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Stomatopod By-catch from Prawn Trawling in Moreton Bay, Australia

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Abstract

Eight species of the order Stomatopoda were identified in the by-catch of a Moreton Bay prawn trawl survey between 1988 and 1990. Of these stomatopods six species are marketed as commercial by-catch. The catch (by weight) of stomatopods over the sample period was one sixth that of the penaeid catch and at three of the nine sampling stations they made up over one quarter. Stomatopods were most abundant during December to February with numbers declining dramatically during winter (a trend similar to the penaeid catches). The most abundant species (*Oratosquilla stephensoni*) exhibited bi-modal length frequency distributions, suggesting the presence of two age cohorts. Length frequency analysis indicated that *O. stephensoni* exhibited fast growth (L_∞=163mm, k=1.52 year^{-1}) and a high total instantaneous mortality rate (3.8-4.7 year^{-1}) with an estimated life span of approximately 2.5 years. The importance and utilisation of stomatopods as a marketable by-catch is also discussed.

Introduction

Stomatopods, or mantis shrimps (Crustacea: Stomatopoda), are fished commercially in many parts of the world particularly Japan (Kubo et al. 1958; Yamazaki 1990), North Africa and the Mediterranean (Abello' and Martin 1993). In Australia, stomatopods are found in virtually all coastal marine waters (Jones and Morgan 1994) and in recent years they have become more common in Australian fish markets, although they comprise a minor by-catch component of prawn trawl fisheries in general. Logbook records of Queensland commercial trawl fishers (CFISH[1]) indicate that only three tonnes were marketed over the four year period between 1988 and 1992, and one tonne between

[1]*Logbook information from commercial fishers is recorded by QDPI on a database known as CFISH.*

1994 and 1995. However, in some areas of Moreton Bay they can comprise a major component of the crustacean trawl catch.

Grant (1993), refers to stomatopods from Moreton Bay as "scientific curiosities" until the advent of otter trawling for prawns, indicating the status of stomatopods before prawn trawling operations compared to their present utilisation in Australia. Stomatopods in Moreton Bay are not a target species, nor are they currently a widely marketed resource within Australia when considering their commercial application in the Japanese sushi market (Yamazaki 1990) or their economic importance as dried poultry feed in India (James and Thirumilu 1993). Their comparatively lower status in Australia appears to be a result of both low local marketing potential and variation in catch. For example, Pender et al. 1992, identifies stomatopods caught as by-catch in Australia's Northern Prawn Fishery (NPF) as having a minor potential in Australia's seafood market due to low catch weights (which may reflect their abundance) and insufficient continuity of supply to markets due to seasonally varying catch rates and closures in fishing season. However, stomatopods recorded in databases of prawn trawl fisheries may not be accurately represented in logbook returns, which tend to focus more on the penaeid catch, and in other areas their relative abundance is not well known nor their biology well understood.

Considering the importance and widespread acceptance of stomatopods in the Asian market the species present in Australia could be a potential export resource depending on the level of sustainable harvest, while other avenues exist such as aquaculture where fast growing species are advantageous. Additionally, the utilisation of these stomatopods, which are a non targeted species, is significant in terms of reducing discards in prawn trawl operations. At present there is little information on stomatopods in Australia. Here we describe population aspects of a number of common species in Moreton Bay and present information on growth and mortality of *Oratosquilla stephensoni*.

Methods

Stomatopod sampling

Stomatopods were collected during a Queensland Department of Primary Industries (QDPI) prawn sampling program, conducted within Moreton Bay from December 1988 to July 1990. Nine stations in areas utilised by commercial prawn trawlers (Figure 1) were sampled on the new and full moon, each lunar month, in order to avoid variations in catch due to lunar periodicity. The trawl gear consisted of 2 four-fathom nets; the starboard side was a standard 40 mm commercial mesh size, and a 31 mm mesh size for selecting smaller species was used on the port side. Stations were sampled for thirty minutes bottom time at approximately 1.3 $m \cdot second^{-1}$ ground speed.

Stomatopods were separated from the catch and frozen on board. In the laboratory, samples were identified to species, weighed (wet weight of undamaged whole samples), sexed and measured (from the base of the rostrum to the

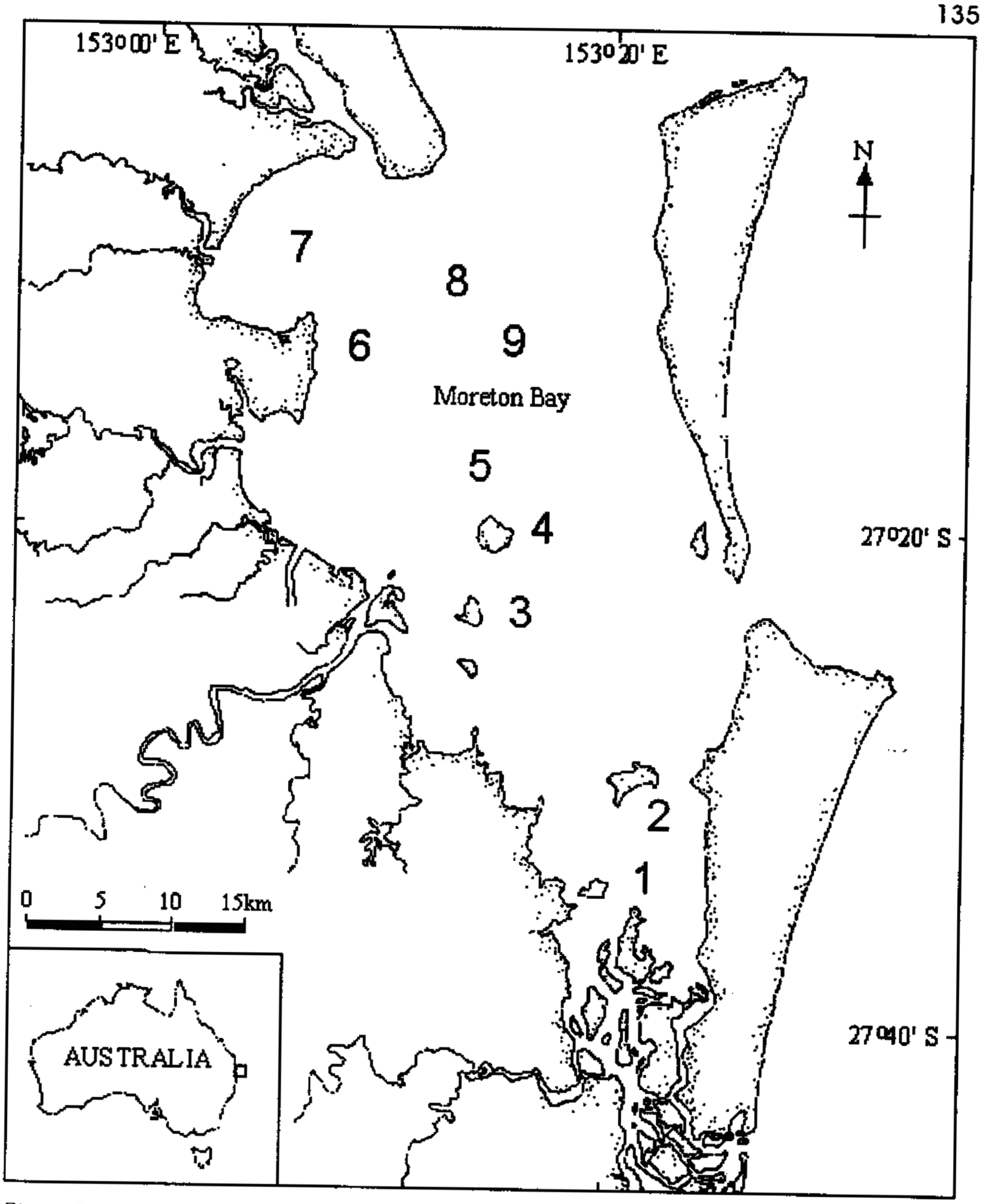

Fig. 1. Sample station locations within Moreton Bay.

posterior edge of the telson). The shell hardness of individuals was classified as either hard (those individuals whose exoskeleton was hard and rigid) or soft (pre or post moult with flexible or soft exoskeleton). Wet weights of commercial penaeid species were also recorded.

Data analysis

One way analyses of variance (ANOVA) were performed to test for differences in mean weight among stations. Tukey's multiple comparison tests were applied to test for catch weight differences among sample stations. Paired t tests were performed to indicate if there were any differences ($P<0.05$) between sexes in the length-weight relationships. Chi squared tests ($P<0.05$) were used to determine if any differences in sex ratio occurred for each sample month.

Estimates of $L\infty$ (asymptotic length), k (growth rate per year) and Z (annual total instantaneous mortality) were obtained for *O. stephensoni*. An approximation of $L\infty$ was gained using the largest individual $(L_{max})/0.95$ (King 1994). This approximation assumes that the sample (on which this estimation of $L\infty$ is based) is large and from an unexploited or lightly exploited stock (King 1994). A Wetherall plot was used to estimate the Z/k relationship, $L\infty$ and Z via the Beverton and Holt Z formula used in a regression plot (Wetherall 1986, Wetherall *et al.* 1987, King 1995). Independent estimates of Z were derived from length based catch curves where Z is the negative slope of the plot of relative age against the natural logarithm of frequency/change in age (Pauly 1983, King 1995). Values for k were determined from a plot of relative age against $-Ln[1-Lt/L\infty]$. Data for this method were obtained from modal progression of monthly length-frequency distributions (King 1995).

Results

Eight species of Stomatopoda were identified, six of which are currently marketed with the catch from prawn trawl fisheries in Moreton Bay (Table 1). The catch of stomatopods over the sample period was one sixth that of the penaeid catch. *O. stephensoni* and *Alima laevis* were the two most common species accounting for 81% of the total stomatopod catch. *Harpiosquilla stephensoni* was the largest stomatopod sampled (mean length 195 mm) however, only 21 individuals of that species were caught. Of the stomatopods sampled, four species (*O. stephensoni*, *Oratosquilla interrupta*, *Anchisquilla fasciata* and *A. laevis*) were captured in sufficient quantities to allow a more detailed analysis.

Analyses of variance and Tukey's multiple comparison methods indicated that the greatest number of marketable stomatopods (*O. stephensoni*, *A. laevis*, *O. interrupta*, *Erugosquillina woodmasoni*, *H. stephensoni* and *Raoulius cultrifer*) were caught at station five, the deepest station, followed by both stations two and four (Figure 1). Eighty seven percent of all stomatopods captured at station one were *O. stephensoni*, with little representation from the other stomatopod species. The greatest diversity in the number of species occurred at station nine where there was a more even distribution of the four most numerous species (*O. stephensoni*, *O. interrupta*, *A. fasciata* and *A. laevis*), again with *O. stephensoni* being the most abundant (51% of the stomatopod catch for that station). All of the remaining stations (stations two-eight) had a prevalence of three species making up 95 to 99% of the stomatopod abundance at each station, with *O. stephensoni* always present as one of the three most abundant stomatopods (Figure 2).

There were no significant differences (t test, $P>0.05$) in abundance between sexes for any monthly sample, however, stomatopod abundance varied

Table 1. Stomatopods sampled, their relative overall abundances and length - weight relationships of the cubic curve equation ($W = aL^b$). The coefficient of determination (r^2) for the relationship between the natural logarithms of length and weight (with the 95% confidence limits of parameter b).

Stomatopod species:	Percentage of Total	Constant a (10^{-3}xN)	Constant b	r^2	95% confidence intervals of b
Oratosquilla stephensoni (Manning 1978)*	53.95	7.774	2.975	0.976	2.868 - 3.082
Alima laevis (Hess, 1865)*	27.15	13.089	2.746	0.845	2.523 - 2.968
Anchisquilla fasciata (de Hann, 1844)	11.01	8.549	2.94	0.899	2.796 - 3.085
Oratosquilla interrupta (Kemp 1911)*	6.78	6.943	3.041	0.971	2.944 - 3.138
Erugosquillina woodmasoni (Kemp 1911)*	0.66	7.373	3.021	0.993	2.958 - 3.086
Harpiosquilla stephensoni (Manning 1969)*	0.2	32.322	2.307	0.378	1.795 - 2.819
Clorida granti (Stephenson 1953)	0.14	9.298	2.954	0.921	2.816 - 3.091
Raoulius cultrifer (White, 1850)*	0.12	22.126	2.525	0.869	2.410 - 2.641

*Indicates those species presently marketed

Table 2. Stomatopod weight, abundances and ratio of the stomatopod to penaeid catch at each sampling station.

Sample station	Depth range (m)	Weight Kg/station	Ratio of Stomatopod catch to penaeid catch	Number of Stomatopod species (of 8 species found)	Number of individuals
1	4-5	5	1:9	7	516
2	5-6	14	1:4	6	838
3	8-10	12	1:6	7	1026
4	10-11	28	1:4	7	1978
5	16-18	34	1:4	6	2146
6	7-8	12	1:10	6	1058
7	5-6	9	1:14.25	6	778
8	6-8	8	1:16.67	6	870
9	9-10	16	1:6	6	1021

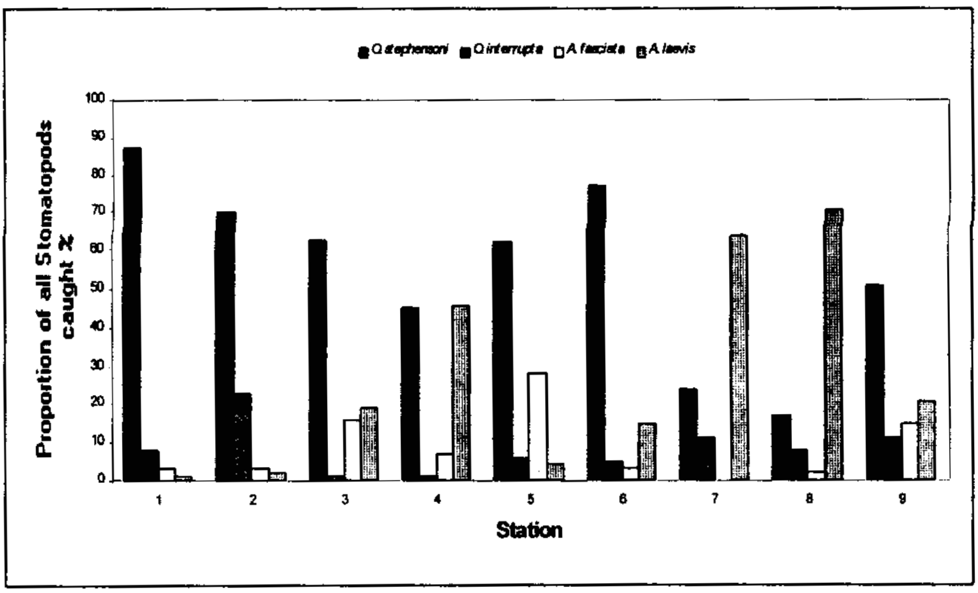

Fig. 2. Proportion of all stomatopods caught at each station (the four most abundant species are displayed).

seasonally over the sample period (Figure 3). There was a sharp decline in numbers around July and August in both years (and June 1990). Following this decline, the abundance of *O. stephensoni* in particular, as well as *A. laevis*, *A. fasciata* and to a lesser extent *E. woodmasoni* increased during September and October as summer approached.

Moulting activity, as indicated by the percentage of soft shelled individuals, did not appear to vary seasonally over the 20 month sampling period. The monthly abundance of stomatopods fluctuated from 1 to 16 percent but at least some soft shelled individuals were present in all sample months (Figure 3).

Length-weight relationships are presented in Table 1. The length-weight analysis was based on combined male and female data since an ANOVA indicated that there were no significant differences (P>0.05) between sexes for all species tested. Six of the eight stomatopods (Table 1) were found to have a cubic relationship between length and weight, confirming isometric growth (ie; b values in the cubic equation were close to three or were incorporated in the 95% confidence interval range). It is likely that the length - weight relationships derived for *Harpiosquilla stephensoni* and *Raoulius cultrifer* are inaccurate, as the data was insufficient for the length-weight analysis.

Length-frequency distributions of the four most abundant species indicate that fishing gear selectivity limited the sampling of small (< 40mm) individuals (Figure 4). Two separate modes were noticeable for *O. stephensoni* and *O. interrupta*, however *O. stephensoni* was the only species for which sufficient data was collected to allow growth estimation from modal progression of monthly length frequency distributions (Figure 5). Estimates of L∞ and k for *O. stephensoni* produced utilising different methods (Table 3), confirmed relatively high growth rates. These growth parameters were used in a von Bertalanffy

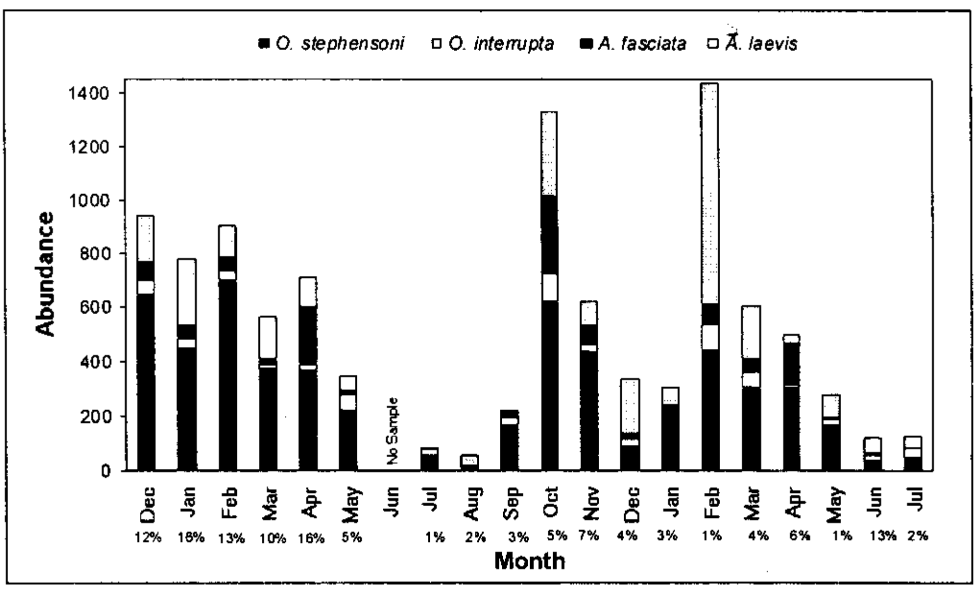

Fig. 3. Abundance of the main species over the sampling period. Percentage values represent the proportion of "soft" exoskeleton individuals.

Table 3. Estimations of the parameters L_∞: asymptotic length (mm), k: growth rate /yr, the Z/k relationship and Z: the total instantaneous mortality rate/yr for the stomatopod *O. stephensoni*.

Application	Parameter	Estimate
L max/0.95	L_∞	174.80
Slope of the von Bertalanffy plot: -Ln[1-Lt/(Lmax/0.95)] against relative age	k	1.33
Wetherall plot	L_∞	162.77
Slope of the von Bertalanffy plot: -Ln[1-Lt/Wetherall L_∞] against relative age	k	1.52
Wetherall plot:	Z/k	2.92
	Z	3.87
Length converted catch curve:		
-Applying L_∞=174.80, k=1.33	Z	4.68
-Applying L_∞=162.77, k=1.52	Z	4.29

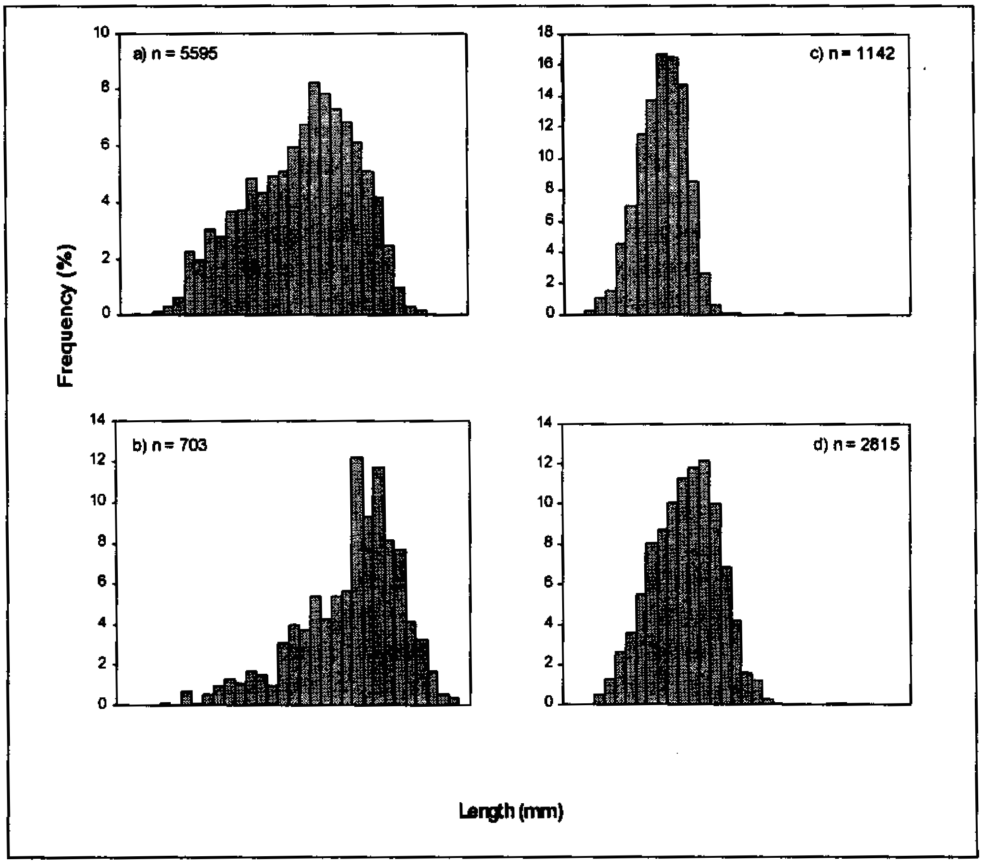

Fig. 4. Length - frequency distributions for all months of the main stomatopod species: a) *O. stephensoni* , b) *O. interrupta*, c) *A. fasciata*, and d) *A. laevis*.

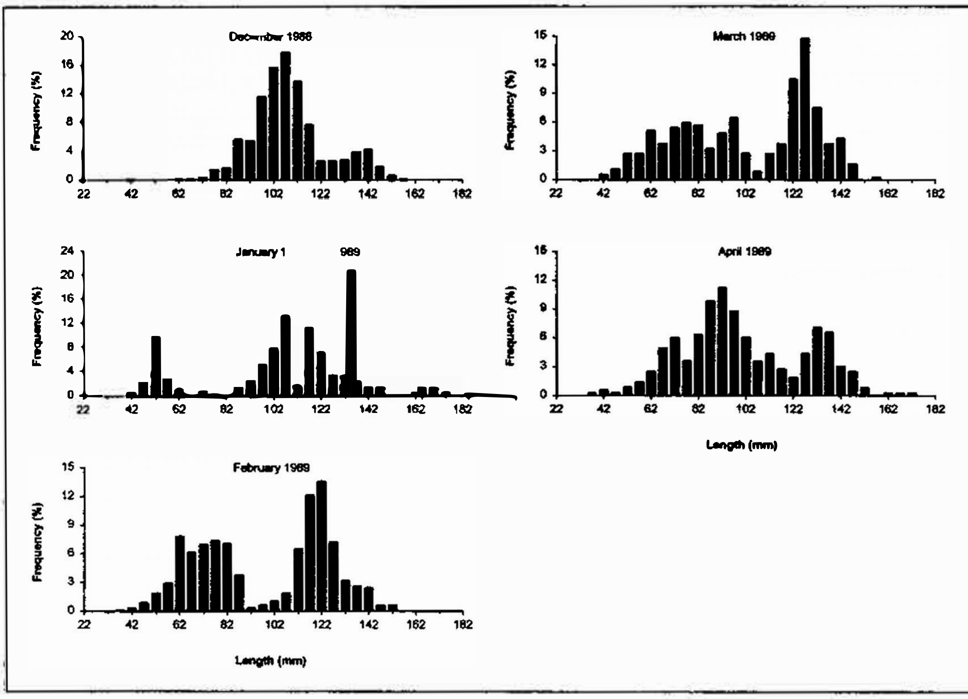

Fig. 5. Monthly length frequency distributions of *O. stephensoni*.

growth curve (Figure 6) revealing only minor variations in growth over the life span of this species when utilising both the estimated $L\infty$ and k values.

Estimations of the total instantaneous mortality rates for *O. stephensoni* (Table 3), produced from length based catch curves, ranged between 3.9 and 4.7 year^{-1}. The length based catch curve, utilising the growth parameters derived from the Wetherall plot and corresponding von Bertalanffy plot, produced the closest fitting regression (Figure 7). The age structure of the sample suggested a life span of approximately 2.5 years (30 months) for this species.

Discussion

Stomatopods are an incidentally captured species, but they are retained and utilised in the Moreton Bay prawn fishery. Nontarget species have in the past become a target species in response to market demand. This has occurred with Morton Bay bugs (*Thenus* spp) which were discarded until 1975 but are now a major by-product generating revenue greater than five million $Aust. (Anon. 1996). Utilisation of stomatopods as commercial by-catch is a practice that is economically important in reducing discards from prawn trawl operations, which may also lead to greater future market demand because of increased value and status as a seafood product (thus greater marketability). Pender et al. (1992) identified stomatopods as having minor seafood market potential in the NPF (most likely due to limited catch and low market demand). However, Pender and Willing (1990) commented on the current use

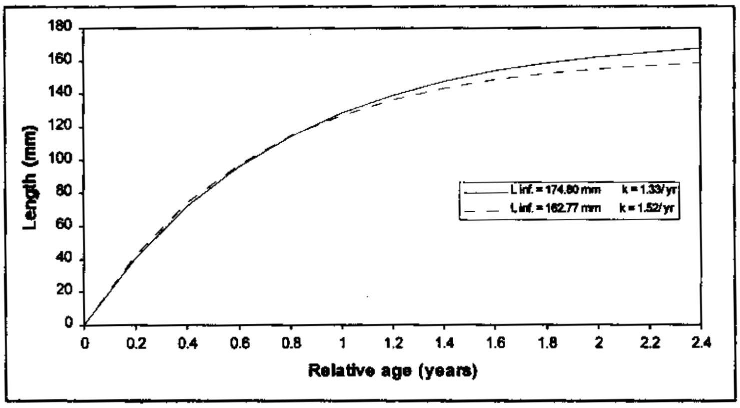

Fig. 6. von Bertalanffy growth curves for *O. stephensoni*. The two curves represent the derived growth trend using both estimations of L_∞ and k from the sample data.

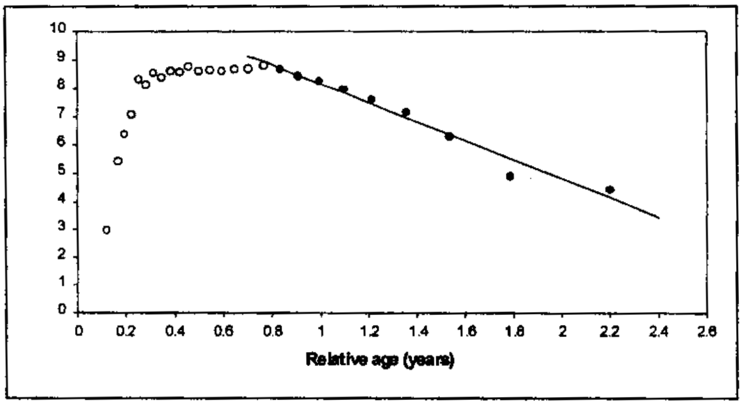

Figure 7. A length converted catch curve for *O. stephensoni* using L_∞ = 162.77 and k = 1.52/yr. The clear symbols represent data not used in calculating the regression as those stomatopods are not considered to have been fully recruited (r^2 = 0.974).

and potential of stomatopods as seafood in Brisbane markets. The utilisation of stomatopods in Moreton Bay may provide a market that enables stomatopod by-catch utilisation from the NPF to become more economically feasible.

The greatest stomatopod catch rates occurred during the summer months in both years. This trend is similar to previous work by Stephenson et al. (1982), who identified *O. stephensoni, E. woodmasoni, O. interrupta, A. laevis* and *R. cultrifer* as having greater abundances in mid December to mid January. The four most abundant species of this study have also been identified in previous studies by Jones (1986) and Stephenson et al. (1982).

Stomatopod catch declined dramatically during winter for both sexes and during both years. This trend could be the result of post spawning disappearance behaviour as observed for *Squilla mantis* in the north western Mediterranean (Abello' and Martin 1992). Alternatively, or possibly in conjunction, the decline observed in Moreton Bay during this period may also be the result of winter burrowing activity as observed in studies of the stomatopod *Squilla empusa* in the USA (Myers 1979). The low numbers of pre and post moult individuals in the catch may be related to moulting behaviour. Reclusive behaviour and burrowing is believed to reduce vulnerability to other aggressive stomatopods and predators (Reaka 1976), and thus protect them from the sampling gear during periods of moulting. Alternatively, if there is high activity before moulting and mobility immediately after moulting (Reaka 1975), then the sample trends presented could be expected (ie low numbers recorded moulting and seasonal variation in abundance). While stomatopods are burrowers, they are also highly active and many exhibit nocturnal activity (Froglia and Giannini 1989) explaining their vulnerability to trawling at certain times.

Different species of stomatopod frequently live in assemblages where as many as five to seven species occupy indistinguishable microhabitats in one area (Reaka 1976). A similar pattern of species assemblage appeared in Moreton Bay where each location harboured six or more species of stomatopod (refer to Table 2). Within these assemblages three species dominated with different combinations of dominant species at each location.

With the probable exception of *H. stephensoni* (largest species), stomatopod by-catch was composed primarily of adults. This was due to the gear being selective towards individuals of greater than approximately 50-mm length. Additionally, the von Bertalanffy curves for *O. stephensoni* most likely reflect adult growth since the curves extrapolated back to a zero length at zero age (refer to Figure 6; Results). Theoretically, if juveniles were represented then the stomatopod's age at zero length would be expected to have a negative value for faster growing juveniles or a positive value if juveniles grew more slowly than the predicted growth of adults (King 1995). If the current prawn trawl gear is selective toward stomatopod adults then juvenile mortality would not be a by-catch concern, however length at recruitment and gear selectivity trials would need to be carried out to confirm such an inference.

Monthly cohort analysis of *O. stephensoni* indicated bi-modal distribution of length classes indicating two distinct periods of spawning and recruitment are likely each year. These two cohorts coupled with the fast growing and short-lived population dynamics of *O. stephensoni* support that trend and would suggest a high turnover stock. This stomatopod is not targeted in Moreton Bay but its total mortality rate was similar to those of other intensively exploited shallow water shrimps and stomatopods (Abello' and Martin 1992; Edwards 1978; Pauly et al. 1984; Garcia 1985; Garcia and Le Reste 1986). These characteristics suggest that *O. stephensoni* may sustain a fishery similar in population characteristics to the penaeid species, but possibly having a lower biomass and yielding lower catch sizes.

Overall stomatopods are a presently utilised nontarget species in the Moreton Bay prawn trawl fishery (identified as commercial by-catch or by-product). Depending on the levels of sustainable harvest they are a potentially marketable export resource in that they are a recognised and utilised species in Asian seafood markets. The most abundant stomatopod species present in Moreton Bay, *O. stephensoni*, is a fast growing, short lived species (lifespan approximatly 30 months) characteristically similar to the target penaeid species trawled.

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