately. Data of the weight dimensions of the 2 sexes, which were more limited, were pooled.

Growth phase two (G.P.II) - crabs of carapace widths in the range 2.0 cm to 10.0 cm. Data of the linear and weight dimensions of each sex were treated separately as were data of all larger crabs.

Growth phase three (G.P.III) - all juvenile females of carapace widths exceeding 10.0 cm and males of carapace widths exceeding 10.0 cm which do not conform with the definition of growth phase four males.

Growth phase four (G.P.IV) - all sexually mature females and 'massive clawed' males. These ranged from 13.0 cm carapace width upwards.

1.32 Secondary treatment

a) General

Carapace width was utilized as the standard 'reference' dimension for all other 'selected' linear dimensions. Total intact wet weight was adopted as the standard 'reference' dimension for all other 'selected' weight dimensions. Relationships between carapace width and total intact weight and carapace width and limbless weight, were also determined. To do this, Log_{10} transformed data were allocated to appropriate growth phases. These data were then subjected to least squares linear regression analysis