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Examination of Tidal Flats Vol. 1. Research Report

R. J. Diaz
Virginia Institute of Marine Science

G. Markwith
Virginia Institute of Marine Science

R. J. Orth
Virginia Institute of Marine Science

W. Rizzo
Virginia Institute of Marine Science

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Examination of Tidal Flats

Vol. 1. Research Report

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FOREWORD

This report is one of three volumes on tidal flat values. The first volume summarizes the data collected on the biological communities and processes in tidal flats, and recommends that evaluation guidelines consider habitat (grass bed, sand or mud), season, and geographic location. Volume two is a state-of-the-art report which discusses tidal flat values as documented in the literature. Volume three is a methodology for evaluating tidal flats and established a basis for comparing sites.

These reports will be of value to anyone concerned with the values associated with tidal flats in general and with the possible impact of highways on these systems. It is especially appropriate for environmental specialists, biologists, and hydrologists and engineers concerned with highway location and design.

for Charles F. Scheffey
Director, Office of Research

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16. Abstract

This report is the first volume of three, documenting a study titled "Evaluation of Tidal Flat Areas for Highway Planning and Design." The companion volumes to this report are the research report, "Examination of Tidal Flat Areas: Vol. 2, A Review of Identified Values" and "Examination of Tidal Flat Areas: Vol. 3, Evaluation Methodology."

This report summarizes the data collected on the biological processes and communities of tidal flats. It is an aid in determining which processes and communities would be best suited for inclusion in the evaluation methodology.

From analyzing these and other data on tidal flats it appears that attempts to establish guidelines for evaluation need to include the type of habitat (grass bed, sand or mud flat), season, and geographic location. These are most important for animal communities. The relationship between primary productivity and the above mentioned considerations is not as clear cut. In light of the large number of physical and biological variables influencing tidal flats value, any scheme for their evaluation must provide adequate consideration of primary and secondary (invertebrate) production, and fisheries data as well as corresponding spatial and temporal variation within these components.

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PART I: ANIMAL COMMUNITIES

Introduction

The purpose of this report is to present the data collected for establishment of preliminary guidelines for the evaluation of wetland tidal flat areas of highway planning and design. Tidal flats share some valuable functions with both tidal marshes and deeper subtidal habitats, including primary and secondary production, nutrient storage and recycling, waterfowl and wildlife utilization, etc. In many instances, wetland tidal flats may provide better nursery grounds and/or feeding areas for important species of fish, crustacea, and molluscs than the adjacent marshes or subtidal areas themselves.

In order to develop an accurate evaluation scheme, tidal flat habitats from several areas have been sampled and described in terms of their biota (infauna and motile epibenthos), physiography, sedimentology and possible resource values.

Site Descriptions

A total of 6 sites were examined from Maryland to North Carolina as being representative of wetland tidal flat habitats. The area of intensive investigation was in the Guinea Marsh (GM) York River, VA. Areas examined in less detail were:

SF - Susquehanna flats, Chesapeake Bay, MD

KI - Kent Island, Chesapeake Bay, MD

VS - Vaucluse Shores, Chesapeake Bay, VA

CS - Currituck Sound, NC

OI - Oregon Inlet, Albemarle Sound, N.C. (Figure 1).

At each site an attempt was made to sample four basic habitat types dense submerged aquatic vegetation beds, sparse grass beds, unvegetated mud, and unvegetated sand. The general description of the sites are as follows:

GM - The Guinea Marsh site was characterized by expansive shoals covered in part with a monospecific stands of eelgrass (*Zostera marina*). All four of the habitat types were sampled. The sparsely vegetated and nonvegetated mud flats were intertidal and the dense grass bed and sand flats subtidal. The sparsely vegetated flat was between two marsh islands. The mud flat was within a cover of another marsh island. The dense grass bed was adjacent and offshore of the marsh island and the bare sand habitat immediately offshore of the grass bed.

SF - The Susquehanna flats site was near the mouth of the Susquehanna River on a sandy substrate with sparse pondweed (*Potamogeton*).

KI - At the Kent Island site three of the four habitat types were sampled. A sandy unvegetated habitat was sampled at the north end of Kent Island. A shoal area between Eastern Neck and Eastern Neck Island was the sparse grass area with *Ruppia maritima* and *Potamogeton pectinatus* present on a sandy substrate. A small embayment at the mouth of the Chester River was also a sparse grass habitat but with a muddy substrate. A dense grass bed of *Potamogeton perfoliatus*, *Myriophyllum spicatum*, *P. pectinatus*, *Nais* sp., *Netella* sp., and *Elodea* sp. east of Kent Island was also sampled.

VS - The Vaucluse Shores site is at the south end of Church Neck on the Bay side of the Eastern Shore. Dense grass beds of *Ruppia* and *Zostera* were sampled. The grass beds were separated by extensive sand bars running parallel to the shore. These dynamic sand bars were also sampled.

CS - The Currituck Sound site was near the highway bridge across the sound. The substrate was sandy with *Vallisneria americana*, *Potamogeton pectinatus*, *Ruppia* and *Myriophyllum* present.

OI - At Oregon Inlet only unvegetated sand and dense grass habitats were sampled. The unvegetated sand areas were just north of Oregon Inlet bridge behind the small dredged material islands and on the channel side of the islands. Dense grass beds were sampled south of Oregon Inlet (*Zostera* and *Ruppia*) and near Bodie Island (*Eleocharis parvula*).

The physical characteristics of these areas are summarized in Table 1.

Methods and Materials

Infauna - Infauna was sampled in all areas with a 0.007 m^2 plexiglass core, bagged, labeled and returned to the laboratory for sieving. The samples were then gently washed through 1.0 mm screen with river water and the organisms remaining were transferred to an appropriately labeled jar and preserved with a solution of 10% buffered formalin. After all organisms were properly identified, they were lumped together as either Polychaetes, Crustacea, or Mollusca and wet weights were determined to the nearest 0.1 g with a Mettler balance. Any balance weights below 0.01 g were labeled as 0.005 g or simply as trace. Both biomass and abundance values were then calculated for all polychaetes, crustaceans and molluscs converted to an average number of individuals and total wet weights per m^2 for each area and habitat.

Motile Epibenthos - Motile epibenthic animals such as fish and crustacea were either sampled with a 16 ft. otter trawl with 3/4" mesh wings and a 1/4" mesh cod end liner or a 50 ft. bag seine (in very shallow areas where the trawl could not be utilized). The trawl was towed at a constant speed (3 knots) and time (2 minutes) covering an average area of 602 m^2, while the seine covered approximately 418 m^2. All organisms captured were then properly identified, preserved in 10% formalin, and weighed as either fish, crabs, or shrimp with a pan balance. All wet weights were determined to the nearest 0.1 g for samples 1.0-10.0 g, to the nearest 1.0 g for samples 10.0 g - 100.0 g and to the nearest 10.0 g for all those weights over 100.0 g. Samples that weighed less than 0.1 g were recorded as 0.05 g or Trace. Biomass and abundance values were then calculated for all fish, crabs and shrimp converted to an average number of individuals and total wet weights per m^2 for each area and habitat.

Results

Infauna - The results of the analysis of the faunal data are summarized in tables 2 (Intensive site) and 3 (Extensive sites). All species are lumped as either Polychaetes, Molluscs, or Crustacea. Total abundance and biomass are calculated for all four habitats.

Motile Epibenthos

Crabs and Shrimp - Both crabs and shrimp are most abundant in dense grass habitats, followed by sparse grass, mud, and sand (of the total abundances 67% of the crabs and 83% of the shrimp biomass occurred in dense grass). A summary of the abundance and biomass of crabs and shrimp by area and habitat may be found in Table 4 and 5.

Fish - Abundance data are available for all fishes by site and habitat and are included in Table 6.

Discussion

Spatial Changes

Intensive Site. Referring to the average biomass and abundance values for the Guinea Marsh infauna contained in table 1, it is evident that definite patterns exist between the four habitats sampled. For example, polychaetes were most abundant in the dense grass (60% of the total) followed by mud, patchy grass, and sand. Molluscs and crustaceans also exhibited exactly the same pattern of abundance with 39% and 80% of the totals (respectively) occurring within the dense grass habitat. Biomass values, however, represent somewhat more of a confusing picture and did not show any clearly recognizable pattern. For example, the largest biomass of polychaetes was found in unvegetated mud representing 42% of the total followed closely by dense grass (31%), patchy grass (21%) and finally by sand (6% of the total biomass). On the other hand, molluscs exhibited the highest total biomass in unvegetated sand representing 39% of the total followed by unvegetated mud (37%), patchy grass (16%) and last by dense grass (8% of the total). The biomass of the Crustacea sampled paralleled the exact trend exhibited in their pattern of abundance with 74% of the total in dense grass, 16% in unvegetated mud, 5% in patchy grass and only 5% in unvegetated sand.

Extensive Sites

Kent Island - In the lower salinity areas of the upper Chesapeake Bay, the distribution and abundance of major infaunal species also followed a recognizable pattern. The majority of the individuals as well as the biomass were distributed in areas of submerged aquatic vegetation (either patchy or dense grass). For example, polychaetes were the most abundant in areas of patchy grass (53% of the total) followed by dense grass (28%), mud (12%) and sand (6%). On the other hand, molluscs were the most abundant in the dense grass (41% of the total) followed by unvegetated mud (37%), patchy grass (12%) and finally by unvegetated sand (10%). Crustacea exhibited a similar pattern of distribution with the highest abundance in areas of patchy grass (82%), followed by unvegetated sand (7%), dense grass (6%) and unvegetated mud (5%).

Patterns in the distribution of biomass generally paralleled those values obtained for abundance in each of four habitats described. For example, the highest biomass for polychaetes was also found in areas of sparse vegetation (65% of the total) followed by dense vegetation (22%), unvegetated sand (8%) and unvegetated mud (5%). Biomass values for molluscs were, however, the highest is unvegetated mud (93% of the total), followed by dense grass (7%), patchy grass (0.1%) and unvegetated sand (0.05%). Crustaceans exhibited the highest biomass in areas of their highest abundance (patchy grass with 60% of the total) followed by unvegetated mud (24%), dense grass (9%) and unvegetated sand (7%).

Oregon Inlet - All habitats sampled in Oregon Inlet demonstrated a striking correlation between highest biomass and abundance values and the presence of submerged aquatic vegetation. Polychaetes were by far the most abundant in dense grass (95%), followed by unvegetated sand (5%) and patchy grass (0.3%). Probable reasons for extremely low abundance and biomass values in the patchy grass habitat was its exposure to extreme wind and wave action. Submerged aquatic vegetation in this area was patchy as the bottom sediments were extremely unstable. Molluscs and crustaceans also followed this pattern with 86% and 88% respectively of the total number of individuals found occurring within the dense grass areas, followed by unvegetated sand (14% for molluscs and 9% for crustaceans), and patchy grass (0 for molluscs and 3% for crustaceans). Values obtained for biomass again paralleled those previously described for total abundances. Polychaetes represented 79% of the total biomass in dense grass, followed by 16% in unvegetated sand and 4% in unvegetated mud. Similar trends were also exhibited by molluscs and crustaceans (86% and 93% respectively of total biomass found in dense grass), followed by unvegetated sand (15% and 4% respectively), and unvegetated mud (3% for crustaceans). No molluscs were recorded from the unvegetated mud area sampled in Oregon Inlet.

Susquehanna Flats - The only area sampled in the Susquehanna Flats represented a patchy grass habitat with a relatively sand bottom. Polychaetes were the most abundant organism found (1486/m^2), followed by molluscs (571 m^2) and crustaceans (57 m^2). Biomass, however, was the highest for the molluscs (2.7 g/m^2), followed closely by the polychaetes (2.1 g/m^2) and finally the crustaceans (0.3 g/m^2).

Currituck Sound - Dense grass was the only habitat sampled in this area. Polychaetes were by far the most abundant taxa (1571/m^2) followed by crustaceans (200/m^2) and molluscs (29/m^2). Biomass values were also the highest for the polychaetes (35.2 g/m^2), with molluscs contributing 11.3 g/m^2 and crustaceans 0.4 g/m^2.

Temporal Changes

Intensive Site - Just as biomass and abundance values vary between habitats, they are subject to seasonal fluctuations as well (Table 7). Some general trends are obvious. Polychaetes are at their lowest abundances in all habitats in May and June reaching maximum numbers in August and November. Except for the unvegetated sand area, molluscs are also present in the lowest numbers in May and gradually increase in the summer months. In the unvegetated sand habitat lowest abundances are experienced during August (possibly a reflection of increased predation by species such as the blue crab) and are the highest in November (after such predator species have migrated out of the area). Abundances of crustaceans present somewhat of a confusing picture with lowest values obtained in both May (for unvegetated mud and dense grass) and August (unvegetated sand and patchy grass). Peak abundances occur in November (patchy grass and mud), June (dense grass), and May (sand).

Biomass values for the polychaetes show patterns similar to those obtained for abundances with the lowest biomass in May and June and highest in November (except for unvegetated sand which showed peak biomass in May). Molluscs exhibit the lowest biomass values in August for all habitats except patchy grass which was lowest in November. Crustaceans also generally show the lowest biomass values in August (except for unvegetated mud where the lowest biomass was in June). The highest biomass was at patchy grass and unvegetated mud in November, dense grass in June, and unvegetated sand in May.

Trawl and Seine Data for Crabs and Shrimp

Data were collected on crabs and shrimp at all sites (Figure 1). Most of the crabs were blue crabs (*Callinectes sapidus*) but occasionally a spider crab or hermit crab was taken. The shrimp were mainly grass shrimp (*Palaemonetes*) and sand shrimp (*Crangon*) with an occasional brown shrimp (*Penaeus*). Blue crabs are a very important commercial species on both the East and Gulf Coast. Several species of shrimp (*Penaeus*) are also commercially important but as a general group, shrimp are a very important trophic link to carnivorous fish (striped bass, trout). By examination of crab and shrimp abundance and size distribution in the various tidal flat habitats it is possible to evaluate the importance of each habitat type.

For the four basic habitat types examined (dense grass, sparse grass, unvegetated mud, unvegetated sand) at the six sampling sites there were definite patterns of abundance and biomass between habitats (Table 4 and Table 5). Crabs were most abundant in dense grass habitats followed by patchy grass, mud, and sand. This relation between abundance and habitat was also generally true for shrimp, except at the Guinea Marsh site in November where there was a very large catch of shrimp in the unvegetated mud habitat raising the average abundance in mud above the dense grass by a factor of two (Table 4). Of the total 67% of the crabs and 83% of the shrimp biomass occurred in dense grass. While most of the larger crabs and shrimp occurred in the muddy and sandy habitats their numbers were low compared to dense grass.

The data indicate a general preference for crabs and shrimp to utilize dense grass habitats. As with the infauna, the value of this habitat to crabs and shrimp is most probably both trophic and refuge. The increased habitat structure provided by the grass (1) supports a more productive community than that found in mud and sand areas, providing more food for the crabs and shrimp and (2) protects crabs and shrimp from predation.

The data also indicate that there are some differences between the sites sampled in terms of habitat utilization. No crabs or shrimp were found at the Susquehanna Flats and very few at the Kent Island site. However, Kent Island crabs had the largest mean biomass of all sites sampled. Greatest abundances and biomass were found to occur at the Guinea Marsh, Vaucluse Shores, Oregon Inlet, and Currituck Sound, sites (Table 4).

At the intensively studied site, Guinea Marsh there was a changing pattern of habitat utilization through time. In the early summer crabs in the grass habitats were much larger than those in sand. Through the summer the size of crabs in the grass declined while the size of crabs in unvegetated areas increased. In the fall and winter the size of crabs in all habitats was similar (Table 4). This pattern indicates that possibly both grass and unvegetated habitats are used by crabs during a growing season. Shrimp showed no preference for a particular habitat with time. The size of shrimp in grass habitats was fairly uniform through the year, except for the occurrence of two very large individuals in September. Shrimp from the unvegetated habitats were of similar size but in the fall and winter were much larger than those found in grass habitats.

By putting the crab and shrimp data into a matrix form we can make a partial comparative evaluation of the tidal flat habitat types (Table 8). It appears that grass habitats are of greatest importance to crabs and shrimp followed by muddy habitats with sand habitats being least important. Tidal freshwater areas seem not to be important to crabs or shrimp. Oligohaline areas begin to show some importance with mesohaline and higher salinity areas being most important.

Fish Data - In all cases, fish abundance was greater in vegetated habitats than nonvegetated habitats (except for Guinea Marsh, where fish were most abundant over unvegetated mud -- the bulk of which were pelagic *Anchoa* sp. and *Menidia* sp.). Evaluation of fish utilization of tidal flat habitats is given in Table 8.

Infauna Data - By placing in the infaunal data into a matrix form, it is possible to make a comparative evaluation of the various types of tidal flat habitats that were sampled (Table 9). As previously shown for crabs, shrimp, and fish, it appears that submerged aquatic vegetation is also of the greatest importance to the infauna, followed by muddy habitats with sandy habitats being of least importance (Table 10). This general trend is also revealed in values for abundance and biomass taken from the literature and compiled by ecoregion (Table 11).

Conclusions

From analyzing the data on tidal flats it appears that any attempt to establish guidelines for the evaluation of wetland tidal flat habitats needs to include the following considerations:

1 - Type of habitat - The ecological importance of wetland tidal flat areas will vary in accordance to the type and area of habitat considered. Of the four habitat types described in this report (dense grass, patchy grass, unvegetated mud, unvegetated sand), alterations involving unvegetated sand habitats would produce the least probable impact, while those alterations involving areas of submerged aquatic vegetation hold the highest potential for a change of habitat value.

2 - Season - Adequate consideration must also be given to the time of year that an evaluation is to take place. As is indicated by the data in Table 2 and 4, biomass and abundance values may vary considerably throughout the year. Care should be taken in selecting the time of evaluation, with due consideration for periods of reproduction, peak productivity, or migration of important species within the habitat.

3 - Geographical location [Ecoregion] - As is shown by the matrices developed for comparison of habitats between sites and the general values for abundance and biomass taken from this study the geographical location (along with the variation in the physico-chemical regime, such as salinity, temperature, etc.) can greatly influence the overall value of the habitat.

Any scheme for the evaluation of wetland tidal flats must provide adequate consideration of the entire community, including primary and secondary (invertebrate) production, and fisheries data as well as corresponding spatial and temporal variations within these components.

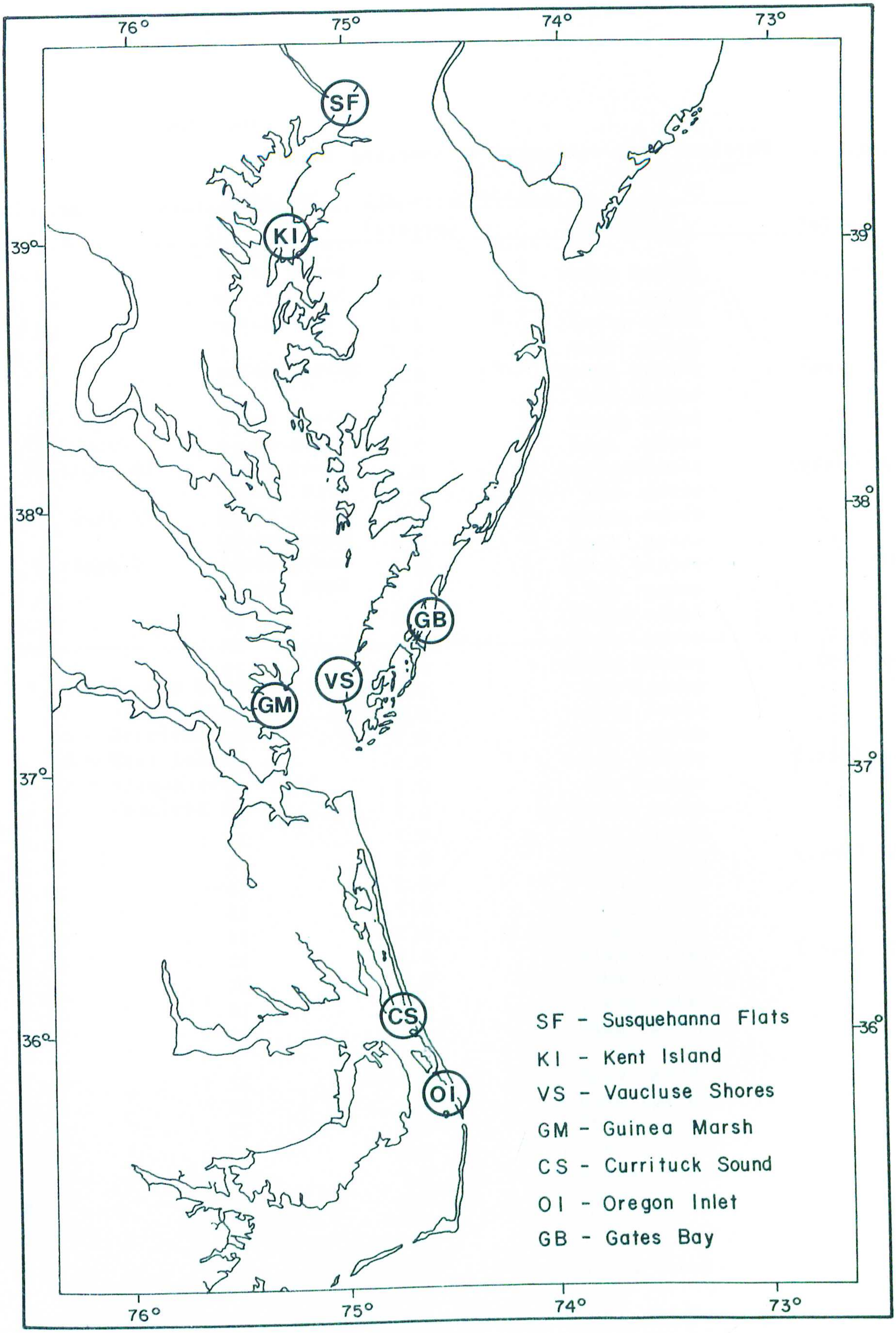

Figure 1. Location of sampling sites.

TABLE 1. Physical data collected at sampling sites.

Site*	Habitat	Depth-MLW (meters)	Temperature (°C)	Salinity (⁰/oo)
GM (May)	patchy grass	0.3	17	10.6
	unveg. mud	0.3	17	10.6
	dense grass	0.7	17	10.6
	unveg. sand	0.7	17	10.6
GM (Jun)	patchy grass	0.3	23	13.1
	unveg. mud	0.3	23	13.1
	dense grass	0.7	23	13.1
	unveg. sand	0.7	23	13.1
GM (July)	patchy grass	0.3	24	18.2
	unveg. mud	0.3	24	18.2
	dense grass	0.7	24	18.2
	unveg. sand	0.7	24	18.2
GM (Aug.)	patchy grass	0.3	28	19.6
	unveg. mud	0.3	28	19.6
	dense grass	0.7	28	19.6
	unveg. sand	0.7	28	19.6
GM (Sept.)	patchy grass	0.3	26	24
	unveg. mud	0.3	26	24
	dense grass	0.7	26	24
	unveg. sand	0.7	26	24
GM (Oct.)	patchy grass	0.3	17	25.8
	unveg. mud	0.3	17	25.8
	dense grass	0.7	17	25.8
	unveg. sand	0.7	17	25.8
GM (Nov.)	patchy grass	0.3	16	20.3
	unveg. mud	0.3	16	20.3
	dense grass	0.7	16	20.3
	unveg. sand	0.7	16	20.3
GM (Dec.)	patchy grass	0.3	10	23.1
	unveg. mud	0.3	10	23.1
	dense grass	0.7	10	23.1
	unveg. sand	0.7	10	23.1
OI	unveg. sand	intertidal	22	24.1
OI	unveg. sand	0.3	24	13.8
OI	unveg. sand	0.8	25	11.6
OI	unveg. sand	0.3	26	13.5
OI	dense grass	0.7	21.5	28.7
OI	unveg. sand	0.1	>30	3.8
			~27°-28	0.5
CS	dense grass	0.3		

TABLE 1. (continued)

Site	Habitat	Depth-MLW (meters)	Temperature (°C)	Salinity ($^o/oo$)
KI	patchy grass	0.2	27	7.7
KI	dense grass	0.3	28	7.3
KI	unveg. sand	1.0	27	8.1
KI	unveg. mud	0.7	29	8.0
SF	patchy grass	0.3	29	0.3
VS (May)	dense grass	1		
VS (June)	dense grass	1		
VS (July 6)	dense grass	1		
	unveg. sand	1		
VS (July 29)	dense grass	1		
	unveg. sand	1		
VS (Sept.)	dense grass	1		
	unveg. sand	1		

* GM - Guinea Marsh
OI - Oregon Inlet
CS - Currituck Sound
KI - Kent Island
SF - Susquehanna Flats
VS - Vaucluse Shores

TABLE 2. Abundance of individuals/m^2 and wet weight biomass g/m^2 (B) for polychaetes, molluscs, and crustaceans from Guinea Marsh.

	Dense Grass						Patchy Grass					
	Poly.		Moll.		Crust.		Poly.		Moll.		Crust.	
	A	B	A	B	A	B	A	B	A	B	A	B
May	4151	22.5	319	61.8	238	13.9	1248	8.7	312	232	445	1.4
June	18698	52.7	1784	69.1	7377	37.0	2375	12.0	456	25.6	143	0.7
August	23038	52.1	583	1.6	3929	5.2	7694	37.1	386	20.4	141	0.5
November	23261	70.4	864	4.8	3088	10.1	5651	72.8	700	2.4	452	2.0
Total	69148	197.7	3550	137.3	14632	66.2	16968	130.6	1854	280.4	1181	4.6
Average	17287	49.4	888	34.3	3658	16.6	4242	32.7	464	70.1	295	1.2

TABLE 2. (concluded)

	Unvegetated Mud						Unvegetated Sand					
	Poly.		Moll.		Crust.		Poly.		Moll.		Crust.	
	A	B	A	B	A	B	A	B	A	B	A	B
May	4825	83.8	401	45.8	175	0.6	442	17.0	292	666	467	1.7
June	4324	43.9	450	169.0	233	0.4	543	6.3	369	5.5	89	0.4
August	8086	52.5	560	10.1	328	4.6	960	8.7	157	3.8	56	0.3
November	8796	89.6	455	435.0	817	9.1	869	8.4	902	21.3	256	1.2
Total	26031	269.8	1866	659.9	1553	14.7	2814	40.4	1720	696.6	868	3.6
Average	6508	67.4	467	165.0	388	3.7	704	10.1	430	174.2	217	0.9

TABLE 3. Abundance of individuals/m^2 (A) and wet weight biomass g/m^2 (B) for polychaetes, molluscs, and crustaceans from Oregon Inlet, Susquehanna Flats, Kent Island, Currituck Sound.

	Dense Grass						Patchy Grass					
	Poly.		Moll.		Crust.		Poly.		Moll.		Crust.	
	A	B	A	B	A	B	A	B	A	B	A	B
OI	8229	15.5	86	0.4	914	4.0	29	0.9			29	0.1
SF							1486	2.1	571	2.7	57	0.3
KI	10200	63.2	486	38.7	1586	4.5	19286	185.0	143	0.7	21714	30.0
CS	1571	35.2	29	11.3	200	0.4						

	Unvegetated Mud						Unvegetated Sand					
	Poly.		Moll.		Crust.		Poly.		Moll.		Crust.	
	A	B	A	B	A	B	A	B	A	B	A	B
OI							1786	12.9	57	0.3	390	0.7
SF												
KI	4486	13.4	429	524.0	1343	12.0	2271	22.7	114	0.3	1800	3.4
CS												

TABLE 4. Trawl and seine data for crabs and shrimp.

			Crabs			Shrimp		
Date	Area	Gear**	Ind/100 m^2	g/100 m^2	$\bar{w}$*	Ind/100 m^2	g/100 m^2	$\bar{w}$
Susquehanna Flats								
Aug.	Sparse Grass	S	0	0	-	0	0	-
Kent Island								
Aug.	Dense Grass	S	0.24	11.24	47.0	16.51	4.15	0.2
	Sparse Grass	S	0.0	0.0	0.0	2.71	0.68	0.2
	Unveg. Mud	S	0.08	0.12	1.5	0.16	0.08	0.5
	Unveg. Sand	S	0.0	0.0	0.0	0.24	0.08	0.3
Guinea Marsh								
May	Dense Grass	T	0.53	2.85	5.4	12.43	3.01	0.2
	Sparse Grass	T	0.14	0.86	6.2	3.89	0.86	0.2
	Unveg. Mud	S	0.16	0.04	0.3	0.32	0.08	0.3
	Unveg. Sand	T	0.06	4.46	80.6	0.08	0.04	0.5
June	Dense Grass	T	5.40	243.63	45.1	63.59	55.07	0.3
	Sparse Grass	T	0.28	11.76	42.5	0.03	0.01	0.5
	Unveg. Mud	S	0.08	0.04	0.5	0.32	0.24	0.8
	Unveg. Sand	T	0	0	--	0	0	--
July	Dense Grass	T	9.14	274.09	30.0	124.28	30.12	0.2
	Sparse Grass	T	0.64	14.67	23.0	4.35	1.52	0.3
	Unveg. Sand	T	0.06	1.50	27.0	0.03	0.01	0.5
	Unveg. Mud	S	0	0	-	0	0	--

TABLE 4. Trawl and seine data for crabs and shrimp. (Continued)

Date	Area	Gear**	Crabs			Shrimp		
			Ind/100 m^2	g/100 m^2	$\bar{w}$*	Ind/100 m^2	g/100 m^2	$\bar{w}$
Guinea Marsh (continued)								
Aug.	Dense Grass	T	6.40	165.28	25.8	8.89	3.57	0.4
	Sparse Grass	T	14.04	202.94	14.5	93.52	27.96	0.3
	Unveg. Mud	S	2.95	128.39	43.5	0.0	0.0	--
	Unveg. Sand	T	0.14	6.20	44.8	0.0	0.0	--
Sept.	Dense Grass	T	2.93	47.77	16.30	0.53	0.72	1.4
	Sparse Grass	T	0.06	0.03	0.5	6.53	2.38	0.4
	Unveg. Mud	S	2.15	61.81	28.8	5.74	10.54	1.8
	Unveg. Sand	T	2.77	14.51	52.4	0.0	0.0	--
Oct.	Dense Grass	T	1.69	34.11	20.2	1.30	0.35	0.3
	Sparse Grass	T	1.19	22.07	18.5	1.88	0.39	0.2
	Unveg. Mud	S	6.14	82.14	13.4	19.14	3.03	0.2
	Unveg. Sand	T	0.11	1.91	17.3	0.06	0.03	0.5
Nov.	Dense Grass	T	4.51	3.77	0.8	24.56	7.28	0.3
	Sparse Grass	T	2.24	31.59	14.1	10.74	4.71	0.4
	Unveg. Mud	S	6.86	24.08	3.5	430.54	80.54	0.2
	Unveg. Sand	T	0.06	0.03	0.5	0.22	0.18	0.8
Dec.	Dense Grass	T	0.39	0.29	0.8	4.10	1.20	0.3
	Sparse Grass	T	0.83	0.03	0.3	4.18	1.32	0.3
	Unveg. Mud	S	0.0	0.0	--	27.27	3.64	0.1
	Unveg. Sand	T	0.0	0.0	--	0.39	0.35	0.9

TABLE 4. (concluded)

Date	Area	Gear**	Crabs			Shrimp		
			Ind/100 m^2	g/100 m^2	$\bar{w}$*	Ind/100 m^2	g/100 m^2	$\bar{w}$
Oregon Inlet								
July	Dense Grass	S	6.22	9.25	1.5	183.49	40.67	0.2
	Unveg. Sand	S	1.20	2.32	1.9	0.96	0.22	0.2
	Unveg. Sand	S	0.16	0.08	0.5	0.32	0.04	0.1
	Unveg. Sand	S	0.40	0.89	2.2	0.64	0.16	0.3
	Unveg. Sand	S	0.16	0.12	0.8	11.16	2.48	0.2
Currituck Sound								
July	Dense Grass	S	4.63	27.35	5.9	5.74	1.67	0.3
Vancluse Shores								
May	Dense Grass	T	12.04	14.01	1.2	166.25	28.54	0.2
June	Dense Grass	T	2.27	14.59	6.4	50.06	22.20	0.4
July 6	Dense Grass	T	4.21	18.02	4.3	349.64	91.09	0.3
	Unveg. Sand	T	0.08	3.99	4.8	3.57	1.06	0.3
July 29	Dense Grass	T	10.13	--	--	128.02	22.97	0.2
	Unveg. Sand	T	0.11	0.27	2.5	3.65	1.08	0.3
Sept.	Dense Grass	T	4.57	8.49	1.9	41.97	11.66	0.3
	Unveg. Sand	T	2.57	2.09	0.8	0.31	0.16	0.5

* Mean weight per individual.

** S = Seine T = Trawl

TABLE 5. Average abundance and biomass of crabs and shrimp from trawl and seine samples by habitat type.

		Crabs			Shrimp		
		Ind/100 m^2	g/100 m^2	$\bar{w}$	Ind/100 m^2	g/100 m^2	$\bar{w}$
GM	Dense Grass	3.87	96.10	18.0	29.96	12.67	0.4
	Sparse Grass	2.43	35.49	15.0	15.64	4.89	0.3
	Unveg. Mud	2.29	37.06	15.0	60.42	12.27	0.6
	Unveg. Sand	0.40	3.58	37.1	0.10	0.08	0.7
OI	Dense Grass	6.22	9.25	1.5	183.49	40.67	0.2
	Unveg. Sand	0.48	0.85	1.4	3.27	0.72	0.2
CS	Dense Grass	4.63	27.35	5.9	5.74	1.67	0.3
KI	Dense Grass	0.24	11.24	47.0	16.51	4.15	0.2
	Sparse Grass	0.0	0.0	0.0	2.71	0.68	0.2
	Unveg. Mud	0.08	0.12	1.5	0.16	0.08	0.5
	Unveg. Sand	0.0	0.0	0.0	0.24	0.08	0.3
SF	Sparse Grass	0.0	0.0	--	0.0	0.0	--
VS	Dense Grass	6.64	13.78	3.4	147.19	35.29	0.3
	Unveg. Sand	0.92	2.12	2.7	2.51	0.77	0.4

TABLE 6. Fish Data Abundances Inds./m^2.

	Habitat			
Site	Dense Grass	Patchy Grass	Unveg. Mud	Unveg. Sand
GM	103.4	27.1	145.5	2.0
KI	410.8	255.3	23.0	3.2
VS	100.8	-	-	38.8
OI	77.1	-	-	50.0
CS	113.0	-	-	-
SF	-	3.5	-	-

TABLE 7. Monthly ranges in abundance and biomass for the Guinea Marsh site.

		Abundance	Biomass
Dense grass	Polychaeta	4151(M) - 23261(N)	22.5(M) - 70.4(N)
	Mollusca	319(M) - 1784(J)	1.6(A) - 69.1(J)
	Crustacea	238(M) - 7377(J)	5.2(A) - 37.0(J)
		Abundance	Biomass
Patchy grass	Polychaeta	1248(M)* - 7694(A)	8.7(M) - 72.8(N)
	Mollusca	312(M) - 700(N)	2.4(N) - 232(M)
	Crustacea	141(A) - 452(N)	0.5(A) - 2.0(N)
		Abundance	Biomass
Unveg. mud	Polychaeta	4324(J) - 8796(N)	43.9(J) - 89.6(N)
	Mollusca	401(M) - 560(A)	10.1(A) - 435(N)
	Crustacea	175(M) - 817(N)	0.4(J) - 9.1(N)
		Abundance	Biomass
Unveg. sand	Polychaeta	442(M) - 960(A)	6.3(J) - 17.0(M)
	Mollusca	157(A) - 902(N)	3.8(A) - 666(M)
	Crustacea	56(A) - 467(M)	0.2(A) - 1.7(M)

*M = May
J = June
A = August
N = November

TABLE 8. Matrix approach to comparative evaluations of tidal flat habitat types for crab, shrimp, and fish.

Sample Site	OI				VS				GM				KI, CS				SF			
Salinity	Coastal Lagoon				Polyhaline				Mesohaline				Oligohaline				Tidal Fresh Water			
Habitat*	S	M	PV	DV	S	M	PV	DV	S	M	PV	DV	S	M	PV	DV	S	M	PV	DV
Crab utilization	2**	2	3	3	2	2	3	3	2	3	3	3	0	1	1	3	0	0	0	0
Shrimp utilization	3	3	3	3	2	2	3	3	1	3	3	3	2	1	1	3	0	0	0	0
Fish utilization	2	2	2	2	1	1	3	3	1	3	2	3	1	1	3	3	1	1	1	1

* S - sand flat
M - mud flat
PV - patchy submerged vegetation
DV - dense submerged vegetation

** scale of Importance 0 to 3, 3 being highest. (Assigned from data in tables 4,5,6 with some extrapolation)

TABLE 9. Average abundance, ind./m^2 (A) and biomass, g wet weight/m^2 (B), for all sites examined.

Dense Grass

Site	Polychaeta A	Polychaeta B	Mollusca A	Mollusca B	Crustacea A	Crustacea B
GM	17287	49.4	888	34.3	3658	16.6
KI	10200	63.2	486	38.7	1586	4.5
OI	8229	15.5	86	0.4	914	4.0
CS	1571	35.2	29	11.3	200	0.4

Patchy Grass

Site*	Polychaeta A	Polychaeta B	Mollusca A	Mollusca B	Crustacea A	Crustacea B
GM	4242	32.7	464	70.0	295	1.1
KI	19286	185.0	143	0.7	21714	30.0
OI	29	0.9	0	0	29	0.1
SF	1486	2.1	571	2.7	57	0.3

Unvegetated Mud

Site	Polychaeta A	Polychaeta B	Mollusca A	Mollusca B	Crustacea A	Crustacea B
GM	6508	67.0	467	165	388	3.7
KI	4486	13.4	429	524	1343	12.0

Unvegetated Sand

Site	Polychaeta A	Polychaeta B	Mollusca A	Mollusca B	Crustacea A	Crustacea B
GM	704	10.1	430	174.0	217	0.9
KI	2271	22.7	114	0.3	1800	3.4
OI	1786	12.9	57	0.3	390	0.7

* GM - Guinea Marsh
KI - Kent Island
OI - Oregon Inlet
SF - Susquehanna Flats
CS - Currituck Sound

TABLE 10. Matrix approach to comparative evaluation of tidal flat habitat types for polychaetes, molluscs and crustaceans.

Sample Site	OI				GM				KI, CS				SF			
Salinity	Coastal Lagoon				Mesohaline				Oligohaline				Tidal Fresh Water			
Habitat*	S	M	PV	DV	S	M	PV	DV	S	M	PV	DV	S	M	PV	DV
Polychaetes	2**	2	1	3	1	3	3	3	2	2	3	3	-	-	1	1
Molluscs	1	1	1	2	3	3	2	2	1	3	1	2	-	-	1	1
Crustaceans	1	1	1	2	1	1	2	3	3	3	3	2	-	-	1	1

* S - Sand flat
M - Mud flat
PV - Patchy submerged vegetation
DV - Dense submerged vegetation

** Scale of importance to 3, 3 being highest (assigned from data in table 9 with some extrapolation)

TABLE 11. Abundance and biomass values for infauna and fish compiled from the literature on tidal flats.

Habitat	Range in density (Ind./m^2)		Range in Biomass (g/m^2)		References*
			Boreal and Continental		
Unveg. Mud	Mollusca	868	Mollusca	1.0	20
	Polychaeta	38,442	Polychaeta	115.2	20
	Crustacea	69,007	Crustacea	16.6	20
Dense Grass	Mollusca	915 ± 431 ($\bar{x}$-Range)	Mollusca	87.8 ± 41.1	6
Unveg. Sand	Mollusca	556 - 307,057	Mollusca	0 - 3.8	20
	Polychaeta	725 - 23,468	Polychaeta	12.4 - 182	20
	Crustacea	78 - 10,503	Crustacea	39.9 - 70	20
			Temperate and Subtropical		
Unveg. Mud	Crustacean	0 - 10			24
	Mollusca	17 - 61			24
	Polychaeta	106 - 437			24
Dense Grass	Crustacea	0 - 2.5	Crustacea	.02 - 3.5	13
	Total Fish	.07 - 3.5	Total Fish	.02 - 2.4	13
	Total Inverts	.29 - 7.7	Total Inverts	.3 - 3.4	13
	Total Infauna	15,143			18
	Callinectes	5-57			16
	Polychaeta	1353			24
	Mollusca	255			24
	Crustacea	40			24

TABLE 11. (continued)

Habitat		Range in density (Ind./m^2)		Range in Biomass (g/m^2)	References
	Polychaeta	29 - 899			25
	Crustacea	0 - 146			25
	Total fish	0.08 - 6.6			1
Unveg. Sand	Polychaeta	16 - 3,073			8, 22
	Mollusca	27 - 78			8, 22
	Crustacea	3 - 292			8, 24
	Polychaeta	7 - 28			25
	Mollusca	0 - 17			25
	Crustacea	381590			25
			Tropical		
Dense Grass	Mollusca	270 - 637	Mollusca	16.7	5
	Crustacea	75 - 760	Crustacea	17.9	5
	Polychaeta	91 - 542	Polychaeta	38.6	5
Unveg. Sand	Mollusca	4.6 - 6.8	Mollusca	0.3 - 3.2	9
	Polychaeta	2.6 - 52.6	Polychaeta	.04	9
	Crustacea	66.6 - 447	Crustacea	0.2 - 1.8	9
			Molluscs	172.8	17 (1.6 mm)
			West Coast		
Unveg. Sand	Polychaeta	90.9			10
	Mollusca	38.1	Mollusca	351 - 603	10, 19
	Crustacea	213.9			10

TABLE 11. (continued)

Habitat	Range in density (Ind./m^2)		Range in Biomass (g/m^2)		References
European					
Unveg. Mud	Mollusca	42 - 3188	Mollusca	33 - 8	2,21,23,12,14
	Polychaeta	8 - 1796	Polychaeta	18.1	21, 23
Dense Grass	Total Infauna	8540 ± 830/m^2		447 ± 126	15
Unveg. Sand			Total Infaunal	127 - 133	4
	Mollusca	1041	Mollusca	115.5	3
	Polychaeta	208	Polychaeta	53.5	3
	Crustacea	599	Crustacea	4.0	3
Commercially Important Species					
Temperate and Subtropical					
Unveg. Mud			*Callinectes*	0.1 - 1.4	7
Dense Grass	*Callinectes*	5 - 57 (<6.0 cm)	*Callinectes*	0 - 1.4	13, 16
			Penaeus	0 - 2.5	13
	Fish	.08 - 6.6	Fish	0 - 3.37	1, 13
			Total Epibenthic	0.8 - 4.9	13
Tropical					
Dense Grass	Fish (Day)	.13 - 12.6		0.8 - 15.2	5
	Fish (Night)	.14 - 2.1		0.6 - 2.6	5

Table 11 (concluded)

Reference #	Reference	Time of Year
1	Adams 1976	Sept. 71 - Sept. 72 Seasonal - each month 2 - monthly intervals
2	Barnes 1973	Jan. 1970 - Jan. 1972
3	Beukema 1976	July 23 - Oct. 30th 1970-74 Seasonal
4	Beukema et al. 1978	1971, 1972, 1977
5	Brook 1977	Seasonal - each month
6	Burke & Mann 1974	
7	Day et al. 1973	Seasonally
8	Dexter 1969	
9	Dexter 1972	
10	Dexter 1978	Seasonally
12	Hibbert 1976	Winter 1972, 1973
13	Hoese & Jones 1963	Seasonal, 1962
14	Hughes 1970	Seasonal
15	Lappalainen et al. 1975	1968 - 1971
16	Miller, unpublished	Summer, 1975
17	Moore et al. 1968	Summer, 1965
18	Orth 1971	March & July, 1970
19	Rae 1979	every 2 months, Aug. 1974 - Aug. 1975
20	Sanders et al. 1962	Summer (1959, 1960)
21	Sneli 1968	Autumn, 1966
22	Virnstein 1977	May - Nov. 1974
23	Warwick & Price 1975	Oct. 1972-73 Seasonal
24	Williams & Thomas 1967	Aug. - Nov. (1963)
25	Matta 1977	Oct. 1975 - July 1976

PART II: PRIMARY PRODUCTION ASSESSMENT

Introduction

The primary production studies were undertaken to assess the magnitude and fluxes of community metabolism, sediment carbon and microautotrophic pigments in various types of tidal flat habitats. Information gained from the study was used to develop methods for assessing the potential primary productivity of tidal flat areas for the purpose of selecting highway routes.

Intensive studies were carried out in the Guinea Marshes area of the lower York River, Virginia. These studies were primarily designed to elucidate differences in primary production parameters. In addition, studies of many extensive sites have been included to show that conclusions derived from the intensive site investigations are likely to apply to other cases.

Site Description

The intensive site consisted of five habitats in the Guinea Marsh (GM) area of the lower York River (Figure 1):

1) Intertidal sandflat having a firm silty sand sediment

2) Intertidal mudflat having a soft mud bottom, containing large amounts of detritus

3) A fringing *Spartina alterniflora* marsh

4) An eelgrass bed, *Zostera marina*

5) An unvegetated sand area

Depths at these sites ranged from 1-2 m during sampling. Additional data on primary production were collected from a number of locations as described in Part I.

Materials and Methods

Measurements of gross productivity, net productivity, and respiration in water were done by following *in situ* changes in dissolved oxygen in four one-liter plexiglass chambers, two light and two dark.

Dissolved oxygen was determined using the azide modification of the Winkler method (Strickland and Parsons 1968). Incubation times ranged from 1 to 3 hours.

Following completion of the *in situ* experiments, the same cores were collected from the three intertidal areas and returned to the laboratory for determination of community metabolic rates in air. At the time of the experiment, water was siphoned out of the chambers, which were then sealed with rubber stoppers and incubated for one hour under ambient light and temperature conditions. Metabolic rates were determined from changes in carbon dioxide within the chambers.

Respiration rates were determined by differences between initial and final gas concentrations in the dark chambers. Net productivity rates were determined by difference in initial and final gas concentrations in the light chambers. Mean respiration rates and mean net productivity rates were added to yield a gross productivity rate.

Chlorophyll *a* was determined using a standard acetone extraction procedure (Vollenweider 1974). However, this procedure does not adequately assess chlorophyll *a* or pheophytin *a* (Jacobsen 1978, Whitney and Donley 1979, Wun *et al*. 1980). Consequently, three different estimates of pigment fluxes were used. Apparent chlorophyll *a* was calculated using the optical density reading of the unacidified extract. Functional chlorophyll *a* was calculated using the value attained by subtracting the optical density value of the acidified extract from the value of the unacidified extract. Pheophytin *a* was estimated using the optical density reading of the acidified extract.

Total organic carbon was determined in five centimeter vertical sections from the surface to 15 cm. Analyses were performed using a Leco carbon analyzer.

Surface water concentrations of nitrate, nitrite, ammonia and phosphate were collected in 60 cc syringes and filtered immediately. Filtered samples were kept on ice and frozen immediately upon return to the lab. Analyses were performed using a Technicon Auto-Analyzer.

All data were analyzed using the Kruskal-Wallis nonparametric analysis of variance, or the Mann-Whitney test in the case of two treatments. Significant results were further examined using a multiple range test (Zar 1974), designed to statistically separate different groups. All analyses were performed using 95% significance levels.

Results and Discussion

Data on metabolic rates, sediment pigments, sediment carbon, and surface water nutrients collected from the intensive sites appears in Tables 12-29. Seasonal fluxes in metabolic rates, sediment pigments and sediment carbon at these sites appear in Figures 2-10.

Sediment pigment measurements from the extensive sites are shown in Table 30. Pigment concentrations are not appreciably different from those found at the intensive site or from values given in the literature.

Results of the statistical analyses are given in Tables 31-35. There were no significant differences among habitats over the entire study in gross productivity, net productivity, respiration, gross productivity/respiration ratios, or assimilation rates in either water or air (Table 31). Table 17 also shows that only the mudflat operates heterotrophically in both air and water, i.e. the mudflat has a P/R ratio less than 1.0. Similarly, there were no differences among habitats over the entire study in apparent chlorophyll a, functional chlorophyll a or pheophytin (Table 32). There were, however, significant among habitat differences over the study in chlorophyll/phenophytin ratios and sediment carbon, for each sediment stratum. Four significantly different chlorophyll/phenophytin groups were found overall (Table 32). The two sandy sites are equally high, the mudflat and two vegetated sites are all lower and statistically different from each other. Compared to the higher group, these three sites have very similar means and a much smaller range of monthly means.

The mudflat was higher in total organic carbon at each depth sampled. Over the 0-5 cm level the vegetated sites were equally high, while at deeper levels, the marsh site contained more carbon than the eelgrass site. The two sandy sites were equally lowest over the first two strata, while between 10-15 cm the sandflat contained significantly more carbon than the submerged sand site (Table 32).

Surface nutrient samples were not statistically analyzed because of 1) small sample size, 2) high variability among replicates, 3) lack of information or vertical or spatial variability, and 4) lack of information on nutrient interactions between the water and the sediments for most of these communities, therefore rendering differences among habitats or seasons uninterpretable.

Those parameters which could be analyzed for among habitat differences each month are also presented in Tables 31-32. The metabolic parameters were usually significantly different among habitats, but no groups could be distinguished by multiple range testing. Pigment analyses also showed significant differences among habitats in most months, but distinct groupings were also found in most months. However, constant relationships among the habitats through time did not exist, e.g. for apparent chlorophyll, functional chlorophyll, and phenophytin, no single arrangement of habitat groups was ever repeated. Tables 33-34 show statistical results of tests among sampling dates by habitat and by combining habitats overall.

Several points become evident in viewing these seasonal changes:

1) With regard to any particular parameter, each habitat has a pattern of seasonal change different from any other habitat.

2) Each habitat has generally uniform metabolic rates or standing crops of pigments.

3) The seasonal behavior of any parameter when combining samples over all habitats often does not represent any individual habitat very closely.

4) Maximum or minimum values for a given parameter do not occur the same time in all habitats.

It was also of interest to look at possible relationships among various parameters by correlation analysis (Table 35). Chlorophyll concentrations were not correlated with any metabolic parameter except for a negative correlation with respiration in the eelgrass bed. This is perhaps to be expected since increases in respiration would be associated with increases in plant biomass and the fauna it supports, and not with increases in chlorophyll alone. The overall lack of correlation between biomass as chlorophyll and metabolism is a frequent finding in sediments dominated by microautotrophs (see literature review Vol. 1 of this series).

Gross productivity was correlated with respiration in air for the mudflat and marsh and in water for the sandflat only. This indicates that for these habitats under these conditions, changes in gross productivity are largely due to changes in respiration. Metabolic rate changes in air are not correlated with changes in the same parameters in water, except for sandflat respiration, indicating that the dynamics of metabolism follow different seasonal patterns in air vs. water.

Tests were also made to determine differences in air vs. water regarding magnitude of the metabolic rates (Table 34). Rates of gross productivity, net productivity, respiration and assimilation, and P/R ratios were much greater in water than in air at the sandflat site. At the mudflat and marsh sites rates in air were not different from rates in water except for mudflat respiration. As an artifact of the large differences in the measurements at the sandflat, lumping values from all three habitats still showed higher rates in water.

Conclusions

The lack of overall differences among habitats in rate measurements or pigment concentrations is due to the lack of relationship among these habitats with regard to seasonal dynamics. Each habitat has a relative constant rate of metabolism and density of microautotrophs, as chlorophyll *a*. Deviations from the typical condition occur as pulsed inputs during a peak month or couple of months, or as a brief reduction of metabolism or standing crop during a month or couple of months. These high or low periods are different for each habitat, and may occur at any time of year, e.g. two habitats reaching a peak in net productivity in the same month would be an exceptional case, not a typical one.

The net result is that the benthic metabolism of the habitats comprising the intertidal and shallow water communities of the lower York River constitute a group of subsystems which have complementary seasonal fluxes of productivity such that 1) there is no annual difference among different habitats in productivity and, 2) the productivity of the lower York River benthic system as a whole remains constant.

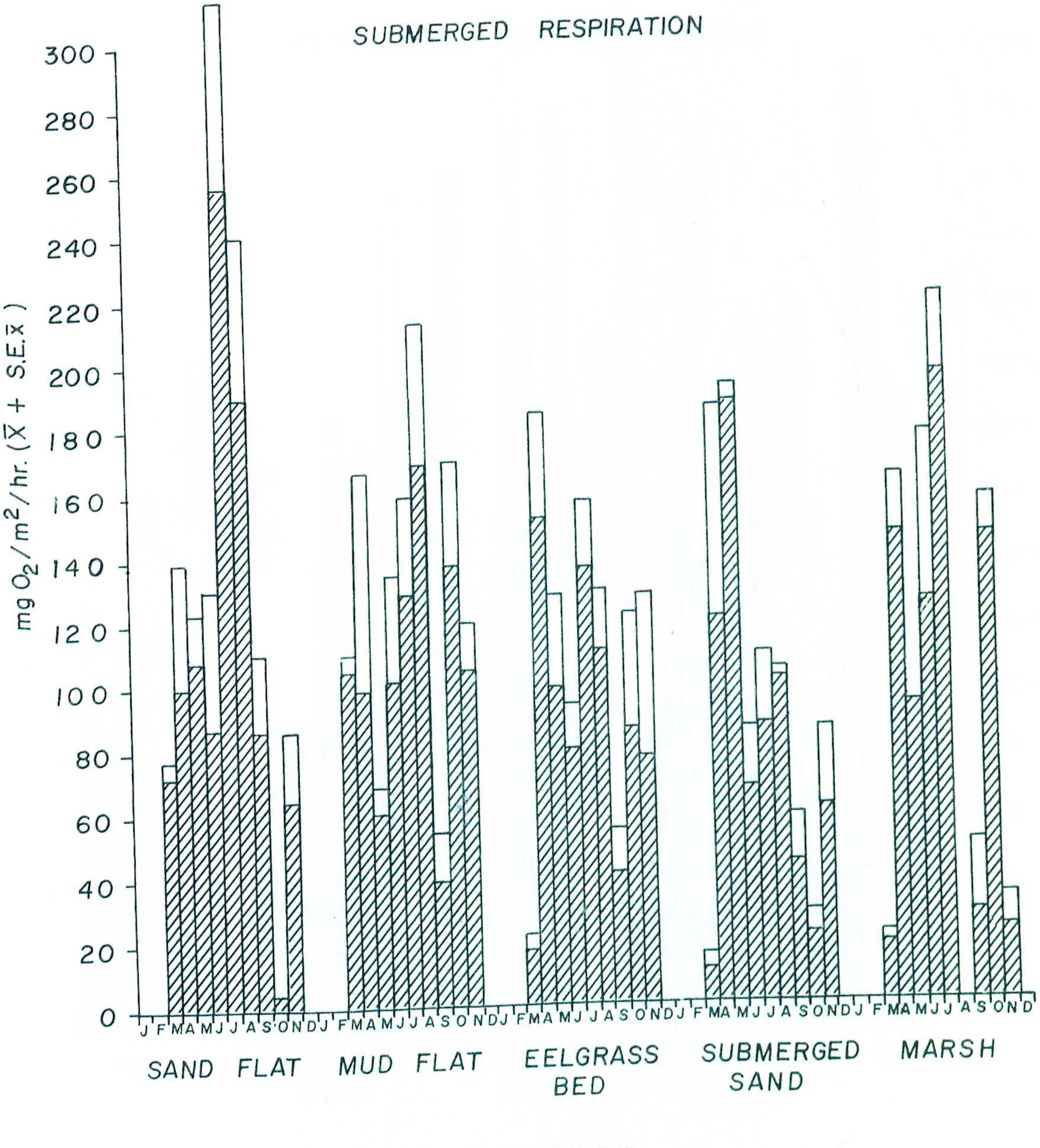

Figure 2. Seasonal flux in submerged respiration rate.

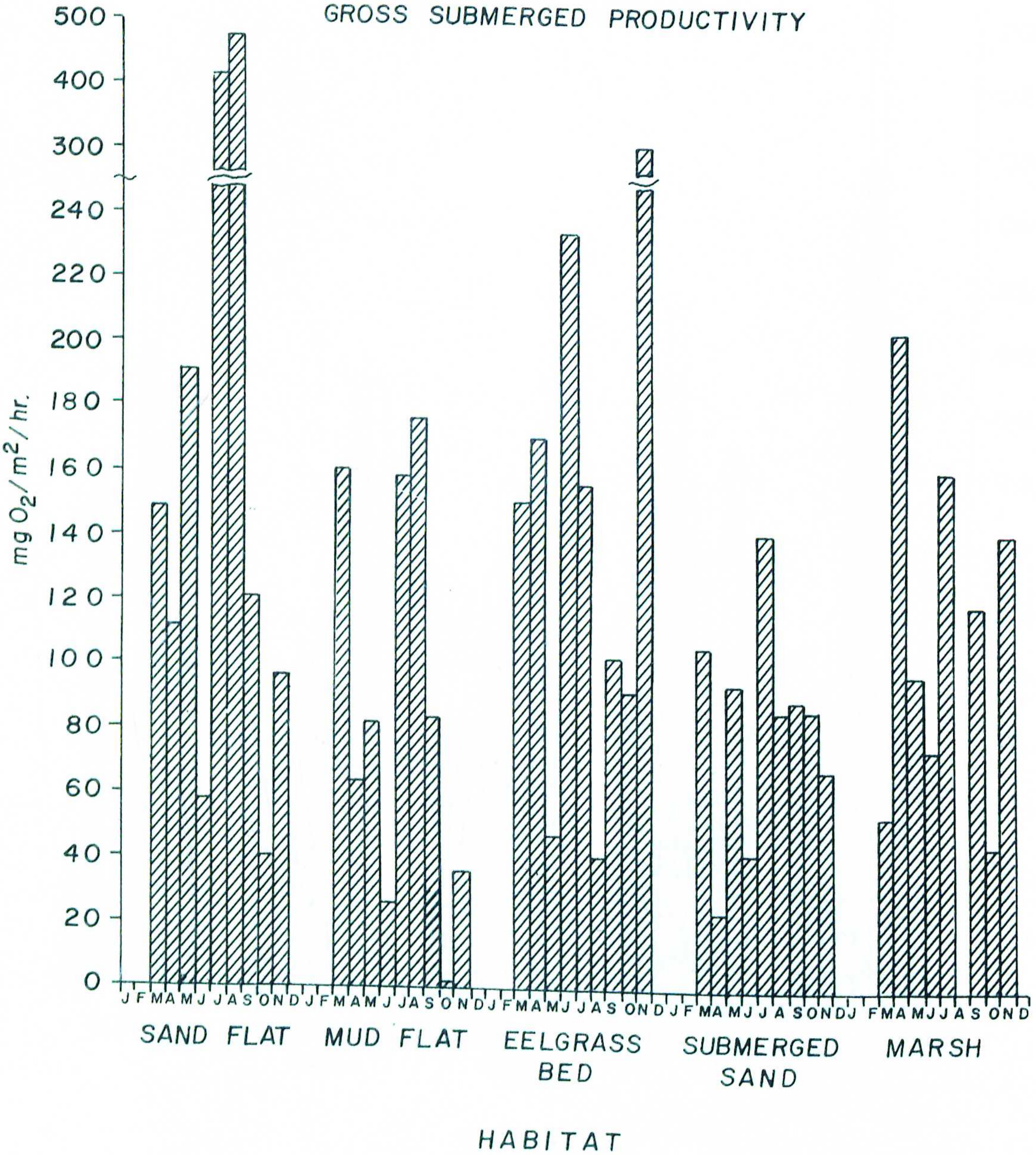

Figure 3. Seasonal flux in submerged gross productivity.

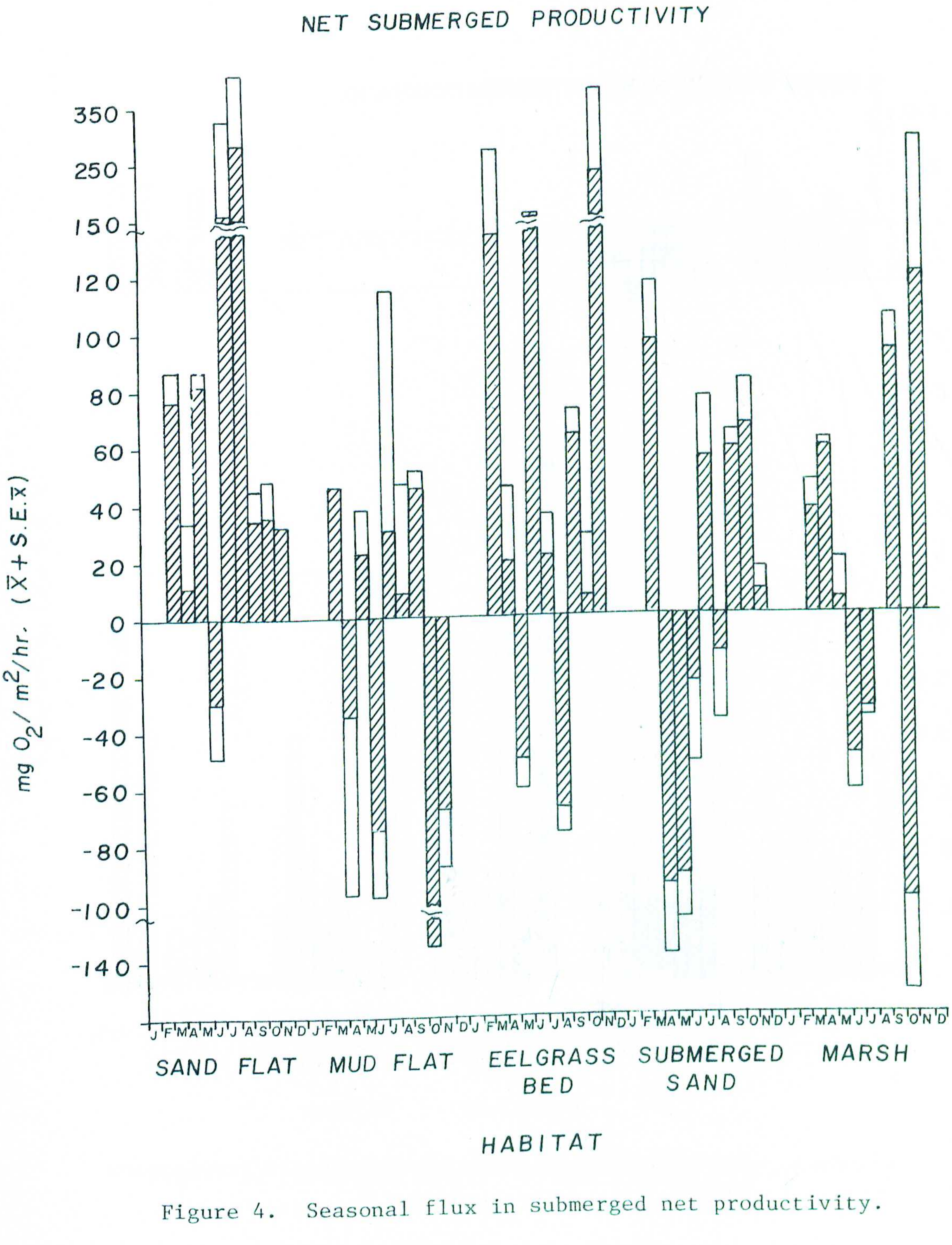

Figure 4. Seasonal flux in submerged net productivity.

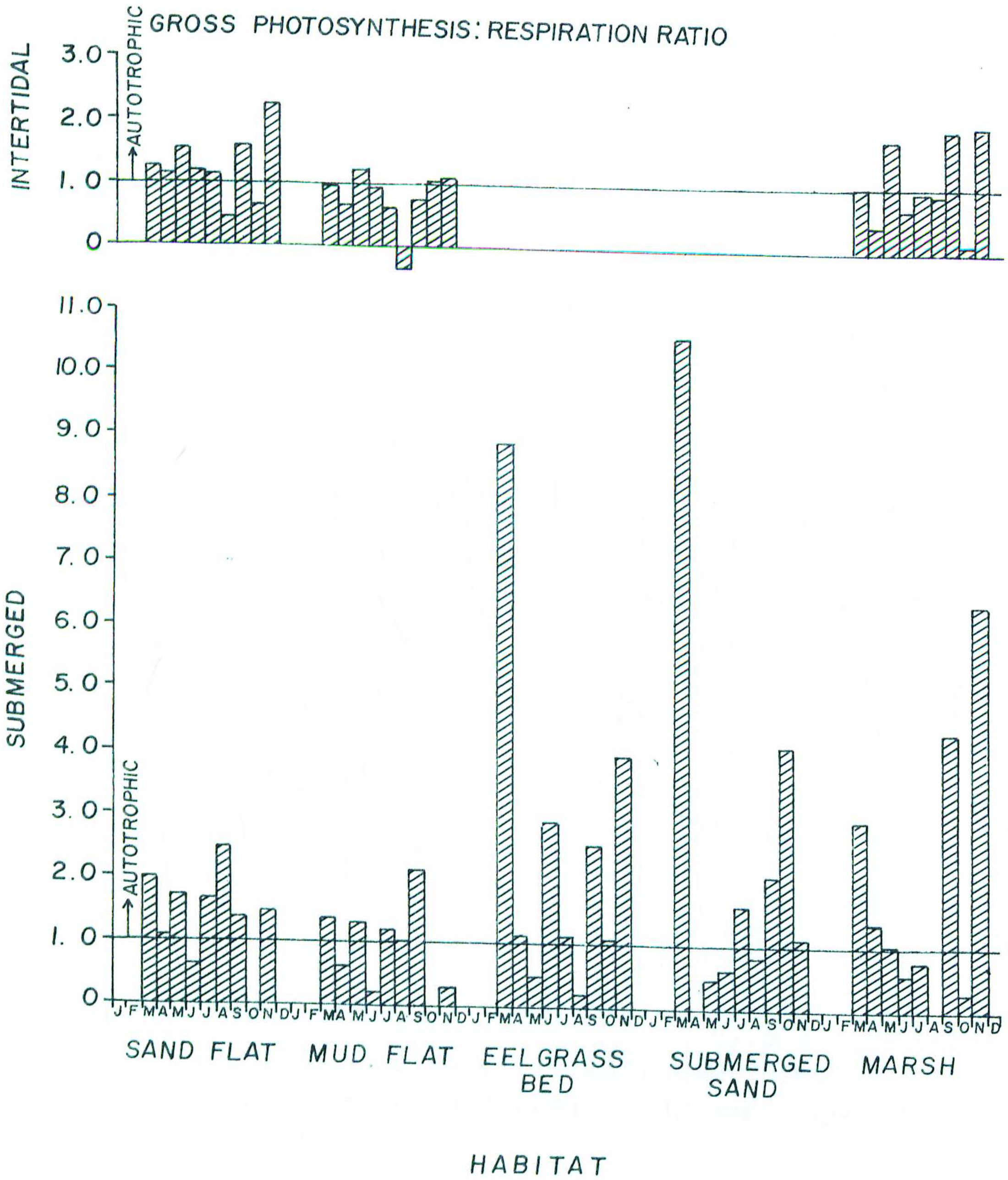

Figure 5. Seasonal flux in gross photosynthesis/respiration ratio.

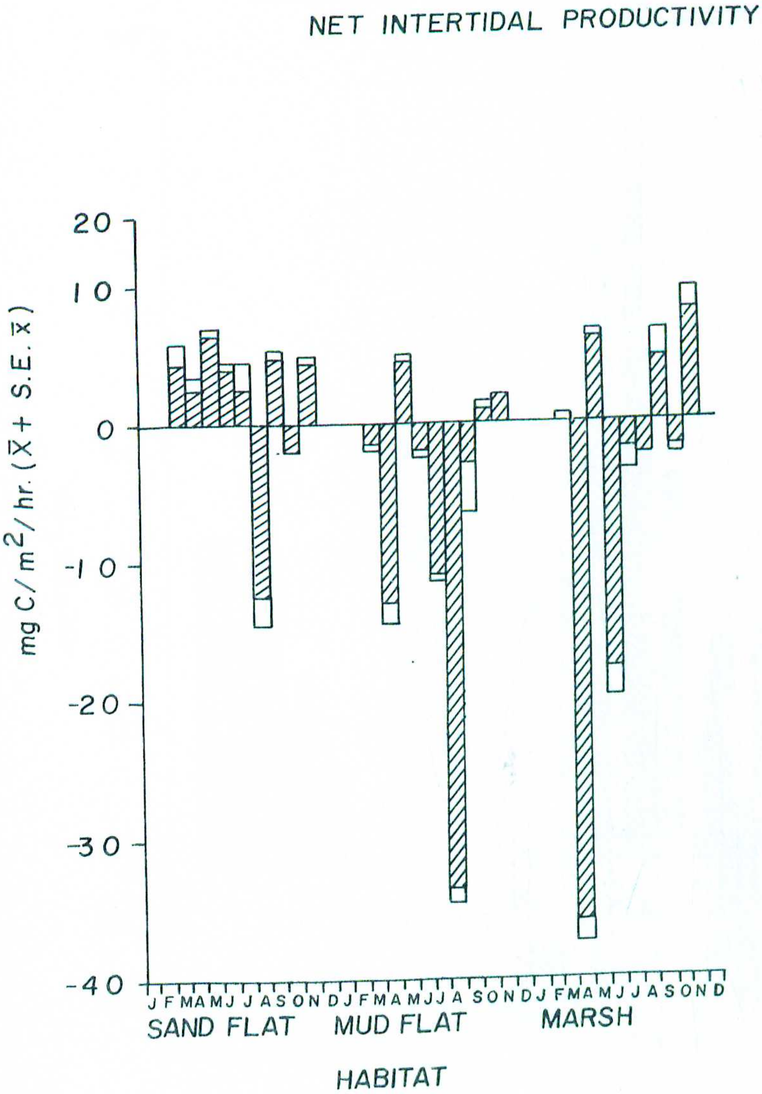

Figure 6. Seasonal flux in intertidal net productivity.

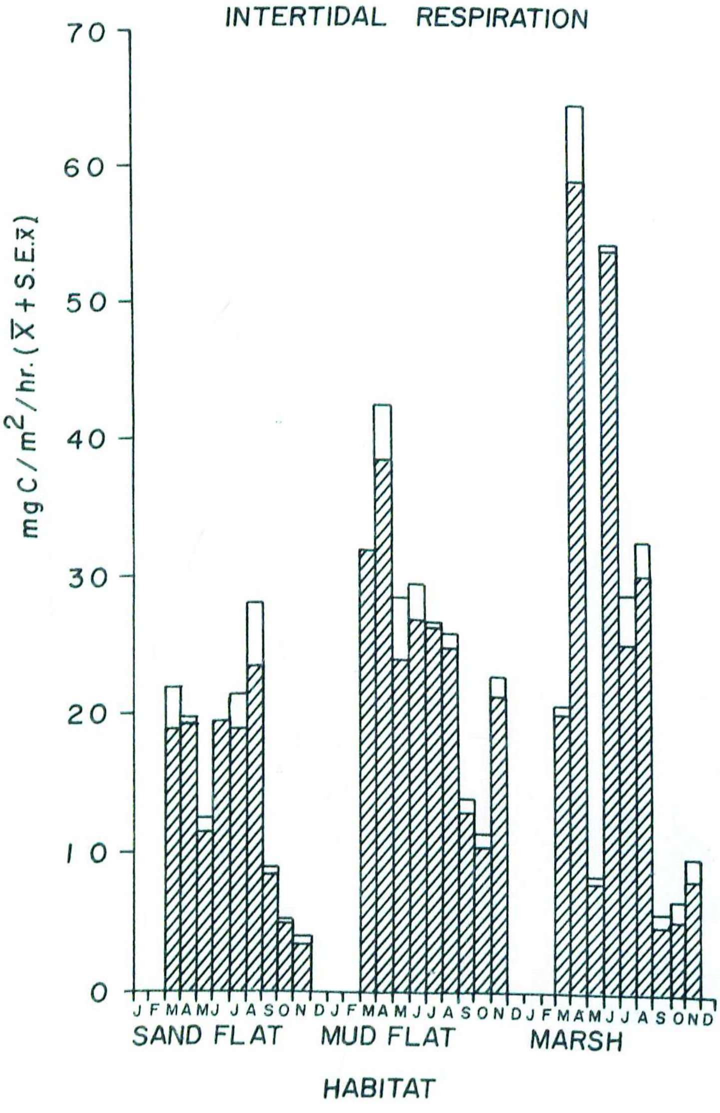

Figure 7. Seasonal flux in intertidal respiration.

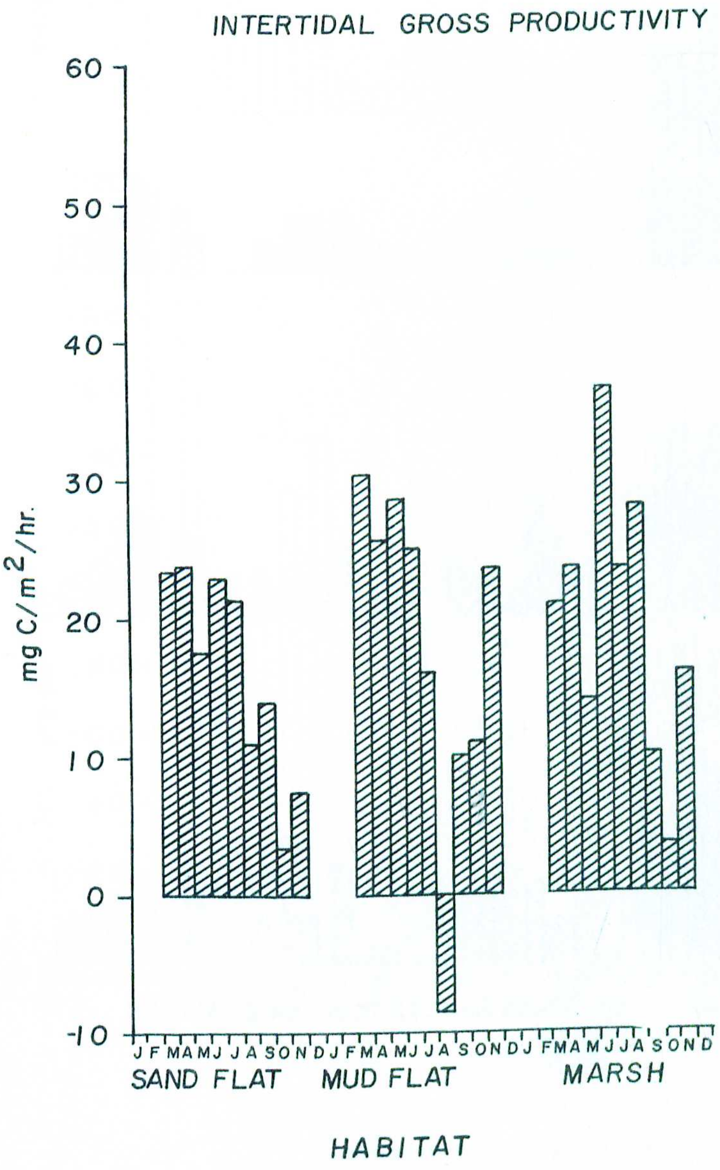

Figure 8. Seasonal flux in intertidal gross productivity.

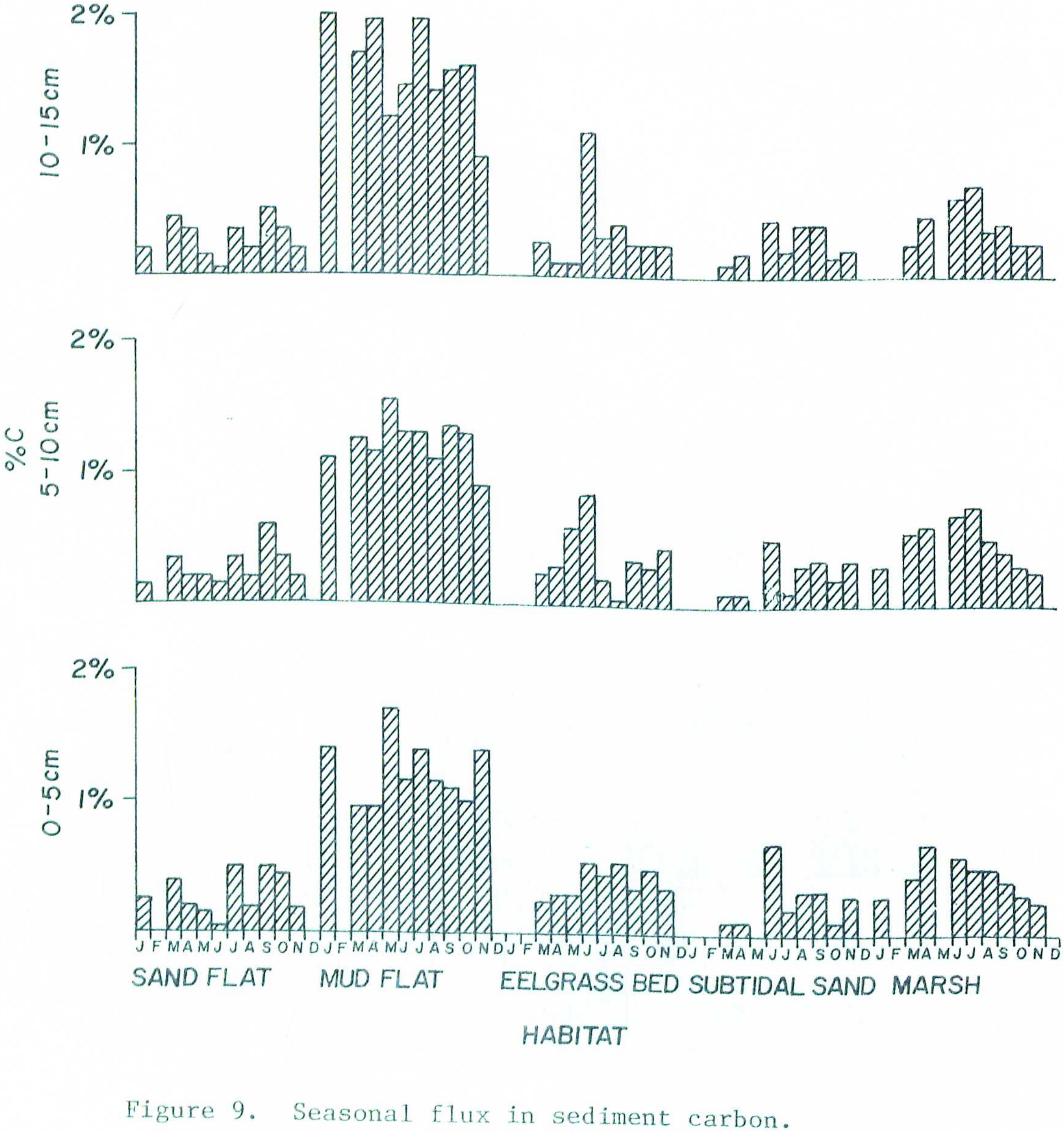

Figure 9. Seasonal flux in sediment carbon.

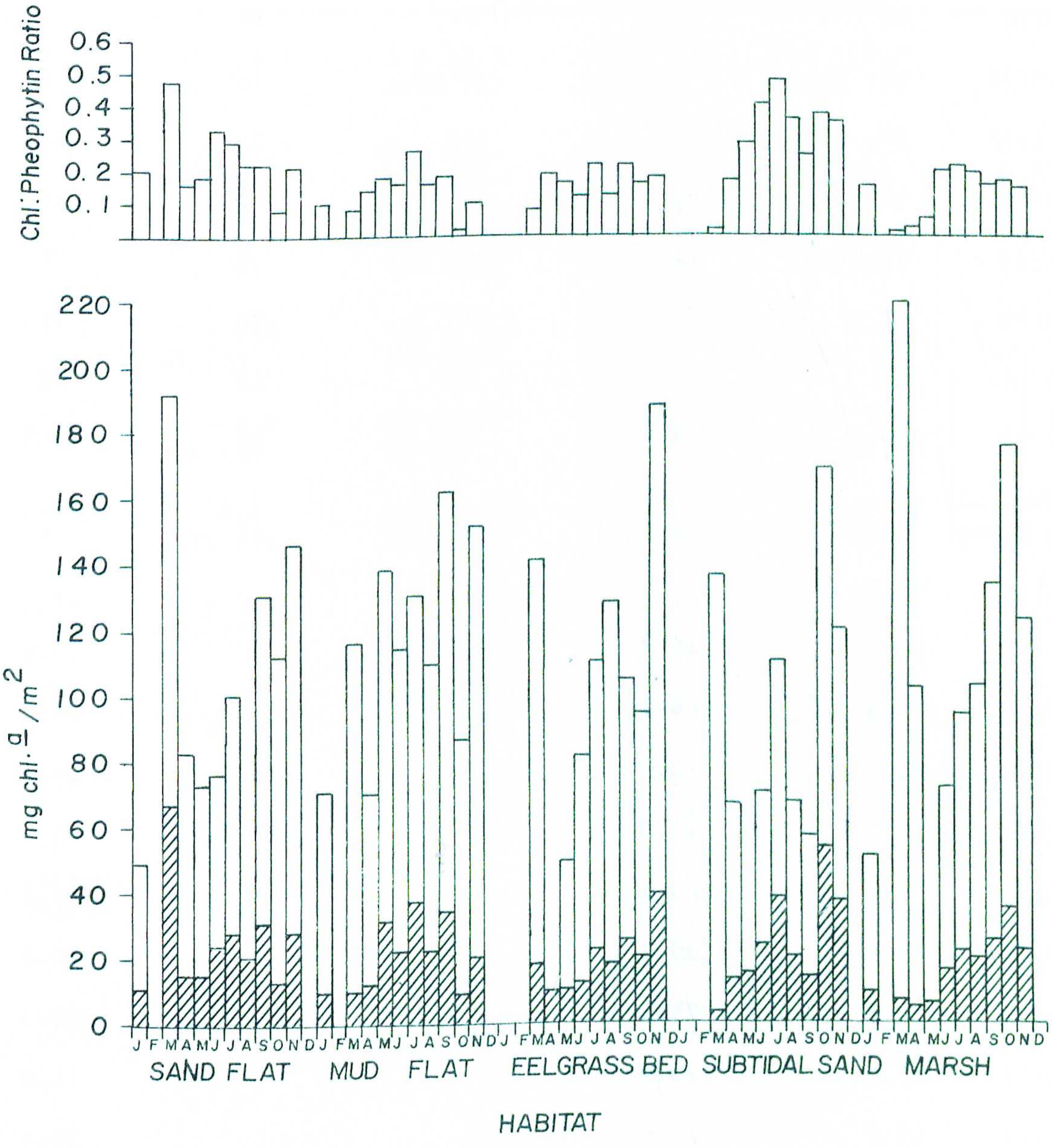

Figure 10. Seasonal flux in sediment pigments.

TABLE 12. Community gross productivity (mg C/m^2/hr) monthly mean.
Rates in water (top) and in air (bottom).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
8/78	177	66	15	32	
9/78	45	31	39	34	45
10/78	15	0.4	34	33	16
11/78	36	13	114	25	53
3/79	55	60	57	40	20
4/79	42	24	64	9	76
5/79	71	31	18	36	36
6/79	21	10	88	15	28
7/79	155	59	58	53	60
Over all Dates	69	33	54	31	42
7/78	21.6	16.2			23.6
8/78	11.0	-8.7			28.0
9/78	13.8	10.0			9.8
10/78	3.3	11.0			3.5
11/78	7.7	23.5			16.2
3/79	23.6	30.4			20.8
4/79	20.8	25.5			23.3
5/79	17.6	28.4			14.0
6/79	23.0	25.0			36.4
7/79	29.6	65.3			53.6
Over all Dates	17.0	22.7			23.0

TABLE 13. Community net productivity (mg C/m^2/hr) in water. Monthly Mean ± S.E. of Mean, Coefficient of Variation (sample size).

Date	Sandflat	Mudflat	Eelgrass Bed	Submerged Sand	Marsh
8/78	106 ± 8.1 13% (3)	3 ± 13.7 885% (4)	-25 ± 2.8 22% (4)	-5 ± 8.7 327% (4)	
9/78	13 ± 4.1 64% (4)	17 ± 2.1 22% (3)	24 ± 3.2 27% (4)	22 ± 2.4 19% (3)	34 ± 4.8 24% (3)
10/78	13 ± 4.9 76% (4)	-51 ± 3.9 15% (4)	3 ± 7.8 576% (4)	25 ± 5.8 41% (3)	-37 ± 12.1 65% (4)
11/78	12 ± 0.0 0% (2)	-25 ± 7.4 58% (4)	86 ± 8.6 20% (4)	3 ± 2.8 170% (3)	45 ± 17.9 70% (3)
3/79	28 ± 4.2 30% (4)	17 ± 0.0 0% (1)	50 ± 11.2 39% (3)	36 ± 7.8 44% (4)	13 ± 3.7 55% (4)
4/79	4 ± 8.8 357% (3)	-13 ± 2.3 301% (3)	7 ± 9.6 267% (4)	-36 ± 9.0 51% (4)	22 ± 1.1 9% (3)
5/79	31 ± 1.9 9% (2)	8 ± 5.9 146% (4)	-21 ± 3.9 40% (4)	-34 ± 5.5 32% (4)	-2 ± 5.1 521% (4)
6/79	-11 ± 7.0 123% (4)	-28 ± 8.7 62% (4)	58 ± 0.0 0% (2)	-9 ± 10.6 242% (4)	-19 ± 4.4 41% (3)
7/79	59 ± 12.4 42% (4)	11 ± 31.8 575% (4)	8 ± 5.1 131% (4)	21 ± 7.8 77% (4)	-13 ± 1.1 17% (4)
Over all Dates	28.0	-7.0	21.0	3.0	6.0

TABLE 14. Community net productivity (mg C/m^2/hr) in air. Monthly mean ± S.E. of mean, Coefficient of Variation, and (sample size).

Date	Sand Flat	Mud Flat	Marsh
7/78	2.5 ± 2.07 166% (4)	-10.3 ± 0.37 7% (4)	-1.8 ± 1.48 165% (4)
8/78	-12.4 ± 2.10 34% (4)	-33.5 ± 1.05 6% (4)	-2.7 ± 0.08 6% (4)
9/78	5.1 ± 0.42 17% (4)	-2.8 ± 3.47 248% (4)	4.7 ± 2.05 88% (4)
10/78	-1.9 ± 0.09 9% (4)	0.7 ± 0.60 166% (4)	-2.2 ± 0.79 73% (4)
11/78	-4.3 ± 0.49 23% (4)	2.2 ± 0.03 3% (4)	7.8 ± 1.30 34% (4)
3/79	4.7 ± 1.41 61% (4)	-1.5 ± 0.35 34% (2)	0.1 ± 0.58 932% (4)
4/79	2.4 ± 0.98 82% (4)	-13.1 ± 1.41 21% (4)	-35.8 ± 1.32 7% (4)
5/79	6.3 ± 0.29 9% (4)	4.4 ± 0.36 16% (4)	59 ± 0.54 18% (4)
6/79	3.6 ± 0.46 26% (4)	-1.8 ± 0.31 35% (4)	-17.7 ± 2.11 9% (4)
7/79	5.1 ± 0.03 3% (4)	1.3 ± 0.66 106% (4)	14.7 ± 5.75 78% (4)
Over all Dates	1.1	-5.5	2.6

TABLE 15. Community respiration (mg C/m^2/hr) in water. Monthly mean ± S.E. of mean, Coefficient of Variation, (sample size).

Date	Sandflat	Mudflat	Eelgrass Bed	Submerged Sand	Marsh
8/78	71 ± 19.1 38% (2)	63 ± 16.3 52% (4)	41 ± 7.0 34% (4)	37 ± 1.1 6% (4)	
9/78	32 ± 9.1 49% (3)	15 ± 5.5 75% (4)	15 ± 5.3 71% (4)	16 ± 5.6 49% (2)	10 ± 8.2 115% (2)
10/78	2 ± 0.0 0% (1)	51 ± 11.9 47% (4)	32 ± 12.5 68% (3)	8 ± 2.5 62% (4)	54 ± 4.5 17% (4)
11/78	24 ± 8.4 70% (4)	39 ± 5.7 25% (3)	28 ± 17.6 87% (2)	22 ± 9.5 85% (4)	8 ± 3.7 64% (2)
3/79	27 ± 2.8 18% (3)	43 ± 1.9 6% (2)	6 ± 1.7 47% (3)	4 ± 1.8 85% (3)	7 ± 1.2 36%(4)
4/79	37 ± 14.6 55% (2)	37 ± 25.3 119% (3)	57 ± 12.4 38% (3)	45 ± 24.8 96% (3)	54 ± 6.9 25% (4)
5/79	40 ± 5.8 29% (4)	22 ± 3.1 24% (3)	37 ± 10.8 51% (3)	70 ± 1.9 6% (4)	34 ± 5.0 29% (4)
6/79	33 ± 16.1 99% (4)	38 ± 12.2 65% (4)	30 ± 4.7 31% (4)	25 ± 7.0 49% (3)	46 ± 18.6 80% (4)
7/79	84 ± 21.7 45% (4)	48 ± 11.2 47% (4)	51 ± 7.7 26% (3)	32 ± 8.1 50% (4)	78 ± 9.4 26% (4)
Over all Dates	39.0	41.0	33.0	29.0	36.0

TABLE 16. Community respiration (mg C/m^2/hr) in air. Monthly mean ± S.E. of mean, Coefficient of Variation, and (sample size).

Date	Sand Flat	Mud Flat	Marsh
7/78	19.1 ± 2.48 26% (4)	26.5 ± 0.23 2% (4)	25.4 ± 6.34 36% (4)
8/78	23.4 ± 4.51 39% (4)	24.8 ± 1.06 9% (4)	30.7 ± 2.51 16% (4)
9/78	8.7 ± 0.26 6% (4)	12.8 ± 0.78 12% (4)	15.1 ± 1.24 49% (4)
10/78	5.2 ± 0.23 9% (4)	10.4 ± 1.04 20% (4)	5.7 ± 1.59 56% (4)
11/78	3.4 ± 0.35 20% (4)	21.3 ± 1.45 14% (4)	8.4 ± 2.28 54% (4)
3/79	18.9 ± 2.84 30% (4)	31.9 ± 0.0 0% (2)	20.7 ± 0.30 3% (4)
4/79	18.4 ± 0.78 7% (4)	38.6 ± 3.80 20% (4)	59.1 ± 5.61 19% (4)
5/79	11.3 ± 0.82 15% (4)	20.4 ± 4.54 38% (4)	8.1 ± 0.39 10% (4)
6/79	19.4 ± 0.33 3% (4)	26.8 ± 2.60 19% (4)	54.1 ± 0.58 2% (4)
7/79	24.5 ± 2.14 6% (4)	64.0 ± 3.36 10% (4)	38.9 ± 7.97 41% (4)
Over all Dates	15.5	27.8	26.6

TABLE 17. Ratios of gross productivity to respiration. Ratios in water and in (air).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
7/78	(1.13)	(0.61)			(0.93)
8/78	(0.47) 2.49	(-0.35) 1.04	0.37	0.86	(0.91)
9/78	(1.59) 1.40	(0.78) 2.15	2.58	2.09	(1.92) 4.41
10/78	(0.63)	(1.07) 0.01	1.08	4.14	(0.61) 0.31
11/78	(2.26) 1.50	(1.10) 0.35	4.01	1.13	(1.93) 6.41
3/79	(1.25) 2.06	(0.95) 1.40	8.88	10.60	(1.00) 3.00
4/79	(1.13) 1.11	(0.66) 0.64	1.13	0.20	(0.39) 1.40
5/79	(1.56) 1.76	(1.18) 1.37	0.48	0.51	(1.73) 1.05
6/79	(1.19) 0.66	(0.93) 0.26	2.96	0.64	(0.67) 0.60
7/79	(1.21) 1.69	(1.02) 1.23	1.16	1.64	(1.38) 0.82
Over all dates (air)	1.22	0.80			1.15
(water)	1.58	0.94	2.52	2.42	2.25

TABLE 18. Assimilation Rates (mg C/mg CHL. a/m^2/hr.) Rates in water and (in air).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
7/78	(0.78)	(0.44)			(1.07)
8/78	(0.57) 9.12	(-0.41) 3.11	0.82	1.63	(1.40
9/78	(0.44) 1.45	(0.29) 0.90	1.57	2.41	(0.40) 1.83
10/78	(0.26) 1.17	(1.25) 0.05	1.83	0.63	(0.10) 0.46
11/78	(0.27) 1.28	(1.19) 0.66	2.91	0.68	(0.73) 2.39
3/79	(0.35) 0.82	(3.17) 6.25	3.13	6.67	(2.97) 2.86
4/79	(1.37) 2.76	(2.13) 2.00	7.11	0.68	(4.31) 14.07
5/79	(1.38) 5.55	(1.89) 2.07	1.70	8.18	(2.41) 6.21
7/79	(2.43) 12.70	(6.53) 5.90	6.30	6.97	(6.70) 7.50
Over all dates (air)	0.87	1.83			2.23
(water)	4.36	2.67	3.17	3.48	5.05

TABLE 19. Apparent chlorophyll *a* (mg/m^2) mean ± S.E., CV, (sample size).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	73 ± 5.1 16% (5)	138 ± 13.5 22% (5)	49 ± 0.7 3% (5)	53 ± 4.3 18% (5)	
6/78	76 ± 4.1 12% (5)	114 ± 6.3 7% (5)	81 ± 5.2 14% (5)	70 ± 7.0 23% (5)	72 ± 4.3 13% (5)
7/78	101 ± 6.2 14% (5)	130 ± 8.1 14% (5)	110 ± 27.0 55% (5)	110 ± 2.1 4% (5)	94 ± 8.8 21% (5)
8/78	83 ± 5.1 14% (5)	109 ± 12.7 26% (5)	128 ± 27.3 43% (4)	67 ± 13.0 43% (5)	103 ± 23.2 50% (5)
9/78	131 ± 6.1 10% (5)	162 ± 30.9 43% (5)	104 ± 11.1 24% (5)	57 ± 3.3 13% (5)	134 ± 12.3 21% (5)
10/78	112 ± 5.8 12% (5)	86 ± 8.5 22% (5)	94 ± 9.8 23% (5)	169 ± 6.4 8% (5)	176 ± 14.6 19% (5)
11/78	146 ± 5.4 8% (5)	151 ± 9.7 13% (4)	188 ± 27.7 33% (5)	120 ± 4.9 9% (5)	123 ± 9.1 16% (5)
1/79	49 ± 2.9 14% (5)	71 ± 8.9 28% (5)			51 ± 5.6 25% (5)
3/79	192 ± 17.4 20% (5)	116 ± 17.4 34% (5)	141 ± 26.7 42% (5)	136 ± 10.4 17% (5)	220 ± 30.9 31% (5)
4/79	83 ± 1.5 4% (5)	70 ± 2.0 6% (5)	41 ± 4.2 23% (5)	66 ± 3.2 11% (5)	112 ± 4.3 9% (5)
5/79	78 ± 2.8 8% (5)	85 ± 5.6 15% (5)	72 ± 3.2 10% (5)	54 ± 2.7 11% (5)	61 ± 2.2 7% (4)
6/79	83 ± 1.5 4% (5)	45 ± 6.0 30% (5)	69 ± 3.8 12% (5)	62 ± 3.3 12% (5)	75 ± 4.5 13% (5)
7/79	88 ± 5.7 14% (5)	68 ± 7.0 23% (5)	63 ± 8.9 32% (5)	34 ± 1.2 8% (5)	82 ± 1.2 3% (5)
Over all Dates	100	103	95	83	109

TABLE 20. Functional chlorophyll *a* (mg/m^2) mean ± S.E., CV, (sample size).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	15.2 ± 2.06 30% (5)	30.8 ± 4.41 32% (5)	10.2 ± 1.07 23% (5)	14.6 ± 1.86 28% (5)	
6/78	22.8 ± 1.82 18% (5)	22.0 ± 1.30 13% (5)	12.2 ± 1.65 30% (5)	23.2 ± 3.51 34% (5)	15.8 ± 0.80 11% (5)
7/78	27.8 ± 1.53 12% (5)	36.8 ± 2.63 16% (5)	22.0 ± 6.13 62% (5)	38.4 ± 0.68 4% (5)	22.0 ± 3.23 33% (5)
8/78	19.4 ± 2.40 28% (5)	21.2 ± 4.57 48% (5)	18.3 ± 5.91 65% (4)	19.6 ± 2.76 32% (5)	20.0 ± 4.20 47% (5)
9/78	31.1 ± 1.63 12% (5)	34.3 ± 1.86 49% (5)	24.9 ± 3.90 35% (5)	14.1 ± 0.99 16% (5)	24.6 ± 1.69 15% (5)
10/78	12.8 ± 1.16 20% (5)	8.8 ± 1.71 44% (5)	18.6 ± 2.27 27% (5)	52.8 ± 2.22 9% (5)	34.6 ± 4.34 28% (5)
11/78	28.2 ± 1.77 14% (5)	19.8 ± 0.85 9% (4)	39.2 ± 7.47 43% (5)	36.6 ± 1.29 8% (5)	22.2 ± 1.56 16% (5)
1/79	10.6 ± 1.12 24% (5)	9.0 ± 8.4 21% (5)			9.2 ± 1.20 29% (5)
3/79	67.0 ± 8.8 29% (5)	9.6 ± 2.75 64% (5)	18.2 ± 12.81 157% (5)	3.0 ± 1.90 141 % (5)	7.0 ± 4.88 156% (5)
4/79	15.2 ± 0.97 14% (5)	12.0 ± 0.55 10% (5)	9.0 ± 1.64 41% (5)	13.2 ± 0.73 12% (5)	5.4 ± 1.47 61% (5)
5/79	12.8 ± 4.75 83% (5)	15.0 ± 3.15 47% (5)	10.6 ± 2.40 51% (5)	4.4 ± 1.94 99% (5)	5.8 ± 1.19 41% (4)
7/79	12.2 ± 1.46 27% (5)	10.0 ± 1.10 24% (5)	9.2 ± 0.58 14% (5)	7.6 ± 0.81 24% (5)	8.0 ± 1.03 29% (5)
Over all Dates	22.9	19.1	17.5	20.7	15.9

TABLE 21. Pheophytin *a* (mg/m^2). Mean ± S.E., CV, (sample size).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	84 ± 6.8 18% (5)	154 ± 14.6 21% (5)	58 ± 3.0 12% (5)	52 ± 2.0 9% (5)	
6/78	71 ± 4.9 16% (5)	135 ± 8.7 14% (5)	106 ± 6.9 15% (5)	58 ± 5.7 22% (5)	81 ± 5.7 16% (5)
7/78	97 ± 7.0 16% (5)	133 ± 5.6 10% (5)	107 ± 25.9 54% (5)	83 ± 4.3 12% (5)	102 ± 6.7 15% (5)
8/78	90 ± 2.7 7% (5)	125 ± 9.5 17% (5)	144 ± 22.6 31% (4)	64 ± 15.3 54% (5)	121 ± 29.5 55% (5)
9/78	139 ± 6.1 10% (5)	183 ± 33.4 41% (5)	110 ± 9.1 19% (5)	58 ± 3.9 15% (5)	171 ± 17.4 24% (5)
10/78	161 ± 11.7 16% (5)	127 ± 15.7 28% (5)	120 ± 16.7 31% (5)	144 ± 6.2 10% (5)	207 ± 13.7 15% (5)
11/78	152 ± 16.3 24% (5)	200 ± 15.0 15% (4)	213 ± 30.5 32% (5)	105 ± 4.9 10% (5)	150 ± 13.1 20% (5)
1/79	55 ± 4.1 17% (5)	99 ± 13.4 30% (5)			62 ± 7.8 28% (5)
3/79	143 ± 8.5 13% (5)	171 ± 34.5 45% (5)	203 ± 28.3 31% (5)	229 ± 18.5 18% (5)	356 ± 42.5 27% (5)
4/79	101 ± 3.8 8% (5)	89 ± 3.8 10% (5)	47 ± 3.8 18% (5)	79 ± 6.7 19% (5)	176 ± 10.9 14% (5)
5/79	99 ± 10.0 23% (5)	105 ± 16.3 35% (5)	94 ± 2.5 6% (5)	81 ± 6.0 17% (5)	89 ± 2.7 6% (4)
7/79	118 ± 12.7 24% (5)	91 ± 10.9 27% (5)	84 ± 13.4 36% (5)	38 ± 1.0 6% (5)	118 ± 4.4 8% (5)
Over all Dates	109	134	117	90	148

TABLE 22. Ratios of functional chlorophyll *a*/pheophytin *a*.

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	0.18 ± 0.028 34% (5)	0.20 ± 0.028 30% (5)	0.18 ± 0.027 33% (5)	0.28 ± 0.027 21% (5)	
6/78	0.33 ± 0.031 21% (5)	0.16 ± 0.098 13% (5)	0.12 ± 0.016 30% (5)	0.40 ± 0.069 37% (5)	0.20 ± 0.008 9% (5)
7/78	0.29 ± 0.014 11% (5)	0.26 ± 0.017 15% (5)	0.22 ± 0.054 56% (5)	0.47 ± 0.027 13% (5)	0.21 ± 0.020 21% (5)
8/78	0.22 ± 0.023 23% (5)	0.16 ± 0.023 32% (5)	0.12 ± 0.031 54% (4)	0.36 ± 0.027 45% (5)	0.18 ± 0.034 43% (5)
9/78	0.22 ± 0.005 5% (5)	0.18 ± 0.015 18% (5)	0.22 ± 0.24 24% (5)	0.25 ± 0.005 10% (5)	0.16 ± 0.013 18% (5)
10/78	0.08 ± 0.010 26% (5)	0.007 ± 0.014 20% (5)	0.16 ± 0.018 25% (5)	0.37 ± 0.010 6% (5)	0.17 ± 0.010 14% (5)
11/78	0.21 ± 0.045 48% (5)	0.10 ± 0.007 14% (4)	0.18 ± 0.028 34% (5)	0.35 ± 0.010 6% (5)	0.15 ± 0.014 21% (5)
1/79	0.20 ± 0.027 30% (5)	0.10 ± 0.013 31% (5)			0.15 ± 0.016 24% (5)
3/79	0.47 ± 0.047 23% (5)	0.08 ± 0.086 97% (5)	0.08 ± 0.051 142% (5)	0.02 ± 0.010 144% (5)	0.01 ± 0.046 148% (5)
4/79	0.15 ± 0.013 19% (5)	0.14 ± 0.009 15% (5)	0.19 ± 0.028 34% (5)	0.17 ± 0.024 31% (5)	0.03 ± 0.010 71% (5)
5/79	0.16 ± 0.068 97% (5)	0.17 ± 0.043 56% (5)	0.11 ± 0.026 51% (5)	0.06 ± 0.027 102% (5)	0.06 ± 0.011 35% (4)
7/79	0.11 ± 0.026 51% (5)	0.12 ± 0.020 39% (5)	0.12 ± 0.016 29% (5)	0.20 ± 0.026 30% (5)	0.07 ± 0.010 31% (5)
Over all Dates	0.22	0.15	0.15	0.27	0.12

TABLE 23. Sediment carbon, surface to 5 cm. Mean (mg/m^2) ± S.E. of mean, (% carbon), Coefficient of Variation, (sample size).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	76 ± 76.0 (0.13%) 173% (3)	1405 ± 169.2 (1.68%) 21% (3)	56 ± 40.7 (0.28%) 127% (3)		
6/78	79 ± 51.5 (0.05%) 113% (3)	1961 ± 258.4 (1.14%) 23% (3)	999 ± 98.7 (0.56%) 17% (3)	1323 ± 98.7 (0.72%) 13% (3)	1032 ± 63.5 (0.59%) 11% (3)
7/78	657 ± 265.5 (0.51%) 70% (3)	2767 ± 361.3 (1.40%) 23% (3)	910 ± 148.6 (0.47%) 28% (3)	404 ± 104.8 (0.20%) 45% (3)	1096 ± 269.4 (0.48%) 43% (3)
8/78	698 ± 39.5 (0.24%) 10% (3)	3320 ± 256.0 (1.15%) 13% (3)	1466 ± 176.9 (0.56%) 21% (3)	872 ± 62.1 (0.33%) 12% (3)	1352 ± 226.5 (0.52%) 29% (3)
9/78	1412 ± 130.7 (0.51%) 16% (3)	3165 ± 299.1 (1.09%) 16% (3)	1061 ± 46.2 (0.36%) 8% (3)	1027 ± 16.7 (0.34%) 3% (3)	1046 ± 108.6 (0.41%) 18% (3)
10/78	1354 ± 223.1 (0.43%) 29% (3)	2215 ± 472.8 (.98%) 37% (3)	1154 ± 120.3 (0.48%) 18% (3)	272 ± 23.3 (0.10%) 15% (3)	803 ± 78.3 (0.30%) 17% (3)
11/78	608 ± 20.8 (0.22%) 6% (3)	4696 ± 891.0 (1.41%) 33% (3)	901 ± 98.6 (0.33%) 19% (3)	865 ± 553.0 (0.31%) 111% (3)	747 ± 120.1 (0.25%) 28% (3)

TABLE 23. Continued

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
1/79	693 ± 55.8 (0.24%) 14% (3)	3799 ± 737.9 (1.39%) 34% (3)			1359 ± 595.2 (0.30%) 76% (3)
3/79	511 ± 69.0 (0.38%) 23% (3)	1720 ± 180.9 (0.95%) 18% (3)	456 ± 82.5 (0.26%) 31% (3)	142 ± 44.9 (0.08%) 55% (3)	776 ± 559.4 (0.46%) 125% (3)
4/79	354 ± 42.4 (0.21%) 21% (3)	1562 ± 282.1 (0.93%) 31% (3)	317 ± 208.0 (0.28%) 114% (3)	210 ± 101.7 (0.11%) 84% (3)	1149 ± 175.5 (0.70%) 26% (3)
Over all Dates	644	2661	813	639	1040

TABLE 24. Sediment carbon, 5-10 cm. Mean (mg/m^2) ± S.E. of mean, (% carbon), Coefficient of Variation, (sample size).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	167 ± 105.8 (0.18%) 110% (3)	1303 ± 142.5 (1.54%) 19% (3)	315 ± 268.0 (0.58%) 147% (3)		
6/78	265 ± 54.8 (0.15%) 36% (3)	2363 ± 184.1 (1.29%) 13% (3)	1473 ± 147.3 (0.89%) 17% (3)	1023 ± 73.7 (0.55%) 12% (3)	1392 ± 102.5 (0.69%) 13% (3)
7/78	686 ± 250.6 (0.36%) 63% (3)	2601 ± 132.9 (1.31%) 9% (3)	506 ± 12.0 (0.27%) 4% (3)	300 ± 61.0 (0.11%) 35%(3)	1697 ± 240.5 (0.75%) 25% (3)
8/78	548 ± 130.4 (0.20%) 41% (3)	3031 ± 337.3 (1.11%) 19% (3)	1059 ± 184.3 (0.40%) 30% (3)	760 ± 38.5 (0.32%) 9% (3)	1393 ± 442.3 (0.51%) 55% (3)
9/78	1619 ± 141.4 (0.58%) 15% (3)	3741 ± 522.1 (1.36%) 24% (3)	954 ± 319.0 (0.33%) 58% (3)	987 ± 83.2 (0.35%) 15% (3)	1088 ± 69.2 (0.40%) 11% (3)
10/78	1043 ± 87.7 (0.34%) 15% (3)	3721 ± 693.0 (1.29%) 32% (3)	904 ± 116.2 (0.30%) 22% (3)	558 ± 226.6 (0.19%) 70% (3)	871 ± 225.3 (0.32%) 45% (3)
11/78	552 ± 64.4 (0.20%) 20% (3)	3223 ± 173.5 (1.20%) 8% (2)	1125 ± 491.7 (0.45%) 76% (3)	963 ± 647.7 (0.35%) 116% (3)	734 ± 100.5 (0.26%) 24% (3)
1/79	459 ± 46.7 (0.17%) 18% (3)	3353 ± 198.1 (1.08%) 10% (3)			841 ± 124.3 (0.30%) 26% (3)

TABLE 24. Continued

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
3/79	470 ± 154.6 (0.37%) 57% (3)	3198 ± 783.2 (1.32%) 42% (3)	527 ± 21.1 (0.30%) 7% (3)	188 ± 61.5 (0.11%) 57% (3)	934 ± 469.3 (0.57%) 87% (3)
4/79	364 ± 130.7 (0.21%) 62% (3)	1847 ± 617.7 (1.14%) 58% (3)	108 ± 61.2 (0.06%) 98% (3)	345 ± 199.8 (0.09%) 100% (3)	960 ± 385.0 (0.58%) 69% (3)
Over All Dates	617	2838	775	641	1101

TABLE 25. Sediment carbon, 10-15 cm. Mean (mg/m^2) ± S.E. of mean, (% carbon), Coefficient of Variation, (sample size).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	172 ± 172.3 (0.14%) 172% (3)	1127 ± 400.5 (1.22%) 62% (3)	834 ± 630.8 (0.12%) 131% (3)		
6/78	119 ± 45.9 (0.06%) 67% (3)	2565 ± 335.6 (1.46%) 23% (3)	1963 ± 79.1 (1.09%) 7% (3)	881 ± 38.0 (0.46%) 7% (3)	1197 ± 194.3 (0.62%) 28% (3)
7/78	572 ± 226.0 (0.36%) 69% (3)	3047 ± 404.6 (1.97%) 23% (3)	624 ± 98.8 (0.36%) 27% (3)	247 ± 89.1 (0.20%) 63% (3)	1606 ± 397.1 (0.73%) 43% (3)
8/78	555 ± 204.8 (0.20%) 64% (3)	3791 ± 289.1 (1.39%) 13% (3)	1104 ± 285.6 (0.43%) 45%(3)	1037 ± 153.3 (0.38%) 26% (3)	825 ± 167.6 (0.34%) 35% (3)
9/78	1858 ± 529.2 (0.48%) 49% (3)	4325 ± 249.2 (1.53%) 10% (3)	811 ± 109.5 (0.27%) 19% (2)	1412 ± 230.2 (0.40%) 28% (3)	1159 ± 134.2 (0.39%) 20% (3)
10/78	1176 ± 128.4 (0.37%) 19% (3)	5013 ± 1324.9 (1.61%) 46% (3)	681 ± 326.8 (0.26%) 83% (3)	413 ± 39.7 (0.15%) 21% (3)	809 ± 126.3 (0.24%) 27% (3)
11/78	565 ± 28.1 (0.20%) 9% (3)	2564 ± 484.2 (0.92%) 33% (3)	746 ± 89.5 (0.26%) 21% (3)	595 ± 319.8 (0.20%) 93% (3)	886 ± 191.0 (0.27%) 37% (3)
1/79	689 ± 0.0 (0.20%) 0% (1)	5771 ± 1754.2 (1.99%) 53% (3)			

TABLE 25. Continued

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
3/79	494 ± 108.9 (0.46%) 38% (3)	2800 ± 144.4 (1.68%) 9% (3)	462 ± 140.8 (0.26%) 53% (3)	137 ± 52.0 (0.08%) 66% (3)	450 ± 191.0 (0.28%) 60% (3)
4/79	623 ± 125.0 (0.37%) 28% (2)	3303 ± 1329.5 (1.93%) 70% (3)	155 ± 8.0 (0.09%) 9% (3)	515 ± 204.3 (0.22%) 69% (3)	790 ± 169.6 (0.47%) 37% (3)
Over all Dates	682	3431	820	655	965

TABLE 26. Nitrate concentrations (uM/l). Monthly mean ± S.E. of mean, Coefficient of Variation, (sample size).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	0.39 ± 0.117 53% (3)	0.13 ± 0.037 49% (3)	0.24 ± 0.043 31% (3)	1.27 ± 0.035 4% (3)	
6/78	0.32 ± 0.175 95% (3)	56 ± 0.35 39% (3)	0.25 ± 0.054 40% (3)	0.03 ± 0.033 45% (3)	
7/78	0.26 ± 0.176 161% (3)	0.06 ± 0.021 60% (3)	0.07 ± 0.146 113% (3)	0.02 ± 0.010 71% (2)	0.62 ± 0.000 0% (1)
8/78	5.37 ± 0.528 17% (3)	2.57 ± 0.250 17% (3)	0.37 ± 0.151 71% (3)	0.46 ± 0.328 125% (3)	2.43 ± 0.918 65% (3)
9/78	0.070 ± 0.0285 70% (3)	0.046 ± 0.0205 77% (3)	0.017 ± 0.0022 22% (3)	0.033 ± .0318 165% (3)	0.063 ± 0.0310 85% (3)
10/78	0.60 ± 0.139 40% (3)	2.16 ± 1.335 107% (3)	0.77 ± 0.347 78% (3)	0.74 ± 0.041 9% (3)	1.20 ± 0.766 110% (3)
11/78	0.80 ± 0.315 68% (3)	2.60 ± 1.423 95% (3)	1.75 ± 0.759 75% (3)	1.26 ± 0.780 107% (3)	0.80 ± 0.245 44% (3)
Over all Dates	1.12	1.22	0.49	0.54	1.02

TABLE 27. Nitrite Concentrations (um/1). Monthly Mean ± S.E. of Mean, Coefficient of Variation, (Sample Size).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	0.20 ± 0.577 6% (3)	0.35 ± 0.108 54% (3)	0.20 ± 0.011 9 % (3)	0.53 ± 0.085 28% (3)	
6/78	0.07 ± 0.013 32% (3)	0.10 ± 0.025 42% (3)	0.05 ± 0.007 25% (3)	0.007 ± 0.008 21% (3)	
7/78	0.28 ± 0.025 16% (3)	0.27 ± 0.010 6% (3)	0.23 ± 0.021 16% (3)	0.17 ± 0.035 36% (3)	0.31 ± 0.000 0% (1)
8/78	0.44 ± 0.029 11% (3)	0.41 ± 0.058 25% (3)	0.47 ± 0.036 13% (3)	0.37 ± 0.032 15% (3)	0.44 ± 0.125 49% (3)
9/78	0.109 ± 0.0057 9% (3)	0.128 ± 0.0074 10% (3)	0.121 ± 0.0028 4% (3)	0.119 ± 0.0009 1% (3)	0.141 ± 0.0072 9% (3)
10/78	0.35 ± 0.048 24% (3)	0.97 ± 0.502 90% (3)	0.66 ± 0.084 22% (3)	0.69 ± 0.040 10% (3)	0.60 ± 0.139 40% (3)
11/78	0.52 ± 0.155 52% (3)	0.29 ± 0.042 25% (3)	0.39 ± 0.075 33% (3)	0.47 ± 0.052 19% (3)	0.64 ± 0.265 59% (2)
Over All Dates	0.28	0.36	0.30	0.34	0.43

TABLE 28. Ammonia Concentrations (um/1). Monthly Mean ± S.E. of Mean, Coefficient of Variation, (Sample Size).

Date	Sandflat	Mudflat	Eelgrass Bed	Submerged Sand	Marsh
5/78	2.01 ± 1.717 147% (3)	1.83 ± 0.072 7% (3)	0.37 ± 0.111 52% (3)	0.52 ± 0.413 139% (3)	
6/78	0.59 ± 0.036 9% (2)	5.36 ± 0.737 24% (3)	0.81 ± 0.245 53% (3)	1.40 ± 0.575 71% (3)	
7/78	2.99 ± 0.290 14% (3)	1.27 ± 0.353 48% (3)	1.32 ± 0.577 61% (3)	1.17 ± 0.300 36% (2)	2.05 ± 0.393 27% (2)
8/78	1.53 ± 0.261 30% (3)	1.25 ± 0.126 17% (3)	4.40 ± 0.618 24% (3)	3.46 ± 2.040 102% (3)	3.69 ± 2.232 105% (3)
9/78	1.22 ± 0.128 18% (3)	1.31 ± 0.134 18% (3)	1.03 ± 0.064 11% (3)	0.97 ± 0.042 8% (3)	1.08 ± 0.043 7% (3)
10/78	1.74 ± 0.559 54% (3)	3.48 ± 0.650 32% (3)	1.75 ± 0.229 23% (3)	1.73 ± 0.172 17% (3)	2.54 ± 0.814 56% (3)
11/78	6/72 ± 0.532 14% (3)	2.96 ± 0.569 33% (3)	4.65 ± 1.920 70% (3)	2.27 ± 0.680 52% (3)	9.52 ± 3.900 71% (3)
Over all Dates	2.26	2.49	2.05	1.65	3.78

TABLE 29. Phosphate concentrations (uM/l). Monthly mean ± S.E. of mean, Coefficient of Variation, (sample size).

Date	Sand Flat	Mud Flat	Eelgrass Bed	Submerged Sand	Marsh
5/78	0.49 ± 0.103 36% (3)	0.34 ± 0.124 63% (3)	0.19 ± 0.038 35% (3)	0.24 ± 0.029 21% (3)	
6/78	0.43 ± 0.158 64% (3)	0.74 ± 0.139 33% (3)	0.40 ± 0.045 19% (3)	0.33 ± 0.047 25% (3)	
7/78	1.03 ± 0.139 23% (3)	0.98 ± 0.171 30% (3)	0.78 ± 0.042 9% (3)	0.61 ± 0.097 28% (3)	1.27 ± 0.000 0% (1)
8/78	1.12 ± 0.096 15% (3)	1.19 ± 0.040 6% (3)	1.60 ± 0.062 7% (3)	1.31 ± 0.070 9% (3)	1.28 ± 0.031 4% (3)
9/78	0.26 ± 0.024 13% (2)	0.37 ± 0.030 14% (3)	0.33 ± 0.009 5% (3)	0.31 ± 0.044 25% (3)	0.33 ± 0.012 7% (3)
10/78	0.56 ± 0.018 5% (3)	0.74 ± 0.029 7% (3)	0.63 ± 0.06 13% (2)	0.63 ± 0.038 11% (3)	0.55 ± 0.028 9% (3)
11/78	0.72 ± 0.055 13% (3)	0.64 ± 0.009 2% (3)	0.59 ± 0.047 14% (3)	0.56 ± 0.089 23% (3)	0.67 ± 0.055 14% (3)
Over all Dates	0.65	0.71	0.65	0.57	0.82

TABLE 30. Sediment pigment measurements from extensive sites.

Site	Date	Apparent Chlorophyll *a*	Functional Chlorophyll *a*	Pheophytin *a*	Functional Chl. *a*/ Pheophytin *a* Ratio
01-1	7/10/78	95 ± 10.3 22% (4)	27 ± 8.8 66% (4)	91 ± 10.1 22% (4)	0.32 ± 0.105 65% (4)
01-2	7/10/78	65 ± 7.7 21% (3)	21 ± 3.0 26% (3)	56 ± 5.6 17% (3)	0.37 ± 0.027 13% (3)
01-3	7/10/78	89 ± 10.3 23% (4)	25 ± 3.7 30% (4)	86 ± 8.0 19% (4)	0.28 ± 0.017 12% (4)
01-4	7/10/78	83 ± 10.0 24% (4)	35 ± 4.1 23% (4)	79 ± 4.8 12% (4)	0.44 ± 0.048 22% (4)
01-5	7/10/78	95 ± 4.7 10% (4)	18 ± 3.3 37% (4)	123 ± 9.7 16% (4)	0.15 ± 0.017 23% (4)
01-6	7/10/78	63 ± 2.4 7% (4)	15 ± 5.1 67% (4)	67 ± 16.3 49% (4)	0.31 ± 0.109 70% (4)
01-7	7/10/78	62 ± 3.4 11% (4)	14 ± 3.6 53% (4)	69 ± 14.7 43% (4)	0.25 ± 0.074 60% (4)
KI-1		73 ± 3.9 12% (5)	15 ± 1.1 16% (5)	100 ± 8.2 18% (5)	0.16 ± 0.03 38% (5)
KI-2	7/10/78	84 ± 2.5 7% (5)	12 ± 0.8 15% (5)	121 ± 5.3 10% (5)	0.10 ± 0.03 3% (5)
KI-3	7/10/78	92 ± 2.2 5% (5)	15 ± 1.0 14% (5)	130 ± 2.5 4% (5)	0.10 ± 0.01 12% (5)
KI-4	7/10/78	66 ± 2.8 9% (5)	9 ± 0.5 12% (5)	97 ± 5.4 12% (5)	0.09 ± 0.01 18% (5)
KI-5		30 ± 2.8 21% (5)	6 ± 1.1 40% (5)	40 ± 5.0 28% (5)	0.16 ± 0.04 53% (5)
Mudflat, Sapelo Isl., Ga.	4/2/79	64 ± 6.4 22% (5)	8 ± 0.7 20% (5)	87 ± 11.6 30% (5)	0.10 ± 0.004 40% (5)
Oceanside sandflat Sapelo Isl., Ga.	5/25/80	40 ± 15.0 65% (3)	4 ± 1.0 43% (3)	62 ± 24.6 69% (3)	0.09 ± 0.032 61% (3)
Mudflat, Sapelo Isl., Ga.	5/25/80	206 ± 14.9 13% (3)	54 ± 6.1 20% (3)	259 ± 15.3 10% (3)	0.20 ± 0.012 10% (3)

TABLE 31. Results of statistical analyses of metabolic rates among habitats. S = Significant, NS = Not Significant.

Test	Kruskal-Wallis Result	Test	Kruskal-Wallis Result
Gross productivity in water over all dates	NS	Respiration in water: 4/79	NS
		5/79	S
Gross productivity in air over all dates	NS	6/79	NS
		7/79	NS
Net productivity in water: 8/78	S	over all dates	NS
9/78	S		
10/78	S	Respiration in air: 7/78	S
11/78	S	8/78	NS
3/79	NS	9/78	S
4/79	S	10/78	S
5/79	S	11/78	S
6/79	NS	3/79	NS
7/79	S	4/79	S
over all dates	NS	5/79	S
		6/79	S
Net productivity in air: 7/78	S	7/79	S
8/78	S	over all dates	NS
9/78	NS		
10/78	S	Gross productivity/Respiration ratios	
11/78	S	in water over all dates	NS
3/79	S		
4/79	S	Gross productivity/Respiration ratios	
5/79	S	in air over all dates	NS
6/79	S		
7/79	S	Assimilation rates in water	
over all dates	NS	over all dates	NS
Respiration in water: 8/78	NS	Assimilation rates in air	NS
9/78	NS	over all dates	NS
10/78	S		
11/78	NS		
3/79	S		

TABLE 32. Results of statistical analyses of sediment pigments among habitats. S = Significant, NS = Not Significant. Multiple range test results are presented from lowest mean to highest mean, left to right. Underlining is used to group habitats with means statistically indistinguishable from each other.

Test	Kruskal-Wallis Result	Multiple Range Test Result*
Apparent chlorophyll *a*		
5/78	S	EB SS SF MF
6/78	S	M SS SF EB MF
7/78	NS	
8/78	NS	
9/78	S	SS EB M SF MF
10/78	S	MF EB SF SS M
11/78	S	SS M MF SF EB
1/79	NS	
3/79	S	None distinguishable
4/79	S	EB SS MF SF M
5/79	S	SS M EB SF MF
6/79	S	MF SS EB M SF
7/79	S	SS EB MF M SF
over all dates	NS	
Functional chlorophyll *a*		
5/78	S	EB SS SF MF
6/78	S	EB M SS MF SF
7/78	S	M EB SF MF SS
8/78	NS	
9/78	S	SS M EB MF SF
10/78	S	MF SF EB M SS
11/78	S	MF M SF EB SS
1/79	NS	
3/79	S	SS M EB MF SF
4/79	S	M EB MF SS SF
5/79	NS	
7/79	NS	
over all dates	NS	

TABLE 32 . (continued)

Test	Kruskal-Wallis Result	Multiple Range Test Result*
Pheophytin a		
5/78	S	SS EB SF MF
6/78	S	SS SF SF M EB MF
7/78	S	SS EB SF M MF
8/78	S	None distinguishable
9/78	S	SS EB SF M MF
10/78	S	EB MF SS SF M
11/78	S	SS M SF MF EB
1/79	S	SF M MF
3/79	S	SF MF EB SS M
4/79	S	EB SS MF SF M
5/79	NS	
7/79	S	SS EB MF SF M
over all dates	NS	
Chlorophyll/Pheophytin ratio		
5/78	NS	
6/78	S	EB MF M SF SS
7/78	S	EB M MF SF SS
8/78	S	EB MF M SF SS
9/78	S	M MF EB SF SS
10/78	S	MF SF EB M SS
11/78	S	MF M EB SF SS
1/79	S	MF M SF
3/79	S	SS M EB MF SF
4/79	S	M MF SF SS EB
5/79	NS	
7/79	S	M SF MF EB SS
over all dates	S	M MF EB SF SS

TABLE 32 . (concluded)

Test	Kruskal-Wallis Result	Multiple Range Test Result*
Sediment carbon (0-5 cm) over all dates	S	SS SF EB M MF
(5-10 cm) over all dates	S	SS SF EB M MF
(10-15 cm) over all dates	S	SS SF EB M MF

* SF = sandflat MF = mudflat EB = eelgrass bed M = fringing marsh
SS = unvegetated sand

TABLE 33. Results of statistical analyses of sediment pigments and carbon among sampling dates. S = Significant, NS = Not Significant. Multiple range test results are presented from lowest mean to highest mean, left to right. Underlining is used to group sampling dates with means statistically indistinguishable from each other.

Test	Wallis Result	Multiple Range Test Result											
Apparent Chlorophyll a													
sandflat	S	5/78	6/78	5/79	4/79	8/78	6/79	7/79	7/78	10/78	3/79	9/78	11/78
mudflat	S	6/79	7/79	1/79	4/79	5/79	10/78	3/79	6/78	11/78	9/78	7/78	5/78
eelgrass bed	S	4/79	5/78	7/79	6/79	6/78	5/79	8/78	7/78	10/78	9/78	3/79	11/78
submerged sand	S	7/79	5/78	5/79	9/78	6/79	8/78	4/79	6/78	7/78	11/78	3/79	10/78
marsh	S	5/79	6/78	6/79	7/79	8/78	7/78	4/79	9/78	11/78	10/78	3/79	
over all habitats	S	6/79	5/78	7/79	5/79	4/79	6/78	8/78	7/78	9/78	10/78	11/78	3/79
Functional Chlorophyll a													
sandflat	S	1/79	7/79	10/78	5/79	5/78	4/79	8/78	6/78	7/78	11/78	9/78	3/79
mudflat	S	1/79	10/78	7/79	3/79	4/79	5/79	11/78	8/78	6/78	9/78	5/78	7/78
eelgrass bed	S	7/79	4/79	5/78	3/79	5/79	6/78	8/78	10/78	7/78	9/78	11/78	
submerged sand	S	3/79	5/79	7/79	4/79	9/78	5/78	8/78	6/78	11/78	7/78	10/78	
marsh	S	5/79	4/79	3/79	7/79	1/79	6/78	8/78	7/78	11/78	9/78	10/78	
over all habitats	S	7/79	5/79	4/79	3/79	5/78	10/78	8/78	6/78	9/78	7/78	11/78	

TABLE 33. (continued)

Test	Kruskal-Wallis Result	Multiple Range Test Result											
Pheophytin a													
sandflat	S	1/79	6/78	5/78	8/78	7/78	5/79	4/79	7/79	9/78	3/79	11/78	10/78
mudflat	S	1/79	10/78	7/79	3/79	4/79	5/79	11/78	8/76	6/78	9/78	5/78	7/78
eelgrass bed	S	4/79	5/78	7/79	5/79	7/78	8/78	6/78	9/78	10/78	3/79	11/78	
submerged sand	S	7/79	5/78	9/78	6/78	8/78	4/79	5/79	7/78	11/78	10/78	3/79	
marsh	S	1/79	6/78	5/79	7/78	8/78	7/79	11/78	9/78	4/79	10/78	3/79	
over all habitats	S	3/79	11/78	10/78	9/78	8/78	7/78	4/79	5/79	7/79	6/78	5/78	
Chlorophyll/ Pheophytin ratio													
sandflat	S	10/78	7/79	4/79	5/79	5/78	11/78	1/79	8/78	9/78	7/78	6/78	3/79
mudflat	S	10/78	3/79	11/78	1/79	7/79	4/79	8/78	5/79	6/78	9/78	5/78	7/78
eelgrass bed	S	None distinguishable											
submerged sand	S	3/79	5/79	4/79	7/79	9/78	5/78	8/78	11/78	6/78	10/78	7/78	
marsh	S	3/79	4/79	5/79	7/79	11/78	1/79	9/78	10/78	8/78	7/78	6/78	
over all habitats	S	7/79	3/79	5/79	4/79	10/78	5/78	11/78	8/78	6/78	9/78	7/78	

TABLE 33. (continued)

Test	Kruskal-Wallis Result	Multiple Range Test Result									
Sediment carbon (0-5 cm)											
sandflat	S	6/78	5/78	4/79	1/79	11/78	8/78	7/78	3/79	10/78	9/78
mudflat	NS										
eelgrass bed	S	5/78	3/79	4/79	11/78	9/78	7/78	10/78	8/78	6/78	
submerged sand	S	3/79	10/78	7/78	11/78	4/79	9/78	8/78	6/78		
marsh	NS										
over all habitats	NS										
Sediment carbon (5-10 cm)											
sandflat	S	6/78	5/78	1/79	11/78	4/79	8/78	3/79	7/78	10/78	9/78
mudflat	NS										
eelgrass bed	S	4/79	7/78	9/78	10/78	11/78	3/79	5/78	8/78	6/78	
submerged sand	NS										
marsh	S	3/79	11/78	1/79	10/78	4/79	9/78	8/78	6/78	7/78	
over all habitats	NS										
Sediment carbon (10-15 cm)											
sandflat	S	1/79	6/78	8/78	5/78	4/79	7/78	10/78	3/79	9/78	
mudflat	NS										

TABLE 33. (concluded)

Test	Kruskal-Wallis Result	Multiple Range Test Result								
Sediment carbon (10-15 cm)	(continued)									
eelgrass bed	S	4/79	5/78	9/78	10/78	11/78	3/79	8/78	7/78	6/78
submerged sand	S	5/78	3/79	10/78	11/78	7/78	4/79	8/78	9/78	6/78
marsh	S	3/79	10/78	11/78	8/78	9/78	4/79	7/78	6/78	
over all habitats	NS									

TABLE 34. Results of statistical analyses comparing metabolic rates in water vs. air. S = Significant, NS = Not Significant.

Test	Result of Mann-Whitney Test
Gross productivity	
sandflat	S water greater than air
mudflat	NS
marsh	NS
over all habitats	S water greater than air
Net productivity	
sandflat	S water greater than air
mudflat	NS
marsh	NS
over all habitats	S water greater than air
Respiration	
sandflat	S water greater than air
mudflat	S water greater than air
marsh	NS
over all habitats	S water greater than air
Gross productivity/ Respiration ratio	
sandflat	S water greater than air
mudflat	NS
marsh	NS
over all habitats	NS
Assimilation rates	
sandflat	S water greater than air
mudflat	NS
marsh	NS
over all habitats	S water greater than air

TABLE 35. Results of correlation analyses. NS = No Significant Correlation. Numbers indicate a statistically significant correlation.

Test Parameter vs.	Gross Prod. Water	Gross Prod. Air	Net Prod. Water	Net Prod. Air	Resp. Water	Resp. Air	Pheo. *a*	App. Chl. *a*
Functional chlorophyll a								
sandflat	NS	NS	NS	NS	NS	NS	NS	NS
mudflat	NS	NS	NS	NS	NS	NS	NS	NS
eelgrass bed	NS		NS		NS		NS	NS
submerged sand	NS		NS		NS		NS	NS
marsh	NS	NS	NS	NS	NS	NS	NS	NS
Apparent chlorophyll a								
sandflat	NS	NS	NS	NS	NS	NS	0.71	
mudflat	NS	NS	NS	NS	NS	NS	0.79	
eelgrass bed	NS		NS		-0.61		0.69	
submerged sand	NS		NS		NS		0.54	
marsh	NS	NS	NS	NS	NS	NS	0.75	
Gross productivity (air)								
sandflat	NS					NS		
mudflat	NS					0.56		
marsh	NS					0.73		
Net productivity (air)								
sandflat			NS					
mudflat			NS					
marsh			NS					
Respiration (air)								
sandflat					0.72			
mudflat					NS			
marsh					NS			
Gross productivity (water)								
sandflat					0.61			
mudflat					NS			
eelgrass bed					NS			
submerged sand					NS			
marsh					NS			

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Examination of tidal flats:
Research report

FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

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1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

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Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

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