COMMUNITY STUDIES IN SEAGRASS MEADOWS: A COMPARISON OF TWO METHODS FOR SAMPLING MACROINVERTEBRATES AND FISHES[1]

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ABSTRACT

The effectiveness of using an otter trawl for estimating macrofaunal species ranks and abundances in seagrass meadows is unknown. In this study, we compare the catch effectiveness of the commonly used 5 m otter trawl with that of a 0.9 m wide epibenthic crab scrape for fishes, decapod crustaceans, molluscs, and echinoderms, using data from both day and night collections from a northeast Gulf of Mexico seagrass meadow. The crab scrape collected significantly more individuals and species of all taxa except (water-column) fishes. Clear discrepancies existed between trawl and scrape estimates of species ranks and relative abundances, with trawl collections estimating a higher degree of dominance within groups of shrimps and demersal fishes, and lower dominance among crabs. Whereas the crab scrape was clearly superior to the trawl for sampling macroinvertebrates and demersal fishes, the trawl was the better device for collecting water-column fishes. Explanations for observed differences in the sampling effectiveness of these gears are discussed. Sampling was considerably more productive at night than during the day. The combined approach of day-night sampling with both a crab scrape (for demersal fishes and epibenthic invertebrates) and an otter trawl (for water-column fishes) is recommended for community-wide studies in seagrass meadows.

Hypotheses concerning ecological community dynamics should be based upon accurate descriptions of the habitats and species involved. It is thus essential that collection methods maximize sampling efficiency in "community" (sensu Pielou 1977) studies. Because estimates of species composition, relative abundances, and biomass in aquatic environments may vary with different sampling devices (e.g., Lewis and Stoner 1981; Stoner et al. 1983), knowledge of sample gear effectiveness allows a more rigorous approach to sampling design and interpretation of results from studies of aquatic communities.

Seagrass community studies often employ a small, semiballoon otter trawl (try net) for sampling fishes and epibenthic invertebrates (Kikuchi 1966; Livingston 1975, 1976, 1982; Heck 1976, 1977, 1979; Hooks et al. 1976; Heck and Wetstone 1977; Weinstein and Heck 1979; Heck and Orth 1980; Orth and Heck 1980; Ryan 1981; Dugan and Livingston 1982; Dugan 1983). Although a small otter trawl may be one of the most effective samplers for estimating relative abundances of juvenile and small pelagic fishes in shallow nonvegetated waters (Kjelson and Johnson 1978; Orth and Heck 1980), there are few published accounts of its effectiveness in sampling benthic fishes or epibenthic invertebrates in vegetated habitats. Greening and Livingston (1982) noted that a Chesapeake Bay crab scrape appeared to collect more invertebrate species per sample effort in vegetated habitats than did an otter trawl. Miller et al. (1980) found a crab scrape to be more effective than either an otter trawl or a push net for collecting juvenile blue crabs, *Callinectes sapidus*, in the Chesapeake Bay area. Blue crab fishermen routinely use crab scrapes, rather than trawls, in grassbeds in Chesapeake Bay (Warner 1976).

In this study, the catch effectiveness of a 5 m otter trawl is compared with that of a 0.9 m epibenthic scrape in the shallow grassbeds of Apalachee Bay, FL. Species richness and abundance are examined within four taxonomic groups (decapod crustaceans, molluscs, echinoderms, and fishes). Because many grassbed organisms are more susceptible at night to certain sampling methods (Ryan 1981; Greening and Livingston 1982), both day and night samples are considered.

METHODS

Day and night samples were taken in about 1.7 m of water from seagrass beds in Apalachee Bay, FL.

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The sample site was located 5 km southwest of the Econfina River mouth (permanent station E-12 (Livingston 1975)). This site is characterized by relatively uniform, dense stands of the seagrasses, *Thalassia testudinum* and *Syringodium filiforme*, with seasonal occurrence of red drift algae (mean annual macrophyte biomass = 320 g dry wt/m^2; see Zimmerman and Livingston 1979 for a description of macrophytes). Station E-12 was polyhaline, with salinities during collections ranging from 22 to 30 ppt ($\bar{x}$ = 27.0 ppt). Water temperatures ranged from 12.0° to 31.0°C ($\bar{x}$ = 19.9°). Depth varied from 1.6 to 2.1 m. Physical characteristics are summarized in Table 1.

TABLE 1.—Physical characteristics of the sampling station for collection dates, Apalachee Bay, FL.

	Temp. (°C)	Salinity (ppt)	Depth (m)
Jan. 1979			
Day	12	31	2.0
Night	10	30	1.8
Apr. 1979			
Day	22	23	2.1
Night	21	22	1.6
July 1979			
Day	31	25	1.7
Night	30	25	2.1
Oct. 1979			
Day	17	30	2.1
Night	16	30	1.7

A 90 cm wide commercial Chesapeake Bay crab scrape (Miller et al. 1980) was fitted with the cod end of a 5 m otter trawl (6 mm mesh liner). The crab scrape was towed at about 1.4 knots for 1 min (after Greening and Livingston 1982; Leber 1983), yielding a standardized tow of 42 m (mean of 10 preliminary measured 1-min tows). A 42 m weighted line was then used to standardize scrape tows during collections. A 5 m otter trawl (19 mm mesh wings, 6 mm mesh liner in the cod end) was towed at the same speed for 2 min (as in Livingston 1975, 1982; Hooks et al. 1976; Heck 1977, 1979; Orth and Heck 1980; Stoner 1980; Stoner and Livingston 1980; Dugan and Livingston 1982; Dugan 1983), covering an average measured distance of 84 m. Under tow, the trawl mouth tickler chain fished a 2.1 m wide path over the substratum (Leber, pers. obs.). Hence, each individual trawl tow fished over 4.6 times the substratum surface area sampled by each tow of the crab scrape (176 m^2 vs. 38 m^2). Because the scrape collected larger amounts of dead vegetation, it was logistically difficult to sample as much surface area with it as was sampled by the trawl.

Collections were made quarterly (January, April, July, and October). On each sampling date eight scrape and four trawl tows were taken (in the sequence two trawls, eight scrapes, two trawls) during the day, and again beginning 1 h after dark. Greening and Livingston (1982) determined that eight 1-min scrapes were sufficient for sampling >95% of the species of macroinvertebrates at our sample site in Apalachee Bay. Because each scrape was towed for only half the 2-min towing time used for each trawl (scrape tows lasting longer than 1 min often resulted in clogging the net with red drift algae), only four trawls were taken during each sampling period. Thus, the combined length of the eight scrape tows (8 × 42 m = 336 m) matched that of the four trawl tows. All samples were collected from a 0.25 km^2 area immediately south of the station marker. Replicate tows were taken along transects spaced at least 30 m apart to prevent overlapping samples.

Organisms were preserved in 10% Formalin[4] (buffered with seawater) in the field, then identified, counted, and measured in the laboratory. A two-way, Model II, factorial ANOVA design for unequal but proportional cell sizes (Sokal and Rohlf 1969) was used to compare mean numbers of species and individuals of each taxon group in scrape vs. trawl (Factor 1) and day vs. night (Factor 2) samples. Log_{10} transformations were used where F-max tests indicated heterogeneity of variance. Rather than extrapolating our data to numbers per unit area, we compared the collections made with these two gears using absolute numbers per tow in our calculations (which are biased in favor of the trawl by a factor of 4.6). We used these absolute abundances because 1) we wanted a strongly conservative test of our premise that the scrape is the more effective of these two sample gears in vegetated aquatic habitats, and 2) we believe that extrapolations of semiquantitative data to abundances per unit area yield highly unrealistic results, which may be misinterpreted by readers as accurate densities (cf. Howard 1984, who determined that a towed beam trawl was only 4.7% efficient in estimating densities of shrimp in an Australian seagrass meadow).

RESULTS

Factor 1: Trawl vs. Scrape

Although the surface area sampled by the otter

[4]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

trawl during each tow exceeded that sampled with the crab scrape by a factor of 4.6, mean numbers of individuals collected in scrape samples were significantly greater than those in trawl samples in 44% of the 16 scrape-trawl comparisons (Table 2). The trawl was a significantly more effective collecting device for number of individuals of fishes (Table 2; April, July, and October fishes), but interaction terms were significant for April and October analyses (see Interactions, below). Mean numbers of individuals were greater in trawl, than in scrape, samples in two other cases (Fig. 1, January and July decapods in night samples); however, scrape-trawl differences on those dates were nonsignificant (Table 2). The crab scrape was clearly the better gear for sampling epibenthic individuals.

Species numbers were never significantly greater in trawl, than in scrape, samples (Fig. 1). In contrast, the crab scrape collected significantly more species than the trawl in 75% of the scrape-trawl comparisons (Table 2). Because the scrape often sampled greater numbers of individuals than the trawl, the presence of more species in scrape, than in trawl, samples may be simply a sampling phenomenon. By chance alone, one would expect to encounter more rare species in larger samples. Using rarefaction analysis (Simberloff 1978), we have factored out the influence of sample size on species number for a better comparison of scrape vs. trawl sampling effectiveness (Fig. 2). Eight of the 12 cases in which the scrape sampled significantly more species than the trawl (Table 2) can be attributed to a sampling phenomenon; there were generally more species in scrape samples because so many more individuals were collected in each scrape tow. However, it is clear in Figure 2 that the greater numbers of decapod species in January and July scrape samples, and fish species in April and October scrapes, represent real differences in the catch effectiveness of these gears for species within these two taxa.

Factor 2: Day vs. Night

Day-night differences were clear. None of the combined (scrape-trawl) daytime collections contained significantly more species or individuals than night collections. But nocturnal samples contained significantly more individuals than daytime samples in 69%, and more species in 62%, of the 16 day-night comparisons (Table 2).

Interactions

Significance of an interaction term indicates dependence of one factor upon the other; in this case, when sampling differences between scrape and trawl exist but are dependent upon time of day. Scrape-trawl vs. day-night interactions were significant in 8 of the 32 ANOVAs in Table 2. For these eight cases, either the trawl sampled better only at night for a certain taxon/month combination (one of the eight interactions), or the scrape sampled better only during the day (five of the eight cases), or both of these events occurred (two of the eight cases, scrape was better during the day but the trawl was better at night).

Although fish were taken in greater abundances by the trawl on three of the four sampling dates, interactions were significant on two of those dates (April and October, Table 2). With the exception of July collections, fish were equally as abundant in daytime scrape samples as in trawls (see Figure 1).

TABLE 2.—Two-way ANOVA, *F*-values. Underlined values indicate trawl samples significantly larger, all other significant values are scrape samples. All significant day-night values indicate night significantly larger than day samples.

Date	Sample	Decapods		Molluscs		Echinoderms		Fishes	
		No. indiv.	No. species	No. indiv.	No. species	No. indiv.	No. species	No. indiv.	No. species
Jan.	Day Night	0.48	35.81***	0.02	0.31	0.73	1.22	57.98***	42.14***
1979	Scrape Trawl	0.02	27.77***	56.71***	58.48***	1.92	4.29	0.44	0.08
	Interaction	0.00	5.07*	0.01	0.15	1.73	0.03	0.35	0.33
Apr.	Day Night	37.72***	31.16***	63.17***	21.41***	0.00	1.01	103.02***	29.93***
1979	Scrape Trawl	106.26***	68.13***	206.89***	55.30***	111.27***	29.71***	<u>61.55</u>***	27.47***
	Interaction	5.24*	0.62	22.51***	2.21	0.51	0.50	68.10***	0.03
July	Day Night	97.55*	139.64***	16.93***	24.75***	6.64*	2.79	14.06**	4.00
1979	Scrape Trawl	4.16	66.94***	70.39***	30.56***	3.06	1.72	<u>6.93</u>*	0.35
	Interaction	55.35***	3.67	4.32	0.29	2.57	2.48	0.03	0.09
Oct.	Day Night	7.29*	45.12***	8.03*	20.32***	1.87	3.27	20.36***	5.04*
1979	Scrape Trawl	0.42	32.14***	34.46***	99.21***	10.12**	7.91*	<u>5.04</u>*	9.62**
	Interaction	10.63**	0.02	5.01*	1.43	8.28**	3.20	23.85***	0.13

* = $P < 0.05$.
** = $P < 0.01$.
*** = $P < 0.001$.

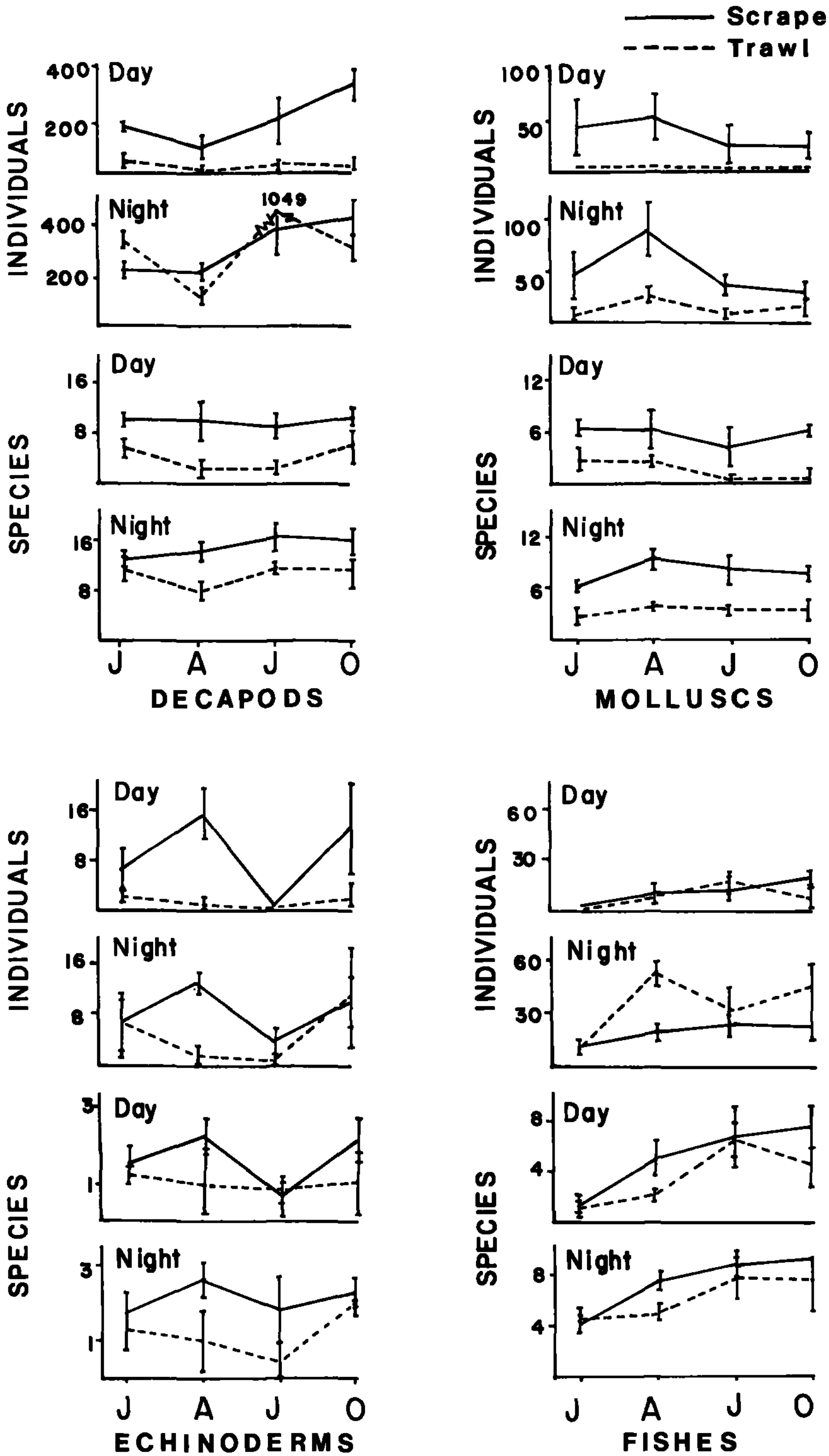

FIGURE 1.—Mean numbers of individuals and species (±1 SD) collected by the crab scrape (solid line) and trawl (dashed line) during day and night sampling in January, April, July, and October 1979.

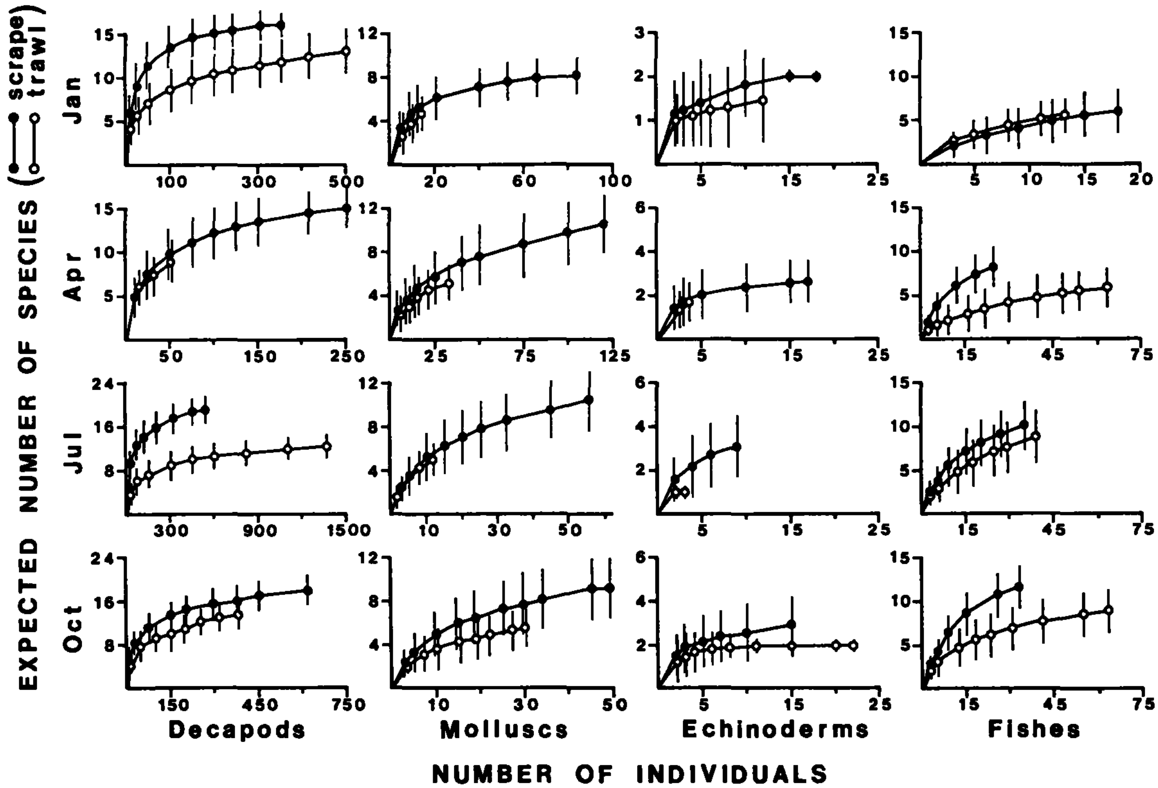

FIGURE 2.—Rarefaction curves for crab scrape (closed circles) and trawl data (open circles) from 1979 night samples. Expected numbers of species (±2 SD) are plotted against numbers of individuals. Length of curves indicates maximum number of individuals taken in any single tow.

Hence, with only one exception (July fish abundance), the otter trawl never outperformed the scrape during daylight collections.

The trawl was more effective in sampling a taxonomic group other than fish in only one case. Significantly more decapod individuals were taken in July trawl samples at night, reflecting high densities of two caridean shrimps, *Tozeuma carolinense* and *Periclimenes longicaudatus*, which appear to be more susceptable to night trawl, rather than scrape, sampling. However, decapod abundances were notably higher in July daytime collections made with the crab scrape (see Figure 1), thus the highly significant interaction term for the July analysis (decapod individuals, Table 2).

Relative Abundance

Numerical rankings of the most abundant organisms in each taxonomic group (combined over all sample dates) taken in night scrape samples are compared with those from night trawl samples in Table 3. Clear discrepancies exist between scrape and trawl estimates of species ranks and relative abundances. Relative to scrape samples, trawl collections overestimated the degree of dominance (DI = combined proportions of the two most abundant species, $(n_1 + n_2)/N$, McNaughton 1967) contributed by the most abundant shrimp *Tozeuma carolinense* and demersal fish *Gobiosoma robustum*, and underestimated dominance of the most important crab *Pagurus maclaughlinae* and mollusc *Argopectin irradians* in our samples (Table 3). Relative to trawl collections, the scrape underestimated dominance for the most abundant water-column fishes, *Lagodon rhomboides* and *Bairdiella chrysura*. Species ranks of subdominants in trawl samples also differed from rankings based on data from scrape samples.

DISCUSSION

Scrape-trawl and day-night differences in sampling effectiveness were conspicuous and generally constant throughout the year. Although more (by a fac-

TABLE 3.—Species ranks, relative abundances, and dominance for each taxonomic group. Combined night samples. $\bar{x}$ = mean number of individuals per sample (per group), DI = dominance (McNaughton 1967).

Scrape Rank	Scrape Relative abundance		Trawl Rank	Trawl Relative abundance
		Shrimp		
1	0.324	*Tozeuma carolinense*	1	0.667
2	0.157	*Penaeus duorarum*	4	0.027
3	0.143	*Periclimenes longicaudatus*	2	0.191
4	0.127	*Hippolyte zostericola*	3	0.066
5	0.099	*Thor dobkini*	6	0.016
6	0.049	*Latreutes fucorum*	5	0.018
7	0.049	*Ambidexter symmetricus*	8	0.003
8	0.038	*Alpheus normanni*	10	0.0002
9	0.009	*Palaemon floridanus*	7	0.010
10	0.006	*Periclimenes americanus*	9	0.001
$\bar{x}$ = 219.98			$\bar{x}$ = 423.38	
DI = 0.481			DI = 0.858	
		Crabs		
1	0.735	*Pagurus maclaughlinae*	1	0.578
2	0.117	*Neopanope packardii*	3	0.101
3	0.039	*Epialtus dilatatus*	4	0.055
4	0.032	*Libinia dubia*	5	0.048
5	0.027	*Podochela riisei*	6	0.041
6	0.026	*Metaporaphis calcerata*	2	0.133
7	0.016	*Neopanope texana*	9.5	0.007
8	0.004	*Pitho anisodon*	9.5	0.007
9	0.003	*Pilumnus sayi*	7	0.018
10	0.002	*Pilumnus dasypodus*	8	0.011
$\bar{x}$ = 75.1			$\bar{x}$ = 10.9	
DI = 0.852			DI = 0.711	
		Echinoderms		
1	0.659	*Echinaster* sp.	1	0.824
2	0.255	*Ophiothrix angulata*	2	0.176
3	0.056	*Lytechinus variegatus*	—	0
4	0.027	*Ophioderma brevispinum*	—	0
$\bar{x}$ = 8.42			$\bar{x}$ = 5.12	
DI = 0.914			DI = 1.00	

Scrape Rank	Scrape Relative abundance		Trawl Rank	Trawl Relative abundance
		Molluscs		
1	0.413	*Argopectin irradiens*	1	0.383
2	0.145	*Modulus modulus*	4	0.118
3	0.130	*Cerithium muscarum*	6	0.077
4	0.096	*Anachis avara*	2	0.169
5	0.086	*Columbella rusticoides*	3	0.131
6	0.064	*Turbo castanea*	5	0.101
7	0.025	*Urosalpinx perrugata*	7	0.009
8	0.013	*Nassarius vibex*	8	0.006
9	0.008	*Hyalina veliei*	—	0
10	0.007	*Fasciolaria hunteri*	—	0
$\bar{x}$ = 48.92			$\bar{x}$ = 13.32	
DI = 0.558			DI = 0.501	
		Demersal Fishes		
1	0.360	*Gobiosoma robustum*	1	0.544
2	0.291	*Opsanus beta*	4	0.097
3	0.246	*Paraclinus fasciatus*	2	0.194
4	0.086	*Centropristis melana*	3	0.106
5	0.017	*Ophidion beani*	5	0.058
$\bar{x}$ = 7.2			$\bar{x}$ = 2.6	
DI = 0.651			DI = 0.738	
		Water-Column Fishes		
1	0.345	*Lagodon rhomboides*	1	0.621
2	0.158	*Monacanthus ciliatus*	4	0.044
3	0.154	*Syngnathus floridae*	5	0.042
4	0.151	*Orthopristis chrysoptera*	3	0.099
5	0.067	*Hippocampus zosterae*	7	0.007
6.5	0.052	*Micrognathus crinigerus*	8.5	0.002
6.5	0.052	*Haemulon plumieri*	6	0.013
8	0.015	*Bairdiella chrysura*	2	0.168
9	0.004	*Monacanthus hispidus*	8.5	0.002
$\bar{x}$ = 11.5			$\bar{x}$ = 31.7	
DI = 0.503			DI = 0.789	

tor of 4.6) substratum surface area was sampled per tow by the otter trawl, the crab scrape collected more species and individuals per tow, across taxa, with few exceptions. The trawl was the better faunal collecting gear in this seagrass habitat only for numbers of individuals of certain water-column fishes and for two species of caridean shrimps. The scrape was notably more effective than the trawl (day and night) for collecting penaeid, alpheid, and processid shrimps, brachyuran and pagurid crabs, molluscs, echinoderms, syngnathid fishes, and demersal fishes (*Opsanus*, *Paraclinus*, *Gobiosoma*, and *Centropristis*).

The otter trawl appears to collect fewer species and individuals of demersal animals in grassbeds than does the scrape because the weighted (tickler) chain on the trawl is not in contact with the substratum. Under tow, the cylindrical bottom crossbar of a crab scrape bends grassblades flat against the substratum, sweeping demersal and epifaunal organisms over the bar and into the net, whereas the otter trawl tickler chain is generally supported 8-10 cm above the substratum by the buoyant vegetation (Leber, pers. obs.). Grassblades do not yield as much to the relatively light weight of a tickler chain (as they do to a scrape crossbar), and any organisms remaining close to the substratum as the chain passes over them evade capture. Most epibenthic inhabitants of grassbeds, including several fishes, are more closely associated with seagrasses and red drift algae than with the water column above the vegetation or bare patches within beds (Hooks et al. 1976; Heck and Wetstone 1977; Stoner 1980; Stoner and Livingston 1980; Gore et al. 1981). The crab scrape is more effective because it samples more grassblade surface area, including an additional microhabitat, the region <10 cm above the substratum (Leber, pers. obs.).

The greater effectiveness of both devices at night is probably accounted for, in part, by nocturnal increases in faunal activity on the substratum, on blade tips, and in the water column above vegetation.

Several crustaceans emerge from the substratum and forage at night in grassbeds, including pink shrimp, *Penaeus duorarum*, some majid crabs (notably *Pitho* and adult *Libinia* at our site), and alpheid and processid shrimps (Fuss 1964; Fuss and Ogren 1966; Hughes 1968; Kikuchi and Peres 1977; Saloman 1979; Greening and Livingston 1982; Leber 1983). Emergence of nocturnal organisms from the substratum after dark would explain some of the variability between day and night collections of invertebrates. Higher densities of diurnally active animals in night samples may be due to nocturnal vertical migrations up grass-blades. Animals located near the tips of blades are clearly more vulnerable to capture by either device; even the scrape misses individuals trapped between grass-blades and substratum by the crossbar, an event less likely to occur to an individual near a blade tip. Fishes were probably less abundant in daytime trawl collections because of avoidance reactions to the clearly visible net.

Emergence and vertical migration do not account for all of the increases in invertebrate abundance in night samples. The case of the arrow shrimp, *Tozeuma carolinense*, is interesting in this regard. We expected no day-night sampling differences for *Tozeuma* with either device, based on evidence that *Tozeuma* inhabit the region near tips of grass-blades, both during the day and at night (Main in press). As expected, *Tozeuma* were collected in roughly equal numbers in both day and night scrape samples. However, almost an order of magnitude more *Tozeuma* were taken in night trawl samples than during daytime collections (Leber and Greening, unpubl. data). It appears that *Tozeuma* may be capable of avoiding the trawl, which is highly visible during the day. These shrimp have keen vision in daylight and are capable of rapid movement (up to 30 cm) via a caridoid escape response (Main in press). They need only move down blades, closer to the substratum, to avoid the trawl net.

This study suggests that many demersal fishes and epibenthic invertebrates may be more important numerically in seagrass communities than indicated by collections made with an otter trawl. Species ranks and relative abundances of these organisms determined from trawl collections in seagrass beds should be interpreted with care. Whereas trawl collections may be satisfactory for monthly or year-to-year comparisons of single species abundances within a seagrass habitat, application of such data to examination of predatory-prey relationships (e.g., energy flow and optimal-diet models) or other biotic interactions in grassbeds may lead to erroneous interpretations. The combined approach of day-night sampling with both an otter trawl (for water-column fishes) and a crab scrape (for demersal organisms) is recommended for seagrass studies.

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