15 Species composition, spatial distribution, relative abundance and reproductive biology of mantis shrimps in Moreton Bay, Queensland

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15.1 Abstract

This chapter describes the species composition, spatial distribution, relative abundance and reproductive biology of mantis shrimps in Moreton Bay, Queensland. Eight different species of mantis shrimp were identified from trawl samples. Seasonal trends in the mean monthly reported landings indicated that higher catches were taken during the summer and autumn with catches decreasing to their lowest levels in winter. Timing/seasonality of spawning, size at maturity, sex ratios and morphological data are also discussed for *Oratosquilla stephensoni* and *O. interrupta.* The most abundant species sampled was *O. stephensoni,* which exhibited multi-modal length frequency distributions, suggesting the presence of multiple age cohorts. Seasonal reproductive data indicated that *O. stephensoni* and *O. interrupta* have an annual reproductive cycle with peak spawning from spring to summer. Changes in the frequency of mature *O. stephensoni* and *O. interrupta* and seasonal variations in GSI values suggested that these species may spawn at least twice during the spawning period. The length at first maturity for *O. stephensoni* and *O. interrupta* was 24 mm CL and 28 mm CL respectively. These results are discussed in relation to comparisons between species and other stomatopods, and provide invaluable biological information for assessing the sustainability of current exploitation rates of mantis shrimps within Moreton Bay.

15.2 Introduction

The order Stomatopoda is a group of at least 450 marine predatory crustaceans, commonly known as mantis shrimps. They have received their common name from the presence of large and powerful raptorial appendages, which they use to "spear" or "smash" prey (Ahyong, 2001; Caldwell and Dingle, 1976). Mantis shrimps are primarily distributed throughout tropical and subtropical waters, where they inhabit burrows or crevices within the intertidal and subtidal zones (Ahyong, 2001). Several species are commercially exploited throughout the world with the most important fisheries being for *Squilla mantis* (Linnaeus, 1758) in the Mediterranean, *Oratosquilla oratoria* (de Haan, 1844) in Japan, and *Oratosquilla nepa* (Latreille in India (Ahyong, 2001; James and Thirumilu, 1993; Maynou et al., 2005). They are normally captured during benthic trawl operations and used as a dependable source of raw material in fishmeal, poultry feeds and fertilisers. However, in some countries they are also eaten as the meat is reported to possess medicinal properties (James and Thirumilu, 1993).

A recent review by Ahyong (2001) reported that 146 species within 63 genera inhabit Australian waters, with 99 of these species being reported from Queensland (Haddy, 2000; Ahyong, 2001). In Australia, mantis shrimps have traditionally been a minor bycatch species caught in commercial prawn trawl fisheries (Dell and Sumpton, 1999). However, Queensland *Fisheries (East Coast Trawl) Management Plan 1999,* which was implemented in 2000, lists mantis shrimps as "permitted species", thus allowing them to be retained by trawl fishers and marketed. In 2000 the total reported catch of mantis shrimp was three tonnes with an estimated value of A$9000. The majority of this catch is landed from the Moreton Bay area (QLD Fisheries Service, 2001) and sold into domestic Asian markets.

An objective of the Managment Plan is to ensure fisheries' resources taken in the fishery are harvested in an ecologically sustainable way (QLD DPIF, 1999). In 2004 a productivity susceptibility assessment analysis on mantis shrimps in the Queensland East Coast Trawl Fishery concluded that mantis shrimps had a low capacity to recover from population depletion and a high susceptibility to mortality from trawling (QLD DPIF, 2004). This result was due to the fact that very little reliable data was available on the population dynamics and preferred habitats of Queensland's exploited mantis shrimp species (QLD DPIF, 2004). Consequently, there is a need to obtain more information on the population dynamics of Queensland's mantis shrimp species in order to correctly assess the sustainability of their exploitation in the QECTF. Size at maturity, seasonality of reproduction, spawning sites, growth and spatial distribution are some of the most important life history parameters needed for stock assessment and management of sustainable exploitation levels. However, to date this information is yet to be investigated in Australian species (QLD Fisheries Service, 2001). Therefore the aim of the study was to describe the species composition and population dynamics of commercially important mantis shrimp species within the Moreton Bay region.

15.3 MATERIALS AND METHODS

15.3.1 Sample collection and processing

Monthly mantis shrimp samples were obtained from commercial prawn trawl fishers operating in Moreton Bay (27°30' S) between October 2001 and January 2003. Additional samples were also collected during two fishery-independent research trawl surveys in Moreton Bay in November 2001 and again in November 2002 (Ovenden et al., 2004). The Moreton Bay area was divided into five 6-inch x 6-inch logbook grids (grids 7, 12, 13, 14 and 18). Each grid was allocated between 13 and 27 one-nautical mile transects. Grids with a reduced trawlable area received proportionally less sampling effort. The trawl gear consisted of a 5 m beam trawl fitted with a Florida Flyer net composed of 38 mm mesh (Ovenden et al., 2004).

Individual mantis shrimps in samples were identified to species, and total length, carapace length, total weight, sex, presence of stored sperm in the thoracic segments, ovarian maturity and ovarian weight recorded. Total length (TL) was measured from the apex of the rostral plate to the apices of the submedian teeth of the telson, and carapace length (CL) from the median posterior edge of the carapace to the apex of the rostral plate. Criteria for ovarian maturity and macroscopic descriptions are detailed in Table 15.3.1. The presence of stored sperm could only be determined in fresh specimens; therefore as the survey samples were frozen prior to processing, this data could not be determined for these months.

Table 15.3.1. Macroscopic descriptions of ovarian development in mantis shrimp

Stage	Macroscopic Description
1) Undeveloped	Gonad not visible externally. Gonad small with clear or slightly creamy to rose appearance*.
2) Maturing	Gonad visible as small strip on ventral telson. Gonad enlarging with yellow/orange or red colour*.
3) Mature	Gonad visible as a triangle on ventral telson. Gonad enlarged greatly and bright yellow, orange or red colour*.

*ovarian colour varies between species.

15.3.2 Data analysis

All data were pooled for determination of carapace length–total weight (CL–TW) relationships for males and females of six of the eight species (two species, *C. granti* and *O. cultrifer,* had insufficient sample sizes). The cubic relationship between CL and TW was represented by the power curve equation: $TW = aCL^b$, where *b* is close to 3 in isometric growth, and *a* is a constant determined empirically (King, 1995).

Data from the Moreton Bay trawl surveys were used to determine the species composition and spatial distributions of mantis shrimps by individual numbers and total catch weight for both the 2001 and 2002 surveys. However, due to low catch numbers, spatial information is only presented for the four most common species: *O. stephensoni*, *O. interrupta*, *B. laevis* and *A. fasciata*.

Oratosquilla stephensoni was the only species sampled in sufficient numbers to produce robust monthly length-frequency distributions for both males and females required to determine von Bertalanffy growth parameters. Estimates of L_∞ were determined by averaging the ten largest individual carapace lengths recorded for each sex, and the parameters *k* and t_0 determined by using a von Bertalanffy plot (relative age against $-ln(1-L_t/L_\infty)$) (King, 1995). Data obtained for this method were determined from modal peaks present in monthly length-frequency distributions of males and females, respectively.

Gonadosomatic indices (GSI) were calculated as gonad weight/total weight x 100. Seasonal GSI profiles were generated from individuals larger than 20.5 mm CL to ensure that immature values did not bias seasonal mean GSI values (Haddy et al., 2005). Mandatory logbook data for mantis shrimps from 2000–2005 were used to examine spatial and temporal trends in reported landings.

15.4 RESULTS

15.4.1 Analysis of logbook data

Total reported annual landings of mantis shrimps from 2000 to 2005 were 2425, 651, 723, 1369, 1251 and 654 kg, respectively, with the great majority of the catch (i.e., 96%) reported from Moreton Bay (Figure 15.4.1). Catches were lowest in winter (June, July and August) and peaked between late summer and early autumn (February to April).

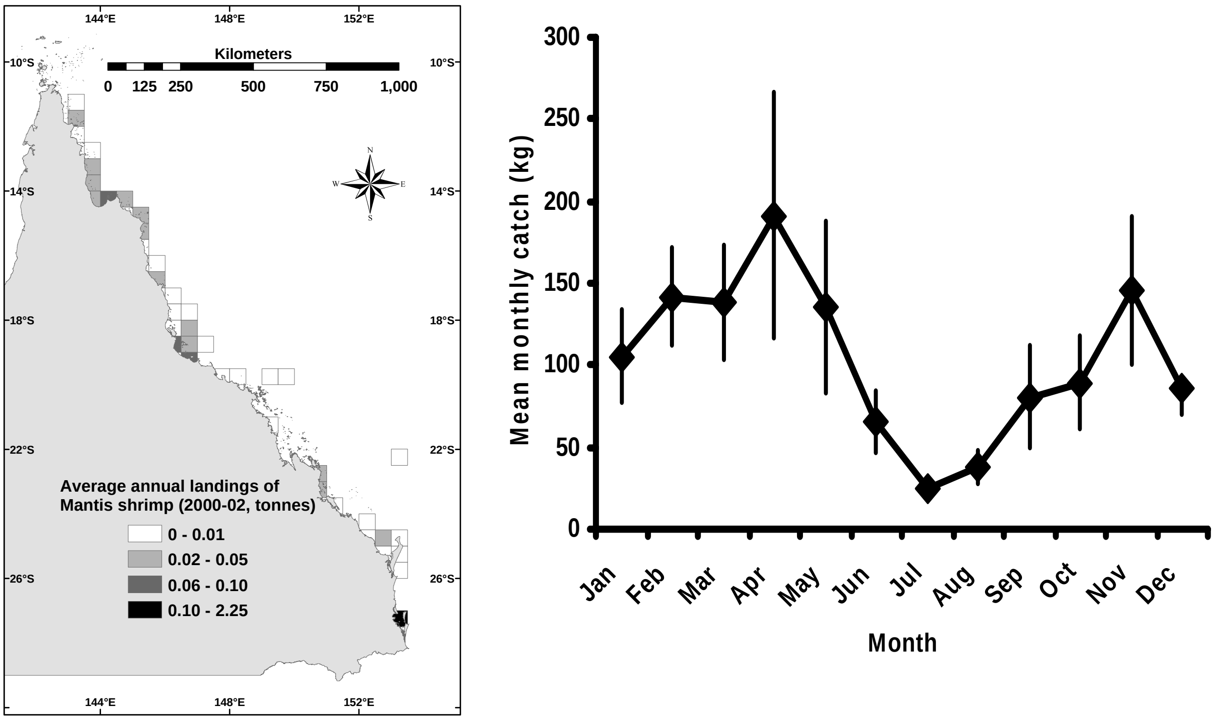

Figure 15.4.1. Spatial and temporal trends of reported mantis shrimp landings from the Queensland East Coast Trawl Fishery

15.4.2 Sample details

A total of 3809 mantis shrimps were collected with eight species being recorded. Combined sample details and morphometric measurements for all species are provided in Table 15.4.1 and Table 15.4.2, respectively. With all samples pooled, *Oratosquilla stephensoni* was the most abundant species, followed by *O. interrupta*, *Belosquilla laevis*, *Erugosquilla woodmasoni*, *Anchisquilla fasciata* and *Harpiosquilla harpax*, with sample sizes of 583, 237, 204, 130 and 60, respectively. Only two specimens of *Odontodactylida cultrifer* and one specimen of *Clorida granti* were collected. *Harpiosquilla harpax* was the largest mantis shrimp encountered with a maximum size and weight of 252 mm TL and 166 g.

Table 15.4.1. Details of the total numbers of mantis shrimp collected and their minimum, maximum and mean carapace lengths (all data pooled)

Species	Sex	Max TW (g)	Max CL (mm)	Mean CL (mm)	Total Numbers
Anchisquilla fasciata	M	9.2	20.7	15.4	75
	F	7.8	19.4	14.0	55
Belosquilla laevis	M	20.5	27.1	18.8	100
	F	17.0	25.2	18.0	137
Oratosquilla interrupta	M	67.4	43.3	35.6	326
	F	76.6	43.8	35.7	257
Oratosquilla stephensoni	M	49.1	36.6	27.4	1271
	F	58.6	41.3	29	1321
Clorida granti	M				-
	F	2.0	9	9	1
Erugosquilla woodmasoni	M	71.4	38.5	31.3	101
	F	64	39.1	31.9	103
Harpiosquilla harpax	M	165.7	52.1	42.7	30
	F	117.7	57.4	45	30
Odontodactylida cultrifer	M				-
	F	12.5	21.1	19.3	2

Table 15.4.2. Regression parameters for the carapace length-total weight (CL-TW) relationship for six species of mantis shrimp (all data pooled)

Species	Sex	n	TW = aCL^b			CL MAX (mm)
			a	b	r^2	
Anchisquilla fasciata	M	75	0.0043	2.7187	0.8392	20.7
	F	55	0.0043	2.4896	0.7872	19.4
Belosquilla laevis	M	100	0.0029	2.6632	0.9299	27.1
	F	137	0.0021	2.7754	0.8804	25.2
Oratosquilla interrupta	M	326	0.0049	2.5299	0.8645	43.3
	F	257	0.0045	2.5551	0.8687	43.8
Oratosquilla stephensoni	M	1271	0.0341	1.9127	0.659	36.3
	F	1321	0.0022	2.7521	0.9446	41.3
*Clorida granti**	M	-	-	-	-	-
	F	1	-	-	-	9
Erugosquilla woodmasoni	M	101	0.0028	2.7386	0.8879	38.5
	F	103	0.0041	2.6313	0.9201	39.1
Harpiosquilla harpax	M	30	0.001	2.9828	0.952	52.1
	F	30	0.0018	2.8378	0.9619	57.4
*Odontodactylida cultrifer**	M	-	-	-	-	
	F	2	-	-	-	21.1

* Note: (-) indicates insufficient data to determine a length-weight relationship

15.4.3 Species composition

The species compositions of the 2001 and 2002 Moreton Bay trawl surveys are shown in Figure 15.4.2. A total of eight species were collected, however *C. granti* was only present in the 2002 survey. The total number of individuals caught in 2001 and 2002 were n = 685 and n = 485, respectively. *Oratosquilla stephensoni* dominated the survey catches and accounted for 50.2% and 72.4% of individuals caught in 2001 and 2002, correspondingly. This species also accounted for 58.8% and 81.0% of the total weight for the 2001 (total catch weight = 11.6 kg) and 2002 (8.4 kg) trawl surveys, respectively. The remaining species in order of numerical abundance from the 2001 and 2002 surveys were as follows: *B. laevis* (24.4 and 13.8%), *A. fasciata* (13.1 and 8.2%), *O. interrupta* (10.4 and 3.7%), *E. woodmasoni* (1.2 and 0.4%), *H. harpax* (0.1 and 0.4%), *O. cultrifer* (0.1 and 0.2%) and *C. granti* (n/a and 0.2%).

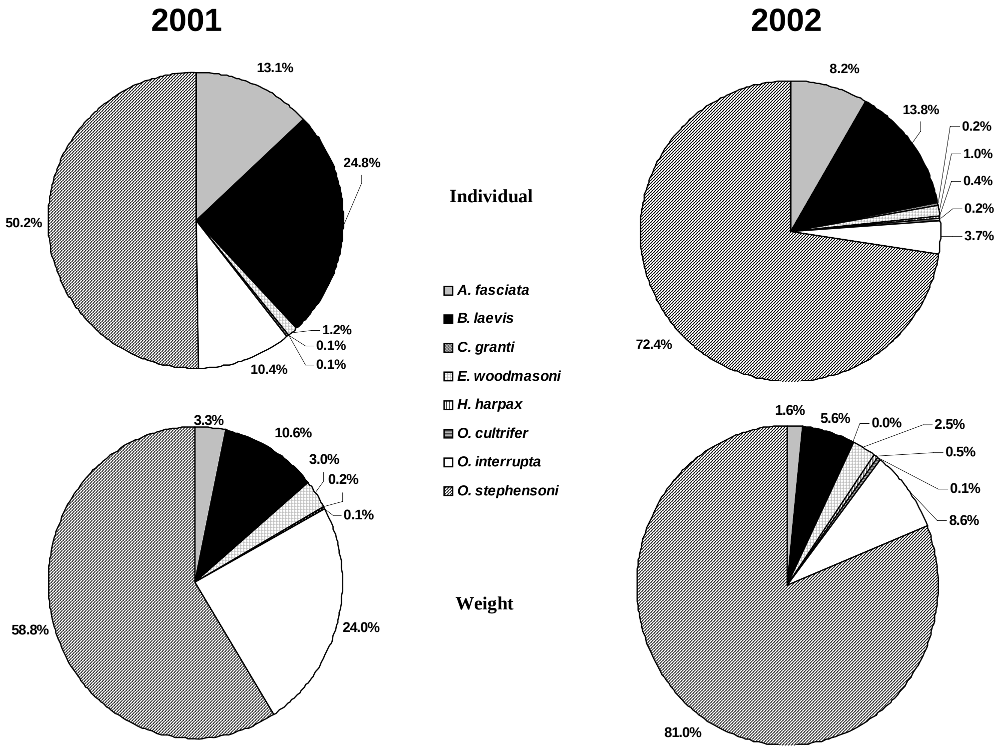

Figure 15.4.2. Proportional catches by individuals and weight of mantis shrimp caught during the 2001 and 2002 Moreton Bay trawl surveys

15.4.4 Species distribution and abundance

Detailed maps of the spatial distribution and relative abundance of the four most common mantis shrimp species, *O. stephensoni*, *B. laevis*, *A. fasciata* and *O. interrupta*, are provided in Figure 15.4.3 through to Figure 15.4.10. In 2001 the highest proportions of *O. stephensoni*, *O. interrupta* and *A. fasciata* were caught in grids 12, 13 and 12, respectively, however in 2002, their abundances were highest in grids 18, 13 and 14, respectively. In contrast *B. laevis* was most abundant in grid 7 for both years. A breakdown of catch rates for each species encountered during the surveys is detailed in Table 15.4.3.

Table 15.4.3. Summaries of mantis shrimp catch rates from Moreton Bay

Species	n	Grid of highest abundance	Max catch rate (g ha^{-1})	mean catch rate (g ha^{-1})	Max catch rate n ha^{-1}	mean catch rate n ha^{-1}
2001 survey						
A. fasciata	90	13	65.37	4.86±1.39	18.5	1.16±0.34
B. laevis	170	7	394.48	15.91±7.31	57.4	2.19±1.01
E. woodmasoni	8	14	86.12	4.50±1.98	1.8	0.1±0.04
H. harpax	1	12	19.82	0.28±0.28	0.9	0.01±0.01
O. cultrifer	1	14	10.56	0.15±0.15	0.9	0.01±0.01
O. interrupta	71	13	269.46	35.16±6.09	6.5	0.89±0.14
O. stephensoni	344	12	475.96	86.71±10.20	22.2	4.32±0.54
Combined spp.	685	7	606.99	147.6±15.7	60.1	8.68±1.18
2002 survey						
A. fasciata	40	14	18.71	1.60±0.43	5.56	0.47±0.14
B. laevis	67	7	65.56	5.55±1.37	8.33	0.79±0.17
C. granti	1	7	1.85	0.02±0.02	0.93	0.01±0.01
E. woodmasoni	5	18	59.26	2.53±1.19	0.93	0.06±0.03
H. harpax	2	7	41.58	0.53±0.53	1.85	0.02±0.02
O. cultrifer	1	14	9.35	0.12±0.12	0.93	0.01±0.01
O. interrupta	18	13	95.47	8.52±2.25	1.85	0.21±0.05
O. stephensoni	351	18	376.51	80.37±9.49	18.52	4.11±0.49
Combined spp.	485	14	475.22	99.22±10.89	21.3	5.68±0.54

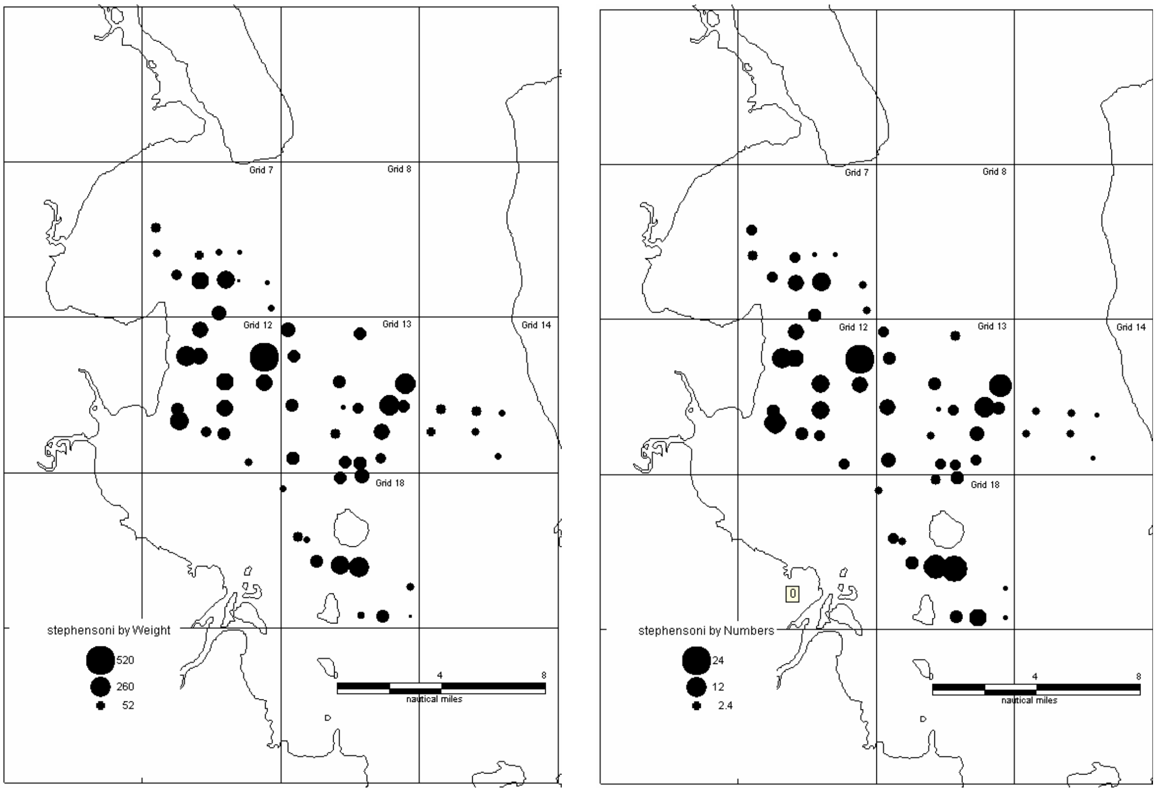

Figure 15.4.3. Spatial distribution and abundance of *O. stephensoni* by weight (g) and number in 2001.

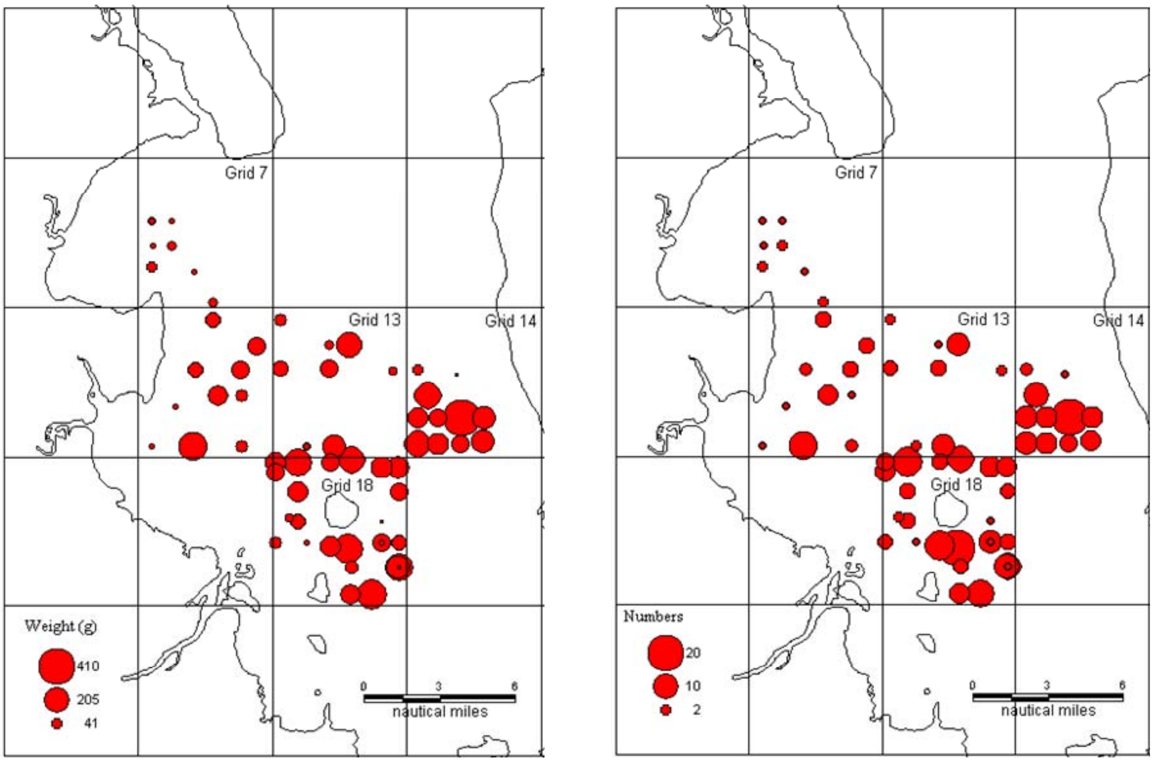

Figure 15.4.4. Spatial distribution and abundance of *O. stephensoni* by weight (g) and number in 2002.

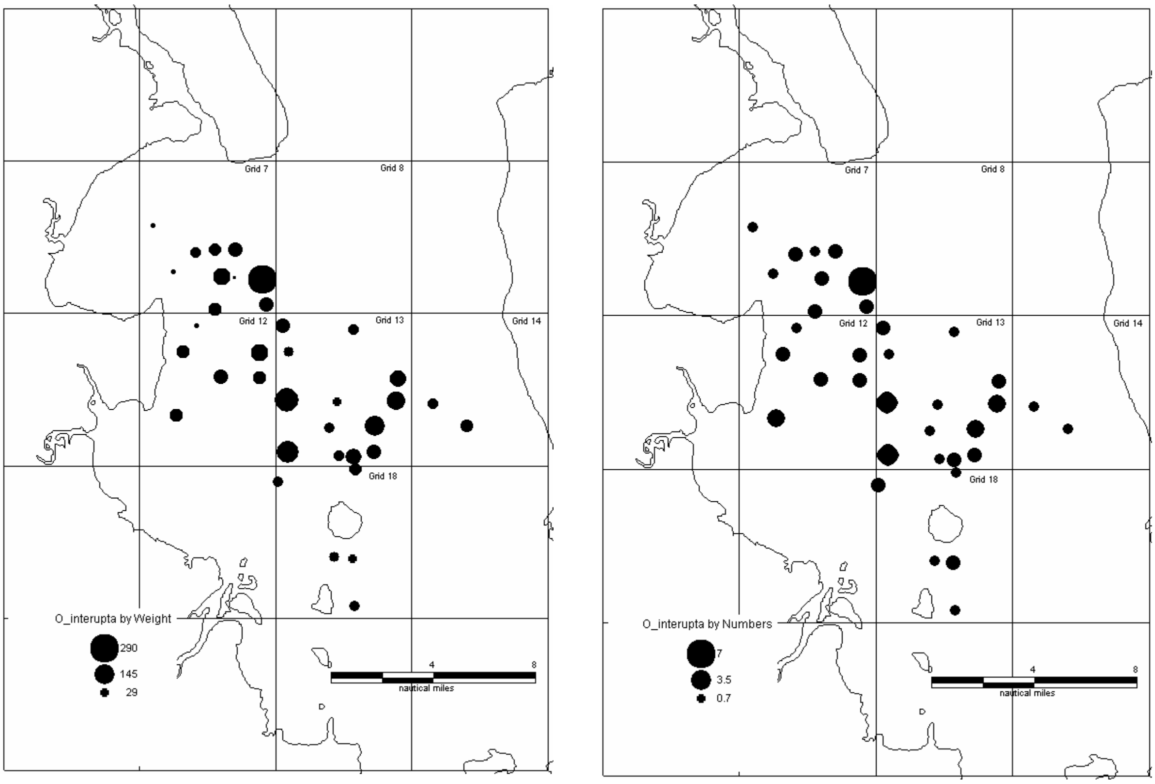

Figure 15.4.5. Spatial distribution and abundance of *O. interrupta* by weight (g) and numbers in 2001.

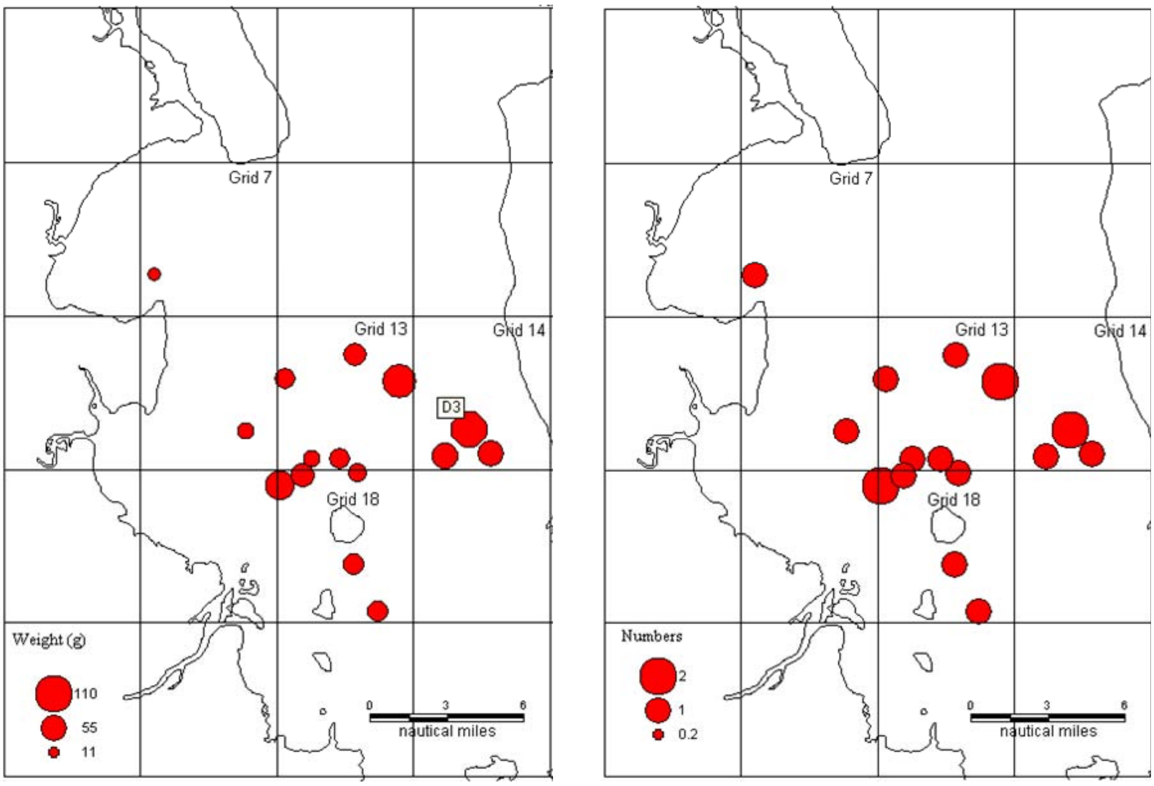

Figure 15.4.6. Spatial distribution and abundance of *O. interrupta* by weight (g) and number in 2002.

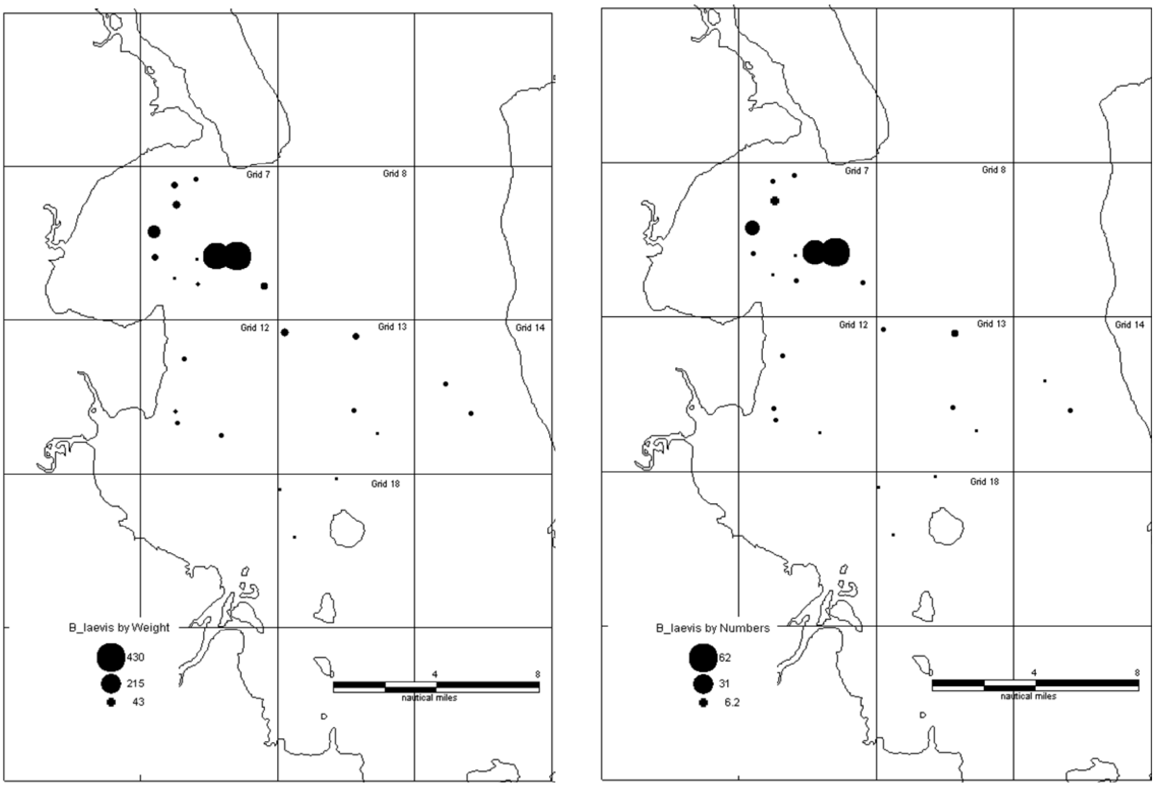

Figure 15.4.7. Spatial distribution and abundance of *B. laevis* by weight (g) and number in 2001.

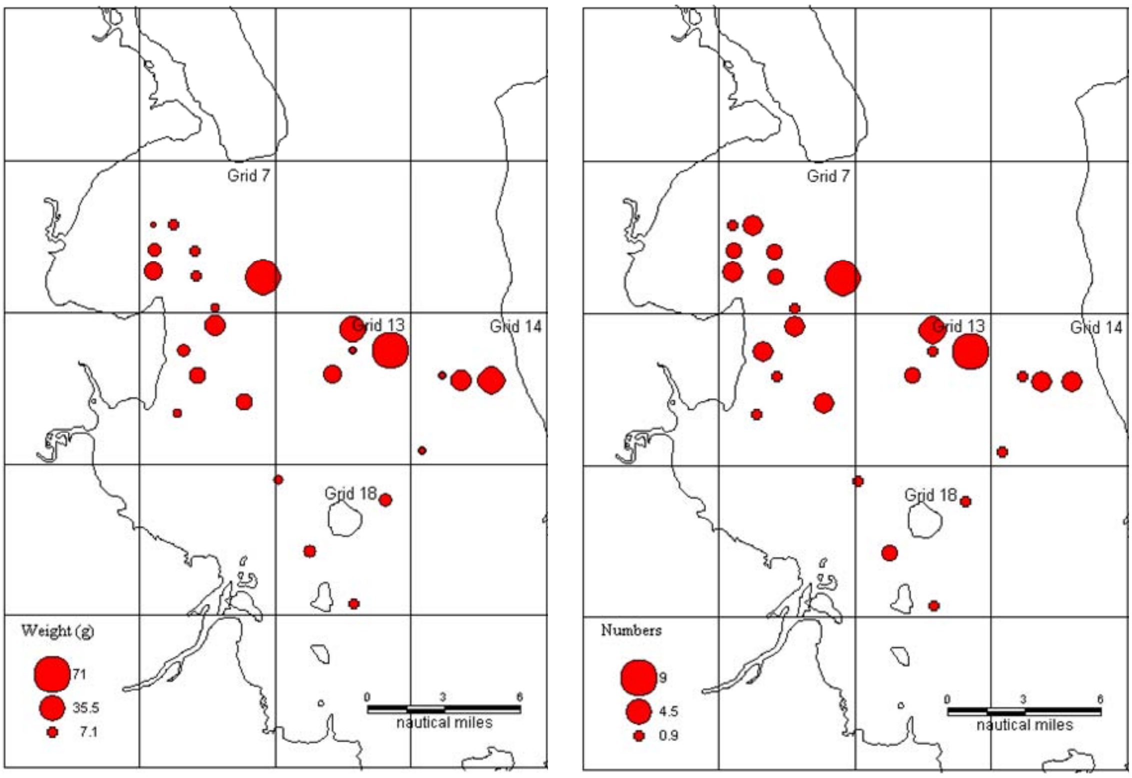

Figure 15.4.8. Spatial distribution and abundance of *B. laevis* by weight (g) and number in 2002.

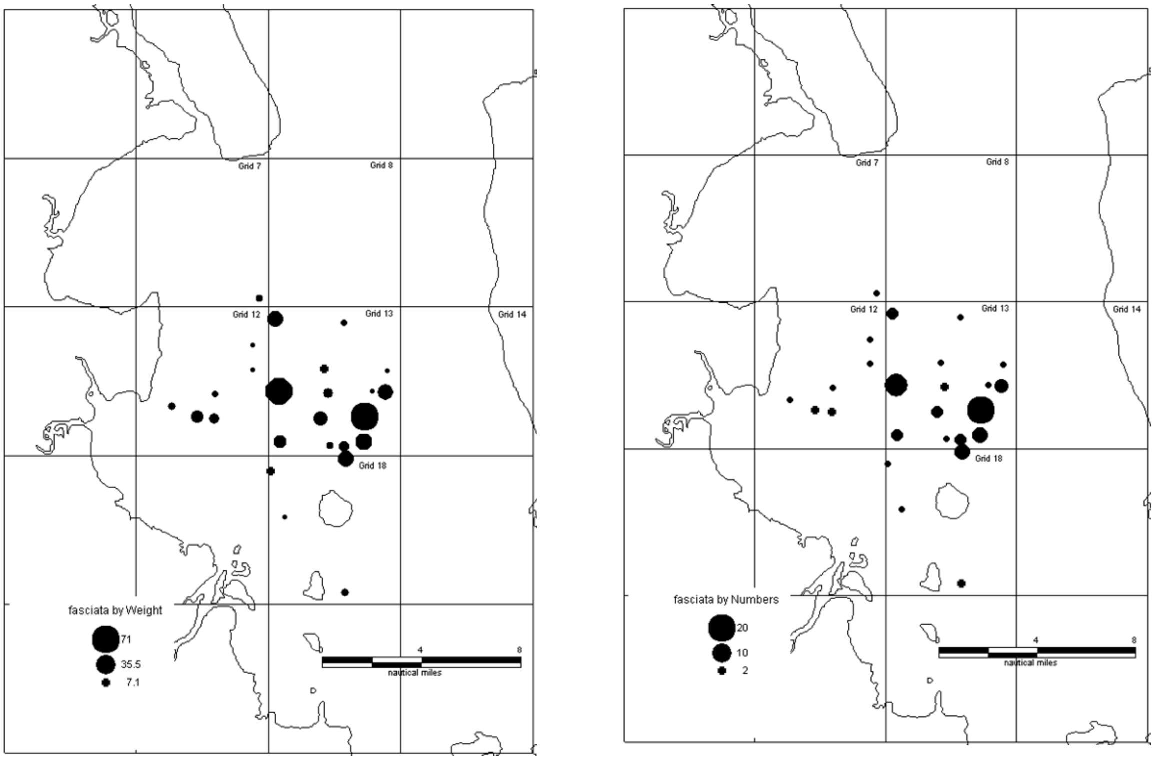

Figure 15.4.9. Spatial distribution and abundance of *A. fasciata* by weight (g) and number in 2001.

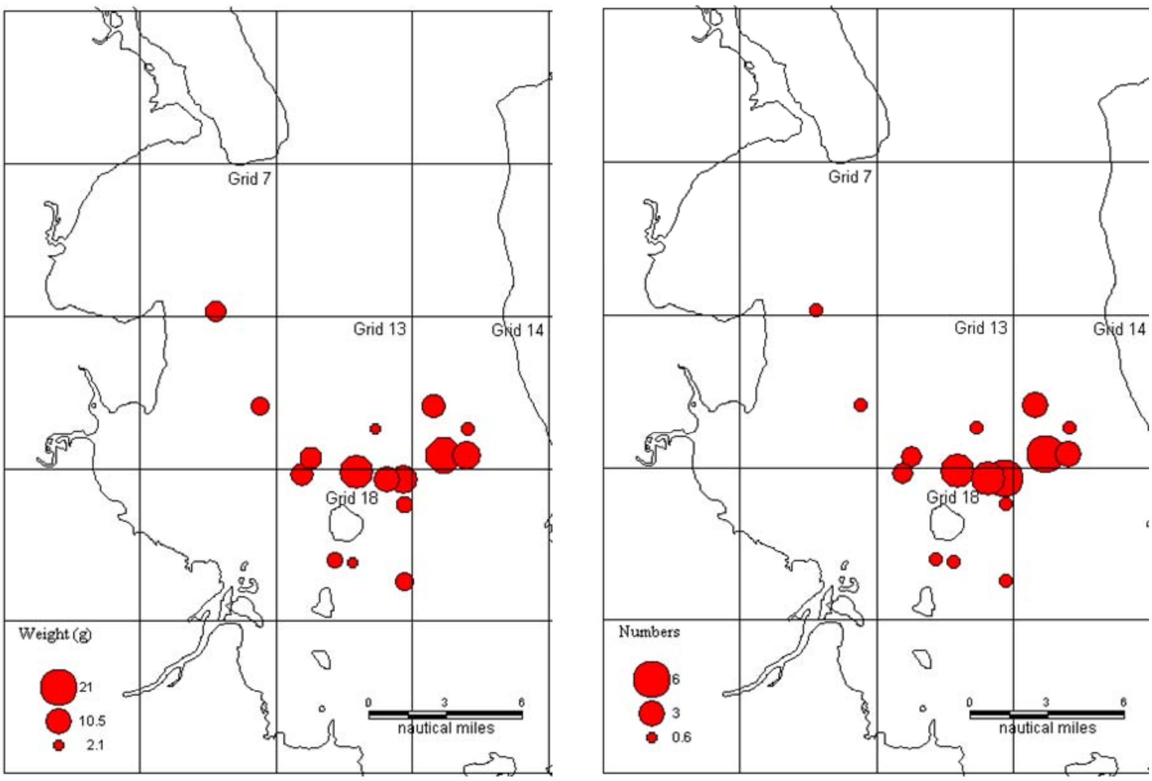

Figure 15.4.10. Spatial distribution and abundance of *A. fasciata* by weight (g) and number in 2002.

15.4.5 Monthly length-frequency distributions and growth of Oratosquilla stephensoni

Oratosquilla stephensoni was the only species sampled in sufficient numbers to derive von Bertalanffy growth parameters. Carapace lengths ranged from 15.4 mm to 41.3 mm CL with length-frequency distributions being either unimodal or multimodal, depending on the month of collection (Figure 15.4.11 and Figure 15.4.12). Multi-modal distributions were most evident in November 2001 and August to November 2002. These additional modes were present due to the capture of smaller sized individuals (14 mm to 20 mm CL) in these months. Estimates of L_∞, k and t_0 were 35.5 mm CL, 1.69 and 0.5 for males, and 38.9 mm CL, 1.40 and 0.49 for females, respectively. Growth curves suggested a life span of approximately 2.5 to 3 years.

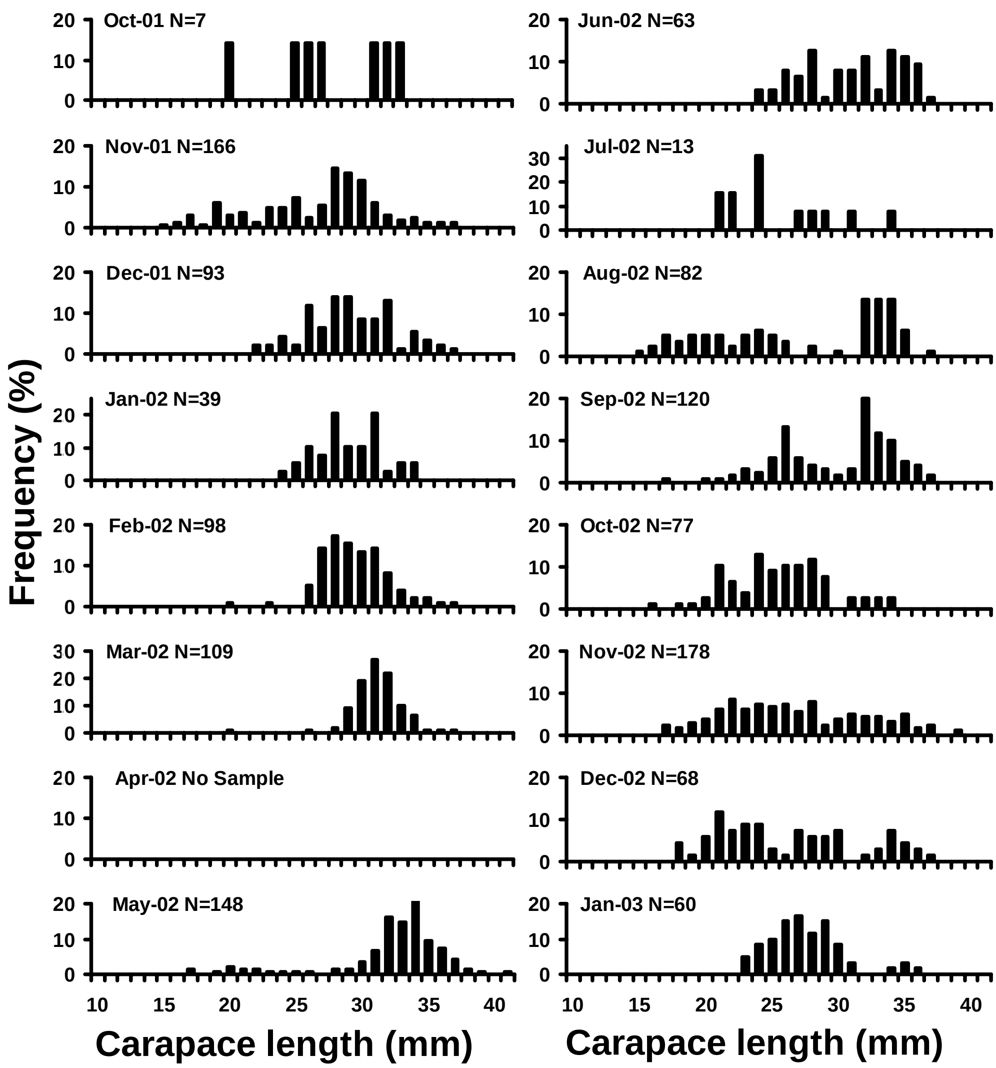

Figure 15.4.11. Monthly carapace length-frequency distributions of female *Oratosquilla stephensoni* (all data pooled). Note: y-axis ranges vary.

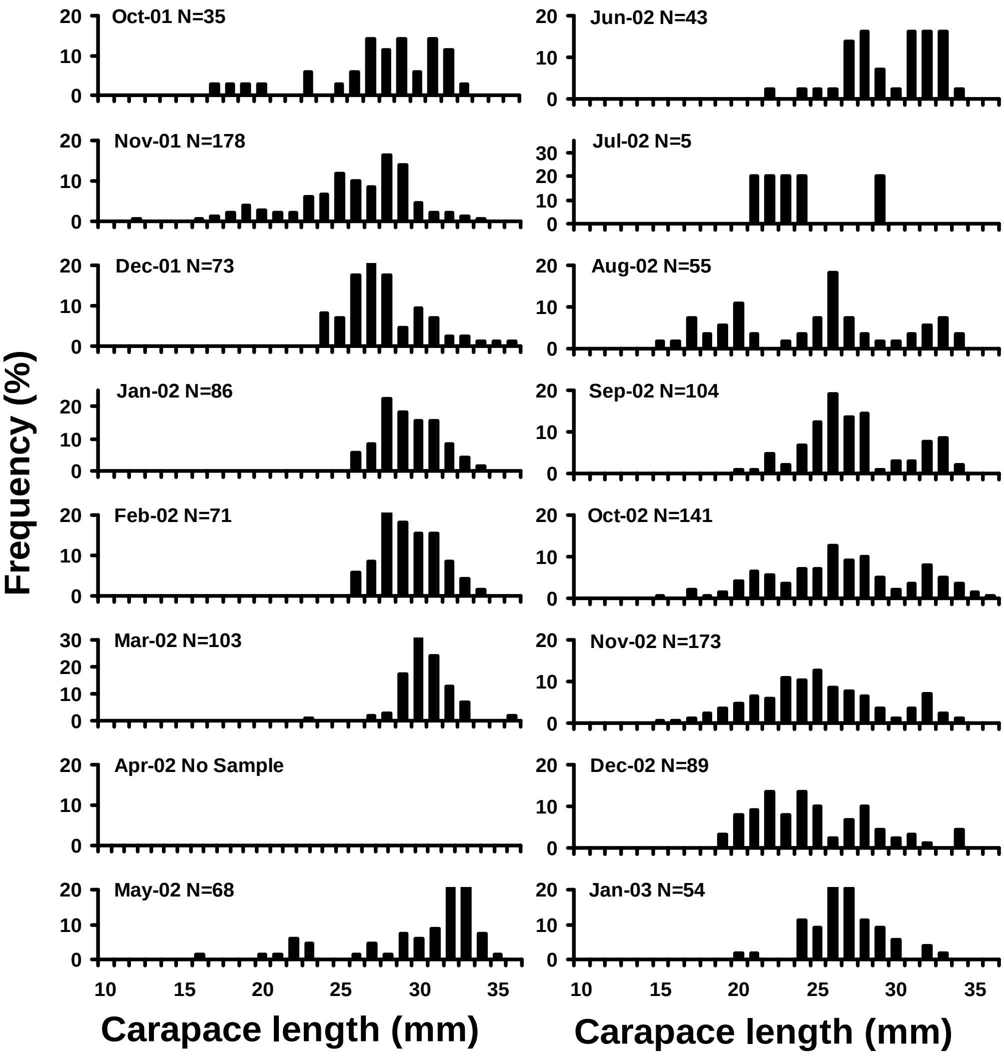

Figure 15.4.12. Monthly carapace length-frequency distributions for male *Oratosquilla stephensoni* (all data pooled). Note: y-axis ranges vary.

15.4.6 Reproductive activity of female Oratosquilla stephensoni

The GSI profile of *O. stephensoni* displayed a clear annual cycle, with values being initially high in October 2001 before declining to their lowest values between March and July 2002. GSI values then rapidly increased to maximum levels between September and November 2002 (Figure 15.4.13). A small secondary peak was also evident in January 2002. Seasonal sex ratios of females to males were at their lowest (< 40%) during October 2001, January 2002 and October 2002. The proportions of mated females were highest (> 50%) in October 2001, August 2002 and September 2002 and were at their lowest in December 2001, May 2002 and July 2002. The proportions of reproductively active *O. stephensoni* displayed a clear seasonality, with maturing and mature stage females abundant over spring and summer. In contrast, inactive females with undeveloped (stage 1) gonads predominated over autumn and winter (Figure 15.4.13). The smallest sexually mature individual measured 20.4 mm CL with 50% size at maturity being reached at 24.0 mm CL.

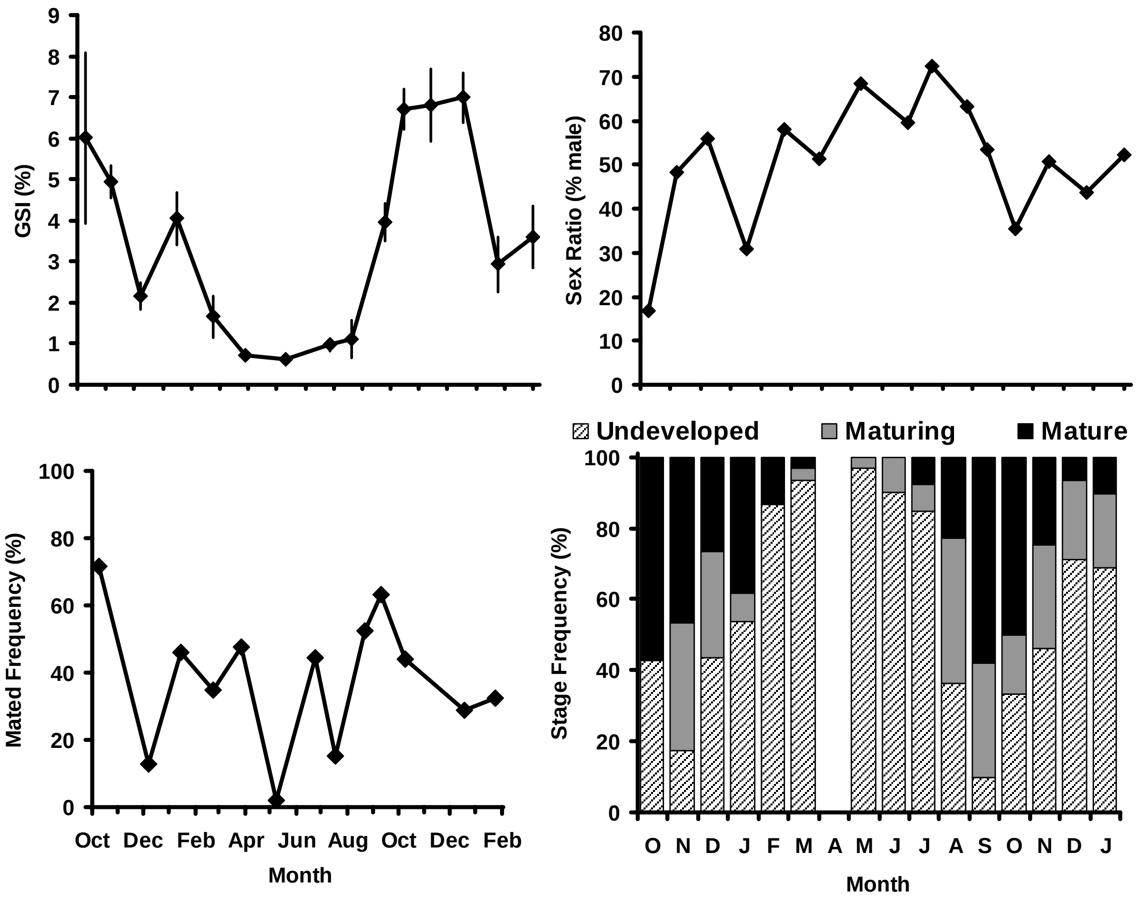

Figure 15.4.13. Seasonal changes in gonadosomatic indices (GSI), sex ratio, mated frequency and ovarian development for female *Oratosquilla stephensoni*

15.4.7 Reproductive activity of female Oratosquilla interrupta

Seasonal reproductive trends in *O. interrupta* displayed a clear cycle similar to that of *O. stephensoni* (Figure 15.4.14). The results highlighted that reproductive activity was highest in spring and summer with high GSI values and the proportions of fully mature individuals abundant at these times. A secondary peak of reproductive activity also occurred in January 2002. The female sex ratio was associated with these peak reproductive events as female presence was lowest during the months of October 2001, January 2002 and October 2002. The presence of mated females was typically high throughout the year except during winter (May–July) when the incidence of mated females was extremely low. The smallest sexually mature individual measured 27.5 mm CL with 50% size at maturity being reached at 28.0 mm CL.

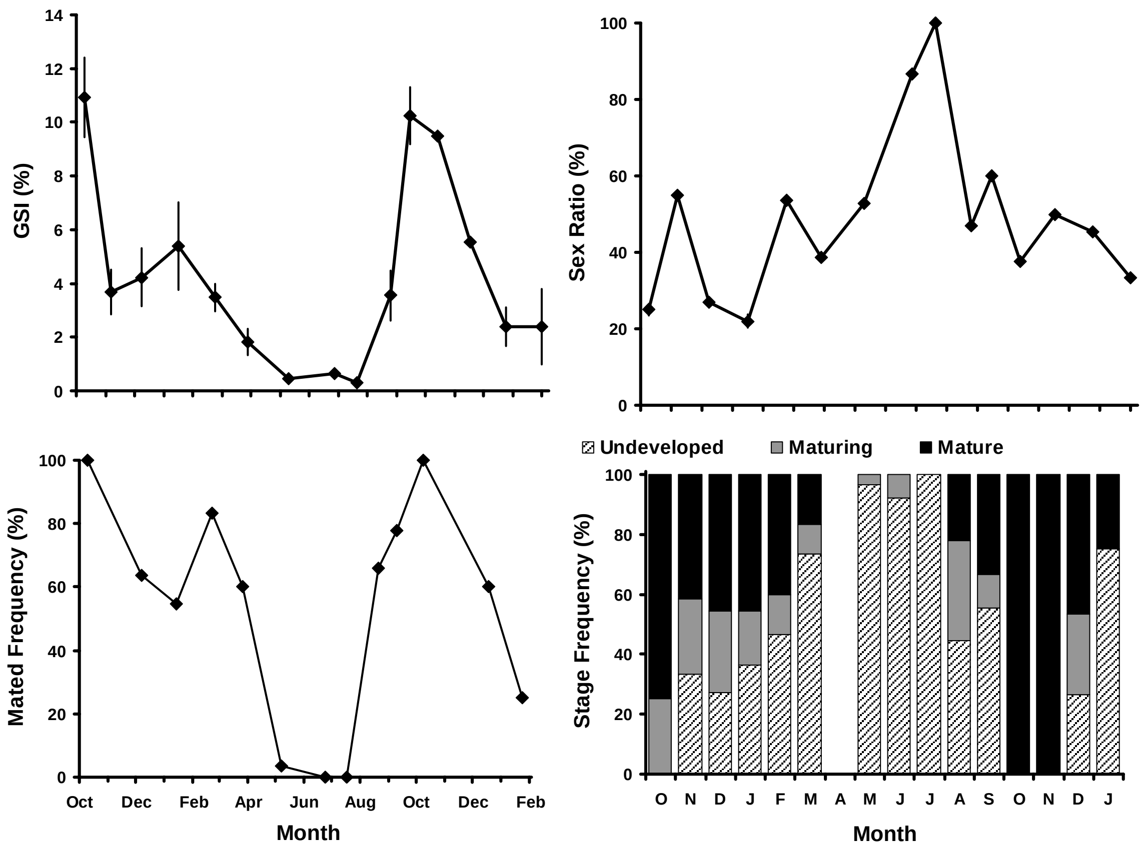

Figure 15.4.14. Seasonal changes in gonadosomatic indices (GSI), sex ratio, mated frequency and ovarian development for female *Oratosquilla interrupta*

15.5 DISCUSSION

A total of eight species of mantis shrimp were caught in the Moreton Bay region using commercial prawn trawl nets during the sampling period. Seven of the species – *A. fasciata, B. laevis, E. woodmasoni, H. harpax, O. cultrifer, O. interrupta* and *O. stephensoni* – are known to be harvested and marketed by fishers within the Moreton Bay Otter Trawl Fishery (MBOTF) (Dell and Sumpton, 1999; Haddy, 2000). *O. stephensoni* was the most abundant species during the sampling period; it was also the most common species caught during a similar study in this area by Dell and Sumpton (1999). The reported mean monthly landings of mantis shrimps varied seasonally with the greatest catch rates occurring during summer and autumn before declining during winter. Similarly Dell and Sumpton (1999) observed greater abundances of *O. stephensoni, O. interrupta, A. fasciata* and *B. laevis* in Moreton Bay over summer and dramatically decreased catch rates during winter. Giovanardi and Piccinetti-Manfrin (1984), and Froglia (1996) (in Maynou et al., 2005), from studies of *Squilla mantis* in the Adriatic and Mediterranean seas, concluded that decreased catch rates resulted from reduced female out-of-burrow activity when incubating their eggs and disappearance from the population of adults after spawning. Maynou et al. (2005)

suggested that the seasonal differences in catch rates of *S. mantis* in the Mediterranean were due to the dynamics of the exploited stock, not a seasonal relocation of effort. Maynou et al. (2005) went on to explain that the seasonal variation in the population structure was consistent with the addition of recruits (winter–spring) and the disappearance of adults (summer–autumn).

The spatial distribution and abundance of *O. stephensoni* and *A. fasciata* varied between the two sampling years of the Moreton Bay survey. However, catches of these species occurred in Grid 13 each year. Dell and Sumpton (1999) observed the area of grid 13 as being the deepest station (station 5) in their study and also with higher densities of different species in this area. The fact that *B. laevis* was mostly abundant in grid 7 for both years is consistent with the findings of Ayhong (2001), who suggested that the preferred habitat of this species was intertidal areas to 40 m that were often associated with seagrass beds, which is typical of the grid 7 area. The variations in distribution and abundance may also be the result of seasonal differences in rainfall over the sampling period. This relates to the findings of Froglia (1996) in Maynou et al. (2005) who found the high densities of mantis shrimps in areas of the Adriatic that experienced high levels of river run-off.

The monthly length-frequency distributions of *O. stephensoni* (male and female) displayed multimodal distributions indicating the presence of multiple cohorts up to three years of age. Similarly length-frequency analysis of *O. stephensoni* in Moreton Bay by Dell and Sumpton (1999) reported the species to have a life span of approximately 2.5 years and suggested two distinct periods of spawning and recruitment. Furthermore, Dell and Sumpton (1999) stated that the presence of the two cohorts together with multiple spawning events, fast growth and short-lived population dynamics of *O. stephensoni* would imply a high turnover of stock. Although two recruitment periods were not detected in the present study, the seasonal GSI profiles and ovarian maturity indicated that two spawning events were likely to occur during the reproductive season. In a study of the population dynamics of *Oratosquilla nepa* (Latreille) of the Mangalore Coast, Reddy and Shanbhogue (1994) determined that the fishery was exclusively supported by smaller size groups every November. This indicated bulk recruitment into the fishery around this period. A further recruitment of smaller size groups in May suggested that this species spawned twice a year (Reddy and Shanbhogue, 1994).

Seasonal changes in the proportions of female to male sex ratios, GSI, mated frequency, and ovarian stage of development indicate that *O. stephensoni* and *O. interrupta* displayed an annual cycle of reproduction. Peak spawning is observed to be during spring with a likely secondary spawning period during late summer. Populations of mantis shrimp are known to breed for extended periods often with peaks in frequency in tropical waters (Haddy, 2000). Reddy and Shanbhogue (1994) found *Oratosquilla nepa* of the Mangalore Coast to have an extended spawning period of 10 months with peaks in February to April and September to October. The decreased female to male sex ratios for both species observed during late summer to early autumn and spring of the sampling period suggest that females may be in their burrows incubating their eggs, which is consistent with the spawning periods from the GSI analysis mentioned earlier. Maynou et al. (2005) found *S. mantis* in the Mediterranean to incubate their eggs during summer and spring and not leave the burrow throughout this incubation period. Maynou et al. (2005) concluded that the reproductive behaviour of *S. mantis* influences the proportion of males and females in catches by season – females outnumber males only during the mating season. The high proportions of mated frequency in spring and late summer show a relationship with the frequency of mature and maturing individuals caught. This relationship suggests a mating season in spring to late summer. The high abundance of undeveloped females during autumn and winter correlates with the low GSIs over the same period, which is consistent with the suggestion of a spawning season over this period.

During this study we were able to determine an approximation of size at maturity for female *O. stephensoni* and *O. interrupta.* By inspecting the ovaries and assigning a reproductive stage to each individual, the size at maturity was established from the minimum CL of the mature (stage 2 and 3) females. The size at maturity for *O. interrupta* and *O. stephensoni* was 28 mm CL and 24mm CL, respectively. Maynou et al. (2005) determined a similar size at maturity for female *S. mantis* in the Mediterranean as 20–24 mm CL.

The results provide fishers and fisheries managers with detailed information on the spatial distribution, abundance, species composition and reproductive biology of commercially caught mantis shrimp species in Moreton Bay. While significant catches of mantis shrimp are caught incidentally throughout the East Coast Trawl Fishery (see the Appendices listing bycatch composition in the various sectors), their retention and marketing are largely limited to the Moreton Bay fleet, probably for socio-economic reasons. Based on discussions with fishers, most crews operating outside Moreton Bay are not motivated to retain mantis shrimp. A key component of the study was to provide fisheries managers with information on the population dynamics of mantis shrimps so informed management decisions could be made. The findings highlighted concerns that the current commercial trawl methods are landing immature mantis shrimps. However, as the mantis shrimps studied a) display a relatively fast growth rate with a short life span, b) possess a prolonged spawning season with at least two spawnings per season, c) have a cryptic lifestyle where females remain in their burrows during the egg mass incubation period, and d) are retained almost solely by the Moreton Bay fleet, it is likely that current exploitation rates are within sustainable limits.

15.6 References

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