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NOTE

Quantitative estimates of demersal zooplankton abundance in Onslow Bay, North Carolina, USA

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ABSTRACT: Demersal zooplankton were sampled by reentry trapping at 4 locations in Onslow Bay, North Carolina, USA, from 1983 to 1986. Vertical plankton tows were also taken to compare the fauna in the water column with the demersal zooplankton. Demersal zooplankton are taxonomically distinct from the holozooplankton. Demersal zooplankton were captured in greater numbers at night and over sand substrates. Demersal zooplankton were approximately as abundant as holozooplankton (1 to 6×10^4 ind. m^{-2}). Estimates of demersal zooplankton abundance in Onslow Bay are generally higher than those reported from other habitats. Demersal zooplankton are concentrated at the sediment-water interface, and are likely to be important prey for zooplanktivores in the continental shelf ecosystem off North Carolina.

Demersal zooplankton are distinguished from zooplankton that remain in the water column continuously, here termed 'holozooplankton', by their periodic association with benthic substrates (Alldredge & King 1977, Porter & Porter 1977, Robichaux et al. 1981). Quantitative sampling of demersal zooplankton by methods suitable for holozooplankton sampling is therefore difficult. Because of their association with benthic substrates, specific methods have been developed for estimating demersal zooplankton abundance.

Demersal zooplankton appear to be widely distributed and associated with substrates ranging from mud and sand to rock and coral, but sampling has been restricted to shallow habitats. Reported total average abundances range from 10^2 to 10^3 m^{-2}, but this range includes a preponderance of results from emergence trapping, which appears to include some holozooplankters and to undersample actual demersal zooplankton (Alldredge & King 1980, Cahoon & Tronzo 1988).

We present here the results of a study of demersal zooplankton abundance in Onslow Bay, North Carolina, USA, that employed reentry trapping. Reentry trapping samples demersal zooplankton more accurately than other methods (Cahoon & Tronzo 1988, Cahoon et al. 1992). We compared the abundance and taxonomic composition of demersal zooplankton with those of holozooplankton from the overlying water column. We also compared demersal zooplankton assemblages from several locations in Onslow Bay, by day and night, and at different times of the year from the same location. Our aim was to generate a more complete estimate of demersal zooplankton abundance in an extensive continental shelf ecosystem than previous studies have allowed.

Methods and materials. Onslow Bay is a portion of the southeastern U.S. continental shelf bounded by Capes Lookout and Fear and the Gulf Stream (Fig. 1). The continental shelf in Onslow Bay is approximately 60 to 110 km wide, and breaks at approximately 55 m (Menzies et al. 1966). Approximately 90 % of the bottom in Onslow Bay is soft sediment habitat (Newton et al. 1971).

We sampled demersal zooplankton at 4 sites in Onslow Bay (Fig. 1). The '3-mile' site is within 100 m of an artificial reef consisting of several ships and other debris. The bottom at this site (14 m) consists of patches of sand and exposed limestone rock with < 1 m relief. The '6-mile' site is 19 m deep with a featureless coarse sand bottom. The '23-mile' site is a limestone ledge of up to 5 m relief at depths of 30 to 33 m. The ledge provides substrate for dense populations of macroflora and macrofauna, including various sessile invertebrates and temperate reef fishes (Clavijo et al. 1989). The 'Deep' site is in 41 m of water with a flat, sandy bottom with scattered benthic macroflora.

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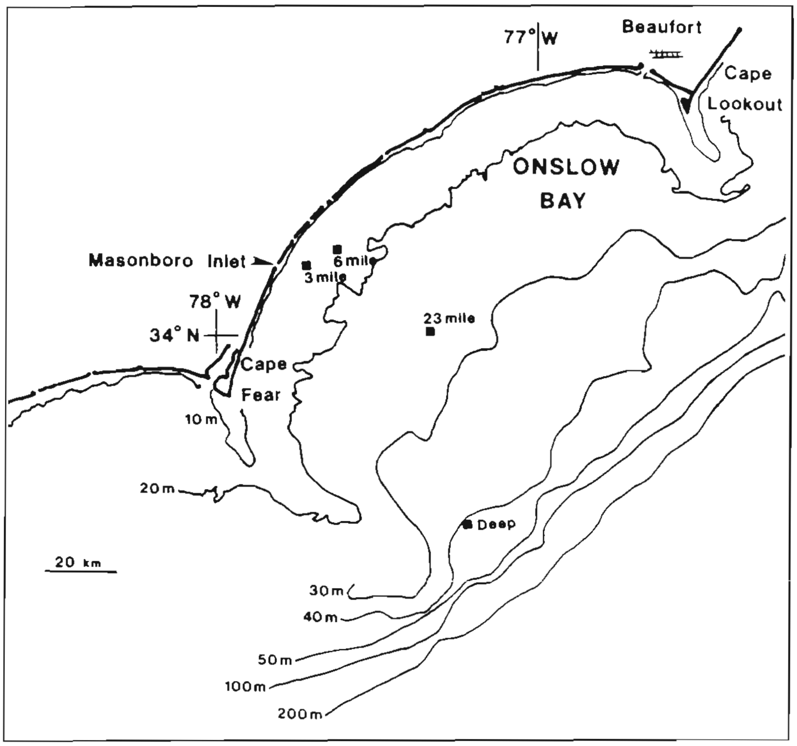

Fig. 1. Study sites in Onslow Bay off North Carolina, USA

Demersal zooplankton sampling commenced in August 1983 and continued through March 1986, as offshore diving opportunities were available. Demersal zooplankton were sampled by reentry traps that were deployed and retrieved by SCUBA divers. Reentry traps consisted of polyethylene trays 21 × 21 cm with snap-top lids. These were filled with 1 l of clean sand to an approximate depth of 2 cm. Divers filled the traps with filtered seawater, carried them to the bottom with their lids attached, spread the traps along the bottom, and removed the lids. Lids were replaced and secured at the end of a deployment and the traps returned to the surface. Most trap deployments were made overnight. Reentry traps, usually 10 at a time, were placed or retrieved within 2 h of dawn or dusk.

The supernatant water in reentry traps was filtered through a 95 µm mesh sieve, followed by at least 6 washings with fresh water to remove any animals from the sand in the reentry traps. Fresh water relaxed the animals, facilitating their quantitative removal. These samples were placed in labeled vials containing filtered seawater and fixed and stained in a 5 % buffered formalin/Rose Bengal solution.

Plankton were sampled by vertical tows of a 95 µm mesh 0.5 m diameter plankton net. These tows were made at least in duplicate 2 or more hours after sunset on overnight trips. Zooplankton captured in these tows were bottled, fixed, and stained as above.

Zooplankton samples were identified to species whenever possible using published keys and consultation with taxonomic experts. Species lists are published elsewhere (Tronzo & Cahoon 1989, Cahoon & Tronzo 1990). Zooplankton are grouped here by higher taxa (family, order, etc.) to facilitate quantitative comparisons.

Results. The overall average abundance of demersal zooplankton at Onslow Bay sites during the period August 1983 to March 1986 was 18 600 ind. m^{-2} (Table 1). The lowest average abundance occurred at the lowest temperature, but no clear seasonality was otherwise evident in the abundance data.

Demersal zooplankton were as abundant as holozooplankton sampled by vertical net tows on 4 occasions when direct comparisons were made (Table 1). However, percent similarity values [using higher taxa abundances and the percent similarity index of Brower & Zar (1977)] for the assemblages captured simultaneously by reentry trapping and vertical net tows were always low, indicating the very different taxonomic composition of the demersal zooplankton and holozooplankton. In general, the demersal zooplankton was dominated by harpacticoid and cyclopoid copepods, copepod nauplii, and nematodes. In some cases (see below) cumaceans, gammarid amphipods, and mysids were dominant. The holozooplankton was dominated by calanoid and cyclopoid copepods, ostracods, chaetognaths, and larvaceans.

Significantly more demersal zooplankton were captured in overnight trap deployments than in the daytime in 2 direct comparisons (Table 1). Also, significantly more demersal zooplankton were associated with soft substrates than with hard substrates in a direct comparison (Table 1).

Large demersal forms (cumaceans, gammarid amphipods, and mysids) were relatively more abundant at soft substrate sites and at night than at sites with hard bottom substrate or during the day. These taxa constituted 82 % of the demersal zooplankton at the deep site vs only 5 % at the 23-mile site in April 1985. They also represented 23 % of the demersal zooplankton caught by day but 33 % of those caught at night at the 6-mile site in August 1984.

Table 1. Abundance of demersal zooplankton (sampled by reentry trapping) and holozooplankton (sampled by vertical net tows) in Onslow Bay, North Carolina, 1983 to 1986. Data are means ± SD. Sites as in Fig. 1. D: day; N: night; H: hard substrate; S: soft substrate; –N: nematodes not counted, not included in total; n.s.: not significant

Date	Site	°C	Assemblage: Demersal zooplankton	(n)	Holozooplankton	(n)	Comments
Aug 1983	23-mile	26	3200 ± 1240	(10)	–		D/H, –N[a]
		26	9530 ± 3240	(20)	–		D/S, –N
		26	20 000 ± 3400	(9)	–		N/H, –N
		26	32 600 ± 7050	(10)	–		N/S, –N
Aug 1983	3-mile	25	21 300 ± 4830	(9)	–		N/S, –N
Jul 1984	3-mile	24	20 900 ± 8680	(10)	–		N/S
Aug 1984	6-mile	25	12 500 ± 6260	(10)	–		D/S[b]
		25	29 800 ± 6740	(5)	–		N/S
Apr 1985	3-mile	17	54 100 ± 8250	(9)	–		N/S
	Tugs	17	12 800 ± 4250	(10)	14 000 ± 4490	(2)	N/S[c]
	23-mile	18	15 600 ± 7250	(19)	10 200 ± 2400	(6)	N/S[d]
	Deep	20	18 700 ± 5550	(10)	20 300 ± 3110	(4)	N/S[e]
Sep 1985	23-mile	27	20 200 ± 57	(2)	32 800 ± 5840	(3)	N/S[f]
Mar 1986	3-mile	9	7040 ± 5100	(6)	–		

[a] A 2-way ANOVA compared demersal zooplankton abundances for substrate type and time of collection; day vs night: $F = 253.5$, df = 1, 45, $p < 0.001$; soft vs hard substrate: $F = 24.9$, df = 1,45, $p < 0.001$; interaction effect: $F = 34.6$, df = 1,45, $p < 0.001$
[b] A 1-way ANOVA compared demersal zooplankton abundances for time of collection; day vs night: $F = 22.7$, df = 1,13, $p < 0.001$
[c] A 1-way ANOVA for demersal zooplankton vs holozooplankton abundance: $F = 0.12$, df = 1,10, n.s. Percent similarity = 19.2 %
[d] A 1-way ANOVA for demersal zooplankton vs holozooplankton abundance: $F = 3.22$, df = 1,23, n.s. Percent similarity = 25.7 %
[e] A 1-way ANOVA for demersal zooplankton vs holozooplankton abundance: $F = 0.24$, df = 1,12, n.s. Percent similarity = 7.2 %
[f] A 1-way ANOVA for demersal zooplankton vs holozooplankton abundance: $F = 8.40$, df = 1,3, n.s. Percent similarity = 23 %

Discussion. Our estimates of the concentrations of holozooplankton and demersal zooplankton are each in the general range of 1 to 6 × 10^4 ind. m^{-2}. Paffenhöfer (1985) recorded total holozooplankton abundances in Onslow Bay that were up to an order of magnitude higher, but quite variable in space and time. Thus demersal zooplankton abundances may frequently be a large portion of the total zooplankton population in Onslow Bay. Moreover, demersal zooplankton are concentrated close to the bottom.

Other studies of demersal zooplankton abundances have usually reported much lower values than we found in Onslow Bay (Table 2). The abundance of demersal zooplankton in the habitats we sampled in Onslow Bay may be significantly greater than in the habitats sampled by others owing to differences in depth or the effects of planktivores. It is also likely that the use of emergence trapping by others has led to systematic underestimates of actual demersal zooplankton abundances in those habitats (Alldredge & King 1980, Cahoon & Tronzo 1988). Finally, the abundant demersal zooplankton

Table 2. Summary of demersal zooplankton abundances reported from other studies, sampled by emergence trapping over sand substrate at night. Data are maximum values reported, no. ind. m^{-2} (± SD)

Source	Location	Depth (m)	Mean total abundance
Alldredge & King (1977)	Great Barrier Reef, Australia	1–2	ca 1300–2200
Alldredge & King (1980)	Danzante Island, Gulf of California, Mexico	3–5	8887 ± 2688
Hammer (1981)	Santa Catalina, California, USA	10	2076 ± 1020
Hobson & Chess (1979)	Midway Island, USA	5–7	235
Jacoby & Greenwood (1988)	Great Barrier Reef, Australia	0.75–3.75	63
		2.5–5.5	590
McWilliams et al. (1981)	Great Barrier Reef, Australia	4–6	2721 ± 1513
Robichaux et al. (1981)	San Salvador, Bahamas	3	247 ± 34
Thomas & Jelley (1972)	Bideford River estuary, Prince Edward Island, Canada	1.5	23
Youngbluth (1982)	Bahamas	8–15	3344 ± 187

populations we sampled may be supported by the abundant and productive benthic microalgae populations found in Onslow Bay (Cahoon & Cooke in press).

The abundance and distribution of demersal zooplankton may be controlled by planktivores, especially fishes. Our comparisons of demersal zooplankton abundances by day and night and between soft and hard substrate habitats show that fewer demersal zooplankton enter the water by day and that fewer and smaller demersal zooplankton are captured over hard substrates (Table 1). The demersal zooplankton sampled at the deep site, with little relief and few associated fishes, was dominated by large animals, but smaller zooplankters dominated at the 23-mile site, which supports numerous planktivorous fishes (Clavijo et al. 1989). These results suggest that visually orienting and/or tactile planktivores associated with hard substrate habitats feed readily on at least some demersal taxa, and may explain why so many of the abundances reported by others from such hard substrate communities are mostly lower than ours (Table 2).

Soft substrates are prevalent in Onslow Bay, so the relatively high numbers of demersal zooplankton associated with them argue that demersal zooplankton are an important component of this continental shelf ecosystem. Currents may transport demersal zooplankton into hard bottom habitats, making them available to resident planktivores. Planktivores may forage over soft bottom habitats (Bolden 1990, Bell & Coull 1978). Predatory holozooplankters are also likely to feed on migrating demersal zooplankters. Thus, there may be several links between demersal zooplankton and higher trophic levels in the continental shelf ecosystem.

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