Studies Of Soft-Bottom Benthic Assemblages And Levels Of Contaminants In Sediments And Biota At Gray's Reef National Marine Sanctuary And Nearby Shelf Waters Off The Coast Of Georgia, 2000 And 2001.

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ABSTRACT

As part of an ongoing ecological characterization of Gray's Reef National Marine Sanctuary (GRNMS) and nearby shelf waters, surveys of soft-bottom benthic community characteristics, contaminant levels in sediments and biota, and other habitat conditions were conducted during spring 2000 and 2001. The first survey was conducted at 20 stations within the sanctuary to document baseline environmental conditions. The second survey was conducted at 20 stations, including a subset of Year-1 stations within the sanctuary and a new series of inner-shelf stations positioned along three cross-shelf transects of five stations each. These transects provide a means to examine spatial patterns in the measured environmental variables in relation to both natural factors (e.g., depth) and potential anthropogenic factors (e.g., proximity to land-based sources of contaminants). An important goal of this work has been to determine the extent to which land-based sources of pollutants and other materials are transported through river systems to the offshore shelf environment, inclusive of GRNMS, and the potential effects that these materials may have on biological resources along the way. A significant finding from the first year of sampling was the presence of trace concentrations of pesticides and other man-made chemicals in both sediments and biota within GRNMS, which demonstrated that these materials are capable of making their way to the offshore sanctuary environment (albeit at low concentrations not likely of being associated with adverse bioeffects). Results of the spring 2001 survey reveal cross-shelf patterns in both benthic communities and trace concentrations of chemical contaminants in sediments.

INTRODUCTION

A series of studies was initiated to assess the condition of benthic macroinfauna and chemical contaminant levels in sediments and biota of the Gray's Reef National Marine Sanctuary (GRNMS) and nearby shelf waters off the coast of Georgia. Benthic research in the sanctuary by previous investigators has focused largely on live-bottom assemblages associated with rocky outcrops. In contrast, there has been limited work on the ecology of unconsolidated sandy substrates, which characterize the majority of the seafloor within the sanctuary and surrounding continental shelf. The soft-bottom benthos is a key component of coastal ecosystems, playing vital roles in detrital decomposition, nutrient cycling, and energy flow to higher trophic levels. Moreover, because of their relatively stationary existence within the sediments, benthic infauna (Fig. 1) can serve as reliable indicators of potential environmental disturbances to the seafloor.

Key objectives of the research are: (1) to document existing environmental conditions within the sanctuary in order to provide a quantitative benchmark for tracking any future changes due to either natural or human disturbances; (2) to examine broader cross-shelf spatial patterns in benthic fauna and sediment contaminant concentrations and to identify potential controlling factors associated with the observed patterns; (3) to assess any between-year temporal variability in benthic fauna; and (4) to evaluate the importance of benthic fauna as prey for higher trophic levels. Such questions are being addressed to help fulfill long-term science and management goals of the GRNMS. However, it is anticipated that the information will be of additional value in broadening our understanding of the surrounding South Atlantic Bight (SAB) ecosystem and in bringing the knowledge to bear on related resource-management issues of the region.

Figure 1. Examples of dominant macroinfaunal species at GRNMS.

Figure 2. Sampling design. Station numbers are shown for sites sampled in spring 2001. Station numbers for sites sampled in spring 2000 are identified below.

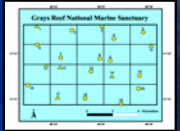

Figure 3. Station locations within GRNMS. Stations were randomly selected within each of the 20 cells (2.9 km² each). All stations were sampled in spring 2000 and ones with triangles were resampled in spring 2001.

METHODS

The study was designed around a two-year field effort with one sampling event in each year. The first cruise was conducted April 3-7, 2000 (NOAA Ship FERREL Cruise FE-00-06-GR) and the second was conducted April 29-May 5, 2001 (NOAA Ship FERREL Cruise FE-01-08-MA: Leg 1).

To address Year-1 objectives, 20 stations were established all within the sanctuary boundaries (Fig. 2 and 3). A random sampling design was applied to support probability-based estimates of the percentage of area with degraded versus non-degraded condition relative to various measured environmental indicators. The resulting sampling framework is a 58-km² grid of 20 individual cells, each of which is 2.9 km², and which together are representative of the total area of the sanctuary (Fig. 3). One station was randomly located within each cell.

The second year of sampling (spring 2001) included additional sites outside the sanctuary in nearby inner-shelf areas (Fig. 2). Sampling was conducted at a total of 20 stations: three cross-shelf transects of five stations each, including one of the previous Yr-1 stations within the sanctuary (Station 12) serving as the seaward end of the middle transect; and five additional Yr-1 stations within the sanctuary boundaries (Stations 1, 10, 11, 14, and 17).

During both years, samples were collected at each station for characterization of general habitat conditions (depth, temperature, salinity, pH, dissolved oxygen, total organic carbon, grain size), concentrations of sediment contaminants (metals, pesticides, PCBs, PAHs), diversity and abundance of macroinfauna (> 0.5 mm), and aesthetic quality (presence of anthropogenic debris, visible oil, noxious sediment odor, and water clarity based on secchi depths). During the first year, samples of benthic and demersal fauna (the turkey wing arc shell *Arca zebra* and black sea bass *Centropristis striata*) also were collected in selected areas (by divers for the molluscs and by fish traps for the bass) and analyzed for concentrations of chemical contaminants in tissues. Sediment samples for macroinfaunal analysis were collected at each station in triplicate using a 0.04 m² Young grab sampler. Each replicate was sieved in the field through a 0.5-mm mesh screen and preserved in 10% buffered formalin with rose bengal. All infaunal samples were transferred to 70% ethanol once in the laboratory. Animals were sorted from sample debris under a dissecting microscope and identified to the lowest practical taxon (usually to species). The upper 2 – 3 centimeters of sediment from additional multiple grabs were taken at each station, combined into a single station composite, and then subsampled for analysis of metals, organic contaminants (PCBs, pesticides, PAHs), total organic carbon (TOC), and grain size, duplicates were run at ~10% of the stations for quality control purposes. A total of 12 inorganic metals, 25 polynuclear aromatic hydrocarbons (PAHs), 26 polychlorinated biphenyls (PCBs), and 21 pesticides were measured at each station.

Sediment quality guidelines (SQG) for each corresponding chemical were used (where available) to help in interpreting the biological significance of the observed contaminant levels. Two types of SQGs were used: (1) Effects Range-Low (ERL) and Effects Range-Median (ERM) values; and (2) Threshold Effects Level (TEL) and Probable Effects Level (PEL) values. ERL and TEL values are both lower-threshold bioeffect limits, below which adverse effects of the contaminants on sediment-dwelling organisms are not expected to occur. In contrast, ERM and PEL values both represent mid-range concentrations of chemicals above which adverse effects are more likely to occur. Concentration-to-SQG comparisons were based on the lower ERL and upper ERM values for most chemicals; in some cases, however (e.g., where updated ERL and ERM values were not available), the alternative TEL and PEL values were used.

ACKNOWLEDGEMENTS

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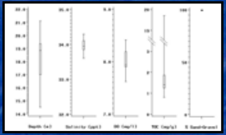

Figure 4. Key habitat characteristics at GRNMS in April 2000 (n = 20 sites). Boxes are interquartile ranges, horizontal lines within boxes are medians and wisker endpoints are high/low extremes. Note in the last plot that values of % sand-gravel fall within a very narrow range of 99-100%.

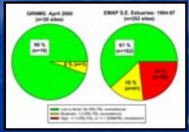

Figure 5. Comparison of sediment contamination (% area) at GRNMS during the present study (April 2000) vs. southeastern estuaries sampled during EMAP (unpublished data from J. Hyland, NOAA).

Figure 6. All measured analytes in tissue samples collected in April 2000 (10 black sea bass, 9 ark shell composites; pictured above) were below human-health guideline values.

Table 1. Characteristics of benthic macroinfauna (> 0.5mm) at stations sampled in GRNMS, April 2000. Three replicate grabs (0.04m² each) were taken at each station.

Station	Mean No. Taxa (per grab)	Total No. Taxa[a]	Mean Density (No./m²)	H' Diversity[b]
1	32	66	2542	4.96
2	58	113	5775	5.11
3	53	102	5217	5.25
4	32	96	4492	5.29
5	57	98	4083	5.61
6	31	62	2617	4.39
7	32	57	2233	4.86
8	59	117	9850	4.28
9	41	84	3125	5.16
10	64	115	7967	4.82
11	34	71	6650	2.37
12	49	96	5933	4.52
13	40	81	40642	0.82
14	45	89	50258	0.71
15	46	94	4300	4.78
16	27	53	1642	4.88
17	42	80	3608	3.59
18	41	85	5900	3.64
19	47	91	1858	4.91
20	45	86	423	5.32

a. Grand total from all 20 stations = 349 taxa.
b. Calculated using base 2 logarithms.

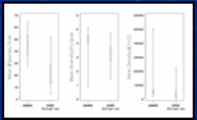

Figure 7. Comparison of benthic species richness, diversity and abundance at GRNMS sites sampled in April 2000 (n = 20) vs. estuarine sites of similar salinity (> 30 ppt) in EMAP Carolinian Province (n = 38). Boxes are interquartile ranges, horizontal lines within boxes are medians and wisker endpoints are high/low extremes. Base 2 logarithms were used to calculate H'.

Table 2. Dominant macroinfaunal species at GRNMS (April 2000) contributing to >= 1% of total species abundance individually and to 75% of cumulative % abundance collectively.

Taxon	Group	Average Density (#/m²)	% of Total Abundance	Cum % Abundance	% Station Occurrence
Ervilia sp. A*	Bivalve	4938	55.9	55.9	75
Caecum johnsoni	Gastropod	301	3.4	59.3	95
Crassinella lunulata	Bivalve	268	3.0	62.4	100
Branchiostoma spp.	Chordate	251	2.8	65.2	95
Aspidosiphon muelleri	Sipunculid	218	2.5	67.7	95
Spiophanes bombyx	Polychaete	164	1.9	69.5	100
Spio pettiboneae	Polychaete	158	1.8	71.3	100
Oxyurostylis smithi	Cumacean	155	1.7	73.0	100
Ophiuroidea	Ophiuroid	125	1.4	74.5	90
Actiniaria	Anthozoan	102	1.2	75.6	80

* Possible new subspecies of *Ervilia concentrica*.

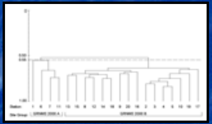

Figure 8. Dendogram resulting from clustering of stations sampled within GRNMS in 2000, using group-average sorting and Bray-Curtis similarity. Samples within each station are combined over all 3 replicates. A similarity level of 0.55 (dotted line) was used to define the two major site groups.

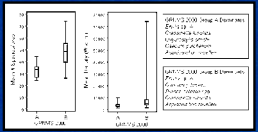

Figure 9. Comparison of benthic species richness (# species/grab), abundances (#/m2), and dominants at GRNMS 2000 site groups A vs. B. For the # species and abundances: boxes are interquartile ranges, horizontal lines within boxes are medians, and wisker endpoints are high/low extremes.

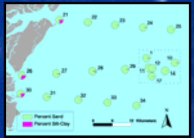

Figure 10. Cross-shelf patterns in % silt-clay vs. sand content of sediment, based on spring 2001 data.

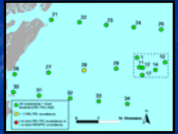

Figure 11. Summary of chemical contaminants concentrations in sediments (spring 2001) relative to sediment quality guidelines (SQG).

Figure 12. Cross-shelf patterns in chemical contaminant levels expressed as mean ERM quotients. Data are from spring 2001.

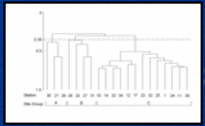

Figure 13. Dendogram resulting from clustering of stations sampled in spring 2001, using group-average sorting and Bray-Curtis similarity. Samples within each station are combined over all 3 replicates. A similarity level of 0.35 (dotted line) was used to define the major site groups.

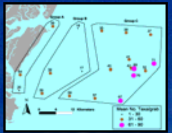

Figure 14. Comparison of species richness (mean no. taxa/grab) among the three site groups (Spring 2001).

Table 3. Comparison of benthic characteristics by site group (spring 2001): P = polychaete, G = gastropod, B = bivalve, C = crustacean, O = oligochaete, E = echinoderm, and Ch = Chordate.

Site Group	Taxa	Dominant Fauna: Ind. m⁻²	Cumulative %	Frequency %	Mean Abundance (m⁻²)[a]	Mean No. taxa/grab	Mean H'/grab[b]	Total No. Taxa
A	*Mediomastus* spp. (P)	15875	31	67	17192	41	3.28	189
	Polycirrus eximius (P)	9958	50	67				
	Tharyx acutus (P)	5650	61	67				
	Streblospio benedicti (P)	2833	67	100				
	Mediomastus ambiseta (P)	2092	71	67				
	Spiophanes bombyx (P)	1825	74	100				
	Tubificidae (O)	1458	77	100				
	Exogone rolani (P)	1158	79	67				
	Eumida sanguinea (P)	1125	81	67				
	Mediomastus californiensis (P)	1017	83	100				
B	*Mediomastus* spp. (P)	4513	26	60	5860	31	2.75	143
	Spiophanes bombyx (P)	1856	36	100				
	Owenia fusiformis (P)	1600	45	60				
	Oxyurostylis smithi (C)	1594	54	100				
	Mediomastus ambiseta (P)	900	60	60				
	Tellina spp. (B)	500	62	80				
	Asteroidea (E)	450	65	80				
	Phoxocephalidae (C)	331	67	60				
	Prionospio cristata (P)	306	69	60				
	Rhynchocoela	288	70	100				
C	*Caecum johnsoni* (G)	1735	8	100	7382	54	3.60	382
	Fabricinuda trilobata (P)	1421	14	23				
	Protodorvillea kefersteini (P)	1175	20	92				
	Tubificidae (O)	1129	25	100				
	Branchiostoma spp. (Ch)	1083	30	92				
	Spiophanes bombyx (P)	975	34	100				
	Crassinella duplinana (B)	717	37	92				
	Parapionosyllis longicirrata (P)	587	40	92				
	Sphaerosyllis piriferopsis (P)	577	42	54				
	Erichthonius brasiliensis (C)	525	45	62				

a. All species combined, averaged over all replicates and stations within a site group.
b. Calculated using base 2 logarithms.

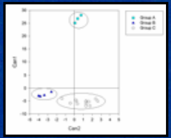

Figure 15. Separation of site groups (spring 2001) on the first and second canonical function derived from canonical discriminant analysis performed on abiotic environmental variables. Can 1 = first canonical function (98% of variability). Can 2 = second canonical function (2% of variability).

Table 4. Summary of abiotic environmental variables by site group (spring 2001). Included are the site group means and univariate test statistics for significance of among-group differences (df = 2, 17 for F statistics).

Variable	Site Group Means: A	B	C	F Statistics: F Value	Pr > F
Depth (m)	8.1	9.2	14.7	13.81	0.0003
Temperature (°C)	21.8	20.3	19.4	38.38	< 0.0001
DO (mg/L)	7.3	7.3	7.2	0.16	0.8538
pH	7.9	7.9	7.9	3.05	0.0738
% Silt-Clay	24.2	1.6	0.4	320.39	< 0.0001
Mean ERM Quotient	0.010	0.012	0.006	14.47	0.0002
phi (Median Particle Size)	1.95	2.08	1.03	9.20	0.0020
TOC (mg/g)	4.6	3.7	2.3	8.52	0.0570
Salinity (‰)	29.9	34.5	35.6	3.41	0.0027
Distance from Shore (km)	2	11	28	39.43	< 0.0001

Table 5. Total structure coefficients (TSC) of abiotic environmental variables on the first two canonical functions associated with variations among site groups. Coefficients considered important in each function are underlined.

Variable	TSC: Can1	Can2
Depth	-0.580	<u>0.605</u>
Temperature	0.861	-0.324
Salinity	-0.705	0.091
TOC	0.453	0.325
% silt-clay	<u>0.990</u>	0.050
Mean ERM Quotient	0.328	-0.819
Phi	0.426	<u>-0.660</u>
Distance from Shore	-0.735	0.570

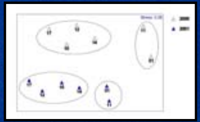

Figure 16. Results of non-metric, two-dimensional MDS ordination on the Bray-Curtis similarity matrix of double square-root transformed species abundance data from six GRNMS stations sampled in spring 2000 and 2001. Sampling points similar at Bray-Curtis similarity of ≥ 0.6 are encircled.

CONCLUSIONS

2000

- In general, chemical contaminants in sediments throughout the sanctuary are at background levels, below probable bioeffect guidelines. Trace concentrations of man-made pesticides (DDT, chlorpyrifos) and other chemical substances from human sources (PCBs, PAHs) were detected in these sediments, though not at concentrations likely to cause significant bioeffects.
- Contaminants in tissues of target benthic species are below human-health guidelines (where available) based on a limited sample population (10 fillets of black sea bass and 9 arc-shell composites). Similar to results for sediments, tissues of both species contained trace concentrations of additional chemical contaminants associated with human sources (pesticides, PCBs, PAHs).
- The vast stretches of sands throughout the sanctuary support a highly diverse and abundant infaunal community. Measures of diversity (number of species and H'), for example, are about twice as high as those observed for the benthos in neighboring estuaries of comparable high salinity.
- At present, zero % of the sanctuary area shows any significant evidence of impaired benthic condition coupled to adverse levels of chemical contaminants in sediments. However, the presence of trace concentrations of pesticides, PCBs, and PAHs in both sediments and biota demonstrate that chemical substances originating from human activities are capable of reaching the offshore sanctuary environment and thus should be monitored to ensure that future problems do not develop.

2001

- In general, chemical contaminants in sediments of the surrounding inner-shelf sampling area appeared to be at low background levels, similar to conditions observed within the sanctuary during the previous year. Importantly, there was a general pattern of decreasing concentrations with increasing distance from shore, thus suggesting possible outwelling of these materials from inland sources through the coastal sounds.
- There were distinct cross-shelf patterns in the structure and composition of benthic fauna. Variations in the fauna appeared to be associated with the sediment characteristics (% silt-clay and median particle size) and other factors related to distance to shore (e.g., depth). Additional unmeasured controlling factors also related to distance from shore may be contributing to these patterns.
- There also were notable cross-shelf differences in species diversity. Stations furthest offshore in Group C had the greatest numbers of species. This result supports the view that the sanctuary, and probably much of the offshore South Atlantic Bight region, is an important reservoir of marine biodiversity.
- Additional finer-scale spatial variations in benthic fauna were detected among stations within the sanctuary boundaries and may be related to differences in the proximity to live-bottom habitat. However, any such spatial variability in benthic fauna within the sanctuary is less pronounced than the broader spatial patterns observed across the shelf.
- Minor differences in benthic community structure were detected between sampling periods (spring 2000 vs. spring 2001) at sites within GRNMS. As for the interpretation of small-scale spatial variability, it is important to recognize that such variability is much less pronounced than the broader spatial patterns observed across the shelf. Albeit small, such temporal variability will need to be taken into account in any future efforts to monitor potential long-term environmental changes due to human or natural disturbances.