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Migration and growth of two tropical penaeid shrimps within Torres Strait, northern Australia

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Abstract

In total 9259 brown tiger shrimp, *Penaeus esculentus* and 4705 endeavour shrimp, *Metapenaeus endeavouri*, were tagged and released in Torres Strait. Within 4 months 8% of tagged *P. esculentus* and 2% of tagged *M. endeavouri* were recaptured by commercial shrimp trawlers. Return rates were three to six times greater for shrimp released within the commercial fishery to the east of Warrior Reefs, than those released to the west. Shrimp released to the west of the Warrior Reefs, which is permanently closed to fishing, averaged 7–10 weeks at liberty and travelled an average of 55 km before recapture, compared with a 3–4 week, 5-km journey for those released in the east. We established that the growth parameter K should be estimated separately for males and females of the two species. In contrast to *P. esculentus*, a common estimate of the growth parameter L_{∞} was indicated for both sexes of *M. endeavouri*. Although female *M. endeavouri* generally did not grow as large as female *P. esculentus* the males of the two species grew to a similar size. Net migration speeds, distance and direction were estimated. After correction for the spatial-temporal distribution of fishing effort there was still evidence of an eastward and southward movement of all tagged shrimp indicating that *P. esculentus* and *M. endeavouri* migrated from the unfished West into the East and contributed to commercial catches in the fishery.

Introduction

The trawl fishery for penaeid species is economically important to the Torres Strait area of far northern Australia with landings exceeding 1000 t year^{-1} and a landed value of more than 10 million Australian dollars. The fishery is for three penaeid species: *Penaeus esculentus*, *Metapenaeus endeavouri*, and *P. longistylus*; of which the first two make up 90% of the catch (Somers et al., 1987; Watson et al., 1990b).

The fishery is located to the east of Warrior Reefs (East), in Torres Strait (Fig. 1) and to the east of the fishery are reefs surrounded by deep untrawlable waters. The area to the west of the Warrior Reefs (West), had not been commercially fished since 1981, and was not commercially fished during our study. Although the West is shallow and trawlable the fishing industry re-

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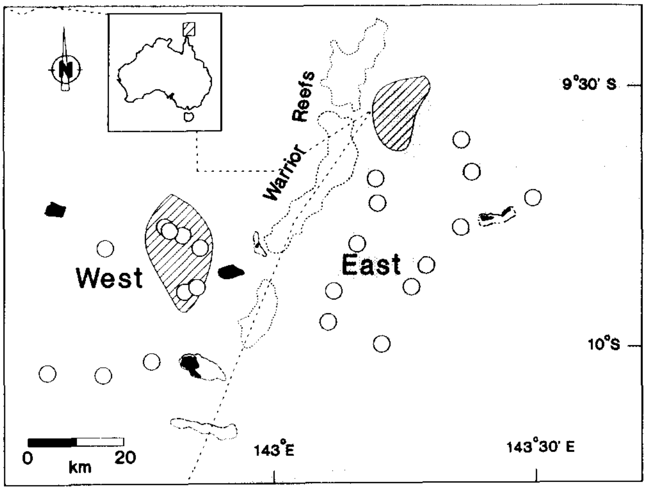

Fig. 1. Map of study area showing 1987 and 1988 release sites to the west and east of Warrior Reefs in Torres Strait, northern Australia. Cross-hatched areas represent the 1987 release areas while the 1987 release sites are shown as circles. Approximate area of the commercial shrimp fishery is shaded. The dotted line indicates the boundary of the western spatial closure.

garded it as a 'nursery area' and requested in 1980 that it be permanently closed to protect smaller, less valuable sizes of commercial shrimp. If this spatial closure in the West is to be of economic benefit to the fishing industry then the shrimp need to migrate eastward into the fishery. In addition they would need to grow, and hence increase in value, as they migrate.

In recent years managers of the Torres Strait and other northern Australian shrimp fisheries have attempted to optimise the value of commercial catches by using a variety of methods to control and direct fishing effort (Watson and Mellors, 1990). Seasonal and spatial closures have been important strategies to control harvests. The choice of closures has been assisted by the use of computer simulations which are in turn dependent on estimates of growth and migration rates. Estimates differ between species and with the same species between different fisheries.

The major commercial shrimp species in the Torres Strait fishery differ in their life-histories from the generalised pattern described by Garcia and Le Reste (1981) because juveniles of these species use seagrass habitats on offshore reef platforms in Torres Strait rather than estuarine habitats used elsewhere (Blyth et al., 1990). Until recently the only studies of these species in northern Australia have been from the Gulf of Carpentaria. Differences in latitude, sediments and general habitat have limited the use of growth and migration rate estimates from research elsewhere to models of the Torres Strait fishery.

Migration of *P. esculentus* was described by Somers and Kirkwood (1984) and for *M. endeavouri* by Buckworth (1989) for the Gulf of Carpentaria. Recently Derbyshire et al. (1990) described the migration of *P. esculentus* in Torres Strait based on a tagging study, but to date no information on the migration of the other major commercial species, *M. endeavouri*, in Torres Strait has been published. Information on *M. endeavouri* migration is important because of the spatial closure west of the Warrior Reefs, and although Derbyshire et al. (1990) established that *P. esculentus* migrates eastward into the fishery, this has not yet been shown for *M. endeavouri*.

Derbyshire et al. (1990) released tagged *P. esculentus* in only two areas on the western boundary of the commercially fished area of Torres Strait. Their tagged shrimp were returned by fishermen and they were, therefore, unable to detect any migration away from the fishery. Our study used multiple release sites in the fishery and beyond to the west. We were, therefore, able to examine whether migrating shrimp converged on areas of the fishery or continued to migrate eastward beyond the fishery. This information is important to fisheries managers when they plan seasonal or spatial closures.

Estimates of the growth parameters for *P. esculentus* by Derbyshire et al. (1990) used similar methodology to that which we have used, however, in their analysis they included only shrimp which increased in size during their time at liberty. We believe that this may introduce a bias in the estimation of growth parameters. To allow our results to be compared with theirs we have reanalysed their original data without this selection bias.

In addition to the work done by Derbyshire et al. (1990) growth rates for *P. esculentus* have been described from the Gulf of Carpentaria by Kirkwood and Somers (1984). The only previous study of *M. endeavouri* growth rates in northern Australia is from the Gulf of Carpentaria (Buckworth, 1989). Waffy (1990) reported growth rates for males of the related species *Metapenaeus ensis* from the Gulf of Papua in Papua New Guinea to the north of Torres Strait.

Estimates of growth and migration rates of *P. esculentus* and *M. endeavouri*, the major commercial species in Torres Strait fishery, are essential to simulation models which are used to assess seasonal and spatial closures (Watson and Restrepo, 1993). Our research was directed to provide these important prerequisites to successful resource management.

Methods

The present study was conducted between 16–22 February, 1988. For comparative and illustrative purposes we have included new and reanalysed material from a similar study conducted in January and February, 1987 described by Derbyshire et al. (1990).

In 1988 brown tiger shrimp, *P. esculentus*, and endeavour shrimp, *M. endeavouri*, were tagged and released at 22 sites in Torres Strait, far northern

Australia (Fig. 1). These sites were also surveyed monthly before and after the releases as part of an ongoing research trawl programme.

In total 9259 shrimp were tagged and released. Of these 4705 (51%) were *P. esculentus*, and 4554 (49%) were *M. endeavouri* (Table 1). Most tagged shrimp (93%) were 20–35 mm carapace length (CL) on release; females were larger than males. Shrimp were tagged in proportion to their abundance at each site at the time of capture. At each site an average of just over 200 (3–650) *P. esculentus* and an equal number (29–531) of *M. endeavouri* were tagged. The number of shrimp tagged and released at the western sites (49%), was approximately equal to that at the eastern sites (51%).

Tagged shrimp released in the West (Fig. 1), which did not migrate to the East into the commercial fishery, could be recovered only through our monthly research surveys.

Shrimp tagging and recovery

Shrimp were captured using 30 min shots of twin 6-fathom wide, 48 mm mesh otter trawl gear hauled by the 18 m RV 'Gwendoline May'. All undamaged *P. esculentus* and *M. endeavouri* larger than 10 mm CL were tagged.

Shrimp were tagged through the abdomen with streamer tags coated in antibiotic (aureomycin) cream (Derbyshire et al., 1990). We recorded the tag number, CL (to nearest 0.1 mm), sex and moult stage of each shrimp. The

Table 1
Number of tagged *P. esculentus* and *M. endeavouri* released in 1988 study

Carapace length (mm) at release	*P. esculentus*				*M. endeavouri*				Total
	West		East		West		East		
	Male	Female	Male	Female	Male	Female	Male	Female	
10–15	–	3	1	–	–	2	–	–	6
15–20	10	21	6	5	56	88	9	9	204
20–25	580	524	111	63	905	275	431	111	3000
25–30	270	326	870	503	387	504	441	541	3842
30–35	83	96	406	487	10	304	40	373	1799
35–40	8	31	16	215	2	18	4	41	335
40–45	–	20	2	38	1	–	1	1	63
45–50	–	2	–	6	–	–	–	–	8
50–55	–	1	–	1	–	–	–	–	2
Totals by sex and area	951	1024	1412	1318	1361	1191	926	1076	9259
Totals by area	1975		2730		2552		2002		
Total for species	4705				4554				

ovary condition and maturity of female shrimp was designated to stages as described by Tuma (1967).

Vigorous shrimp were released on the bottom using a manual release cage in a single batch at each trawl site. Releases were completed before daybreak to minimise predation.

The cooperation of the fishing industry in the return of tagged shrimp was solicited through leaflets, newspaper and radio articles, and directly by fisheries staff prior to tagging. A lottery with major prizes was conducted and one lottery ticket was given as a reward for the return of each tagged shrimp with supporting documentation. Although a few tagged shrimp were recovered by our research vessel, most were caught by commercial fishing vessels and collected by fisheries research or enforcement staff.

Migration analysis

Vectors that indicate the mean direction and distance that tagged shrimp moved from each release site, were calculated for both the current tagging study and the previous one. Contour plots of days at liberty were plotted for the 1987 tagging data (Derbyshire et al., 1990) by using a surface contouring software package (SURFER). Due to the scattered release sites of the current study it was not possible to produce contours of days at liberty.

Logbook records for the period immediately after the release of tagged shrimp provided commercial landings for *P. esculentus* and *M. endeavouri* for the study area. Commercial landings and tag returns were assigned to a the 6′ by 6′ logbook grid system. The number of tag returns of each species, per tonne of that species landed by the fleet, were calculated for each month. Although this analysis was done for both tagging programmes (1987 and 1988), only the results from the 1987 study (Derbyshire et al., 1990) are provided. The pattern of movement is more defined in the earlier study because of the higher return rates obtained in that study and the concentration of the release sites in two areas.

Growth analysis

Only shrimp at liberty for more than 20 days were included in our analysis of shrimp growth, as the type of model used was not suitable for predicting growth increments for shrimp with short periods at liberty relative to the intermoult period (Kirkwood and Somers, 1984). Residuals from nonlinear regressions were examined to identify extreme outliers, and these were omitted from the data.

Individual growth increments of shrimp were used to assign growth parameters to the Von Bertalanffy growth model. The form of the model used was

$$I=(L_\infty - L_t)(1-e^{-kd})$$

I is the growth increment, L_t is the initial size, d is the time at liberty, L_∞ and K are the Von Bertalanffy growth parameters.

Estimates of K and L_∞ were obtained using the nonlinear least squares minimisation algorithm LMM (Osborne, 1976). When fitting the model, our aim was to minimise the number of parameters needed to describe the data. We made an a priori decision to keep the species separate in our growth studies. The sexes were analysed separately after confirming that their growth characteristics were quite different. Within each sex, estimates of K and L_∞ were made from data pooled across tagging locations, provided that pooling did not significantly increase the residual variance based on F-tests. Residual diagnostic procedures were used to check the adequacy of the fitted models.

Owing to the generally high negative correlation between estimates of K and L_∞ (Kirkwood and Somers, 1984), joint 95% confidence regions were estimated and presented graphically.

Results

Recapture rate, mean growth and liberty period

In total 468 tagged shrimp or 5% were returned. There was a considerable difference between species as 376 or 8% of tagged *P. esculentus* were recaptured compared with only 92 or 2% of *M. endeavouri*. Best recapture rates were for shrimp whose size at release exceeded 30 mm CL (Table 2). Recapture rates did not differ with the sex of the shrimp but were higher for shrimp released in the East than the West. Rates for eastern releases were six times higher for *P. esculentus* and four times higher for *M. endeavouri* than for those released in the West (Table 2).

We confirmed that the mean size of shrimp at recapture was significantly greater than at release (Kruskal–Wallis (K–W) $P<0.01$) for all groups except male *M. endeavouri* which were recaptured at approximately the same size as at release (Table 3). For both species and sexes, shrimp released in the West were at liberty for longer than those released in the East (K–W $P<0.01$). With the exception of male *M. endeavouri*, those groups at liberty longer also grew more (K–W $P<0.01$). Shrimp released from the East had no significant differences in time at liberty regardless of species or sex (Table 3). There were intraspecific differences for western releases; *P. esculentus* were at liberty longer than *M. endeavouri* (K–W $P<0.01$), and this was mainly attributed to differences between females.

Table 2
Number of tagged *P. esculentus* and *M. endeavouri* returned in 1988 study. Percent return of those released are shown in parentheses

Carapace length (mm) at release	*P. esculentus*				*M. endeavouri*				Total
	West		East		West		East		
	Male	Female	Male	Female	Male	Female	Male	Female	
10–15	–	–	–	–	–	–	–	–	–
15–20	–	–	–	–	–	–	–	–	–
20–25	10 (2)	4 (1)	5 (4)	8 (13)	2 (0)	6 (2)	14 (3)	1 (1)	50 (2)
25–30	7 (3)	7 (2)	108 (12)	65 (13)	2 (1)	-	19 (4)	26 (5)	234 (1)
30–35	1 (1)	2 (2)	64 (16)	66 (13)	-	3 (1)	-	18 (5)	154 (9)
35–40	1 (12)	2 (6)	2 (12)	19 (9)	-	-	-	1 (2)	25 (7)
40–45	-	1 (5)	-	3 (8)	-	-	-	-	4 (6)
45–50	-	–	-	1 (17)	-	-	-	-	1 (9)
50–55	-	-	-	–	-	-	-	-	-
Totals by sex and area	19 (2)	16 (2)	179 (13)	162 (12)	4 (0)	9 (1)	33 (4)	46 (4)	468 (5)
Totals by area	35 (2)		341 (12)		13 (1)		79 (4)		
Total for species	376 (8)				92 (2)				

Table 3
Mean sizes of groups of *P. esculentus* and *M. endeavouri* at release (all animals and only those subsequently recaptured) and at recapture. Mean time at liberty for groups is shown. Standard deviations are shown in parentheses

Species	Group	Sex	Mean size of all tagged at release (mm)	Mean size at release (mm)	Mean size at recapture (mm)	Mean time at liberty (days)
P. esculentus	West	Female	25.9 (4.7)	28.9 (5.5)	35.1 (4.2)	86 (39)
		Male	25.0 (3.3)	26.3 (3.7)	31.1 (2.4)	83 (53)
	East	Female	31.3 (4.5)	31.1 (3.9)	33.3 (3.3)	30 (22)
		Male	28.7 (2.9)	29.4 (2.4)	30.0 (2.1)	29 (24)
M. endeavouri	West	Female	27.1 (4.4)	26.1 (8.9)	30.2 (3.0)	50 (19)
		Male	24.0 (2.5)	25.8 (2.2)	26.8 (1.2)	51 (24)
	East	Female	29.0 (3.4)	29.5 (3.2)	31.4 (2.6)	30 (17)
		Male	25.5 (2.6)	25.5 (1.8)	26.1 (1.8)	32 (33)

Growth parameters

P. esculentus

To allow comparison between data collected by Derbyshire et al. (1990)

and the present study, we analysed their data using our methods. In agreement with their original results, we found that there were three groups: females from the West, females from the East, and males (Table 4, Fig. 2). Using our methods the values of K and L_∞ for these groups were different from those reported by Derbyshire et al. (1990), particularly our estimates of K. Their estimates of K for most groups were 20–34% lower than ours except for females from the East which was 28% higher. Some of the differences resulted from the use of different data selection criteria. Derbyshire et al. (1990) did not include shrimp which had not grown since their release which may have biased their estimates.

Table 4
Growth parameters estimated for female and male *Penaeus esculentus* and *Metapenaeus endeavouri* based on tag returns from 1987 and 1988. Numbers of shrimp used in analysis are shown. Approximate standard errors appear in parentheses. Values for 1987 are based on a reanalysis of data from Derbyshire et al. (1990)

Year	Species	Group	Number used	L_∞ (mm)	$K_{year^{-1}}$
1987	*P. esculentus*	Female West	387	49.2 (1.4)	1.6 (0.2)
		Female East	276	43.6 (0.9)	2.6 (0.3)
		Male West	380	34.7 (0.3)	3.5 (0.3)
		Male East	303		2.9 (0.2)
1988	*P. esculentus*	Female	92	39.9 (0.9)	3.9 (0.5)
		Male	101	34.1 (0.5)	3.3 (0.4)
	M. endeavouri	Female	32	34.9 (1.0)	4.9 (1.0)
		Male	28		1.0 (0.2)

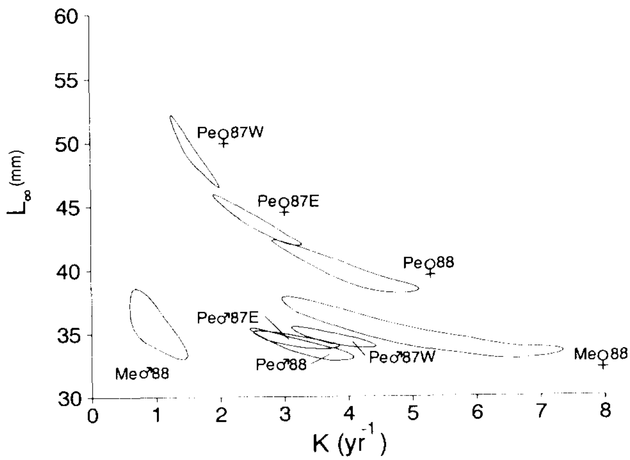

Fig. 2. Joint 95% confidence regions for the growth parameters L_∞ and K_{ann} for (a) *P. esculentus* tagged and released to the west and east of Warrior Reefs in Torres Strait (males share a common estimate of L_∞) and (b) *M. endeavouri* females and males sharing a common L_∞.

Of the tagged *P. esculentus* returned in 1988, 193 (51%) were returned with data useable for our analysis of growth parameters. As in the 1987 study, females had different growth parameters than males (Table 4). Males generally did not grow as large as females. The joint confidence limits for K and L_∞ for females and males were clearly separated (Fig. 2). Although in 1988, L_∞ was lower and K higher than for females in 1987, they appeared to be part of the same general K–L_∞ relationship. Values for 1988 males were very similar to those from the 1987 data (Fig. 2).

M. endeavouri

Of the 92 tagged *M. endeavouri* recaptured, 60 (65%) were used in our growth study. The estimates of L_∞ for females and males were not significantly different, however, the estimates of K were significantly different (Table 4, Fig. 2). The joint confidence limits of L_∞ and K for *M. endeavouri* were distinct from those estimated for any of the groups for *P. esculentus*. Although female *M. endeavouri* generally did not grow as large as female *P. esculentus* the males of the two species grew to a similar size (Fig. 2).

Net migration direction, distance and speed

Returns from tagged *P. esculentus* released in 1987 (Derbyshire et al., 1990) showed an average migration of 50 km due east for those released in the West (Fig. 3(a)) but only 8 km south-east for those released in the East (Fig. 3(b)). Contours of days at liberty confirm the generally eastwardly migrations (Fig. 3).

The results for 1988 were similar, the net migration direction and distance for *P. esculentus* was 55 km to the east (Fig. 3(c)) for those released in the West. Those released in the East travelled an average of only 4 km in a slightly easterly direction before recapture. Findings for *M. endeavouri* (Fig. 3(d)) were similar with an easterly migration of 56 km for western releases and 6 km for eastern releases before recapture. Though the overall pattern is one of a continuous migration to the east, this was not clear for shrimp released in the more easterly sites. There is some evidence for the north–south convergence of tagged animals. There appeared to be one main area of convergence for *P. esculentus*, and this was different than the two areas of convergence found for *M. endeavouri*.

Net migration speeds were faster for shrimp from western releases regardless of species or sex (K–W $P<0.01$), about twice that of eastern releases (Table 5). There was no difference between sexes with the same species and release area.

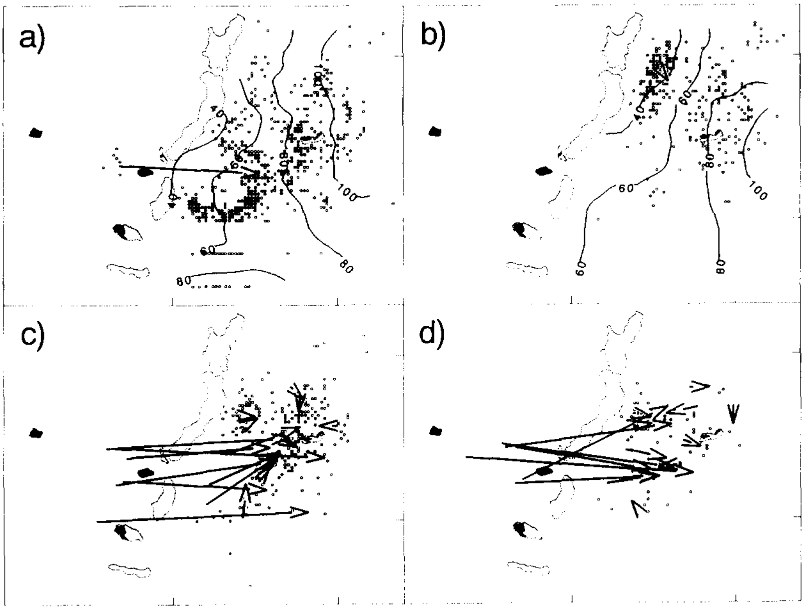

Fig. 3. Map of Torres Strait showing tagged shrimp recapture locations (circles), vectors showing net movement (arrows) and contours of days at liberty for: (a) 1987 western release of *P. esculentus*; (b) 1987 eastern release of *P. esculentus*; (c) 1988 releases of *P. esculentus* and (d) 1988 releases of *M. endeavouri* shrimp.

Table 5
Net migration speeds for groups of shrimp. Standard deviations are shown in parentheses

Species	Group	Month of release	Net migration speed km day^{-1} (SD)	Number of shrimp
P. esculentus	West	Female	0.87 (0.38)	14
		Male	0.94 (0.55)	19
	East	Female	0.46 (0.46)	150
		Male	0.42 (0.41)	169
M. endeavouri	West	Female	1.17 (0.27)	10
		Male	1.03 (0.31)	5
	East	Female	0.34 (0.42)	41
		Male	0.27 (0.21)	33

Distribution of time at liberty

The distribution of tag return frequency vs. weeks at liberty was similar for males and females regardless of species. In both 1987 and 1988 those shrimp released in the West were at liberty for longer and the recapture period was

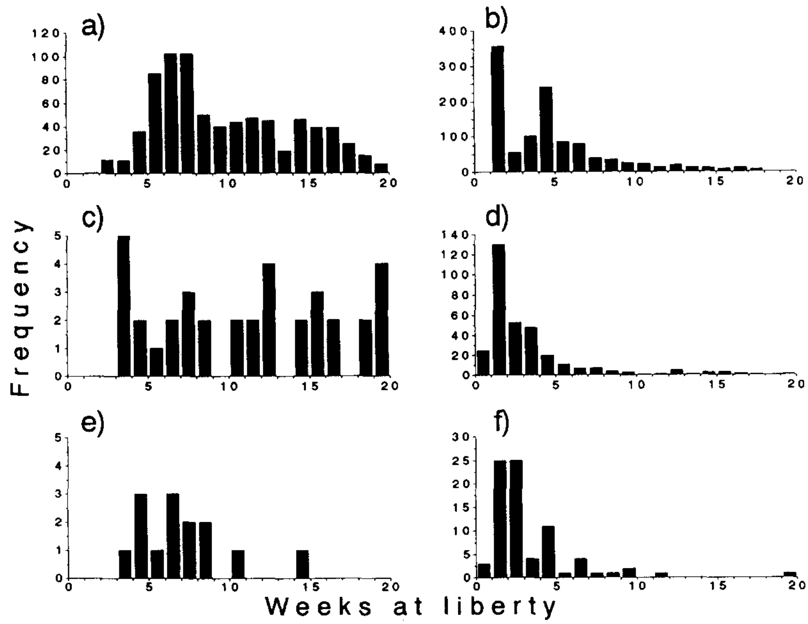

Fig. 4. Frequency of weeks at liberty for tagged shrimp: (a) 1987 western release of *P. esculentus*; (b) 1987 eastern release of *P. esculentus*; (c) 1988 western release of *P. esculentus*; (d) 1988 eastern release of *P. esculentus*; (e) 1988 western release of *M. endeavouri* and (f) 1988 eastern release of *M. endeavouri*. (Last period, 20 weeks, includes all shrimp at liberty for more than 19 weeks.)

extended compared with those from the East (Fig. 4). Those released in the East in 1988 (regardless of sex or species) were mostly recaptured within 50 days (7 weeks) with a mean of 30 days (4 weeks) (Table 3 and Figs. 4(d), 4(f)). Those released in the West in 1988, however, had a mean liberty period of 84 days (12 weeks) for *P. esculentus* (Table 3 and Fig. 4(c)) and 50 days (7 weeks) for *M. endeavouri* (Table 3 and Fig. 4(e)).

Returns vs. commercial landings

A few tagged shrimp were recaptured in 1987 by our research vessel (Fig. 3(a)) and these accounted for all recaptures in the West. All other shrimp were recovered by commercial trawlers. Very little commercial fishing from the study area was reported in 1987 until February. The ratio of tagged *P. esculentus* returned, to the tonnes of *P. esculentus* landed, revealed the movements of tagged shrimp independent of the movements of the trawling fleet. Following this correction, there is still evidence of an eastward and southward movement of tagged *P. esculentus* from their release locations, to the boundaries of the fishery (and possibly beyond) (Fig. 5). After August few tagged

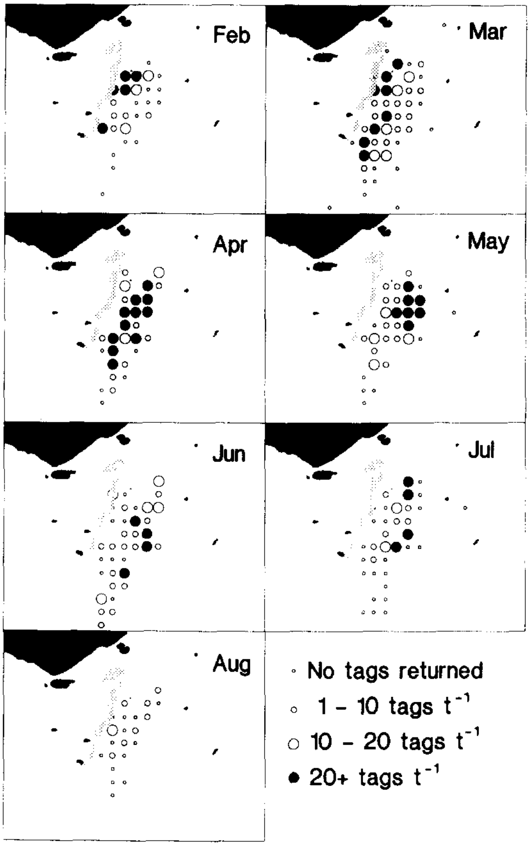

Fig. 5. Frequency of tagged *P. esculentus* returns for each tonne of *P. esculentus* landed commercially in 6′ by 6′ logbook grids for February to August 1987.

shrimp were returned. The results for the return of *P. esculentus* and *M. endeavouri* in 1988 were similar to those presented for 1987 and also suggested an easterly migration.

Discussion

In 1988 the overall return rate for tagged *P. esculentus* (8%) was somewhat lower than that reported by Derbyshire et al. (1990) for 1987 (11%). In 1988 tagged prawns were released at sites spread throughout the fishery, this may have contributed to the lower return rate for that year. Tagged shrimp released in the eastern sites could escape capture by migrating a short distance to the east into untrawlable waters. In contrast, in 1987 all shrimp were released in the shallower waters on the western boundary of the fishery. These shrimp had to traverse the fishery to reach the deeper waters to the east and therefore would have had a higher probability of capture.

The return rate for *M. endeavouri* was 2% with only 1% of those tagged in the West returned. Although this was much lower than for *P. esculentus*, it was comparable to the 2.5% return rate reported in the Gulf of Carpentaria by Buckworth (1989). There is evidence that this species is not as migratory as *P. esculentus*. Buckworth (1989) found that few were returned more than 100 km from their release site and that most recorded movements could be explained by the imprecision of position reporting. This species is not the preferred catch in Torres Strait, and species habitat segregation based on sediment (Somers, 1987) may allow fishermen to preferentially fish for *P. esculentus*, increasing the return rate of this species compared to *M. endeavouri*.

It is also possible that the survival rate for *M. endeavouri* was lower after tagging than for *P. esculentus*. Although the mean time at liberty was similar for the two species when released in the East (about 30 days) it was shorter for *M. endeavouri* (50 days) than for *P. esculentus* (85 days) released in the West, which may reflect a shorter mean survival period. Our observations of immediate post-tagging mortality also suggest higher survival rates for *P. esculentus*. After tagging, only 1% of tagged *P. esculentus* died before release compared with 4% for *M. endeavouri* (C.T. Turnbull, unpublished data, 1990). Future laboratory studies are required to separate the confounding effects of migration from those of survival.

When a tagging study relies on the fishing industry to return tagged shrimp it is difficult to isolate the migration of tagged animals from movements of the fleet. Undoubtedly professional fishermen are very proficient at following shrimp migrations and much can be learned of shrimp migration by observing fleet movements. Watson et al. (1990a) established that the fishing fleet of Torres Strait generally moves eastward from the beginning of the season which is consistent with our tagging results. We used the reported landings of each shrimp species to attempt to correct for the effects of fleet movement instead of using fishing effort because the latter could not be partitioned between target species, and because logbook records sometimes reported catch without hours fished. Even when we corrected tag return data for differences in commercial landings we still found evidence for an easterly migration. This pattern was independently confirmed by size data from our research trawl surveys conducted between January 1986 and July 1991 (R.A. Watson and C.T. Turnbull, unpublished data, 1991). These surveys fished the same sites monthly and were unaffected by fleet movements. Somers et al. (1987) also suggested a south-easterly movement of *P. esculentus* on the basis of size data collected during 1984.

Unlike Derbyshire et al. (1990) we released tagged shrimp at sites throughout the fishery to establish whether tagged shrimp converge on areas of the fishery or continue to migrate beyond the range of the fishery. Though there was some evidence for a north–south convergence for tagged shrimp, especially for *M. endeavouri*, size data from our research trawl surveys (R.A. Watson and C.T. Turnbull, unpublished data, 1991) does not support this. There was however, clear evidence for a strong easterly migration, and this was confirmed by size distributions from research trawl surveys. There was no evidence of any westerly migration from eastern release sites.

Our estimates of *P. esculentus* growth parameters were generally similar to those calculated by Derbyshire et al. (1990) and in all cases the joint confidence limits of K and L_∞ overlapped with at least one estimate of the former. For females our estimate of K was larger with a correspondingly smaller estimate for L_∞. Estimates of male growth rates were very similar between the studies. Our estimates of the growth parameters for *P. esculentus* tagged east of the Warrior Reefs in 1987 and in both the East and West in 1988, were similar to those obtained for the same species in the Gulf of Carpentaria and Exmouth Gulf Fisheries. Kirkwood and Somers (1984) obtained estimates of $L_\infty = 44.8$ mm and $K = 2.1$ year^{-1} for females and $L_\infty = 37.5$ mm and $K = 2.1$ year^{-1} for males and White (1975) obtained $L_\infty = 40.9$ mm and $K = 2.3$ year^{-1} for females and $L_\infty = 32.6$ mm and $K = 2.5$ year^{-1} for males. As expected interspecific differences in growth parameter estimates were greater than those between studies of the same species.

Our estimates of *M. endeavouri* growth parameters were similar to those reported by Buckworth (1989) for the Gulf of Carpentaria. Our estimates had a common L_∞ for males and females which was intermediate to that reported for these sexes by Buckworth (1989). Though there was no overlap in the joint K–L_∞ confidence region for males there was considerable overlap for female estimates. Our male estimates were significantly different from those reported for male *Metapenaeus ensis* by Waffy (1990) which had higher L_∞ and K estimates.

Differences in growth parameter estimates for female *P. esculentus* released in the West compared with those from the East cannot be attributed to stock differences as tagging studies also established that shrimp from these areas intermix freely. Taken separately, comparisons of estimates of K and L_∞ show significant differences. The joint confidence limits, however, indicate that these estimates are part of the same general K–L_∞ relationship. Estimates of the Von Bertalanffy parameters are often highly negatively correlated (Kirkwood and Somers, 1984). Differences in estimates are probably related to the size of the shrimp used in the estimation from the two areas, those in the West were generally smaller on release and on recapture. Die (1992) demonstrated that differences in sizes between groups of penaeids can introduce differences in growth parameter estimates. Buckworth (1989) reported that estimation of the K parameter is largely determined by the growth information of smaller shrimp while L_∞ is dependent on information from larger shrimp.

As expected, considerably fewer *P. esculentus* or *M. endeavouri* (Tables 1 and 2) were recaptured from western than from eastern releases. Recaptured shrimp from the West were at liberty longer and travelled much further. During this time it is likely that they suffered greater losses through natural mortality, which may be size-specific. Western shrimp were recaptured over a longer period than those from the East. Those from the East were recaptured within 6 weeks and appear to have been the target of intense fishing pressure. During the additional time that it took for shrimp to migrate from the western release sites into the fishery, it appears that the fishing fleet dispersed and generally moved eastward following migrating eastern shrimp (after Watson et al., 1990a), thus further delaying the recapture of western shrimp.

Our study established, despite the relatively poor return rate, that in addition *P. esculentus*, tagged *M. endeavouri* also moved in considerable numbers from the unfished West and contributed to commercial catches in the East. This information is important to the managers of the fishery as the West has been closed to fishing since 1981 and *M. endeavouri* forms about half of the annual catch of the fishery (Watson et al., 1990b).

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