

Relationship Between Seagrass Standing Crop and the Spatial Distribution and Abundance of the Natantian Fauna at Green Island, Northern Queensland

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Abstract

The natantian fauna of the seagrass bed at Green Island (16°46'S, 145°58'E) was sampled monthly at night by using a small beam trawl along three transects. Most of the catch consisted of members of the caridean families Processidae, Palaemonidae and Hippolytidae (in order of numerical abundance). The remainder consisted of members of the penaeidean families Sergestidae and Penaeidae. Seagrass standing crop and a living-space index correlated significantly with the abundances of carids but not those of penaeids. The most appropriate regression models explaining the variation in processid and palaemonid densities included only the living-space index and explained between 25 and 38% of the variance. The most appropriate model for the abundance of the hippolytid family was a combination of living-space index and standing crop, which explained 21% of the variance.

Introduction

Many laboratory, field and review studies have explored the effects of habitat complexity on the abundance and/or diversity of seagrass-associated macrofauna (e.g. Heck and Wetstone 1977; Virnstein 1977; Nelson 1979; Peterson 1979; Heck and Orth 1980; Stoner 1980a, 1982; Gore *et al.* 1981; Lewis and Stoner 1983; Lewis 1987; Staples and Poiner 1987). Macrophyte complexity, as measured by plant biomass or plant surface area, is generally considered a predictor of the abundance of motile epifauna in seagrass systems (Heck and Wetstone 1977; Orth 1977; Heck and Orth 1980; Stoner 1980a). Although the biotic parameters of seagrass (i.e. biomass, leaf height and width, and species composition) may be important in structuring the seagrass community, it is the abiotic parameters (i.e. temperature and light) that influence the life histories, population dynamics and productivity cycles of the fauna (Livingston 1984), particularly those animals that have a meroplanktonic stage (Anger 1983). It is likely that a combination of abiotic and biotic factors influences fluctuations in the abundance and distribution of animals within a seagrass bed. Abiotic factors determine the number of animals that settle into the bed, whereas biotic factors determine the distribution of the settled animals within the bed.

This study documents the relationship, over the course of a year, between changes in habitat complexity and the effect of these changes on the spatial distribution and abundance of the natantian crustaceans in a tropical seagrass bed at Green Island, northern Queensland, and evaluates the relative importance of seagrass standing crop (Mellors *et al.* 1993) and leaf area in determining the spatial distribution and abundance of this fauna.

Materials and Methods

Study Site

Green Island (16°46'S, 145°58'E) is a vegetated sand cay on the inner edge of the Great Barrier Reef. An extensive multispecific seagrass meadow interspersed with coral bommies (coral heads) surrounds most of the cay. The meadow is subtidal and densest on the sheltered north-western side of the island, where *Halodule uninervis* (Forsk.) Aschers. (wide-leaved variety) is the dominant species. *Cymodocea serrulata* (R. Br.) Aschers. & Magnus and *C. rotundata* Ehrenb. et Hempr. ex Aschers. are also present. *Halophila minor* (Zoll.) den Hartog is sparsely scattered throughout the entire meadow. On the north-eastern and southern sides of the island, the seagrasses are intertidal and less dense, and *Thalassia hemprichii* (Ehrenb.) Aschers. and *C. rotundata* are the main species present.

Sampling

Sampling was carried out monthly in the subtidal, dense north-western meadow (dominated by *H. uninervis* and *C. serrulata*) around a week before or after the new moon from May 1987 to April 1988. Of the three sampling sites (Mellors *et al.* 1993), Station 1 was the most protected from the south-easterly winds. Station 2 was the most heterogenous site; it was situated near two coral bommies and had two blowouts (bare sand patches) along the trawl path. Station 3 was more exposed to the south-easterly winds than the other two stations.

Fauna

The seagrass fauna was sampled at night, when decapods are most active (Young and Wadley 1979; Howard 1981; Bauer 1985; Gray and Bell 1986; Bell and Pollard 1989), by using a small beam trawl (1.5 m wide and 0.5 m high, fitted with 2-mm mesh). The three trawl stations were marked at each end of a 50-m trawl path with a hemispherical polystyrene float equipped with a flashing light. Two trawls were made at each station during each sampling period. All six trawls were completed within 1 h to reduce the confounding effect of time or tide. As trawls at the same station did not cover the same ground, they were regarded as replicates. The resultant samples were bagged and frozen for transport to the laboratory.

In the laboratory, the fauna was separated from the seagrass, sediment and algae caught in the beam trawl, and the natantians were separated from the by-catch. Large samples of natantians (lower limit 300–2000 individuals per trawl) were subsampled with a mechanical sample splitter. Owing to the difficulty in identifying tropical carids (many species have not yet been described), the subsamples of natantians were identified only to family level according to Holthius (1955) and Wadley (1978).

As exploratory data analysis showed that the variance between replicates (trawls) at each station was large, we transformed (ln) the data for subsequent analysis. We excluded four outlying data points because the sample size (<35 individuals) indicated that the beam trawl had sampled above the seagrass canopy.

Each trawl swept an area of 75 m². All abundance data are presented as ln individuals per trawl (estimated from the subsample) rather than as absolute numbers per square metre because the efficiency of the beam trawl was not tested.

Seagrass Standing Crop

Changes in seagrass standing crop at the three trawl stations were monitored (Mellors *et al.* 1993) by using the visual census technique detailed in Mellors (1991). The standing crop within quadrats was ranked systematically with respect to a set of reference quadrats. Observers took it in turn to rank the standing crop within the 0.25-m² quadrats, which were placed every 5 m along a marked 50-m transect. The reference quadrats were preselected to provide a scale of standing crop dry weights. At the end of each sampling period, 10 quadrats away from the trawl sites were harvested to calibrate the ranked scale for that period.

Leaf Area

The above-ground seagrass harvested from each calibration quadrat was mixed well, and a subsample weighed to within 0.01 g was passed through a Paton electronic planimeter to measure leaf area.

Measurements of leaf area per gram of seagrass were multiplied by the appropriate correction factor and doubled to give an area for both sides of the leaves. These measures were then converted to estimates of leaf area per square metre by using a technique similar to that developed for estimating standing crop (Mellors 1991), and these estimates were used as indices of living space in subsequent analyses.

Statistical Analysis

Analysis of variance was used to determine the effect of site on the abundance of each natantian family group. Station was treated as a fixed factor in the analyses because the choice of stations was dictated by the availability of trawlable ground. Trawls at the same station were treated as replicates because they did not sample exactly the same area each time. An analysis of variance using quadrat as a repeated measure was used to examine the effect of site on seagrass standing crop and living-space index because the same quadrats were sampled on each occasion.

Parametric correlations were performed between the abundance of the various families of natantians and the seagrass biotic parameters (living-space index and seagrass standing crop). Although seagrass standing crop and living-space index were correlated, both parameters were included in the all-subsets regression analyses to identify a regression model that best explained (on the basis of Mallow's C_p and adjusted r^2 ; Weisberg 1985) the association between the ln-transformed natantian abundances (response) and the biotic variables of seagrass standing crop and living-space index.

Results

Six families of natantian crustaceans were consistently caught by the beam trawl (section Caridea: Alpheidae, Processidae, Hippolytidae, Palaemonidae; section Penaeidea: Sergestidae, Penaeidae). As beam trawls effectively sample only animals associated with the leaf canopy, the alpheids, which are commonly found in burrows, were not included in further faunal analysis. The Processidae comprised more than 50% of each monthly catch (Fig. 1). The second largest component of the catch was the Palaemonidae, contributing around 33%; the remainder was made up of the Hippolytidae, Sergestidae and Penaeidae in that order (Fig. 1).

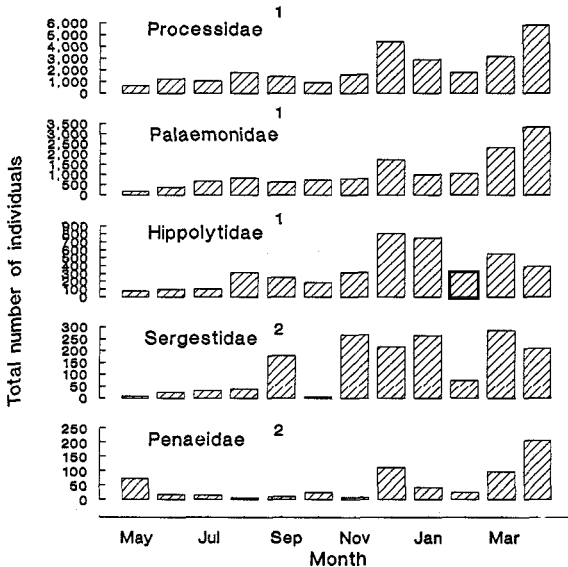


Fig. 1. Monthly abundances of faunal family groups (1, carid families; 2, penaeid families), all stations combined. Note the different scales on the vertical axes.

An analysis of variance detected no significant differences between stations for the Processidae ($F=1.670$, 2×32 d.f., $P=0.1259$). However, the Palaemonidae ($F=14.206$, 2×32 d.f., $P<0.001$) and the Hippolytidae ($F=10.9870$, 2×32 d.f., $P=0.0002$) were more

abundant at Station 1 than at Stations 2 or 3, and the Sergestidae ($F=8.79$, 2×32 d.f., $P=0.009$) and the Penaeidae ($F=7.533$, 2×32 d.f., $P=0.0021$) were most abundant at Station 3 and least abundant at Station 1 (Fig. 2).

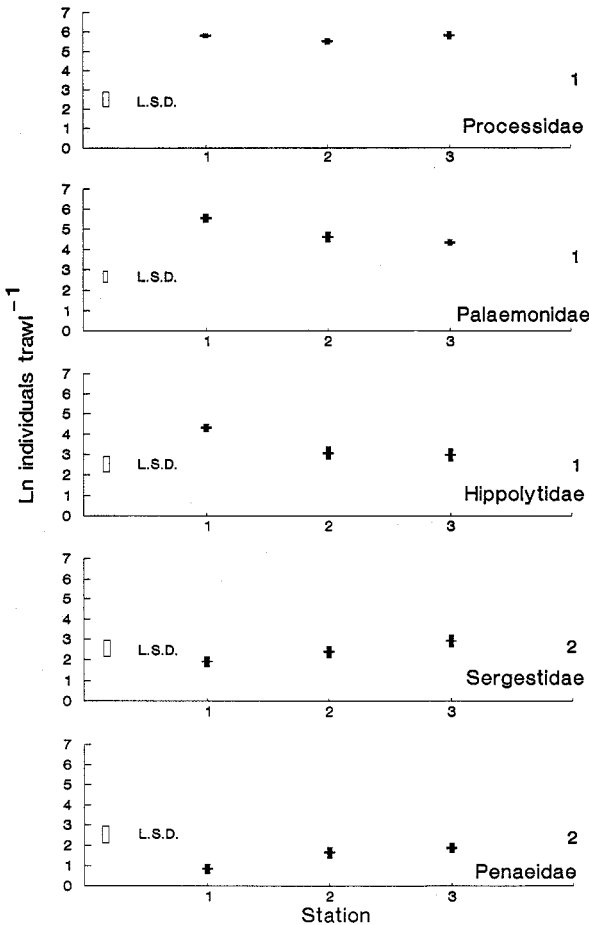


Fig. 2. Mean densities of faunal family groups (1, carid families; 2, penaeid families) at each station. Standard error and least significant difference (L.S.D.) are also shown.

Analyses of variance by using a repeated-measures design detected significant differences between stations in both seagrass standing crop ($F=26.79$, 2×27 d.f., $P<0.0001$) and living-space index ($F=36.46$, 2×27 d.f., $P<0.001$). In both instances, Station 1 had the largest estimates of standing crop and living-space index, Station 2 had the smallest, and Station 3 was intermediate (Fig. 3).

Standing crop and living-space index correlated significantly with the abundance of each carid family (Table 1). In contrast, the abundance of members of the penaeid families did not correlate with either seagrass standing crop or living-space index (Table 1). Inspection of adjusted r^2 and Mallows' C_p (Weisberg 1985) and an examination of the significance levels of the independent variables showed that variation in the abundances of the processid and palaemonid families was best explained by living-space index only (Table 2). However, the model explained only 25 and 38% of the variance, respectively (Table 2). The most appropriate model for the hippolytid family was a combination of standing crop and living-space index, which explained 17% of the variance (Table 2). None of the models tested explained a significant proportion of the variation in the abundance of either the sergestids or the penaeids.

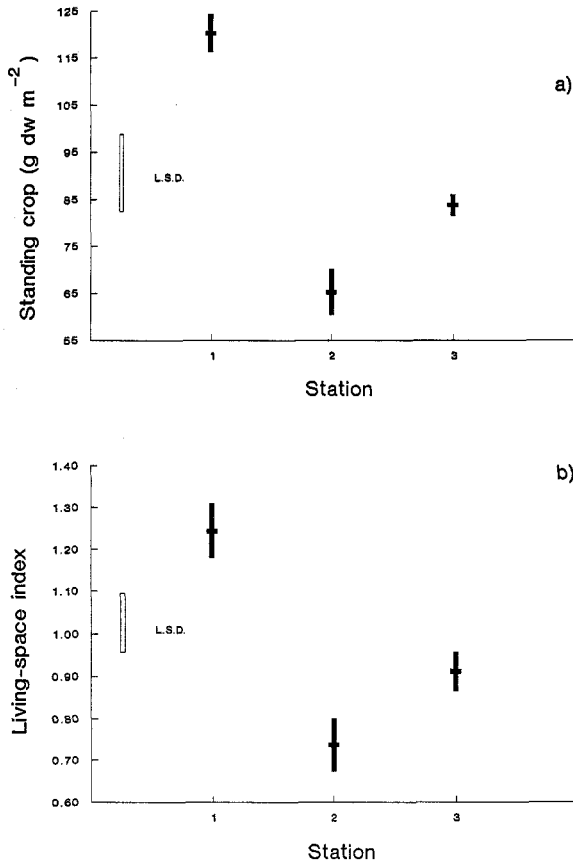


Fig. 3. Estimates of (a) seagrass standing crop and (b) living-space index for each station. Mean, standard error and least significant difference (L.S.D.) are shown. (Fig. 3a reproduced from Mellors *et al.* 1993.)

Table 1. Correlations between the abundance of five families of natantian crustaceans and two biotic parameters for a seagrass bed at Green Island, northern Queensland
Critical $r_{(31)} = 0.291$

Family	Standing crop	Living-space index
Processidae ^A	0.2948	0.5028
Palaemonidae ^A	0.4442	0.6108
Hippolytidae ^A	0.4497	0.3408
Sergestidae ^B	-0.0898	0.0007
Penaeidae ^B	-0.1066	0.2682

^A Carid families.

^B Penaeid families.

Discussion

Effect of Biotic Parameters on Abundance of Seagrass Fauna

The structural complexity of a seagrass bed is often equated to seagrass biomass (Heck and Wetstone 1977; Heck and Orth 1980; Gore *et al.* 1981; Orth *et al.* 1984), and several authors have demonstrated a positive correlation between faunal richness and abundance

Table 2. Regression models for the relationship between abundances of five families of natantian crustaceans and standing crop (A) and living-space index (B) at Green Island, northern Queensland

Family	Model variables	Mallow's C_p	r^2	Adjusted r^2	Residual s.s.	d.f.	P
Processidae ^A	A	10.9	0.0581	0.0304	16.64	34	0.1568
	A, B	3.0	0.2752	0.2313	12.81	33	0.0049
	B	1.0	0.2750	0.2537	12.81	34	0.0010
Palaemonidae ^A	A	16.8	0.1299	0.1043	32.03	34	0.0309
	A, B	3.0	0.4113	0.3756	21.67	33	0.0002
	B	1.5	0.4024	0.3849	21.99	34	0.0000
Hippolytidae ^A	A	3.1	0.1625	0.1379	50.18	34	0.0148
	A, B	3.0	0.2128	0.1651	47.17	33	0.0193
	B	4.0	0.1423	0.1170	51.39	34	0.0233
Sergestidae ^B	A	2.0	0.0202	-0.0086	58.55	34	0.4000
	A, B	3.0	0.0492	-0.0084	56.82	33	0.4348
	B	2.4	0.0084	-0.0208	59.26	34	0.5955
Penaeidae ^B	A	4.6	0.0064	-0.0288	43.13	34	0.6410
	A, B	3.0	0.1031	0.0487	38.93	33	0.1661
	B	2.6	0.0602	0.0325	40.80	34	0.1493

^A Carid families.^B Penaeid families.

and seagrass above-ground biomass (Nelson 1979, 1981a, 1981b; Stoner 1979, 1980b, 1982; Coen *et al.* 1981; Leber 1985; Bell and Pollard 1989). Other studies have found that seagrass biomass and leaf area are poor predictors of epifaunal abundances and that seagrass species and morphology may be important in structuring faunal assemblages (Virnstein *et al.* 1984; Virnstein and Howard 1987a).

The significant relationships between seagrass biotic parameters and the density of the members of various Caridean crustaceans found in this study support previous findings that faunal abundance is associated with seagrass complexity. Although many of the ecological patterns would be obscured and lost with the family grouping, the strong patterns involved in recruitment and spawning would be apparent even across family groups because within each family group there was a numerically dominant species group. Our results indicate that both seagrass biomass and living-space index were significantly associated with Caridean density (Table 1). Although these seagrass variables were correlated, their differential importance to individual families suggested that the Carideans were discriminating among different structural aspects of the seagrass canopy (Table 2). Except for the hippolytids, the addition of seagrass standing crop did not significantly improve the models once living-space index had been taken into account (Table 2), implying that living-space index was a better indicator of abundance than standing crop. Stoner (1980a) showed experimentally that, when amphipods were offered substrata of varying biomass, they favoured the group of plants with the greatest biomass. However, when the animals were offered plants of the same biomass, they were found on the plant with the greatest surface area. This led Stoner to believe that blade surface area and not biomass *per se* was the chief determining factor in the choice of habitat. Our results are consistent with this conclusion. Seagrass biomass and living-space index were not correlated with the abundance of penaeids, suggesting that other factors such as habitat heterogeneity, sediment preferences or larval dispersal may be responsible for the distribution of the (noncommercial) penaeids that occur on the reef flat at Green Island.

Causes of Spatial Distribution of Natantian Families at Green Island

Differences in abundance among stations were evident for four of the five family groups. Postlarval individuals were collected at all stations, which were in close proximity to each other. Thus, differential dispersal of larvae seems to be an unlikely explanation of differences in abundance among stations, and these differences are assumed to be associated with differences in habitat. Two of the three carid families whose abundance correlated significantly with plant structure (the palaemonids and the hippolytids) were more abundant at Station 1 than at the other two stations (Fig. 2). Station 1 consistently had the greatest biomass and living-space index (Fig. 3), suggesting that carid densities were related to the plant parameters at that station. The sergestids and the penaeids had higher densities at Stations 2 and 3 (Fig. 2). Station 2 was more physically heterogeneous than the other two stations because of the presence of bare sand patches along the trawl path. Areas with a higher degree of heterogeneity or patchiness of vegetation and consequently a higher percentage of edges or 'ecotones' may support a higher density of some mobile foraging species than do more homogeneous areas (Weinstein and Heck 1979).

The confirmation of strong plant-animal associations does not reveal the mechanisms of these associations. Heck and Wetstone (1977) conceived of four possible (though not mutually exclusive) mechanisms by which heavily vegetated areas might affect the number and abundance of invertebrate species: (1) food availability, (2) protection from predation, (3) increased living space, and (4) additional habitats. These four mechanisms can be ascribed to two processes: differential survivorship and/or active habitat selection. Both of these processes have been acknowledged as important in macrophyte-dominated communities (Virnstein and Howard 1987b), and they help to explain the spatial distribution of natantians at Green Island. The relative importance of these processes needs to be evaluated experimentally.

Acknowledgments

We gratefully acknowledge Anto Wilson for his assistance in the field and laboratory sorting of the beam trawls. We thank the anonymous reviewers for their constructive comments on this paper and the Northern Fisheries Centre, Queensland Department of Primary Industries, Cairns, for providing logistical support.

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Manuscript received 30 October 1991; revised 7 August 1992; accepted 9 November 1992