Asian Fisheries Science 7(1994): 103-113.
Asian Fisheries Society, Manila, Philippines

https://doi.org/10.33997/j.afs.1994.7.2-3.004

Reproduction and Growth of the Commercial Sand Crab, *Portunus pelagicus* (L.) in Moreton Bay, Queensland

WAYNE D. SUMPTON, MICHAEL A. POTTER* and GLEN S. SMITH

Queensland Department of Primary Industries
Southern Fisheries Research Centre
PO Box 76, Deception Bay
Queensland, 4508, Australia

Abstract

The biology of the commercial sand crab *Portunus pelagicus* is described in subtropical Moreton Bay, Queensland, Australia. The population samples were characterized by more males than females. Recruitment of O+ yr individuals occurred throughout the year, although it was greatest during spring. Crabs attained sexual maturity in their first year of life. After rapid growth of juveniles in shallow inshore habitats during summer and autumn, molting and growth slowed during winter. Von Bertalanffy growth functions were derived as follows $l_t = 175 (1-e^{-1.597(t-0.203)})$ for males, and $l_t = {}^{613}170\ (1-e^{-1.(^{19}t-0.18)})$ for females. Crabs moved further offshore as they in-creased in size. Ovigerous females were present throughout the year, although their proportion peaked during August-October. Maximum gonad development of male *P. pelagicus* was during May, whereas the peak period of female gonad activity occurred in July. The presence of many postmolt mature females with spermatophores in their spermathecae during May-June, confirmed those months as the major mating period.

Introduction

The sand crab, *Portunus pelagicus* (Linnaeus), is an important commercial species throughout most of its range in the Indo-West Pacific. Most research has focused on particular aspects of the crabs' reproductive biology, including changes in gonosomatic index (Pillay and Nair 1971; Rahaman 1980) and variation in the proportion of gravid females in the population (Dhawan et al. 1976; Penn 1977; Potter et al. 1983). Bawab and El-Sherief (1988) have also examined anatomical changes in the spermatheca associated with the reproductive cycle.

In Australia, studies of sand crab biology have been predominantly confined to temperate latitudes of southern Australia (Meagher 1971; Penn 1977; Smith 1982; Potter et al. 1983). In subtropical waters, Thomson (1951) examined the composition of the commercial Moreton Bay catch but described little of

* Present address: Northern Fisheries Centre, C/- Post Office Box 5396, Cairns Mail Centre, Cairns, Australia 4870

the crabs' growth or reproductive biology. More recently Weng (1992) compared the biology of *P. pelagicus* from the Gulf of Carpentaria and Moreton Bay, and Sumpton et al. (1989) described the commercial pot and trawl fisheries. Other Australian work on *P. pelagicus* has concentrated on parasitic infection by *Sacculina granifera* (Phillips and Cannon 1978; Bishop and Cannon 1979), the crabs' feeding habits (Williams 1982; Wassenberg and Hill 1987) and trap entrance behavior (Smith and Sumpton 1989).

Despite these studies little is known about the recruitment and growth of *P. pelagicus* in subtropical waters. The fishery for sandcrabs in Queensland is the largest in Australia (Australian Bureau of Statistics) with the Moreton Bay region contributing the overwhelming majority of the Queensland catch. This investigation describes the crab's recruitment, growth and reproductive cycles and compares the biology of the Moreton Bay population of *P. pelagicus* with the biology of those found in more temperate latitudes.

Materials and Methods

Monthly samples of *P. pelagicus* were taken at seven sites in Moreton Bay, Queensland (27°S; 153°E) between October 1984 and June 1986 (Fig. 1). Each sample was a composite of three 30-minute otter trawls taken at each site. Fishing gear consisted of twin 7.3 m "Yankee Doodle" commercial prawn trawls commonly used by Moreton Bay trawlers. Crabs were iced within 30 minutes of collection and examined in the laboratory within 48 hours.

The carapace width (cw) was measured to the nearest millimeter across the tips of the epibranchial spines and individual wet weights were recorded to the nearest gram. Crabs were classified as juveniles if the abdominal flap was firmly attached to the thorax (Van Engel 1958). The molt stage of each crab was as-

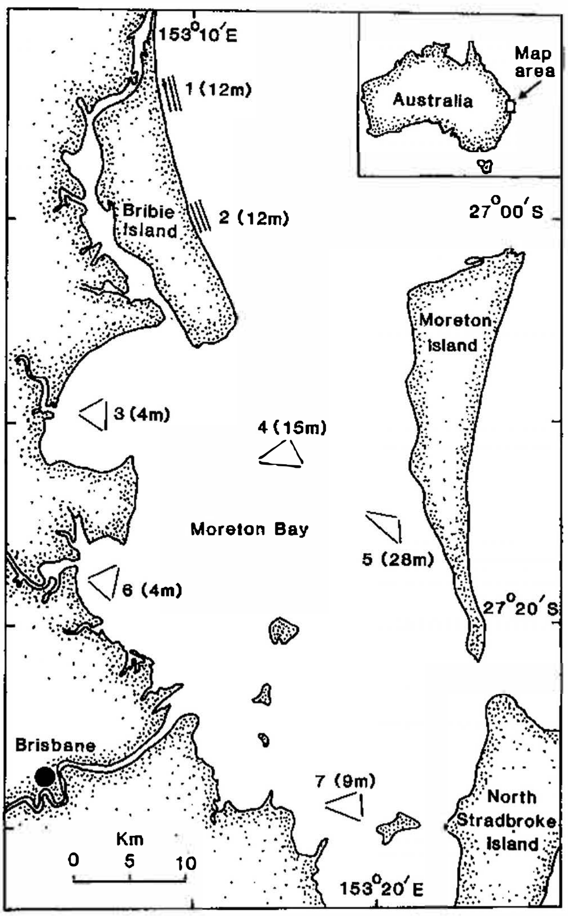

Fig. 1. Locations of sampling sites for *Portunus pelagicus* in Moreton Bay. Water depths are shown in parentheses beside each site number.

sessed using the method of Hiatt (1948), i.e., newly molted, recently molted, intermolt, premolt and ecdysis.

From September 1985 to June 1986 gonads of male crabs were removed and gonosomatic indices (GSI) were calculated as the percentage wet weight of the gonad (±1 g) to the wet body weight for each male crab.

Female crab gonads were categorized as one of the following stages after measurement of oocytes with an ocular micrometer:

Stage 1: No macroscopic sign of gonad;
Stage 2: Gonad immature, white or translucent, oocytes up to 0.14 mm in diameter;
Stage 3: Gonad maturing, light orange, not extending into hepatic region, oocyte diameter 0.15-0.21 mm;
Stage 4: Gonad mature, bright orange, extending into hepatic region, oocyte diameter 0.22-0.40 mm.

A spermathecum of each mature female was examined for spermatophores and the incidence of ovigerous females was recorded and females staged as follows:

Stage 1: Non-ovigerous;
Stage 2: Ovigerous with pale to dark yellow egg mass (no eyespots visible in eggs)
Stage 3: Ovigerous with yellow-grey egg mass (eyespots present);
Stage 4: Ovigerous with grey egg mass (eyespots and chromatophores discernible);
Stage 5: Egg remnants (spent).

Von Bertalanffy growth functions were derived from length frequency information using MULTIFAN (a likelihood-based method of estimating growth parameters) (Fournier and Sibert 1990).

Results

Carapace width (cw) of sampled crabs ranged from 28 to 194 mm and the cw of the smallest ovigerous female was 99 mm. Small individuals (30-50 mm) were sampled mostly during November-April (Fig. 2a and 2b) suggesting an extended spawning period. However, recruitment was greatest during December-February. The bimodal nature of the distributions through summer and autumn suggest the sampling of predominantly two age classes. The extended spawning period complicated the modal progression analysis, however, von Bertalanffy growth functions were derived for both males and females as follows:

$$l_t = 175\ (1-e^{-1.597(t-0.203)})\ \text{males}$$
$$l_t = 170\ (1-e^{-1.613(t-0.189)})\ \text{females}$$

Relatively high "K" values confirm rapid growth with many male crabs spawned during spring reaching 15 cm cw (legal size limit in Queensland) within 18 months.

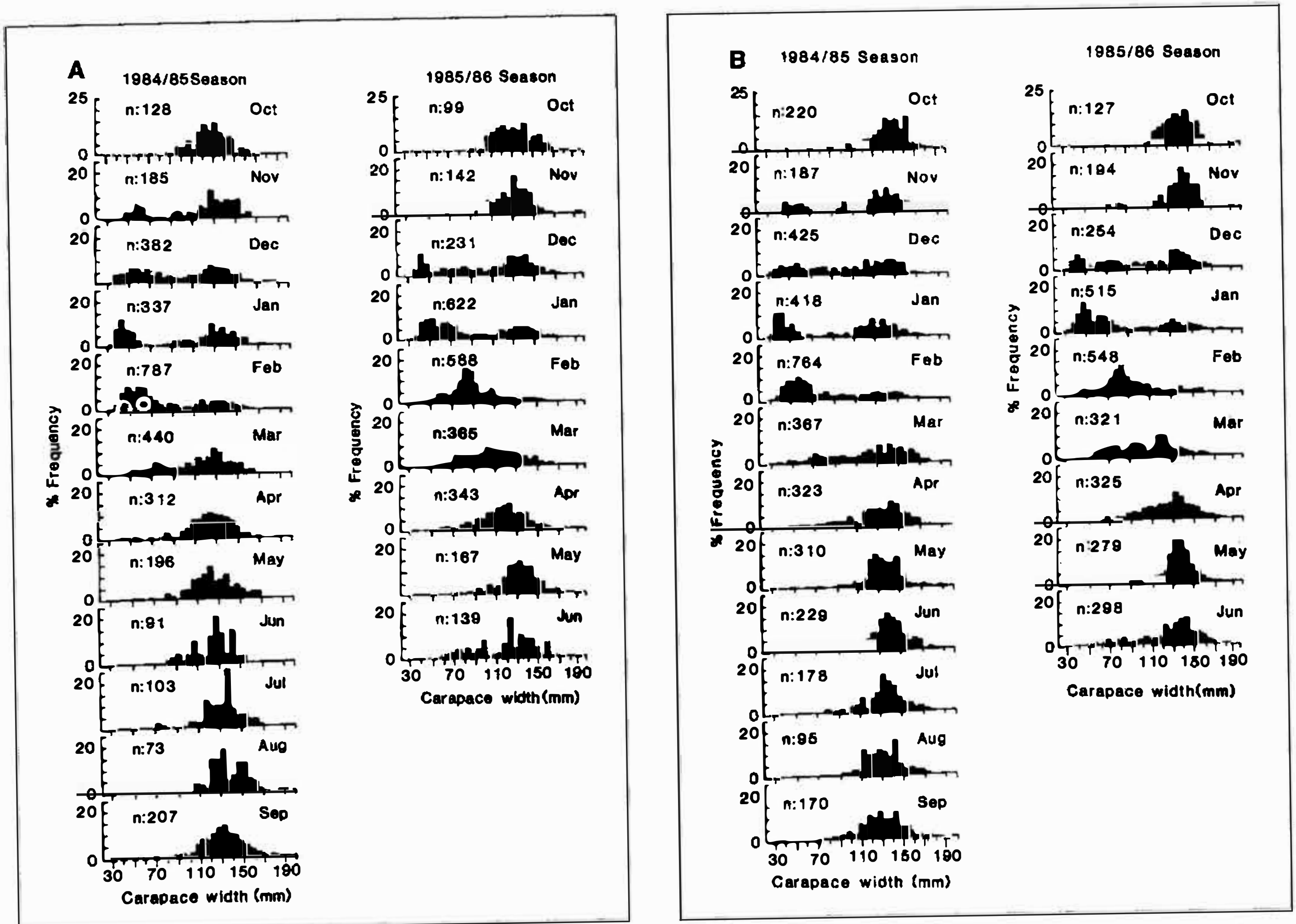

Fig. 2. Carapace width frequency distributions of female (a) and male (b) *P. pelagicus* (all sites pooled) Sample sizes are shown beside each histogram.

Fig. 3 presents length frequency histograms of male and female crabs caught at Sites 1-7. Small juveniles < 90 mm cw were abundant at the shallower inshore sites (Sites 3 and 6) while crabs > 100 mm cw predominated at sites outside the Bay (Sites 1 and 2). Site 4 also had large numbers of juvenile crabs although these were on average larger than those found further inshore. Length frequency histograms were unimodal at Sites 5 and 7 with few crabs < 90 mm cw being taken at those sites.

In all months (except September 1985 and January 1986) there were significantly more (x^2=218.2, $P<0.001$, df=20) mature males than mature females in the sampled population (Fig. 4). There was a marked increase in the proportion of mature male crabs around June of both years when over 70% of all crabs sampled were males.

Nearly 45% of females were in a soft shelled (either pre-molt, ecdysis, newly or recently molted) condition during May and June 1986 although this peak was not as noticeable the previous year (Fig. 5). Another molting activity peak occurred in November 1985, and a minimum during August-September 1985, when < 3% of females were soft shelled. In contrast, the proportion of soft males rarely exceeded 20%. No soft shelled male crabs were collected during June 1985 and there were correspondingly few (2.5%) soft shelled males in June the following year.

Two peaks were discernible in average gonosomatic indices for male *P. pelagicus* (Fig. 6). The first in November 1985 (0.84) and the second in May 1986 (1.18). The lowest average index (0.50) was obtained in February 1986. Peaks in male gonad maturity occurred when most males were in an intermolt condition and coincided with peaks in female molting activity (see Fig. 5).

Ovigerous females were present throughout the year (Fig. 7) although during June in both 1985 and 1986 their proportion was low (<3%). During much of the year the proportion of ovigerous females fluctuated around 25%, however there was a dramatic increase during August 1985 when 66% of mature females were carrying eggs. Both recently extruded (Stage 2) and maturing (Stages 3 and 4) eggs were present throughout the year. Female gonad development paralleled egg production (Fig. 7), although, as expected, maximum gonad condition occurred a month earlier.

The proportion of females which were both ovigerous and had maturing or mature gonads (Stages 3 and 4) is shown in Fig. 8. The most noticeable feature here was the large proportion of females during August and September 1985 which were carrying eggs and also had mature gonads (29% and 17%, respectively). During most other months, fewer than 5% of ovigerous females also had mature gonads. Mating activity (as estimated by the presence of spermatophores in the female spermathecae) was greatest during May-June 1986 when over 25% of all mature females contained spermatophores (Fig. 8). There were also secondary peaks during November and March. Throughout the study all postmolt females examined had recently implanted spermatophores in their spermathecae indicating that they had mated.

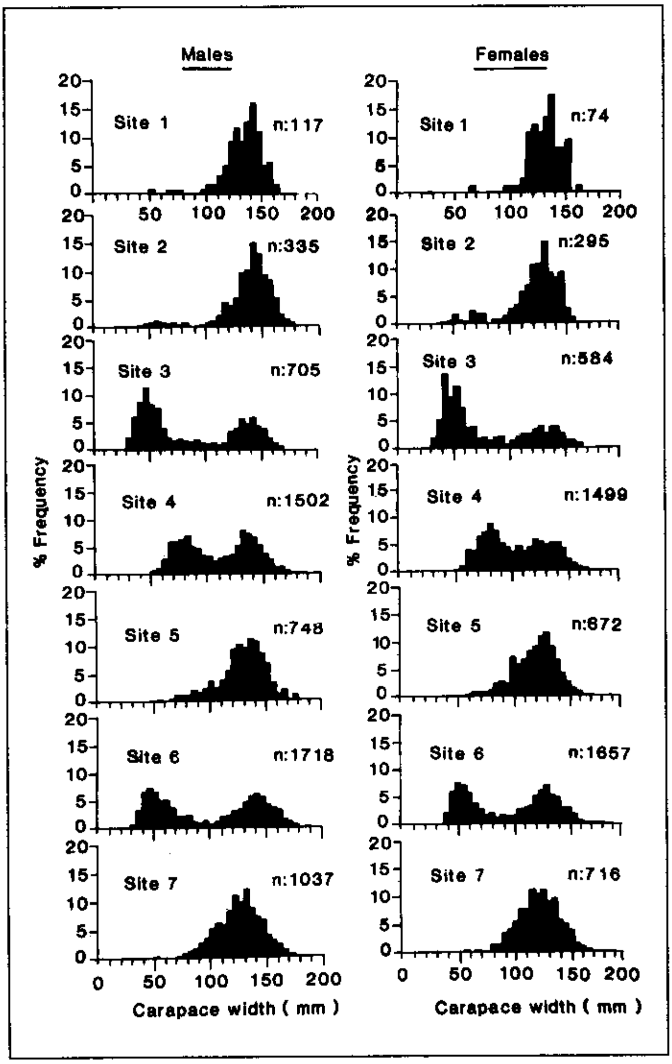

Fig. 3. Carapace width frequency histograms of male and female *P. pelagicus* at seven sampling sites in Moreton Bay and inshore oceanic waters (all samples pooled from October 1984 to June 1986).

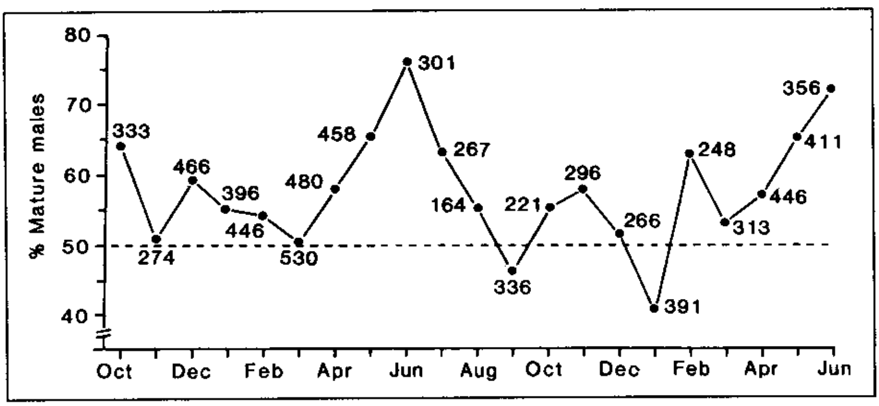

Fig. 4. Mature males as a percentage of the total adult sampled population of *P. pelagicus*.

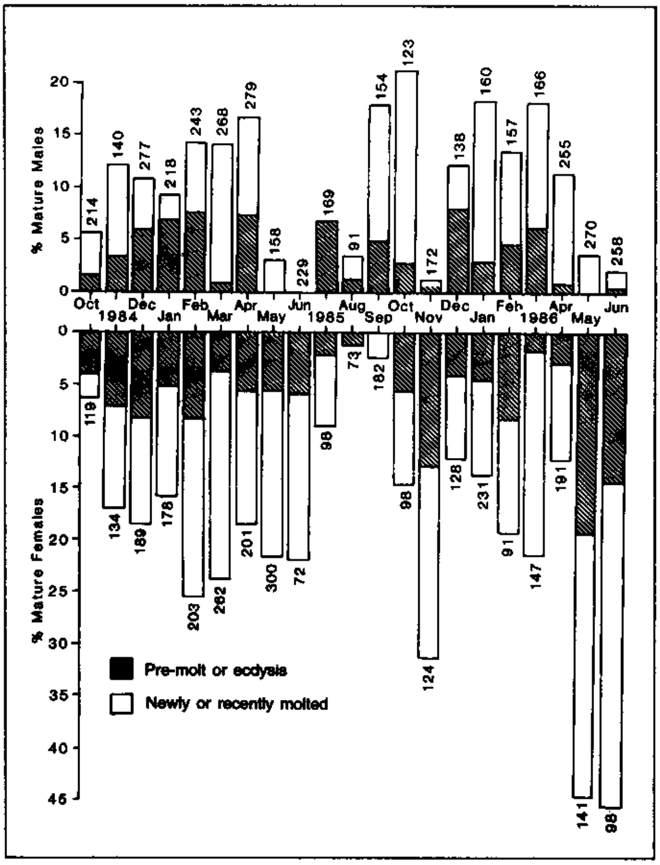

Fig. 5. Proportion of mature male and mature female *P. pelagicus* either pre-molt, ecdysis, newly molted or recently molted.

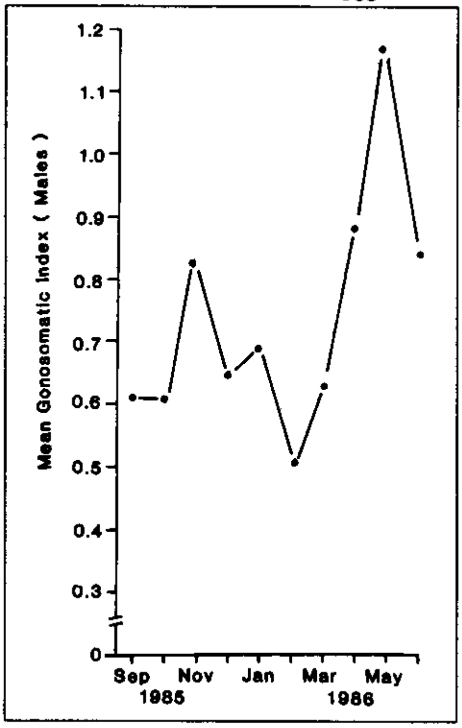

Fig. 6. Seasonal variation in mean gonad indices of male *P. pelagicus*.

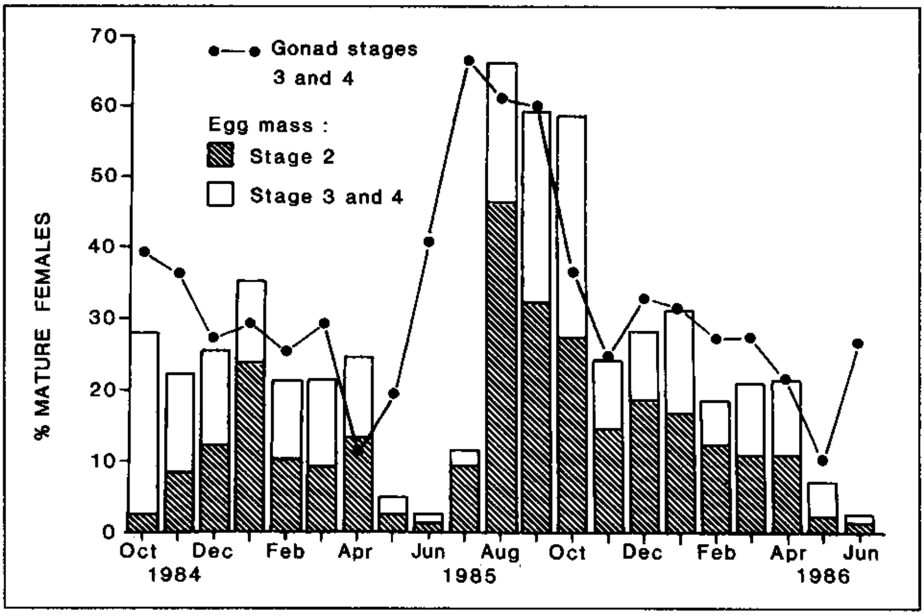

Fig. 7. Histograms of seasonal variation in the proportion of ovigerous female *P. pelagicus*. The proportion of mature females with gonad stages 3 or 4 is also shown as a continuous line.

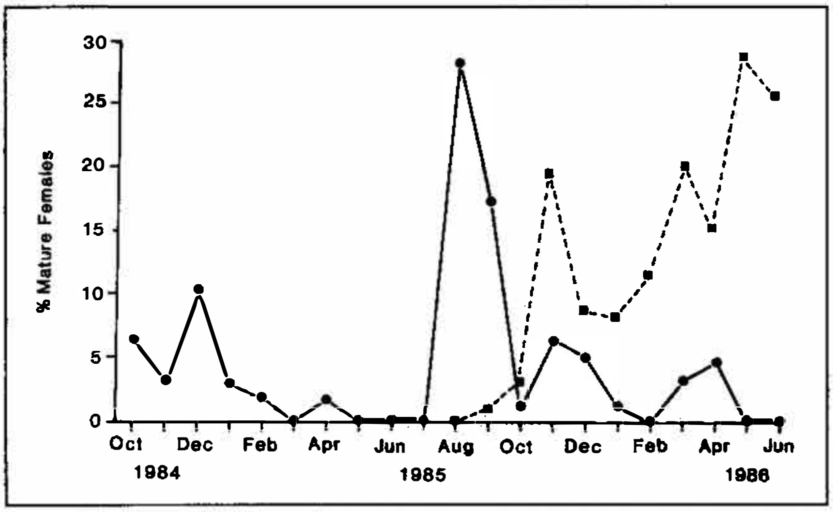

Fig. 8. Percentage of ovigerous female *P. pelagicus* with stage 3 or 4 gonads (continuous line) and percentage of adult female *P. pelagicus* with spermatophores (broken line).

Discussion

In Moreton Bay, *P. pelagicus* were more abundant in samples in summer and autumn when large males (cw > 15 cm) are the target of an extensive commercial and recreational fishery (Sumpton et al. 1989). Prasad and Tampi (1951) in India, and Potter et al. (1983) in Western Australia, among others have found similar seasonal catch changes. The latter authors attributed declining numbers during winter to low salinities causing crab movement out of the estuary being studied. In Moreton Bay, however, sandcrab tagging experiments (Potter et al. 1991) failed to provide evidence of large scale movement of crabs out of the Bay. Kinne (1963) found that low temperatures caused reduced feeding and inactivity in many marine invertebrates. At water temperatures of 20°C and 25°C the portunid *Scylla serrata* emerged from the substrate for approximately 10 hours per day, while at 16°C emergence time was almost halved (Hill 1980). In the laboratory, Smith and Sumpton (1989) have also shown that crab activity declines when water temperatures fall below 20°C. Low sand crab catches may thus have been the result of decreased catchability caused by crabs remaining inactive and buried in the substrate during winter when water temperatures fall below 20°C (Sumpton et al. 1989).

Meagher (1971) showed that male and female *P. pelagicus* have different habitat preferences at various times of the year, and both Thomson (1951) and Weng (1992) suggested that sex-segregated aggregations were a feature of sand crab populations. The sampling regime undertaken in the present investigation sampled most habitats except sandbanks in shallow water (< 4 m depth). Females are known to require a sandy substrate for successful egg extrusion and attachment to the pleopods (Campbell 1984). It is likely that migrations of mature females onto sandbanks for egg extrusion was at least partially responsible for the variation of sex ratios which were most noticeable immediately prior to the spawning season.

Early growth of juvenile crabs takes place predominantly in shallow inshore areas of Moreton Bay, as shown by the high proportion of juvenile crabs at Sites 3 and 6. The paucity of juveniles and adults from the oceanic locations (Sites 1 and 2) confirms the preference of *P. pelagicus* for estuarine waters. Growth of 0+ year individuals in Moreton Bay was rapid during the summer and autumn months. Once crabs reached carapace widths of about 90 mm, it became difficult to follow growth patterns because of the presence of small 1+ yr crabs, probably spawned late in the previous breeding season. During winter the relative stability of size distribution modes for both males and females shows growth was restricted during that time. This is reinforced by the molting cycle which showed few pre- or postmolt male or female crabs during July and August 1985. Most crabs > 90 mm cw were sexually mature. This, and the absence of small-size classes (< 90 mm cw) after June suggests that most juveniles hatched during spring had reached sexual maturity within their first 12 months.

As with other brachyurans, mating of *P. pelagicus* takes place between hard (intermolt) males and soft (newly molted) females (Fielder and Eales 1972). It was therefore not surprising to find the times when large numbers of intermolt males were present coincided with the peak in molting of females. A higher reproductive potential was attained by the population since all postmolt females at all times of the year had mated (as shown by the presence of spermatophores). This has important management implications as it suggests that the current size limit and exploitation rate of male *P. pelagicus* allows the conservation of enough mature males to enable insemination of all reproductively active females.

Based on the molt cycle, male gonad maturity and condition of the female spermathecum, two mating activity peaks were clearly discernible: the first, a minor peak in November 1985, and a second major peak in May-June 1986. At those times, male gonads reached maximum maturity and the proportion of mature females with recently implanted spermatophores was at its highest. By contrast, Penn (1977) and Smith (1982) both found mating activity was greatest during February-March in more temperate Australian waters. Following mating, sperm is stored in the female spermathecum until the eggs are fertilized on extrusion (Smith 1982). Van Engel (1958) found that sperm in a female *Callinectes sapidus* spermathecum can remain viable for at least 12 months. During 1985 in Moreton Bay, egg extrusion and fertilization took place predominantly during August-October, only 3 or 4 months after mating in May-June. In temperate Australian latitudes, because of the earlier mating period, sperm is stored for approximately 9 months before egg extrusion and fertilization (Smith 1982).

The spawning cycle of *P. pelagicus* is known to be highly variable. In India, Pillay and Nair (1976) have reported that spawning peaks varied annually and geographically. In Australia, Penn (1977) found summer spawning peaks in Cockburn Sound, western Australia, and in south Australia. Smith (1982) reported ovigerous females from October to April, with the highest incidence in November. Some early work in Moreton Bay by Stead (1988) recorded August-November as the major spawning period, while Weng (1992) found the highest incidence of ovigerous females in Moreton Bay during August-September. In Moreton Bay, peaks in the proportion of ovigerous females occurred 2 or 3 months earlier than temperate Australian populations (Smith 1982; Potter et al. 1983) suggesting temperature as a probable reproductive controlling factor. The peak in numbers of ovigerous females, however, cannot always be interpreted as an indication of imminent spawning. Ryan (1967) pointed out that the presence of ovigerous females in populations of *P. sanguinolentus* did not necessarily represent spawning periods since eggs would not always hatch at low temperatures. In the laboratory, Campbell (1984) studied the rate of development of *P. pelagicus* eggs and noted that although egg extrusion occurred at 18°C, no eggs matured after 68 days incubation at that temperature. Our results have shown that in Moreton Bay, egg extrusion was limited during winter. Although egg extrusion was delayed, female gonad maturation continued through winter until rising temperatures apparently initiated extrusion and fertilization of eggs in August/September. By comparison, in slightly higher latitudes in the northern hemisphere (Alexandria), Bawab and El-Sherief (1988) have reported that all adult hard shelled females had immature reproductive systems during winter.

Laboratory rearing of sand crabs has shown that female sand crabs have two maturity molts and, during each of these molts, can extrude up to four batches of eggs (Campbell 1984). The high incidence of ovigerous females which also had mature gonads during August and September indicated that shortly after the first spawning, many females extruded another batch of eggs thus resulting in a high reproductive output.

Acknowledgements

We particularly acknowledge the assistance of Mr. Phil Smith, Master of the FRV "Bar-ea-Mul," and his crew. This study was largely sponsored by a grant from the Australian Fishing Industry Research Trust Account.

References

Bawab, F.M. and S.S. El-Sherief. 1988. Stages of the reproductive cycle of the female crab *Portunus pelagicus* (L. 1758) based on the anatomical changes of the spermatheca. Crustaceana 54:139-148.

Bishop, R.K. and L.R.G. Cannon. 1979. Morbid behaviour of the commercial sandcrab, *Portunus pelagicus* (L.), parasitized by *Sacculina granifera* Boschma, 1973 (Cirripedia : Rhizocephala). Journal of Fish Diseases 2: 131-144.

Campbell, G.R. 1984. A comparative study of adult sexual behaviour and larval ecology of three commercially important portunid crabs from the Moreton Bay region of Queensland, Australia. University of Queensland, Australia. 253 pp. Ph.D. thesis.

Dhawan, R.M., S.N. Divivedi and G.V. Rajamanickam. 1976. Ecology of the blue crab, *Portunus pelagicus* (Linnaeus) and its potential fishery in Zuari Estuary. Indian Journal of Fisheries 23: 57-64.

Fielder, D.R. and A.J. Eales. 1972. Observations on courtship, mating and sexual maturity in *Portunus pelagicus* (L. 1766) (Crustacea, Portunidae). Journal of Natural History 6: 273-277.

Fournier, D.A. and J.R. Sibert. 1990. MULTIFAN a likelihood-based method for estimating growth parameters and age composition from multiple length frequency data sets illustrated using data for southern bluefin tuna (*Thunnus maccoyii*) Canadian Journal of Fisheries and Aquatic Sciences 47: 301-317.

Hiatt, R.W. 1948. The biology of the lined shore crab *Pachygrapsus crassipes* Randall. Pacific Science 2: 135-213.

Hill, B.J. 1980. Effects of temperature on feeding and activity in the crab *Scylla serrata*. Marine Biology 59: 189-192.

Kinne, O. 1963. The effects of temperature and salinity on marine and brackishwater animals. I. Temperature. Oceanography and Marine Biology: An Annual Review 1: 301-340.

Meagher, T.D. 1971. Ecology of the crab *Portunus pelagicus* in south western Australia. University of Western Australia, Australia. 232 pp. Ph.D. thesis.

Penn, J.W. 1977. Trawl caught fish and crustaceans from Cockburn Sound. Report, Department of Fisheries and Wildlife, Western Australia 20: 1-24.

Phillips, W.J. and L.R.G. Cannon. 1978. Ecological observations on the commercial sand crab, *Portunus pelagicus* (L.), and its parasite, *Sacculina granifera*, Boschma 1973 (Cirripedia : Rhizocephala). Journal of Fish Diseases 1: 137-149.

Pillay, K.K. and N.B. Nair. 1971. The annual reproductive cycles of *Uca annulipes*, *Portunus pelagicus* and *Metapenaeus affinis* (Decapoda : Crustacea) from the south west coast of India. Marine Biology 11: 152-166.

Pillay, K.K. and N.B. Nair. 1976. Observations on the breeding biology of some crabs from the southwest of India. Journal of Marine Biological Association of India 15: 754-770.

Potter, I.C., P.J. Chrystal and N.R. Loneragan. 1983. The biology of the blue manna crab *Portunus pelagicus* in an Australian estuary. Marine Biology 78: 75-85.

Potter, M.A., W.D. Sumpton and G.S. Smith. 1991. Movement, fishing sector impact, and factors affecting the recapture rate of tagged sand crabs, *Portunus pelagicus* (L.), in Moreton Bay, Queensland. Australian Journal of Marine and Freshwater Research 42: 751-760.

Prasad, R.R. and P.R.S. Tampi. 1951. An account of the fishery and fishing method *Neptunus pelagicus* Linnaeus) near Mandapam. Journal of the Zoological Society of India 3: 335-339.

Rahaman, A.A. 1980. Ecological observations on spawning of a few invertebrates of the Madras coast. Journal of the Madurai Kamaraj University 9: 71-77.

Ryan, E.P. 1967. Structure and function of the reproductive system of the crab *Portunus sanguinolentus* (Herbst) (Brachyura : Portunidae) II. The female system. Proceedings of the Symposium of the Crustacean Marine Biological Association of India Part II: 522-544.

Smith, H. 1982. Blue crabs in South Australia - their status potential and biology. South Australian Fishing Industry Council (Adelaide, Australia) 6: 6-9.

Smith, G.S. and W.D. Sumpton. 1989. Behavior of the commercial sandcrab *Portunus pelagicus* (L.) at trap entrances. Asian Fisheries Science 3: 101-113.

Stead, D.G. 1988. Contributions to our knowledge of the Australian Crustacean fauna. I. Observations on the genus Neptunus. Proceedings of the Linnean Society of New South Wales 4: 746-758.

Sumpton, W.D., M.A. Potter and G.S. Smith. 1989. The commercial pot and trawl fisheries for sandcrabs (*Portunus pelagicus*) in Moreton Bay, Queensland. Proceedings of the Royal Society of Queensland 100: 89-100.

Thomson, J.M. 1951. Catch composition of the sand crab fishery in Moreton Bay. Australian Journal of Marine and Freshwater Research 2: 237-244.

Van Engel, W.A. 1958. The blue crab and its fishery in Chesapeake Bay. Part I. Reproduction, early development, growth and migration. Commercial Fishing Review 20: 6-17.

Wassenberg, T.G. and B.J. Hill. 1987. Feeding by the sand crab *Portunus pelagicus* on material discarded from prawn trawlers in Moreton Bay, Australia. Marine Biology 95: 387-393.

Weng, H.T. 1992. The sandcrab (*Portunus pelagicus* (Linnaeus)) populations of two different environments in Queensland. Fisheries Research 13: 407-422.

Williams, M.J. 1982. Natural food and feeding in the commercial sand crab *Portunus pelagicus* Linnaeus, 1766 (Crustacea : Decapoda : Portunidae) in Moreton Bay, Queensland. Journal of Experimental Marine Biology and Ecology 59: 165-176.

Manuscript received 20 August 1993; accepted 16 February 1994.