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CHEMICAL INTERACTIONS BETWEEN SEAGRASSES AND CARBONATE SEDIMENTS

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ABSTRACT

While the importance of the role that seagrasses play in maintaining sediment stability is well documented, little is known of the chemical interactions between sediments and seagrasses. A series of studies was established on San Salvador Island, Bahamas to determine selected interactions between seagrasses and the chemical composition of carbonate sediments. Sediments supporting seagrasses (predominately, *Thalassia* and *Syringodium*) contained significantly ($P < 0.05$) higher concentrations of magnesium, potassium, organic matter and chloride, and significantly lower concentrations of sulfate than sediments without seagrasses. Calcium and iron concentrations in the sediments were not affected by the presence of seagrasses. It was also observed that *Thalassia* tended to alter sediment chemistry more than *Syringodium*. A near pure stand of *Thalassia* induced increases in magnesium, potassium; organic matter and chloride while a pure stand of *Syringodium* increased organic matter and chloride levels.

A large number of correlations were determined between sediment chemistry, and *Thalassia* and *Syringodium* biomass, acetylene reduction (an estimate of nitrogen fixation), tissue nitrogen concentrations and tissue carbon concentrations. Generally the two species were significantly correlated to the same sediment parameters. However, their orientation, i.e. positive or negative, were opposite. For example, biomass of *Thalassia* was directly correlated to sediment calcium and inversely correlated to magnesium and chloride concentrations. Similar significant, but opposite, correlations were noted in acetylene reduction measurements and tissue nitrogen levels. These studies showed that seagrasses may play an important role in carbonate sediment chemistry, however the extent of their effect is species dependent.

INTRODUCTION

Seagrasses are found world-wide in shallow coastal waters. They contribute a large portion of the total primary productivity of the ecosystem (Thayer et al., 1975) and can fix carbon at rates equivalent to or exceeding the rates of the most intensively farmed agricultural crops (Aieman and Wetzel, 1980). No less important is the favorable habitat these grasses provide for a variety of epiphytic organisms. Total biomass of the epiphytic community may exceed that of the grass (Harlin, 1980) while primary productivity of this component can be as much as 35% of the productivity of the seagrass leaves (Penhale, 1977).

Seagrass meadows also have a profound effect on the chemistry of the sediments they grow on. They create depositional environments such that quantities of organic-matter and fine-textured sediments tend to be larger in meadow sediments than in unvegetated substrates (Kenworthy et al., 1982). Typically, meadow sediments also have large rates of metabolism and reduced oxygen concentrations resulting in anoxic conditions. The lower oxygen concentrations as well as the pH of meadow sediments produce an environment such that, except iron and manganese, most metals occur in insoluble forms (Lindsey, 1979). According to redox stability equations, most of these metals are immobilized in insoluble complexes of sulfide (Burrell and Schubel, 1977) or iron (Sajwan and Lindsey, 1989).

Most seagrasses of the world grow in either terrigenous or carbonate sediments. In a recent review of the effects of sediment nutrition on seagrasses, Short (1987) concluded that knowledge of the geochemistry of seagrass beds is imperative in determining the limiting nutrient to seagrass growth. He reported that seagrasses grown in terrigenous sediments generally have sufficient phosphorus but lack nitrogen. In contrast, seagrasses grown in carbonate sediments were phosphorus deficient due to the absorption of phosphorus to anionic sites on the sediment surface.

While there have been numerous studies evaluating phosphorus and nitogen chemistry of seagrass beds, comparable research of other essential nutrients is clearly lacking. The objectives of this study were to determine the effects of two seagrass species on calcium, magnesium, potassium, iron, organic matter, chloride, and sulfate concentrations in carbonate sediments and to evaluate the importance, through correlation statistics, of each of these chemical components on a number of seagrass biochemical and growth parameters.

MATERIALS AND METHODS

Two separate studies were conducted: a Vegetated versus Unvegetated Sediment Study and a *Syringodium* versus *Thalassia* Meadow Study.

Vegetated versus Unvegetated Sediment Study

Root-rhizome, stem-leaves and the top 5 cm depth of sediment were collected from Grahams Harbor, West Snow Bay and Rice Bay on San Salvador Island, Bahamas in July, 1988. A detailed explanation of the sampling techniques and site location are included in Smith et al. (1989). All plant tissues were carefully separated by species and plant part (root-rhizome and stem-leaves), then washed by soaking in successive water baths. The washed tissues were analyzed for acetylene reduction (nmoles C_2H_2 hr^{-1} gram dry $weight^{-1}$, Smith and Hayasaka, 1982) then stem-leaves were placed in paper bags and oven-dried at 70°C. Once dried, the samples were weighed to the nearest 0.01 g to obtain biomass estimates on a per meter basis. Plant samples were then ground in a Wiley mill with a 20-mesh (0.841 mm) sieve, and analyzed for carbon and nitrogen using a Carlo Erba Strumentazione - NA 1500 Automatic Nitrogen/Carbon/Sulfur Analyzer. Each reported mean had at least 9 replicates.

Sediment samples (0-4 cm depth) were collected from the center and 15 m from the edge of each of the seagrass meadows. Samples were air-dried, then stored in polyethene containers at 5°C. A 10.00 ± 0.03 g aliquot, which had been passed through a 2-mm sieve, was extracted by Mehlich's double acid (Council, 1980) and analyzed for calcium, magnesium, potassium and iron using an inductively coupled plasma emission spectrometer. Organic matter was determined by complete oxidation (Council, 1980) while chloride and sulfate were determined on an ion chromatograph. All analyses were conducted in acid- washed glassware and several National Bureau of Standards plant tissue samples (NBS, Washington, DC, NBS no. 1573 -- tomato leaves) were simultaneously analyzed for quality control. Data were statistically analyzed by the general linear model, while means were separated by Duncan's new multiple range test on the SAS computer program (SAS Institute, Inc., Box 8000, Cary, NC 27511).

Syringodium versus *Thallasia* Meadow Study

In East Bay, a meadow dominated by *Syringodium* (87% *Syringodium* and 13% *Thalassia* on a g m^{-2} basis) and a second meadow located approximately 100 m away dominated by *Thalassia* (2% *Syringodium* and 98% *Thalassia* on a g m^{-2} basis) were sampled. Sediment samples (0-4 cm depth) were also collected from each meadow and from unvegetated areas located 5 m from each meadow perimeter. Identical parameters as in the previous study were measured on these plant and sediment samples.

RESULTS AND DISCUSSION

Vegetated Versus Unvegetated Sediment Study

On a total weight per square meter basis, Grahams Harbor contained 80% *Thalassia*, 15% *Syringodium*, and 5% *Halodule*, while Rice Bay contained 4% *Thalassia*, 93% *Syringodium* and 3% *Halodule* and finally, West Snow Bay contained 96% *Thalassia*, 3% *Syringodium* and 1% *Halodule*. The chemistry of unvegetated sediments were quite similar at all three sites (Table 1). This can be attributed to the fact that all three sites were relatively close to each other, within 20 km, and the sediments originated from a similar geological carbonate source.

Sediments supporting seagrasses contained significantly ($P < 0.05$) higher concentrations of magnesium, potassium, organic matter and chloride, and significantly lower concentrations of sulfate than sediments without seagrasses (Table

Table 1. Effect of plants on selected chemical properties of sediments from Grahams Harbor, West Snow Bay and Rice Bay.

Location	Plant	Ca	Mg	K	Fe	OM	Cl	SO_4
		(mg kg^{-1})				(%)	(mg kg^{-1})	
Grahams Harbor	-	522	79	29	0.08	2.26	3.71	1.02
	+	482	110	37	0.20	2.62	3.94	1.08
West Snow Bay	-	486	61	21	0.10	2.29	2.36	9.44
	+	503	104	85	0.10	2.69	3.88	1.10
Rice Bay	-	494	92	22	0.13	2.00	2.86	1.89
	+	453	144	35	0.02	2.08	6.09	1.34
Mean	-	501	77	24	0.10	2.18	2.98	4.12*
	+	479	119*	52*	0.11	2.46*	4.64*	1.17

*Significantly greater mean concentration for a - and + comparison ($P < 0.05$).

1). Calcium and iron concentrations in the sediments were not affected by the presence of seagrasses.

Other researchers have observed increases in organic matter in marine sediments supporting vegetation (Kenworthy et al., 1982). In terrestial environments large quantities of all of these measured chemical parameters (except chloride) have been reported in soils supporting plant growth, as opposed to those not supporting plants (Adriano, 1986).

Tables 2 and 3 display correlations between the different soil chemical parameters and biomass, acetylene reduction, tissue nitrogen and tissue carbon concentrations. In general, soil chemical parameters were best correlated with tissue biomass and worst correlated to tissue carbon. A consistant trend noted in both tables was that the two species were significantly correlated to the same sediment parameters. However, their orientation, i.e., positive or negative, were opposite. For example, biomass of *Thalassia* was directly correlated to sediment calcium and inversely correlated to magnesium and chloride levels. Conversely, the *Syringodium* biomass was inversely correlated to calcium, but directly correlated to magnesium and chloride concentrations. Similar significant, but opposite, correlations were observed in acetylene reduction (calcium, magnesium and potassium) (Table 2) and tissue nitrogen concentration (sediment potassium). This phenomena may in part explain why these two species are often found in near pure stands. It appears that *Syringodium*, a pioneering species, grows better in sediments containing more magnesium while *Thalassia*, a non-pioneering species, grows better in sediments high in calcium and potassium (Table 3).

Syringodium Versus *Thalassia* Meadow Study

It is quite clear from Table 4 that the changes induced by vegetation on sediment chemistry is species dependent. Overall, the *Thalassia* meadow tended to increase concentrations of the measured parameters more than the *Syringodium* meadow. In the *Thalassia* meadow, magnesium concentrations increased by 60%, potassium by 70%, organic matter by 31%, chloride by 88% and sulfite by 18% above the unvegetated sediments. In the *Syringodium* meadow, potassium, organic matter and chloride concentrations all increased by 26% while calcium concentrations decreased by 27%, with respect to the unvegetated sediments.

The *Thalassia* meadow may have induced greater changes in sediment chemistry because it had a greater total biomass per unit area then the *Syringodium* meadow. Further evidence of the specie dependent nature of the effects seagrasses have on sediment chemistry can be seen in the data from the Vegetated Versus Unvegetated Sediment Study (Table 1). A comparison of the sediment chemistry of the Grahams Harbor meadow, which was predominately *Thalassia*, (Table 1) with that of the *Thalassia* meadow in Rice Bay (Table 4) shows strong agreement in the effect *Thalassia* had on sediment chemistry.

In summary, these studies showed that seagrasses may play an important role in carbonate sediment chemistry. In the presence of seagrasses, sediments generally had higher nutrient concentrations. This can be attributed to the ability of plants to biomagnify these elements.

Table 2. Correlation coefficients between soil chemical properties and biomass and acetylene reduction of samples collected at Grahams Harbor, Rice Bay and West Snow Bay (n > 12).

	Biomass				Acetylene Reduction			
	Thalassia		Syringodium		Thalassia		Syringodium	
	SL	RR	SL	RR	SL	RR	SL	RR
Ca	.87	.82	-.92	-.92	-.84	--	.88	.79
Mg	-.89	-.77	.97	.87	.88	--	-.77	-.81
K	.87	.83	--	--	-.81	--	.83	.74
Fe	--	--	--	--	--	--	--	--
OM[3]	--	--	-.90	-.92	--	--	--	--
Cl	-.82	-.89	.88	.81	.79	--	--	--
SO_4	--	--	.83	.79	--	--	--	--

[1]SL, RR = Stem-leaves, root-rhizome

[2]__ = not significant at P < 0.05

[3]OM = organic matter

Table 3. Correlation coefficients between soil properties and tissue nitrogen and carbon concentrations of samples collected at Grahams Harbor, Rice Bay and West Snow Bay (n > 12).

	Tissue Nitrogen				Tissue Carbon			
	Thalassia		Syringodium		Thalassia		Syringodium	
	SL[1]	RR	SL	RR	SL	RR	SL	RR
Ca	--	--	.72	--	--	--	-.81	--
Mg	--	--	-.79	-.88	--	.81	--	--
K	-.77	--	.89	.81	--	--	--	--
Fe	--	--	--	--	--	--	--	--
OM[3]	.81	--	--	--	--	-.80	--	--
Cl	--	--	--	--	--	--	--	--
SO_4	--	--	--	--	--	--	--	--

[1]SL, RR = Stem-leaves, root-rhizome.

[2]-- = not significant at P < 0.05.

[3]OM = organic matter.

Table 4. Effect of Thalassia and Syringodium on Sediment Chemical Composition at East Beach.

Plant Bed	Ca	Mg	K	Fe	OM	Cl	SO_4
	(mg kg^{-1})				(%)	(mg kg^{-1})	
Unvegetated	762	107	27	0.10	1.99	3.19	1.07
Thalassia	774	171	46	0.09	2.60	6.00	1.27
Syrigodium	563	103	34	0.09	2.51	4.01	1.12

Once these plants die, the detritus not only provides an increase nutrient base but it also provides additional exchange sites for both anion and cation adsorption.

Also observed in these studies was that seagrasses altered sediment chemistry, and the extent to which the chemistry was altered was a function of the type of seagrass growing over the sediment. The *Thalassia* meadows, which generally contained more biomass than the *Syringodium* meadows contributed more nutrients to the sediment.

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REFERENCES CITED

Adriano, D. C. 1986. Trace Elements in the Terrestrial Environment. Springer-Verlag, New York.

Burrell, D. C., and Schubel, J.R., 1977. Seagrass ecosystem oceanography. p. 196-225. In C. P. McRoy and C. Helfferich (eds), Seagrass Ecosys tems, a Scientific Perspective. Marcel Dekker, New York.

Council on Soil Testing and Plant Analysis. 1980. Handbook on reference methods of plant and soil testing. University of Georgia, Athens, Georgia.

Harlin, M. M. 1980. Seagrass Epiphytes. p. 117-1-51. In R. C. Phillips and C. P. McRoy (eds), Handbook of seagrass biology, an ecosystem perspective. Garland STPM Press, New York.

Kenworthy, W.J., Zieman, J.C., and Thayer, C.W., 1982. Evidence for the influence of seagrass on the benthic nitrogen cycle in a coastal plain estuary near Beaufort, North Carolina (USA). Oecologia 54:152-158.

Linsay, W. L. 1979. Chemical Equilibria in Soils. Wiley Interscience, New York.

Penhale, P. A. 1977. Macrophyte-epiphyte biomass and productivity in an eel-grass (*Zostera marina* L.) community. J. Exp. Mar. Biol. Ecol. 26:211-224.

Sajwan, J. S. and Lindsay, W.L., 1988. Effect of redox, zinc fertilization and incubation time on DTPA-extractable zinc, iron and manganese. Commun. in Soil Sci. Plant Anal. 19:1-11.

Short, F. T. 1987. Effects of sediment nutrients on seagrasses: Literature review and mesocosm experiments.

Smith, G. W. and Hayasaka, S.S., 1982. Nitrogenase activity associated with *Zostera marina* from a North Carolina estuary. Can. J. Microbiol. 28:448-451.

Smith, G. W., Short, F.T., and Kaplan, D.I., 1990. Distribution and biomass of seagrasses in San Salvador, Bahamas. (This Volume)

Strickland, J. D. H. and Parsons, T.R., 1972. A practical handbook of seawater analysis. Fisheries Research Board of Canada, Ottawa.

Thayer, G. M., Wolfe, D.A., and Williams. R.B., 1975. The impact of man on seagrass systems. Am. Sci. 63:288-296.

Zieman, J. C., and Wetzel, R.G., 1980. Productivity in seagrasses: Methods and rites. p. 87-116. In R. C. Phillips and C. P. McRoy (eds), Handbook of seagrass biology, an ecosystem perspective. Garland STPM Press, New York.