

SEDIMENT METABOLISM
AT
TIVOLI SOUTH BAY
AND
A VALLISNERIA BED IN THE HUDSON RIVER

by

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ABSTRACT

This study measured the oxygen consumption of sediments in a shallow embayment adjacent to the Hudson River to estimate the aerobic decomposition of its organic matter and also measured the concentration of other terminal electron acceptors. Oxygen consumption rates in Tivoli South Bay varied from 19.00 to 89.74 mg/m²/hr with an average of 49.44 mg/m²/hr. Oxygen consumption in a Vallisneria bed in the Hudson River varied from 36.12 to 70.56 mg/m²/hr with a mean of 52.39 mg/m²/hr. Organic matter content in the Vallisneria bed was lower than that of South Bay. Water column sulfate concentration was higher than interstitial concentrations for both South Bay and the Hudson River. Both the water column and the interstitial sulfate concentrations were higher in Tivoli South Bay than the river, indicating potential for greater anaerobic respiration. Bubbles collected from agitated sediments were analyzed on a gas chromatograph and were shown to consist almost entirely of methane, another indication of substantial anaerobic respiration.

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INTRODUCTION

In Tivoli South Bay, a shallow tidal Hudson River embayment, sediments are expected to be the most important sites of organic matter decomposition due to a shallow water column and rapid sedimentation. Oxygen consumption can be used as a measure of aerobic respiration whereas a variety of terminal electron acceptors are used under anaerobic conditions (Lovely and Klug 1982). This study measured the oxygen consumption of Tivoli South Bay sediments to estimate the aerobic decomposition of organic matter and also examined the concentration of other terminal electron acceptors.

There are varied sources of organic matter for Tivoli South Bay. There is a predominant macrophyte biomass that senesces each fall, and there are large inputs of particulate organic carbon from the Hudson River (Goldhammer and Findlay 1988) and the Sawkill, a tributary creek. Most of this detritus is deposited in the sediment where it is decomposed by detritivores.

The breakdown of organic matter is carried out both aerobically and anaerobically. It has been shown, however, that in thick sediments similar to those of the bay, aerobic respiration does not continue more than one centimeter below the sediment surface. Anaerobic respiration can be carried on at much greater depths. In a study on the sediments of Lake Washington, anaerobic

activity was found to a depth of thirty-one centimeters (Pamatmat and Bhagwat 1973). Measuring the rates of oxygen consumption alone is not sufficient to determine the turnover rates of organic matter in Tivoli South Bay. The products of anaerobic respiration also need to be recorded to present an accurate organic matter budget.

METHODS

I picked a sampling station in South Tivoli Bay that represented typical sediment composition. It is the same sampling station that Austin-Gill used for her study on benthic bacteria in 1986 and is described in Austin-Gill and Findlay (1987).

Each week, eight 25 mm diameter cores were taken by PVC pipe and stoppered with butyl rubber stoppers. Two 20L carboys of water were also sampled. On July 18 and on July 25 this same sampling was done on a Vallisneria bed located mid-stream in the Hudson River under the Kingston - Rhinecliff bridge. The sediment and water were then returned to the lab. The cores were allowed to settle with the top stopper off for about three hours, then the top seven centimeters from each core were extruded into a 7.5 cm subcore. The subcores were allowed to settle for two days in a water bath containing Tivoli South Bay water.

After settling for two days, three of the subcores were placed in a chamber designed to permit monitoring of

dissolved oxygen and withdrawal of water samples (Fig. 1). The chamber was filled with water from the bay and sealed without trapping any air bubbles. Inserted in the lid of the chamber was a YSI oxygen probe that monitored dissolved oxygen concentrations. A stirrer bar was used to keep the water circulating. Water samples were withdrawn by syringe through a serum stopper placed in the lid. The water samples were analyzed for dissolved inorganic carbon, nutrient, and dissolved organic carbon concentrations. An alternate chamber was set up with only water from the bay to correct for metabolism in the water column. Both chambers were placed in a water bath and allowed to run for eight hours. Every half hour, dissolved oxygen was recorded off the oxygen meter. Every two hours, water samples were withdrawn for dissolved inorganic carbon analysis, and every four hours, samples were withdrawn for dissolved organic carbon and nutrient analysis.

The nutrient samples were analyzed for sulfate, phosphate and nitrate on a Dionex ion chromatograph, and ammonium concentration by a Technicon Autoanalyzer. Dissolved organic carbon was analyzed with an Astro 2001 automatic carbon analyzer. The concentration of dissolved inorganic carbon was determined by gas chromatography. A fifteen mL sample water sample was withdrawn into a plastic syringe and acidified with 0.5 mL of 10% sulfuric acid. Then a 15 mL headspace of helium was drawn into the

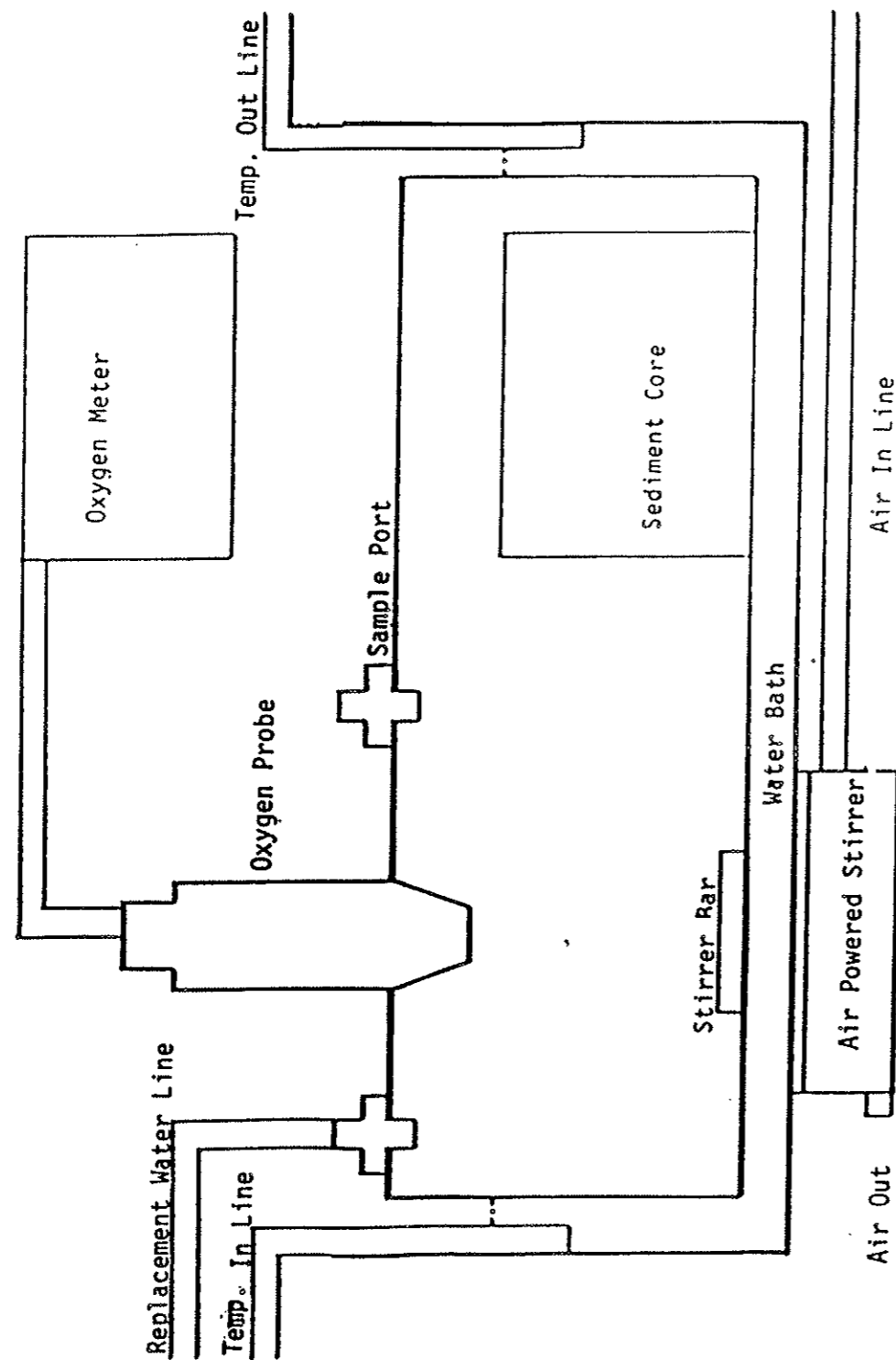


Fig. 1: Diagram of apparatus for incubating sediment cores.

syringe. After being shaken one hundred times the headspace was injected into the gas chromatograph. Concentrations were determined by comparing carbon dioxide peaks with the peaks of known standards.

Organic content of each of the subcores was determined by loss on ignition at 450 °C for five hours.

RESULTS

Water Column Conditions in Tivoli South Bay

Water column temperature ranged from 17.0 to 26.5 °C over the study period. Dissolved oxygen concentration usually remained 1 mg/L lower than saturation. Nitrate concentration ranged from 2.9 to 4.7 mg/L, ammonium concentration ranged from 0.04 to 0.35 mg/L, and sulfate concentration from 18.0 to 25.1 mg/L. There was no obvious seasonal pattern in nutrient concentration over the course of this study.

Oxygen Consumption in Tivoli South Bay

Oxygen consumption was linear for eight hours and chambers with sediment cores always showed significantly greater decreases in oxygen concentration than blanks containing only water (Fig 2). Oxygen consumption rates varied from 19.00 to 89.74 mg/m²/hr with an average of 49.44 mg/m²/hr. Oxygen consumption rates decreased steadily from May to October (Fig. 3). This decline did

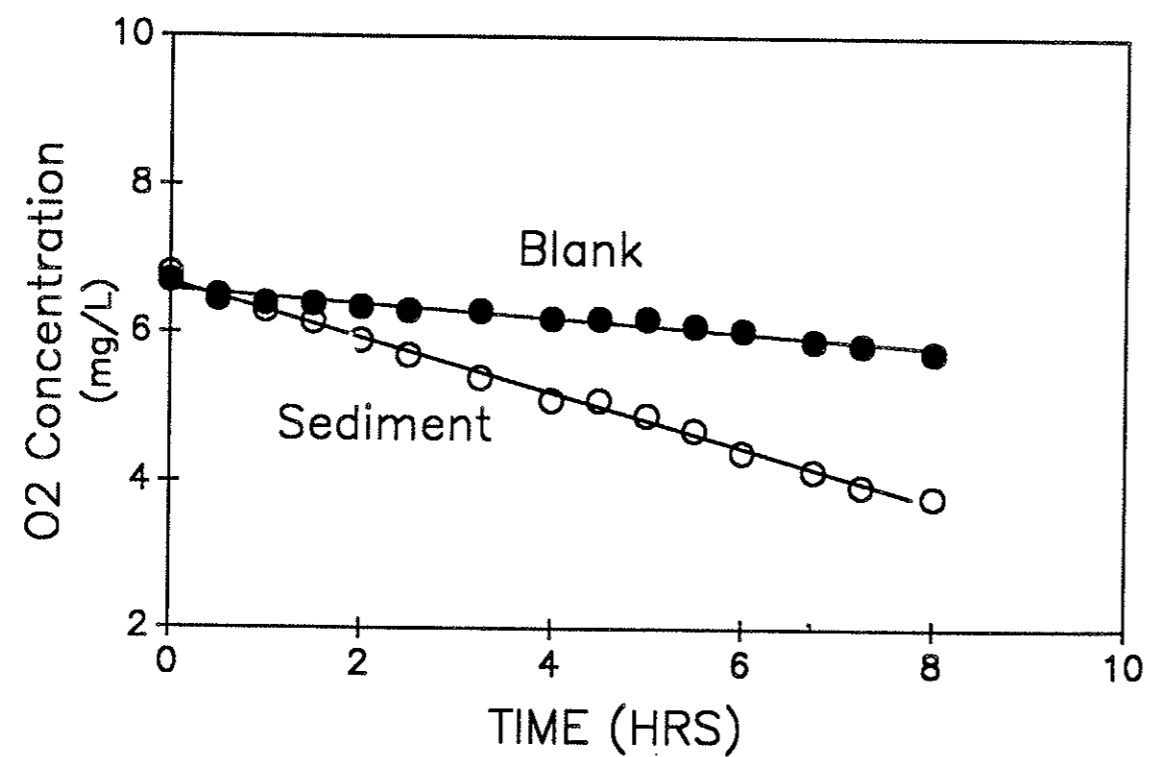


Fig. 2: Plot of dissolved oxygen concentration versus time for a chamber with sediment cores and a chamber filled only with water.

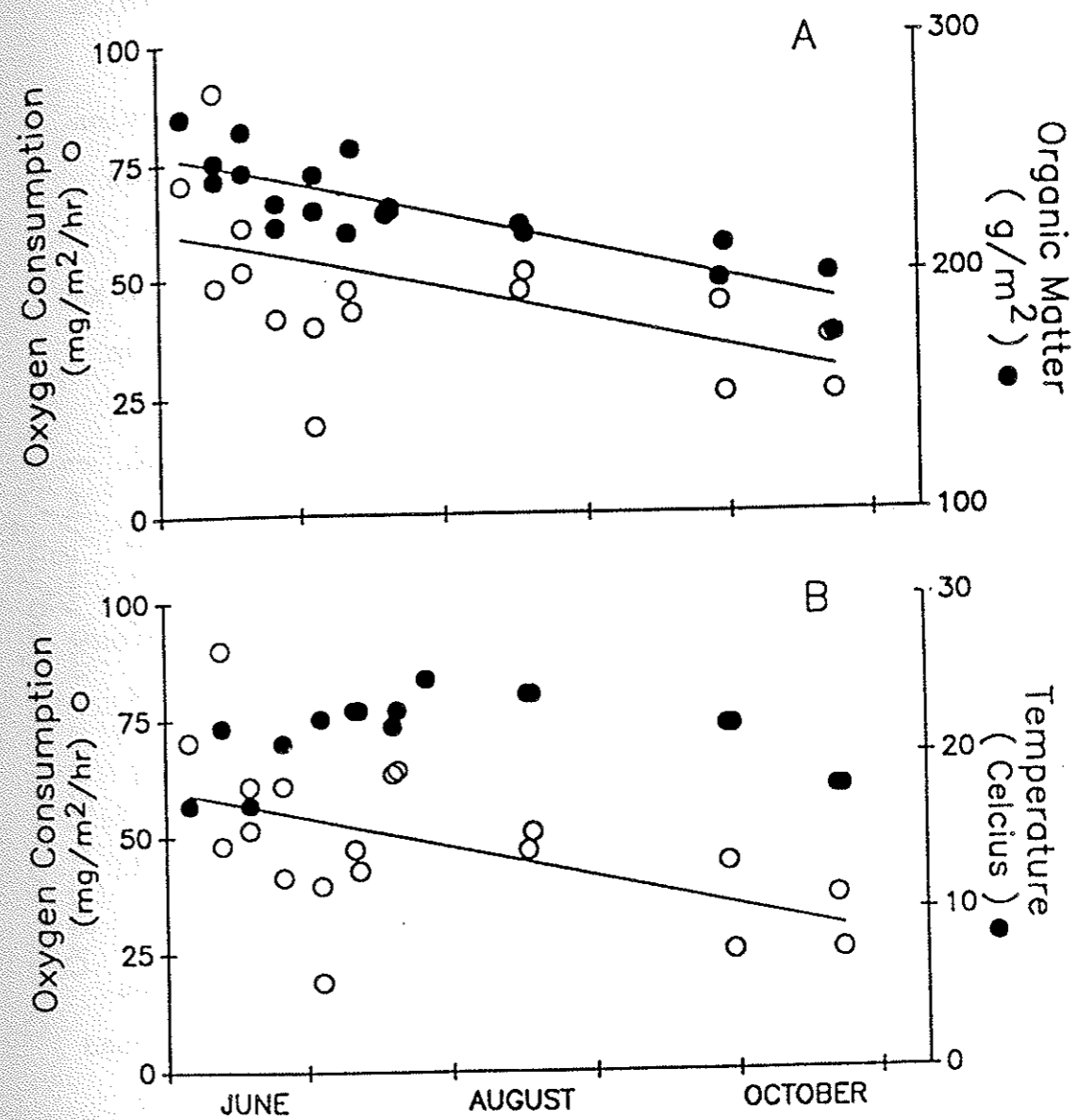


Fig. 3: (A) Temporal trends in oxygen consumption and organic matter in sediments from Tivoli South Bay

(B) Temporal trends in oxygen consumption and temperature

not correlate with changes in water column temperature at the sampling site. However, organic matter was declining over the same period.

The rate of dissolved inorganic carbon (DIC) production from sediment cores could not be determined due to high rates of DIC release observed in the "blank" chambers containing only water. Dissolved organic carbon (DOC) and nutrient releases were not statistically different from zero net flux.

Water Column Conditions in the Hudson River

There were two sampling trips to the Vallisneria bed located mid-stream in the Hudson river near the Kingston-Rhinecliff bridge (river mile ~ 100). The temperature ranged from 26 to 27 °C. There was a mean dissolved oxygen concentration of 6.25 mg/L ranging from 6.0 to 6.7 mg/L. Ammonium concentrations ranged from 0.32 to 0.42 mg/L on July 18 and from 1.84 to 1.95 mg/L on July 25. Sulfate concentration ranged from 19.4 to 20.1 mg/L the first sampling trip and from 20.3 to 22.2 mg/L the second trip. Ammonium concentration ranged from 0.09 to 0.12 mg/L over both sampling dates.

Oxygen Consumption Rates of the Vallisneria Bed

Oxygen consumption rates in the Vallisneria bed ranged from 36.12 to 70.56 mg/m²/hr with a mean of 52.39 mg/m²/hr (Fig. 4). Organic matter was lower than in Tivoli

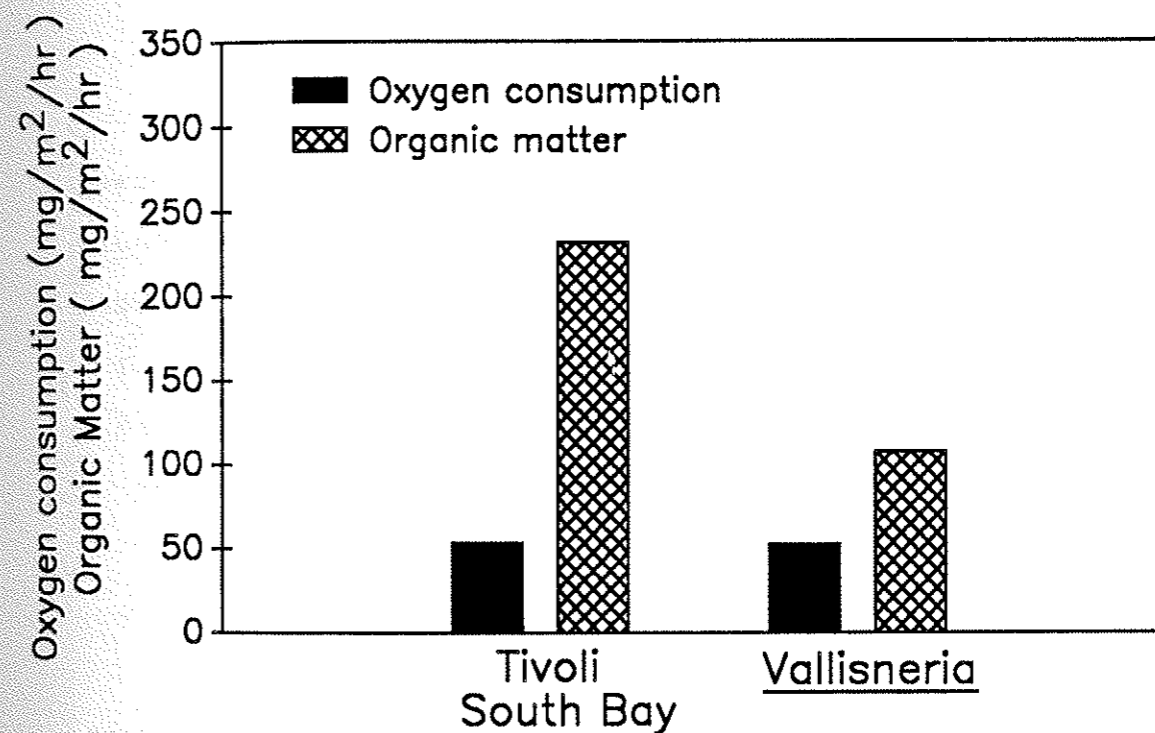


Fig. 4: Oxygen consumption and organic matter content of Tivoli South Bay and Vallisneria sediments

South Bay, but substantially higher than in a nearby sandflat (Austin-Gill and Findlay 1987).

Water Column Versus Interstitial Sulfate Concentrations

Water Column concentrations of the sulfate ion were greater than interstitial concentrations for both Tivoli South Bay and the Vallisneria site (Fig. 5).

DISCUSSION

Two of the foci of this paper initially were the measurement of dissolved inorganic carbon and nutrient fluxes. Difficulties arose almost immediately with these aspects of the study. Lack of a measurable net flux could be due to two factors. DIC production from blank chambers was greater than DIC production from chambers with sediment. The reasons for this remain a mystery. There was no measurable net flux of DOC or nutrients. Either the flux was too small to significantly change the background concentrations or the consumption and release of these materials was about equal.

I was able to record satisfactory measurements of oxygen consumption and organic matter. In Tivoli South Bay I recorded a decrease in both these parameters from May to October 1988 (Fig. 3a). I believe that the organic matter content is augmented in the spring and is metabolised over the summer. As the organic matter is used up, the oxygen consumption rates drop. The drop in oxygen consumption is

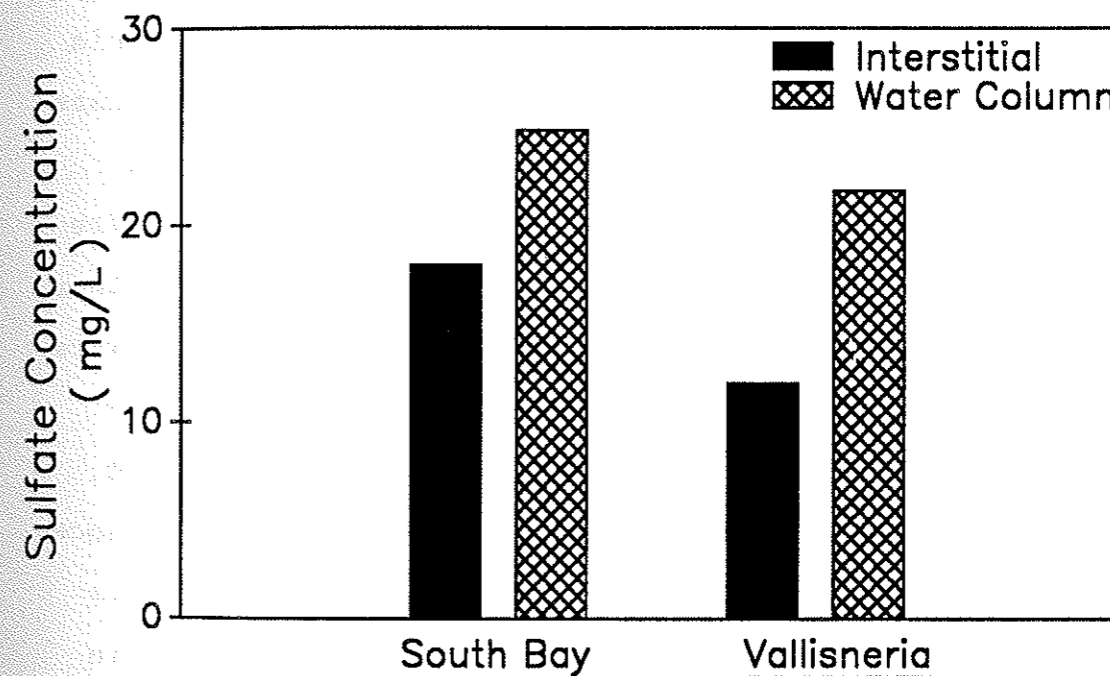


Fig. 5: Interstitial and water column sulfate concentrations in Tivoli South Bay and Vallisneria sediments

not directly related to temperature because the temperature did not fluctuate dramatically over the course of the study period (Fig. 3b)

Oxygen consumption rates of both the Vallisneria and Tivoli South Bay sites correlated with the organic matter content of the sediments when the systems were considered individually. When these parameters from both sites were reviewed together, we saw that there was a substantial difference in organic matter content, but no significant variation of oxygen consumption (Fig. 5). I believe this is because the organic matter of Tivoli South Bay consists of more refractory carbon than that of the Vallisneria bed. The peak oxygen consumption rates of South Bay were within the range of peak oxygen consumption rates of other wetlands in literature (Table 1). In some cases they were slightly lower, but this too was probably due to the higher refractory carbon content of South Bay sediments.

This study collected evidence pointing to the importance of anaerobic metabolism in Tivoli South Bay. Sulfate is recognized as an important terminal electron acceptor in marine sediments (Howarth 1984), but concentrations in freshwater are usually considered to be too low for sulfate reduction to be a significant process. Concentrations of SO_4 in Hudson River and Tivoli South Bay water were around 20 mg/L. Significant sulfate reduction has been reported to occur at concentrations of 8 mg/L in an alder swamp (Westermann and Ahring 1987).

	Temperature (°C)	Oxygen Uptake (mg/m ² /hr)	Source
Atchafalaya- Fourleague	35 °C	-143	(Teague et al. 1988)
Patuxent	30 °C	-171	(Boynton et al. 1980)
Narragansett Bay	24 °C	-150	(Nixon et al. 1976)
Potomac	-	-104	(Callender and Hammond 1982)
Neuse	-	-69	(Fisher et al. 1982)
Tivoli South Bay	27 °C	-90	(This Study)

Table 1) Comparison of oxygen consumption in Tivoli South Bay sediments with rates measured in other wetland sediments.

Additionally, the fact that interstitial concentrations of SO_4 were lower than water column concentrations (Fig. 4) implies a consumption of sulfate in the sediments.

Another indication of anaerobic respiration in the Tivoli South Bay is the amount of methane being produced. Originally, the concentration of methane in the water column was going to be measured, but methane was too insoluble to remain in the water column and escaped as bubbles. In order to demonstrate that methane was being produced, bubbles from agitated sediments in the field were collected in glass bottles and analyzed on the gas chromatograph. This analysis showed that the bubbles consisted almost entirely of methane. It is believed that methanogenesis is being carried on very productively in the bay because at low tide large amounts of bubbles may be observed degassing. It was impossible to attempt to trap the bubbles because of extreme low tides when the entire bay was above the tide line.

CONCLUSION

This study provided valuable data on sediment metabolism in Tivoli South Bay and the Hudson River. As well as documenting expected products and rates, some new questions about the Hudson River ecosystem also surfaced. These are things that I feel need to be studied further in conjunction with more extensive research on predicting oxygen consumption rates in the river. There are several

questions I feel would be worth looking into in the future: 1) to what extent is methanogenesis occurring in the bay, 2) what is the fate of carbon dioxide produced in South Bay, and 3) what is the contribution of different components of the Hudson ecosystem (bays, macrophyte beds, water column, etc.) to the overall oxygen budget of the estuary?

The most important product of this study is its contribution to our existing knowledge of carbon fluxes in the bay. It has provided oxygen consumption rates and organic matter content data that can be used in improving knowledge of the carbon budget for Tivoli South Bay.

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