5. SPAWNING, RECRUITMENT AND LIFE HISTORY STUDIES OF *PENAEUS ESCULENTUS* HASWELL, 1879 IN TORRES STRAIT.

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5.1 Introduction

Penaeus esculentus, the brown tiger prawn, is endemic to Australian waters (Grey *et al.* 1983). It is found northward from southern New South Wales, through the Gulf of Carpentaria and around to Shark Bay in Western Australia (Grey *et al.* 1983). Torres Strait is the most northerly extent of its distribution. Catches of *P. esculentus* form the main component of catches from the Torres Strait Prawn Fishery (Section 2).

Except for the habitat utilized by the juvenile stage, in Torres Strait *P. esculentus* conforms to the penaeid life cycle as outlined by Garcia and Le Reste (1981). Juvenile *P. esculentus* in this region, use seagrass beds on reef-platforms as nursery areas (Section 4), and not estuaries as in other brown tiger prawn fisheries.

Information on spawning and recruitment patterns of *P. esculentus* is essential to the implementation of management strategies such as temporal and spatial closures and effort limitation. However, there is little life history information available for this species in Torres Strait. Studies on the reproductive activity of *P. esculentus* in the Gulf of Carpentaria (Crocos 1987; Buckworth 1985; Robertson *et al.* 1985) found major spawning periods from July-November. Other studies on *P. esculentus* in Torres Strait (Somers *et al.* 1987) and the Low Islet region of the East Coast Prawn Fishery (O'Connor 1979) found a major spawning period occurred in March.

Information on *P. esculentus* recruitment patterns is confusing. Recruitment to the fishery of sub-adults (< 26 mm carapace length) occurred from March-May in the Exmouth Gulf (Penn and Caputi 1986) and November-March in the Gulf of Carpentaria (Somers *et al.* 1987b). In Torres Strait, Somers *et al.* (1987a) found continuous recruitment to the fishery of *P. esculentus* from March-September followed by a decrease in December.

The differences in spawning and recruitment periods between the Torres Strait, Queensland East Coast and the Northern Prawn Fisheries, poses a problem for fisheries managers with regard to blanket management policies for *P. esculentus.* This study provides biological information on spawning and recruitment timing of *P. esculentus* in Torres Strait. This information can be used to formulate management strategies designed to maintain high yields in the short term, and long term productivity of the Torres Strait Prawn Fishery.

5.2 Materials and Methods

5.2.1 Selection of sampling stations

A range of sampling stations were selected which differed in distances from reefs (sources of recruitment) and seagrass areas (settlement areas), and traversed environmental gradients such as depth and sediment type (Figure 1). At each station, depth profiles and monthly sea surface temperatures were recorded. The temperatures were averaged for Torres Strait. Maximum and minimum monthly air temperatures for Torres Strait were based on the average of 34 years obtained from the Bureau of Meteorology, Brisbane. Sediment samples were taken from the northern and southern extremes of each station. Particle size and organic content of these samples were analysed by the Ocean Science Institute of the University of Sydney.

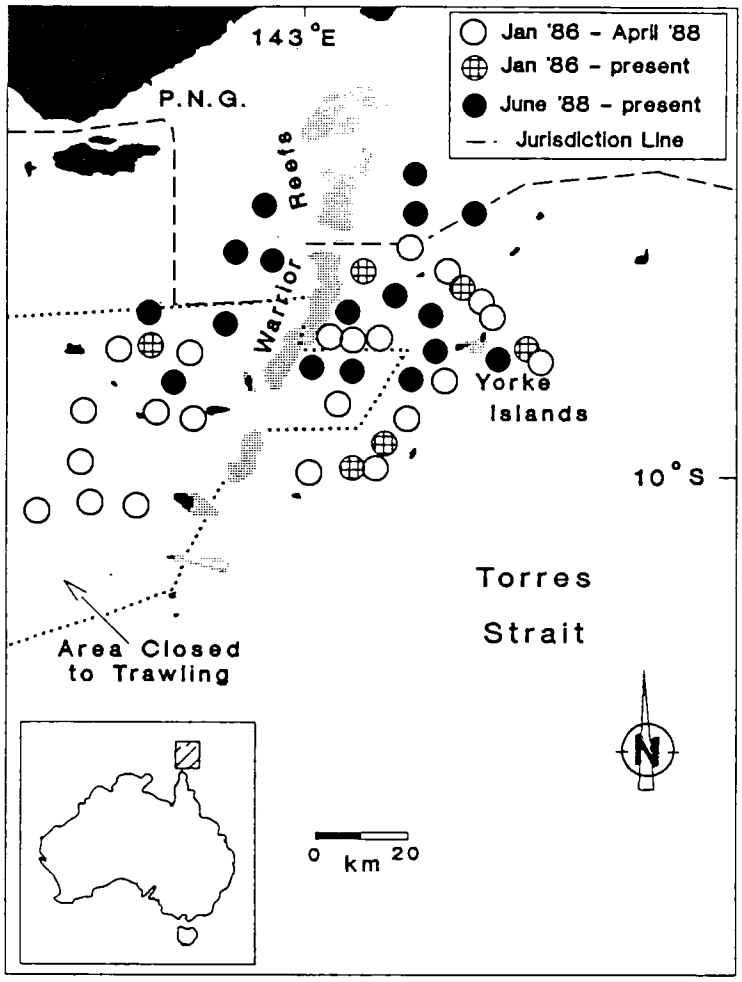


Figure 1. Map of Torres Strait showing sampling stations and the seabed jurisdiction line.

5.2.2 Sampling schedule

Sampling commenced in January 1986 using the fisheries research trawler R.V. 'Lumaigul', a 14 m, planing-hull vessel of Stebercraft design. Data was collected from trawl sites at the time of the new moon each month from January 1986 to April 1988 (Figure 2).

5.2.3 Trawl gear

The R.V. 'Lumaigul' was set up as a stern trawler. Initially, a single three-fathom wide 48 mm-mesh net was used (Section 11). In November 1987 a second smaller (32 mm) mesh net was added and the pair operated as twin gear separated by a sled.

Trawl starting points were fixed by radar distances from two nearby islands. Trawl paths using a single net, would follow an arc around one of these islands for 30 minutes in one direction and then turn 180° returning along the arc for another 30 minutes. Swept area or the area of the sea floor covered by the trawl gear was calculated using vessel speed, duration of the trawl and the spread or width of the trawl net. When twin nets were used the trawl duration was reduced to 30 minutes, following the arc in one direction, to maintain the same total swept area as the single net.

5.2.4 Sample processing

Samples from port and starboard nets were kept separate to provide data for selectivity trials (Section 11). If for any reason, trawl efficiency was considered impaired (such as the mouth of the net was blocked by a large animal), the sample collected was used only for qualitative purposes (Figure 2). Samples were labelled and frozen for later examination in the laboratory.

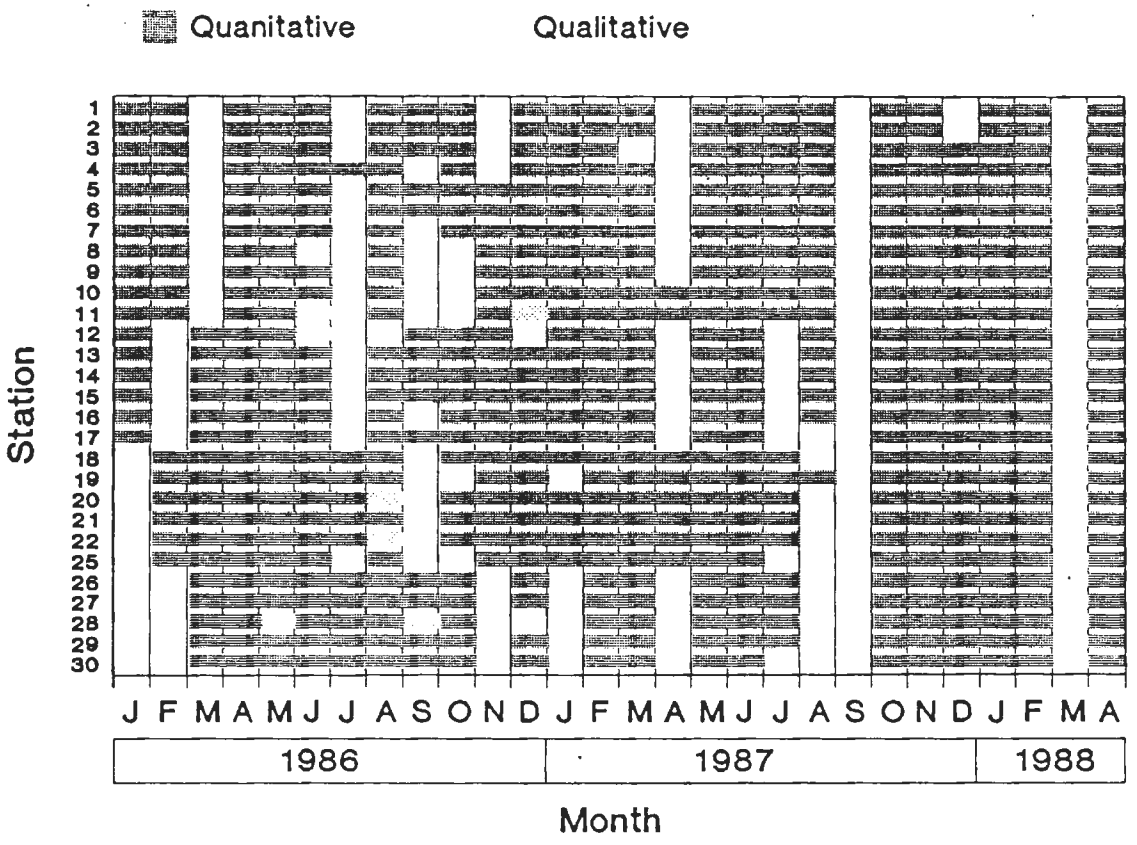


Figure 2. Sampling schedule from January 1986 to April 1988.

In the laboratory all prawn species (commercial and non-commercial) were identified and measured. Prawn size was determined by measuring carapace length (CL) to the nearest 0.1 mm. Sex, ovary development and moult stage were recorded for each prawn. Ovary stages (after Tuma 1967) were referred to as quiescent (stage I), developing (stage II), early maturity (stage III), ripe (stage IV) and spent (stage V). As stages I and V could not be differentiated, they were combined. Moult staging was a visual method involving three stages of shell softness which covered the range from immediate post-moult to normal inter-moult hardness.

5.2.5 Definition of areas within fishery

Sampling commenced in January 1986 and analysis included a total of 28 monthly samples to April 1988 (Figure 2). The fishery was divided into two areas: (1) west of Warrior Reef (West) an area not fished for prawns since 1981, and (2) east of Warrior Reef (East) the current fishing grounds (Figure 1). The name, Torres Strait, is used when the two areas are considered together.

5.2.6 Spawning areas

Ripe females are those with visual ovary stages III and IV. A population fecundity index (PFI), measured in number of eggs ha^{-1} (Section 6), was used to represent spawning activity. The major spawning areas were deduced from a spatial analysis of the highest PFI values obtained over the time series. This method is similar to that used by Crocos and Kerr (1983) and Crocos (1987) using egg production indices.

5.3 Results and Discussion

5.3.1 Spawning

Seasonality. Analysis of PFI data averaged from all stations for each month showed two major spawnings occurred each year in the East (Figure 3a). The peaks were January-March and August-September in 1986, January-February and May-June in 1987, and January-March in 1988 (Figure 3 and Section 6-Figure 2). PFI values for the West showed the major spawning to occur in July-August, October-November, 1986 and January, July and October, 1987 (Figure 3a and Section 6-Figure 2). In the West, minor spawnings mirrored major spawnings in the East. We can conclude that throughout Torres Strait, the intensity and duration of spawning showed a considerable degree of annual variation.

The abundance of females in the East reached an annual maximum between January-March 1986, May 1987 and February 1988 (Fig.ure 3b). Abundance of female *P. esculentus* in the East, declined sharply in March 1986 and 1988 (Figure 3b). This decline coincided with the opening of the fishing season and is probably due to fishing mortality. This pattern is not evident in 1987 and is a consequence of noclosure being implemented. Low abundances of female *P. esculentus* in the East after May in each of the years (Figure 3b), could have been caused by reduced catchability induced by falling water temperatures (Figure 3c). In the West the abundance of females reached a maximum in February 1986, April 1987 and April 1988. The abundance of females in the West was generally higher throughout the 28 months than in the East (Figure 3b).

The proportion of ripe females in the East reached maximum values in July-August 1986, and January and December 1987, although a high proportion were caught throughout the year (Figure 3d). An increase in the proportion of ripe females in the East and in the West (Figure 3d) is associated with a change in absolute water temperature which is believed to trigger ovary maturation (Penn 1980) (Section 6).
This increase in numbers could also have been attributed to the high catchability of ripe females during periods of low water temperatures (Figure 3c and Section 6). In the West, the pattern was similar for 1986 but a decline in the proportion of ripe females from October-November is evident (Figure 3d). The proportion fell as the abundance of smaller prawns recruiting into the area increased (Figure 6a), and older prawns either migrated through to the East (Section 7) or died.

The mean carapace length of ripe females in the West showed a slight decrease after November (Figure 3e), probably due to the migration of smaller ripe females into the area (Figure 6a). The mean carapace length of ripe females in the East remained relatively stable over the three years.

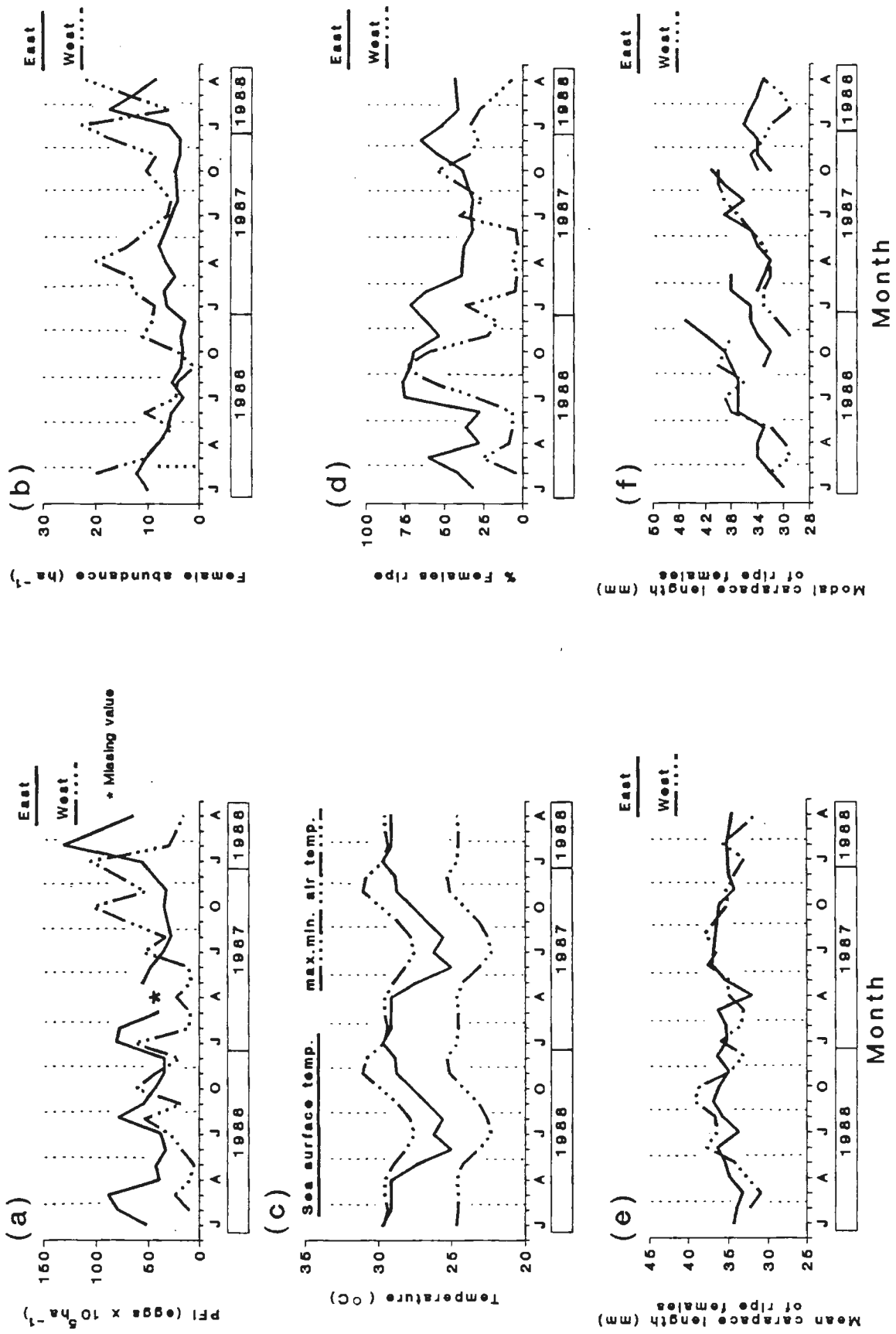


Figure 3. (a) Population Fecundity Index (PFI) of *P. esculentus*. (b) Abundance of females. (c) Monthly mean surface sea water temperature (°C) and long term average maximum and minimum air temperature (°C) for Torres Strait. (d) The percentage of ripe females (stages III and IV). (e) The monthly mean carapace length (mm) of ripe females (stages III and IV). (f) The monthly modal carapace length (mm) of ripe females

A small number of large (33 - 38 mm CL) ripe females (Figure 3f) produced the 1986 August-September spawning in Torres Strait (Figures 3a and 4b). This peak was not as pronounced in 1987. The October-November spawning, in Torres Strait (Figures 3a and 4c), comprised of two size groups of female prawns: the more abundant, recruiting females of 28 - 34 mm CL; and a group of less abundant, but older ripe females of 38 - 40 mm CL. By comparison, a single group of female prawns, comprising of few ripe females, of 30 - 34 mm CL (Figure 3f) produced the 1986 January-March spawning in Torres Strait (Figures 3a and 4a).

Somers *et al.* (1987a) used the percentage of mature females with visible ovaries and the abundance of ripe females as indicators of spawning activity in Torres Strait. They found maximum spawning periods in March with some spawning occurring throughout the year. The timing of their quarterly sampling and the degree of interannual variation in the timing of spawning seasons could have caused them to miss a potential spawning peak during the colder months of 1985.

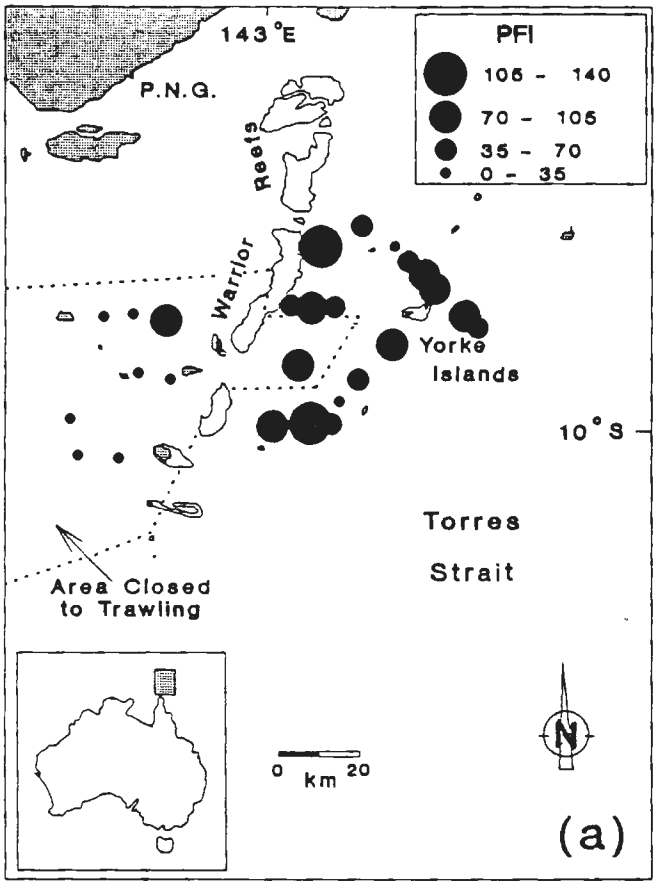
Spatial. As there was only small annual spatial variation, our 1986 results were presented as representative. The optimum recruitment areas were nominated in a similar manner. PFI values were calculated for each station.

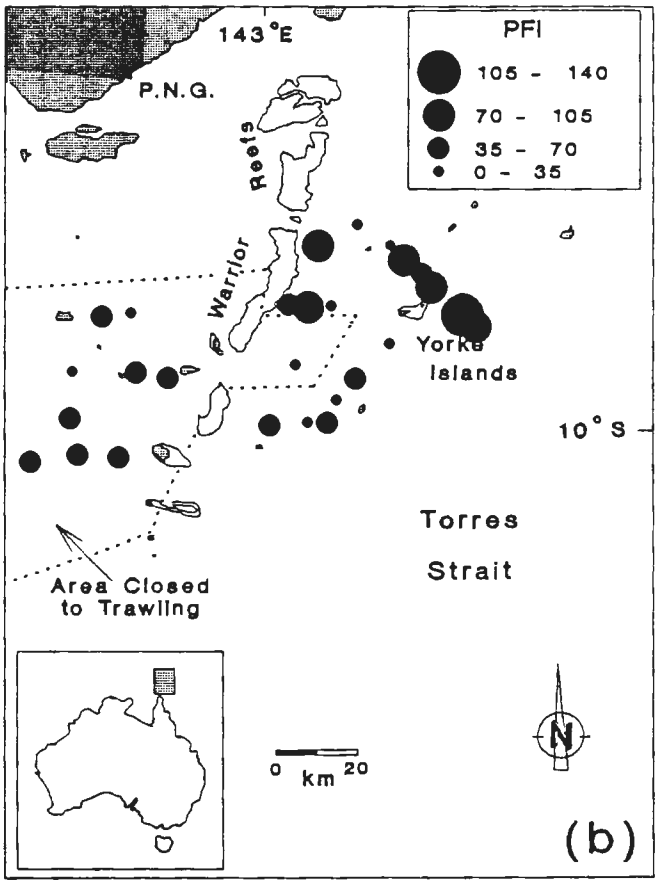
Areas located just east of Warrior Reef had high PFI values (105 - 140) in January-March (Figure 4a). Further east, the PFI values decreased before increasing again near the Yorke Islands (Figure 4a). In the West, the only significant spawning in January-March occurred in close proximity to south-west of Warrior Reef where PFI values ranged from 70 - 105 (Figure 4a).

High PFI values (70 - 140) were found in the Yorke Islands area and just east of the Warrior Reefs from August-September (Figure 4b). Elsewhere there was a relatively low level of spawning (Figure 4b).

The October-November spawning was most notable in the West with PFI values ranging from 60 - 240 (Figure 4c). East of Warrior Reef, a low level of spawning occurred from October-November but the major spawning area was again concentrated around the Yorke Islands (Figure 4c and Section 6-Figure 2).

Spawning was protracted (Figures. 4a, 4b and 4c) in the deeper waters around the Yorke Islands, an area which lies to the east of the fishery. This area in the East, yields larger ripe female prawns and hence higher PFI values throughout the year compared with other areas in Torres Strait (Figure 5). The West predominated in the October-November spawning (Figure 3a and 4c) as smaller, developing females, joined older ripe females (Figure 3f). These older females may have failed to migrate to the East (Section 7) during the previous January-June recruitment period.





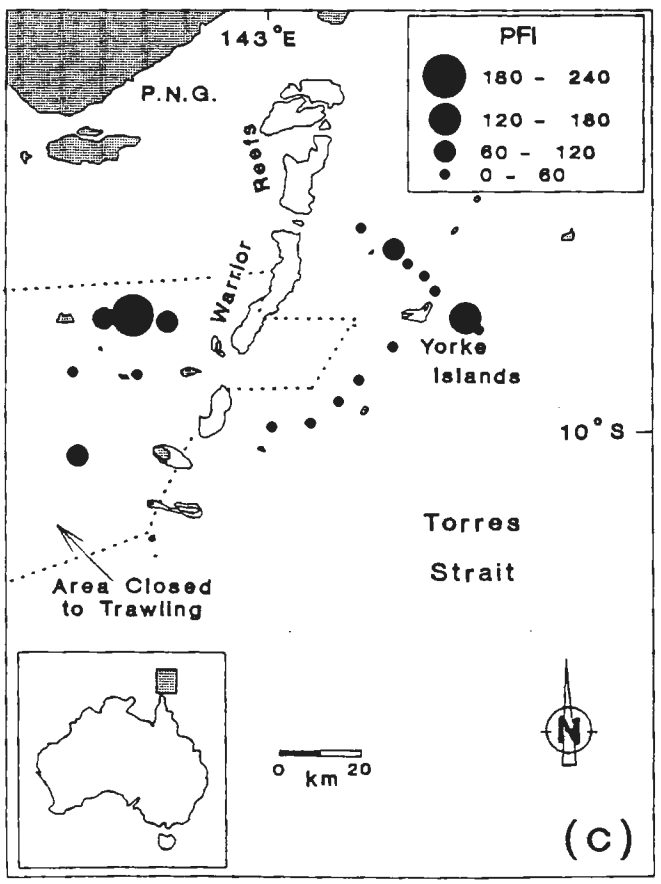


Figure 4. Population Fecundity Index (PFI) of *P. esculentus* for 28 sampling stations, scaled from the maximum for: (a) January-March 1986, (b) August-September 1986 and (c) October-November 1986.

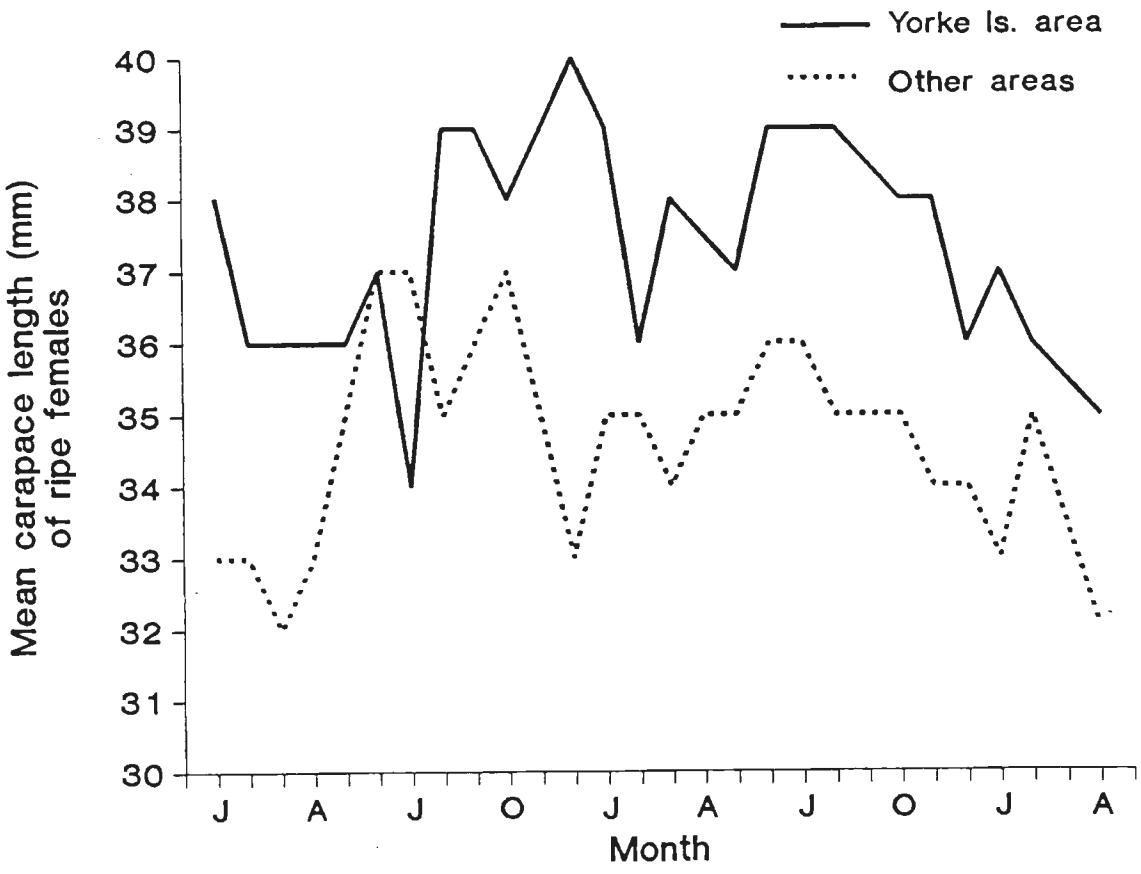


Figure 5. A comparison between the Yorke Islands area and other areas in Torres Strait for mean carapace length (mm) of ripe females (stages III and IV).

5.3.2 Recruitment

Seasonality. Recruitment of small *P. esculentus* (< 26 mm CL) into the fishery in the East was at a continuously low level in 1986 and 1987, although a small peak was observed in April 1987 (Figure 6a). By comparison, movement into our western sampling sites commenced in October 1986, peaked in February 1987, and then declined rapidly to a minimum in July-August 1987, before rising again in November 1987 (Figure 6a). The greater number of small prawns in the West suggests that this area is more important as a pre-recruitment habitat for small prawns than the East. The total abundance of all prawns is greater in the West than in the East for the 28 months sampled (Figure 6b). This can be attributed to the abundance of small prawns in the West. Movement of smaller prawns from the Warrior Reefs to the West decreased by May (Figure 6a) as did the emigration to the East (Section 7) of resident larger prawns. This resulted in an increase through growth, of the mean carapace length of prawns in the West from May to September (Figure 6c). Prawns in the East were smaller than those in the West from May-September (Figure 6c) probably due to size-selective fishing mortality.

P. esculentus length frequency data for the West and East confirmed recruitment timing (Figure 7). This data, combined with growth rate data (Section 7), established that the small prawns (< 26 mm CL) in the West from April-July 1986 (Figure 6a and Figure 7a) were spawned from the previous January-March spawning (Figure 3a). As only small numbers of these prawns can be seen (Figures 6a and 7a), it is assumed that these prawns overwintered in an area just behind the reef before migrating in August-October into our sampling stations in the West as large prawns (Figsure 6c and 7a). These prawns recruited to the fishing grounds in the East (Section 7), in the following January-February (Figure 7). Similarly, small prawns in the West in November 1986 (Figure 7a), were spawned in the previous August-September spawning (Figure 3a). These prawns migrated to the East and recruited in January-February of 1987 (Figures 6c and 7). Small prawns in the West in February-1987 and January 1988 (Figure 7a) were spawned in the previous October. These prawns recruited into the fishery in the East in the following April-May (Figures 6c and 7).

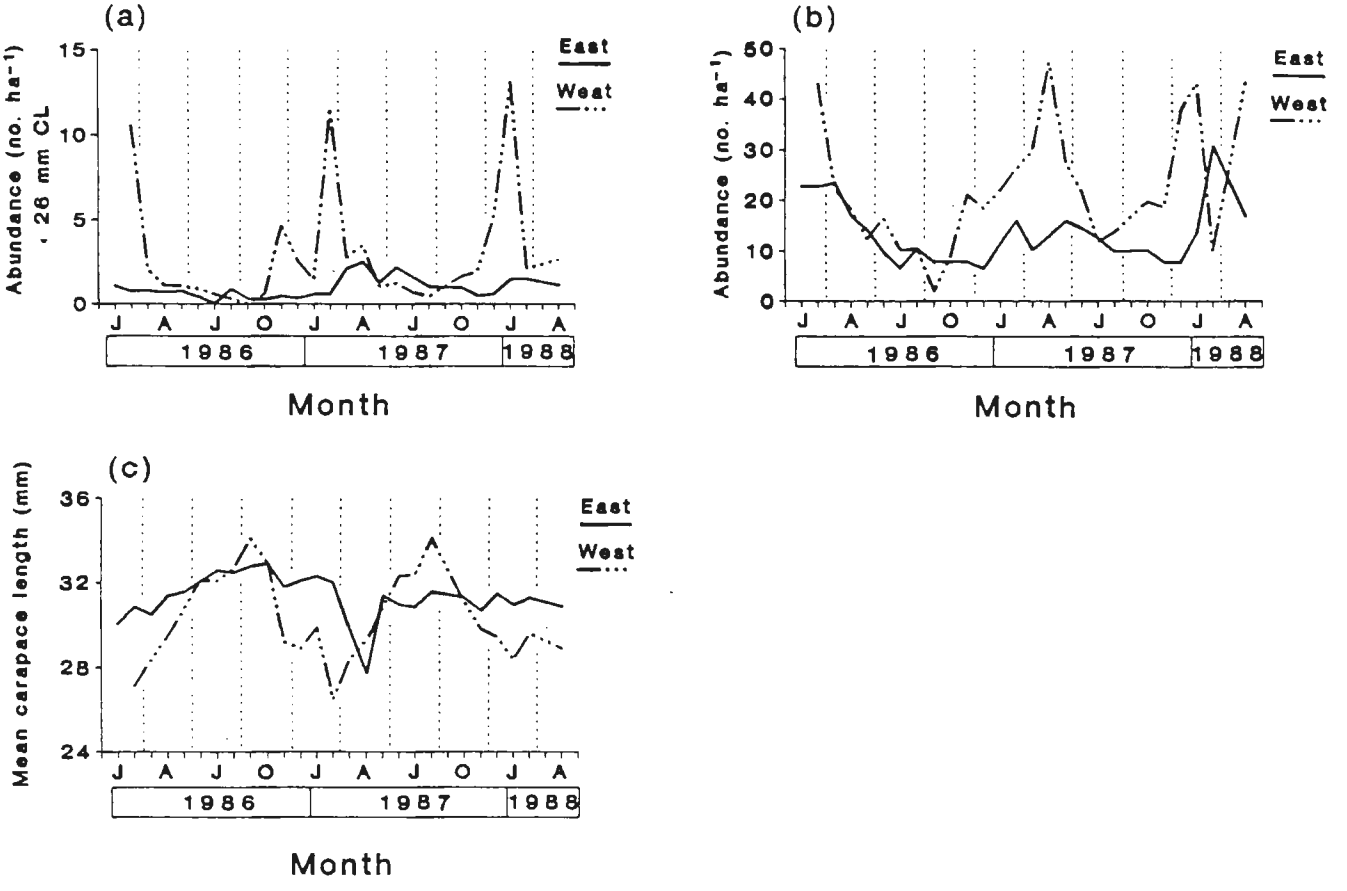


Figure 6. (a) Monthly abundances of all *P. esculentus* < 26 mm carapace length. (b) Monthly abundances of all *P. esculentus*. (c) Monthly mean carapace length of all *P. esculentus*.

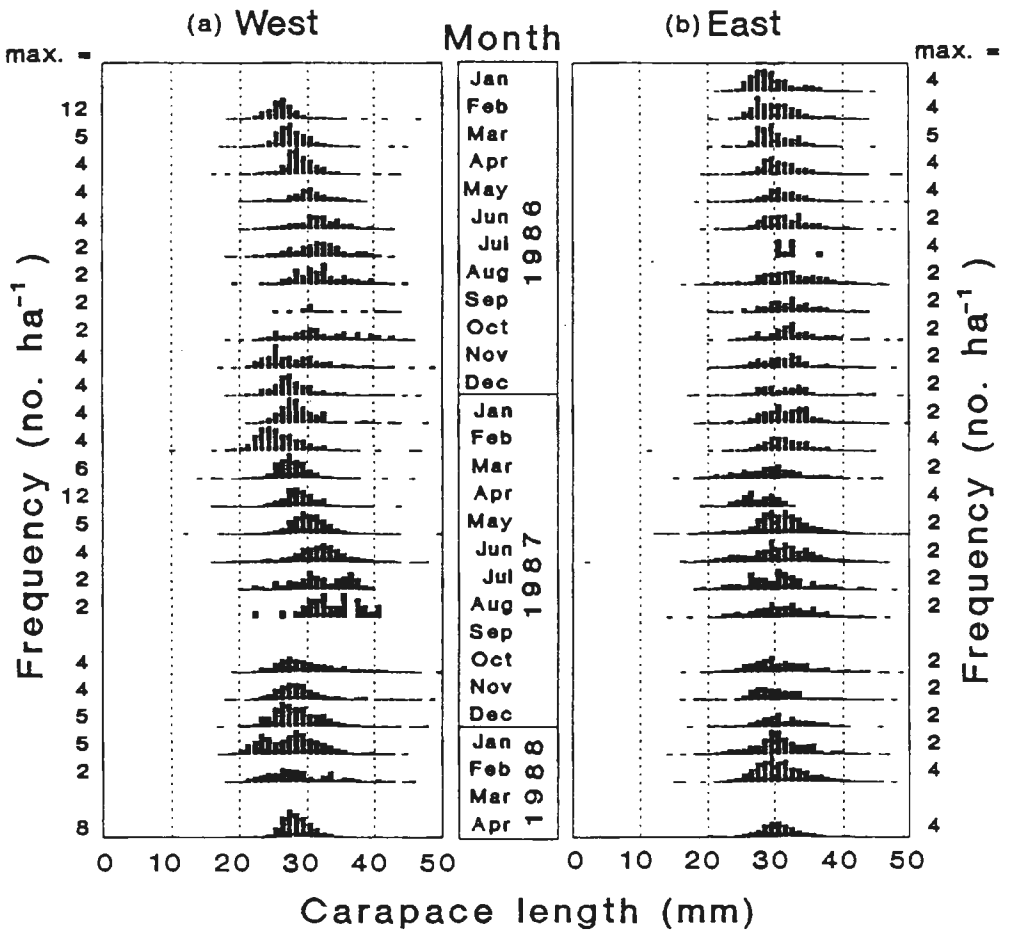


Figure 7. Length frequency distribution of *P. esculentus* from January 1986 to April 1988 for: (a) West and (b) East.

Annual variation in the timing of spawning influenced the pattern of recruitment. Spawning in the East, occurred in August-September of 1986 compared with May-June in 1987 (Figure 3a). Cold watertemperatures would have slowed the growth rate of the May-June 1987 spawning. As a result, the migration of prawns from the pre-recruitment habitat in the West to our sampling areas in the West occurred one month earlier in January 1988 compared with February 1987 (Figures 6a and 7). These prawns formed the peak of the distribution of February 1987 and probably the right peak of January 1988 (Figure 6c and 7a). A strong association or correlation between environmental factors such as rainfall, water currents or water temperature and timing of spawning and of subsequent recruitment may explain annual changes. This has not been fully investigated in this report.

The relatively low recruitment rate of small prawns (< 26 mm CL) into the East found by this study was also reported by Somers *et al.* (1987a). These authors did not detect spawning or recruitment in the West because of their sampling design.

Spatial. In January 1988, small (<26 mm CL) recruiting prawns were found in the West (Figure 8), close to the northern seabed jurisdiction line that divides Papua New Guinea and Australia (Figure 1). Monthly analysis for the 28 months, found that this is the only area where recruiting small prawns are numerous.

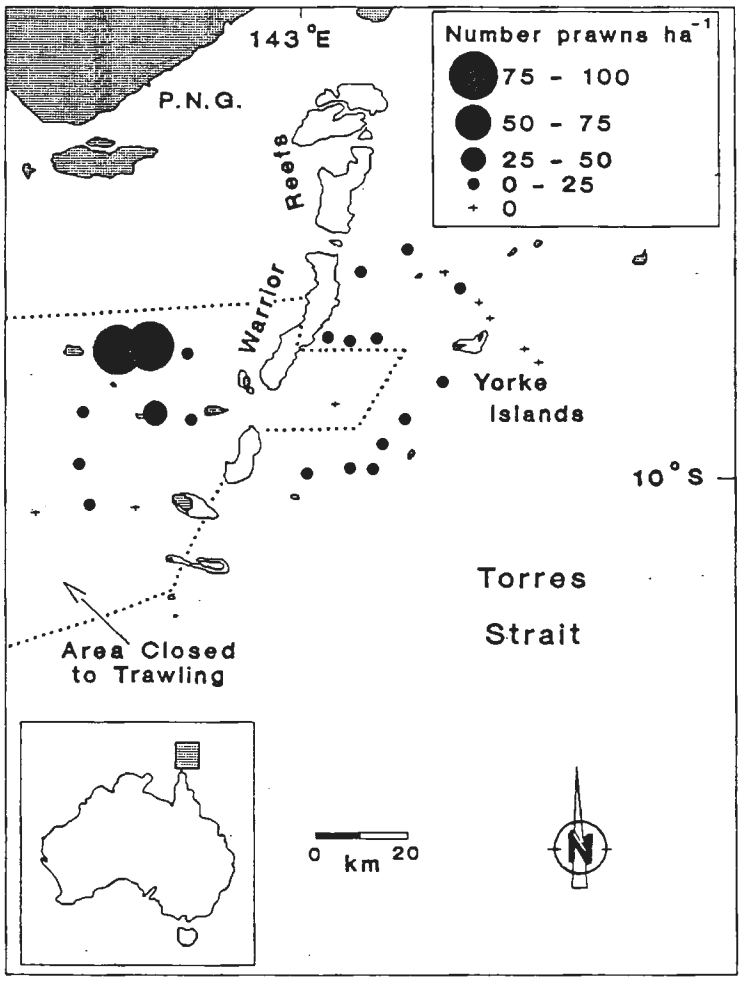


Figure 8. Location of small (< 26 mm CL) *P. esculentus,* scaled from the maximum for January 1988.

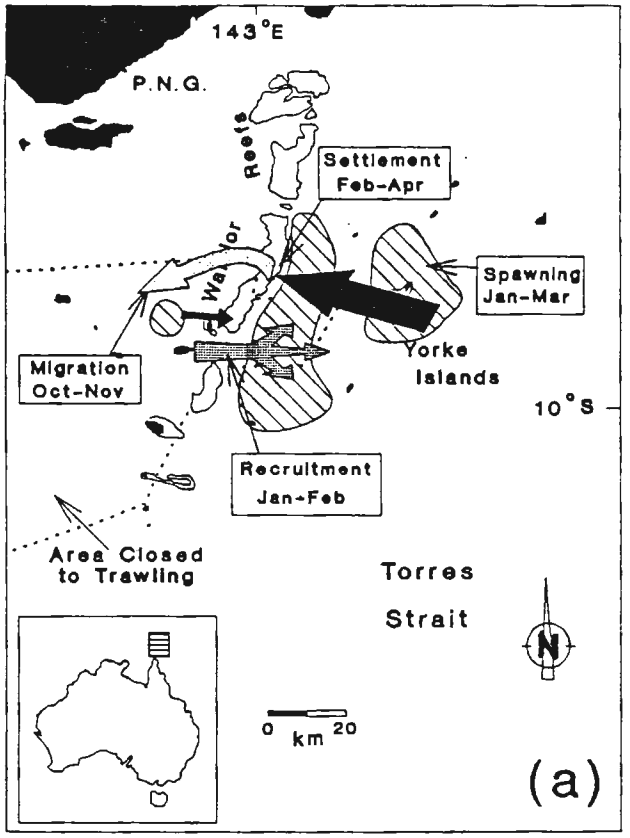
5.4 General Discussion

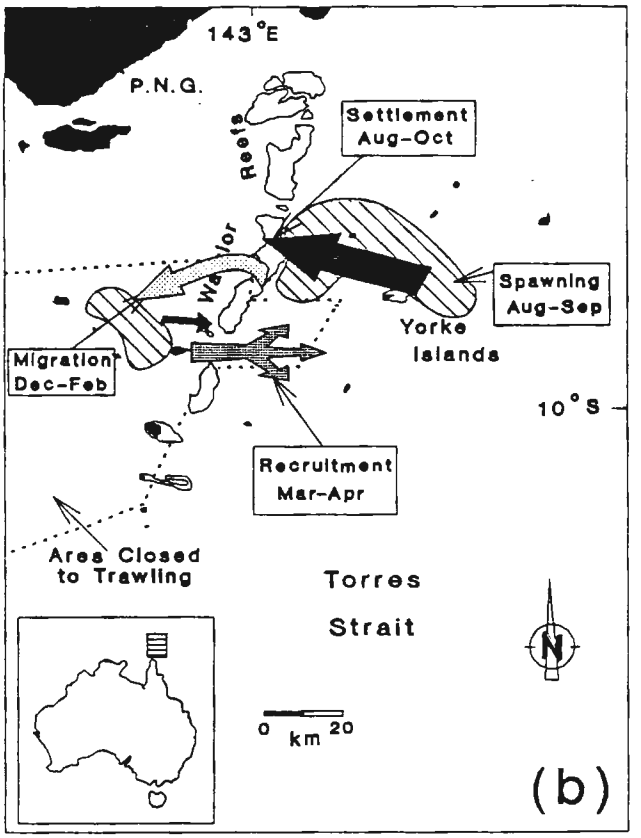
This discussion is based on 1986 data only and describes a hypothetical life cycle for *P. esculentus* in Torres Strait. *P. esculentus* had three major spawning periods in Torres Strait: January-March and August-September in the East, and October-November in the West. These periods of spawning activity preceded peaks of larval settlement on Warrior Reef which forms the major juvenile nursery ground in Torres Strait (Section 4).

Some juvenile prawns may recruit directly from the nursery areas on Warrior Reef into the fishery to the East while the remainder migrate to the West (Figures 6a and 7). The latter remain in the West for nine months or more before they emigrate to the deeper waters east of Warrior Reef (Section 7) and recruit to the fishery. Prawns recruit into the fishery in the East at a range of ages and sizes.

From October, the abundance of small prawns began to increase in the West (Figure 6a) as prawns from the previous January-March spawning (Figure 3a) began to migrate into our sampling stations (Figure 9a). From December 1986 to April 1987 there is a further influx of small prawns into the West (Figures 6a and 7a) as prawns from the August-September and October-November spawnings migrate from the nursery areas (Figures 9b and 9c). Abundance of all prawns in the West reached a maximum in March-April 1987 (Figure 6b). Prawns from the 1986 January-March spawning then migrated to the East in January-February 1987 and recruited into the fishery (Figure 9a). Prawns from the previous August-September and October-November spawnings (Figures 9b and 9c) emmigrated into our western sampling stations in February and April. These prawns then migrated east and recruited into the fishery in March-April and May-June respectively (Figures 9b and 9c).

Prawns from the August-September and October-November spawning periods moved through the early phases of this migration-recruitment cycle more quickly than did prawns from the January-March spawning. Prawns from the January-March spawning experienced cooler water temperatures thereby reducing metabolism and slowing growth rate. Compared with those from the winter spawnings, these prawns could have lingered up to two months or longer in this shallow water area (6-10m) and fine silty mud close to the west of Warrior Reef. This area was unsampled by this study until September 1988. Observations so far have shown this area to nurture small prawns and further investigation will determine if small prawns use this area to overwinter in.





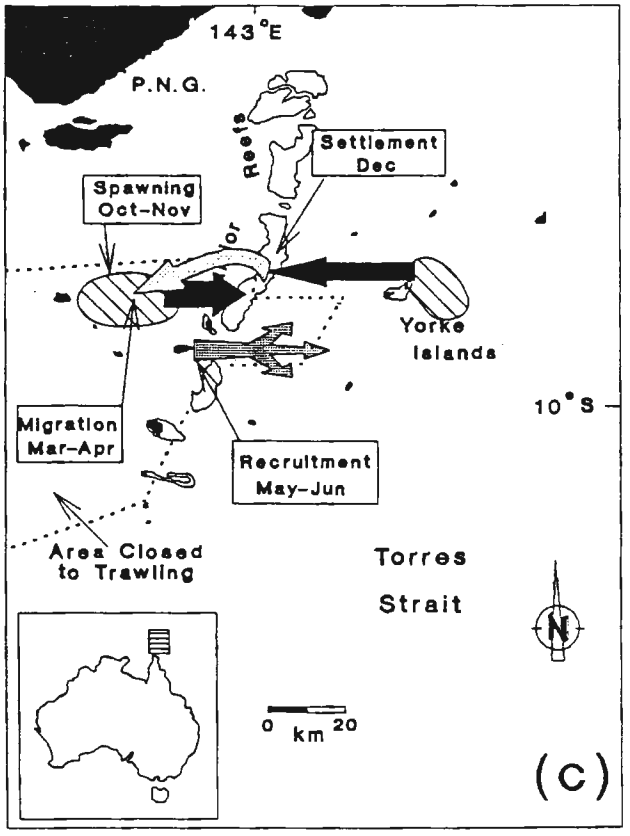


Figure 9. Areas of spawning and subsequent movement of *P. esculentus* for: a) January-March, (b) August-September and (c) October-November.

5.5 Acknowledgements

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5.6 References

Buckworth, R.C. (1985). Preliminary results of a study of commercial catches, spawning and recruitment of *Penaeus esculentus* and *Penaeus semisulcatus* in the western Gulf of Carpentaria. In 'Second Australian National Prawn Seminar'. (Eds P.C. Rothlisberg, B.J. Hill and D.J. Staples) pp. 213-220. (NPS2, Cleveland, Australia.)

Crocos, P.J. (1987). Reproductive dynamics of the tiger prawn *Penaeus esculentus,* and a comparison with *Penaeus semisulcatus,* in the North-western Gulf of Carpentaria, Australia. *Aust. J. Mar. Freshw. Res.* **38,** 79-90.

Garcia, S. and Le Reste, L. (1981). Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. *FAO Fish. Tech. Paper* **203,** 215pp.

Grey, D.L., Dall, W., and Baker, A. (1983). "A Guide to the Australian Penaeid Prawns". (Northern Territory Department of Primary Production: Darwin).

O'Connor, C.Y. (1979). Reproductive periodicity of a *Penaeus esculentus* population near Low Islets, Queensland, Australia. *Aquaculture* **16,** 153-62.

Penn, J.W. (1980). Spawning and fecundity of the western king prawn, *Penaeus latisulcatus* Kishinouye, in Western Australian waters. *Aust. J. Mar. Freshw. Res.* **31,** 21-35.

Penn, J.W., and Caputi, N. (1986). Spawning stock relationships and environmental influences on the tiger prawn *Penaeus esculentus* fishery in Exmouth Gulf, Western Australia. *Aust. J. Mar. Freshw. Res.* **37,** 491-505.

Robertson, J.W.A., Coles, R.G., and Goeden, G.B. (1985). Distribution patterns of commercial prawns and reproduction of *Penaeus esculentus* around the Wellesley Islands in the southeastern Gulf of Carpentaria. In 'Second Australian National Prawn Seminar'. (Eds P.C. Rothlisberg, B.J. Hill and D.J.Staples.) pp. 71-75. (NPS2, Cleveland, Australia.)

Somers, I.F., Poiner, I.R., and Harris, A.N. (1987a). A study of the composition and distribution of commercial Penaeid prawns of Torres Strait. *Aust. J. Mar. Freshw. Res.* **38,** 47-61.

Somers, I.F., Crocos, P.J., and Hill, B.J. (1987b). Distribution and abundance of the tiger prawns *Penaeus esculentus* and *Penaeus semisulcatus* in the North-western Gulf of Carpentaria, Australia. *Aust. J. Mar. Freshw. Res.* **38,** 63-78.

Tuma, D.J. (1967). A description of the development of primary and secondary sexual characters in the banana prawn, *Penaeus merguiensis* de Man (Crustacea: Decapoda: Penaeinae). *Aust. J. Mar. Freshw. Res.* **18,** 73-88.