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COMPARISON OF CARBON CONTENT OF THE SEDIMENTS AND THEIR PORE WATERS IN SALT MARSHES AT KINGSPORT AND GRAND PRÉ, MINAS BASIN, BAY OF FUNDY, NOVA SCOTIA*

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In the salt marshes along the Bay of Fundy, Nova Scotia, large standing crops of plant biomass are developed during the spring and summer when relatively high levels of primary production are maintained. The effect of this fixed carbon (both particulate and dissolved) on the open Bay of Fundy is difficult to determine. In this study, the organic carbon in the sediment and in the interstitial or pore waters were measured using methods which are described. There were large differences in measured organic matter between the 2 physically different marshes studied. Although the influence of such areas on production in the Bay of Fundy cannot be estimated from this preliminary study, the high organic levels observed indicate that marsh areas may be a source of organic matter.

Introduction

Production in the Bay of Fundy may be enhanced by organic matter from salt marshes in this region. During spring and summer, the primary production of these marshes is relatively high and large standing crops of plant biomass develop (Smith 1978). Because of the large tidal range in the Bay of Fundy, export from the marshes of fixed carbon (living and detrital) with drainage during the ebbing tide is expected (Odum & de la Cruz 1967; Shisler & Jobbins 1977). The study of the flux of particulate organic matter from marshes has been examined (Valiela et al. 1978). However the flux of dissolved organic carbon from marsh areas is not well understood (Woodwell et al. 1971; Shisler & Jobbins 1977). In marsh environments, with high levels of productivity, with excretion from plants (Wetzel & Renhale 1979), and with high microbial activity, high levels of organic matter will be found in the sediments which may be a major source of dissolved organic matter (Pomeroy et al. 1976). The pore or interstitial waters of sediments are rich in dissolved organic matter (Martens & Goldhaber 1978) which can be added to overlying waters by diffusion from or resuspension of the sediments.

In this study, the sediments in 2 marshes were examined. The organic carbon and water content of sediments along specific transects were measured during the summer of 1978. The dissolved organic content of the pore waters was measured by a simple technique allowing rapid analysis of small sediment samples with water contents in the range 25 to 60%. The results obtained from these marshes showed differences which will be discussed.

Materials and Methods

Samples were collected at low tide along transects on marshes near Kingsport and Grand Pré on the Minas Basin of the Bay of Fundy, Nova Scotia. Fine grained

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sediments of clay-silt nature were found in both marshes (Smith 1978). The marsh at Kingsport is older with well-developed drainage channels and with relatively high diversity of angiosperm species; the Grand Pré marsh is younger, in the early stages of physical development and with low species diversity (Smith 1978). Surface sediment samples (0.5-1.0 cm depth) were collected with a stainless steel spatula. After digging a small hole, subsurface sediments were sampled with the spatula (8-10 cm depth). Samples were stored frozen (-20°) in precleaned (400° for 4 h) glass bottles sealed with caps lined with aluminum foil.

The water content (%) of the sediment was determined gravimetrically by drying aliquots (20-30 g) of the sediment at 100 to 110°.

The organic carbon content (% of dry sediment) of the sediment was determined by high-temperature oxidation (900°) of aliquots of sediment which had been homogenized after drying. The inorganic carbon was either removed by acid treatment (HCl) or measured to allow for correction of the calculated organic carbon contents. Dried sediment samples (1-3 mg) were weighed into quartz tubes (25 mm x 4 mm ID). The organic matter was oxidized to CO_2 and measured with a non-dispersive infrared analyzer (MacKinnon 1978).

The dissolved organic carbon concentration in the sediment pore waters was determined by a high-temperature oxidation method. The separation of pore waters by a centrifugation procedure was found to be unsatisfactory because of the low water content and clay-silt nature of the sediments. Therefore, a simple squeezing procedure was developed, by which water from small sediment samples was extracted quickly and then analyzed for the organic content. A portion of thawed sediment was transferred to the bottom half of a petri dish, cleaned (400°) of organic matter. A cleaned (400°) glass fiber filter (47 mm, Whatman GF/C) was placed on the sample so that water in the sediment was absorbed. Then smaller segments of preweighed (10-20 mg) glass filters (cleaned at 400°C) were patted on the wetted larger filter to absorb pore waters without contamination from the sediment or any suspended particles. This filter segment with its absorbed water was quickly weighed to determine the volume of water absorbed (75-100μ ℓ). The filter was placed in a quartz tube (25 mm x 5 mm ID), acidified with H_3PO_4, and dried in an atmosphere free of organic matter (MacKinnon 1978). After drying, the quartz container with sample was introduced into a high-temperature oxidation furnace and the organic matter was measured as CO_2. The DOC concentrations are expressed as mg C ℓ^{-1} or ppm C. When this method was tested with standard dextrose solutions, high efficiency of recoveries was obtained (Table I). Standards were prepared by slurrying dried, homogenized organic-free sediment (600°) with dextrose solutions (50-500 ppm C) to yield muds of various water contents (40-65%). The extraction method described above proved useful for measuring the DOC concentrations in the pore waters of clay-silt marsh sediments with high organic carbon concentrations and of variable water content (24-55%).

The concentration of the dissolved inorganic carbon (DIC—includes carbonates and dissolved CO_2) was determined using the method described above to extract pore water. After absorbing a measured amount (100-200 μ ℓ) of pore water, the glass-fiber filter was added to a phosphoric acid solution (10%). The CO_2 purged from the solution was measured with an infrared analyser. The inorganic carbonate concentration is expressed in mmolar (mM) units.

Results

The results of analyses of samples from the study areas for water content, organic carbon content of the sediments, and for the dissolved organic and inorganic carbon

Table I. Evaluation of method used for extraction and measurement of DOC concentration in pore waters

A. Effect of varying DOC concentration of pore water

Calculated* DOC concentration (ppm C)	Measured DOC concentration (ppm C)	% Recovery
50.5	63.3 + 1.4	125
106.4	126.4 + 0.9	119
240.0	280.7 + 0.8	117
511.8	546.0 + 16	107

Mean % Recovery = 117 + 7

B. Effect of % water content on efficiency of recovery

Water content of mud** (%)	Calculated DOC concentration (ppm C)	Measured DOC concentration (ppm C)	% Recovery
40	106.4	129.7 + 1.5	122
50	106.4	126.4 + 0.9	119
57	106.4	121.9 + 8.9	115
63	106.4	121.9 + 8.9	115

Mean % Recovery 118 + 3

*50% Slurry of organic-free sediment plus various concentrations of dextrose solutions.

**Various amounts of dextrose standard solution (106.4 ppm C) added to organic-free sediment to yield mud.

concentration in the pore waters are shown in Figures 1 and 2. During the period of this study, there was little change in the various parameters measured in either marsh, even though plant biomass increased considerably during the summer months (Smith 1978). In both marshes, organic carbon and water contents of the sediment, and concentrations of dissolved organic carbon in the pore waters were generally higher in surface than in subsurface sediments. However, higher concentrations of dissolved inorganic carbon were found in the reducing zone of the subsurface sediments where there was probably a high level of microbial activity. Differences were observed in the parameters measured on the 2 marshes (Table II). The organic carbon content of both the sediment and the pore waters (surface and subsurface zones) of the older marsh at Kingsport were higher than those measured on the marsh at Grand Pré. As well as higher concentrations, a higher variability (standard deviations, Table II) in both the surface and subsurface zones was observed on the Kingsport marsh. On the Kingsport marsh, higher plant diversity was observed yet a similar level of above ground biomass production was measured on both marshes (Smith 1978). The high variability of parameters measured on the Kingsport marsh indicate this marsh is more heterogeneous than the Grand Pré marsh, where a more homogeneous distribution of the biota was observed and the measured parameters, that we report, were less variable.

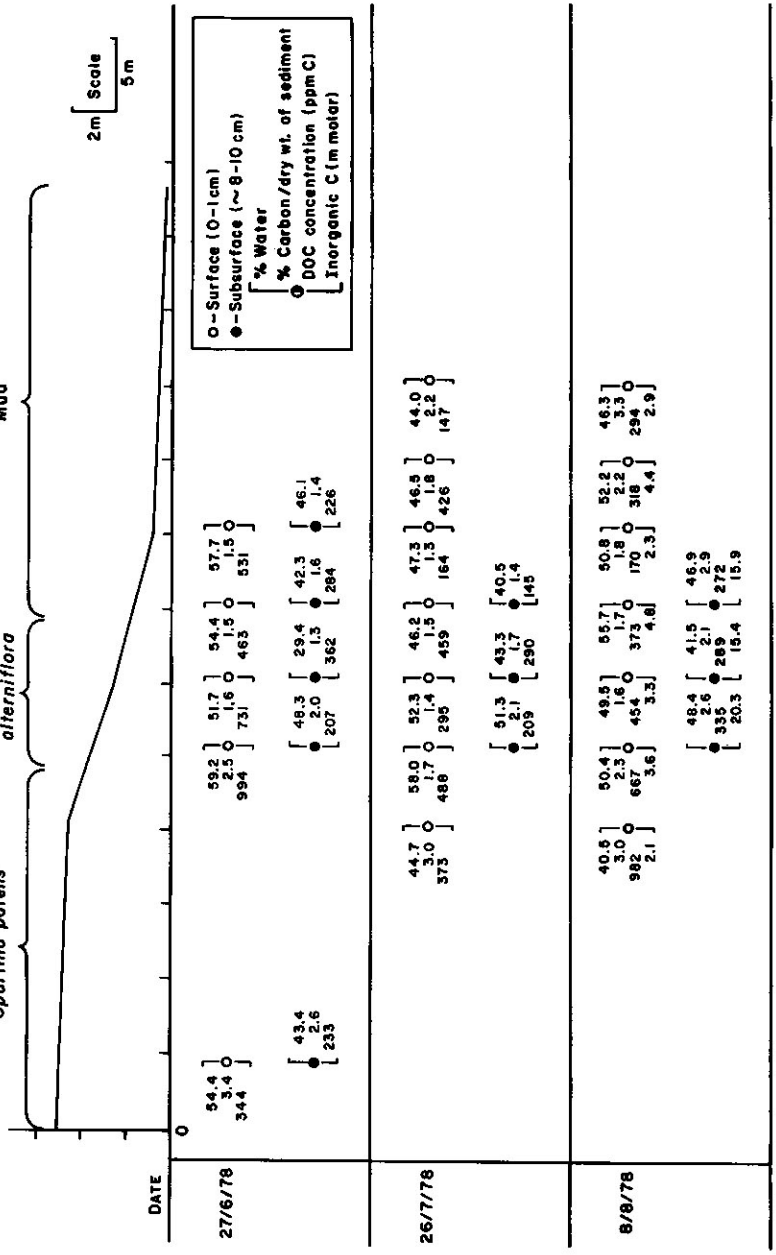

Fig 1. Cross section of Kingsport marsh on which transect was run at various times during summer of 1978. O - surface (0-1 cm) zone; ● - subsurface (8-10 cm) zone. The water content (%), carbon content of sediment (%), and DOC concentration (ppm C), and dissolved inorganic concentration (mmolar) of pore waters are shown for each sample.

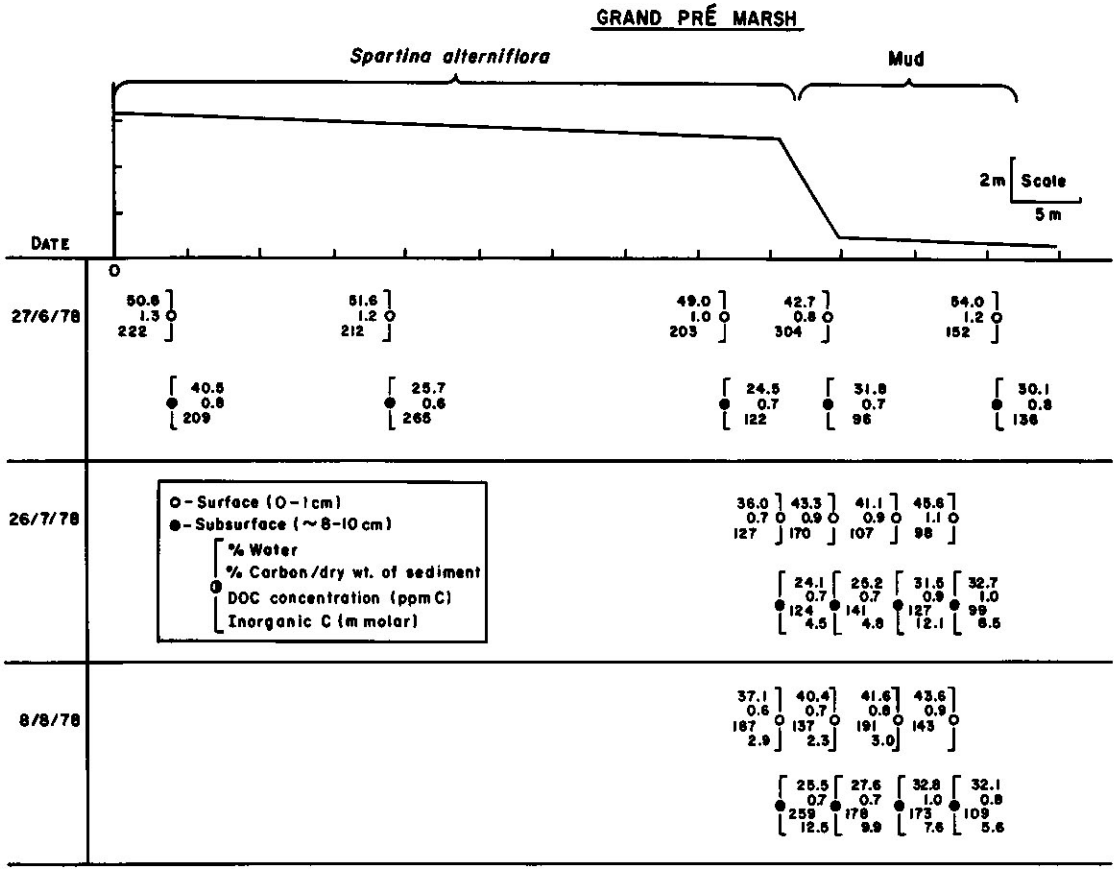

Fig 2. Cross section of Grand Pré marsh on which transect was run at various times during summer of 1978. O - surface (0-1 cm) zone; ● - subsurface (8-10 cm) zone. The water content (%), carbon content of sediment (%), and DOC concentration (ppm C), and dissolved inorganic concentration (mmolar) of pore waters are shown for each sample.

Conclusion

Concentrations of organic matter in pore waters of the marshes studied were high and variable. Average concentrations of DOC (100-300 ppm C) in the pore waters were about 2 orders of magnitude higher than the concentrations expected in the incoming tidal waters from the open Bay of Fundy (1.2-1.7 ppm C; MacKinnon & Walker, in preparation). Even in the established drainage channels of the marshes, high DOC concentrations (up to 900 ppm C) were measured in the pore waters (Fig 1), which indicates either there is little flux of organic carbon from the sediments to the tidal water or the rate of production of dissolved species in the pore waters is extremely rapid. If the former is the case, the main pathway of input of dissolved species from these marsh sediments should be by the process of diffusion (Gardner 1973) rather than advection and mixing. Because of their clay-silt nature, the sediments in these areas are highly compacted and there is probably little advective exchange between the subsurface sediments and the overlying waters. Thus, even at 5-10 cm depths, reducing zones were established with concentrations of sulfide high enough to be evident by color and odor. Diffusion is a slower process than advection and if this is the main mechanism of transport (Gardner 1973), this may explain why no dramatic changes in measured DOC concentrations were noted over the period of this study. However, there were large differences in the organic carbon content of these 2 marshes; areas which also had obvious physical and biological

Table II. Comparison of the mean results obtained on the Kingsport and Grand Pré marshes during the summer of 1978

Date	Location	Depth in core (cm)	Mean carbon content of sediment (% dry wt)	Mean water content (%)	Mean DOC concentration (ppm C)	Mean carbonate concentration (mM)
27/6/78	Kingsport	0-1	2.08 + .8	55.5 + 3.0	613 + 250	-
		8-10	1.77 + .5	42.0 + 7.4	263 + 63	-
	Grand Pré	0-1	1.08 + .2	49.6 + 6.3	219 + 55	-
		8-10	0.72 + .1	30.5 + 6.3	166 + 70	-
26/7/78	Kingsport	0-1	1.85 + .6	47.8 + 5.5	325 + 145	-
		8-10	1.72 + .3	45.0 + 5.6	215 + 72	-
	Grand Pré	0-1	0.89 + .2	41.5 + 4.0	126 + 32	-
		8-10	0.83 + .2	28.4 + 4.3	123 + 17	7.5 + 3.6
8/8/78	Kingsport	0-1	2.36 + .7	49.2 + 7.0	430 + 250	3.4 + 1.2
		8-10	2.53 + .4	45.6 + 3.6	299 + 33	17.3 + 2.7
	Grand Pré	0-1	0.74 + .1	40.7 + 2.7	165 + 28	2.9 + 0.4
		8-10	0.80 + .1	29.5 + 3.5	180 + 61	8.9 + 3

differences. The older and more developed Kingsport marsh had higher and more variable organic carbon values than were observed on the younger marsh at Grand Pré.

The estimation of input of organic matter from such marsh areas to the Bay of Fundy can not be based on the results obtained from 2 such small areas. However, it is clear from this study that concentrations of organic carbon are high in these marshes and pathways for its input into the Bay are available. The methods described in this study allow the organic matter in the sediment and their pore waters to be easily and reliably measured. Differences in the concentrations and in the variability of the parameters measured on the 2 marshes studied were large as were other properties of the marshes such as age and physical development and plant diversity. In both marshes concentrations of organic carbon were much higher than in the waters of the incoming tides and dissolved organic matter is probably exported. However, estimation of the export from the marshes will require more extensive analyses of the waters throughout tidal cycles. This should lead to a better understanding of the relation between dissolved organic matter in the marshes and production in the Bay of Fundy.

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