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Seine nets and beam trawls compared by day and night for sampling fish and crustaceans in shallow seagrass habitat

Michaela A. Guest[a,*], Rod M. Connolly[a], Neil R. Loneragan[b]

[a] School of Environmental and Applied Sciences, Gold Coast Campus, Griffith University, PMB 50, Gold Coast Mail Centre, Qld 9726, Australia
[b] CSIRO Marine Research, PO Box 120, Cleveland, Qld 4163, Australia

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Abstract

Densities of nekton were estimated by comparing catch rates of two previously uncompared gear types, a beam trawl and a seine net, by day and night in a shallow seagrass (*Zostera capricorni*) habitat in Moreton Bay, Queensland, Australia. A total of 39,676 fish and crustaceans representing 42 species was caught. The catch rates of nekton were 1.4–68.1 times higher at night than in the day for 8 of the 17 common species, and were 1.4–9.2 times higher in seines than trawls for 11 of the common species. None of the common species had higher catch rates in the day than the night, or in the trawls than the seines. For some species there was no significant difference in catch rates amongst the sampling combinations. Night-time seine collections had a greater proportion of larger individuals than day and trawl samples. The differences in catch rates and size of nekton are probably a consequence of both gear avoidance and the movement of nekton out of seagrass during the day. Catch rates were estimated more accurately and precisely with the seine than the trawl, with higher catch rates at night. An analysis of the overall composition of the catch (based on presence/absence data) by multi-dimensional scaling separated the samples into four main groups: day-trawl, night-trawl, day-seine and night-seine. The results suggest that seine nets are a better choice for determining the relative proportion of species in a seagrass habitat, and estimating the density of most species. Such sampling should also be done by day and night, or by night alone.

Keywords: Seagrass; Nekton; Gear selection; Diel stage comparisons

1. Introduction

Shallow seagrass meadows support large numbers of small fish and nektonic crustaceans, and there have been many studies on the ecology of these animals around the world (e.g. Bell and Pollard, 1989). Two of the factors that affect the effectiveness of the various strategies used to sample nekton in seagrass are the method, and the time of sampling. The biases of some commonly used methods have been described using depletion experiments (e.g. Weinstein and Davis, 1980; Allen et al., 1992), mark-recapture experiments (e.g. Charles-Dominique, 1989) and comparative studies (e.g. Leber and Greening, 1986; and review by Rozas and Minello, 1997). However, there is little information on the effectiveness of different methods for sampling in seagrass. For studies comparing the species composition among assemblages (e.g. Laegdsgaard and Johnson, 1995), or where results of different studies have been compared or combined

* Corresponding author. Tel.: +61-7-5552-8638; fax: +61-7-5552-8067.
E-mail address: m.guest@griffith.edu.au (M.A. Guest).

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(e.g. Pollard, 1984), it is important to understand the biases of the methods used. For example, seagrass fish communities sampled using rotenone were found to be more similar to those sampled using the same method in a different estuary, than those from the same estuary sampled with a beam trawl (Pollard, 1984). In such cases, any observed differences in community assemblage or abundance may be explained by methodological bias alone, and disguise any real ecological differences amongst communities.

Of the 127 papers published between 1966 and 2000 on small fish and crustaceans in seagrass, the two most widely used sampling methods were the beam trawl (32 papers, e.g. Gray and Bell, 1986; Loneragan et al., 1994; Halliday, 1995) and the seine net (39 papers, e.g. Blaber et al., 1992; Worthington et al., 1992; Connolly, 1994a). Both of these gear types are relatively easy to deploy compared with passive sampling methods such as pop or drop nets (Gilmore et al., 1978; Connolly, 1994b), and this may account for their popularity. The greater effort required to deploy passive samplers is manageable over small areas, and results in accurate sampling (e.g. Connolly, 1994c), but precludes their use for broad-scale surveys.

Despite the widespread use of beam trawls and seine nets, the relative effectiveness of these two methods for estimating nekton densities has not been determined. The beam trawl is commonly used for sampling prawns (e.g. Vance et al., 1994), while the seine net is typically used for sampling fish (e.g. Blaber and Blaber, 1980; Laegdsgaard and Johnson, 1995). The efficiency of the beam trawl has been estimated for sampling prawns in seagrass by depletion experiments (Loneragan et al., 1995), but little is known of its efficiency for sampling fish. In contrast, the efficiency of the seine net has been estimated for sampling fish in seagrass (Connolly, 1994b), but its efficiency for sampling prawns in seagrass has not been investigated.

Differences in nekton densities between day and night have been more thoroughly explored than differences between methods. In general, sampling at night or in both day and night has frequently caught more species or higher densities than sampling in the day (e.g. Robertson, 1980; Greening and Livingston, 1982; Gray et al., 1998). Diel differences in density, however, vary among species (e.g. Jansson et al., 1985), and may be a consequence of net avoidance or movement between seagrass and adjacent habitats, or burying behaviour. Determining the most effective diel stage for sampling has important practical implications for the design of sampling programs.

The aim of this study is to compare the effectiveness of a beam trawl and seine net by day and night in estimating catch rates, faunal composition and species richness of fish and crustaceans in shallow seagrass habitats.

2. Methods

The study location was east of Coomera Island in The Broadwater at the southern end of Moreton Bay, Queensland, Australia (27°50′S, 153°23′E). Sampling was done in a 9 ha area of a monospecific stand of the seagrass *Zostera capricorni*, which is the dominant seagrass species in shallow waters along the east coast of Australia. The average seagrass biomass at this site during the time of sampling was 12.6 g m^{-2}.

Sampling was done over 10 consecutive 24 h periods in June 1999. In each 24 h period, nekton was sampled by day and night, within 1.5 h after the low tide, using a seine net and a beam trawl on each occasion. Tidal stage was standardised during sampling to remove any influence on catch rates, since some pelagic fish species move into seagrass as the tide rises, and out of seagrass as the tide recedes (Sogard et al., 1989).

Within the *Zostera* bed, 40 samples were taken, 10 for each sampling combination (day-trawl, day-seine, night-trawl, night-seine). A sample was the average catch of two hauls for each gear type (seine net and beam trawl) during both day and night sampling events. These averages reduced the influence of zero catches in each sampling combination, and were therefore used in subsequent analyses. Each haul was done at 1 of the 80 sites selected a priori to be within the seagrass bed, and separated from each other by at least 10 m. The water depth at the time of sampling ranged from 40 to 60 cm, water temperature from 12 to 15 °C, and salinity from 32.6 to 34.3 ppt.

The seine net was 5 m wide (with an effective width of 4 m, see Connolly (1994b)) by 2 m high, constructed of a 2 mm fibreglass square mesh and weighted along the bottom, with floats at the top. The seine net was hauled by hand over a measured distance of 20 m. The dimensions of the beam trawl were 1 m wide × 0.50 m high, with a body of 2 m and a 1 m long cod end, constructed of a 2 mm square mesh throughout. Each beam trawl was towed for a distance of 80 m. The total area sampled by each gear type was approximately 80 m^2. All nekton species were identified, counted and measured, except Caridean shrimps which were counted as a single taxon.

Data for abundant species (>20 individuals caught) were $\log_{10}(x + 1)$ transformed and analysed using a two-factor analysis of variance (ANOVA) to test for differences in density between gear type (seine net, beam trawl) and time of day (day, night). The analysis was treated as a split plot design to take into account the 24 h period in which samples were taken. The length distributions of the 12 most abundant species were compared between each of the four sampling combinations using Kolmogorov–Smirnov tests.

The overall compositions of the four sampling combinations (day-trawl, day-seine, night-trawl and night-seine) were compared using non-metric multi-dimensional scaling (with the Bray–Curtis similarity coefficient). Differences in the composition of samples between methods and times of day were tested by an analysis of similarities (ANOSIM) from the PRIMER package (Clarke, 1993). ANOSIM compares ranked similarities between and within groups selected a priori using a randomisation test for significance. Pairwise ANOSIM comparisons were made between all groups, using 5000 simulations in each case. The contribution of each species to the dissimilarity between pairs of groups was determined using the SIMPER routine of the PRIMER package.

Precision (S.E./mean) was estimated for each of the abundant species in each of the combinations of gear type and time of day. The ratio of day and night catch rates was also calculated for the most abundant species using the overall mean of the ten 24 h periods of sampling combined. The ratios were not calculated using data from each 24 h sampling period because for all

Table 1
Mean catch rates (individuals 80 m^{-2}) and relative abundance (%) of the 17 most common species caught in seine nets and beam trawls during the day and night ($n = 10$ for each combination of time of day and method of sampling)

Species name	Common name	Day		Night		% Abundance
		Trawl	Seine	Trawl	Seine	
Fish						
P. sexlineatus	Striped trumpeter	18.8	87.7	33.4	124.6	27.9
A. jacksoniensis	Port Jackson glassfish	2.6	38.3	24.1	118.6	19.4
G. semivestitus	Glass goby	6.0	8.8	10.5	38.9	6.8
Favonigobius exquisites	Exquisite sand goby	1.7	11.3	8.0	18.4	4.2
C. australis	Fortesque	0.2	2.1	1.7	10.6	1.5
Petroscirtes lupus	Brown sabretooth blenny	1.9	6.2	1.9	4.4	1.5
A. australis	Yellowfin bream	1.2	3.3	1.6	6.5	1.3
U. carinirostris	Hairy pipefish	0.2	1.5	1.1	3.5	0.7
M. chinensis	Fan-belly leatherjacket	0.5	1.6	0.1	2.0	0.4
A. frenatus	Half-bridled goby	0.3	4.2	1.3	5.9	0.3
T. hamiltoni	Common toadfish	0.1	0.7	0.1	1.5	0.3
A. marianus	Ramsay's glassfish	0.1	0.1	0.3	1.1	0.2
Syngnathoides biaculeatus	Double-ended pipefish	0.3	0.4	0.1	0.5	0.1
H. cyanospilus	Blue-speckled pipefish	0	0.1	0.3	0.7	0.1
Total number of fish		739	3841	1795	7149	64.7
Total number of fish species		18	25	21	35	
Crustaceans						
P. plebejus	Eastern king prawn	3.1	7.5	69.7	126.4	21.2
M. bennettae	Bay prawn	0.1	0.4	19.2	27.2	4.9
P. esculentus	Brown tiger prawn	2.7	8.4	5.8	11.4	3.0
Total number of crustaceans		1903	3825	6052	14732	29.1
Total number of crustacean species		5	6	6	6	
Total number of individuals 80 m^{-2}		52.2	155.4	166.9	465.5	

but a few species, catch rates were sometimes very low on any particular day.

3. Results

3.1. Species richness, composition and catch rates

Forty-two species of fish and crustacean, and 39,676 individuals were caught during the study. More species of fish and more individuals were caught at night than during the day for both seines and trawls (Table 1). The total number of fish and crustacean, and the number of species of fish were higher in seines than trawls. The most abundant species of fish were *Pelates sexlineatus* and *Ambassis jacksoniensis*, contributing 27.9 and 19.4% respectively to the total catch. Only one other species of fish (*Gobiopterus semivestitus*) contributed more than 5% to the total catch. The most abundant crustacean caught during this study was *Penaeus plebejus*, comprising 21.2% of the total catch.

The catch rates of 11 of the abundant species were significantly greater in seines than trawls, irrespective of the time of day of sampling (Table 2). This difference was particularly marked for *Arenigobius frenatus*, where the catches were about 5–10 times higher in seines than trawls (Fig. 1a). The mean catches of the abundant species were from 1.4 to 9.2 times greater in seines than in trawls. The total density of all species combined was also higher in seines than trawls (Table 1). The catch rates of eight species were significantly higher at night than in the day (by from 1.4 to 68.1 times, Tables 1 and 2) (e.g. *P. plebejus*, Fig. 1b). Six species had higher catch rates at night and in seine samples (e.g. *P. sexlineatus*, Fig. 1c). Only *Centropogon australis* showed an interaction between diel stage and gear type (Fig. 1d). For this species, the difference between seine and trawl catch rates was significantly greater at night than during the day.

3.2. Length distributions

The length distributions of 5 of the 11 most abundant species differed significantly between methods or times of day (Table 3). Considering only the night data, the lengths of three species were significantly longer

Table 2
Summary of the split plot ANOVA results testing for differences in catch rates between gear types and times of sampling for the 18 most abundant species[a]

Species	Trawl versus seine		Day versus night	
	P	Direction of difference	*P*	Direction of difference
Fish				
P. sexlineatus	<0.001	S	0.040	N
A. jacksoniensis	0.001	S	<0.001	N
G. semivestitus	0.089	–	0.063	–
F. exquisites	0.001	S	0.017	N
C. australis	<0.001	S	<0.001	N
P. lupus	0.001	S	0.269	–
A. australis	0.102	–	0.341	–
U. carinirostris	<0.001	S	0.003	N
M. chinensis	0.001	S	0.430	–
A. frenatus	<0.001	S	0.148	–
T. hamiltoni	0.002	S	0.375	–
A. marianus	0.156	–	0.076	–
S. biaculeatus	0.102	–	0.795	–
H. cyanospilus	0.143	–	0.005	N
Crustaceans				
P. plebejus	0.053	–	<0.001	N
M. bennettae	0.046	S	<0.001	N
P. esculentus	0.034	S	0.069	–

[a] ‘S’ indicates greater density in seines than trawls. ‘N’ indicates greater densities at night than day. No direction is given where the result is not significant. None of the interaction terms were significant except for *C. australis* ($P = 0.04$).

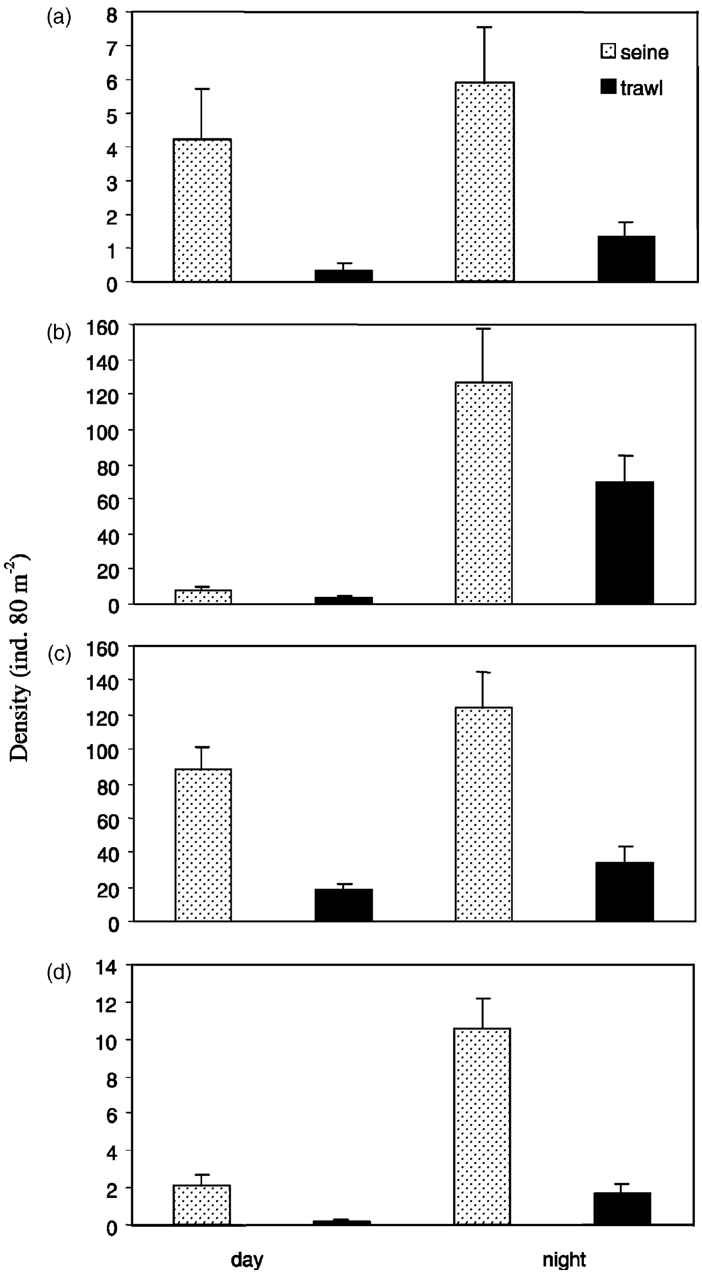

Fig. 1. Mean density (+1 S.E.) for different species in seines and trawls during the day and night, $n = 10$ for each mean. (a) *A. frenatus*: significant difference for gear type but not diel stage; (b) *P. plebejus*: significant difference for diel stage but not gear type; (c) *P. sexlineatus*: significant differences for both gear type and diel stage; (d) *C. australis*: significant interaction between gear type and diel stage.

Table 3
Probability values for Kolmogorov–Smirnov tests comparing the length distributions of the most abundant species between gear and time of day[a]

Species	Comparisons			
	Seine versus trawl		Day versus night	
	Night only	Day only	Seine only	Trawl only
Fish				
P. sexlineatus	0.015*	0.800	0.007*	0.494
A. jacksoniensis	0.811	0.285	0.137	0.160
G. semivestitus	0.011*	0.840	<0.001*	0.643
F. exquisites	0.959	0.058	0.715	0.258
C. australis	0.922	0.975	0.270	0.819
P. lupus	0.529	0.245	0.667	0.826
A. australis	0.923	1.000	0.031*	0.569
M. chinensis	–[a]	0.523	0.356	–
A. frenatus	0.150	0.594	0.577	0.215
Crustaceans				
P. plebejus	0.189	1.000	<0.001*	0.019*
M. bennettae	<0.001*	–	–	–
P. esculentus	0.350	0.469	0.634	0.130

[a] Too few fish were caught for comparison.
* Significant probability = 0.05.

in the seine than the trawl (e.g. *G. semivestitus*, Fig. 2a, Table 3). For the seines, four species were longer at night than in the day (e.g. *Acanthopagrus australis*, Fig. 2b). When length distributions for trawl samples were examined, only those of *P. plebejus* differed significantly between day and night, with more, larger individuals caught at night (Table 3, Fig. 2c). During the day, no significant differences in length distributions were found between seines and trawls (Table 3).

3.3. Precision of sampling

Precision ranged from 15 to 100% for the most abundant species (Table 4). The lowest ratios, hence the highest precision, were found for eight species by sampling at night with the seine net, compared with four species for each of the other combinations of method and time of sampling (Table 4). The average ratio for the total catch rates (i.e. all species combined) was the lowest for night-seine collections (29%) compared with all other sampling combinations. The average ratios of total catch rates for night-trawl and day-seine collections were similar (about 40%). The average ratio for the day-trawl was higher than all other sampling combinations (48%, Table 4).

3.4. Comparison of catch rates in seine nets between day and night

The mean catch rate of *P. sexlineatus* in a seine was 1.4 times higher at night than in the day (Table 5). The mean catch rates of four other species in seines were between ∼2 and 5 times higher at night than in the day. Much greater differences were found for *Hippichthys cyanospilus* (15) and *P. plebejus* (∼17), with the greatest difference in mean catch rates for *Metapenaeus bennettae* (∼68 times, Table 5).

3.5. Nekton assemblages

The two-dimensional MDS ordination plot produced from presence/absence data shows strong groupings of day-trawl, day-seine, night-trawl and night-seine samples (Fig. 3). Night samples were clearly separated from day samples, and trawl samples separated from seine samples in all cases except one day-seine sample. This was a seine sample averaged over two hauls with low catch rates and few species. The samples from day-trawls were more widely dispersed than those from other sampling combinations. A similar pattern was found for the MDS plot based

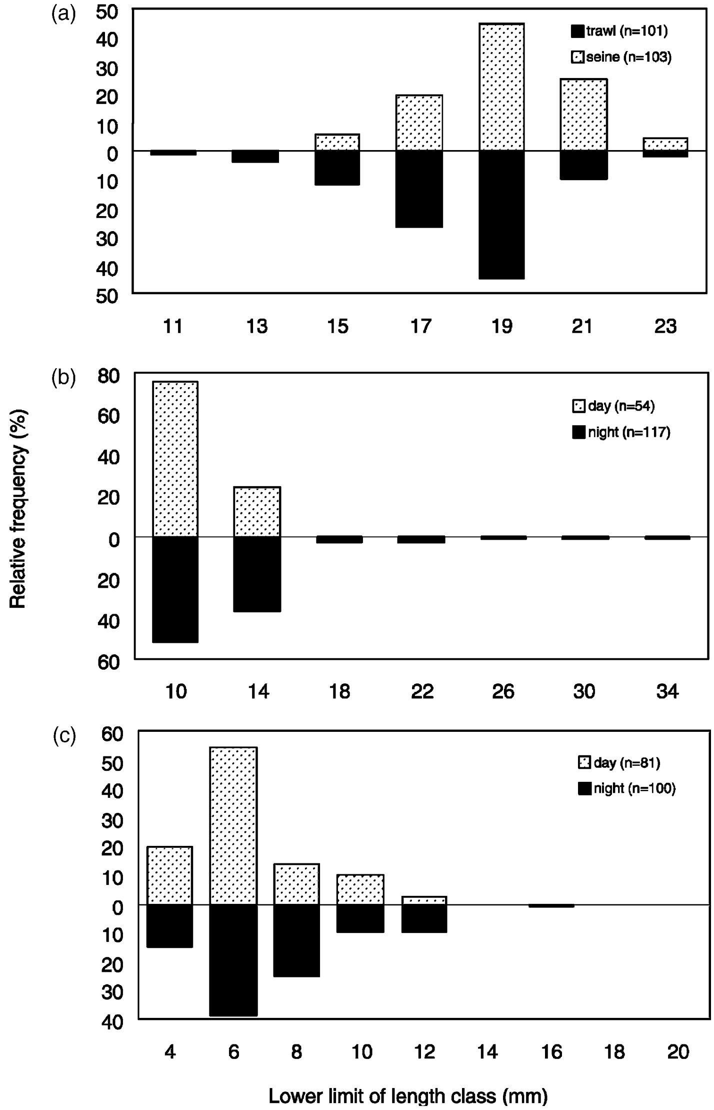

Fig. 2. Differences in length distributions of (a) *G. semivestitus*: seine versus trawl samples for night-only collections; (b) *A. australis*: day versus night samples for seine-only collections; (c) *P. plebejus*: day versus night samples for trawl-only collections.

on abundance data, indicating that it was the presence/absence of a suite of species rather than the relative abundance of those species that separated the four groups.

The non-parametric ANOSIM tests showed that the compositions of the combinations of methods and times of sampling differed significantly from each other (Table 6). The composition of trawl samples also differed significantly from that of seines, irrespective of day and night. The composition of day samples differed significantly from that of night samples, regardless of the sampling method. *C. australis* was a good separator of day-trawl samples compared to all other sampling combinations (Table 6) as it was only caught in three day-trawl samples, but in at least nine samples from each of the other sampling combinations. *Urocampus carinirostris* was also a good separator of the day-trawl samples and followed the

Table 4
The ratio of the S.E. to the mean (%) for each combination of diel stage and gear type (a smaller value indicates a greater precision)

Species	Day		Night	
	Trawl	Seine	Trawl	Seine
Fish				
P. sexlineatus	18	15[a]	30	16
A. jacksoniensis	49	59	23	21[a]
G. semivestitus	74	52	31[a]	35
F. exquisites	49	22	30	17[a]
C. australis	55	32	27	15[a]
P. lupus	17[a]	17[a]	22	27
A. australis	20[a]	30	24	39
U. carinirostris	45	21	24	15[a]
M. chinensis	29[a]	29[a]	100	37
A. frenatus	60	37	32	28[a]
T. hamiltoni	100	26[a]	100	42
A. marianus	100	71	60	47[a]
S. biaculeatus	67	45	67	33[a]
H. cyanospilus	–[b]	100	37[a]	37[a]
Crustaceans				
P. plebejus	35	24	21[a]	25
M. bennettae	67	45	22[a]	27
P. esculentus	15[a]	27	18	23
# species showing the greatest precision	4	4	4	8[a]
Average precision of all species combined	48	37[a]	38[a]	29[a]

[a] The most precise method for each species.
[b] No estimate possible.

Table 5
A ratio of day and night catch rates for the most abundant species (only those having significant day–night differences) caught in seine nets

Species	Ratio
Fish	
P. sexlineatus	1.4
A. jacksoniensis	3.1
F. exquisites	1.6
C. australis	5.0
U. carinirostris	2.3
H. cyanospilus	15.0
Crustaceans	
P. plebejus	16.7
M. bennettae	68.1

pattern for *C. australis*, as it was only caught in four day-trawl samples, but at least eight samples from each of the other sampling combinations. *M. bennettae* was a good separator of the day and night ignoring gear type (Table 6), as it was captured in all 10 samples for night-seine and night-trawl combinations, but was only captured in two day-trawl samples and four day-seine samples. *Tetractenos hamiltoni* was a good separator of trawls and seines as it was captured in no more than two trawl samples, but in at least seven seine samples irrespective of the time of sampling.

4. Discussion

4.1. Species richness

More species were caught during the night than in the day, which is consistent with previous studies of nekton in seagrass habitat (Heck, 1977; Robertson, 1980; Gray et al., 1998). Increased activity and therefore 'catchability' at night of some species may, in part, explain these trends of greater night-time species richness. For example, some species of penaeid prawns bury in the sediment during the day and re-emerge at

Table 6
Results of pairwise ANOSIM tests for differences amongst the four combinations of diel stage and gear type, and species that make major contributions to between group differences

Comparison	ANOSIM results (P)	Main contributing species
Trawl versus seine	<0.001	*T. hamiltoni, A. jacksoniensis, P. sexlineatus*
Day versus night	<0.001	*M. bennettae, P. plebejus, A. jacksoniensis*
Day-trawl versus night-trawl	<0.001	*M. bennettae, C. australis, U. carinirostris*
Day-trawl versus day-seine	0.008	*C. australis, U. carinirostris, P. sexlineatus*
Day-trawl versus night-seine	<0.001	*M. bennettae, C. australis, U. carinirostris*
Day-seine versus night-seine	<0.001	*M. bennettae, Gerres subfasciatus, Glossogobius biocellatus*
Day-seine versus night-trawl	0.004	*M. chinensis, M. bennettae, T. hamiltoni*
Night-trawl versus night-seine	<0.001	*T. hamiltoni, M. chinensis, G. subfasciatus*

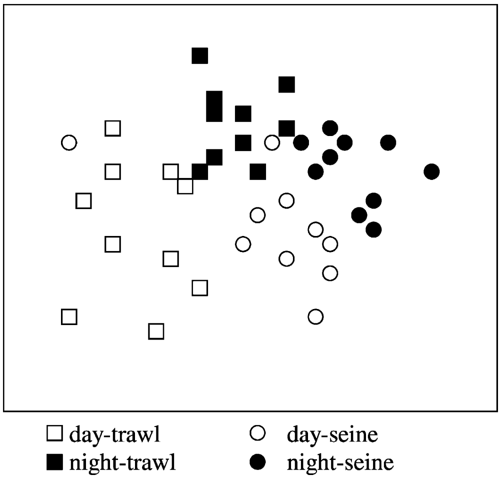

Fig. 3. Two-dimensional MDS ordination based on presence/absence data (stress = 0.18).

night (Dall et al., 1990; Vance, 1992). Increased prey availability at night may also contribute to these diel activity differences (Sogard et al., 1989).

More species were caught in the seine than in the trawl during this study. This may be a consequence of the greater width of the seine (effective width of 54 m) than the trawl (1 m), resulting in a lower chance of escape from the seine for fast-moving species.

4.2. Catch rates

For most of the abundant species, higher catch rates were obtained at night in seines than the day and from trawls. The lower catch rates from trawls could be a consequence of propellor disturbance alerting nekton to the oncoming gear whilst trawling, or again, the narrower width of the trawl than the seine. The lower catch rates during the day are most likely due to the increased ability of nekton to see the gear approaching and move out of its path.

The trend for greater total number at night is consistent with the conclusions from other diel studies of the epifauna in seagrass beds (e.g. Gray and Bell, 1986; McNeill and Bell, 1992; Edgar and Shaw, 1995; Mattila et al., 1999). The differences between day and night catch rates have been attributed both to factors associated with the sampling method, and to the biology of different species. As mentioned previously, day and night differences in total numbers could be a result of increased net avoidance during the day. The behaviour of different species may also contribute to the day/night differences in the following ways: (i) the lateral movement of nekton from the seagrass bed into adjacent habitat and thus being unavailable for capture during daylight hours, and/or (ii) the reduced activity of some nekton as they move vertically within the seagrass bed, and bury during daylight hours (e.g. *P. plebejus*). In this study, the higher catch rates in day-seine collections compared to day-trawl collections indicate that some nekton were able to actively avoid capture by the trawl. This is also true for night-seine and night-trawl collections.

Whilst the trend of greater catch rates in seine and night collections was widespread, some species did not follow this pattern. For example, catch rates of *A. australis*, *Monacanthus chinensis* and *Ambassis marianus* did not differ significantly between gear types and time of day. Blaber et al. (1992) also found no significant difference between day and night catch rates of *M. chinensis*. This varying response of species both to the gear type and time (i.e. day or night) of sampling is consistent with other comparisons of sampling time and methods (e.g. Greening and Livingston, 1982; Jansson et al., 1985; Blaber et al., 1992). However, it should be noted that the catch rates of *A. australis*, *M. chinsensis* and *A. marianus* were relatively low during our study and this partly explains the lack of difference between day and night catch.

Finally, the volume of water sampled could influence the number of individuals captured. In deeper water, this may be an important consideration for species that swim in the water column above the seagrass bed. At shallow water depths, these pelagic species are thought to move off seagrass beds into deeper water (Sogard et al., 1989). Water volume is unlikely to have been a significant factor affecting catch rates in this study because both the area sampled by each gear type, and the tidal height was standardised. At all sampling events, water depth was only as high as the top of the trawl or seine.

4.3. Length distributions

Night-seines captured a greater proportion of both the larger individuals of some species, than trawls or day-seines, and the smaller individuals that dominated day catches. The predominance of larger individuals captured by night-seines is most likely a result of larger individuals being more able to swim out of the path of the oncoming net during the day when visibility is the greatest. No other studies of seagrass nekton have compared the length distributions of species between day and night sampling. Similarly, few studies that compared different gear types have compared species length distributions. Of these few comparisons, Gilmore et al. (1978) compared the wet weight of individuals in a comparison of a drop net and a seine net done during the day. Fewer, larger individuals were captured by the drop net compared to the seine. No significant differences in length distributions of the three most common species in seagrass habitat, *Sillaginodes punctata*, *Favonigobius lateralis* and *Atherinosoma microstoma*, were observed between a pop and a seine net from day sampling (Connolly, 1994b).

4.4. Precision and accuracy of estimates

The precision of catch rates taken during day and night, and for the beam trawl and seine net, varied among species. This is consistent with other studies that reported the precision of density estimates. For example, Howard (1989) recorded values of precision ranging from 11% for *Shuettea woodwardi* to 62% for *Arripis georgianus*. Other studies have reported the precision of estimates of density for groups of crustaceans and fish, but not for individual species (Leber and Greening, 1986; Howard, 1987; McNeill and Bell, 1992). In two of the studies which reported the precision of density estimates for groups of nekton, precision varied among groups depending upon the time (i.e. day or night) and season of sampling (Leber and Greening, 1986; Howard, 1987). McNeill and Bell (1992) found no differences in the precision of density estimates among nekton groups.

In this study, the higher catch rates of a species from night-seine sampling were considered more accurate than the lower catch rates obtained from other sampling combinations. Whilst it is theoretically possible that the higher catch rates observed are an artefact of the sampling method used, it is unlikely. For example, towed nets are typically thought to encourage net *avoidance* behaviour by fish (e.g. Rozas and Minello, 1997), rather than acting as fish attractants.

Catch rates of most abundant species were the highest from night-seine sampling combinations, and were therefore considered more accurate. For 8 of the 17 most abundant species, the catch rates were also more precise. The difference between the precision and accuracy of the remaining abundant species demonstrates that it is possible to develop a sampling strategy that is accurate but not precise. Caution must therefore be taken to ensure the sampling strategy is able to meet the objectives of the study for the target species. The variation among species in the precision of a particular gear type observed in this study may be related to the behaviour of individual species; for example, the poorest precision was found for the strongly schooling species *A. marianus*. Equal highest precision (15%) was found for four species: *Penaeus esculentus* (day-trawl), *P. sexlineatus* (day-seine), *C. australis* (night-seine), and *U. carinirostris* (night-seine). For *P. sexlineatus* however, a similar precision (16%) was found in night-seines suggesting that this species is more easily caught by seines than trawls irrespective of the time of sampling. The high precision for *U. carinirostris* in night-seines may be due to the cryptic behaviour of this species during the day, and increased activity at night making it more susceptible to capture.

4.5. Comparison of catch rates in seine nets between day and night

More studies of seagrass nekton have been carried out in the day than the night, probably because of the additional difficulty and expense associated with night sampling. In this study, and other studies that compare nekton catch rates in day and night (e.g. Gray and Bell, 1986; Stoner, 1991; Vance et al., 1994), catch rates were higher at night than the day for most species. Whilst the ratio of day and night catch rates is limited to the location and time of sampling of this study, it does illustrate the general disparity between day and night catch rates. For example if, in a future sampling event, day catch rates of *P. sexlineatus* were 100 individuals 80 m^{-2}, then in the current context, night catch rates would be estimated at 140 individuals 80 m^{-2}. These indices are a guide to average catch rates; they are not intended to predict the exact number of individuals present on any one day or night sampling event.

4.6. Nekton assemblages

The four different combinations of diel stage and gear type resulted in the collection of distinctly different nekton assemblages. These assemblages could be separated on the presence/absence of suites of species regardless of the catch rates of those species. This is likely to be due to the differing gear selectivity for sampling different types of fish, and the diel behaviour of some species. For example, *M. bennettae* was present in a greater proportion of samples from night-seine and night-trawl combinations than day-seine and day-trawl combinations. This is most likely because *M. bennettae* buries during the day, which makes it unavailable to capture during daylight sampling (Vance, 1992). The wider dispersion of samples from day-trawls is consistent with the low precision values for most species collected in day-trawls, and means that more samples would be needed using day-trawls than other sampling combinations to properly represent nekton assemblages.

4.7. Ecological implications

For some species the methods used in this study did not affect the abundance of individuals captured. However, for many species, the use of the trawl and/or day sampling would grossly underestimate the density of individuals present. This is also true if an accurate estimate of species richness were required, as the present study found that day and trawl sampling captured only a subset of those species captured by night or seine sampling methods. For studies that aim to combine or compare the results of previous studies, make spatial comparisons, or use the relative proportion of species within assemblages, these sampling biases may seriously mislead ecological interpretations.

5. Conclusions

Night and seine sampling resulted in more effective sampling (both higher catch rates and more precise estimates) of nekton in a shallow seagrass habitat in Moreton Bay. Additionally, a greater proportion of larger individuals was caught in night-seines than in the day and trawl samples. This may be a result of both the characteristics of the different gear and the behaviour of different species. This study shows that seines are more effective than beam trawls for sampling nekton in seagrass habitat for most species. Seine nets are therefore considered a better choice for determining the relative proportion of species, making spatial comparisons of seagrass nekton density within a study, or comparing or combining data from multiple studies done in seagrass. This study also supports other studies that have recommended night sampling for estimations of nekton density in seagrass habitat.

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