The Biology of *Callianassa (Trypaea) australiensis* Dana 1852 (Crustacea, Thalassinidea)

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I. Summary

Methods are described for collecting burrowing crustacea from intertidal sand flats by the use of "yabby pumps".

Ecological observations indicate the dominance of *Callianassa australiensis* in intertidal sand flats on parts of the east Australian coast.

Biometric data collected at different sampling sites over several years are analysed for growth and breeding activities, and the main events of the life cycle are outlined.

The possible over-exploitation of the species by bait collectors is shown to be very localized.

II. Introduction

Callianassid crustacea have been recorded from most of the oceans and from habitats which range from 400 fm. to between tidemarks (de Man, 1928). The genus *Callianassa* contains the greatest number of known species in the family, probably because several of its species are found on accessible intertidal mud and sand flats.

In North America callianassids are common on both the east coast (Lunz, 1937; Pearse, 1945; Pohl, 1946) and the west (Stevens, 1928, 1929; MacGinitie, 1930, 1934, 1949; Ricketts and Calvin, 1948; Barnard and Hartman, 1959), and here most of the previous ecological work has been done. They have also been reported in quantities in Africa from both the east coast (Day and Morgans, 1956; Macnae and Kalk, 1958; Broekhuysen and Taylor, 1959) and the west (Monod, 1927). In less intensive studies their abundance has been noted in the Mediterranean (Popovici, 1940; Picard, 1957), northern European coasts (Gustafson, 1936; Lutze, 1938), and New Zealand (Ralph and Yaldwyn, 1956).

Although specimens are numerous in many of these areas, when the present work commenced there were no literature records which suggested population densities approaching those observed for *Callianassa australiensis* along the Australian coasts of New South Wales and Queensland. However, recent works by Day and Morgans (1956) and by Broekhuysen and Taylor (1959) suggest similar densities in South Africa.

In eastern Australia, *Callianassa* can be obtained in quantities with relative ease by using a local invention (the "yabby pump") which will be described. Previous workers have either dug callianassids with spades (Stevens, 1928, 1929; MacGinitie, 1930, 1934, 1949; Lunz, 1937; Pearse, 1945; Pohl, 1946; Day and Morgans, 1956) or referred to specimens stranded after storms (Popovici, 1940), to migrating specimens collected in midwater (Monod, 1927), or to material obtained by bottom samplers (Barnard and Hartman, 1959).

In view of its abundance, the east Australian coast is particularly suited for studies on the biology of *Callianassa*. Only three such studies have been made in this area; that of Dakin and Colefax (1940) on planktonic stages; and the generalized accounts of Dakin, Bennett and Pope (1952) and of Stephenson (1957).

Callianassa australiensis is known in southern New South Wales as the "ghost-nipper" (Dakin, Bennett and Pope, 1952), and in northern New South Wales and Queensland as the "yabby" (a word of aboriginal origin also applied to freshwater crayfish).

The sale of yabby pumps and live yabbies for bait is an important aspect of amateur angling in southern Queensland and northern New South Wales. As bait, the species is taken readily by most demersal fish and especially by bream (*Mylio australis* Gunther), tarwhine (*Rhabdosargus sarba* Forskål) and whiting (*Sillago* spp.). Yabbies are collected in such numbers from accessible "yabby beds" in Moreton Bay for the possibility of over-exploitation to exist. Data were collected on growth and reproduction to investigate this possibility.

III. METHODS

(i) *Planktonic specimens*

Plankton was collected from Dunwich Pier (Fig. 1) with a plankton net (length 4 ft., opening diameter 15 in., c. 75 meshes/in.) towed against an ebbing tide of c. $1\frac{1}{2}$ knots. Subsurface horizontal hauls of c. 30 min. duration were made at monthly intervals.

The numbers of different larval stages (see Dakin and Colefax, 1940) in each haul were recorded. Total length, carapace lengths, and maximum depths of first pereiopods of the formalin preserved material were measured (by calibrated *camera lucida*) to the nearest 0.05 mm.

(ii) *Post-planktonic specimens*

(*a*) *Collecting methods*

Shallow-burrowing juveniles were washed from sand which had been dug with spades or trowels.

The larger, deep-burrowing individuals were collected with yabby pumps.

The earlier model (Plate 1, Fig. 1) is a galvanised-iron tube (c. 4 in. diameter, c. 24 in. long) with a circular plate containing two $\frac{1}{4}$ in. thumb holes enclosing the top and with a handle of galvanised-iron tubing (c. $\frac{1}{2}$ in. diameter). With thumb holes uncovered, the pump is pushed deeply into the substratum (Plate 1, Fig. 2). The thumb holes are covered, and the core of sand is extracted (Plate 1, Fig. 3), then discarded with the thumb holes uncovered (Plate 1, Fig. 4). The pump is re-inserted rapidly into the hole in the sand, and the contents removed two or three times. Yabbies are picked from the spoil of the later pumpings. This pump is cheap and robust, but is inefficient in loosely-packed sand, and fatiguing to operate.

The later model (Plate 1, Fig. 1) is a brass syringe (c. 2 in. diameter, c. 24 in. long). The plunger has a handle attached to a rubberised washer which can be adjusted with a thumb screw. The pump is pushed into the sand and the plunger simultaneously withdrawn to give slight suction (Plate 1, Fig. 5). The core of sand is removed and discarded by pushing down the handle (Plate 1, Figs. 6, 7). The tube is re-inserted into the hole, the plunger pulled out vigorously, the spoil discarded, and the process repeated. The yabbies are finally picked from the spoil. The pump can be used in about 18 in. of water, and in relatively loose sand, but is relatively costly (c. £A2/10/-) and the washers need frequent attention.

Neither pump is effective: (1) if there are too few burrows and little free liquid (two burrows per 0.1 m.^{2} represents approximately the lowest density for effective operations); (2) in substrata where most of the particle diameters are greater than c. 0.5 mm. (here either insufficient suction is obtained to dislodge the yabbies or the pumps do not penetrate).

Where these restrictions prevented collection of samples, the presence of specimens was recognized by their characteristic burrows.

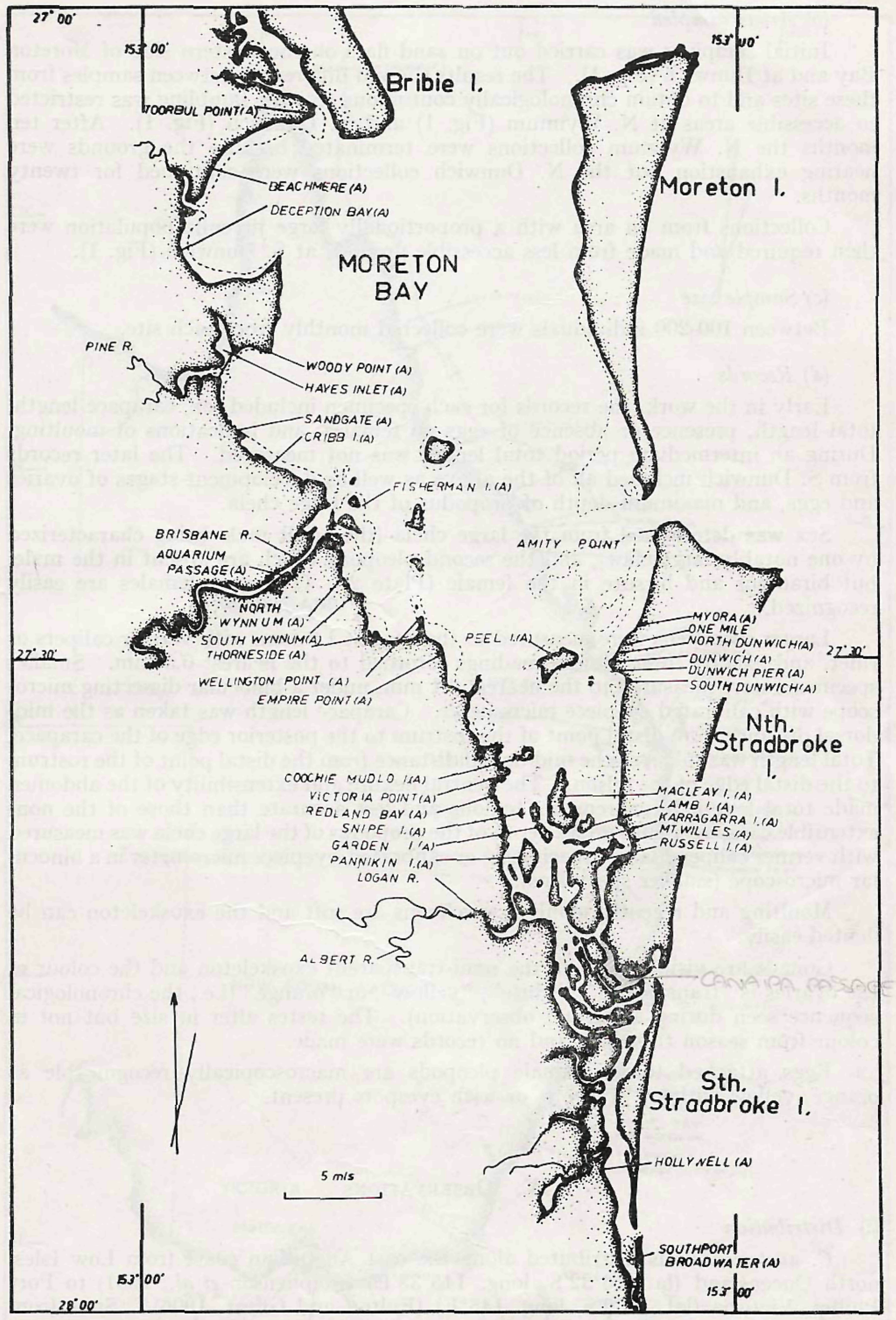

FIG. 1.—Map of Moreton Bay showing sites from which *C. australiensis* has been collected by the authors. These are indicated by "A".

(*b*) *Areas sampled*

Initial sampling was carried out on sand flats on the western side of Moreton Bay and at Dunwich (Fig. 1). The results showed differences between samples from these sites and to obtain chronologically continuous records, sampling was restricted to accessible areas at N. Wynnum (Fig. 1) and N. Dunwich (Fig. 1). After ten months the N. Wynnum collections were terminated because the grounds were nearing exhaustion but the N. Dunwich collections were continued for twenty months.

Collections from an area with a proportionally large juvenile population were then required and made from less accessible grounds at S. Dunwich (Fig. 1).

(*c*) *Sample size*

Between 100-200 individuals were collected monthly from each site.

(*d*) *Records*

Early in the work, the records for each specimen included sex, carapace length, total length, presence or absence of eggs on females, and indications of moulting. During an intermediate period total length was not measured. The later records from S. Dunwich included all of the above as well as development-stages of ovaries and eggs, and maximum depth of propodus of the large chela.

Sex was determined from the large chela (the adult male being characterized by one notably large claw), and the second pleopods which are absent in the male, but biramous and hirsute in the female (Plate 2). Ovigerous females are easily recognized.

Larger specimens were measured to the nearest 1.0 mm. with vernier calipers or ruler, and exactly intermediate readings recorded to the nearest 0.5 mm. Smaller specimens were measured to the nearest 0.1 mm. under a binocular dissecting microscope with calibrated eyepiece micrometer. Carapace length was taken as the mid-dorsal distance from distal point of the rostrum to the posterior edge of the carapace. Total length was taken as the mid-dorsal distance from the distal point of the rostrum to the distal edge of the telson. The ventral flexure and extensibility of the abdomen made total length measurements tedious and less accurate than those of the non-extensible carapace. Maximum depth of the propodus of the large chela was measured with vernier calipers (larger specimens) or calibrated eyepiece micrometer in a binocular microscope (smaller specimens).

Moulting and recently moulted specimens are soft and the exoskeleton can be dented easily.

Gonads are visible through the semi-transparent exoskeleton and the colour of the ovaries is "transparent", "white", "yellow", or "orange" (i.e., the chronological sequence seen during aquarium observation). The testes alter in size but not in colour from season to season and no records were made.

Eggs attached to the female pleopods are macroscopically recognizable as orange, yellow without eyespots, or with eyespots present.

IV. OBSERVATIONS

(i) *Distribution*

C. australiensis is distributed along the east Australian coast from Low Isles, north Queensland (lat. 16°32′S, long. 145°33′E) (Stephenson *et al.*, 1931) to Port Phillip, Victoria (lat. 38°2′S, long. 145°E) (Fulton and Grant, 1906). Sites from which specimens have been collected are shown in Figures 1 and 2.

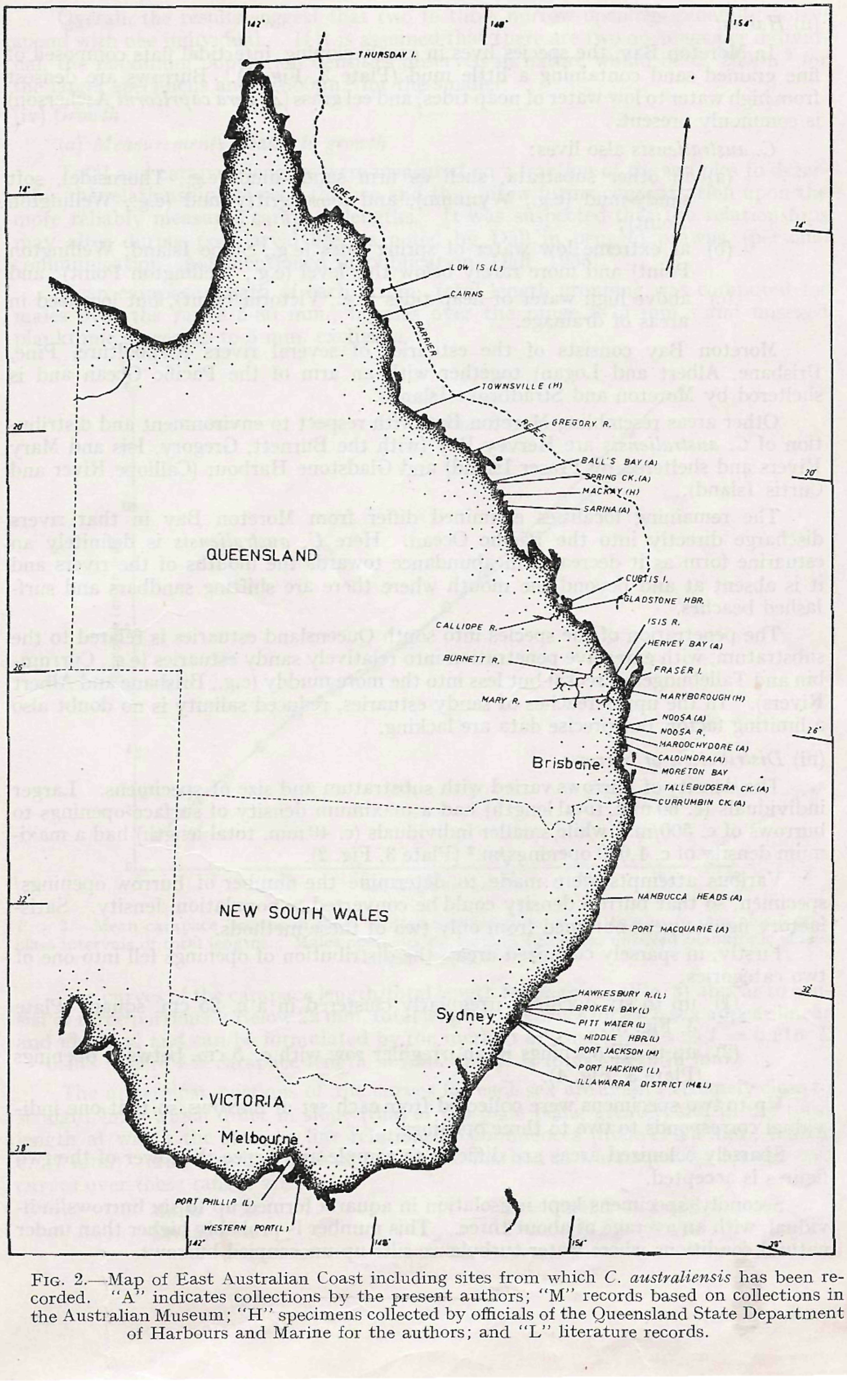

FIG. 2.—Map of East Australian Coast including sites from which *C. australiensis* has been recorded. "A" indicates collections by the present authors; "M" records based on collections in the Australian Museum; "H" specimens collected by officials of the Queensland State Department of Harbours and Marine for the authors; and "L" literature records.

(ii) *Habitat*

In Moreton Bay, the species lives in gently sloping, intertidal flats composed of fine grained sand containing a little mud (Plate 3, Fig. 1). Burrows are densest from high water to low water of neap tides, and eel grass (*Zostera capricorni* Ascherson) is commonly present.

C. australiensis also lives:

(a) in other substrata, such as firm sandy-mud (e.g., Thornside), soft sandy-mud (e.g., Wynnum), and loose gritty-mud (e.g., Wellington Point);

(b) at extreme low water of spring tides (e.g., Snipe Island, Wellington Point) and more rarely below this level (e.g., Wellington Point); and

(c) above high water of neap tides (e.g., Victoria Point), but localized in areas of drainage.

Moreton Bay consists of the estuaries of several rivers (Caboolture, Pine, Brisbane, Albert and Logan) together with an arm of the Pacific Ocean and is sheltered by Moreton and Stradbroke Islands.

Other areas resembling Moreton Bay with respect to environment and distribution of *C. australiensis* are Hervey Bay (with the Burnett, Gregory, Isis and Mary Rivers and sheltered by Fraser Island) and Gladstone Harbour (Calliope River and Curtis Island).

The remaining localities examined differ from Moreton Bay in that rivers discharge directly into the Pacific Ocean. Here *C. australiensis* is definitely an estuarine form as it decreases in abundance towards the mouths of the rivers and it is absent at and beyond the mouth where there are shifting sandbars and surf-lashed beaches.

The penetration of the species into south Queensland estuaries is related to the substratum, with extensive penetration into relatively sandy estuaries (e.g., Currumbin and Tallebudgera Creeks) but less into the more muddy (e.g., Brisbane and Albert Rivers). In the upper reaches of sandy estuaries, reduced salinity is no doubt also a limiting factor, but precise data are lacking.

(iii) *Distribution of burrows*

The density of burrows varied with substratum and size of specimens. Larger individuals (c. 60 mm. total length) had a maximum density of surface openings to burrows of c. 500/m.^{2}, while smaller individuals (c. 40 mm. total length) had a maximum density of c. 1,000 openings/m.^{2} (Plate 3, Fig. 2).

Various attempts were made to determine the number of burrow openings/specimen, so that burrow density could be converted to population density. Satisfactory figures were obtained from only two of these methods.

Firstly, in sparsely colonized areas, the distribution of openings fell into one of two categories:

(1) up to six openings irregularly clustered in a c. 25 cm. square (Plate 3, Fig. 3);

(2) up to six openings in an irregular row with c. 5 cm. between openings (Plate 3, Fig. 4).

Up to two specimens were collected from each set of burrows, so that one individual corresponds to two to three openings.

Sparsely colonized areas are difficult to sample and hence the lower of the two figures is accepted.

Secondly, specimens kept in isolation in aquaria formed up to six burrows/individual, with an average of about three. This number is probably higher than under natural conditions where water turbulence silts up unoccupied burrows.

Overall, the results suggest that two to three burrow openings generally correspond with one individual. If it is assumed that there are two openings per individual, the maximum population densities observed in nature would be c. 250/m.^{2} for the larger specimens and c. 500/m.^{2} for the smaller.

(iv) *Growth*

(*a*) *Measurements related to growth*

Total and carapace lengths were measured on a fraction of the samples to determine the relationship between the two and thus allow future concentration upon the more reliably measured carapace lengths. It was suspected that the relationships may alter during post-larval life, as noted by Dall in penaeid prawns (personal communication—not mentioned in publication, Dall, 1958).

Mean carapace length of each 5 mm. total length grouping was computed for males over the range 5-80 mm., females over the range 5-75 mm., and unsexed planktonic stages up to 5 mm. exclusive.

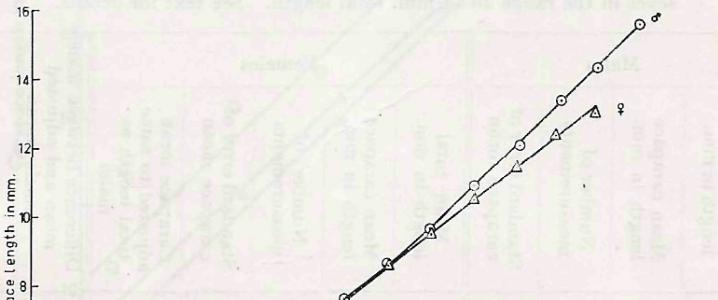

FIG. 3.—Mean carapace lengths in mm., plotted against mean total lengths, in mm., for 5 mm. class intervals of total lengths. Males open circles, females triangles, unsexed planktonic stages closed circles.

The curves of the carapace length/total length for each sex (Fig. 3) appear to consist of three portions. Below 22 mm. total length the curves for each sex appear linear and identical and can be formulated by the method of least squares as $\boldsymbol{l} = 0.216\ L + 0.458$ (where $\boldsymbol{l}$ is carapace length in mm. and L is total length in mm.).

The uppermost portions of the curves for each sex are again extremely close to straight lines which differ in slope (that of the male being greater) and in the total length at which the straight line relationship commences (male c. 47 mm., female c. 37 mm.). The formulae (calculated by the method of least squares) for the two curves over these ranges are:

Males . . . . $\boldsymbol{l} = 0.242L - 1.686$
Females . . . . $\boldsymbol{l} = 0.197L + 0.410$

The central portion of the graph for each sex shows a curved transition from the lower to the upper straight lines, the curvature being more abrupt in the female graph.

Formulae for these curved portions were not obtained but instead equivalent points on the two curves were compared to determine the smallest total length at *which males were significantly different from females.* Because the mean total length for each group of females is unlikely to be the same as that of the males, an adjustment to the female data is necessary. This was effected by (1) determining the tangent to the female curve at a given point by reference to the graph (Fig. 3), (2) from the difference between the male and female mean total lengths, calculating the equivalent difference to be expected in the female mean carapace length, and (3) adjusting the female mean carapace length accordingly.

TABLE 1

Comparison of relationship between carapace lengths and total lengths for the two sexes in the range 25-44 mm. total length. See text for details.

Class interval total length in mm.	Males				Females					Difference between male mean and adjusted female mean	Probability level of significance of difference
	Mean total length in mm.	Mean carapace length in mm.	Number of measurements	Standard error of carapace mean	Mean total length in mm.	Mean carapace length in mm.	Number of measurements	Standard error of carapace mean	Carapace mean adjusted to same total length as males		
25–29	27·14	6·06	79	0·0875	27·14	5·85	44	0·1082	—	0·21	13%
30–34	31·75	6·75	76	0·0707	32·24	6·69	62	0·0603	6·61	0·14	14%
35–39	36·96	7·65	129	0·0168	37·13	7·55	105	0·0187	7·44	0·21	$<<0·1\%$
40–44	41·91	8·70	140	0·0535	42·07	8·64	154	0·0475	8·61	0·09	21%

The data are given in Table 1 which shows a significant difference only in the 35-39 mm. class interval. The fact that the points in the 25-29 mm. and 30-34 mm. class intervals both show the same tendency and are both only slightly below the level of significance is taken to indicate that the real point of divergence may lie at 30 mm., or possibly as low as 25 mm. (total length).

Summarizing, the above data show:

(1) that relationships between carapace length and total length are complex;

(2) conversions from carapace length to total length are more easily effected graphically than by calculation;

(3) there is a conspicuous divergence of male and female curves at a total length of c. 47 mm., above which the male carapaces are noticeably longer than the female carapaces;

(4) *over the range c. 30-47 mm. total length, the male carapaces are slightly* longer than the female carapaces, and this tendency may commence at a total length of c. 25 mm.;

(5) at the following approximate total lengths there appear to be changes in the form of the curve of carapace length/total length:
male 22 mm., 47 mm.; female 22 mm., 37 mm.

Since sex ratios differed between the three main collecting areas, the possibility of similar differences in carapace length/total length relationships was investigated.

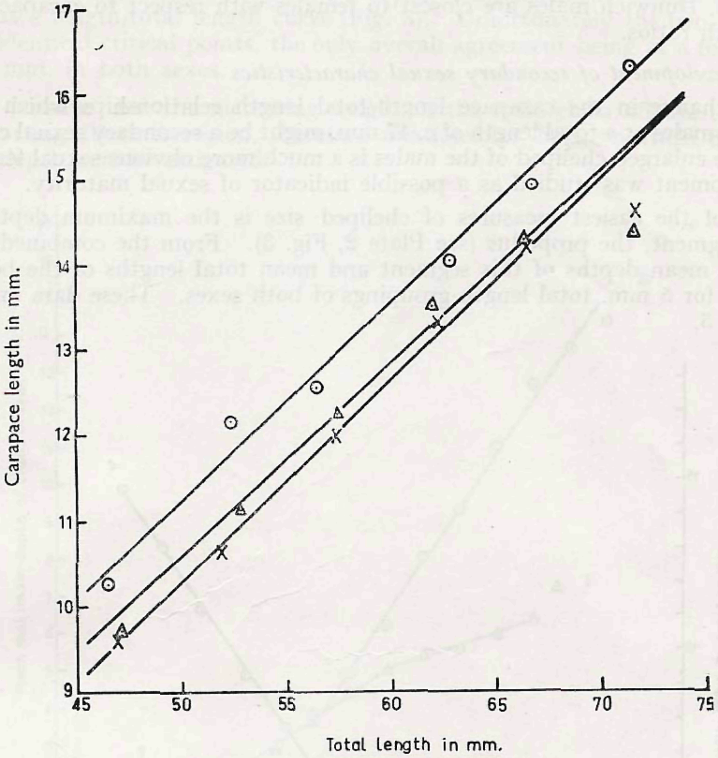

FIG. 4.—Mean carapace lengths in mm., plotted against mean total lengths in mm. (5 mm. class intervals) for males (45-74 mm. total length range) from the three main sampling sites. *N. Wynnum* open circles, *N. Dunwich* triangles, *S. Dunwich* crosses.

The analysis was restricted to the upper portions of the male curves with total lengths above 45 mm. and the relevant data are plotted on Figure 4. The formulae of the best fitting lines (calculated by the method of least squares) for each sampling area are:

N. Wynnum . . . . . . $l = 0.2352\,L - 0.5154$
N. Dunwich . . . . . . $l = 0.2273\,L - 0.7839$
S. Dunwich . . . . . . $l = 0.2377\,L - 1.5974$

A test for significance of differences between N. Dunwich and S. Dunwich values was made. Mean values of carapace length were calculated and a correction factor (based upon the slope of the curves) was applied to bring each to a common total length suitable for comparison.

The difference between the corrected values was highly significant (less than 0.001 level, t. test). Thus the males from N. Dunwich and S. Dunwich in the 45-74 mm. total length range constitute different populations with respect to the carapace length/total length relationship.

Since the best fitting straight line to the N. Wynnum data is situated further from either of the Dunwich lines than they are from each other, the N. Wynnum data indicate that another separate population is there present.

The S. Dunwich males are closest to females with respect to carapace length/total length ratios.

(*b*) *Development of secondary sexual characteristics*

The change in the carapace length/total length relationships which becomes obvious in males at a total length of c. 47 mm. might be a secondary sexual characteristic. The enlarged cheliped of the males is a much more obvious sexual feature and its development was studied as a possible indicator of sexual maturity.

One of the easiest measures of cheliped size is the maximum depth of the deepest segment, the propodus (see Plate 2, Fig. 3). From the combined Moreton Bay data, mean depths of this segment and mean total lengths of the body were computed for 5 mm. total length groupings of both sexes. These data are plotted on Figure 5.

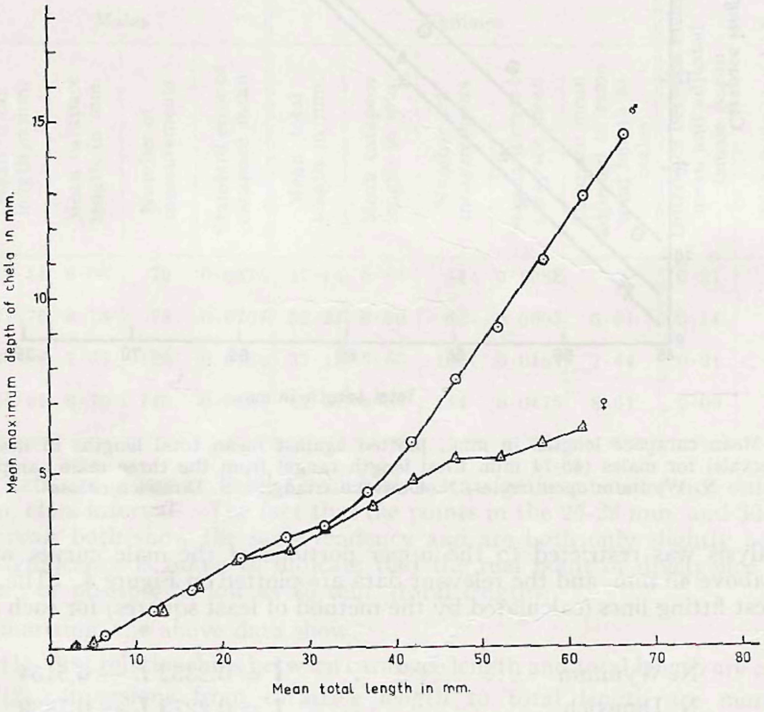

FIG. 5.—Mean maximum depths of the larger chelipeds in mm., plotted against mean total lengths in mm. (5 mm. class intervals). Males open circles, females triangles.

Each graph approximates to a series of straight lines with abrupt inflections between them. Up to a total length of c. 22 mm. the two sexes follow the same curve, but thereafter differ. In the female curve three straight line portions are recognizable, these being roughly parallel to each other, and with two marked inflections in the total length ranges between c. 22-27 mm. and c. 47-52 mm. In the male curve two straight line portions are recognizable, the upper having a greater slope than the lower. The transition from one line to the other covers a broad range (c. 27-37 mm. total length).