ABSTRACT

David A. Syster. PATTERNS OF INFAUNAL RECRUITMENT ON THE NORTH CAROLINA CONTINENTAL SHELF, ONSLOW BAY, NORTH CAROLINA (Under the direction of Dr. William G. Ambrose) Department of Biology. July 1995.

Patterns of infaunal recruitment were studied at sites adjacent to a submarine rock ledge located 50 km south east of Wrightsville Beach, North Carolina. Comparisons of infaunal abundance in defaunated sediment and defaunated sediment enriched with either food (dried algae) or nutrients (nitrogen and phosphorous) were placed at sites 10 m and 75 m from the ledge for approximately 30 days during spring and summer, and for 14 days during autumn to test hypotheses that the distance from the scarp and the increase of food and nutrients (fertilizer and algae) will affect infaunal recruitment.

One infers from results that recruitment on the mid-shelf is limited by food and larval supply. During spring the abundance of no taxa or group of taxa were significantly different between 10 m or 75 m sites. Infaunal predators (when analyzed as a guild) were, however, significantly higher in abundance at the 10 m site compared to the 75 m site during summer. Autumn sampling was characterized by significantly higher recruitment of most taxa at the 10 m site compared to the 75 m site. During this experimental period carbon and benthic pigment concentrations were significantly higher at the 10 m site than the 75 m site,

allowing one to infer that food availability may affect recruitment. Results of grain size analysis also allow one to infer that hydrodynamics associated with the scarp may cause a difference in recruitment due to larval supply.

Total infaunal abundances in control trays at the 10 m site ranged from < 190,000 per m^2 during summer to > 290,000 per m^2 during autumn with spring being intermediate. Conversely, total infaunal abundances in control trays at the 75 m site ranged from < 110,000 per m^2 during autumn to > 280,000 per m^2 during spring with summer being intermediate.

Algal enriched trays placed at the 10 m site during spring had significantly higher abundances of most infauna compared to all other treatment types. Fertilizer enriched trays placed at the 10 m site during summer had significantly higher abundances of total capitellid polychaetes, total polychaetes, and deposit feeders compared to control trays.

These results allow one to infer that hydrodynamics associated with the scarp and food resources indirectly controlled by the scarp influence infaunal recruitment in this system. Results of the enriched treatments indicates that infaunal recruitment along the shelf may be subject to food-limitation. Temporal differences in recruitment among experimental periods at the same site indicate that seasonal patterns of recruitment exist on the continental shelf.

PATTERNS OF INFAUNAL RECRUITMENT ON THE NORTH CAROLINA CONTINENTAL SHELF, ONSLOW BAY, NORTH CAROLINA

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In Partial Fulfillment

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by

David A. Syster

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PATTERNS OF INFAUNAL RECRUITMENT

ON THE NORTH CAROLINA CONTINENTAL SHELF,

ONSLOW BAY, NORTH CAROLINA

by

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INTRODUCTION

Studies in marine soft-bottom communities have addressed how competition, (Levinton, 1972; Peterson, 1977; Peterson and Andre, 1980) predation (Virnstein, 1977; Peterson, 1979; Ambrose, 1984, 1991; Summerson and Peterson, 1984; Commito and Ambrose, 1985), and disturbance (Oliver and Slattery, 1985) structure adult populations. Recent lab and field studies have also demonstrated that patterns of settlement and recruitment are important determinants of community structure (Butman, 1987; Woodin, 1991).

Although closely related, settlement and recruitment are two different processes. Settlement is the change of larvae from a planktonic to a benthic lifestyle, assuming that once settled the individual does not reappear in the water column (Butman, 1987). Recruitment is not a stage in the life history but rather a measure of all individuals present in a given volume of sediment after a set period of time. These individuals, unlike settlement, may include post-larvae, juveniles, and adult organisms (Butman, 1987).

Recruitment has been examined in numerous habitats, including the rocky intertidal (Grosberg, 1981; Fairweather, 1988; Sutherland, 1990; Gaines and Bertness, 1992),

intertidal salt marshes (Kneib, 1984; Levin, 1984, tsutsumi, 1990), seagrass beds (Bell and Westoby, 1986; Eckman, 1983, 1987), estuaries (Marsh and Tenore, 1990; Feller et al. 1992), reef systems (Hutchings, 1984), and deep sea communities (Grassle and Morse-Porteous, 1987; Snelgrove et al., 1992; Snelgrove et al., 1994). In these habitats recruitment has been shown to be the basis upon which all other community interactions take place.

Hydrodynamics play a major role in larval dispersal, supply, and resulting settlement (Butman, 1987). Downstream eddies associated with capes and headlands (Wolanski and Hamner, 1988) may aggregate zooplankton (Alldredge and Hamner, 1988) resulting in enhanced larval supply in some places and less in others. Rock outcrops and reef formations may also cause eddies on a small scale. These eddies may then result in different larval densities near the reef structure relative to adjacent sand flat habitats causing differences in subsequent recruitment.

In addition to the potential difference in larval density, other factors may play a role in infaunal community development. Once settled, metamorphosing larvae are subjected to a number of settlement processes including food limitation. Studies done in the laboratory and field suggest that some soft-sediment benthic communities may be

food-limited (Weinburg, 1979; Levinton and Bianchi, 1981; Cohen et al., 1984; Zajac, 1986). Post-settlement mortality due to starvation may then help to explain adult patterns of abundance in marine soft-sediment systems (ólafsson et al., 1994). Although studies of recruitment have been carried out, the major implications of post-settlement events on determining adult infaunal abundances has not been determined (ólafsson et al. (1994). In particular, the effects of post-settlement mortality events caused by starvation rather than limited larval supply, have received little interest.

Although much work has been done investigating recruitment in estuaries and other near shore soft-bottom communities, little work has been carried out in soft-bottoms on the continental shelf. The continental shelf in Onslow Bay, North Carolina, has a variety of hard-bottom reefs and, in some areas, nutrient-rich ground-water discharge (Riggs et al., in review). These habitats support a substantial fishery of commercially important fish species (Lindquist and Harris, 1979; Sale, 1980; Grimes et al., 1982; Sedberry and VonDolah, 1984; Bohnsack and Sutherland, 1985) and may have a trophic linkage with the surrounding soft-bottom community (Posey and Ambrose, 1994).

A recent study in Onslow Bay by Posey and Ambrose (1994) found that the density of adult soft-bottom infauna was lower immediately adjacent to a hard-bottom compared to 75 m away. Caging and video studies suggest that predatory fish residing on the hard-bottom forage in the surrounding soft-sediment causing the observed pattern in adult infaunal densities (Posey and Ambrose, 1994). It is equally possible, however, that differential recruitment, due to either hydrodynamics or food availability, could explain the observed patterns.

This project examines the patterns of recruitment in a soft-bottom community adjacent to a hard-bottom community and the role of food and nutrient availability affecting recruitment. The objectives are to determine 1) how infaunal recruitment changes with increasing distance from the reef, 2) how infaunal recruitment differs with increased nutrient availability, and 3) how infaunal abundances respond to increased food availability.

MATERIALS AND METHODS

Study Site :

The study was carried out adjacent to a rock ledge (scarp) 50 km SE of Wrightsville Beach, North Carolina located at 33°59'63" N latitude and 77°21'18" W longitude (Figure 1). The lower scarp is 27.5 m below sea level and runs along the sea floor for approximately 5 km. Relief in the area of the study site ranges from 2.5 to 4.5 m (sand bottom to lower scarp edge, Figure 2) (Riggs et al., in review).

A vertical scarp and erosional ramp separate the upper and middle flat hard-bottoms and the lower sand flats, respectively (Figure 2). At the base of the vertical scarp and erosional ramp is a rubble field composed of debris from the eroding rock faces (Riggs et al., in review). Dense macroalgae on the outer edge of the upper and middle flat hard-bottoms are dominated by *Dictyopteris* sp. and *Sargassum* sp., while *Zonaria tournefortii* and *Chrysymenia enteromorpha* are dominant on the rubble blocks themselves (Renaud et al., 1995). Adjacent to the erosional ramp is the lower sand-flat habitats characterized by rippled sand gravels and overlain in some areas by fine sands (Riggs et al., 1994; Schmid and Riggs, 1994).

Figure 1. Map of North Carolina and Onslow Bay showing location of the study area (Figure from Stephen W. Snyder).

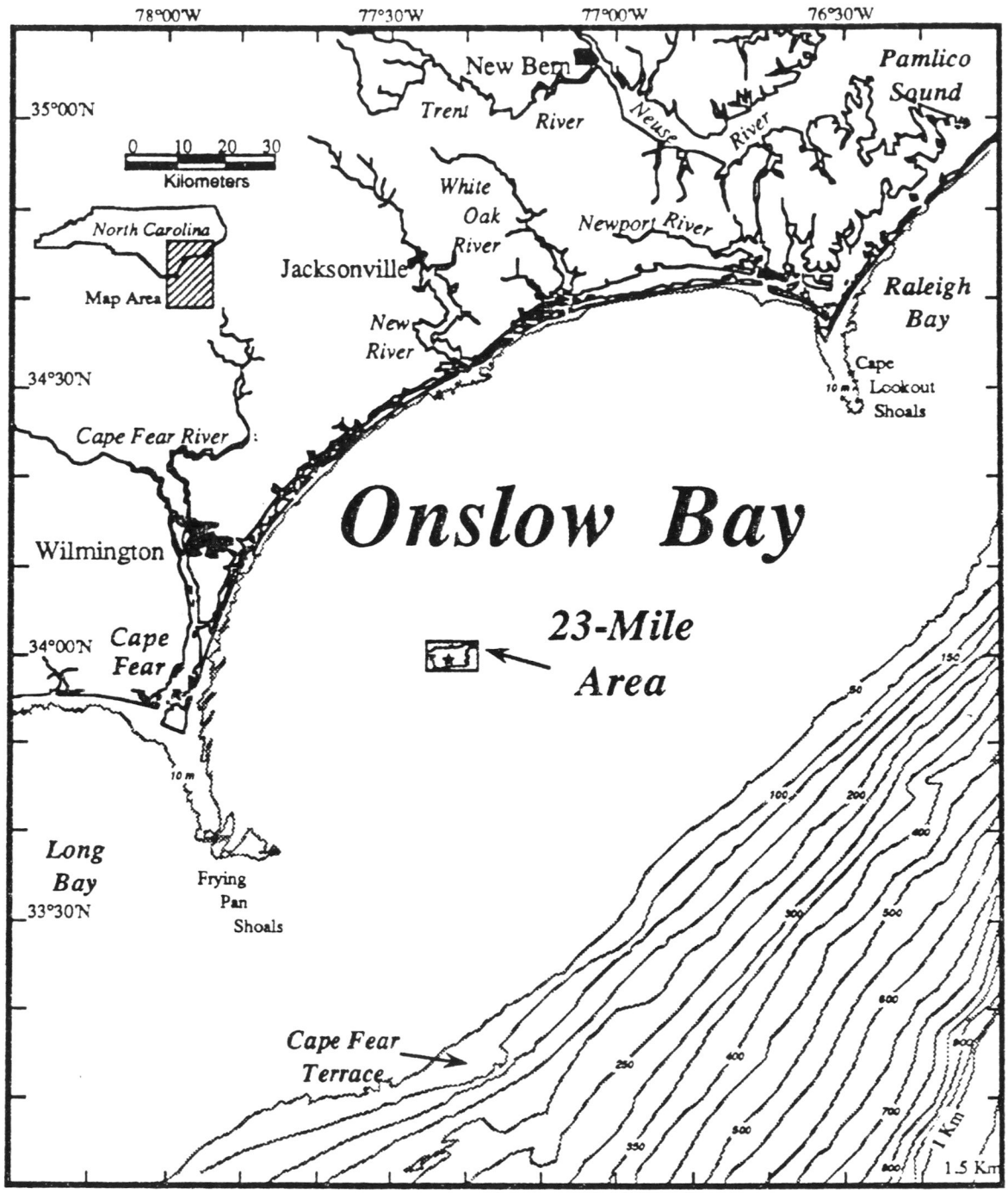
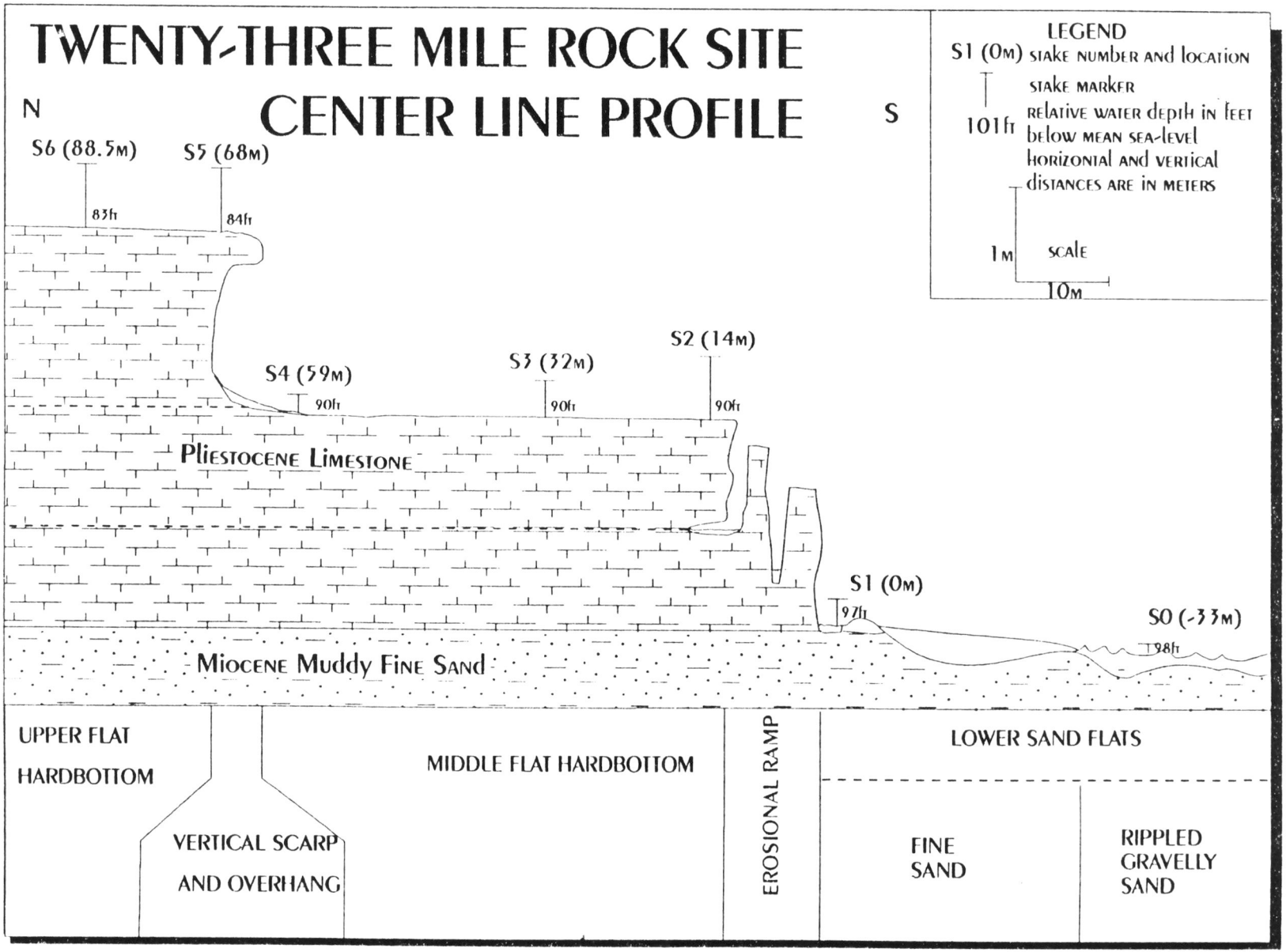

78°00'W
77°30'W
77°00'W
76°30'W
35°00'N
34°30'N
34°00'N
33°30'N
0 10 20 30
Kilometers
North Carolina
Map Area
New Bern
Trent River
Neuse River
Pamlico Sound
White Oak River
Newport River
Jacksonville
New River
Raleigh Bay
Cape Lookout Shoals
Cape Fear River
Onslow Bay
Wilmington
23-Mile Area
Cape Fear
Long Bay
Frying Pan Shoals
Cape Fear Terrace
10 m
50
100
150
200
400
500
600
700
800
900
1000
1 Km
1.5 Km

Figure 2. Profile of the 23 Mile area showing the scarp-ramp complexes (Figure is from Riggs et al., in review).


TWENTY-THREE MILE ROCK SITE
CENTER LINE PROFILE
N
S
LEGEND
S1 (0M) STAKE NUMBER AND LOCATION
STAKE MARKER
101ft RELATIVE WATER DEPTH IN FEET BELOW MEAN SEA-LEVEL
HORIZONTAL AND VERTICAL DISTANCES ARE IN METERS
1M SCALE
10M
S6 (88.5M)
S5 (68M)
83ft
84ft
S4 (59M)
S3 (32M)
S2 (14M)
90ft
90ft
90ft
PLIESTOCENE LIMESTONE
S1 (0M)
97ft
S0 (-33M)
98ft
MIOCENE MUDDY FINE SAND
UPPER FLAT HARDBOTTOM
VERTICAL SCARP AND OVERHANG
MIDDLE FLAT HARDBOTTOM
EROSIONAL RAMP
LOWER SAND FLATS
FINE SAND
RIPPLED GRAVELLY SAND

Experimental Trays :

Treatments: Control trays filled with defaunated sediment (See below) were used to measure recruitment at different distances from the reef. Fertilizer enriched trays were designed to observe the effects of increase nutrients and subsequent food availability on infaunal recruitment. Algal enriched trays were utilized to directly increase food availability and the effect it had upon recruitment.

Beach sand from the upper dune system of Wrightsville Beach, North Carolina, was used as a settlement medium, because it was dry and contained virtually no marine organisms. Prior to sampling, grain size was visually determined to be similar to sand at the study site. Grain size analysis was then conducted, according to Folk (1980), after sampling (see results). Square plastic containers (Rubbermaid #3872 2.8 qt, 20.3 X 20.3 X 8.5 cm) were used as experimental trays. Trays were filled with 3.5 to 4 cm of cement in order to minimize transport by bottom currents. Each tray was soaked in fresh water for 24 hrs in order to leach any toxins from the cement. The water was then poured off and treatment sediment was added.

Control trays were filled with the defaunated beach sand until there was approximately 1 cm between the sediment surface and top of the tray. One gram of fertilizer was

added to the sand in fertilizer enriched trays. Osmocote 18-6-12 (N:P:K) (Sierra Chemical Company, Milpitas California) slow release fertilizer was used to allow a slow, steady release of nitrogen and phosphorus (Fonseca et al., 1987; Kenworthy and Fonseca, 1992).

This fertilizer is encapsulated in a copolymer coating of vegetable oil and resin. Once these capsules become wet the resin becomes semi-permeable and allows release of the nutrients. During the manufacture of this fertilizer, capsule size is not consistent. In order to obtain a more uniform size, all capsules were sieved through a 2 mm sieve. The < 2 mm capsules which passed through the sieve were then mixed into the sand to a depth of approximately 1.5 - 2 cm. Another 1 cm of defaunated sand was then placed on top to ensure that the fertilizer was not lost in transport to the sea floor or carried away by bottom currents.

Once the capsule is wet and fertilizer is released, approximately 0.2% of the nitrogen will be released per day increasing the nitrogen flux by 7 times that of the ambient or natural community. This increased nutrient supply will then support a greater density of benthic diatoms and bacteria, which should in turn increase the density of meiofaunal and macrofaunal organisms which consume

microfaunal organisms.

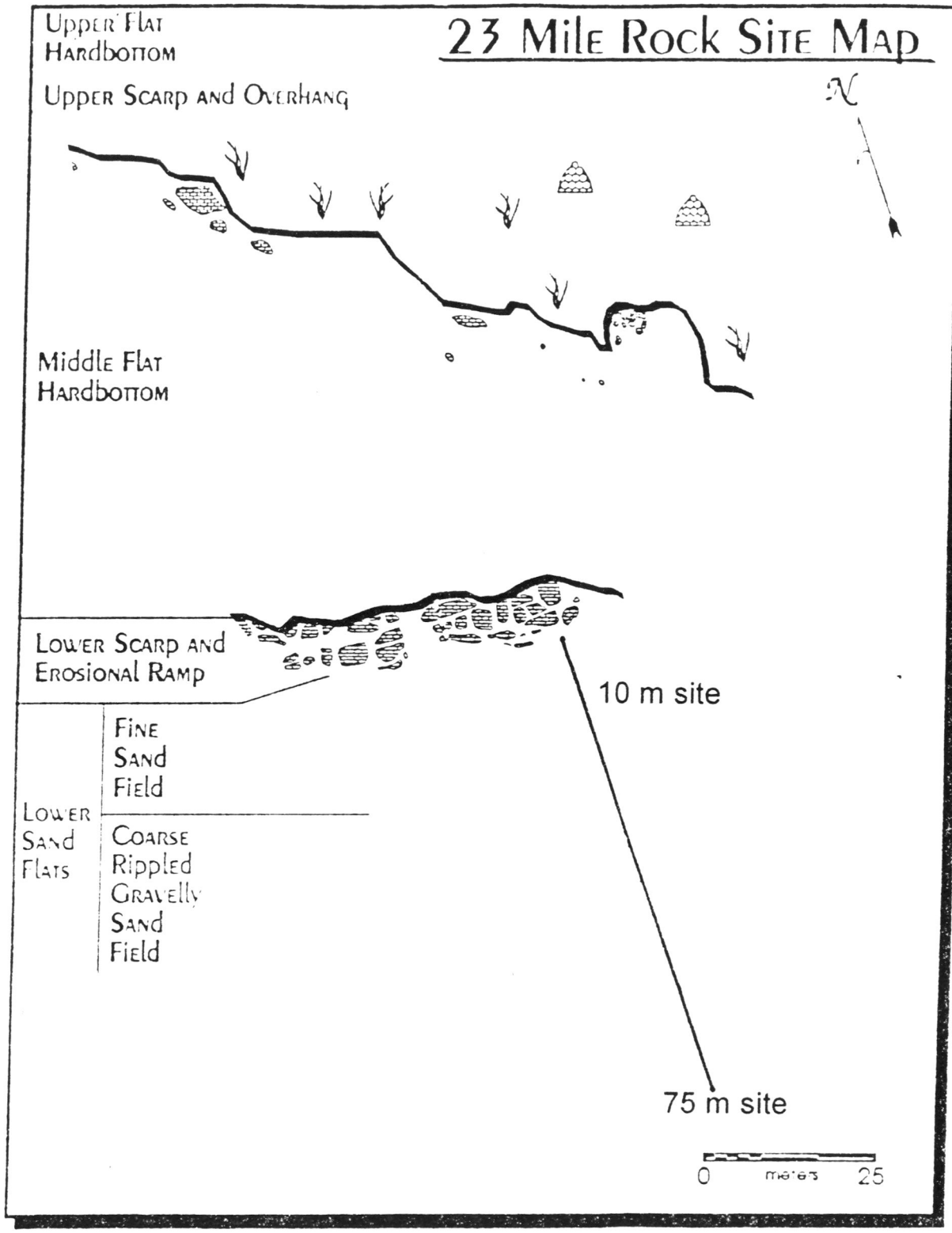
The green algae *Enteromorpha* spp. and *Ulva* spp., collected along intertidal areas of Morehead City and Beaufort, North Carolina, were used as food sources in algal enriched trays. The algae were dried and pulverized until they were able to pass through a 2 mm sieve. Ten grams of pulverized algae were mixed thoroughly into the top 4 cm of sand in each of 24 trays. Synthetic sea water (Instant Ocean, 36 ppt) was added to wet the algal enriched sand followed by an additional 1 cm of defaunated sand. The addition of algae increased the carbon to approximately .7%.

The algae present in these trays served as a direct and indirect food source. Those organisms which are capable of consuming algae may have enhanced densities due directly to the increased food source. Predatory infauna may then have increased densities due to an increased numbers of prey species.

Field Work :

General deployment and recovery: Trays were covered with lids and placed at sites 10 m and 75 m from the reef (Figure 3) in a blocked design of 6 trays by 6 trays. This array consisted of 2 replicates of each treatment per row, resulting in a total of 12 replicates for each treatment.

Figure 3. Map of the study area with 10 m and 75 m sites shown in relation to the lower scarp and erosional ramp (Figure is modified from Riggs et al., in review).


23 Mile Rock Site Map
Upper Flat Hardbottom
Upper Scarp and Overhang
N
Middle Flat Hardbottom
Lower Scarp and Erosional Ramp
10 m site
Lower Sand Flats
Fine Sand Field
Coarse Rippled Gravelly Sand Field
75 m site
0
meters
25

After placing the trays in the array outlined above, divers dug a small hole (approximately 20 X 20 X 7.5 cm) in the sediment and placed the tray into the hole so that approximately 1 cm of the tray was above the natural sediment. Divers allowed sufficient time for any disturbed sediment to settle (approximately 2-3 min.) and then removed the lid from each tray.

During retrieval of trays, divers first placed lids on all of the trays then carefully placed the trays in baskets to bring them to the surface. Once on board, three infaunal cores (4.5 cm diameter X 3 cm deep) were taken from each tray. Core contents were fixed with 10% formalin containing Rose Bengal to stain any organisms. Four cores (2 cm diameter X 2 cm deep) were also taken from each tray and stored frozen. Two of these were used for pigment concentration and two for analysis of carbon and nitrogen (C-H-N) concentration. In order to compare experimental trays to natural sediment, plots were haphazardly chosen within 5 m of the experimental array and sampled in situ as if they were actual trays (n=4 at 10 m and 75 m from the scarp).

Spring and summer experiment: A complete array of trays (n = 12 of each treatment) was placed at the 10 m site on 29 April 1993. However, only control trays were placed at the

75 m site due to poor sea conditions (configured in 3 rows of 4 trays). After a period of two weeks, it was observed that approximately 10% of the trays were being scoured or buried by strong bottom currents. Therefore, on 17 May 1993 additional trays, 8 control and 8 fertilizer trays, were deployed at the 10 m site and an additional 8 control trays were deployed at the 75 m site (referred to from here on as summer experiment).

On 31 May 1993, the first set of trays (spring) were recovered; 4 control, 5 fertilizer, and 7 algal trays were still intact (little or no sediment scour observed in tray sediment) at the 10 m site, while 7 control trays were intact at the 75 m site. The remaining trays were destroyed, as they had either been emptied of sand or covered with moving sand. Of those trays deployed on 17 May 1993, 4 control and 5 fertilizer trays at the 10 m site and 4 control trays at the 75 m site were recovered intact on 08 June 1993 (See Table 1 for summary of sample periods).

Autumn experiment: Full arrays (n = 12 of each treatment) plus an additional 9 control trays at each site (10 m and 75 m) were deployed 21 September 1993. The additional control trays were placed within 5 m of the large array and 5 (control trays) were recovered and were replaced with

another set of control trays (n=9) at each site on 04 October 1993. Unfortunately an October storm subsequently destroyed all the remaining trays (See Table 1 for summary of sample periods).

Laboratory :

Infaunal samples: Infauna were separated from sediment using an elutriation technique similar to that of Koosman and Newburg (1977). Samples were placed in a 1000 ml graduated cylinder which was tilted at a 70 degree angle. Tap water was then introduced at the bottom via a 0.64 cm diameter tube. Due to differences in density between the organisms and sediment, less dense organisms were carried up in the water column and out of the cylinder while sediment fell back to the cylinder bottom. Water pouring out the top of the cylinder was passed through a 63 μm sieve. This was first done with a water flow of approximately 60 ml s^{-1} for 15 min., after which material retained on the sieve was washed into a vial. The water flow was then increased to 120 ml s^{-1} for 15 min., after which period the sieve contained a small amount of sediment. This sediment was then examined for organisms under a dissecting microscope. Finally, the sediment in the cylinder was examined for organisms under 120X magnification. Organisms were then identified to the lowest taxanomic level and grouped into guilds by their feeding type: deposit feeder, suspension

Table 1. Summary of times of deployment and recovery, and treatments during each sampling period. Numbers represent n deployed or recovered. Treatments: Ambient = natural site sediment sampled in situ, Control = defaunated sediment only, Algal = defaunated sediment plus 10 g algae, and Fertilizer = defaunated sediment plus 1 g fertilizer.

Experimental period	Treatments	Site			
		10 m		75 m	
(Deployment - Recovery)		Deployed	Recovered	Deployed	Recovered
Spring					
(29 April - 31 May 1993)	Ambient	N/A	4	N/A	4
	Control	12	4	12	7
	Algal	12	7	0	0
	Fertilizer	12	5	0	0
Summer					
(17 May - 08 June 1993)	Control	8	4	8	4
	Fertilizer	8	5	0	0
Autumn					
(20 September - 04 October 1993)	Ambient	N/A	4	N/A	4
	Control	21	5	21	5
	Algal	12	0	12	0
	Fertilizer	12	0	12	0

feeder, or predator (Fauchald, 1977; Day, 1973; Barnes, 1980; Uebelacker and Johnson, 1984; Brusca, 1990; see Appendix 1. for summary of guilds).

Only taxa comprising 5% or more of the total abundance during a sample period were included in the statistical analyses. Separate two-way analysis of variance (ANOVA) was performed for each sample period with distance (10 m or 75 m) and treatment (ambient plots or control trays) as the main effects. This was done to examine differences in recruitment at different distances from the reef during spring and autumn sampling (see Appendix 1. for summary of percent abundance of taxa).

Residuals from the ANOVA indicated that variances were not homogeneous; therefore, data were log $(x + 1)$ transformed and the ANOVA was repeated. During the summer sampling period, no ambient cores were obtained so, a one-way ANOVA using distance (10 m and 75 m) as the main effect was performed.

A separate one-way ANOVA was performed for each sample period with treatment type used as the main effect (SAS, 1988). This was done to examine differences in recruitment due to food and nutrient availability during the spring and summer sampling periods.

Residuals indicated that variances were not homogeneous; so data were log (x + 1) transformed, and the ANOVA was repeated. Analysis of the spring sampling period included algal trays, fertilizer trays, control trays, and ambient plots from only the 10 m site. Fertilizer and control trays at the 10 m site were used in the analysis for the summer sampling.

Duncans Multiple Range test was used to compare infaunal means when no interaction between main effects was observed (Sokal and Rolf, 1981). When a significant interaction was present ($p < 0.05$), Tukeys Paired Comparison was used to compare treatment means at each distance within each sampling period (Neter et al., 1985).

Sediment Analysis: Grain size analysis was performed as described by Folk (1980) in order to compare grain size between treatment sediment and natural sediment. Statistical analyses were then carried out as described above for infauna.

Chlorophyll samples: Sediment chlorophyll was analyzed according to the acetone double-extraction technique of Whitney and Darley (1979). Sediment was thawed and pigments were first extracted using 10 ml 100% acetone buffered with

$MgCO_3$ for 12 hrs at 14°C. The sample was then centrifuged at 2500 rpm for 10 minutes and the extract decanted. A second extraction was done using 10 ml 90% acetone for 2 hr and centrifuged as above. Extracts were then combined and absorbances were read at 663 and 750 nm using a Milton Roy Spectrophotometer (Whitney and Darley, 1979). One drop of 50% hydrochloric acid (HCl) was then added and the sample was re-read to obtain phaeopigment concentrations. Actual pigment concentrations were obtained as described in Standard Methods (1992). Statistical analyses were carried out as described above for infauna.

C-H-N samples: Cores taken for analysis of carbon (C) and nitrogen (N) were thawed, placed in ashed tins, and dried at 60°C overnight. Residual fertilizer capsules were first removed from the cores taken from the fertilizer enriched trays. Sediment was dried and pulverized using a mortar and pestle.

One gram sub-samples were taken from each of the pulverized samples, and treated with 2 ml of 1N (HCl) to remove any inorganic carbon present in the form of calcium carbonate ($CaCO_3$) (Grebmeier, 1993). Sub-samples were then dried again at 60°C for 5 days. Acidification with 2 ml HCl was repeated if necessary until no reaction between the HCl and the sediment was observed. Number of acidifications

ranged from 2 to 7 times. Two 3 - 5 mg sub-samples of this treated sediment were weighed and analyzed using a carbon and nitrogen elemental analyzer (Leeman Labs, Inc.). Statistical analyses were carried out as described above for infauna and chlorophyll.

RESULTS

Seventy five taxa were observed in the spring of 1993 infaunal cores, whereas 64 and 58 taxa were observed in summer and autumn cores, respectively. No differences in abundance were observed between control trays at the 10 m site and the 75 m site for any taxa during spring. During summer predators, analyzed as a guild, were significantly more abundant at the 10 m site than the 75 m site in control trays. Autumn sampling was characterized by higher recruitment in control trays at the 10 m site than the 75 m site for many taxa.

During the enrichment portion of the study algal enriched trays sampled during spring also had higher recruitment compared to control trays, fertilizer trays and ambient plot treatments. Fertilizer enriched trays sampled during spring had a higher abundance of capitellid polychaetes, total polychaetes, and deposit feeders.

Effects due to distance from the reef :

Spring experiment: Control trays and ambient plots were used for the analyses of distance effects. No significant differences in recruitment occurred in control trays at the 10 m and 75 m sites for any taxa or combination of taxa (Families, feeding guilds, etc.; see Appendix 1 for lists of

taxa) ($p > 0.05$, Table 2). Nematodes, total other fauna (fauna excluding polychaetes, bivalves, and crustaceans, see Appendix 1 for lists of taxa), and total fauna were statistically more abundant in ambient plots at the 10 m site than ambient plots at the 75 m site ($p < 0.05$, Table 2). Differences between control trays and ambient plots were observed for the following fauna: total bivalves, nematodes, flatworms, total other fauna, and total fauna ($p < 0.05$, Table 2). With the exception of bivalves, all fauna were more abundant in ambient plots.

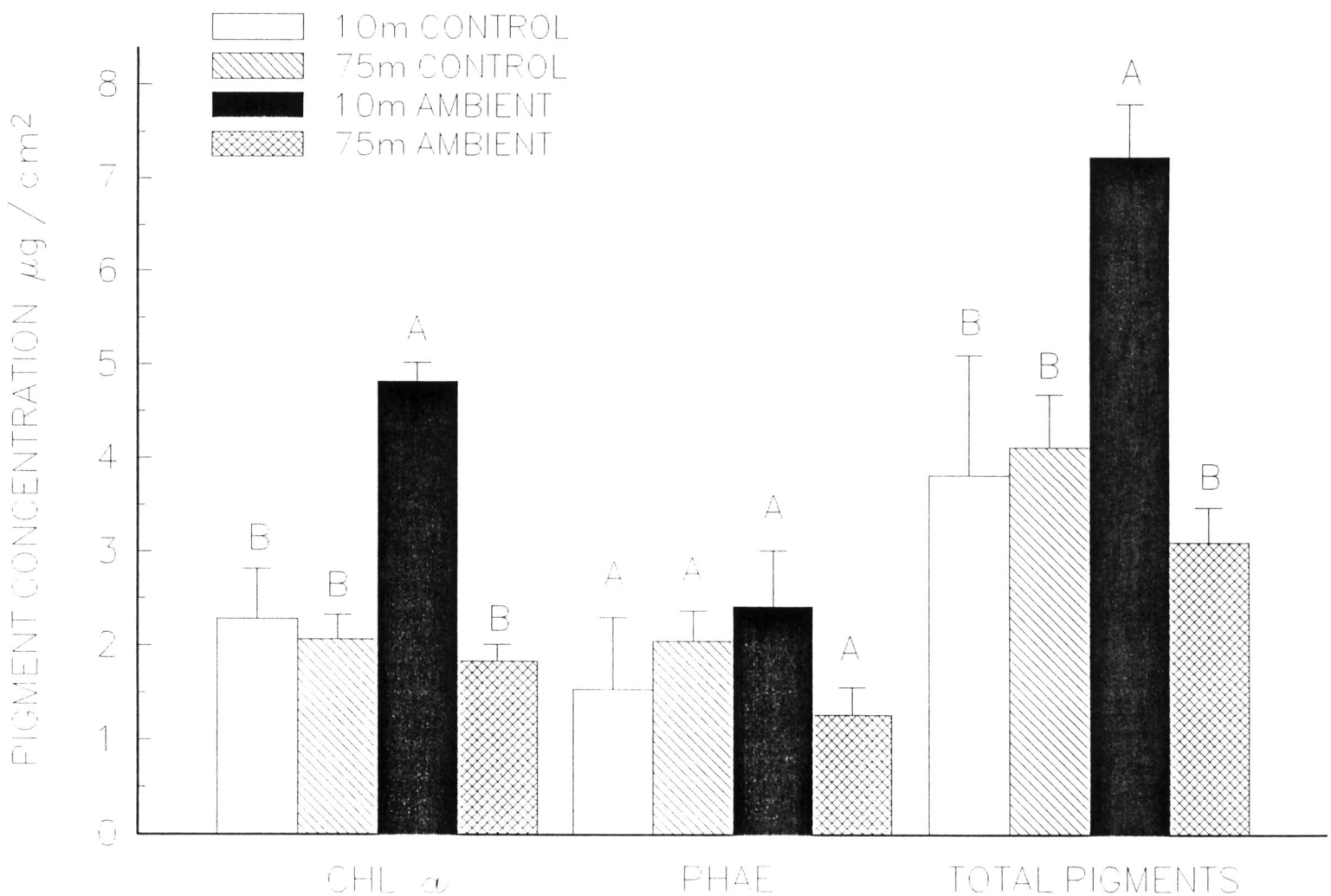
Chlorophyll *a* and total pigment concentration were significantly higher in ambient plots than control trays ($p < 0.05$, Figure 4), and did not statistically differ between control trays at different distances. They were, however, significantly higher in ambient plots at the 10 m site than ambient plots at the 75 m site ($p < 0.05$, Figure 4). Phaeopigments were not significantly different between distances or treatments ($p > 0.05$, Figure 4).

Despite significant differences in chlorophyll concentration, no significant differences were observed for C or N between distances or treatments at an alpha level of 0.05 (Table 3). However, the higher concentration of

Table 2. Results of two-way ANOVA comparing abundant taxa between control trays and ambient plots during spring sampling. Numbers represent mean density per m^2 (± 1 standard error) with n = 4. Dist. = distance (10 m and 75 m), Trt. = treatment (Control and Ambient), DistxTrt = distance (10 m or 75 m) by treatment (Control or Ambient) interaction, * = means are significantly different.

	Control		Ambient		P value		
Taxa	10 m	75 m	10 m	75 m	Dist.	Trt.	DistxTrt
Capitellid sp. A	2201(832)	314(314)	2201(1593)	1572(545)	.1845	.5066	.1654
Total Capitellidae	2201(831)	314(314)	2358(1569)	1572(545)	.1610	.4534	.1943
Opheliid sp. B	16662(7463)	14461(5147)	7388(2214)	10217(2454)	.8499	.2904	.5758
Total Opheliidae	17762(8151)	16348(5279)	8331(2330)	10532(2316)	.7867	.2445	.7421
Total Polychaetes	44485(12293)	55331(12412)	32881(4716)	41655(7285)	.3386	.4469	.9163
Total Bivalves	29080(6764)	30809(10927)	13047(1944)	10217(1007)	.6248	.0112*	.7578
Harpacticoid Copepods	33953(10574)	47629(4573)	29866(4022)	44799(9979)	.0937	.9276	.7381
Total Crustaceans	43227(11934)	53602(6305)	31124(4014)	46214(9950)	.1373	.4200	.9893
Nematodes	85983(15466)	110661(17985)	311708(46244)	160806(15034)	.2514	.0002*	.0156*
Flatworms	16505(5934)	16505(5684)	150117(18082)	41498(4944)	.4097	.0022*	.1173
Total Other Fauna	171966(22037)	202461(27690)	527530(59489)	263294(27553)	.0604	.0002*	.0069*
Total Fauna	245531(35287)	288601(49106)	572958(62777)	315166(29272)	.1426	.0050*	.0259*
Deposit Feeders	91799(25141)	105475(21169)	57689(3688)	74665(8864)	.6550	.0927	.8173
Suspension Feeders	3930(1748)	6759(2863)	1415(827)	2201(791)	.4054	.1317	.9011
Predators	124809(19192)	161592(22932)	480216(62006)	227926(21270)	.3437	.5600	.2267

Figure 4. Results of two-way ANOVA comparing Chl *a*, phaeopigments, and total pigment in control trays and ambient plot treatments deployed during spring. Chl *a* p values : distance (10 m and 75 m) = .0018, treatment (Control trays and Ambient plots) = .0359, distance*treatment = .0047. Phaeopigment p values : distance = .9971, treatment = .8540, distance*treatment = .1736. Total Pigment p values : distance = .0447, treatment = .2187, distance*treatment = .0048. Bars within a group (Chl *a*, phaeopigment, or total pigment) which have the same letter are not statistically different from each other (Tukey's test). n = 4 for each treatment at each distance. Error bars represent ± 1 standard error.


Spring Pigments
10m CONTROL
75m CONTROL
10m AMBIENT
75m AMBIENT
PIGMENT CONCENTRATION µg / cm2
0
1
2
3
4
5
6
7
8
B
B
A
B
A
A
A
A
B
B
A
B
CHL a
PHAE
TOTAL PIGMENTS

nitrogen at the 10 m site compared to the 75 m site is nearly significant p = 0.0591 (Table 3).

Table 3. Results of two-way ANOVA comparing carbon and nitrogen between control trays and ambient plot treatments collected during spring sampling. Numbers represent percent C or N (± 1 SE) with n = 4. Dist. = distance (10 m and 75 m), Trt. = treatment (Control and Ambient), DistxTrt = distance (10 m or 75 m) by treatment (Control or Ambient) interaction.

	Control		Ambient		P		
	10m	75m	10m	75m	Dist	Trt	DistxTrt
C	.024(.014)	.030(.006)	.024(.003)	.010(.005)	.9686	.3755	.3755
N	.015(.004)	.028(.005)	.015(.005)	.021(.005)	.0591	.5217	.5217

Grain size in control trays were significantly finer than those found in ambient sediments, p = .0001 (Table 4). Grain size at the 10 m site was also significantly finer than found at the 75 m site, p = .0013 (Table 4).

Table 4. Results of two-way ANOVA comparing mean grain size between distances (10 m and 75 m), treatments (Control and Ambient) and distance by treatment interaction from samples collected during spring sampling. Numbers represent mean grain size (± 1 standard error) and standard deviation with n = 4. Dist = distance, Trt = treatment, and DistxTrt = distance by treatment interaction, * =means are significantly different.

Location	Treatment	Mean Grain Size (ϕ)	Standard Deviation	P Dist.	P Trt.	P DistxTrt
10 m	Control	2.363(.019)	0.567			
10 m	Ambient	2.089(.028)	0.583	.0013*	.0001*	.2293
75 m	Control	2.217(.050)	0.593			
75 m	Ambient	1.816(.063)	0.596			

Summer experiment: Predatory infauna, analyzed as a guild, were significantly higher at the 10 m site compared to the 75 m site at an alpha level of 0.05 Table 5. The higher abundance of deposit feeders, analyzed as a guild, at the 75 m site compared to the 10 m site is nearly significant, p = 0.0513, Table 5. Results of analyses of all abundant fauna are summarized in Table 5. Cores taken for carbon analysis and nitrogen analysis resulted in non-significant differences between sites (p > 0.05, Table 6). Concentration of phaeopigments were significantly higher at the 75 m site than the 10 m site (p = .05, Figure 5).

Table 5. Results of one-way ANOVA comparing abundant taxa in control trays collected at the 10 m and 75 m sites during summer sampling. Numbers represent mean density per m^2 (± 1 standard error) with n = 4, * = means are significantly different.

Taxa	10 m	75 m	P
Total Capitellidae	3615(697)	19963(18919)	.9639
Opheliid sp. B	10689(5056)	9117(4914)	.6089
Total Opheliidae	12575(6020)	11632(5496)	.8070
Total Polychaetes	38040(7910)	80639(28773)	.1802
Bivalve sp. A	16977(3693)	13990(3419)	.5909
Bivalve sp. B	10689(3026)	21849(4478)	.0890
Total Bivalves	37254(7542)	40869(7160)	.7521
Harpacticoid Copepods	40241(8036)	40555(11184)	.8838
Total Crustaceans	45428(9366)	48886(12155)	.9182
Nematodes	30809(8999)	42599(6168)	.3102
Flatworms	28294(5115)	20120(3472)	.3046
Total Other Fauna	109562(24259)	121036(17677)	.6128
Total Fauna	184856(35292)	242544(31329)	.2967
Deposit Feeders	97772(16335)	121980(31840)	.5367
Suspension Feeders	3773(679)	6919(1334)	.0513
Predators	76866(16595)	10790(5013)	.0118*

Figure 5. Results of one-way ANOVA comparing pigments in control trays deployed during summer. Chl *a* p value = .9056, phaeopigment p value = .0500, total pigment p value = .2860, with n = 4 at each distance (10 m and 75 m). Error bars represent ± 1 standard error. Bars within the same group (Chl *a*, phaeopigment, or total pigment) which have the same letter are not significantly different (Duncan's test).

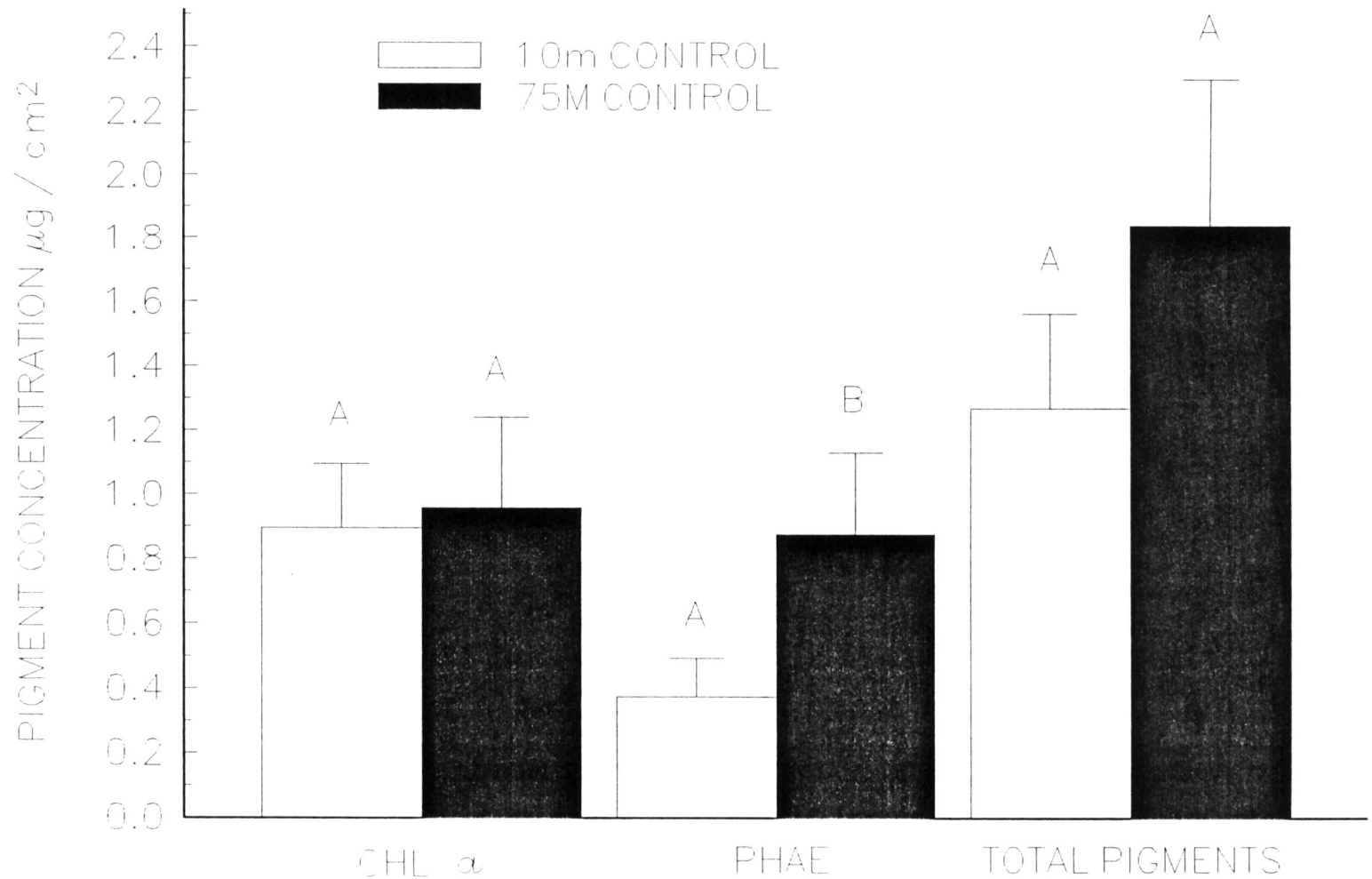

Summer Pigments
10m CONTROL
75M CONTROL
PIGMENT CONCENTRATION μg / cm²
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
A
A
A
B
A
A
CHL a
PHAE
TOTAL PIGMENTS

Table 6. Results of one-way ANOVA comparing carbon and nitrogen between control trays collected during summer sampling. Numbers represent percent C or N (± 1 standard error) with n = 4.

	10m	75m	P
C	.009(.006)	.001(.005)	.3160
N	.006(.003)	.001(.003)	.3435

Grain size between control trays at each site (10 m and 75 m) do not significantly differ from one another, p = .2561 (Table 7).

Table 7. Results of a one-way ANOVA comparing mean grain size between control trays collected at the 10 m and 75 m sites during summer sampling. Numbers represent mean grain size (± 1 standard error) and standard deviation with n = 4.

Location	Treatment	Mean Grain Size (ϕ)	Standard Deviation	P
10 m	Control	2.357(.020)	0.572	
75 m	Control	2.317(.020)	0.543	.2561

Autumn experiment: The following taxa and combinations of taxa were significantly more abundant in control trays located at the 10 m site than those at the 75 m site (Tukey's test): total polychaetes, harpacticoid copepods, total crustaceans, total other fauna, total fauna, deposit

feeders, suspension feeders, and predators ($P < 0.05$, Table 8). Total syllids, total polychaetes, harpacticoid copepods, total crustaceans, and deposit feeders were all significantly more abundant at the 75 m site than at the 10 m site in ambient plots (Tukey's test, $p < 0.05$, Table 8). Harpacticoid copepods, total crustaceans, and suspension feeders were found to be in significantly higher densities in control trays than ambient plots ($p < 0.05$, Table 8). While nematodes, flatworms, total other fauna, total fauna, and deposit feeders were found to be significantly more abundant in ambient plots ($p < 0.05$, Table 8).

Chlorophyll *a* and total pigment concentrations were found to be significantly higher at the 10 m site than at the 75 m site ($p < 0.05$). Their concentrations in control trays were also higher at the 10 m site than at the 75 m site ($p < 0.05$, Figure 6). Ambient plots had higher concentrations of chlorophyll *a*, phaeopigment, and total pigment than control trays ($P < 0.05$ Figure 6).

There was significantly more C and N found in ambient plots than control trays ($p < 0.05$, Table 9). Carbon was also found to be in higher concentration in 10 m ambient plots than in 75 m ambient plots (Tukey's test, $p = .0077$, Table 9).

Table 8. Results of two-way ANOVA comparing abundant taxa between control trays and ambient plot treatments for the autumn sampling period. Numbers represent mean per m^2 (± 1 standard error) n = 4. Dist. = distance (10 m and 75 m), Trt. = treatment (Control and Ambient), DistxTrt = distance (10 m or 75 m) by treatment (Control or Ambient) interaction, * = means are significantly different.

	Control		Ambient		P value		
Taxa	10 m	75 m	10 m	75 m	Dist.	Trt.	DistxTrt
Syllid juveniles	27508(7525)	11789(4486)	4087(1463)	11632(1162)	.5921	.0185*	.0092*
Total Syllidae	29866(8062)	13361(4798)	5816(1767)	20120(574)	.3555	.0591	.0014*
Total Dorvilleidae	10846(697)	3930(2091)	22164(2287)	17762(9239)	.0404*	.1038	.7631
Total Polychaetes	60675(7451)	23736(4118)	32067(3102)	44799(7441)	.0441*	.9737	.0010*
Harpacticoid Copepods	105632(20537)	29866(4055)	21221(3158)	38826(6409)	.0828	.0022*	.0002*
Total Crustaceans	112234(20689)	33167(2480)	22007(3133)	39769(7097)	.0741	.0005*	.0001*
Nematodes	73565(13590)	27665(3491)	214879(23338)	127010(33962)	.0014*	.0001*	.4122
Flatworms	31281(7285)	14461(1683)	61619(5341)	51244(11042)	.0294*	.0003*	.2788
Total Other Fauna	228240(35840)	79695(6894)	303534(22191)	225725(45376)	.0006*	.0008*	.0432*
Total Fauna	299918(44922)	108147(9865)	336701(24224)	273983(45253)	.0005*	.0018*	.0134*
Deposit Feeders	126224(24441)	38040(4151)	24522(4123)	46528(6973)	.2953	.0013*	.0010*
Suspension Feeders	5344(654)	2043(1070)	629(629)	1100(903)	.0866	.0084*	.0270*
Predators	158291(21561)	63190(7939)	307150(23916)	221953(38593)	.0023*	.8114	.0005*

Figure 6. Results of two-way ANOVA comparing Chl *a*, phaeopigments, and total pigment in control trays and ambient plot treatments deployed during autumn. Chl *a* p values : distance (10 m and 75 m) = .0012, treatment (control trays and ambient plots) = .0001, distance*treatment = .3798. Phaeopigment p values : distance = .5250, treatment = .0848, distance*treatment = .6611. Total Pigment p values : distance = .0020, treatment = .0001, distance*treatment = .2462. n = 4 for each treatment at each distance. Error bars represent ± 1 standard error.

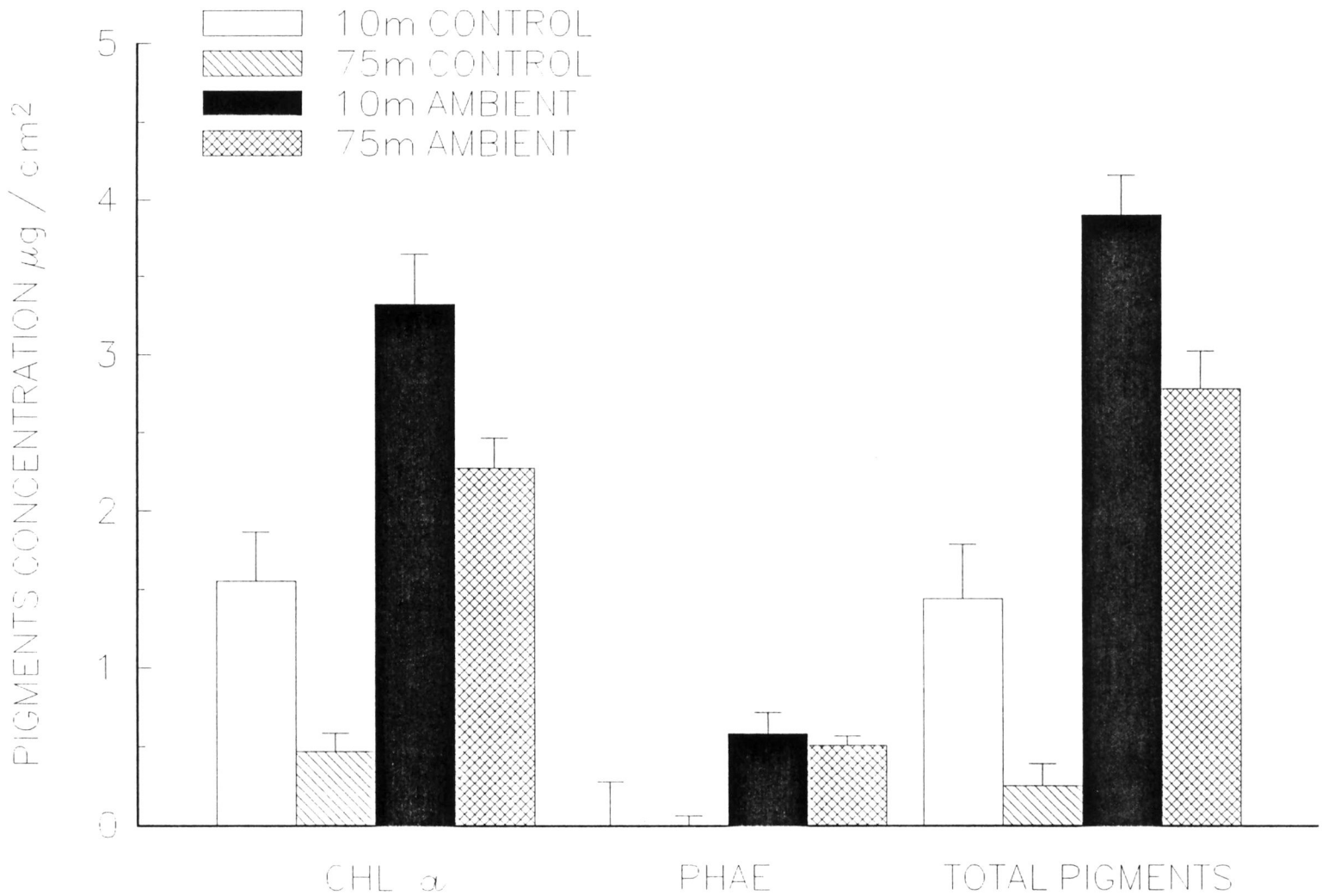

Autumn Pigments
10m CONTROL
75m CONTROL
10m AMBIENT
75m AMBIENT
PIGMENTS CONCENTRATION μg / cm²
0
1
2
3
4
5
CHL a
PHAE
TOTAL PIGMENTS

Table 9. Results of two-way ANOVA comparing carbon and nitrogen between control trays and ambient plot treatments collected during autumn sampling. Numbers represent percent C or N (± 1 standard error) with n = 4. Dist. = distance (10 m and 75 m), Trt. = treatment (Control and Ambient), DistxTrt = distance by treatment interaction. * = means are significantly different.

	Control		Ambient		P		
	10m	75m	10m	75m	Dist	Trt	DistxTrt
C	.000(.004)	.002(.005)	.105(.030)	.056(.006)	.7055	.0001*	.0077*
N	.005(.003)	.000(.002)	.022(.007)	.019(.004)	.5563	.0001*	.6156

Grain size was significantly finer in control trays then in natural or ambient sediments, p = .0001 (Table 10).

Table 10. Results of two-way ANOVA comparing mean grain size between control trays and ambient plot treatments collected during autumn sampling. Numbers represent mean grain size (± 1 standard error) and standard deviation with n = 4. Dist. = distance (10 m and 75 m), Trt. = treatment (Control and Ambient), DistxTrt = distance by treatment interaction. * = means are significantly different.

Location	Treatment	Mean Grain Size (ϕ)	Standard Deviation	P Dist.	Trt.	DistxTrt
10 m	Control	2.381(.014)	0.490			
10 m	Ambient	2.056(.007)	0.592	.3665	.0001*	.2833
75 m	Control	2.393(.015)	0.534			
75 m	Ambient	1.919(.089)	0.724			

Differences due to food or nutrient availability :

Spring sampling: Treatments in the enrichment portion of this study included algal enriched trays, fertilizer enriched trays, control trays and ambient plots (located at the 10 m site only). *Capitellidae* sp. A, total Capitellidae, total polychaetes, harpacticoid copepods, and total crustaceans, were significantly higher in algal enriched trays than all other treatments ($p < 0.05$, Table 11).

Nematodes and flatworms were found to be significantly higher in abundance in ambient plots than algal, fertilizer, or control trays ($p = 0.0007$, Table 11). No differences were detected between algal, fertilizer, or control trays for nematodes. Total other fauna were highest in abundance in ambient plots which did not differ from algal trays ($p = 0.0058$, Table 11). The abundance of total other fauna in fertilizer and algal trays did not statistically differ from one another nor did fertilizer trays statistically differ from control trays. Deposit feeder densities were not statistically distinguishable between algal, fertilizer, and control trays; however, deposit feeders were more abundant in algal trays than ambient plots ($p = 0.0380$).

Total fauna observed in ambient plots and algal trays did not significantly differ from one another but were

significantly higher than fertilizer enriched trays and control trays. Total fauna in fertilizer enriched trays and control trays did not significantly differ from one another ($p = 0.0012$, Table 11).

Chlorophyll *a* concentration was statistically equal in ambient plots and algal trays which were statistically higher than fertilizer trays and control trays ($p = .0043$, Figure 7). Phaeopigments and total pigments were statistically higher in algal treatments then in any other treatment ($p < 0.05$ Figure 7).

For no treatment during this time period was carbon or nitrogen concentration found to be statistically different ($p > 0.05$, Table 12).

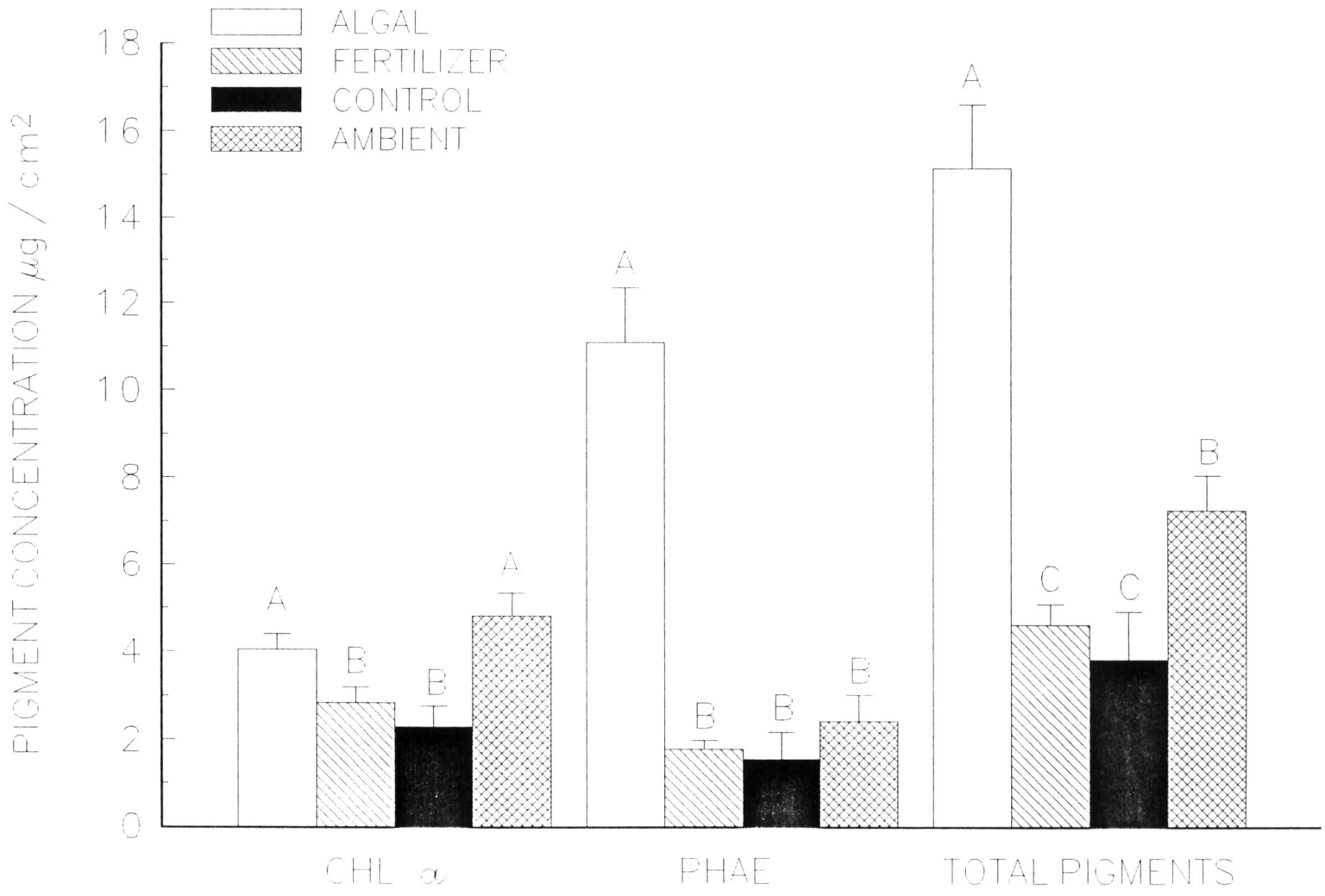
Table 12. Results of one-way ANOVA comparing carbon and nitrogen between treatment trays and ambient plots collected at 10 m during spring enrichment sampling. Numbers represent percent C or N (± 1 standard error) with n = 4.

	Algal	Fertilizer	Control	Ambient	P
C	.028(.008)	.017(.013)	.024(.014)	.024(.003)	.9290
N	.060(.047)	.014(.002)	.015(.004)	.015(.005)	.5251

Table 11. Results of one-way ANOVA comparing abundant taxa for spring enrichment sampling at 10 m. Numbers represent mean density per m^2 (± 1 standard error) with n = 4. * = means are significantly different. Means connected with the same line are not significantly different.

Taxa	Algal	Fertilizer	Control	Ambient	P
Capitellid sp. A	120250(12833)	1572(943)	2201(832)	2201(1593)	.0001*
Total Capitellidae	182498(18594)	1729(866)	2201(832)	2358(1569)	.0001*
Opheliid sp. B	79224(27631)	28294(13878)	16662(7463)	7388(2214)	.0515
Total Opheliidae	88027(28934)	30023(14713)	17762(8151)	8331(2330)	.0465*
Total Polychaetes	303691(46241)	56588(19361)	44485(12293)	32381(4716)	.0006*
Total Bivalves	32381(11469)	28923(10574)	29080(6764)	13047(1944)	.3862
Harpacticoid Copepods	201360(75051)	48257(10665)	33953(10574)	29866(4022)	.0049*
Total Crustaceans	208749(76221)	63976(18804)	43227(11934)	31124(4014)	.0068*
Nematodes	101230(10455)	140214(23936)	85983(15466)	311708(46244)	.0007*
Flatworms	6130(2998)	33639(13462)	16505(5934)	150117(18082)	.0372*
Total Other Fauna	337173(90272)	250404(38740)	171966(22037)	527530(59489)	.0058*
Total Fauna	673246(125505)	335915(51601)	245531(35287)	572958(62777)	.0012*
Deposit Feeders	514012(112284)	117421(37709)	91799(25141)	57689(3688)	.0380*
Suspension Feeders	2515(574)	9431(8186)	3930(1748)	1415(827)	.7660
Predators	126695(12836)	193501(35708)	124809(19192)	480216(62006)	.8451

Figure 7. Results of one-way ANOVA comparing pigment concentrations between treatment sediments during spring enrichment experiment at 10 m. Chl *a* p value = .0006, phaeopigment p value = .0001, and total pigment p value = .0001. Bars within a group (Chl *a*, phaeopigment, total pigment) with the same letter are not significantly different from one another (Duncan's test). n = 4 for each treatment. Error bars represent ± 1 standard error.


Spring Enrichment Pigments
ALGAL
FERTILIZER
CONTROL
AMBIENT
PIGMENT CONCENTRATION µg / cm²
0
2
4
6
8
10
12
14
16
18
A
B
B
A
A
B
B
B
A
C
C
B
CHL a
PHAE
TOTAL PIGMENTS

Summer sampling: During this time period fertilizer and control trays were utilized as experimental treatments. Total capitellids, total polychaetes and deposit feeders all were significantly higher in fertilizer enriched trays than in control trays ($p < 0.05$, Table 13).

No significant differences were found between treatments for carbon analysis, nitrogen analysis or pigment analysis ($p > 0.05$, Table 14 and Figure 8).

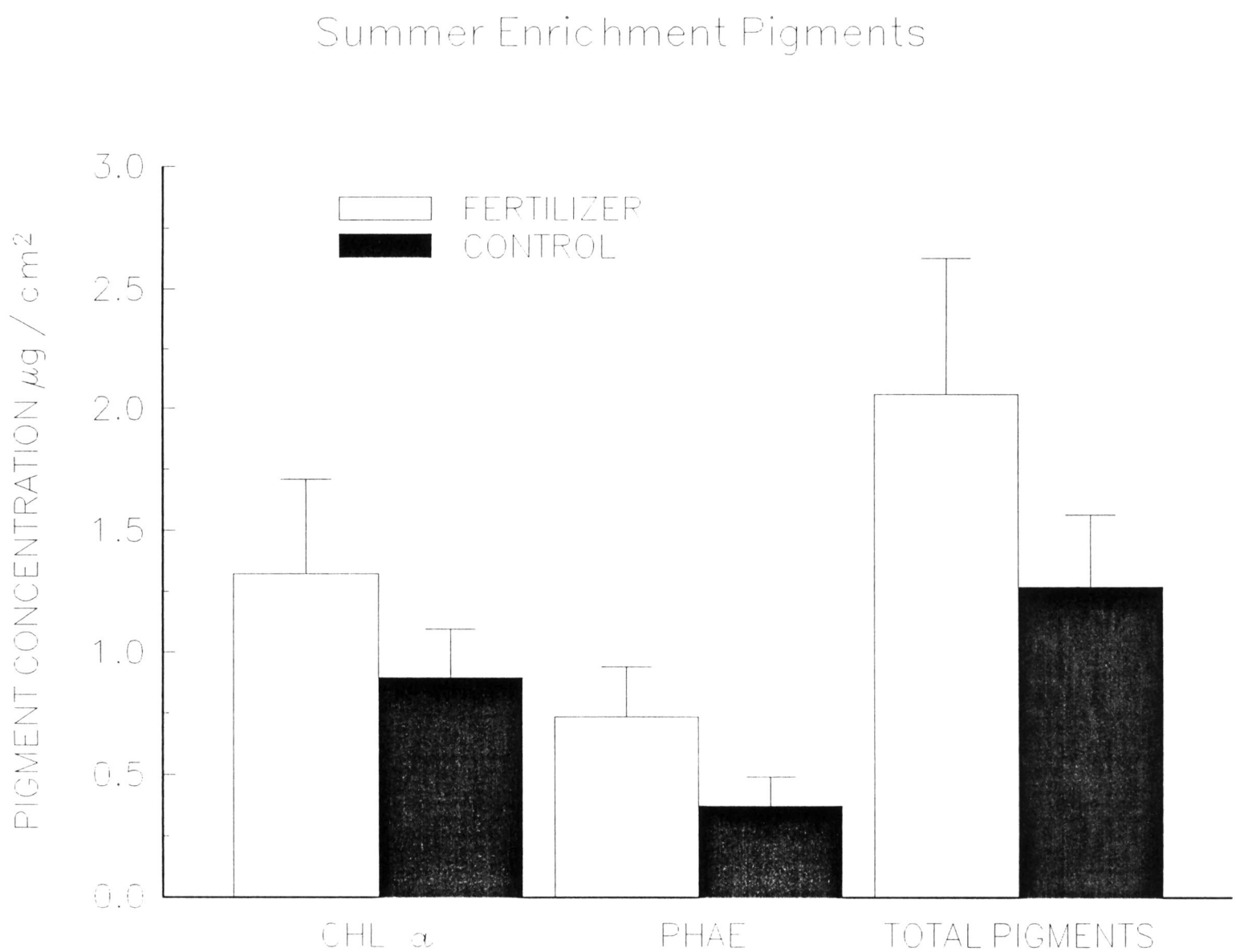
Table 13. Results of one-way ANOVA comparing abundant taxa between fertilizer and control trays collected during summer sampling at 10 m. Numbers represent mean density per m^2 (± 1 standard error) with n = 4. * = means are significantly different.

Taxa	Fertilizer	Control	P
Total Capitellidae	17291(7388)	3615(697)	.0432*
Opheliid sp. B	15405(2216)	10689(5056)	.2480
Total Opheliidae	21221(2769)	12575(6020)	.1584
Total Polychaetes	71522(7379)	38040(7910)	.0302*
Bivalve sp. A	13361(4389)	16977(3693)	.4875
Bivalve sp. B	14304(4298)	10689(3026)	.8246
Total Bivalves	35525(7375)	37254(7542)	.9179
Harpacticoid Copepods	58789(12128)	40241(8036)	.2350
Total Crustaceans	65391(12641)	45428(9366)	.2443
Nematodes	44485(10419)	30809(8999)	.3319
Flatworms	29552(6458)	28294(5115)	.9630
Total Other Fauna	143043(23918)	109562(24259)	.3358
Total Fauna	250090(26749)	184856(35292)	.2070
Deposit Feeders	140056(16907)	97772(16335)	.0403*
Suspension Feeders	4401(994)	3773(679)	.9668
Predators	98244(18479)	76866(16595)	.6699

Table 14. Results of one-way ANOVA comparing carbon and nitrogen between control trays collected during summer enrichment sampling at 10 m. Numbers represent percent C or N (± 1 standard error) with n = 4.

	Control	Fertilizer	P
C	.009(.006)	.015(.010)	.6144
N	.006(.003)	.006(.003)	1.000

Figure 8. Results of one-way ANOVA comparing pigment concentrations in control and fertilizer trays at 10 m during summer enrichment. Chl *a* p value = .4371, phaeopigment p value = .1709, and total pigment p value = .2947. n = 4 for each treatment. Error bars represent ± 1 standard error.


Summer Enrichment Pigments
FERTILIZER
CONTROL
PIGMENT CONCENTRATION µg / cm2
3.0
2.5
2.0
1.5
1.0
0.5
0.0
CHL a
PHAE
TOTAL PIGMENTS

DISCUSSION

Statistically insignificant differences between control trays at different distances for all taxa during spring and all but one group of taxa (infaunal predators) during summer, and the greater abundance of some taxa at the 10 m site than the 75 m site in control trays during the autumn sampling infer a seasonal influence of proximity to the hard-bottom on infaunal recruitment at 23 Mile Rock. These differences may be due in part to hydrodynamics associated with the hard-bottom and seasonal patterns of larval supply. The greater abundance of juvenile (recruited) infauna in algal (spring) and fertilizer (spring and summer) enriched trays infer that food-limitation may affect the success of infaunal recruitment in this system.

Underwater structures are known to affect the abundance of many organisms in surrounding communities. Decreased infaunal abundances have been observed near grass shrimp refuges (Posey and Hines, 1991), adjacent to seagrass beds (Summerson and Peterson, 1984), and near coral reefs (Ogden et al., 1973). Similarly, the abundance of adult organisms have been demonstrated to be significantly lower at sites closest to natural (Posey and Ambrose, 1994) and artificial reef structures (Posey et al., 1992; Ambrose and Anderson, 1990). These halos of low infaunal density surrounding reef

structures can sometimes be attributed to predation by fish (Posey and Ambrose, 1994). No significant differences in recruitment were observed between the 10 m site and the 75 m site during spring (Table 2) and only infaunal predators where significantly higher at the 10 m site during summer (Table 5), the high abundance of infauna observed at the 10 m site in control trays during autumn (Table 8) infers that a halo of increased recruitment exists near the scarp during autumn. These results indicate that if halos of decreased infaunal densities exist near the scarp they occur after settlement and recruitment events.

The observed increase in recruitment at the 10 m site in control trays compared to the 75 m site during the autumn experiment may be explained by hydrodynamics associated with the reef structure itself. Hydrodynamics are a major mechanism for larval dispersal and supply (Butman, 1987). Under water formations such as seagrass beds (Eckman, 1983), have been demonstrated to effect the recruitment of some infaunal species by influencing larval supply and dispersal. On a scale larger than 23 Mile area, the NC capes and cape-shoal structures produce downstream eddies in the Gulf Stream (Wolanski and Hamner, 1988) which may aggregate zooplankton (Alldredge and Hamner, 1988). These eddies may locally enhance larval supply and subsequent recruitment on the adjacent continental shelf. Therefore, it is possible

that during the autumn experiment, larvae in the water column and near the sediment surface may have become aggregated near the reef where they subsequently settled and survived until collected.

Grain size analysis also supports the hypothesis that hydrodynamics may influence recruitment. Results of the grain size analysis, in which the ambient or natural grain size at the 10 m site was finer than that at the 75 m site (Table 10), indicates that the 75 m site may be subjected to stronger currents. This may cause fewer larvae to settle at the 75 m site so recruitment is then observed to be lower. While, weaker currents at the 10 m site may create a depositional area there causing an increase in larval supply and subsequent recruitment. Also, those that settle at distances away from the scarp may be carried away due to a more dynamic current regime.

Temporal differences in larval supply of infauna, rather than spatial differences in larval supply may explain the differences in abundance among experimental times. A higher abundance of total infauna was observed in control trays at the 10 m site during autumn (Table 8) than in spring (Table 2) and summer (Table 5). These patterns allow one to infer that seasonal recruitment fluxes exist for infauna in shelf

sediments similar to those in near-shore communities. Although the exact timing of benthic infaunal recruitment is unpredictable, some annual cycles do exist. Feller et al. (1992) observed an annual recruitment cycle was present for polychaetes and bivalves in North Inlet, South Carolina. They showed that over a 5 yr period major peaks of planktonic polychaete larvae consistently occurred in the late summer. This planktonic peak was then followed by a peak of meiofaunal and macrofaunal polychaetes in the benthos. Bivalve abundance in the plankton of North Inlet peaked during mid summer and was followed by peak abundance of meiofaunal and macrofaunal bivalves during fall and winter.

Thus, infaunal recruitment success (results of larval supply, settlement, post-settlement mortality and juvenile immigration) near underwater formations may have a more profound effect upon community structure in autumn when larval supply is high, than in the spring and summer when larval supply is low and other community interactions, such as predation by fish, is a more important factor controlling community structure. The low total infaunal abundance in control trays during summer (Table 5) may be explained by low larval supply. Conversely, the high abundance of infauna in 10 m control trays in autumn (Table 8) may be explained by high larval supply due to seasonal cycles.

Seasonal patterns of food availability may also help to explain the recruitment patterns observed during this study. Laboratory and field studies suggest that some soft-sediment benthic communities are food-limited (Weinburg, 1979, Levinton and Bianchi, 1981; Cohen et al., 1984; Zajac, 1986) Post-settlement mortality events due to starvation may then limit the success of recruiting organisms and their subsequent adult populations (ólaffson et al., 1994). When an increase in infaunal abundance was observed in experimental trays (algal enriched, autumn 10 m control trays), relative to the other experimental trays or ambient plots sampled, it coincided with an increase in benthic pigment concentration.

Benthic pigment concentration and carbon was higher at the 10 m site than at the 75 m site during autumn in ambient plots and control trays, as was total infaunal abundance (Figure 6, Table 8). During late summer and early fall many of the macroalgae taxa on the hard-bottom die (Schneider and Searles, 1991). These algae are frequently seen drifting along and adjacent to the hard-bottom (personal observation). It is possible that the degrading algae and epiphytes associated with them supply food and nutrients not available at distances further away from the reef. Taxa such as nematodes, flatworms, copepods and deposit feeders

which are able to utilize the bacteria, microalgae and degrading algae found here were all in higher abundance in control trays at the 10 m site compared to those at the 75 m site (Table 8). Increases observed for predatory infauna such as syllid and dorvilleid polychaetes may then be explained by the increase in their prey species. Thus the enhanced recruitment present at 10 m from the hard-bottom during autumn sampling may be a factor of food availability caused by degrading macroalgae.

Increased recruitment for most taxa into algal enriched trays and increased recruitment for some taxa into fertilizer enriched trays compared to control trays support the hypothesis that food and nutrient availability can structure patterns of infaunal recruitment. Other studies have shown nutrients and organics to effect recruitment in salt marshes (Lee et al., 1977; Sardá et al., 1992), estuaries (Marsh and Tenore, 1990), and in the deep sea (Levin and Smith, 1984; Grassle and Morse-Porteous, 1987; Snelgrove et al., 1992; Snelgrove et al., 1994).

Most taxa which positively responded to the algal enriched treatment, such as the capitellid polychaetes (Table 11) are opportunistic species which are known to quickly colonize disturbed areas (Tsutsumi, 1990) and areas with high organics (Butman et al., 1988; Tsutsumi, 1990;

Tsutsumi et al., 1990). Such opportunistic species are capable of reaching reproductive maturity quickly and under going direct development (some in a matter of weeks). Thus, quickly colonizing an area where an available resource was previously limiting.

Results of the enrichment experiments also support the autumn results, such that, during autumn where an increase in food resources, [e.g. abundance of drift algae at the 10 m site], is observed, recruitment is higher in contrast to an area with less food input (75 m). During spring when no differences due to distance from the reef were observed in control trays or ambient plots, the abundance of total infauna in algal enriched trays was significantly higher than in control or ambient plot treatments. This suggests that larvae are present which can settle and may if the right condition exists (i.e. food). This indicates that seasonal food availability is a factor which controls patterns of recruitment and subsequent adult populations of benthic infauna in this system.

CONCLUSION

Recruitment in shelf sediments is very dynamic and is affected by a number of biotic and abiotic factors. Reef structures along the continental shelf tend to affect recruitment by influencing larval supply and post-settlement mortality events associated with food availability. Differences in hydrodynamics caused by the presence of reef structures may increase larval supply and subsequent recruitment near compared to distances further away. Food availability near these structures may also increase recruitment by reducing post-settlement mortality events. Whether the food input is from other areas or is directly supplied by the hard-bottom itself is not known. Seasonal patterns of larval supply do exist in this system and are similar to those observed in near-shore communities. The combined effects of hydrodynamics, larval supply, and food availability may explain the spatial and temporal patterns of recruitment at the scarp. The way in which larval supply and variation in food availability interact with one another will be a factor in controlling infaunal recruitment and subsequent adult community structure in this soft-bottom community.

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Appendix 1.
Summary of taxa, their feeding type and abundance, collected from all treatment types during each sample period. Abundance given for a taxa which has lower taxanomic levels is a sum of those lower taxon. Feeding types: D = deposit feeder, S = suspension feeder, and P = predator.

Taxon	Feeding type	% Abundance		
		Spring	Summer	Autumn
Annelida				
Polychaeta				
Capitellidae	D	7.84	6.03	0.15
sp. A	D	5.27	4.92	0.15
sp. A with spine	D	1.32	0.79	0.00
sp. A with egg	D	0.77	0.07	0.00
sp. B	D	0.48	0.26	0.00
Spionidae	D	1.10	1.28	0.32
sp. A	D	0.11	0.00	0.02
sp. B	D	0.02	0.23	0.00
sp. C	D	0.04	0.00	0.00
sp. D	D	0.16	0.12	0.05
Spiophanes sp. A	D	0.01	0.00	0.00
Spiophanes bombyx	D	0.32	0.09	0.00
Prionospio sp. A	D	0.13	0.32	0.08
Prionospio sp. B	D	0.12	0.37	0.17
Paraprionospio sp. A	D	0.12	0.12	0.02
Paraprionospio sp. B	D	0.03	0.02	0.00
Polydora spp.	D	0.02	0.00	0.00
Scolopeliss spp.	D	0.02	0.00	0.00
Opheliidae	D	7.03	6.71	0.56
sp. A	D	0.19	1.02	0.03
sp. B	D	6.43	5.20	0.48
sp. C	D	0.03	0.42	0.05
sp. D	D	0.01	0.00	0.00
Ophelina sp. A	D	0.23	0.00	0.00
Ophelina cylindricaudata	D	0.16	0.07	0.00
Syllidae	P	1.78	4.78	6.79
sp. A	P	0.50	0.16	0.83
sp. B	P	0.18	0.19	0.23
sp. C	P	0.01	0.00	0.05
sp. D	P	0.01	0.00	0.00
sp. E	P	0.02	0.00	0.02
Sphaerosyllis sp. A	P	0.15	0.09	0.26
juveniles	P	0.91	4.34	5.70

Appendix 1 Continued

Taxon	Feeding type	% Abundance		
		Spring	Summer	Autumn
Hesionidae	P	0.15	0.51	0.08
spp.	P	0.08	0.35	0.05
juveniles	P	0.07	0.16	0.03
Sphaerodoridae				
spp.	P	0.11	0.14	0.31
juveniles	P	0.00	0.00	0.32
Oweniidae				
spp.	D	0.20	0.14	0.08
Ampharetidae				
spp.	D	0.12	0.30	0.28
Cirratulidae				
spp.	D	0.29	0.46	0.35
Dorvilleidae	P	2.17	4.78	5.37
spp.	P	0.80	0.58	4.04
juveniles	P	1.37	4.20	1.33
Nereidae				
spp.	P	0.02	0.00	0.03
Nephtyidae				
spp.	P	0.05	0.00	0.00
Phyllodocidae				
spp.	P	0.04	0.00	0.05
Terebellidae				
spp.	D	0.01	0.49	0.00
Sabellidae	S	0.24	0.67	0.15
spp.	S	0.03	0.05	0.03
juvenile	S	0.21	0.63	0.12
Glyceridae				
spp.	P	0.01	0.12	0.12
Onuphidae	P	0.02	0.07	0.03
spp.	P	0.01	0.07	0.03
Diapatra spp.	P	0.01	0.00	0.00
Flabelligeridae				
spp.	D	0.08	0.12	0.00
Chrysopetalidae				
spp.	P	0.03	0.07	0.00
Magelonidae				
spp.	P	0.02	0.00	0.06
Maldenidae spp.	D	0.00	0.05	0.00
Mollusca				
Bivalvia				
Scallop	S	0.08	0.07	0.02
sp. A	D	1.05	6.54	0.28
sp. B	D	2.35	6.91	1.13
sp. C	D	2.28	3.09	0.45

Appendix 1 Continued

Taxon	Feeding type	% Abundance		
		Spring	Summer	Autumn
Mollusca				
Bivalvia				
sp. D	D	0.05	0.07	0.00
sp. E	D	0.02	0.02	0.08
sp. F	D	0.08	0.02	0.02
sp. G	D	0.03	0.05	0.03
sp. H	D	0.01	0.00	0.00
Gastropoda				
spp.	P	0.60	1.32	0.56
Crustacea				
Amphipoda	P	0.28	0.70	0.14
Isopoda	P	0.05	0.02	0.02
Ostracods	S	0.73	1.42	0.65
Harpacticoid Copepods	D	16.70	20.06	19.20
Penaeid shrimp	S	0.03	0.05	0.05
Mysid shrimp	S	0.00	0.02	0.03
Echinodermata				
Ophiuriodea spp.	P	0.08	0.09	0.09
Other				
Nematoda	P	37.45	17.40	43.50
Nemertean	P	0.32	0.19	0.71
Cecum	D	0.28	0.23	0.19
Hydriod	P	0.05	0.02	0.00
Anemone	P	0.03	0.00	0.00
Flatworm	P	10.87	11.51	15.57
Oligochetae	P	0.02	0.16	0.00
Sponge larvae	S	2.35	0.58	1.13