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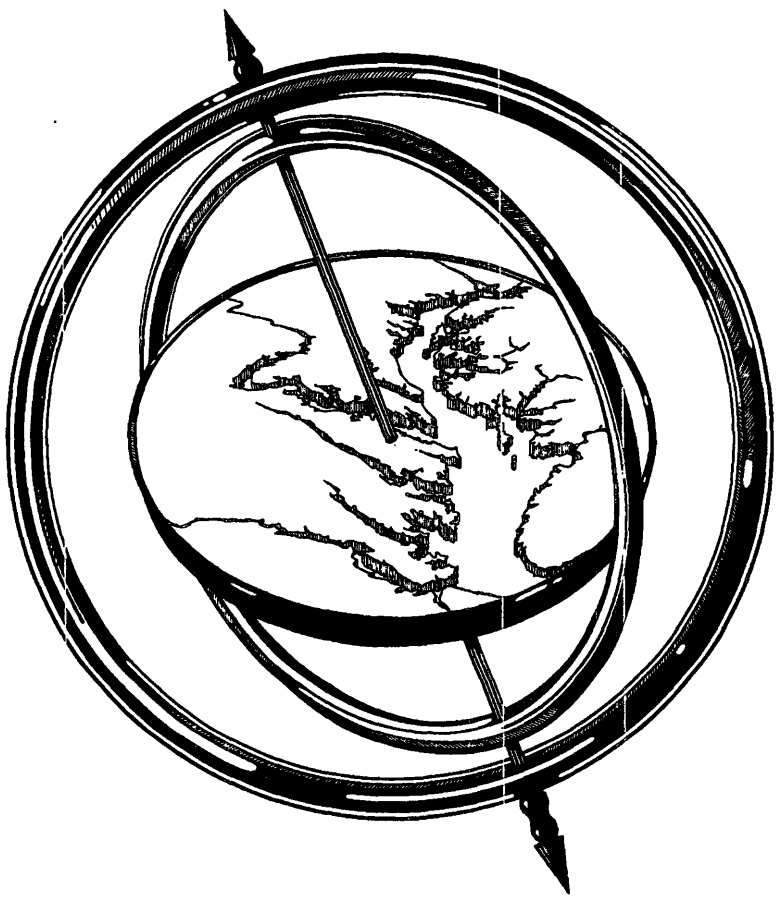

Toward a Sustainable Coastal Watershed: The Chesapeake Experiment

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Sediment Characteristics and Inorganic Fluxes Associated with Vegetated and Nonvegetated Subtidal Habitats of the Goodwin Islands, Virginia

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Abstract: The Goodwin Islands Ecosystem is a National Estuarine Research Reserve location and consisting of about 200 ha of intertidal mudflat and marshes surrounded by about 600 ha of vegetated and nonvegetated subtidal habitats extending to the -2.0 m depth contour. It is hypothesized that vegetated subtidal and intertidal habitats are seasonal sources of oxygen and fixed carbon and sinks for inorganic nutrients while sediments represent longer- term carbon storage for the ecosystem as a whole. This study focuses upon subtidal sediment microalgal distribution and biomass, sediment organic and inorganic content, and sediment/water oxygen and nutrient exchange processes in vegetated and nonvegetated habitats. Sediments and microalgae are sampled according to a stratified randomized design and flux measurements are performed on large, intact sediment/water cores. Preliminary analysis of sediment characteristics and microalgal biomass shows great spatial variability over the subtidal environment and seasonal flux studies have supported the source/sink hypothesis. Nonvegetated subtidal habitats appear to contain sufficient sediment microalgal biomass to maintain autotrophic status throughout much of the year. Sampling of subtidal and intertidal sediment characteristics and microalgal biomass will continue during 1994. The results of this study will be compared to simulated sediment stocks and processes derived from a dynamic spatial model of ecosystem primary production being developed for the Goodwin Islands ecosystem.

INTRODUCTION

The Goodwin Islands National Estuarine Research Reserve is a pristine, polyhaline littoral ecosystem in lower Chesapeake Bay that includes intertidal marshes and mudflats surrounded by a wide, partially vegetated subtidal shoal that extends to the -2.0 m depth contour (MLW). The subtidal shoal constitutes almost 70% of the entire ecosystem area (810 ha) and supports eelgrass (*Zostera marina L.*), widgeongrass (*Ruppia maritima*), macroalgae, and sediment microalgal communities with variable distribution and production. Tidal advection, sediment organic decomposition, and water column heterotrophic regeneration provide inorganic nutrients for the primary productivity of the macrophytes, sediment algae, and phytoplankton (Fisher et al. 1982, Rizzo 1990). Sediment/water inorganic exchanges are a primary mechanism of linking sediment and water column processes in estuaries and can be more seasonally variable than either primary or secondary production (Asmus 1986). Physical factors such as insolation, wind, and tidal currents and biological processes such as autotrophic uptake and nitrification/denitrification influence the sediment and water concentrations of inorganic nutrients (Asmus 1986, Rizzo 1990). Sediments with sufficient insolation to support rooted macrophytes and microalgal communities are often net autotrophic (Asmus 1986, Rizzo 1990). Approximately 38% of the subtidal York River estuary is less than the historical -2.0 m depth maximum for eelgrass survival and maintains a photic sediment environment (Rizzo 1990).

OBJECTIVE

The primary objective of this study was to investigate seasonal and spatial variability in

sediment characteristics and sediment/water inorganic exchanges for the subtidal environments of the Goodwin Islands Ecosystem. This study is part of two larger studies on spatial and temporal processes over the various habitats of the Goodwin Islands ecosystem. One study utilized continuous, platform sampling of water column variables such as temperature, light, and nutrients to analyze seagrass habitat criteria (Moore and Goodman, 1995). The other study employs a hypsometric approach to integrate modelling, geographic, and field data in the analysis of intertidal and subtidal pattems and productivity. The data presented in this paper were collected during spring and summer 1993.

METHODS

An area approximately 200 m x 1000 m from nearshore to farshore was divided into 260 numbered grids. This area encompassed the monitoring platforms of the Moore and Goodman intensive study (figure 1). Three primary habitats (farshore nonvegetated, eelgrass meadow, nearshore partially vegetated) were delineated within the grids and used as individual strata for a stratified random sampling design in order to determine overall sediment characteristics and *chlorophyil a* (Chla) (concentrations. Four replicate cores (5.6 cm ID x 10.0 cm) for sediment characteristics and 5-7 replicate cores (2.4 cm ID x 1.0 cm) for sediment chl a (were randomly selected from each of the three strata during May/June and August 1993. The large sediment cores were extruded and sectioned into 0-2, 2-5, and 5-10 cm increments. Increment fractions were then either weighed wet, dried at 60° C, and combusted and weighed again to determine water and organic contents or were extracted in 2 N KCI for 10 minutes for nutrient analysis. The centrifuged and filtered extracts were analyzed for total extractable $NH4^+$ in nmol gdw^{-2} I using the phenolhypochlorite technique. Total extractable NO_{x-} (NO_{3-} + $N0_{2-}$) was determined using a Alpkem AutoAnalyzer (APHA 1992). The small cores were extruded and sectioned into 0-2, 2-5, and 5-10 mm sections using a microsectioning device. The sections were placed into scintillation vials, frozen overnight, and then extracted with 10 ml of a 4.5:4.5:1 solution of methanol: acetone: water (Pinkney et al. in press). The sections were kept in a dark freezer and shaken daily until the third day. The concentration of chl*a* (and total phaeopigments were determined in filtered extracts by measuring the absorbances at 750 and 665 nm before and after acidification with 10% HCI (Lorenzen 1967).

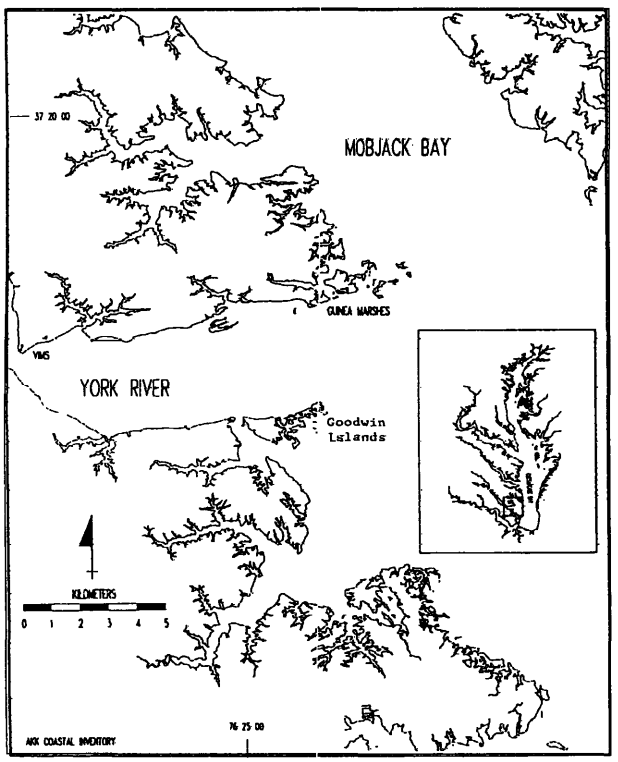

Figure 1. Location map of the Goodwin Islands in the lower York River.

Seasonal subtidal sediment/water inorganic exchange studies (SONE) were also conducted to quantify vertical fluxes and identify community trophic status. Within the seagrass habitat, 3-5 large cores (I 1.6 cm ID x 15 cm) were selected from each of vegetated and nonvegetated patches. The water overlying the sediment within a core was replaced with filtered, partially degassed water from the field site. These cores were placed in a flowing seawater bath of the outdoor mesocosms at the Virginia Institute of Marine Science (VIMS) at Gloucester Point, Virginia. The cores were stirred using battery-powered submersible motors and were incubated for 4-6 daylight hours. Dissolved oxygen and inorganic nutrients in the overlying water were sampled hourly. Oxygen was measured using an Orbisphere Oxygen probe while aqueous nutrients were analyzed using the colorimetric methods previously described. Concentrations in gmoles L^{-1} were multiplied by overlying water volume to derive mass (limoles) and then divided by core surface area (0.0105) to derive units of li moles m^2. The concentrations were then

plotted over time using linear regression to determine the slope (or rate of change) in gmoles $m^2 hr^{-1}$.

RESULTS

Table 1 provides an overview of the subtidal sediment characteristics during spring and summer 1993. In both May/June and August 1993, sediment/ water and organic content decreased with distance from the shoreline. Sediment organic content was highest in nearshore areas (1.86% and 1.48 % during May/June and August, respectively). Within each season, total extractable NH^{4+} was greatest in the eelgrass meadow (table 1). The spring sampling occured at the time of greatest eelgrass biomass in Chesapeake Bay and NH_{4+} concentrations were higher than during the summer (86.17 versus 34.06 nmol gdw-I). During May/June 1993, total extractable NO^{x-} was greatest in the eelgrass meadow (1.22 nmol gdw-1) although the nonvegetated sediment concentration was similar (1.06 nmol gdw^{-1}). The nonvegetated sediment concentration was highest in August 1993 (0.93 nmol gdw^{-1}) and the concentration for each sediment type was less than measured in May/June 1993. Sediment chl*a* (concentrations were similar among nonvegetated, eelgrass, and nearshore partially vegetated sediments in both May/June (41.06, 36.49, 30.96 Mg m^{-2}) and August 1993 (23.85,29.81,30.11 Mg m^{-2}).

The net exchanges of NH_{4+}, NO_{x-}, and $P0_{-3}$ for the vegetated and nonvegetated subtidal sediments for May/June and August 1993 are shown in figures 2 and 3. Vegetated sediments in May/June experienced a net production of NH4+ while NO_{x-} and $P0_{-3}$ were removed from the water column (figure 2). The NH_{4+} efflux was perhaps a function of the high NH_{4+} concentrations measured in the eelgrass sediments during this time (table 1) and was significantly different than the NH^{4+} uptake experienced by the non- vegetated sediments (figure 2). $P0_{-3}$ immobilization was greater in the vegetated sediments than the nonvegetated sediments during the incubation period (figure 2). During the August 1993 experiment both the vegetated and non-vegetated sediments removed NH_{4+}, NO_{x-}, and $P04_{-3}$ from the overlying water.

DISCUSSION

The Goodwin Islands ecosystem includes a wide subtidal shoal that is sandy offshore and progressively more organic over a gradient that leads inevitably to a peaty intertidal marsh (table 1). Sediment microalgal chl*a* (concentrations are consistent over the spring, sunmer, and fall (table 1 and Buzzelli unpublished data) while eelgrass is abundant primarily in the late spring. Eelgrass communities have the capacity to trap organic matter, which leads to enhanced sediment

Table 1. Subtidal sediment charateristics for the Goodwin Islands ecosystem nonvegetated farshore, eelgrass meadow, and partially vegetated nearshore habitats during spring and summer 1993. Values are 0-10 cm means ± SE. Concentrations of total extractable NH_{4+} and NO_{x-} (nitrate + nitrite) are reported in nmol gdw^{-1}. Values for Chl*a* are 0-1.0 cm ± SE and are reported in mg m^{-2}.

	$\%H_2O$	%Organic Matter	NH_4^+ nmol gdw^{-1}	NO_x^- nmol gdw^{-1}	Chla mg m^{-2}
MAY/JUNE 1993					
NonVeg Farshore	21.65±0.20	0.83±0.13	43.45±6.98	1.06±0.30	41.06±4.86
Eelgrass Meadow	26.52±1.39	1.14±0.15	86.17±10.92	1.22±0.20	36.49±5.70
PartVeg Nearshore	29.65±1.76	1.86±0.14	34.03±3.85	0.59±0.21	30.96±1.83
AUGUST 1993					
NonVeg Farshore	18.80±0.48	0.35±0.02	19.86±3.29	0.93±0.13	23.85±2.04
Eclgrass Meadow	21.45±0.63	0.78±0.10	34.06±3.37	0.76±0.08	29.81±2.80
PartVeg Nearshore	24.03±0.52	1.48±0.09	24.27±4.38	0.13±0.03	30.11±6.94

nitrogen concentrations. The eelgrass meadow sediments in 1993 contained higher concentrations of NH_{4+} than either farshore or nearshore nonvegetated habitats (table 1). The increased concentration may be responsible for the net NH_{4+} efflux measured from the vegetated sediments during May/June 1993 although NH4+ exchanges vary widely with microbial metabolic processes such as remineralization, nitrification, and denitrification (Asmus 1986). This is the only example provided here of NE_{4+} efflux as all the other cases resulted in sediment uptake of inorganic N and P (figures 2 and 3). Although calculations are often performed to show the potential for sediment nutrient regeneration to support water column primary production (Fisher et al. 1982, Rizzo 1990), studies involving photic sediments often result in net nutrient flux into the sediment (Asmus 1986, Rizzo 1990). The use of microcosms influences the interpretation of the results as ambient physical factors such as wind and tidal mixing were excluded. Physical processes can sometimes mask the predominant biogeochemical exchanges in the environment (Fisher et al. 1982; deJonge and Colijn 1994) and the Goodwin Islands is a relatively open system (figure 1).

Sediment microalgae are significant components of shoal biogeochemical processes owing to their wide distribution, nutrient uptake capacity, productivity, vertical m-igration, and resuspension (Asmus 1986, Rizzo 1990, dejonge and Colijn 1994). Seasonal to annual mean sediment chl*a* is proportional to primary production based upon the C:Chl a (ratio (deJonge and Colijn 1994). The Goodwin Islands ecosystem is approximately 800 ha in size and includes nonvegetated and vegetated subtidal and intertidal habitats, all containing sediment microalgal communities (Buzzelli unpublished data). Microalgae occupy a 1-5 cm surface sediment layer in which to migrate and regulate their physiology, and this surface layer probably plays an important role in the vertical exchanges of inorganic nutrients between deeper sediment layers and the overlying water column. More research is needed on the effects of sediment microalgae upon shoal water column productivity and biogeochemical cycling.

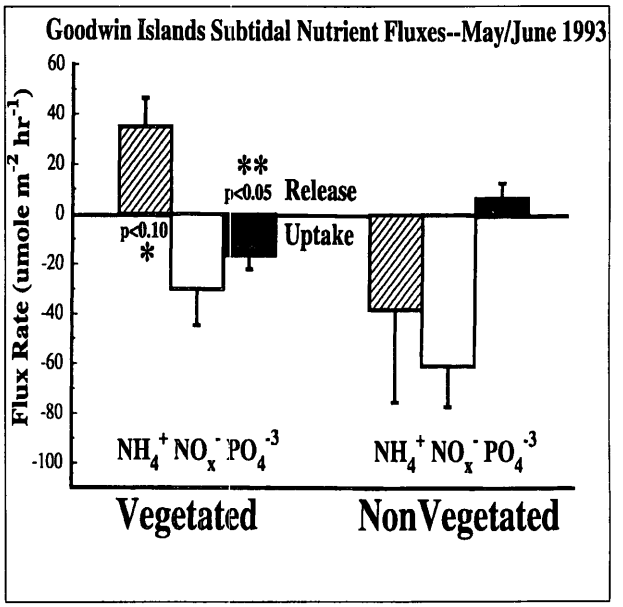

Figure 2. Flux results for May/June 1993. A positive flux value (umoles @ 2 hr^{-1}) indicates a net release of the nutrient from the sediment while a negative flux denotes uptake by the sediment.

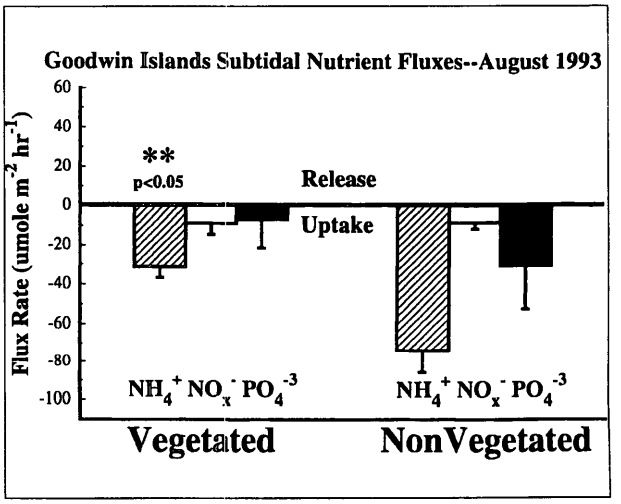

Figure 3. Flux results for August 1993. A positive flux value (umoles $m^{-2}hr^{-1}$) indicates a net release of the nutrient from the sediment while a negative flux denotes uptake by the sediment.

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