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Sledges for daytime sampling of juvenile penaeid shrimp

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ABSTRACT

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Daytime catches of juvenile penaeid shrimp from two modified sledges (providing stimulation by water-jet or electric current) were compared with catches from a conventional sledge (or beam trawl) used at night. The results indicate that the daytime use of a water-jet sledge is a suitable alternative when night-time sampling is precluded. Mean catch rate of the Brown tiger prawn (*Penaeus esculentus*) in the daytime water-jet sledges was not significantly different from the night-time conventional sledges, but catches in the daytime electric trawls were significantly less. In contrast, the catches of the Endeavour shrimp (*Metapenaeus endeavouri*) and the Greentail shrimp (*Metapenaeus bennettae*), in both the daytime water-jet and daytime electric sledges, were significantly lower (approximately one-quarter) than in the night-time trawls. There was no significant difference between the length-frequency distributions of *P. esculentus*, *M. endeavouri* or *M. bennettae* caught in the conventional night-time and in the daytime water-jet sledges.

INTRODUCTION

Juveniles of commercial shrimp are usually sampled at night owing to their generally nocturnal behaviour, using conventional, fine-meshed sledges (also referred to as beam trawls) (Coles and Lee Long, 1985; Staples et al., 1985). A variety of daytime sampling methods such as sled-mounted suction devices (Allen and Hudson, 1970), sledges employing water jets (Penn and Stalker, 1975), and sledges with electrodes (Lewis and Carrick, 1987) have also been used to sample shrimp.

In Torres Strait, northern Australia, the postlarvae of the commercially important Brown tiger prawn (*Penaeus esculentus*) and the Endeavour shrimp (*Metapenaeus endeavouri*) settle on reef-top seagrass meadows (Turnbull and Mellors, 1990). These meadows are interspersed with pieces of dead coral

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that easily snag conventional sledges such as those used by Coles and Lee Long (1985) on the smooth, silty sediments of the Gulf of Carpentaria. During November to February, these seagrass meadows are generally inaccessible by dinghy at night. On evenings when the seagrass meadows are accessible by dinghy (March to September), navigation and trawling is both difficult and dangerous due to the strong tidal currents that flow across the reef, and the presence of large coral outcrops that could damage the outboard motor or snag the sledge. To sample at night-time on reef tops in Torres Strait, it was necessary to deploy flashing marker lights during the daytime to indicate both the location of the seagrass, and a trawl path free of large coral outcrops.

An alternative to trawling at night with a conventional sledge was therefore required to provide monthly samples of the juvenile penaeid populations on the Warrior Reefs of Torres Strait (Fig. 1). A water-jet sledge and an electric sledge were tested; the day-time catches were compared with the night-time catch rates of a conventional sledge.

The study had two basic objectives: to establish the most practical and effective daytime sledge that could be used in place of a conventional sledge used at night, and to allow sledge samples taken during the day to be compared with sledge samples taken at night. This information was needed to analyse data from our monthly juvenile sampling programme, which con-

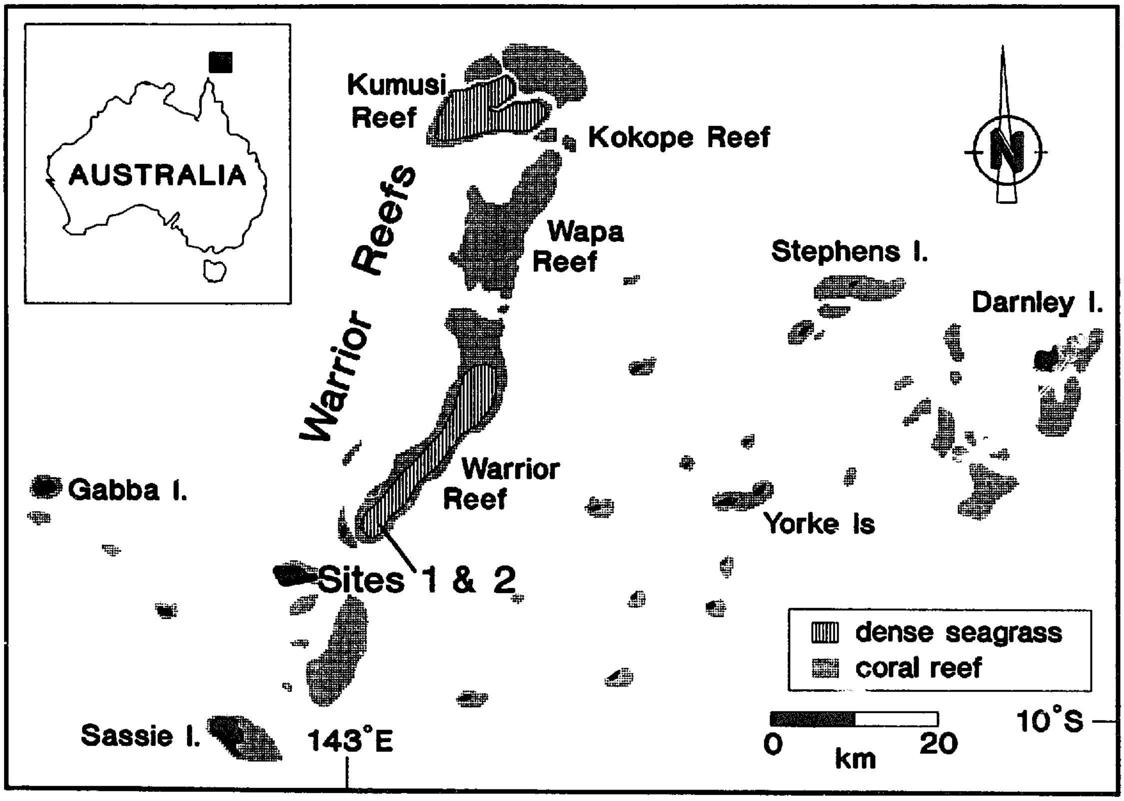

Fig. 1. Map showing location of sampling sites.

sisted of both daytime and night-time samples. Generally, we tried to sample during the daytime; however, during June to September the seagrass sites were only accessible by dinghy, at night. Although the objectives of the study were to meet the specific needs of a much larger research programme, the results produced are of general interest.

MATERIALS AND METHODS

A water-jet sledge which could operate over rough substrates was constructed based on a design by Penn and Stalker (1975) (Fig. 2). An electrode array was suspended from the water-jet beam so that the same trawl could be used in either conventional, water-jet or electric mode.

The aluminium trawl frame and nylon net (2-mm mesh opening) measured 0.5 m high and 1.4 m wide at the mouth (Fig. 2). A light tickler chain, similar to that used by Coles and Lee Long (1985), was not used in our study, as it caught on lumps of coral. A 100-mm-high rubber flap beneath the net mouth allowed the trawl to pass over lumps of coral, while reducing losses of suspended material under the net. The trawl was towed at approximately 25 m min^{-1}, 20 m behind a 4.4 m aluminium dinghy, powered by an outboard motor.

Water-jet sledge

A centrifugal pump (500 l min^{-1} rating) mounted in the dinghy, supplied seawater to the sledge through a 20 m length of 25 mm diameter, reinforced plastic tubing. Seawater flowed out of water-jet nozzles into the seagrass and substrate ahead of the net. The water-jet nozzles were incorporated in 38 mm, galvanised water pipes (Fig. 2), placed 700 mm in front of the net. The water-jet nozzles consisted of 20×5 mm diameter plastic tail pieces screwed into the pipe at 60 mm intervals. The ends of the water-jet nozzles were 100 mm above the substrate.

Diver observations confirmed that the water-jets disturbed the substrate, lifting loose material into suspension ahead of the net. By carefully adjusting the speed of the sledge, most of the disturbed sand settled out in front of the net, leaving less dense materials such as fine silt, seagrass fragments, and shrimp to be caught by the net while still in suspension.

Electric sledge

The design of the electronic-pulse generator and electrode array was based on studies conducted on adult shrimp (McRae and French, 1965; Saila and Williams, 1972). An electrode array was attached behind the water-jet beam, and dragged across the bottom by the trawl (Fig. 2). The electrode array con-

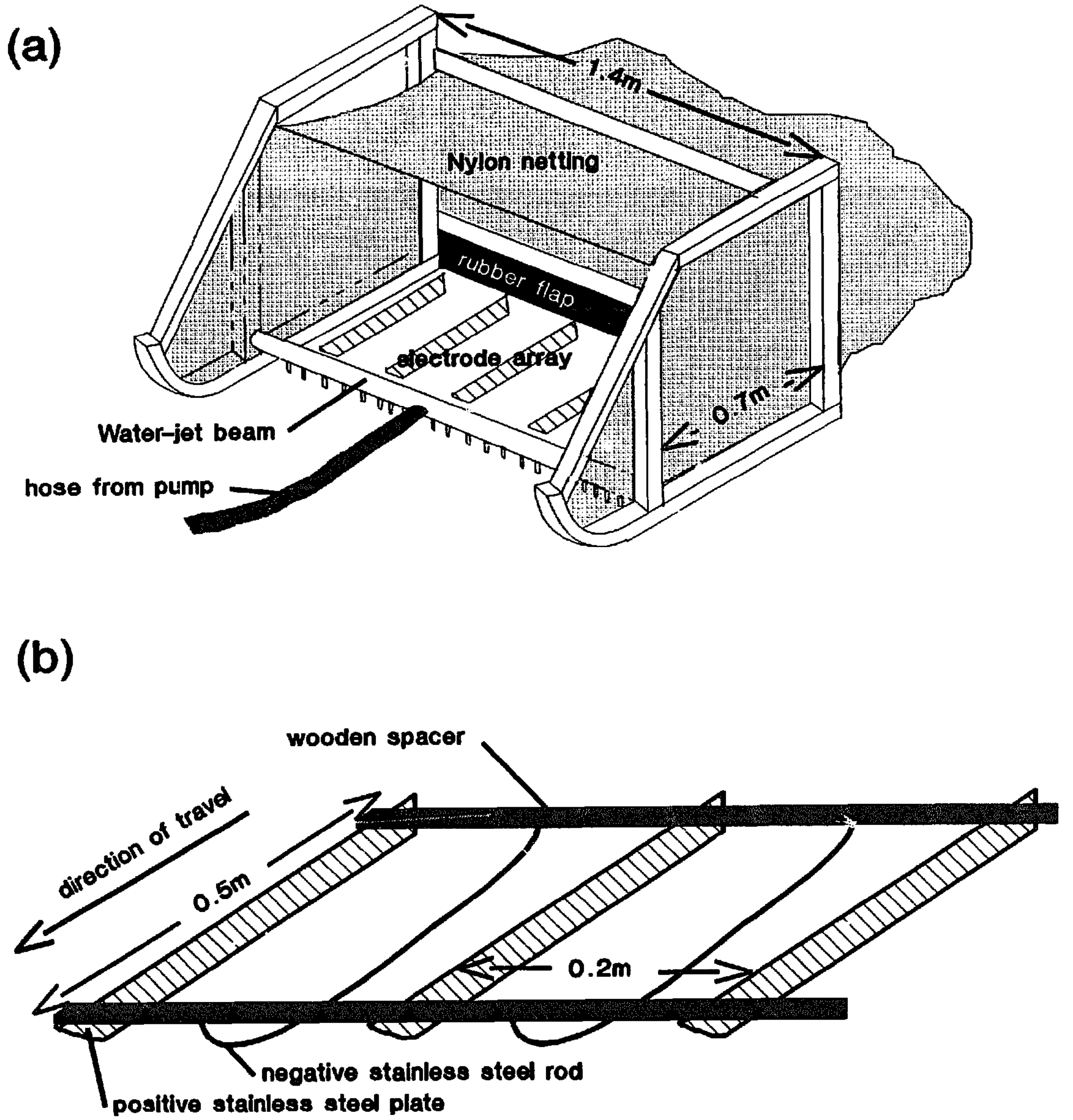

Fig. 2. (a) Design of sledge frame and net used to test the three sledge types. (b) Detailed section of the electrode array for the electric sledge trials.

sisted of parallel, positively charged plates (500 mm long and 50 mm high), with a 200 mm separation. Negatively charged rods, 500 mm long, were positioned parallel to, and midway between, the lower edges of the plates, so that they were in contact with the substrate. Rapid (4 Hz) 20 V direct current pulses of 2 ms duration, were supplied to the electrode array from an electronic-pulse generator powered by two, 12 V batteries. Pease and Seidel (1967) found that the optimum voltage characteristics for shrimp were 3.0 V, at 4–5 Hz. Our laboratory trials indicated that higher voltages (12–20 V) were required to make small juvenile shrimp jump off the substrate.

Site description

The study was conducted at two sites on the southern reef in the Warrior Reef Complex of Torres Strait (Fig. 1). These reefs have extensive and dense seagrass (mainly *Thalassia hemprichii* and *Enhalus acoroides*) meadows, on the top of the reef platform, similar to seagrass communities found in the tropical Caribbean (Poiner et al., 1989). The surfaces of these seagrass meadows are littered with lumps of coral rubble and small coral outcrops. The substrate consists of a coarse coral-rubble matrix, which is filled and covered with a mixture of fine coral, sand, and very fine, silty sediments. The silty surface layer in which the seagrass takes root was easily disturbed by the water-jet sledge.

The two trawl sites were permanently marked by pairs of polystyrene buoys and were 100 m long, and approximately 500 m apart, on the same continuous seagrass bed. Substrate type, seagrass composition, and cover at the two sites were similar when examined by divers.

Experimental design and analysis

Three replicate trawls were made with each sledge at each site; the conventional sledge was used at night, and the water-jet and electric sledges were used during the day. The samples were collected by towing the sledges into the current, and along the trawl paths marked out by the pairs of buoys. The experiment was conducted in March 1988 and was completed within a 24 h period. At Site 1 the daytime electric sledge was used before the daytime water-jet sledge. The order was reversed at Site 2. The daytime samples were col-

TABLE 1

Analysis of variance of the mean catch rate for each sledge type and site for *P. esculentus*, *M. endeavouri* and *M. bennettae*

Source	Degrees of freedom	Sum square	Mean square	*F*-ratio	Probability
P. esculentus					
Sledge	2	0.6339	0.3170	22.63	0.0001
Site	1	0.0611	0.0611	4.36	0.0587
Sledge × site	2	0.0791	0.0396	2.83	0.0988
M. endeavouri					
Sledge	2	108.78	54.389	80.09	0.0000
Site	1	1.3783	1.3783	2.03	0.1797
Sledge × site	2	11.986	5.9930	8.83	0.0044
M. bennettae					
Sledge	2	124.82	62.412	56.54	0.0000
Site	1	28.534	28.534	25.85	0.0003
Sledge × site	2	6.6895	3.3448	3.03	0.0861

lected over a period of 2.5 h and the depth ranged from 0.8 to 1.6 m. The night-time samples were collected over a period of only 1 h and the depth (0.8 m) was only just enough to allow access to the seagrass sites. We could not test the water-jet and electric sledges at night as the evening high-tide allowed access to the seagrass sites for only 1.5 h.

Counts and carapace length measurements were taken for all penaeid shrimp caught in each sledge tow. Only three commercially important species, *P. es-*

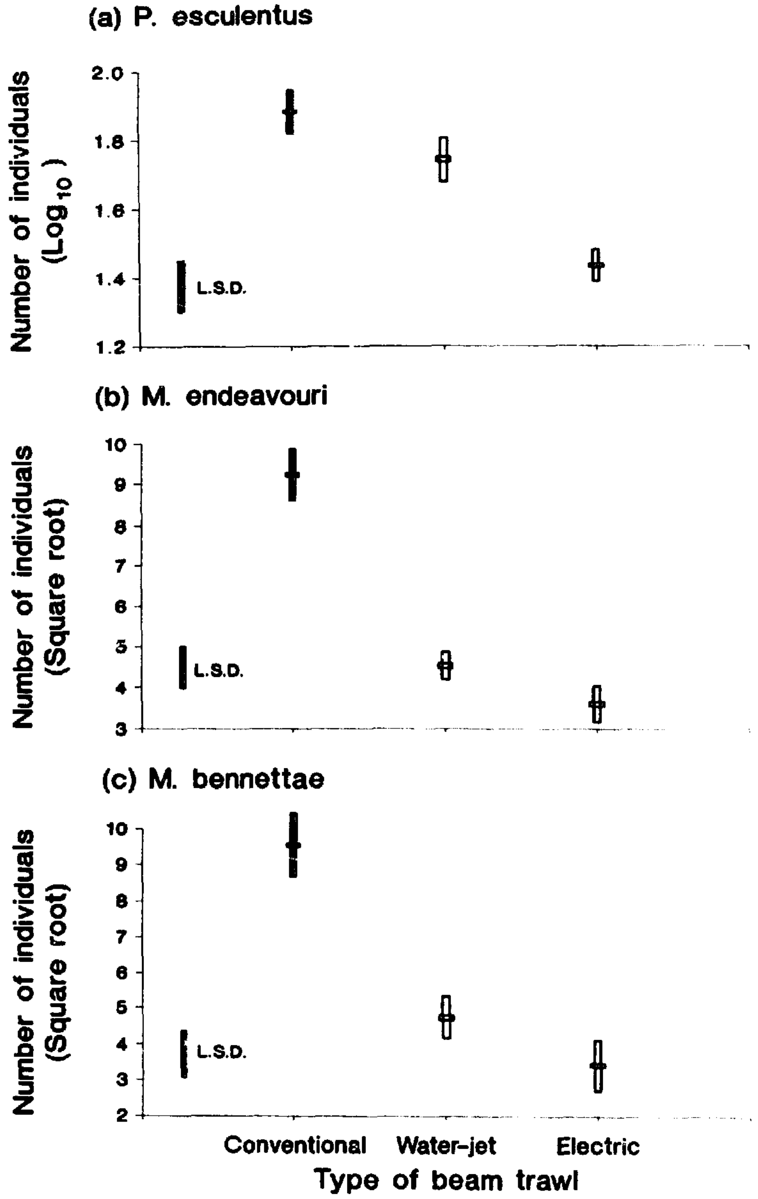

Fig. 3. Mean catch rates and standard errors from the three sledge types for: (a) *P. esculentus*; (b) *M. endeavouri*; (c) *M. bennettae*. Means that are further apart than the length of the LSD bar are significantly different. Night samples are indicated by filled bars and day samples by open bars.

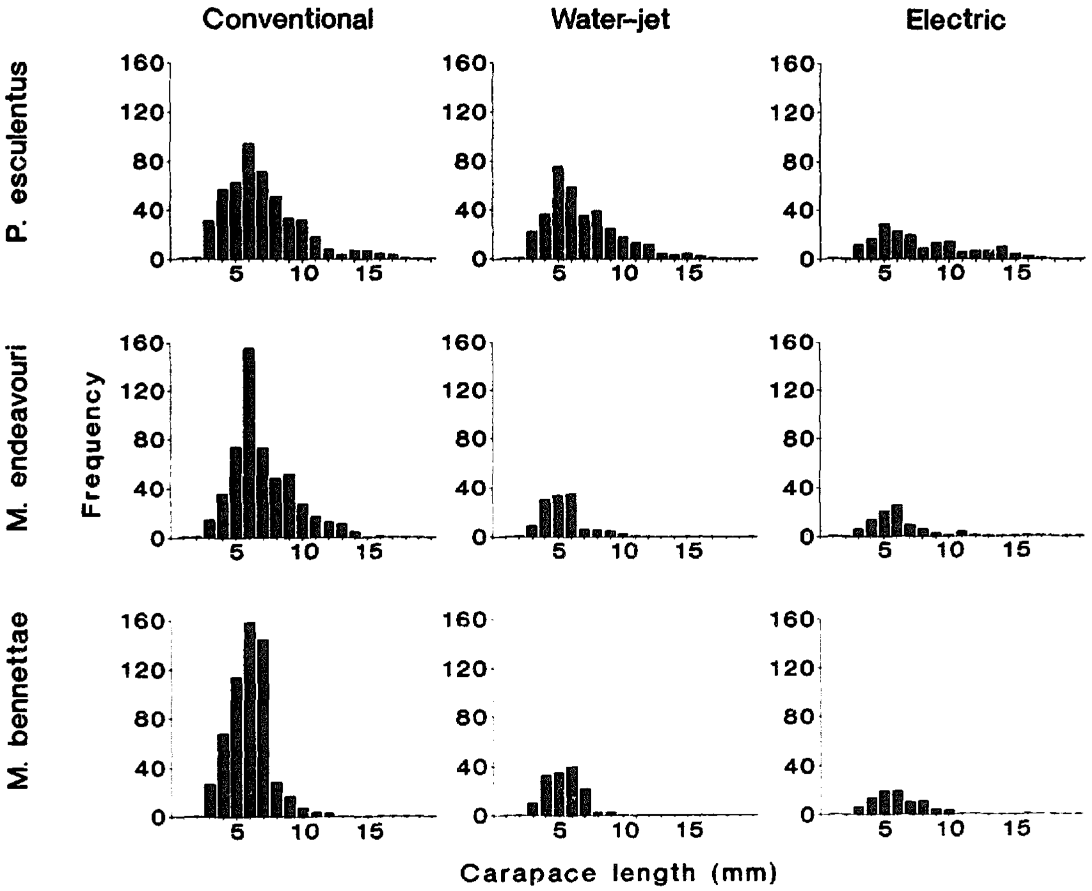

Fig. 4. Histograms showing length-frequency distribution of *P. esculentus*, *M. endeavouri* and *M. bennettae* caught in the three sledge designs. The data for Sites 1 and 2 have been combined in this figure.

culentus, *M. endeavouri* and *Metapenaeus bennettae* were caught in sufficient numbers to enable detailed comparison between sledge types and sites. The distributions of the catch-rate data were normalised by applying a logarithmic transformation to the *P. esculentus* data, and a square-root transformation to the *M. endeavouri* and *M. bennettae* data. Two-way analyses of variance were then used to investigate the effects of trawl type and site on the mean catch rate of each species. The least-significant difference (LSD) between means was used to determine those groups of means which were significantly different (Sokal and Rohlf, 1981). A Kolmogorov–Smirnov two-sample test was used to examine differences in the size–frequency distributions of the catches (Sokal and Rohlf, 1981). Tests were performed between individual tows, and between grouped data for each species, sledge type and site combination.

RESULTS

Catch rates differed significantly amongst sledge types for all species (Table 1). The night-time conventional sledge had the highest mean catch rates, and the electric sledge had the lowest mean catch rate for all species (Fig. 3). The mean catch rates of *P. esculentus* did not differ significantly between the daytime water-jet sledge and the night-time conventional sledge (Fig. 3(a)), but were significantly lower in the daytime electric sledge. In contrast, the catches of *M. endeavouri* and *M. bennettae* were significantly lower (approximately one-quarter), both in the daytime water-jet and the daytime electric sledges, than in the night-time conventional sledge (Fig. 3(b), 3(c)).

The catch rates were significantly different between sites for only one species, *M. bennettae* (Table 1). There was a significant interaction between trawl type and site for *M. endeavouri*. The mean catch rate of *M. endeavouri* in the conventional night-time sledge was considerably higher at Site 2 (111 shrimp) than at Site 1 (63). For the other sledge types, however, the differences between sites was small (water-jet trawl: Site 1 (20), Site 2 (20.3); electric trawl: Site 1 (19), Site 2 (9)).

Replicate sledge tows did not differ significantly in their length–frequency distributions; therefore, data were grouped for each set of replicate tows. The three sledge types were very similar in their catch length–frequency distributions (Fig. 4) for all species expect one, *P. esculentus*. There were fewer shrimp in the smaller carapace-length class sizes (4–8 mm) for catches of the electric sledge than in catches from the water-jet sledge. At Site 1, the difference was significant ($P<0.05$, $D=0.2059>D_{0.05}=0.1833$, Kolmogorov–Smirnov two-sample test). At Site 2, the same trend was apparent but not significant ($P>0.05$).

DISCUSSION

It has been well demonstrated that seagrass meadows are the preferred habitat of juvenile *P. esculentus* and *M. endeavouri* (Staples et al., 1985), and that there was no habitat suitable for them in the deeper water surrounding the reef. We therefore assumed that changes in mean catch rates of different sledges, and different times of the day, reflected real differences in sledge efficiency and species catchability. Although the two sites appeared to be on identical habitats, site did have a significant effect on catch rates for *M. endeavouri* and *M. bennettae*, indicating a clumped distribution pattern for those species within the seagrass habitat.

All species of juvenile shrimps had very low catch rates in the conventional sledge used during daylight hours (Turnbull and Watson, 1990) which suggests they are nocturnal, and remain inactive and buried in the substrate during the day. In contrast, Coles (1979) found that day and night catches of *M. bennettae* were similar, suggesting that this species is not nocturnal. The same study, however, found that tidal condition had a significant effect on the catch rates of *M. bennettae*. Coles (1979) suggests that *M. bennettae* bury into the substrate when currents are present and therefore are less likely to enter a net.

In both this study and the test reported in Turnbull and Watson (1990), most of the daytime sledge samples were collected during periods of strong, tidally-generated currents. This would explain the low catch rates for *M. bennettae* in the daytime sledges in both studies.

Although the adults of many tropical shrimp including *P. esculentus* are nocturnal (Penn, 1984), some researchers (B.J. Hill, personal communication, 1991) have observed that smaller individuals emerge from the substrate more often, and are more easily disturbed during daylight hours than are larger shrimp. To catch juvenile shrimp during daylight hours they must be either mechanically removed from the substrate (e.g. by water jets), or stimulated to swim up from the substrate. The action of the water jet sledge may act in both these ways. Our results indicate that water jets have a greater positive impact on the daytime catchability of *P. esculentus*, than *M. endeavouri* or *M. bennettae*. This suggests that juvenile *P. esculentus* are not buried as deeply in the substrate and hence are more easily washed into the water column by the water jets, or that they are more easily stimulated to emerge by the water jets.

Our results also indicate that the daytime water-jet sledge can be used as an alternative to night trawling without biasing the sample length–frequency distribution (Fig. 4). The electric sledge however, caught less smaller shrimp (4–8 mm size classes) than did the water-jet sledge. The electric trawl relies on inducing an involuntary muscle contraction which causes the animal to jump away from the substrate. The voltage potential across an individual's body is directly related to its width, and reduced catch in the smaller size classes could be the result of the reduced voltage across the bodies of smaller shrimp, or their lesser jumping ability.

Apart from differences in catchability, the day-time water-jet is a more reliable alternative to night trawling than the daytime electric sledge. The electrode array on the electric sledge often caught on small lumps of coral rubble in the substrate, and it was difficult to know when the electrodes were operating effectively. The action of the water-jet trawl could be easily assessed by the dinghy operator because of the visible plume of silty water created by the water jets. The water-jet sledge used in this study was successfully used in a daytime, monthly sampling programme at a variety of reef-top sites in Torres Strait (Turnbull and Mellors, 1990).

An interesting sequel to this study would be to trial the sledge in the three modes (conventional, water-jet and electric) both during the day and during the night. This is a catchability study that, due to tidal constraints, was not possible at our study sites in Torres Strait.

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