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Sampling Zooplankton in Shallow Marsh and Estuarine Habitats: Gear Description and Field Tests

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ABSTRACT: Pump and net samplers for collecting zooplankton from very shallow marsh and estuarine habitats are described. Their use is illustrated with data obtained in salt marshes along the Indian River lagoon in east-central Florida. In general, both pump and net samplers were found to be satisfactory for sampling zooplankton in these areas. Larger sample volumes were obtained with gear utilizing 202 μ mesh sizes than with gear using 63 μ mesh because the latter became clogged very quickly. Quantitative and qualitative similarity between samples collected with different gear was moderate to low. Comparison of the kinds and densities of taxa captured with the various gear indicate that a combination of techniques may be needed to ensure a proper description of the plankton communities of the area.

Introduction

Compared with other estuarine areas, relatively little information about zooplankton communities of coastal wetlands or very shallow estuarine habitats exists, particularly from tropical and subtropical coasts (Odum et al. 1982). One factor contributing to this dearth of data is the difficulty of sampling in such shallow areas. In these habitats, use of many conventional types of gear, such as unsupported circular plankton nets, usually results in contamination of the samples with substrate material and in severe clogging (Cuzon du Rest 1963; Barnett et al. 1984). Clogging also occurs because the water column in such areas often carries a heavy load of suspended particles (Barlow 1955; Barnett et al. 1984). Furthermore, the substrate is usually extremely soft, thus making it difficult to manipulate conventional gear without great disturbance to the areas being sampled.

Techniques developed for sampling zooplankton from shallow salt marsh and mangrove forest habitats, as well as from very shallow areas (≃0–1.5 m) of the Indian River Lagoon in east-central Florida, are reported.

Gear Description and Handling

Pump Sampling Apparatus

Pump samplers were designed to provide as large a filtering area as possible and to provide temporary storage for large volumes of water to prevent overflow of the sample while filtering. Samples were collected with a 5.08 cm pump driven by a 2 hp gasoline engine. The mouth of the intake hose (5.08-cm Canaflex) was attached to a 2-m pole with a styrofoam float near the end. This allowed the operator to maintain the intake in constant vertical and horizontal motion while sampling, with little disturbance to the substrate. The outflow was filtered in PVC cylinders 1.22 m high and 25.4 cm in diameter (Fig. 1). The cylinders were perforated with numerous holes of various sizes covered with either 202 μ or 63 μ plankton netting. Samples were collected at the bottom of the cylinders in removable screens of the appropriate mesh size. A splashguard fitted on the top of each cylinder prevented sample spillage; two baffles inside the cylinders distributed the water stream to prevent damage to the lower collecting screens, and a coarse metal screen on top of the baffles trapped large pieces of debris that might have damaged the side or bottom screens.

For each sample, the outflow hose was maintained in place for a timed interval. Filtered water was collected in buckets placed adjacent to the cylinders and was used to wash organisms attached to the inner walls to the bottom screens. The screens were then removed, and their contents washed with distilled water into prelabeled glass jars. A solution of 10% buffered formaldehyde and rose bengal

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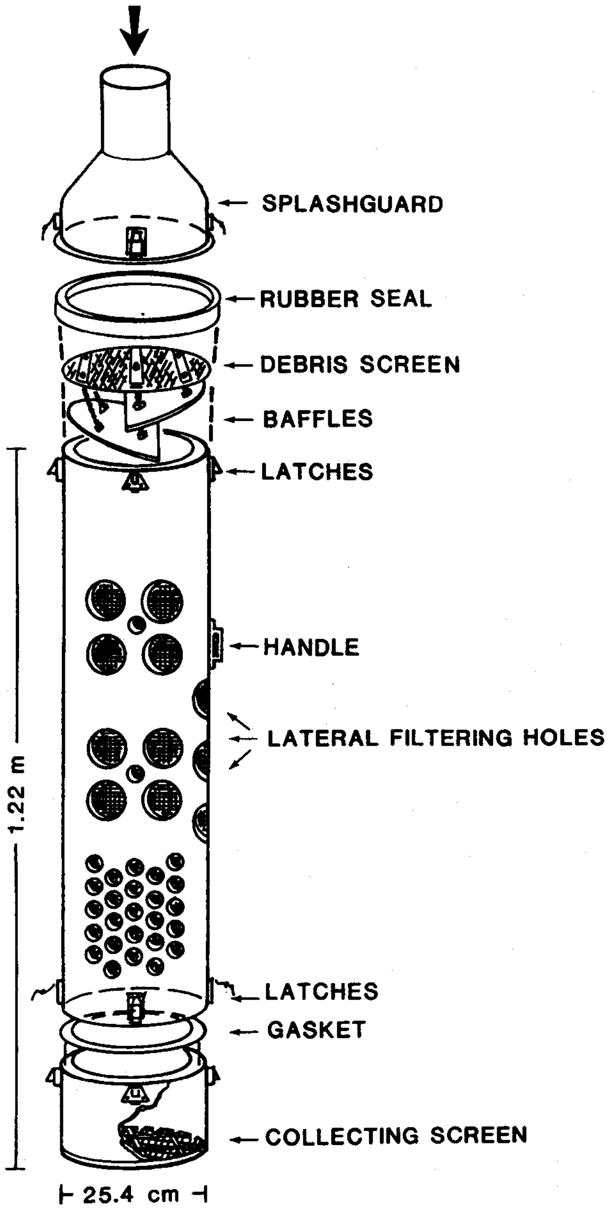

Fig. 1. Schematic diagram of a filtering cylinder.

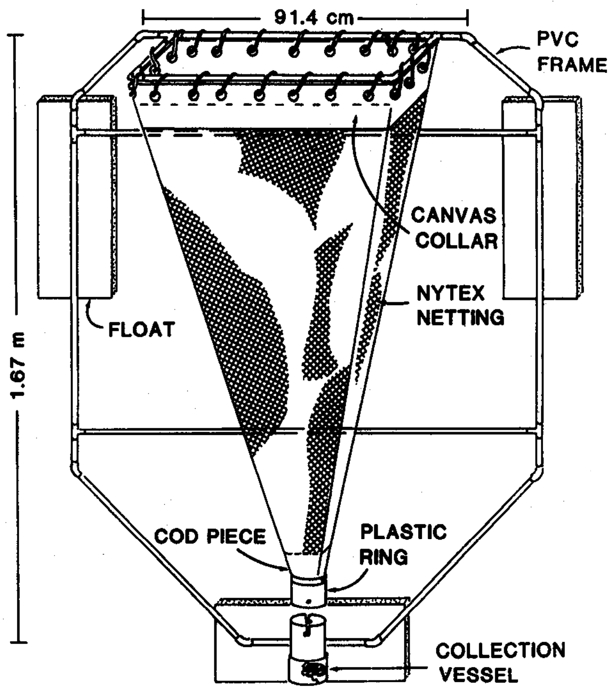

Fig. 2. Schematic diagram of a floating net.

(100 mg l^{-1}) was then added to each jar for sample staining and preservation.

The pump flow rate during each sample was calculated by measuring the amount of time required to fill a container of known volume to overflowing (Barnes 1949). This was done immediately before, and immediately after, each sample; the mean of the two measurements was used to calculate pump flow rate, sample volume, and plankton density. On the average, the two measurements varied by less than 4%.

Floating Nets

The configuration of the plankton nets (Fig. 2) minimizes their vertical profile (draft) for a given net surface area. This was done to maintain an adequate filtering surface while preventing nets from hitting bottom. They are variations of a compressed-mouth, floating net arrangement (Zaitsev 1961; Ellertsen 1977; Schram et al. 1981), modified for very shallow sampling and portability. We found that a net with a rectangular mouth tapering to a conical cod-end worked best for these purposes. We attached the net (91.44 cm × 20.32 cm mouth, 167.64 cm long) to a frame made from PVC pipe and supported the arrangement with styrofoam floats so that when towed the mouth of the net floated just under the water surface. The mouth end of the frame was hinged to allow folding for transport and storage. A General Oceanics Model 2031 flowmeter was installed inside the mouth of each net. At the cod-end of each net we installed collecting vessels with screens of 202 μ or 63 μ. As with the pump samples, 202 μ and 63 μ nets were used during the study.

For each sample, nets were hand-hauled as fast as possible along a premeasured transect. At the end of each transect, the net was removed from the water, its sides were rinsed from the outside, and the collecting vessels removed. The contents of the vessels were processed as those of the pump collecting screens. Volumes filtered were calculated from the flowmeter readings.

Study Sites

The study area is located in the Indian River Lagoon in east-central Florida (30.48°N, 80.75°W). It consists of two impounded salt marshes on the barrier island sides of the lagoon, as well as adjoining lagoon waters.

Impoundment IRC #12 covers an area of 50.4 ha. In 1965 this marsh was impounded for mosquito control by building a dike, 0.5–1.5 m high, around its outer margin. A perimeter ditch, 1–3 m wide and 0–1.5 m deep, runs along the inside of the dike and a 61-cm culvert in the SW corner connects the marsh with the lagoon. Impoundment SLC #24 (122 ha) lies immediately to the south of IRC #12. Although larger than IRC #12, it is similar in structure except that at the time of the study it had no connection with the lagoon.

Methods

Sample Collection

Sampling sites were selected at the following locations: mole hole—a small shallow pond 0.3–1.2 m in depth, at the NW terminus of the perimeter ditch in IRC #12; culvert station—in the IRC #12 perimeter ditch near the SW culvert (depth 0.3–1.5 m); control station—in the perimeter ditch of SLC #24 (depth 0.5–1.5 m); lagoon—in a shallow flat in the lagoon immediately west of the marshes (depth 0.5–1.5 m).

Samples were collected on a biweekly basis at each of the sites. At the perimeter ditch, control, and lagoon sites one sample was collected with each of the following: 63 μ pump, 202 μ pump, 63 μ net, and 202 μ net. At mole hole, only pump samples were taken since this site is too small for sampling with the nets. A floating net sample consisted of a straight-line tow of 61 m. Pump samples with 202 μ and 63 μ mesh sizes were of 10 and 2 min duration, respectively. All samples with the same type of gear (net or pump) were collected on the same day, but at least 24 h were allowed to elapse between pump and net samples at the same site.

Sample Processing

In the laboratory, each preserved sample was washed with distilled water through a 63 μ sieve. Any large organism present in the sample (e.g., adult fish, large insects, etc.) was removed, washed over the sieve with 70% ethanol, and stored in 70% ethanol. The rest of the sample was diluted to a known volume, five subsamples were removed with a Hensel-Stempel pipette, and each subsample was counted in a Bogorov tray, identifying organisms to the lowest possible taxonomic level.

TABLE 1. Results of flowmeter tests.

Run Number	Flowmeter Location	Mesh Size (μ)	Length of Tow (m)	Net Efficiency (%)
1.	Inside	63	30.5	85.6
	Outside	63	30.5	72.8
2.	Inside	63	60.9	8.9
	Outside	63	60.9	56.1
3.	Inside	202	60.9	90.2
	Outside	202	60.9	47.6
4.	Inside	63	60.9	8.2*
	Outside	63	60.9	58.5*
5.	Inside	None	60.9	97.5*

* Mean of two observations from paired flowmeters.

Preliminary Tests

Nets

To check the operation of the nets and flowmeters, several tests were run at the lagoon station. In one series (1–3, Table 1), one flowmeter was installed in its designated location inside the mouth of the net and a second one was installed on the outside, attached to the frame. The second series (4–5, Table 1) compared the efficiencies calculated from flowmeters installed side by side inside the mouth of the frame (with and without nets). Filtering efficiencies were determined by dividing the actual volume sampled by a theoretical one computed from net dimensions and length of tow.

Pumps

Prior to the start of the regular sampling schedule, five replicate samples with the 202 μ pumping apparatus were taken at the mole hole station. Total densities and taxonomic composition were compared between the five replicates.

Similarity Analysis

To get an indication of the taxonomic correspondence between samples collected with pumps and nets of the same mesh size, we computed two similarity indices—Jaccard's qualitative similarity index (JS) and Czekanowski's quantitative index (CZ) (Bloom 1981)—between contemporary samples collected at the same location. Jaccard's index gives an indication of the similarity in the identities of the taxa in the two samples and is not influenced by differences in the abundance of taxa in the two samples. Czekanowski's index, on the other hand, takes into account not only the species identities, but also their relative abundances; its value can be

TABLE 2. Mean similarity between samples. Pump-net values compare the similarity between contemporary samples with the two gear types. Pump-pump values compare the similarity between replicate pump samples at the same site. JS = Jaccard, CZ = Czekanowski.

Comparison	Site	CZ	JS
63 μ	Culvert	0.550	0.672
	Lagoon	0.321	0.627
	Control	0.518	0.437
	All	0.453	0.587
202 μ	Culvert	0.263	0.292
	Lagoon	0.329	0.359
	Control	0.463	0.335
	All	0.347	0.328
Pump-pump*			
63 μ	Mole hole	0.559	0.717

* Five consecutive samples.

overly influenced by a large discrepancy between the two samples in the abundance of a single taxon. We chose this index, however, because of its linear correspondence with actual sample overlap (Bloom 1981). Both indices are nonprobabilistic, and as such are sample-size dependent (Simberloff 1978). This dependency, however, should have little influence on our results since the samples being compared here usually had similar numbers of taxa.

Results

Gear Performance

Nets

Flowmeter readings were influenced little by the frame structure when inside the net (3 and 5, Table 1). As expected, some interference from frame-net turbulence was observed when the meters were located on the outside (1 and 3, Table 1). A moderate loss of efficiency, probably resulting from clogging of the 63 μ net (Smith et al. 1968) was observed in the 30.5 m tows, and a severe loss in the 60.9 m tows (compare run 1 with runs 2 and 4). No such effect was observed with the 202 μ nets. Overall, average efficiencies of the 63 μ nets for all samples were 7% (SD = 3.5), 6% (SD = 3.8) and 6% (SD = 3.0) for the culvert, lagoon, and control stations, respectively. The corresponding values for the 202 μ nets were 95% (8.7), 89% (8.7), and 80% (2.2).

Pumps

The average density per sample in the preliminary pump samples at mole hole was 910 ind. m^{-3}, with average standard deviations per subsample (five each) of 38.2, 58.1, 59.1, 88.9, and 55.6 ind. m^{-3}. A large part of this variation was due to differences in copepod nauplii density which had a coefficient of variation of 52.2 over the 25 subsamples.

Sample Volumes

Average volumes filtered with the different gear types were as follows: 202 μ nets: 9.69 (SD = 0.8) m^3; 202 μ pumps: 2.89 (0.01) m^3; 63 μ nets: 0.721 (0.04) m^3; 63 μ pumps: 0.58 (0.002) m^3. As with the nets, the bottom and side screens of the 63 μ cylinders usually clogged before the prescribed two minutes of pumping had elapsed. When this happened, the pump and timer had to be stopped to prevent overflowing and the screens had to be cleared by tapping them from the outside for several minutes. Only after all the water in the cylinder had filtered through, could pumping be resumed until the full 2-min sample was completed. Clogging of the 202 μ screens was infrequent and the full 10-min interval could usually be pumped without interruption.

Faunal Similarity

As expected, the values of CZ were generally lower than those of JS. This resulted from the aforementioned influence on the index of large differences in abundance of one or a few taxa between the two samples. In general, the similarity between the pump and net catches at the same site was intermediate to low, ranging from 0.263 (CZ) for the 202 μ gear at the culvert station to 0.672 (JS) for the 63 μ gear at the same station. In contrast, replicate samples with the same gear type yielded catches with 0.717 (JS) similarity (Table 2).

Plankton Density

Overall, densities of organisms in the samples were consistent between sites, between gear types, and between different mesh sizes. There was a high correlation in mean densities per taxon between data obtained with the different gear types (Table 3), but there were some major differences in total density between collections on some sampling dates (Table 4). Total density estimates, however, were much higher in pump and net samples collected with the 63 μ mesh gear than with the 202 μ gear. Average overall densities per sample were 5,549 and 2,878 ind. m^{-3} for 202 μ pump and net samples, respectively, whereas the corresponding values for the 63 μ gear were 403,907 and 279,277 ind. m^{-3}.

In general, there was good correspondence between gear types in the relative abundances of the different taxa, but some discrepancies were also observed. Bivalve larvae, copepod nauplii, and larval polychaetes were relatively more abundant in

TABLE 3. Spearman's correlation coefficient between mean density per taxon at all sites. Significance of all coefficients <0.001; n = 65.

	202 μ PUMP	202 μ NET	63 μ PUMP	63 μ NET
202 μ PUMP	—	0.79690	0.68261	0.68441
202 μ NET		—	0.72122	0.77691
63 μ PUMP			—	0.77854
63 μ NET				—

samples collected with the 63 μ gear, probably because they were able to escape through the 202 μ meshes. Ostracods, the copepods *Tortanus setacaudatus* and *Euterpina acutifrons,* and the amphipod *Grandidierella bonnieroides* were relatively more common in the 202 μ samples. Insects, fish eggs, and an as yet unidentified cyclopoid copepod were relatively more abundant in pump samples than in net samples, but the opposite was true for shrimp and crab zoea.

Discussion

Some of the major advantages of the methods described here are the ability to sample areas that cannot be sampled effectively with more conventional gear, low cost, portability, and relative ease of operation. Major disadvantages arise because sampling is possible only to a very limited depth, and, in the case of the nets, because speed of tow is relatively slow when compared with nets towed by boats or by other mechanical means.

Improper sampling of the deep layers of the water column is not a factor in areas for which these methods were designed since the water is at most only a few centimeters deeper than the effective sampling depth of the equipment. Speed of tow, however, may have to be taken into consideration when evaluating results. The slow speed will likely allow escape and/or avoidance by the more actively swimming organisms in the water column. On the other hand, it may reduce the number of organisms escaping through the meshes due to distortion of the meshes and compression of organisms by water pressure (Heron 1968; Vannucci 1968), and may also reduce turbulence in front of and upstream from the net, thus reducing net avoidance (Raymont 1983; Clutter and Anraku 1968).

Recent studies of estuarine zooplankton report sample sizes (i.e., volumes filtered) in the range of 1 to 6 m^3 (Barnes 1949; Barlow 1955; Johnson 1980; Williams 1984); volumes obtained with the 202 μ gear were equal to, or higher than the above, and were limited not by the gear itself but by the physical dimensions of the habitat. Under different conditions, both 202 μ pump and net sample sizes could be increased considerably if so desired, but there are rather severe sample size restrictions (because of clogging) inherent in the 63 μ gear that will have to be considered before its suitability for particular studies can be determined.

The much higher densities calculated from samples taken with the 63 μ gear than with the 202 μ gear are partly due to undersampling of the smaller organisms by the 202 μ pumps and nets. It is possible that the large differences in sample volumes obtained with the two mesh sizes may also contribute to this result. Although the equations used for calculating organism density from sample volumes are designed to compensate for sample size differ-

TABLE 4. Density (ind. m^{-3}) of all taxa captured at the various sites with the 202 μ gear.

	Culvert		Lagoon		Control	
Date	Pump	Net	Pump	Net	Pump	Net
1982						
11 October	631.8	367.8	758.1	1,158.4	16.7	87.2
29 October	48.8	142.0	6.1	83.5	4.8	14.3
10 November	15.7	63.7	23.9	67.8	10.4	19.9
23 November	89.4	—	178.8	—	76.9	—
10 December	9.3	98.0	10.4	56.2	92.5	73.4
21 December	17.4	44.0	14.5	74.4	171.4	100.3
1983						
6 January	133.4	433.2	54.8	285.1	12,163.8	9,103.8
19 January	23.2	145.6	52.0	218.5	13,887.8	10.3
3 February	1,659.8	551.3	462.0	429.1	3,369.4	—

ences, these equations may break down when comparing samples with such different volumes; the lower numbers of individuals expected from the smaller samples may not compensate for the much higher conversion values. For example, if a 63 μ net encounters a clump of organisms at the start of a tow (prior to clogging), it may actually capture a similar number of these organisms as a 202 μ net. Because of its more rapid clogging, the 63 μ net will sample a smaller volume of water over the whole tow than the 202 μ net and will thus generate a higher conversion factor and a higher density estimate for the organisms in the clump than the 202 μ net. Many different situations can result in similar effects; unfortunately, extensive data on the relative abundance and spatial distribution of all species during each sample, as well as knowledge of instantaneous screen clogging rates, would be needed to estimate the frequency and magnitude of these effects. At this time all we can do is identify the process as possibly influencing our density estimates.

If all the organisms collected with each gear type during the study are pooled, the similarity between pump and net samples is close to 70% for the measures used, but comparisons of data from individual sampling dates indicate much lower similarities (Table 2). This could be a result of taking the pump and net samples on subsequent days, rather than on the same day. Alternatively, this observation could indicate that both nets and pumps may be necessary for proper sampling of these habitats.

If the former alternative predominates, we would expect much lower similarities between samples taken with the same gear on subsequent sampling dates (two weeks apart) than with different gear on subsequent days. We calculated sample-to-sample similarity for the lagoon station, which is the most open, and thus more subject to the postulated effect, and found that average similarities were equal to, or higher than the similarities computed between contemporary samples with different gear (Pump-pump—63 μ: CZ = 0.506, JS = 0.604; 202 μ: CZ = 0.206, JS = 254; Net-net—63 μ: CZ = 0.506, JS = 0.653; 202 μ: CZ = 0.466, JS = 0.478). Although these results do not allow us to discount an effect of using the different gear types on subsequent days, they indicate that this fact alone is not likely to be the sole explanation for the observed differences in similarity.

Considerable debate over the advantages and disadvantages of different techniques for sampling zooplankton has occurred (Clutter and Anraku 1968). A combination of methods such as were used in this study usually represents the best possible compromise. Rectangular nets and various forms of pumping have been used successfully before (Barnes 1949; Fulton 1984, 1985) and at present are the only workable configurations for sampling in sites such as the ones described here.

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