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POPULATION CHARACTERISTICS OF THE SALT MARSH COMMUNITIES ON AND AROUND THE PORTSMOUTH NAVAL SHIPYARD: POTENTIAL ECOLOGICAL EFFECTS FROM SHIPYARD ACTIVITIES

Final Report

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TABLE OF CONTENTS

LIST OF FIGURES ii

LIST OF TABLES iii

ACKNOWLEDGEMENTS v

INTRODUCTION 1

MATERIALS AND METHODS
- Sampling Design and Site Selection 2
- Site Descriptions 4
- Plant and Soil Collections and Analyses 6
- Statistical Analyses 7

RESULTS
- Plant Communities 8
- Plant Contaminants 16
- Sedimentary Environments 20
- Sediment Contaminants 22
- Plant and Animal-Sediment Relationships 27

DISCUSSION
- Salt Marsh Habitat Quality and Degradation 32
- Plant, Animal, and Sediment Characterization 34
- Exposure to Contaminants 38
- Ecological Effects of Contaminants 39
- Potential for Trophic Transport 44

CONCLUSIONS 46

REFERENCES 48

APPENDIX I: Standard Operating Procedures: JEL SOP 1.11 and 1.17 52

APPENDIX II: Supplementary Data Tables 61

APPENDIX III: Unreduced Data for Plants and Sediments, 63

LIST OF FIGURES

	Page
Figure 1. Map of the lower Piscataqua River, including the Portsmouth Naval Shipyard, and the lower York River, showing the salt marsh locations sampled.	3
Figure 2. Salt marshes sampled, showing locations with indicators of contaminant exposure: metals, Sum PAHs, and Total PCB in sediments and metals in *Spartina* leaves.	29
Figure 3. Salt marshes sampled, showing locations with potential ecological effects on both plant and animal communities of the salt marsh habitats.	31
Figure 4. Relationship between Sum PAHs in the sediment and plant canopy height in salt marsh communities dominated by tall form *Spartina alterniflora* and *S. patens*.	42
Figure 5. Relationship between sediment moisture content and plant canopy height in salt marsh communities dominated by tall form *Spartina alterniflora* and *S. patens*.	43

LIST OF TABLES

	Page
Table 1. Percentage cover of the substrata by macrophytes and their species richness in salt marshes.	9
Table 2. Aboveground biomass assessed as end-of-season-live-standing-crop in salt marsh communities.	12
Table 3. Population characterization of the dominant *Spartina* grasses in salt marsh communities.	13
Table 4. Animals living on the vegetation and the surface of salt marshes at low tide.	15
Table 5. Correlations of metal concentrations within composite samples of *Spartina* leaf tissues.	18
Table 6. Principal component analysis of metal concentrations in *Spartina* leaves.	19
Table 7. Sediment characteristics of the salt marshes.	21
Table 8. Metal, arsenic, Sum PAHs and Total PCB warning levels for sediment concentrations, and salt marsh locations (either or both tall form *Spartina alterniflora* and *S. patens*) where composite sediment samples exceeded toxicity thresholds.	23
Table 9. Correlations of metal, arsenic, Sum PAHs, and Total PCB concentrations within composite sediment samples of salt marshes.	24
Table 10. Principal component analysis of the metal concentrations, Sum PAHs and Total PCB in salt marsh sediments supporting *Spartina* populations.	26

LIST OF TABLES, Continued

Page

Table 11. Correlations between indicators of contaminant exposure: marsh community scores for sediment principal components #1, #2, and #3, Sum PAHs and Total PCB in the sediments, and scores for plant principal components #1 and #2. 28

Table 12. Aboveground biomass and other characteristics of the dominant species in salt marsh communities of New York and New England. 35

Table 13. Exposure of salt marsh ecosystems to contaminants, and ecological indicators and effects of stress. 40

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INTRODUCTION

In previous work to evaluate the present and potential effects of waste disposal activities at the Portsmouth Naval Shipyard on the marine habitats of the Lower Piscataqua River (Phase I: Johnston et al. 1993), the salt marshes were overlooked. Thus, potential effects on salt marsh habitats were identified as a data gap that needed to be addressed. The effort reported herein addresses contaminant exposure and ecological effects on salt marsh communities. The quality of the salt marsh habitats will be compared to other marshes in the lower Piscataqua River and one marsh in the York River Estuary. Habitat characteristics as well as contaminant levels in the salt marsh grasses and sediments will form the basis for interpretation of habitat quality and the potential for trophic transport in the marine environment. The results of the ecological characterization will be interpreted using comparisons to reference locations and information available from the literature. The characterization is descriptive in nature, and is needed to develop testable hypotheses for future work to assess and protect salt marshes around the Shipyard.

Two dominant features of salt marshes are the monospecific stands of *Spartina* grasses and the peat sediments that the grasses create. In the lower Piscataqua River, salt marsh communities were dominated by tall *Spartina alterniflora* (SAT) stands, short *S. alterniflora* (SAS) stands, and *S. patens* (SPN) stands. Composite leaf samples from each type of *Spartina* stand and the peat deposits on which they grow were sampled for contaminants. Two of these stand types (SAT and SPN) were selected for contaminant analyses. Characterization of the plants, animals, and sediments will form the basis for a correlative approach to assessing the ecological effects from exposure to contaminants. Since ecological impacts to marshes in the form of stress from exposure to contaminants are poorly known (Nixon 1982, Teal and Howarth 1984), and this is a descriptive study, the effects described herein are referred to as potential impacts, and further study is needed to confirm or refute their significance.

The data acquired with this work provides a baseline of ecological conditions in salt marsh communities in and around the Shipyard. The ecological characterization of the salt marshes around the Shipyard will improve recognition and knowledge of these communities by the Shipyard so future activities will be planned to not only minimize the impacts to marshes, but encourage protection and expansion of these valuable habitats.

MATERIALS AND METHODS

Sampling Design and Site Selection

Four small salt marshes (between 100 and 1000 m^2) were found by walking the shoreline around the east side of the Seavey Island complex. Previous surveys of intertidal habitats (Phase I Study) had indicated there were no substantial marshes on the west side of Seavey Island. Two locations on Clark Island were found with well developed peat substrata with three recognizable plant communities: *Spartina patens* (SPN) at the higher elevations up to the high tide wrack line, the short form of *Spartina alterniflora* (SAS) below the *S. patens* but above where the peat began to slope sharply downward (slope break), and the tall form of *Spartina alterniflora* (SAT) fringing the short form, both on and below the sloping peat (see CIPR and CICC on Figure 1). The other two marshes border on the Back Channel. One was a SAT marsh with poorly developed peat on the northwest corner of Jamaica Island (JIBC). The other marsh was on the north side of Seavey Island approximately 200 meters east of the back gate to the Shipyard (BGBC). This marsh was composed of SAT and SPN communities on peat.

Several locations were chosen as references so that the marshes around the Shipyard could be compared with similar marshes in the area and one marsh in a different area (York River Estuary). Fairly well developed marshes were chosen on the southeastern shore of Shapliegh Island in Little Harbour, Portsmouth, NH (SILH), and south of Admiralty Village on Spruce Creek, in Kittery, ME (AVSC, Figure 1). Both of these marshes had SAT and SPN communities on peat substrata. Another marsh on the north side of the Back Channel (the opposite side of the Back Channel from Seavey and Jamaica Islands) was sought to compare with the two Shipyard marshes that face the Back Channel. Only poorly developed fringing marshes dominated by SAT were found, and so one was chosen (BNBC) that had peat and an (SPN) community, though the (SPN) community was too small to sample.

Another well developed marsh was sought in the York River Estuary to provide a reference outside of the Great Bay/Piscataqua River Estuary, as was done for the Phase I study (Johnston et al. 1993). A marsh was chosen on the western shore of the western half of Bragdon Island (BIYR) that had all three plant communities (Figure 1).

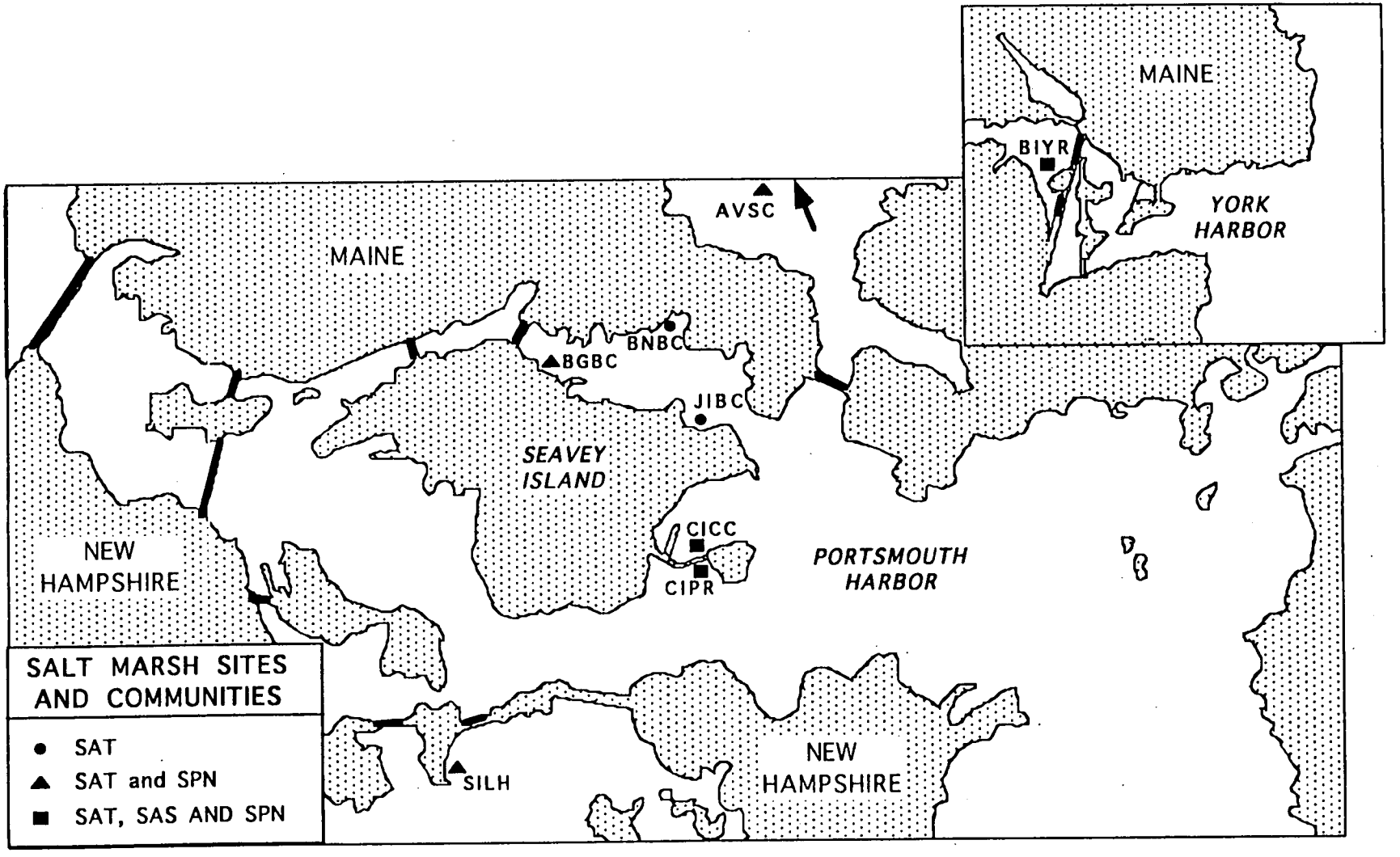

Figure 1. Map of the lower Piscataqua River, including the Portsmouth Naval Shipyard, and the lower York River, showing the salt marsh locations sampled.

Thus, there were 17 communities (6 *S. patens*, 3 short form *S. alterniflora*, and 8 tall form *S. alterniflora* communities) sampled within eight marshes to examine the current and potential effects of past waste disposal activities at the Shipyard. A model was developed to test whether differences occurred among any of the different marshes (see: Statistical Analyses). Because of the substantial differences in physical and biological characters among the three plant communities studied, (SAT, SAS and SPN), variation from these differences were removed before comparing salt marshes. Our null hypothesis was that there were no differences between similar communities of different marshes. If statistical tests indicated there was a low probability of the null hypothesis being true (less than 5% probability), the alternative hypothesis, that similar communities in different marshes exhibited differences for a specific variable, was accepted. There was no reason to believe that exposure from contaminants or potential ecological effects of contaminant exposure within either the Shipyard marshes or the reference marshes was consistent within these groups. Therefore the Shipyard marshes were not tested against all the reference marshes as a group; each marsh was considered separately.

Five sites were sampled to characterize each community of each marsh. Selection of the five sites within a community was performed in such a manner that all areas of that community would have an equal chance of being chosen. A central transect line was placed through the community and five randomly chosen points were located on the line. Then sampling markers were placed a random distance to the right or left (alternating) of the central line. Random distances were obtained from a random number table. Only numbers that resulted in markers being within at least 0.5 meters from the edge of the community were used to select sampling sites. Naturally occurring pools of water in peat depressions without vegetation (salt pannes) were avoided. Sample sites within disjunct or oddly-shaped communities, found in both marshes on Clark Island, were chosen using stratified random sampling based on the relative size of the areas (see Appendix I: JEL SOP 1.17).

Site Descriptions

Southwest of Clark Island, a small marsh (CIPR) fronts directly on the Piscataqua River. To the north it is protected from wave exposure by the causeway leading from Seavey Island to Clark Island. Tall form *S. alterniflora* surrounds the marsh, which juts out westward from the Island, except at the westernmost end of the marsh where the SAS community continues to the edge of a bedrock outcrop. Over most of the marsh the SAS community resides atop the peat

platform, between the SAT and SPN communities. The SPN community runs in a band parallel to the island's high tide line and is bordered landward by upland and to seaward by the SAS community, except at the northern edge where it runs directly into the SAT community.

On the northwestern side of Clark Island a small marsh (CICC) abuts Clark Cove. Tall form *S. alterniflora* is best developed on the eastern side, running along approximately one third of the seaward edge of the marsh. The western two thirds of the seaward edge of the marsh has only poorly developed SAT (a narrow band), except for one larger patch that was included in the sampling. Short form *S. alterniflora* begins at the top of the peat bank and extends over peat deposits to a disjunct band of *S. patens* that runs roughly parallel to the high tide line. The central portion of the SAS community includes several pannes of small (< $3m^2$) to moderate (30 m^2) size that were not sampled.

The marsh at Jamaica Island (JIBC) faces northwest onto the Back Channel. Shoreward of the narrow marsh a steep bank rises then flattens at the road leading to Jamaica Island. The salt marsh consists entirely of SAT with cobbles and boulders at the edges and sometimes within the peat. These rocks, which serve as attachment points for fucoid seaweeds and as refuges for organisms sensitive to physical exposure, were not targeted for sampling.

The Back Gate Marsh (BGBC), like the Jamaica Island Marsh, is a small fringing marsh along the Back Channel with limited exposure to wave energy due to the narrow shape of the channel. It is somewhat better developed than the JIBC marsh, having SAT at the edge and a well defined SPN zone in the high marsh which abuts a steep, tall embankment. Examination of the sediment in the high marsh revealed much of it was composed of cinders (coal ash) and empty *Littorina* spp. shells.

Brown's Marsh (BNBC) is located on the north side of the Back Channel facing southeast, roughly opposite the JIBC. Like the Shipyard marshes on the south side of the Back Channel, it is poorly developed, having a zone of SAT at the lower marsh elevations and some patches of *S. patens* in the higher areas that were not sampled.

The marsh at the southern tip of Shapliegh Island (SILH) is a fairly well developed marsh in Little Harbor, NH. It faces east and has well-defined SAT and SPN zones. Small patches of *Distichlis spicata*, spike grass, and herbaceous

plants occur at the highest elevations of the marsh, but these were not included in the sampling area.

The marsh at Admiralty Village (AVSC) faces northeast onto Spruce Creek and stretches between the residential area of the mainland and a small island. This marsh system is large and well developed. Tall *S. alterniflora* dominates the lower elevations, grading quickly into a band of *S. patens* which then gives way to a mix of short form *S. alterniflora, S. patens* and other herbaceous plants in an extensive high marsh containing large salt pannes. Only the SAT and SPN communities were sampled at this marsh.

The York River Marsh (BIYR) sampling location is located on the northwest corner of Bragdon Island. Tall form *S. alterniflora* fronts on a wide creek. Part of the SAT zone is narrow where it grows on a steep bank, while the other part occupies a wide flat area at a low elevation. The elevation rises steeply up to the high marsh where SAS is found. The SAS community, only a few meters wide, is quickly replaced by SPN, which continues landward to Bragdon Island, being interrupted by patches of wrack and occasionally other species.

Plant, Animal, and Soil Collections and Analyses

After the five sampling locations for a particular community were chosen and flagged, a hoop (1 m^2) was placed around the flag and the percentages of cover of each species of macrophyte were estimated within the hoop. Estimates were based on 100% maximum cover as viewed, undisturbed, from above. That is, species not visible due to a dense canopy were noted, but their cover was largely discounted. Next, a 1/16m^2 quadrat was placed over the flag and all aboveground vegetation was cut and removed within 1-2 cm of the substrata. The vegetation was placed in marked bags. Epibenthic macrofauna (animals > 3mm) were counted in the plot after the vegetation was clipped. Some animals (e.g., snails) had to be removed from the vegetation as it was cut and counted. The presence of small arthropods (spider mites, *Anurida maritima*) were noted, but their size and ofttimes large numbers precluded their accurate quantification. Animals that were hidden and placed in the bags with the vegetation by mistake were counted and recorded during vegetation processing in the lab. Canopy height (cm), stem density (#/m^2), reproductive stems (%) and biomass (g dry weight/m^2) were determined in the lab according to JEL SOP 1.17 (Appendix I). Once all five replicate samples were collected from a community, a representative sample of healthy, live *Spartina* leaves was collected along the community transect and bagged. These leaves were rinsed with distilled water in the laboratory, frozen, and shipped for chemical analyses.

A plexiglass core tube (5 cm diameter) was pressed into the soil within the clipped quadrat to 20 cm depth and exhumed. The core was extruded and sealed in a whirl-pac bag in the field and placed in a 5°C room upon return to the laboratory. At the lab, core lengths, which ranged from 4 to 17 cm and averaged 10.7 cm (Standard Error = 0.26 cm), were measured. Cores were split lengthwise and five-part, depth averaged composites from each community were grouped and frozen for chemical analyses. Sediment characteristics (moisture, loss on ignition, and grain size distribution) were determined as outlined in JEL SOP 1.11 (Appendix I) by Dr. Larry Ward.

Contaminant analyses were performed on the plant leaves and soils from the SAT and SPN salt marsh communities (from frozen composite samples) at Battelle Marine Science Laboratory, Sequim, Washington. Procedures used to determine contaminant levels and data quality criteria are reported in Battelle (1993).

Statistical Analyses

Analyses of variance were performed on the various measures using the ordered model: Y = Community, Marsh, and Community by Marsh. Specific dependent variables analyzed are plant cover and biomass by major species or type, population characters of the dominant *Spartina* grasses, epibenthic macrofauna taxa richness and abundance by group, listed in Tables 1-4, and sediment moisture and LOI in Table 7. If the community by marsh interaction was significant, data were analyzed by community to compare marshes. Residual analyses were performed and the variables were transformed (natural logarithm, square root, and arcsin transformations) to improve normality and homogeneity of variance, if needed. Post hoc comparisons of community means were performed using Fischer's protected F test.

Principal component analyses were performed on plant and soil contaminants to reduce the data complexity and produce patterns for interpretation. Raw data was input and analyses were performed on the correlation matrix (StatView, Abacus Concepts 1992), so the variance of each contaminant was standardized (set equal to 1). Variables loading on a component greater than 0.5 (25% of the variation for that variable) were included for interpretation of that component. Components were rotated obliquely using the Orthotran/Quartimax routine (Abacus Concepts 1992) and the marsh communities were scored for each component.

RESULTS

Plant Communities

Each major plant association of the four salt marshes found on and around Seavey Island and the four reference marshes was sampled to characterize the marshes and assess any ecological effects of chemical contaminants on the habitat quality of the marshes. In this section the following are compared: 1) plant abundance using percent cover; 2) animal abundance using number of individuals in animal groups (molluscs-including *Littorina littorea*, crustaceans-including amphipods, and terrestrial arthropods); 3) plant vigor using shoot height and biomass measurements; 4) reproductive effort of the plants (% reproductive stems of the dominant grasses); and 5) diversity of plants and animals using species or taxa richness (without consideration of relative abundance).

Plant Abundance: As defined by their community names, the dominant plants of each community on a percentage cover basis were tall form *Spartina alterniflora*, short form *S. alterniflora*, and *S. patens* (SAT, SAS, and SPN, respectively). Average cover of *S. alterniflora* ranged from 46 to 70% in the SAT community and 49 to 67% in the SAS community. Differences in *S. alterniflora* cover were found among communities, with about 5% cover of *S. alterniflora* in the SPN community and about 56% cover for the SAT and SAS communities (Table 1). Conversely, *S. patens* ranged from 71 to 80% cover in its habitat and averaged 1% and 6% cover in the SAT and SAS communities, respectively. The pattern of *S. patens* cover among communities was similar in all marshes. In contrast, the pattern of *S. alterniflora* cover among communities differed in some marshes (community by location interaction was significant). The interaction between community and location was significant for two reasons. The first is that the SAS community had greater coverage by *S. alterniflora* in York than its counterparts at the Shipyard. This may be due to stress, or a greater number of species in the SAS community at the Shipyard which are competing for space (another potential indicator of stress: see Plant Species Richness section, below). The second reason is that there was a larger difference between percentage of cover of *S. alterniflora* between SAT and SPN communities at the Back Gate Marsh (70 to 0%) than at the Shapliegh Island (46 to 5%) or Admiralty Village (54 to 15%) marshes, where plant zonation was less distinct. Few vascular plants besides *S. patens* were found in the SAT community, and *S. patens* was found there only when there was no well-developed SAS community.

Table 1. Percentage cover of the substrata by plants and plant species richness (diversity) in salt marshes. Values are means (SE) of five replicate samples.

LOCATION[1]		PERCENTAGE OF PLANT COVER BY SPECIES AND TYPE					DIVERSITY
	Community[2]	*S.alterniflora*	*S.patens*	Other Vascular	Seaweeds	Total	# Species
			PORTSMOUTH NAVAL SHIPYARD				
CIPR	SAT	60 (7)	0 (0)	0 (0)	28 (10)	88 (5)	3.2 (0.2)
	SAS	49 (8)	5 (5)	13 (2)	2 (1)	69 (8)	3.6 (0.5)
	SPN	7 (4)	71 (7)	15 (8)	0 (0)	93 (1)	4.0 (0.6)
CICC	SAT	62 (7)	0 (0)	0 (0)	12 (2)	74 (8)	2.8 (0.2)
	SAS	50 (2)	0 (0)	38 (3)	0 (0)	88 (2)	2.6 (0.2)
	SPN	2(2)	80 (8)	10 (5)	0 (0)	92 (3)	5.0 (0.3)
JIBC	SAT	51 (3)	0 (0)	0 (0)	41 (7)	92 (5)	3.0 (0.0)
BGBC	SAT	70 (6)	2 (2)	1 (1)	17 (7)	90 (2)	3.6 (0.7)
	SPN	0 (0)	79 (5)	14 (4)	0 (0)	93 (1)	4.6 (0.9)
			REFERENCE				
SILH	SAT	46 (2)	3 (1)	0 (0)	40 (4)	89 (2)	3.6 (0.2)
	SPN	5 (2)	73 (3)	3 (1)	1 (1)	81 (3)	3.6 (0.2)
BNBC	SAT	51 (4)	3 (2)	0 (0)	35 (9)	89 (5)	3.2 (0.4)
AVSC	SAT	56 (4)	0 (0)	0 (0)	24 (7)	80 (8)	2.0 (0.0)
	SPN	15 (6)	71 (12)	3 (2)	0 (0)	89 (5)	2.6 (0.5)
BIYR	SAT	58 (4)	0 (0)	0 (0)	29 (7)	87 (4)	3.0 (0.0)
	SAS	67 (3)	12 (3)	0 (0)	6 (1)	85 (0)	3.6 (0.4)
	SPN	0 (0)	73 (6)	2 (1)	0 (0)	72 (7)	2.0 (0.8)
			SHIPYARD AND REFERENCE COMBINED				
	SAT	57 (2)	1 (0)	0 (0)	28 (3)	86 (2)	3.1 (0.1)
	SAS	55 (3)	6 (2)	17 (4)	3 (1)	81 (3)	3.3 (0.2)
	SPN	5 (2)	74 (3)	10 (2)	0 (0)	87 (2)	3.6 (0.3)

[1]Codes to identify marshes are as follows: CIPR = South side of Clark Island on the Piscataqua River, CICC = North side of Clark Island on Clark Cove, JIBC = North side of road adjacent to Jamacia Island on the Back Channel, BGBC = East of the back gate to the Shipyard on the back channel, SILH = Southeast shore of Shapliegh Island in Little Harbor, BNBC = North side of Back Channel seaward of the residence of Mr. Brown, AVSC = South of Admiralty Village on Spruce Creek and connecting to an uninhabited island, BIYR = Southwest corner of th western half of Bragdon Island on the York River.

[2]Plant communities as identified by their dominant vascular species and form: *Spartina alterniflora* tall (SAT) and short (SAS) forms, and *Spartina patens* (SPN).

The percentage of cover of other vascular plants, mainly the herb *Salicornia europaea* (saltwort), differed between communities and locations, as suggested by the *S. alterniflora* interactions detailed above. Vascular plants other than *Spartina* grasses were rarely found in SAT communities. Within the SAS and SPN communities of the high marsh, the Shipyard marshes had more cover from other vascular plants (18%) than the marshes in the lower Piscataqua River and the marsh at York River (2%, Table 1).

The fucoid seaweeds *Ascophyllum nodosum* ecad variety *scorpioides* and *Fucus vesiculosus* ecad variety *spirallis* (described by Chock 1975) were important members of the SAT community, accounting for 12 to 41% of the cover. Their contribution to the other two communities was small (<3%), and this pattern was consistent for all marshes (no significant community by location interaction). In general, the least-developed marshes (JIBC and BNBC) had relatively high percentages of fucoid cover in the SAT community (Table 1). The marsh on the north side of Clark Island (CICC) and the Back Gate Marsh (BGBC) had relatively lower seaweed cover than the other marshes.

Average percentage cover of all the macrophytes ranged from 69 to 93% (Table 1). Although there were differences between communities within and among marsh locations, there were no clear trends with respect to natural or potential contaminant stresses. Total plant cover averaged between 81 and 87% for the three communities.

Plant Species Richness: In general, the number of plant species found within the quadrats increased with the elevation of the community (from low to high marsh areas), but this effect was not significant. Differences between communities occurred within some marshes: from SAS to SPN communities the number of plant species increased on the north side of Clark Island, but fell in the York River Marsh. The largest marsh systems had the lowest number of plant species (York River, Admiralty Village), while the small marshes with at least two communities sampled had the highest number of plant species (Table 1).

Plant Biomass: Overall, the aboveground standing stock of *Spartina alterniflora* was greatest in the SAT community, intermediate in the SAS community and least in the SPN community (Table 2). The location effect and community by location effect were also significant, and low biomass was found at the SAT community of BGBC. The only clear trend for *S. patens* end of season

aboveground standing stock was due to differences between communities. Not surprisingly, the biomass of *S. patens* was greatest in the SPN community. Standing stocks of other vascular plants, primarily *Salicornia europaea,* were significantly greater than zero in all the SAS and SPN communities in the Shipyard marshes and the SPN community at Shapliegh Island Marsh. This suggests that these marshes are stressed, because it appears that the ability of the dominant *Spartina* grasses to outcompete other marsh plants is diminished.

Seaweed biomass was overwhelmingly greater in the SAT community, and this trend held up for all marsh locations. In two marshes (CICC, BGBC) there was only about four times the seaweed biomass at the SAT community as compared to the SPN community, while the other marshes exhibited a 100-fold or greater difference between SAT and the other two communities. The different pattern at the Clark Island and Back Gate marshes was due to lower seaweed biomass in the SAT zone as well as more seaweed in the SPN community.

Total macrophyte biomass exhibited a pattern that was similar for most marshes. Generally, the greatest biomass of aboveground standing stock was found in the SAT communities, the least biomass was found in the SAS communities, and intermediate levels were found in the SPN communities (Table 2). As for the seaweed biomass patterns, this trend was not found in the CICC or BGBC marshes. At these locations, the biomasses in the SAT were less than that in the SPN communities, though these differences were not significant.

Stem Densities: Overall, stem densities (#/m^2) of *S. alterniflora* were greatest in the SAS community, intermediate in the SAT community, and lowest in the SPN community. In the SAT community average stem densities ranged from 301 to 1350/m^2, while in the SAS community they ranged from 1347 to 3331/m^2 (Table 3). Stem densities of *S. patens* were highest in the SPN community, as expected, ranging from 2483 to 14269/m^2, and were much lower in the SAS and SAT communities (Table 3). In the SPN community, stem density of *S. patens* was relatively greater at CIPR and AVSC marshes and lower in the SILH and BGBC marshes.

Stem Height: Canopy height (average of 10 tallest stems) of tall form *S. alterniflora* ranged from 31 to 81 cm (Table 3), with most locations averaging greater than 55 cm and only two locations yielding low values (BGBC and SILH). In marshes where the short form was sampled as a distinct community, *S. alterniflora* ranged from 21 to 39 cm, averaging about 40 cm shorter than the tall

Table 2. Aboveground biomass assessed as end-of-season-live-standing-crop in salt marsh communities. Values are means (SE) of five replicate samples.

LOCATION	Community	ABOVEGROUND BIOMASS BY SPECIES AND TYPE (g dry wt/m^2) *S.alterniflora*	*S.patens*	Other Vascular	Fucoid Algae	TOTAL
			PORTSMOUTH NAVAL SHIPYARD			
CIPR	SAT	716 (111)	0 (0)	0 (0)	773 (316)	1488 (395)
	SAS	160 (32)	16 (16)	38 (8)	5 (3)	218 (47)
	SPN	8 (7)	882 (195)	28 (17)	0 (0)	918 (193)
CICC	SAT	626 (204)	0 (0)	0 (0)	123 (57)	749 (255)
	SAS	254 (44)	0 (0)	152 (25)	0 (0)	406 (67)
	SPN	0 (0)	736 (128)	21 (18)	31 (25)	789 (89)
JIBC	SAT	462 (16)	0 (0)	0 (0)	962 (325)	1424 (333)
BGBC	SAT	348 (26)	0 (0)	2 (2)	115 (60)	465 (76)
	SPN	10 (10)	602 (240)	31 (20)	28 (28)	671 (234)
			REFERENCE			
SILH	SAT	512 (68)	0 (0)	0 (0)	1020 (166)	1532 (225)
	SPN	28 (18)	614 (34)	12 (4)	3 (3)	657 (37)
BNBC	SAT	560 (88)	0 (0)	0 (0)	1348 (398)	1908 (328)
AVSC	SAT	603 (85)	0 (0)	0 (0)	579 (295)	1181 (367)
	SPN	96 (47)	519 (124)	2 (2)	0 (0)	617 (78)
BIYR	SAT	542 (63)	0 (0)	0 (0)	721 (243)	1263 (221)
	SAS	339 (46)	8 (8)	0 (0)	3 (3)	351 (46)
	SPN	0 (0)	536 (91)	0 (0)	0 (0)	536 (91)
			SHIPYARD AND REFERENCE COMBINED			
	SAT	546 (36)	0 (0)	0 (0)	705 (105)	1251 (116)
	SAS	251 (29)	8 (6)	63 (19)	3 (1)	325 (36)
	SPN	24 (10)	648 (61)	16 (5)	10 (6)	698 (56)

Table 3. Population characterization of the dominant *Spartina* grasses in salt marsh communities. Values are means (SE) of five replicate samples.

MARSH	Community	*Spartina alterniflora* DENSITY #/m2	STEM HEIGHT cm	%REPRO. %	*Spartina patens* DENSITY #/m2	STEM HEIGHT cm	%REPRO. %
			PORTSMOUTH NAVAL SHIPYARD				
CIPR	SAT	1091 (158)	61 (8)	16 (9)	0 (0)	-	-
	SAS	1347 (278)	21 (3)	5 (3)	326 (326)	-	-
	SPN	32 (25)	-	-	14269 (4042)	33 (2)	1 (1)
CICC	SAT	1101 (323)	58 (9)	5 (2)	0 (0)	-	-
	SAS	3331 (696)	22 (3)	1 (0)	0 (0)	-	-
	SPN	0 (0)	-	-	6096 (1105)	40 (2)	11 (3)
JIBC	SAT	739 (157)	56 (5)	11 (4)	0 (0)	-	-
BGBC	SAT	1350 (233)	31 (4)	17 (9)	0 (0)	-	-
	SPN	19 (16)	-	-	4237 (1337)	36 (3)	5 (3)
			REFERENCE				
SILH	SAT	650 (60)	33 (5)	23 (10)	0 (0)	-	-
	SPN	42 (23)	-	-	2483 (325)	29 (3)	10 (3)
BNBC	SAT	301 (48)	81 (12)	36 (17)	0 (0)	-	-
AVSC	SAT	995 (243)	67 (7)	13 (5)	0 (0)	-	-
	SPN	758 (561)	-	-	6224 (2223)	30 (3)	15 (9)
BIYR	SAT	557 (54)	79 (5)	1 (1)	0 (0)	-	-
	SAS	1718 (251)	39 (1)	0 (0)	147 (147)	-	-
	SPN	0 (0)	-	-	9501 (2313)	31 (2)	0 (0)
			SHIPYARD AND REFERENCE COMBINED				
MEAN	SAT	848 (79)	58 (4)	15 (4)	0 (0)	-	-
	SAS	2132 (335)	27 (3)	2 (1)	158 (116)	-	-
	SPN	142 (100)	-	-	7135 (1092)	33 (1)	7 (2)

form. Average stem heights of *S. patens* showed no discernible trend, ranging from 29 to 40 cm (Table 3).

Reproductive Effort: The percentage of stems with reproductive structures (flowers/seeds) was generally greater in the SAT community (15%) than the SAS community (2%) for *S. alterniflora* (Table 3). Reproductive stems of *S. patens* averaged 7% of the stems in the SPN community. Marshes associated with the Shipyard showed moderate reproductive effort, while the York River Marsh had very low levels (Table 3).

Animal Abundance: In general, marine animals greater than 3 mm in size were most abundant in the SAT, intermediate in the SAS and lowest in the SPN communities (Table 4). This might be expected since the SAT community is more marine, and the SPN community is more terrestrial in character. Substantially greater animal numbers were found in the SAT community of two marshes (JIBC and CICC), and this was due to the presence of numerous barnacles growing on rocks in these marshes. Total marine animals were relatively less abundant in the CIPR and BGBC marshes (Table 4).

The common periwinkle, *Littorina littorea*, was the most common representative of the phylum Mollusca in the salt marshes. This non-native snail (introduced from Europe) was always found in the SAT community and ranged in abundance from 80 to almost 200 individuals (>0.3mm in size) per square meter (Table 4). It grazes on detritus and microflora that coats the grass shoots.

Of the SAS communities sampled, only York River Marsh had a substantial number of common periwinkles, and these and other molluscs were low in abundance in all the SPN communities. Other molluscs found in the marshes include several gastropods and two mussels (blue and ribbed), but these species comprised less than 5% of the total individuals in the mollusc group (Appendix II). Overall, molluscs composed about half of the marine animals in the SAT plots, and only about 10% of the marine animals in the SAS and SPN communities.

Crustaceans included amphipods (54%), barnacles (41%), and green crabs (5%). Barnacles were numerically important in the SAT community of the JIBC, SILH and CICC marshes and these locations had the highest crustacean numbers (Table 4). Green crabs were only found in the SAT communities and were found in all marshes (16-56/m^2) except for CICC.

Table 4. Animals living on the vegetation and the surface of salt marshes at low tide. Estimates of individuals are reported as means (SE) for one square meter (n = 5).

LOCATION	Community	Molluscs[1]	Crustaceans[2]	Total Marine	Arthropods[3]	#Species[4]
		EPIBENTHIC MACROFAUNA				
		PORTSMOUTH NAVAL SHIPYARD				
CIPR	SAT	80 (47)	58 (15)	138 (55)	3 (3)	3.2 (.9)
	SAS	0 (0)	10 (4)	10 (4)	0 (0)	1.4 (.4)
	SPN	3 (3)	0 (0)	3 (3)	0 (0)	0.2 (.2)
CICC	SAT	198 (63)	397 (174)	595 (157)	0 (0)	3.0 (.5)
	SAS	0 (0)	186 (91)	186 (91)	3 (3)	1.4 (.4)
	SPN	0 (0)	134 (39)	134 (39)	38 (21)	2.6 (.5)
JIBC	SAT	179 (37)	406 (169)	586 (172)	0 (0)	3.8 (.2)
BGBC	SAT	134 (16)	26 (15)	160 (27)	3 (3)	3.6 (.6)
	SPN	16 (16)	32 (28)	48 (28)	3 (3)	1.0 (.5)
		REFERENCE				
SILH	SAT	90 (47)	230 (113)	320 (142)	0 (0)	3.4 (.9)
	SPN	10 (6)	48 (30)	58 (36)	3 (3)	1.8 (1.1)
BNBC	SAT	182 (76)	67 (26)	250 (97)	3 93)	4.4 (.4)
AVSC	SAT	109 (29)	138 (91)	246 (104)	3 (3)	3.2 (.4)
	SPN	10 (6)	61 (28)	70 (34)	26 (19)	2.6 (.2)
BIYR	SAT	176 (43)	115 (41)	291 (41)	6 (4)	3.4 (.4)
	SAS	54 (24)	186 (43)	240 (56)	6 (6)	3.0 (.3)
	SPN	0 (0)	54 (17)	54 (17)	16 (9)	2.2 (.2)
		SHIPYARD AND REFERENCE COMBINED				
MEAN	SAT	144 (17)	180 (40)	323 (44)	2 (1)	3.5 (.2)
	SAS	18 (10)	127 (38)	145 (42)	3 (2)	1.9 (.2)
	SPN	6 (3)	55 (12)	61 (13)	14 (5)	1.7 (.3)

[1]The species with the most individuals (>95%) was *Littorina littorea*, with the remainder composed of other snails and mussels.

[2]This group was composed of amphipods (54%), barnacles (41%), and green crabs (5%).

[3]Arthropods were terrestrial, and included spiders, ants and beetles, in order of their abundance.

[4]Only molluscs and green crabs were determined to species level; banacles, amphipods, spiders and insects were placed in broad taxonomic groups when found.

Amphipods were the most common crustacean in most marshes, and they were normally present in all communities. It is interesting to note that this is the only species that showed no community effect. That is, there were no statistical differences in amphipod abundance between SAT, SAS and SPN communities. Because of this, marshes can be compared using all data from these communities (even though the design is unbalanced). Amphipod abundances were found to be significantly lower in the CIPR and BGBC marshes.

Terrestrial animals were also found in the marshes, and this group was represented by spiders, ants and beetles. As would be expected, numbers generally decreased from high to low marsh. Only low abundances were found in the *S. alterniflora* communities (average of $2/m^2$), and low to moderate abundances were found in the SPN communities (average of $14/m^2$; Table 4).

Animal Species Richness: Spider mites and *Anurida* (springtails), although small in size (<3mm), were regularly observed and included in this measure along with the animals discussed above. Overall, there were more animal taxa living on the marsh surface in the SAT community than either of the other two communities (Table 4). The similarity between number of animal taxa within the SAS and SPN communities of the high marsh allowed the data from these two communities to be analyzed together for marsh location comparisons. Animal diversity of the high marsh was significantly lower in CIPR and BGBC.

Plant Contaminants

Levels: Leaves of *Spartina alterniflora* and *S. patens* were analyzed to determine the metal concentrations in their tissues. The leaf concentrations are reported as ppm on a dry weight basis (Appendix II). Analyses included crustal metals such as aluminium (Al), iron (Fe), and manganese (Mn), and metals considered to be potential contaminants: silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), and zinc (Zn). In addition, arsenic (As) was determined, but the plant concentrations never exceeded the minimum detectable limit (1.2 ppm), so these results are not included in the analyses. Because only 14 composite samples of Spartina leaf tissue were analyzed for metals, issues of metal bioavailability and bioaccumulation are outside the scope of this study. Furthermore, no warning levels are available for tissues of salt marsh plants (but see Alloway 1990), so exploratory analysis focused on patterns of metals within and between marsh locations.

Patterns: Significant correlations were found between metal concentrations in the plant tissues (Table 5). For example, Fe was highly correlated ($P<0.01$) with Al, Cr, Ni, and Pb. In addition to these metals, Cr was also correlated with Ag and Cd. A principal component (PC) analysis was performed on the standardized leaf metal data to simplify some of the metal patterns and to identify which marsh locations possessed a pattern of elevated metals relative to the other locations examined. Al, Fe, and Mn were removed because they are crustal metals and not potential pollutants (i.e., the focus is on contaminant patterns), whereas Hg was removed due to its small range (0.01 to 0.02 ppm). A two factor solution, with the two components describing 72% of the variation in the data, is presented and interpreted.

The loadings of each metal on the components of the oblique transformation solution indicate the correlation of that metal with each component. Correlations of metals with components that are greater than 0.5 (i.e., 25% of the variation in the metal) are interpreted. Component #1 combines Ag, Cd, Cr, Cu, Ni, and Pb, and as was found for the univariate correlations, the correlations were all positive (Table 6). Thus, the pattern of metals found in *Spartina* indicate that some marsh locations have elevated levels of this group of metals relative to other locations. Component #2 features a negative correlation between Cd and Zn, indicating that some locations have relatively high levels of Zn and relatively low levels of Cd, or vice versa.

Once the components are interpreted, each marsh location may be scored for the components, and these values are found in Table 6. High scores for Component # 1 indicate a constellation of high metals were found in leaves from that marsh community. When the marshes are scored for Component #1, both communities of the Back Gate Marsh (BGBC) and the SPN community on Shapliegh Island (SILH) have relatively high scores (≥ 0.8). Relatively low scores (≤ -0.8) were found for the SPN communities in Clark Cove (CICC) and York River (BIYR) marshes (Table 6). Interpretation of the scores was arbitrarily limited to greater or less than 0.8 to include 10-30% of the communities sampled. The 0.8 limit could be higher (1.0) or lower (0.5), and the resultant patterns interpreted differently, but the overall conclusions would remain the same.

High scores for Component # 2 can indicate low Cd and high Zn and low scores indicate high Cd and low Zn. Since this is a fairly simple component (only two metals have substantial loadings), interpretation includes an examination of the levels of these two metals for marshes with high positive or negative loadings.

Table 5. Correlations of metal concentrations within composite samples of *Spartina* leaf tissues from SAT and SPN communities. Boldface underlined type indicates significant correlations at alpha=0.05, n=14.

	Al	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
Al	1.00										
Ag	.42	1.00									
Cd	**.55**	.24	1.00								
Cr	**.86**	**.61**	**.60**	1.00							
Cu	.03	.02	.17	.24	1.00						
Fe	**.98**	.48	.51	**.91**	.14	1.00					
Hg	.12	.12	.17	.32	.03	.19	1.00				
Mn	-.12	**.61**	-.44	.02	-.16	-.01	.04	1.00			
Ni	**.88**	.37	**.67**	**.85**	.30	**.90**	.22	-.18	1.00		
Pb	**.63**	.43	**.54**	**.80**	**.61**	**.73**	.40	-.03	**.84**	1.00	
Zn	.01	.15	-.39	.13	.22	.11	.20	.28	-.10	.13	1.00

Table 6. Principal component analysis of the metal concentrations in *Spartina* leaves. A. Metal loadings on the oblique solution reference structure following Orthotran/Quartimax rotation.

METAL	Oblique Solution Reference Structure Comp. #1	Comp. #2
Ag	.58	.13
Cd	.66	-.56
Cr	.92	.01
Cu	.50	.45
Ni	.90	-.19
Pb	.94	.16
Zn	.11	.91

B. Component scores for metals in leaves of *Spartina alterniflora* and *S. patens* from their corresponding communities (SAT and SPN) of each marsh.

LOCATION Community	Marsh Scores Comp. #1	Comp. #2
Clark Island, Piscataqua River		
SAT	-.64	.76
SPN	-.60	.29
Clark Island, Clark Cove		
SAT	-.15	.73
SPN	-1.24	-.30
Jamaica Island, Back Channel		
SAT	-.46	-.23
Back Gate, Back Channel		
SAT	1.71	.54
SPN	.88	1.44
Brown, Back Channel		
SAT	-.70	1.55
Shapliegh Island, Little Harbour		
SAT	-.74	.48
SPN	2.24	-.24
Admiralty Village, Spruce Creek		
SAT	.05	-1.17
SPN	.19	-1.02
Bragdon Island, York River		
SAT	.26	-1.06
SPN	-.80	-1.78

The two marshes with the highest scores for Component #2 (≥0.8) were the SPN community of BGBC and the SAT community of BNBC. Plants from these communities had relatively high Zn and moderate Cd levels and both marshes are adjacent to the Back Channel. Marshes with low scores (≤-0.8) had relatively low Zn and moderate to high Cd levels (both plant communities at Admiralty Village and York River marshes).

Sedimentary Environments

Sediment character was described, including moisture, organic matter (loss on ignition, LOI), and grain size, to interpret sedimentary processes in these habitats. Sediment grain size was performed on composites of the five cores at each community, so no descriptive statistics comparing locations and communities are possible. Overall, the grain size of the marsh sediments was relatively coarse, especially at locations in and around the Shipyard (Table 7). Only SILH, AVSC and BIYR locations had average grain size of greater than 6 Φ (6 to 9 Φ). The sediments at all the locations were very poorly sorted, with values ranging from 2.5 to over 5 Φ. Although these results are atypical of sediments found in large marsh systems (Frey and Basan 1985), we would expect small, relatively exposed marshes to have larger grain size and poor sorting due to nearby coarse-grained sediment sources and strong physical processes.

Percentage moisture in the sediment did not vary with community, whereas the amount of organic matter (%LOI) did vary significantly. Organic matter was lowest in the SAT, intermediate in the SAS, and greatest in the SPN communities (Table 7). Both percentage moisture and LOI showed similar patterns across communities, but these patterns changed from marsh to marsh (i.e., community by location interactions were significant). Since the patterns of these variables were similar, they will be discussed together as moisture. In the well developed marshes of BIYR, AVSC, and SILH, moisture was relatively high (probably due to small grain size) and increased from low to high marsh (Table 7). In the exposed marshes of Clark Island, sediment moisture was lower (especially at CICC) and peaked at the marsh center (SAS community). In the poorly developed marshes of the Back Channel (JIBC, BGBC, BNBC), sediment moisture of the SAT community was relatively low (55 to 65%), and was very low in the SPN community of BGBC marsh. Here a large portion of the sediment was composed of *Littorina* shells and coal ash that apparently had been dumped on the coastal bank above the marsh some time ago.

Table 7. Sediment characteristics of the salt marshes. Values for moisture and organic matter (LOI) are means (SE) of five cores, while grain size statistics (Gravel/Sand/Mud, Sand/Silt/Clay, Mean Size, and Sorting) are results from a composite of the five sediment cores from each community.

LOCATION	Community	Moisture %	LOI %	G/S/M %	S/S/C %	MeanSize Φ	Sorting Φ
			PORTSMOUTH NAVAL SHIPYARD				
CIPR	SAT	61 (9)	23 (6)	59/12/29	-	-0.03	4.56
	SAS	70 (2)	39 (4)	00/29/71	29/48/23	5.95	2.52
	SPN	61 (4)	26 (5)	18/30/52	-	3.67	4.40
CICC	SAT	47 (8)	13 (6)	66/25/09	-	-1.55	3.42
	SAS	58 (4)	17 (3)	19/43/38	-	2.87	4.13
	SPN	50 (7)	14 (4)	39/48/13	-	0.40	3.18
JIBC	SAT	59 (6)	20 (5)	11/57/32	-	2.60	3.05
BGBC	SAT	65 (1)	19 (2)	23/19/58	-	3.70	5.26
	SPN	48 (8)	11 (3)	48/22/30	-	0.97	3.86
			REFERENCE				
SILH	SAT	72 (1)	36 (2)	00/00/100	00/45/55	8.78	2.74
	SPN	76 (2)	45 (4)	00/18/82	18/48/34	6.97	3.36
BNBC	SAT	64 (8)	27 (7)	03/59/38	62/24/14	3.77	3.30
AVSC	SAT	77 (1)	27 (2)	00/09/91	09/43/48	8.20	3.19
	SPN	79 (1)	46 (4)	00/01/99	01/45/54	8.68	2.89
BIYR	SAT	67 (2)	25 (3)	00/21/79	21/54/25	6.18	3.00
	SAS	69 (1)	26 (3)	00/19/81	19/55/26	6.10	2.53
	SPN	76 (1)	43 (3)	00/03/97	03/60/37	7.47	2.88
			SHIPYARD AND REFERENCE COMBINED				
MEAN	SAT	64 (2)	24 (2)	20/25/55	23/42/36	4.0	3.6
	SAS	65 (3)	27 (3)	06/30/63	24/52/25	5.0	3.1
	SPN	66 (2)	31 (3)	18/20/62	07/51/42	4.7	3.4

Sediment Contaminants

Levels: Metal concentrations were determined in the composites of salt marsh sediments from the SAT and SPN communities. As for the plant tissue, analyses included the crustal metals (Al, Fe, and Mn) and potential contaminants: Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn. Another metal, tin (Sn), was also determined for the sediments, as was a wide array of polyaromatic hydrocarbons (PAHs) that will be reported and discussed as Sum PAHs and a group of 18 polychlorinated biphenyls that will be discussed as Total PCB. In several cases, the concentrations of metals and potential contaminants, reported in ppm, exceeded warning levels for sediment contamination, established by Long and Morgan in 1991 as ER-M (effects range - moderate) and ER-L (effects range - low) toxicity thresholds (thresholds for Sn were not reported; Johnston 1993). These contaminants were: Ag, As, Cr, Cu, Hg, Ni, Pb, Zn, Sum PAHs and Total PCB (Table 8). Sum PAHs is the sum of: naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthrene, benzo(e)pyrene, benzo(a)pyrene, perylene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, C1 alkyl phenanthrenes and anthracenes (Phenans), C2 Phenans, C3 Phenans, and C4 Phenans. Total PCB is the sum of 18 PCB congeners applied to the empirical formula: Total PCB = (2.01*Sum PCB) -1.55 (Johnson et al. 1993). All locations sampled exhibited elevated levels of at least some contaminants relative to the ER-L. By determining the locations with the highest contaminant levels, an indication of salt marsh habitats with the greatest exposure, and hence at the greatest ecological risk, may be identified. Furthermore, the pattern of the elevated contaminants may suggest potential sources.

Patterns: Significant correlations were found between metal concentrations in the sediments (Table 9). The crustal elements Fe, Al and Mn were positively correlated, as were several potential contaminants: Cr with Ag and Hg, Cu with Cd and Ni, Zn with Pb ($P<0.01$). A principal component analysis was performed on the sediment data using the same elements as the PC analysis of the plant data, but the components that were produced were not equivalent, indicating that bioavailability or plant uptake and transport mechanisms controlled at least some of the metal concentrations in the leaf tissue. For example, Pb and Zn were positively correlated in the sediments and loaded on the same component in the sediment PC analysis, but always loaded on different components in the plant leaf analyses. Therefore, PC analysis of contaminants in the sediments proceeded without the constraint of matching variables to the plant contaminant PC analysis.

Table 8. Metal, arsenic, Sum PAHs, and Total PCB warning levels for sediment concentrations, and salt marsh locations (either or both tall form *Spartina alterniflora* and *S. patens*) where composite sediment samples exceeded warning levels (toxicity thresholds of Long and Morgan 1991).

Contaminant	ER-L		ER-M	
	Warning Level (ppm)	Marshes Exceeding	Warning Level (ppm)	Marshes Exceeding
Ag	1.0	BGBC	2.2	
As	33	CIPR	85	
Cd	5.0		9.0	
Cr	80	JIBC	145	CIPR/CICC/BGBC/ SILH/AVSC
Cu	70	CIPR/CICC	390	
Hg	0.15	ALL, but BIYR	1.3	
Ni	30	CICC/BGBC/SILH	50	CIPR
Pb	35	ALL	110	CIPR/BGBC/ JIBC/SILH
Zn	120	CIPR/CICC/ BGBC/JIBC/AVSC	270	
Sum PAHs[1]	4	CIPR/BGBC/ BNBC/SILH/AVSC	35	
Total PCB[2]	0.05	CIPR/CICC/BGBC/ SILH/AVSC	0.40	

[1] Total PAHs is the sum of: naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthrene, benzo(e)pyrene, benzo(a)pyrene, perylene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, C1 alkyl phenanthrenes and anthracenes (Phenans), C2 Phenans, C3 Phenans, and C4 Phenans.

[2] Total PCB = 2.01*(the sum of 18 polychlorinated biphenyl cogeners)-1.55 (Johnston et al. 1993).

Table 9. Correlations of metal, arsenic, Sum PAH and Total PCB concentrations within composite sediment samples of SAT and SPN communities of all salt marshes. Boldface underlined type indicates significant correlations at alpha=0.05, n=14.

	Al	Ag	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sn	Zn	SUM PAHs
Al	1.00													
Ag	.45	1.00												
As	.28	.40	1.00											
Cd	.01	.11	.34	1.00										
Cr	.19	**.72**	**.56**	.22	1.00									
Cu	.09	.28	.43	**.66**	.45	1.00								
Fe	**.54**	.50	**.62**	.10	**.64**	.47	1.00							
Hg	.32	.49	**.65**	.13	**.72**	.23	.53	1.00						
Mn	.27	.02	-.06	-.08	-.16	.13	.34	.09	1.00					
Ni	.02	.07	.17	.10	.40	**.72**	**.54**	.26	.35	1.00				
Pb	.01	.34	.44	-.27	.29	.14	.33	.39	.33	.15	1.00			
Sn	.01	.25	-.15	-.13	.18	.40	.23	.06	-.02	.52	.11	1.00		
Zn	-.08	.47	.34	-.17	.39	.24	**.54**	.28	.34	.30	**.73**	.35	1.00	
SUM PAHs	-.30	-.04	.06	.08	.03	-.17	-.36	.07	-.36	-.32	-.09	-.11	-.30	1.00
Total PCB	.34	.50	.43	-.05	.52	.37	**.57**	.48	.02	.36	.36	.52	.50	.06

In order to simplify some of the metal patterns and to identify which marsh locations possessed sediments with patterns of elevated metals relative to the other locations, a PC analysis was performed that began with all the potential metal contaminants and Sum PAHs. As before, the crustal metals Al, Fe, and Mn were removed. Cadmium had low variability and never exceeded the most conservative concern level (Table 8), so it was removed. Sum PAHs were poorly correlated with the metals, and never loaded on components with metals, so this variable was removed and examined separately, as were the Total PCB levels.

A solution using Orthotran/Quartimax rotation of three components described 78% of the variation in the data. As with the plant analysis, correlations of metals with components of 0.5 or greater are interpreted. Component #1 shows positive correlations among Ag, Cr, and Hg (Table 10). Component #2 shows positive correlations among Cu, Ni, and Sn. Component #3 features a positive correlation between Pb and Zn. These results indicate that sediments of some marsh communities have elevated levels of these groups of metals relative to other marsh communities.

The marsh sediments were scored for the three components (Table 10). Relatively high scores for Component #1 (Ag, Cr, Hg) were found at CIPR in the SAT community, and in both communities at BGBC and AVSC. High scores for Component #2 (Cu, Ni, Sn) were found at the SPN community in CICC and both communities in CIPR. High scores for Component #3 (Pb, Zn) were found in the SAT community at JIBC, and SPN community at BGBC. The high component scores found for all the Shipyard locations show a pattern of elevated contaminants in the Shipyard marshes. York River marsh sediment scores were relatively low for all components, as was BNBC in the Back Channel, indicating these locations are good background estimates for the metals that were included in the PC analysis.

Sum PAHs levels of 4 ppm or greater is above the ER-L effects threshold (Johnston 1993), and above the "high" cutoff for Sum PAHs of the National Status and Trends Program (NS&T, Cantillo et al. 1993) that analyzed 24 PAHs. Although the Sum PAHs reported here do not match those included in the ER-L exactly, the threshold chosen is the best available estimate for ecological effects (Long and Morgan 1991). Sum PAHs in sediments were 4 to 6 ppm in the SAT communities at CIPR, BGBC, BNBC, and SPN at CIPR and AVSC (Table 10). Levels of 14 to 36 ppm were found in the SILH sediments, suggesting pollution by petroleum. Low levels (<3 ppm) were found in the sediments of CICC, BIYR and the SPN community of BGBC (Table 10).

Table 10. Principal component analysis of the metal concentrations and Sum PAHs in salt marsh sediments supporting *Spartina* populations.

A. Metal loadings on the oblique solution reference structure following Orthotran/ Quartimax rotation. Values printed in bold underlined type are interpreted.

METAL	Oblique Solution Reference Structure Comp. #1	Comp. #2	Comp. #3
Ag	**.71**	.00	.20
Cr	**.86**	.19	-.04
Cu	.24	**.78**	-.11
Hg	**.83**	-.03	.00
Ni	.08	**.87**	-.03
Pb	.16	-.04	**.83**
Sn	-.14	**.73**	.23
Zn	.11	.19	**.82**

B. Component scores, Sum PAHs (ppm) and Total PCB (ppb) in sediments of each marsh location. Values printed in bold underlined type are interpreted (component scores) or exceed the ER-L (Sum PAHs and Total PCB; Long and Morgan 1991).

LOCATION Community	Marsh Scores Comp. #1	Comp. #2	Comp. #3	Sum PAHs	Total PCB
Clark Island, Piscataqua River					
SAT	**.90**	**1.68**	-1.23	**4.8**	**53**
SPN	.23	**.99**	.50	**4.7**	**54**
Clark Island, Clark Cove					
SAT	-.59	.15	-.87	1.8	32
SPN	-1.54	**2.45**	.59	1.8	**74**
Jamaica Island, Back Channel					
SAT	-1.21	-.74	**2.68**	2.5	28
Back Gate, Back Channel					
SAT	**1.60**	-.77	-.35	**6.0**	40
SPN	**.81**	.03	**1.32**	0.6	**103**
Brown, Back Channel					
SAT	-.50	-.13	-1.23	**6.3**	27
Shapliegh Island, Little Harbour					
SAT	.00	-.80	-.22	**36.5**	**62**
SPN	.66	-.15	-.50	**13.7**	39
Admiralty Village, Spruce Creek					
SAT	**.81**	-.59	.15	3.5	47
SPN	**1.30**	-.79	-.31	**5.2**	**68**
Bragdon Island, York River					
SAT	-1.18	-.49	-.29	2.8	27
SPN	-1.30	-.82	-.25	2.9	32

Total PCB levels ranged from 27 to 103 ppb dry weight of sediment, with sites at CIPR, CICC, BGBC, SILH, and AVSC exceeding the ER-L of 50 ppb (Table 8; Long and Morgan 1991). Relatively low levels were found in the sediments of the fringing *Spartina alterniflora* marshes (JIBC, BNBC), and both communities at York River.

Plant and Animal - Sediment Relationships

Exposure: Individual metal levels of plants and their corresponding sediment levels showed few significant positive correlations (Al: r=.55, Ag: r=.67, Cr: r=.49). The low correlation for most metals may be due to any of several reasons. The metal concentrations may not reflect the concentrations available for uptake by plants (i.e., not bioavailable). Alternatively, plants may control metal uptake or selectively translocate metals to the leaves. A visual examination of the PC analyses of the plant data and sediment data did not show a correspondence among the metals that correlated with components. Correlations between marsh scores from the plant and sediment components, including Sum PAHs and Total PCB, are presented in Table 11. The only significant correlation ($P<0.05$) was between Component #1 of sediments and plants. This suggests that where elevated levels of Ag/Cr/Hg are found in the soils, elevated levels of Ag/Cd/Cr/Cu/Ni/Pb are likely to be found in the leaves. The locations of concern for plant Component #1 were both communities at BGBC and the SPN community at SILH. The locations of concern for sediment Component #1 were both communities at BGBC and AVSC, and the SAT community at CIPR. In addition, the score of the SPN community at SILH was 0.66, very close to the 0.8 limit. Thus, the positive correlation in Table 11 illustrates that there is likely a connection between some contaminant levels in soils and plants of the salt marshes (e.g. Ag and Cr). Although it did not result in a significant correlation between components, another parallel between plants and soils was relatively high Zn in plant leaves at a location (BGBC SPN community) which scored high for sediment Component #3 (Pb and Zn) and had relatively high Zn levels.

The distribution of constellations of elevated metals in the salt marshes is shown on a map using symbols to mark areas of relatively greater exposure (Figure 2). The resultant pattern shows the areas with high scores for the different plant and sediment variables. Low values for plant Component #2 are not included as concerns since they result, in part, from relatively low Zn levels, and Cd has not been identified as a problem in the lower Piscataqua River (Table 8; Johnson et al. 1993). In accordance with a 'weight of evidence approach,' areas with the most

Table 11. Correlations between indicators of contaminant exposure: marsh community scores for sediment principal components #1, #2, and #3, total PAHs in the sediments, and scores for plant principal components #1 and #2. Number in bold underlined type is significant (n=14; P<0.05).

		Sediment Comp.#1	Sediment Comp.#2	Sediment Comp.#3	Sum PAHs	Total PCB	Plant Comp.#1	Plant Comp.#2
Sediment								
Component	#1	1						
	#2	-.17	1					
	#3	-.24	-.07	1				
Sum PAHs		.14	-.26	-.19	1			
Total PCB		.35	.30	.28	.06	1		
Plant								
Component	#1	**.60**	-.38	-.06	.00	.01	1	
	#2	.25	.28	-.11	.13	.26	.06	1

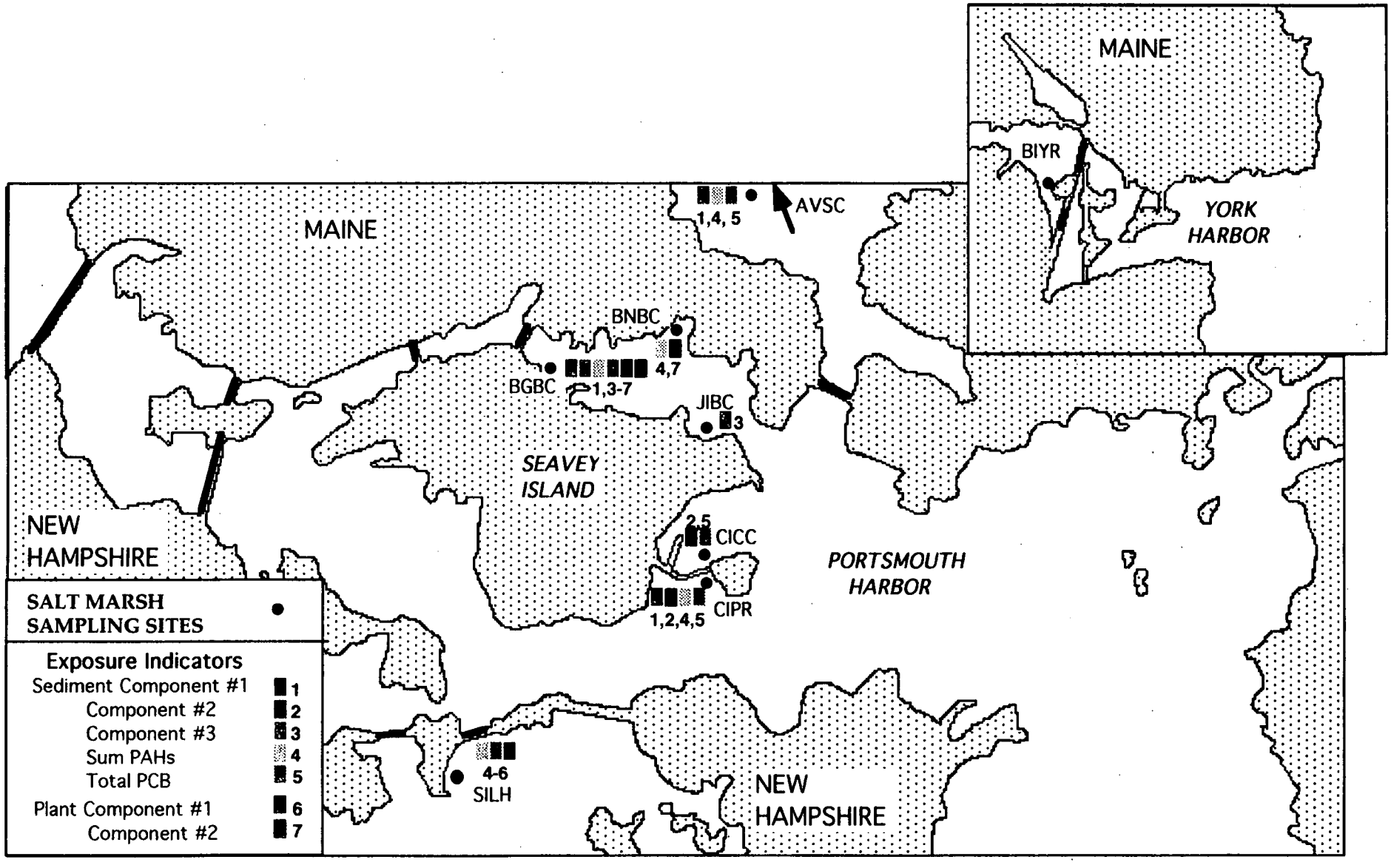

Figure 2. Salt marshes sampled, showing locations with indicators of contaminant exposure: metals and Total PAHs in sediments and metals in *Spartina* leaves.

number of concerns indicate habitats at greater ecological risk than areas with few concerns. Clearly, two marshes around the Shipyard have the most indicators of concern (BGBC, CIPR), while some of the reference marshes have notable, but fewer indicators (SILH, AVSC, BNBC). Conversely, the Shipyard marshes JIBC and CICC had relatively few indicators and the marsh in York (BIYR) had none.

Ecological Indicators and Potential Effects: Significant differences in ecological indicators between locations exposed to elevated levels of contaminants and reference locations that have relatively low contaminant levels are illustrated as potential ecological effects in Figure 3.

Plants: In SAT communities, the canopy height was significantly depressed at the SILH and BGBC marshes. Differences in canopy height of *S. patens* were also found between marsh locations, with SILH lower than CICC and BGBC marshes. When both SAT and SPN data were related to soil PAH levels, the model, ln(Height) = Community and Sum PAHs, was significant (Figure 4). However, the canopy height of *S. patens* may be more closely related to soil waterlogging (represented by the amount of soil moisture) than to soil PAH levels (Figure 5), and was not included as an ecological indicator in Figure 3.

Within SAT communities, the percentage of cover of the dominant plant, *S. alterniflora*, was lowest in SILH, JIBC, and BNBC marshes, and the biomass was lowest at the BGBC marsh. The biomass of the fucoid seaweeds was also significantly lower in the SAT community of the BGBC and CICC marshes. The number of plant species in SAT communities was elevated at the BGBC and SILH marshes relative to reference communities.

There were no significant differences in *S. patens* cover or biomass between SPN communities. The percentage cover of the vascular plants that compete with *Spartina* was significantly greater in both high marsh communities (SAS and SPN) of CIPR and CICC marshes and the SPN community of the BGBC marsh than in reference marshes. Similarly, the biomass of other vascular plants (excluding *Spartina*) was greater in the SPN community of the CIPR and BGBC marshes. The number of plant species in the SPN communities was significantly greater for the BGBC, CICC and CIPR marshes than references (Figure 3).

Total percent cover of all macrophytes showed no differences with respect to marsh locations within any community, except that the cover of the SPN community of BIYR (reference) was lower than that of some of the other marsh locations. Total biomass also showed few significant differences, with the SAT community of the BGBC marsh lower than references. Neither of these measures were used as indicators.

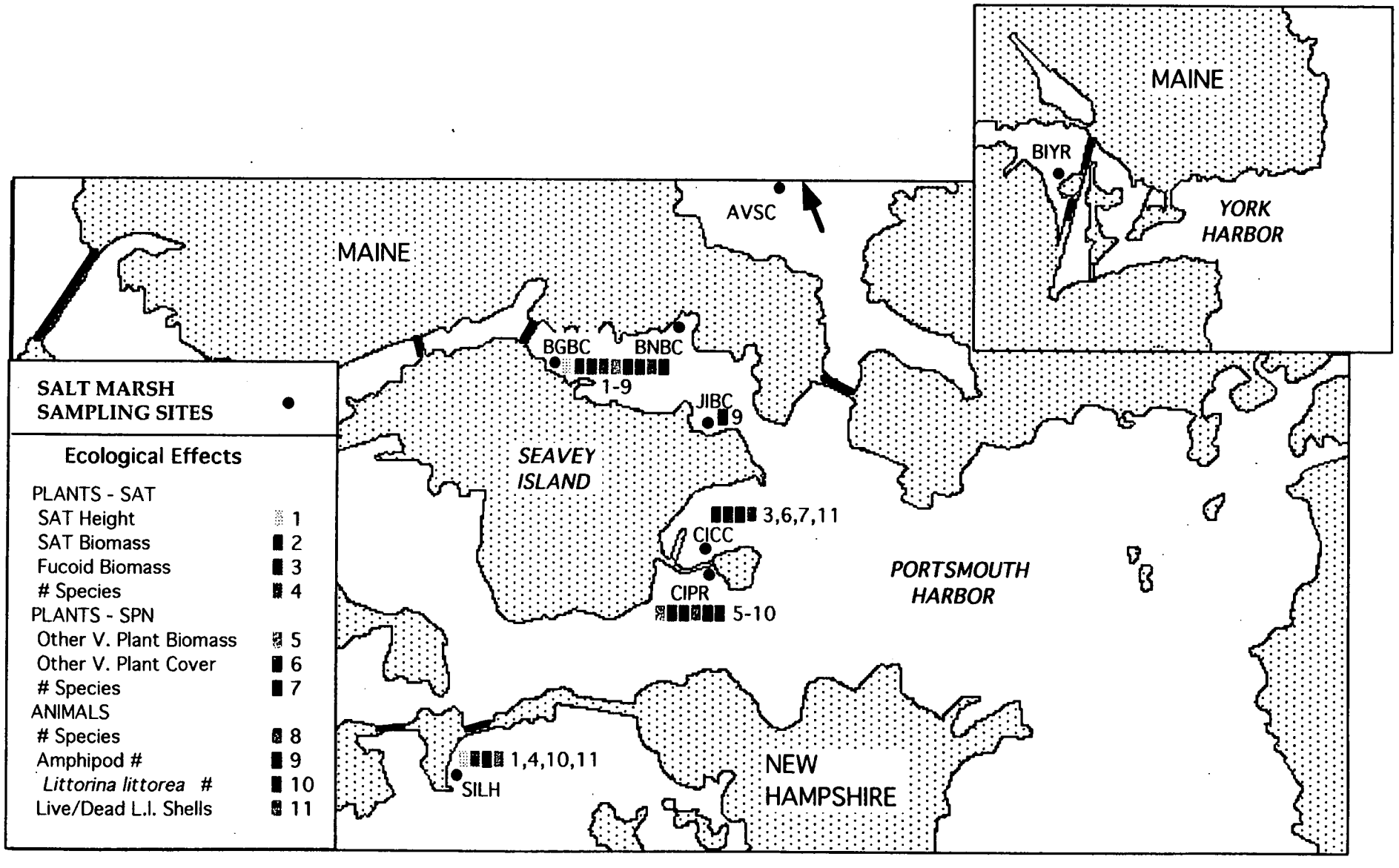

Figure 3. Salt marshes sampled, showing locations with potential ecological effects on both plant and animal communities of the salt marsh habitats.

Animals: The number of taxa found in the SAT communities did not differ between marsh locations, but significant location differences were found in the SAS and SPN communities, with CIPR and BGBC marshes having fewer types of animals. Amphipod abundance was significantly reduced in CIPR, BGBC and JIBC marshes compared to references. Within the SAT communities where *Littorina littorea* was found in the greatest abundance, significantly lower numbers were found in the CIPR and SILH marshes. The ratio of live to dead *Littorina* shells found in the quadrats showed lower ratios in the CICC and SILH marshes. These results point to potential impacts to the animal communities of salt marshes with elevated levels of contaminants (CIPR, BGBC, and SILH marshes; Figure 3).

DISCUSSION

Salt Marsh Habitat Quality and Degradation

The goal of this study was to assess contaminant exposure, ecological effects, and the potential for trophic transport of the contaminants in salt marsh habitats due to past waste disposal activities at the Shipyard. Salt marsh habitat quality was assessed using potential indicators of ecological stress that were developed from community characteristics and contaminant exposure from salt marsh grasses and sediments. The results of the ecological characterization are interpreted in the context of reference locations in the lower Piscataqua River and York River Estuary, and other locations described in the literature. The potential for trophic transport of the contaminants in the marine environment is then discussed in terms of exposure levels, animal activity, and salt marsh sedimentary processes.

Although levels of contaminants in plants and sediments of salt marshes are commonly reported (Nixon 1982, Giblin et al. 1983), the effects of contaminants on salt marshes have rarely been discussed in terms of ecological stress or disturbance (except for oil spills: e.g., Hampson and Moul 1978). At present there are no data, standards or frameworks to assess habitat quality of salt marshes with respect to several important marsh functions (Patience and Klemas 1993). Recent qualitative work has begun to assess salt marsh habitat quality with respect to such ecological values as wildlife resources, and natural vs. invasive plant species (Cook et al. 1993), but these are not related to stress from pollutants. Several ecological indicators of stress are proposed that may prove to be of value for studies of contaminant effects on salt marshes in the future. These indicators include: *Spartina alterniflora* height, number of plant species and non-*Spartina* plant biomass, number of animal species, amphipod and *Littorina* abundance,

and ratio of live to dead *Littorina* shells. A weight of evidence approach will be taken to ascribe stress or impacts on habitat quality of specific marshes to contaminant exposure. It is important to remember that the results presented here are descriptive and the potential effects that are discussed must be tested to refute or confirm them, and to determine specific responses of salt marshes to pollution.

Two levels of habitat degradation are discussed here: stress and disturbance. Under conditions of stress, the dominant plant species will be negatively affected but not displaced, whereas disturbed sites will reflect major losses of the dominant species. Disturbance includes erosional or dieback areas where the cover of the dominant plant is severely reduced or lost, resulting in replacement by another plant species that may become dominant, or by bare, uncolonized substrata. Habitat stress was assessed through measurements of plant vigor (height, biomass), reproductive effort (% reproductive stems), success of plant competitors of *Spartina* (% cover, biomass and diversity), and abundance and variety of epibenthic animals. There is also the potential of identifying a plant or animal whose presence or absence denotes a stress or disturbance; such a plant or animal is called an indicator species. One such group of animals, amphipods, may be an indicator of contaminant exposure in the present study.

Stress and disturbance to salt marshes have natural as well as anthropogenic causes, and the inclusion of reference locations in studies helps to distinguish human from natural effects on the population and community characteristics of the marshes. Natural sources of stress and disturbance include ice and wave damage, sea level rise, burial by wrack (detritus), disease, poor sediment and nutrition, flooding, and salinity. Stresses and disturbance caused by humans include effects of hydrological manipulations and shading that indirectly harm marshes, and direct impacts such as dredging, filling and pollution. Pollutants include organics (oil, petroleum products, pesticides, herbicides, PCBs) and inorganics (metals, excess nutrients). In the present study, metals were measured in plants and sediments; the only available organic contaminant data were PAHs and PCBs from the sediments.

The present study is charged with an assessment of direct anthropogenic impacts to the salt marshes. In general, there was no evidence of direct impacts to the four Shipyard marshes examined (or any other marsh in this study) from dredge or fill operations, or evidence of indirect impacts from hydrological manipulations. Tidal waters must pass through bridges to reach Shapliegh

Island, Spruce Creek, and Bragdon Island in York, but these structures appear to large enough so that there is little effect on tidal exchange, and thus a minimal effect on the marshes. Because there were no significant community, location, or interactive effects on the percentage of total plant cover, the marshes do not indicate recent disturbance. On the other hand, sample site selection methods would have avoided disturbed areas, if present. These observations indicate discussion of impacts should focus on the levels of contaminants found in the sediments and *Spartina* leaves (exposure) and the community responses to these levels (ecological stress indicators). In addition, the possible trophic transport of the contaminants up marine food chains will be addressed. Prior to these discussions, the ecological characterization of the salt marsh communities studied will be compared with previously published work to facilitate the interpretation of the results.

Plant, Animal, and Sediment Characterization of the Salt Marshes

Plants: Community characteristics and production have been assessed for several salt marshes in the Great Bay Estuarine system (Chock 1975, NH Fish and Game 1981, Nelson et al., 1982, Short and Mathieson 1992). While their general results are similar to those of this study, specific measurements are not easily (directly) comparable due to the design limitations that grew out of the objectives of these earlier studies (the efforts focused on fucoid algae or total estuarine productivity). Investigations of other estuarine marshes in Maine and New Hampshire have produced data that is more comparable to the present study (Linthurst and Reimold 1978, Gross et al. 1991). Unfortunately, no measures of habitat quality were given in association with the data presented by any of these reports.

Although all plant species in each community were collected and measured in the present study (Table 2), most published accounts only report results for the dominant species in each community or zone. Therefore, the data presented in Table 12 include only the dominants of each community. In the SAT community, fucoid algal biomass is reported here and in the study by Chock (1975), while fucoids dominated the zone below the SAT community in the study by Roman and colleagues (1990). Thus, the fucoids are summed with the grass biomass to show the total biomass of the SAT community in only the first two studies (Present study, Chock 1975).

Aboveground biomass of *Spartina alterniflora* in the SAT community averaged 0.35 to 0.72 kg/m^2, spanning the range of most other studies, except for marshes in Rhode Island which were stimulated by sewage effluent (1.38 kg/m^2), and some low biomass marshes in the upper portion of the Great Bay Estuary, NH (0.12 kg/m^2). It is unknown if the low biomasses were natural or the result of

Table 12. Aboveground biomass and other characteristics of the dominant species in salt marsh communties of New York and New England. End-of-season-live-standing-crop (all material attached to living stems) or peak live biomass (only live tissues) are presented.

Community	Macrophyte	Biomass (kg dry wt/m^2)	Height (cm)	Reproductive stems (%)	Study (Location)
SAT	*S.alterniflora*	.35-.72	31-81	1-36%	This study (Portsmouth, NH & York, ME)
	Fucoid algae	.12-1.35			
	Total	.47-1.91			
SAS	*S.alterniflora*	.16-.34	21-39	0-5%	
SPN		.52-.88	29-40	0-15%	
SAT	*S.alterniflora*	.83	127		Udell et al. 1969
SAS	*S.alterniflora*	.51	29		(Hempstead, NY)
SPN	*S.patens*	.50	25		
SAT	*S.alterniflora*	.43-1.38	50-142		Nixon & Oviatt 1973 (RI)
SAT	*S.alterniflora*	.35-.54			Valiela et al. 1975
SAS	*S.alterniflora*	.25-.42			(Falmouth, MA)
SPN	*S.patens*	.28-.42			
BANK[1]	Fucoid algae	1.22			Roman et al. 1990
SAT	*S.alterniflora*	.67			(Eastham, MA)
SAS	*S.alterniflora*	.47			
SAS	*S.alterniflora*	.53	39		Gross et al. 1991 (Rye, NH)
SAT	*S.alterniflora*	.63	50-80	7-18%	Chock 1975
	Fucoid algae	.98			(Dover, NH)
	Total	1.61			
SAT	*S.alterniflora*	.12-.72	50-92	4-38%	Nelson et al. 1982
SAS	*S.alterniflora*	.10-.30	26-35	3-15%	(NH)
SPN	*S.patens*	.39-.82			Short & Mathieson 1992 (NH, Wells, ME)
SAT	*S.alterniflora*	.43			Linthurst & Riemold
SAS	*S.alterniflora*	.25			1978 (Bar Harbor, ME)
SPN	*S.patens*	.91			

[1]Tidal creek bank, which was below the elevation of the SAT community, supported algal beds.

pollution stress, since there are other pollution sources in the upper estuary (Short 1992). Only one other study included both fucoid and *Spartina* biomass measurements from the same community (Chock 1975), even though fucoid algae are an important component of other marshes (Brinkhuis 1976). It is likely that fucoids are especially important in the small marshes of the Great Bay Estuary due to the predominance of rocky shoreline in the intertidal zone. Fucoid algal populations found in the salt marsh usually possessed a morphology distinct from the normal forms that are attached to rocks (Chock and Mathieson 1983). Physical removal of fucoid algae from intertidal rocks by storms and by ice in winter provides a major source of unattached algae to populate the lower salt marshes (Chock 1975). When summed, the total macrophyte biomass of the SAT community can become substantially larger than the biomass of systems without significant fucoid contributions (Chock: 1.61 kg/m^2, this study: 0.47 to 1.91 kg/m^2), suggesting there is greater primary productivity in these marshes.

Spartina alterniflora and *S. patens* usually exhibit peak biomass in August. Although collected in September and October, our estimates of end of season live standing crop agree well with the reported peaks because both live and dead leaves (if on live stems) were included. Thus, it appears that if plants are collected before hard frosts, peak biomass can be reasonably estimated. In contrast to *Spartina* peak biomass, the timing of peak biomass of fucoid algae growing in salt marshes has not been firmly established. Brinkhuis (1976) found Spring maxima in a Long Island, NY salt marsh, whereas Chock (1975) recorded maxima in the Fall. The Fall collection in this study found fucoids well represented, accounting for 16% (CICC) to 71% (BNBC) of the total biomass of the SAT community.

Average canopy height of *Spartina alterniflora* in the SAT community ranged from 31 to 81 cm, being somewhat shorter than values reported for other marshes. Shoot heights were similar to earlier work performed in the Great Bay Estuary (Chock 1975, Nelson et al. 1982), except at BGBC and SILH marshes (Tables 3 and 12). The lower values found for the BGBC and SILH marshes at the mouth of the Great Bay Estuary in the present study may reflect: 1) greater wave exposure (SAT locations fronted on open water, not creeks within marshes); 2) poorer drainage (greater soil moisture and soil waterlogging stress, Mendelssohn and Burdick 1988); or 3) stress from pollution (Hampson and Moul 1978). The relatively small grain size of the SILH marsh (Table 7) and the protected shore of the BGBC marsh shows that reduced canopy height cannot be explained by exposure. As shown in Figure 5, *Spartina patens* height may have been strongly influenced by soil moisture, but canopy height was not related to soil moisture in *S. alterniflora*. Both locations had relatively high levels of PAHs in the

sediments and oil contamination of marshes has been shown to stunt *Spartina alterniflora* (Hampson and Moul 1978). Indeed, *Spartina* has been killed by oil in many instances (Teal and Howarth 1984). A model relating height to Sum PAHs in the sediment explained much of the variation among marshes (Figure 4). Furthermore, both locations had other indicators of pollution exposure, specifically elevated levels of metals in sediments and leaves (Figure 2). Even though the concentration of any one metal was not likely to have an effect on the plants by itself, interactions among pollutants may have contributed to the decreased vigor of the plants (Alloway, 1990).

The range of biomasses for short form *S. alterniflora* in the three marshes that had a well defined SAS community was similar to those reported for Maine and NH communities, but lower than the marshes to the south of the study area (Table 12). Conversely, the range of average biomasses of *S. patens* of the six marshes in this study was greater than values reported for marshes to the south and the high end was similar to that reported for a marsh in Maine (Linthurst and Riemold 1978; Table 12). In another study comparing *S. patens* biomass in salt marshes of northern New England, Short found moderate biomass (.50-.67 g/m^2) in three systems south of the Great Bay Estuary, high biomass (.82 g/m^2) at the head of Great Bay, which compared well with values found in the present study, and relatively low biomass (.39 g/m^2) in southern Maine (Short 1992).

Reproductive effort of *Spartina alterniflora*, measured as percentage of stems that were fertile, fell into a range similar to those of other studies in New Hampshire (Table 12). The low end of the range in the present study was due to low number of fertile stems in the marsh at York River, ME (Table 2). *Spartina patens* ranged from 0 to 15% (0% was found at York River), but was not reported for the other studies cited in Table 12.

Animals: Assessments of epibenthic macrofauna in salt marsh communities were not found for the region, but are available for southern New England marshes (Nixon 1982). Many of the taxa observed were only classified by family; not to species level. Thus, the results presented in Table 4 are discussed in general terms. Our results show that not only fucoid algae, but animals of rocky shore habitats were utilizing the salt marshes as habitat. Many of the organisms that were found are normally associated with rocky intertidal habitats (*Littorina obtusata*, *Littorina littorea*, *Mytilus edulis*, *Carcinus maneas*, *Anurida maritima*, and *Balanus spp.*). This was not surprising with the extensive rocky shorelines in the area.

Sediments: The patterns of soil moisture and organic matter, the poor sorting, and the presence of gravel indicate both marshes on Clark Island, especially CICC, are subject to strong physical processes (e.g., waves and ice) that move coarse-grained sediments onto the marsh surface. The poorly developed marshes in the Back Channel also had gravel, but the gravel found in the BGBC *S. patens* community was mostly discarded coal cinder ash and shells of dead periwinkles. The better developed reference marshes (SILH, AVSC, BIYR) also had poorly sorted sediments and were likely exposed to strong physical processes, but had much smaller mean grain size. These locations may not have had coarse-grained sediment sources as near to them as the Shipyard marshes.

Exposure to Contaminants

Generally, levels of specific contaminants in the soils and plants were not alarmingly high. The ER-L for sediments was exceeded in one marsh for Ag (BGBC) and in one marsh for As (CIPR), in two marshes for Cu (CIPR, CICC), and in 4-8 marshes for Cr, Hg, Ni, Pb, Zn, Sum PAHs and Total PCB (Table 8). The ER-M was exceeded in CIPR for Ni, and in several marshes for Cr (CIPR, CICC, BGBC, SILH, AVSC) and Pb (CIPR, BGBC, JIBC, SILH). It is notable that so many contaminants were elevated in a few of the Shipyard marshes. Figure 2 shows the constellations of metals, PCBs and PAHs in the sediments and the constellations of metals in *Spartina* leaves that are elevated in the various marshes that were sampled. The pattern of elevated contaminant levels illustrates two important points. First, levels of some metals on the Shipyard side of the Back Channel (BGBC, JIBC) are relatively high compared to levels on the north side of the Back Channel (BNBC). This suggests the Shipyard is a source for at least some of the contaminants. Second, the relatively high levels of metals and organics in the AVSC and SILH marshes indicate that there are likely other sources of pollution besides the Shipyard. Other potential sources of contaminants include an industrial site in upper Spruce Creek and the Pierce Island Sewage outfall for the City of Portsmouth, which discharges in the main channel of the Piscataqua River just north of SILH (Short 1992). In 1977, Van Vleet and Quinn (1977) reported that sewage effluents were the primary source of petroleum hydrocarbons polluting the waters of Narragansett Bay. Contaminants from sewage may be polluting the Piscataqua River (CIPR) and Little Harbour (SILH) marshes.

Due to the nature of the potential contaminant sources, and the fact that the samples analyzed for contaminants were composites (five soil samples and leaves from *Spartina* along the entire length of the transects), the extent of

exposure to the contaminants appears to be chronic. That is, there is reason to believe that these levels of contaminants are in contact with the plants and animals of these habitats all the time. Thus, although the levels may not be very high, the long term exposure to several contaminants may be placing marsh habitats at risk. To determine whether exposure is chronic and salt marsh habitats are at risk, the distribution and bioavailability of the contaminants that are elevated at the various sites need to be documented. Ecological differences between marsh locations indicate that habitat quality has been degraded at some marshes on Seavey Island, and this degradation is associated with potentially chronic exposure to elevated levels of contaminants at these sites.

Ecological Effects of Contaminants

Disturbance: No dramatic effects of disturbance were seen in the marshes examined. Areas without macrophytes were limited to salt pannes that occur naturally in marshes. The upper edges of the *S. patens* zones of the marshes on Clark and Shapliegh Islands had small areas dominated by other grasses (e.g., *Distichlis spicata*) and herbaceous plants. The presence of these plants indicate disturbance, but these areas were small and may reflect physical disturbance by wrack and exposure to wave-driven debris and ice. No locations were experiencing invasion by exotic species such as *Phragmites* (common reed) or *Lythrum* (purple loosestrife). The total percentage of plant cover was fairly high (86%) and very similar (69-93%) for all sampling locations (Table 1). Any substantial loss of dominant plants could not be examined with the experimental design, since only *Spartina*-dominated communities were included in the sampling. For example, much of the seaward edge of the CICC marsh had a poorly developed SAT community, and was not sampled. Since the seaward edge of salt marshes is normally surrounded by a SAT community, this may be an indication of stress and of erosion (or potential for erosion) of the marsh peat. An analysis of changes in marsh area over time is needed to determine if this marsh has eroded substantially.

Stress: The effects of anthropogenic stresses on plants and animals of salt marsh communities have received little treatment in the literature (Teal and Howarth 1984, Patience and Klemas 1993). Most of the quantitative data that are available are based on studies of oil pollution (Teal and Howarth 1984). Table 13 lists several of the animal and plant parameters for which significant differences between marsh locations were found that represented potential ecological effects from contaminants. Included are the expected results from stress (not disturbance), with the reference for the rationale. While some of the indicators

Table 13. Exposure of salt marsh ecosystems to contaminants, and ecological indicators and effects of stress. .

MEDIA	EXPOSURE INDICATORS	
Sediments	• Levels elevated above ER-L[1]:	Ag, As, Cr, Cu, Hg, Ni, Pb, Zn, Total PAHs
	• Levels elevated above ER-M[1]:	Cr, Ni, Pb
	• Constellations of metals elevated relative to reference:	High scores on PC #1, #2, and#3
Plants	• Constellations of metals elevated relative to reference:	High scores on PC #1 and #2

BIOTA	STRESS INDICATORS[2]	SOURCE[3]	RATIONALE REFERENCE
Plant Communities			
SAT	• Reduced height (vigor)	OS/FS	Hampson & Moul 1978, Mendelssohn et al. 1981, Howes et al. 1986
	• Reduced % cover of SAT	FS	Mendelssohn & McKee 1988
	• Reduced biomass of SAT	FS	Mendelssohn et al. 1981
	• Reduced biomass of algae	OS	Teal & Howarth 1984
	• Greater # plant species	PD	Bertness 1991
	• Greater stem density	FS	Mendelssohn et al. 1981
SPN	• Greater # plant species	PD	Bertness 1991
	• Greater biomass of non-*Spartina*	PD	Bertness 1991
	• Greater % cover of non-*Spartina*	PD	Bertness 1991
Animals	• Reduced # taxa	OS	Hampson & Moul 1978, Sheehan 1984a
	• Reduced # Amphipods	OS/MP	Reish & Barnard 1979, Teal & Howarth 1984, Bonsdorff et al. 1990
	• Reduced # *Littorina littorea*	OS	Teal & Howarth 1984
	• Reduced #live/dead *L. littorea* shells	OS	Teal & Howarth 1984

[1]Toxicity thresholds (L=low, M=moderate) established by Long and Morgan (1991).

[2]Significant differences were found between marsh locations for the overall marsh or specific marsh communities, with at least one marsh that was potentially impacted (as compared to BIYR reference marsh) and that had elevated indicator(s) of exposure.

[3]OS=Oil spill, FS=Flooding stress associated with low oxygen and nitrogen availability and high sulfide concentrations, PD=Physical disturbance, MP=Metal pollution (Cd, Zn).

of stress are intuitively expected and straightforward, others are not (e.g., increase in high marsh diversity with greater stress). Marshes with communities having statistically significant differences in these potential indicators (i.e., differences that appear to be related to contaminant stress) are shown in Figure 3.

In *Spartina alterniflora*, stress has been associated with reduction in plant height (Mendelssohn and Burdick 1988). Reduced plant vigor of *Spartina alterniflora* in the SAT communities of the BGBC and SILH marshes was indicated by lower canopy height. Furthermore, *Spartina alterniflora* biomass at the BGBC marsh and % cover at the SILH marsh were significantly depressed relative to the other locations examined (Figure 3). Following an oil spill, Hampson and Moul (1978) found that the surviving *Spartina* plants were much smaller, especially in the tall community, even after two full growing seasons. Much of the variation found in *Spartina* height could be explained by sediment PAH levels (Figure 4). Besides elevated metal concentrations in the sediments and plant leaves, BGBC and SILH locations had relatively high Sum PAHs in the sediments of the SAT community (Table 10, Figure 2). Thus, contaminants appear to be having an effect on the health of *Spartina* at BGBC and SILH marshes, and since *Spartina* plants are the major primary producers, these contaminants are likely impacting the estuarine ecosystem that interacts with the marsh habitats at these locations. In addition, seaweed biomass, which was shown to be a significant contributor to macrophyte biomass of the SAT community, was depressed at the BGBC and CICC marshes.

The canopy height of *S. patens* did not vary greatly and was closely correlated with the amount of soil moisture ($r^2 = 0.829$) as shown in Figure 5. Edaphic factors such as soil moisture have been cited as important references on plant height in *Spartina alterniflora* (Mendelssohn et al. 1981, Howes et al. 1986), but no height-soil moisture correlation was found for the SAT community, even if the data from the BGBC and SILH marshes were excluded (Figure 5).

In the upper marsh where *S. patens* was dominant (SPN community), neither the height nor the biomass of *S. patens* appeared to be related to contaminant levels. The SPN community may also include upwards of a dozen species of grasses and forbs (Nixon 1982). Natural stresses and disturbances allow these other species to occupy a minor position in the high marsh, with *S. patens* normally outcompeting and replacing these species with time (Bertness 1991). Therefore, stress to *S. patens* may be reflected in greater success of competitors of *Spartina*. This is illustrated by the significantly greater amount of biomass (BGBC, CIPR) and cover (BGBC, CIPR, CICC) contributed by other vascular plants

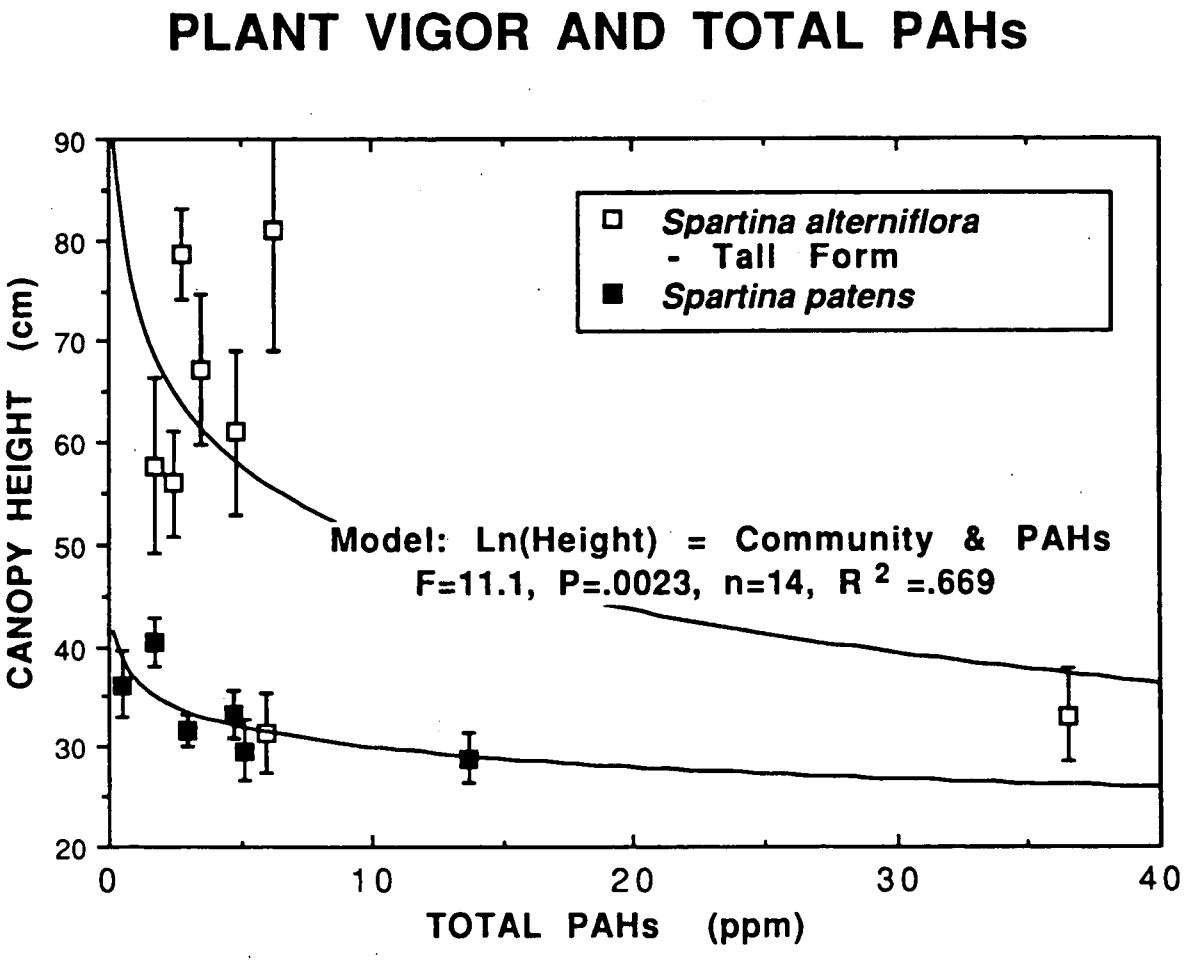

Figure 4. Relationship between Total PAHs in the sediment and plant canopy height in salt marsh communities dominated by tall form *Spartina alterniflora* and *S. patens*.

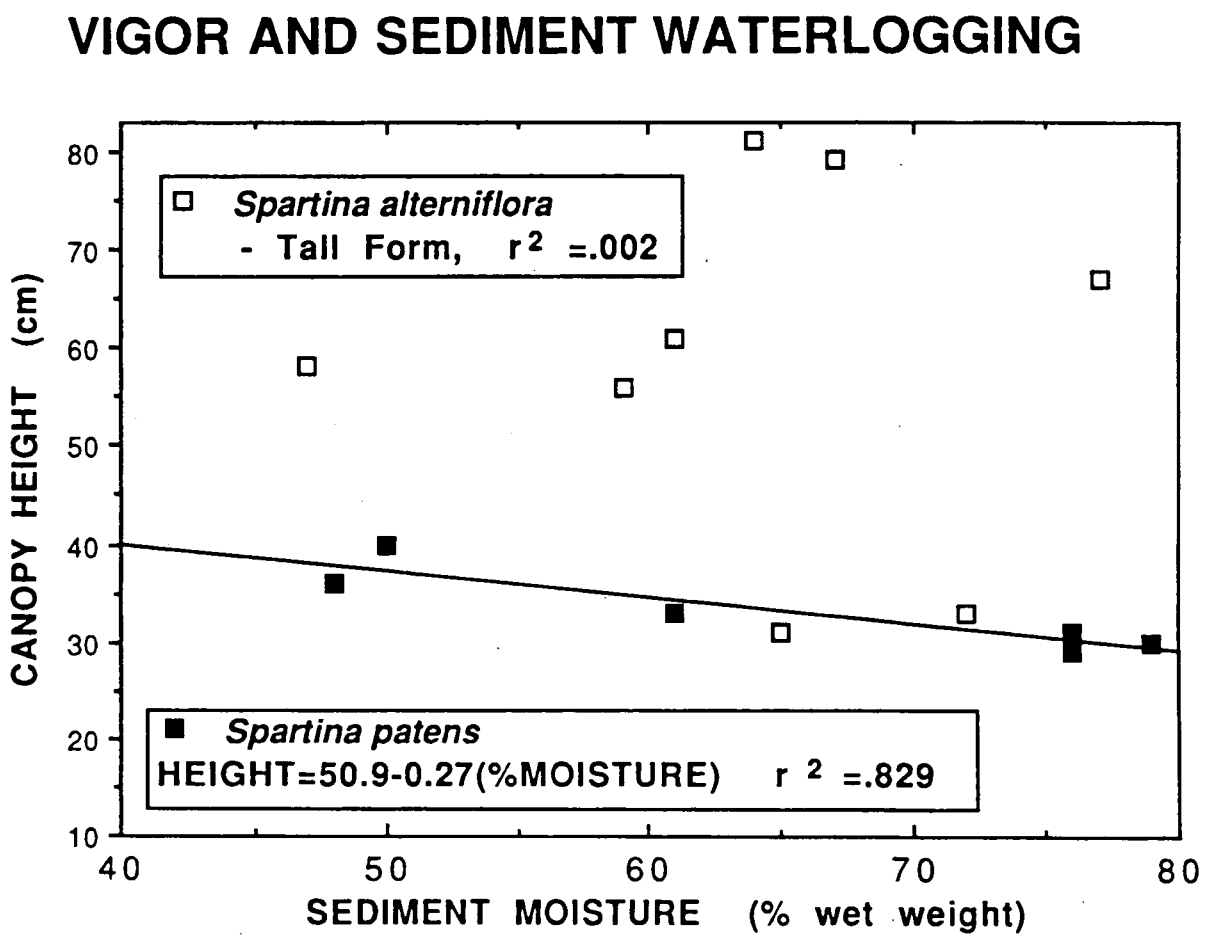

Figure 5. Relationship between sediment moisture content and plant canopy height in salt marsh communities dominated by tall form *Spartina alterniflora* and *S. patens*.

and the significantly greater species number (BGBC, CIPR, CICC) found in the upper marshes of systems exposed to greater contaminant levels (Figure 3).

Only one location had dramatically lower animal abundance: CIPR (SAS and SPN communities; Table 4). In addition, two high marshes (BGBC and CIPR) exhibited low numbers of animal taxa as compared to references (Table 4). These differences were substantial and statistically significant. The BGBC and CIPR high marsh communities had significantly fewer amphipods and only one terrestrial arthropod. As a group, amphipods are very sensitive to both metal and oil pollution (Reish and Barnard 1979, Teal and Howarth 1984). Amphipod populations were shown to be significantly impacted by very low levels of oil or water extracts of oil (40 to 800 ppb; Linden 1976, Lee et al. 1977, Bonsdorff et al. 1990). Reish and Barnard (1979) review literature that demonstrates toxic effects of Cd and Zn on amphipods at low levels of exposure (under 2 ppm). Similarly, it has been reported that other estuarine crustaceans are susceptible to poisoning from very low levels of PCBs (1 ppb Aroclor 1254 and 1016; Couch 1979). However, it is not clear whether the relatively high Total PCB found at the BGBC site (103 ppb) would have an impact on the marsh animals.

Both *Littorina* abundance and the ratio of live to dead shells was lower in the SAT community of the SILH marsh than at reference locations. Reviewing the effects of oil on marine animals, Dunning and Major (1974) report that *Littorina* is very sensitive to oil pollution. Hampson and Moul (1978) found reduced populations of marsh infauna three years after an oil spill when the sum of C1 to C3 naphthalenes and C1 to C3 phenanthrenes in surficial sediment cores at this site were estimated to be 90 ppm on a dry weight basis (Teal et al. 1978). It is likely that the low numbers of animals found at CIPR, BGBC and SILH marshes are indicators of exposure to contaminants and resulting stress, which may be caused by petroleum and/or metal pollution (discussed in: Sheehan 1984a, Teal and Howarth 1984).

Potential for Trophic Transport

Sediments and *Spartina* leaves analyzed for metals and organics showed elevated levels of both types of contaminants in salt marshes of the lower Piscataqua River, indicating marine ecosystem exposure to these toxicants. One path for the contaminants to reach marsh animals is from trophic transfer by macrophytes and microalgae. Another path could be directly from contact or ingestion of the sediments. Future research to determine the most significant pathways could include mark and recapture studies with animals to obtain measures of stress and impacts to ecological success (growth, survival). The most important path of trophic transport of contaminants taken up by *Spartina* could

be through belowground production, since metal (Cd, Cr, Cu, Zn) and arsenic levels are reported to be greatest in *Spartina* roots and rhizomes (Giblin et al. 1983, Alberts et al. 1990, Otte et al. 1993). However, it is generally held that aboveground portions are more important in supporting the estuarine food web (Mitsch and Gosselink 1986), and the reduced carbon sources of the belowground tissues are used for overwintering and spring regrowth (Gross et al. 1991). This suggests that the trapping of contaminants in salt marsh peat sediments removes their activity, for the large part, from the marine food web. An important exception to this is for mercury, which is transported more readily to the shoots of *Spartina* than the previously mentioned contaminants (Giblin et al. 1983, Alberts et al. 1990).

Possible impacts to the animals living on the marsh surface (indicated by low number of taxa, low amphipod and *Littorina* abundances, and low live:dead *Littorina* shell ratio), suggest contaminants are reaching these parts of the food web. The infauna of the marshes were not assessed due to the difficulty in separating animals from the peat matrix, but the surface indicators support the speculation that these animals are impacted as well. Depressed animal abundance or absence of certain taxa could indicate that they are not available as food to higher trophic levels or it could mean that impaired behavioral responses make them easy targets for predators (Teal and Howarth 1984, Sheehan 1984b). At high tide, marine animals such as fish and mobile shellfish have access to marsh food sources, while at low tide wading and sea birds forage in these habitats. Thus, the potential for trophic transport of contaminants from these marshes appears to be significant.

Marshes are depositional areas that accumulate sediments and contaminants and store them in the peat deposits created by the plants. Pollution can cause severe impacts to marsh plants and plant losses can lead to erosion of the peat (Hampson and Moul 1978), and hence to remobilization of the contaminants. If the contaminants stored in the salt marsh sediments are not to be remobilized, these areas must not become stressed to the point that the grasses fail to protect and build peat deposits. Reduced vigor of the plants at the seaward edge of the BGBC marsh (and perhaps the CICC marsh) suggests that these plants are stressed. The marshes around the Shipyard require careful monitoring to ensure that the grasses promote continued peat accumulation, and erosion does not occur. Remediation to halt erosion and rebuild marsh edges could include planting grasses and physical modifications to protect the outer edge from strong erosive forces.

CONCLUSIONS

There appears to be long-term, chronic exposure of Shipyard marsh habitats to Ag, As, Cr, Cu, Hg, Ni, Pb, Zn, Sum PAHs and Total PCBs in the low range and to Cr, Ni, and Pb in the moderate range for ecological effects (Long and Morgan 1991). The sediments in the salt marshes of PNS have elevated levels of contaminants, and the salt marsh sediment and plant patterns suggest at least some of the contaminants may have sources on the Shipyard. Two notable exceptions to this are the relatively high levels of Zn, Cr and Total PCB in the AVSC marsh on Spruce Creek in Kittery, and the Cr, Ni, Pb, Sum PAHs and Total PCB at the SILH marsh in Little Harbor, Portsmouth. Since the BNBC marsh was relatively unimpacted and was very close to the most impacted marsh (BGBC), contaminant flux from uplands and marshes to nearby marshes may not occur to any great extent.

No evidence of large-scale disturbance to marshes was observed in the field, but the sampling design would have avoided quantitative assessment of disturbed areas, if present. An analysis of changes in salt marsh area over time is recommended if impacts that result in significant disturbance and erosion are to be assessed. Ecological differences between locations were found in the plants and animals of the marsh communities that were sampled, and potential impacts were identified when marshes with greater exposure to contaminants were compared with reference sites. The results presented here are descriptive and the potential effects of pollution that are discussed must be tested experimentally to refute or confirm them. Some of the ecological effects may be due to naturally-occurring differences and stresses unrelated to human impacts. The weight of evidence suggests that there are ecological impacts from contaminant exposure in some of the salt marshes around the Shipyard, particularly BGBC, CIPR, and CICC marshes. The number of potential impacts that were revealed by significant statistical differences in ecological variables (ecological effects) indicates measurable reductions in habitat quality at these marshes and is cause for concern and perhaps further examination, assessment and remediation.

It appears that the plants are not translocating large amounts of contaminants to their leaves. What metals are taken up by *Spartina* plants primarily remain in their roots (Giblin et al. 1983, Alberts et al. 1990), and then become part of the peat. Natural maintenance of *Spartina* cover coupled with no increase in physical exposure should result in long term accumulation of the peat and the

contaminants trapped within. Because several of the marshes around the Shipyard appear to be stressed, they require careful monitoring and, if needed, special protection to ensure that the grasses promote continued peat accumulation, and not erosion. If the marshes continue to trap and store contaminants in their peat deposits, the potential for trophic transport could be less than if the contaminants are continually released by eroding peat and are allowed to pass into the lower intertidal flats and subtidal portions of the estuary.

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APPENDIX I: Standard Operating Procedures for the Collection of Salt Marsh Data: JEL SOPs 1.11 and 1.17

UNH, JEL STANDARD OPERATING PROCEDURES SEDIMENT MOISTURE, ORGANIC CONTENT, C/N CONTENT, AND GRAIN SIZE ANALYSIS

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I. OBJECTIVE

Characterization of estuarine sediments: determination of grain size statistics, moisture content, combustible content (as a measure of particulate organics) and particulate carbon and nitrogen of a sediment sample.

II. NECESSARY MATERIALS AND EQUIPMENT:

-Standard set of sieves, sieve shaker and wet sieves (63μ and 2mm)
-Graduated cylinders (1 L), 20 ml pipette, 50 ml beakers, 1 L beakers, stirring rod
-Dispersant (sodium hexametaphosphate - Calgon)
-30% Hydrogen peroxide (H_2O_2) or equivalent oxidizer
-Laboratory drying oven
-Muffle furnace
-Balance accurate to 0.0001 g
-Deionized water
-Aluminum weighing dishes
-Squeeze bottles
-Funnel (greater than 20 cm diameter)
-Stirring rod for a 1 L graduated cylinder
-Dessicator
-CN Analyzer

III. METHODS

A. Moisture And Combustible Content

1. Place 2 to 3 cc of sample in a preweighed aluminum dish and weigh to the nearest 0.0001 g to determine the wet weight. Subsequently, dry in an oven at 50-75 °C for 24 hrs or until completely dry. Remove from oven and cool in a desiccator to room temperature. Place sample in weighing room for about 1 hr or until the sample stops gaining weight due to ambient air moisture. Reweigh to determine the moisture content - the % weight loss ((wet weight - dry weight) / wet weight). Next, heat sample in muffle furnace at 450°C for 4 hrs to determine combustible content - the % weight loss after heating ((dry weight - combusted weight) / dry weight)(Ball 1964). Again, after removing the sample from the oven, place in a dessicator until cooled to room temperature, then place in ambient air until weight is stable.

B. Particulate Carbon and Particulate Nitrogen Analysis

1. Place ~1cc of sample in an aluminum weighing dish and dry in an oven at 75° for 24 hr or until dry. Remove and grind in a mortar and pestle until the sample is homogeneous.

2. Carefully weigh (to 0.001mg) approximately 1.5 to 1.75 mg of sediment into a tared tin sample cup (< 1 cm container).

3. Carefully remove the cup and seal it by crushing the top edige together and then crushing with needle nose pliers.

4. The sample is then oxidized by flash combustion and analyzed by chromatography in a Carlo Erba Nitrogen Analyzer or equivalent instrument.

C. Size Analysis: Wet Sieving

1. Place the sample in a large beaker (1 L) and add approximately 20-30 ml of 30% H_2O_2. Add a small amount of H_2O_2 at a time to be sure the sample does not foam over the top of the beaker (~10-15 ml initially, then 10-15 ml after 24 hours, etc.). The amount of sediment sample to use depends on the analyses to be run. Approximately 10 - 15 g dry weight is needed for pipette analysis and 30 - 70 g for sieve analysis. Stir to break up the sample.

2. After as much of the organics as possible have been removed as indicated by lack of bubbling upon adding more H_2O_2 and the remaining liquid has been decanted, remove the sea salts which may be in the sample. This is done by adding deionized water, stirring and decanting. Place the sample in a bottle and fill with dispersant (~0.2 g/L of Calgon in deionized water). Stir vigorously to be certain that the sediment particles are separate. If the sample appears to have gravel particles (greater than 2 mm), wet sieve the sample through a 2 mm stainless steel sieve to remove the gravel. Rinse the gravel with deionized water into a preweighed beaker, dry and set aside (to determine % gravel).

3. Wet sieve the sample through a 63 μ stainless steel sieve. This is done by placing the wet sieve in a plastic funnel of slightly larger diameter which drains into a 1 L graduated cylinder. Place the sample on the wet sieve and gently rinse all the sediment finer than 63μ through the sieve with dispersant in a squeeze bottle. Be careful not to touch the sieve with your hand or anything that will damage the mesh.

4. Wash the material on the wet sieve into a preweighed beaker using deionized water and dry. This is the sand fraction (63μ to 2mm). The material in the graduated cylinder is the mud fraction (silt and clay).

D. Sieve Analysis of the Sand Fraction

1. Weigh the dry and disaggregated sand fraction to the nearest 0.01 g.

2. Select a set of sieves that cover the range of sediment sizes to be analyzed and place the screens in order with the coarsest at the top and the pan on the bottom. Use a maximum of 1/2 phi intervals. Pour the sand sample on the top sieve and place in the sieve shaker for 15 minutes.

3. Carefully remove the sediment from each sieve and weigh to 0.01 g.

4. Total the weight of the sand in each size interval (sieve). If the weight is not within 2% of the original sediment weight, then rerun the analysis.

5. If the analysis is okay, then proceed with determining the size frequency distribution and graphic grain size statistics (mean size, sorting, skewness and kurtosis) as outlined in Folk (1980).

6. Add any sediment that passes through the 63 μ sieve during the shaking processes to the fine fraction to be used for the pipette analysis.

F. Pipette Analysis of the Silt and Clay (Mud) Fraction

1. Add dispersant (Calgon) to the mud fraction until the graduated cylinder has exactly 1 L in it. Thoroughly mix with stirring rod for approximately 2 to 5 minutes being very careful not to splatter any of the sample. Accurately determine the amount of dispersant added to the sample as this has to be subtracted out during the statistical analysis. This can be done by mixing a large quantity of dispersant, removing 20 ml samples with a pipette, drying and determining dispersant weights.

2. Allow the sample to stand overnight to see if any flocculation occurs. If the sample flocculates, the sample preparation has to be redone or additional dispersant added.

3. If the sample is suitable for analysis, restir for 2 to 5 minutes with a stirring rod or with a mechanical stirrer. Be sure to stir the length of the column.

4. The moment the stirring is stopped is time = 0 and the analysis has begun. At the prescribed time intervals and depths outlined in Folk (1980), carefully pipette out 20 ml samples from the graduated cylinder and place in preweighed (to 0.0001 g) 50 ml beakers or equivalent. Take the appropriate samples to determine the amount of sediment in each size interval from 4 to 14 phi as described in Folk (1980). Normally, the 10 - 14 phi interval is determined by computation.

5. Dry the sediment in each beaker 50-75°C for a minimum of 24 hours or until completely dry. After drying, place the beakers initially in a desiccator until the sample is at room temperature, then place in the weighing room until the samples are at equilibrium with ambient humidity and reweigh.

IV. TROUBLE SHOOTING

Included in Methods.

V. STATISTICAL ANALYSIS AND DATA USAGE

1. Determine the size frequency distribution and graphic statistics (mean, sorting, skewness and kurtosis) using the methods outlined in Folk (1980). If both sieve and pipette analyses were done for a sample, then combine the data sets to determine a single set of statistics (Folk 1980).

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I. OBJECTIVE

To assess the health of salt marsh habitat through the collection and subsequent measures of macrophytes (plants) and sediments. Laboratory measures include plant stature, biomass, and density, and chemical analyses of characteristic salt marsh plants and the sediments.

II.NECESSARY MATERIALS AND EQUIPMENT

- Flags with stakes
- Field notebook for recording data
- Random number tables
- Plastic measuring tape (30 m)
- Quadrats (1 m^2 and 1/16 m^2)
- Collection bags (8-40 l for plants, 4 l for cores), markers and marking tape
- Scissors
- Serrated knife (15 cm)
- Coring device (5 cm diameter, 50 cm length)
- Boots, gloves, and other protective clothing as needed

III. METHODS

A. Setting up vegetative zones, transect locations, and sampling sites

1. Assess the boundaries of the salt marsh to be sampled at low tide. Draw the salt marsh approximatly to scale, using whatever features are available for orientation, etc.

2. On the map, draw the boundaries of the marsh zones that are characterized by the dominant emergent angiosperms present (*Spartina alterniflora* tall form, *Spartina alterniflora* short form, *Spartina patens*, *Distichlis spicata*, *Juncus gerardii*, etc.). Choose sampling transects that will cover each of the zones and mark on the map.

3. Mark each transect with the stakes and measure transect lengths. Using the random number table, collect distances along the transect, making sure samples are not bunched up in one location. For the present study, all marshes to be sampled were less than one half hectare (except for reference marshes), so the number of replicates to characterize a zone at each site was chosen to be 5.

4. At each sampling distance along the transect that was randomly chosen in step #3, estimate the width of the zone and collect a distance from the random number table, using the appropriate number of digits so that any spot on an imaginary line perpendicular to the transect has an equal chance of being sampled. Record all sample locations chosen.

B. Field Assessments and Collections

1. Measure the distance from the transect line to the sampling location and place the 1 m^2 quadrat at the center of the mark. Estimate percent cover of all species and bare substratum (mud or rock) so that the final sum of cover equals 100%.

2. Remove large quadrat and place 1/16 m^2 quadrat at center of mark. Collect all plant material and place in a marked bag, cutting stems about 1 cm above the sediment surface.

3. Identify and count all macroinvertebrates (greater than 2 mm in size) at the surface, on stems, etc. using local guides (Robbins and Yentsch 1973)

4. Twist the sharpened end of a clean soil core into the sediment , plug with a rubber stopper to create a vacuum, rock from side to side to loosen the base of core and extract. Extrude with the stopper rod directly into the marked bag. Rinse core and stopper between samples.

5. For the dominant angiosperm in each marsh zone, 80 g live leaf tissue is collected along the transect(s) and placed in a bag after all other sampling is completed. This tissue will be analyzed for contaminants.

C. Laboratory procedures

1. Upon return to the lab, refrigerate all samples at 0-5 °C until processing is complete.

2. Wash plants collected for contaminant analyses with fresh water and remove any dead tissues. Place in a marked bag and freeze until analysis.

3. Measure the length of each of the five soil cores and cut a pie-shaped wedge the length of each core. Form a composite sample for contaminant analyses by placing the wedges together in a marked bag and freeze (-4°C) until analysis.

4. Separate the plants from each sample site into species, according to Tiner (1980) for angiosperms and Taylor (1960) for seaweeds. Measure and record the number of vegetative and reproductive stems, the length of the ten tallest stems for each species. Place all material from each species into a foil pouch and dry at 60°C until no further weight loss is found with further drying (about a week for most samples). Record dry weight and store in a dry location.

III. TROUBLE SHOOTING

1. A vegetative zone may not be continuous (that is two or three disjunct patches of an important, dominant plant may be present). In this case, create transects for each area that is substantial and split the replicates among the transects.

2. The sharpened core may not be able to cut through the peat. In this case cut around the core with the serrated knife and retry.

IV. STATISTICS

Means of vegetation and soil characteristics are calculated for each zone at each marsh. Characteristics may be compared between marshes using analysis of variance (ANOVA) procedures, with marsh zones considered as blocks. Site differences may be determined using several dependent variables in a multivariate procedure known as MANOVA. Relationships among plant and soil characteristics may be investigated using multivariate procedures such as canonical correlation or principle component analyses.

V. REFERENCES

Robbins, S. F., and C. Yentsch. 1973. The Sea is All About Us. Peabody Museum, Salem, MA, pp. 162.

Taylor, W. R. 1962. Marine Algae of the Northeastern Coast of North America. University of Michagan, Ann Arbor, pp. 509.

Tiner, R. W. 1987. A Field Guide to Coastal Wetland Plants of the Northeastern United States. University of Massachusetts, Amherst, pp. 285.

APPENDIX II A. *Spartina* leaf tissue moisture (%) and metal (ppm) concentrations.

	MARSH	COMMUNITY	EPA ID#	%moist	Al	Ag	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
1	CIPR	SA	112660	.729	180.0	.239	1.2	.028	1.47	2.06	372	.012	103.0	.535	.711	34.0
2	CIPR	SP	112662	.650	205.0	.090	1.2	.049	1.54	2.97	339	.012	48.1	.590	.965	25.3
3	CICC	SA	112663	.752	279.0	.263	1.2	.042	1.97	1.91	480	.019	126.0	.804	1.120	36.1
4	CICC	SP	112665	.667	76.1	.099	1.2	.027	.87	1.84	128	.016	45.4	.520	.590	20.6
5	JIBC	SA	112666	.658	203.0	.139	1.2	.078	1.44	3.23	306	.010	67.3	.680	.630	18.9
6	BGBC	SA	112667	.641	889.0	.400	1.2	.113	3.90	2.72	983	.017	87.7	1.280	2.540	33.0
7	BGBC	SP	112668	.616	489.0	.150	1.2	.112	2.50	3.56	615	.014	16.4	1.110	2.110	47.7
8	BMBC	SA	112671	.703	213.0	.082	1.2	.040	1.62	2.36	367	.020	66.6	.430	.920	48.8
9	SILH	SA	112669	.725	259.0	.165	1.2	.040	1.89	1.84	396	.013	92.0	.405	.730	33.0
10	SILH	SP	112670	.670	688.0	.220	1.2	.158	3.52	3.70	895	.019	64.7	1.750	4.080	22.1
11	AUSC	SA	112672	.736	416.0	.260	1.2	.145	2.36	1.22	470	.013	72.1	.850	.870	23.8
12	AUSC	SP	112673	.580	423.0	.140	1.2	.126	2.88	2.03	556	.019	27.0	.950	1.180	20.1
13	BIYR	SA	112674	.693	1045.0	.120	1.2	.098	2.82	1.27	1050	.013	40.0	1.500	1.270	23.6
14	BIYR	SP	112676	.573	221.0	.110	1.2	.140	1.06	1.89	257	.016	27.2	.590	.540	11.1

APPENDIX II B. Sediment moisture (%) and metal (ppm) concentrations.

	MARSH	COMMUNITY	EPA ID#	%Moisture	Al	Ag	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sn	Zn
1	CIPR	SAT	112680	68.6	50000	.51	32.3	1.93	151	182.2	28000	.345	331	46.9	82.7	13.2	102.5
2	CIPR	SPN	112682	60.3	50000	.26	32.9	.08	124	81.1	30000	.516	465	53.7	154.7	15.8	129.2
3	CIEM	SAT	112683	35.8	42000	.16	12.4	.12	109	28.1	20000	.072	305	39.8	35.8	4.1	89.3
4	CIEM	SPN	112685	41.5	48000	.41	11.1	.18	97	88.2	24000	.159	345	47.9	76.5	48.0	131.0
5	JIBC	SAT	112686	56.9	39000	.34	17.8	.27	82	31.1	19000	.182	450	27.3	192.8	9.0	170.4
6	BGBC	SAT	112687	63.1	60000	1.08	21.7	.45	141	42.8	24000	.382	365	28.7	92.1	12.7	99.5
7	BGBC	SPN	112688	52.2	64000	.77	29.1	.15	148	69.9	35000	.419	478	39.8	169.1	15.2	158.8
8	BMBC	SAT	112691	31.1	53000	.05	10.3	.72	66	28.9	21000	.287	540	34.6	35.8	6.7	60.7
9	SHIM	SAT	112689	64.2	43000	.34	23.9	.54	102	25.2	18000	.261	262	23.2	81.3	10.1	88.0
10	SHIM	SPN	112690	65.4	50000	.32	18.1	.19	146	35.9	23000	.379	265	35.5	116.1	15.1	75.1
11	ADUM	SAT	112692	81.1	50000	.55	28.1	.53	143	28.9	32000	.383	314	29.8	81.5	12.0	136.0
12	ADUM	SPN	112693	79.8	50000	.44	26.3	.54	138	28.3	22000	.577	256	28.7	90.4	12.3	111.5
13	YKRM	SAT	112694	69.2	56000	.08	20.2	.42	62	20.2	24000	.095	361	26.4	48.9	5.5	86.8
14	YKRM	SPN	112696	67.0	53000	.05	20.5	.29	43	16.5	17000	.112	277	21.5	82.4	6.1	54.4

APPENDIX III: Corrected Data for Plants and Sediments

Variable Descriptions For Salt Marsh Ecological Data

VARIABLE A	VARIABLE B	VARIABLE DESCRIPTION	
MARSH		Code for Salt Marsh (CIPR, CICC, JIBC, BGBC, BNBC, SILH, AVSC, BIYR)	
COM		Salt Marsh Community (SAT, SAS or SPN)	
TRANS		Transect Within Marsh	
REP		Repliate for Community Within Marsh	
EPA ID#		Indentification Number Assigned to Sample	
S ALT		% Cover (1m2 quadrat)	*Spartina alterniflora*
SP		% Cover (1m2 quadrat)	*Spartina patens*
V-S		% Cover (1m2 quadrat)	Vascular Plants but not Spartina spp.
DS		% Cover (1m2 quadrat)	*Distichlis spicata*
SE		% Cover (1m2 quadrat)	*Salicornia europaea*
SM		% Cover (1m2 quadrat)	*Suaeda maritima*
LN		% Cover (1m2 quadrat)	*Limonium nashii*
FV		% Cover (1m2 quadrat)	*Fucus spp.*
AN		% Cover (1m2 quadrat)	*Ascophylum nodosum*
O VASC		% Cover (1m2 quadrat)	Other Vascular Plants
BARE		% Cover (1m2 quadrat)	Unvegetated Sediment
ALL V		% Cover (1m2 quadrat)	Sum of All Vascular Plants
ALGAE		% Cover (1m2 quadrat)	Sum of All Algae
TOTAL		% Cover (1m2 quadrat)	Sum of All Macrophytes (Vascular + Algae)
#SPECIES		Number of species within the1square meter quadrat	
#VSTEMS	SA	# of vegetative stems per 1/16m2 of	*Spartina alterniflora*
#RSTEMS	SA	# of reproductive stems per 1/16m2 of	*Spartina alterniflora*
MEAN HT	SA	Height of 10 tallest vegetative stems per 1/16m2 of	*Spartina alterniflora*
BIOMASS	SA	Biomass in grams per 1/16m2 of	*Spartina alterniflora*
#VSTEMS	SP	# of vegetative stems per 1/16m2 of	*Spartina patens*
#RSTEMS	SP	# of reproductive stems per 1/16m2 of	*Spartina patens*
MEAN HT	SP	Height of 10 tallest vegetative stems per 1/16m2 of	*Spartina patens*
BIOMASS	SP	Biomass in grams per 1/16m2 of	*Spartina patens*
#VSTEMS	SE	# of stems per 1/16m2 of	*Salicornia europaea*
MEAN HT	SE	Height of 10 tallest vegetative stems per 1/16m2 of	*Salicornia europaea*
BIOMASS	SE	Biomass in grams per 1/16m2 of	*Salicornia europaea*
#STEMS	SM	# of stems per 1/16m2 of	*Suaeda maritima*
MEAN HT	SM	Height of 10 tallest vegetative stems per 1/16m2 of	*Suaeda maritima*
BIOMASS	SM	Biomass in grams per 1/16m2 of	*Suaeda maritima*
#STEMS	LN	# of stems per 1/16m2 of	*Limonium nashii*
MEAN HT	LN	Height of 10 tallest vegetative stems per 1/16m2 of	*Limonium nashii*
BIOMASS	LN	Biomass in grams per 1/16m2 of	*Limonium nashii*
#STEMS	SPERGM	# of stems per 1/16m2 of	*Spergularia marina*
MEAN HT	SPERGM	Height of 10 tallest vegetative stems per 1/16m2 of	*Spergularia marina*
BIOMASS	SPERGM	Biomass in grams per 1/16m2 of	*Spergularia marina*
#STEMS	OVASC	# of stems per 1/16m2 of	Other Vascular Plants
MEAN HT	OVASC	Height of 10 tallest vegetative stems per 1/16m2 of	Other Vascular Plants
BIOMASS	OVASC	Biomass in grams per 1/16m2 of	Other Vascular Plants
#STEMS	OALGAE	# of stems per 1/16m2 of	Other Algae
MEAN HT	OALGAE	Height of 10 tallest vegetative stems per 1/16m2 of	Other Algae
BIOMASS	OALGAE	Biomass in grams per 1/16m2 of	Other Algae
#STEMS	AN	# of stems per 1/16m2 of	*Ascophylum nodosum*
MEAN HT	AN	Height of 10 tallest vegetative stems per 1/16m2 of	*Ascophylum nodosum*
BIOMASS	AN	Biomass in grams per 1/16m2 of	*Ascophylum nodosum*
#STEMS	FV	# of stems per 1/16m2 of	*Fucus spp.*
MEAN HT	FV	Height of 10 tallest vegetative stems per 1/16m2 of	*Fucus spp.*
BIOMASS	FV	Biomass in grams per 1/16m2 of	*Fucus spp.*
#STEMS	ALLALGAE	# of stems per 1/16m2 of	Sum of All Algae
BIOMASS	ALLALGAE	Biomass in grams per 1/16m2 of	Sum of All Algae
#STEMS	OV (w/o S)	# of stems per 1/16m2 of	Sum of All Vascular Plants minus Spartina spp.
BIOMASS	OV (w/o S)	Biomass in grams per 1/16m2 of	Sum of All Vascular Plants minus Spartina spp.
#STEMS	ALLV	# of stems per 1/16m2 of	Sum of All Vascular Plants plus Spartina spp.
BIOMASS	ALLV	Biomass in grams per 1/16m2 of	Sum of All Vascular Plants plus Spartina spp.
#STEMS	TOTALM	# of stems per 1/16m2 of	Sum of All Macrophytes (Vascular + Algae)
BIOMASS	TOTALM	Biomass in grams per 1/16m2 of	Sum of All Macrophytes (Vascular + Algae)
AMPHIPOD		Number AMPHIPODS per 1/16 m2 quadrat	

ISOPOD	Number ISOPODS per 1/16 m2 quadrat	
Gcrab	Number per 1/16 m2 quadrat of	*Carcinus maenus*
BARNACLE	Number BARNACLES per 1/16 m2 quadrat	
SPIDER	Number SPIDERS per 1/16 m2 quadrat	
*Anurida**	Number per 1/16 m2 quadrat of	*Anurida spp.*
ANT	Number ANTS per 1/16 m2 quadrat	
BEETLE	Number BEETLES per 1/16 m2 quadrat	
Lo	Number per 1/16 m2 quadrat of	*Littorina obtusata*
Ll (live)	Number per 1/16 m2 quadrat of	*L. littorea*
Ll (dead)	Number per 1/16 m2 quadrat of	*L. littorea*
Mb	Number per 1/16 m2 quadrat of	*Melampus bidentatus*
Lv	Number per 1/16 m2 quadrat of	*Lacuna vincta*
Gd	Number per 1/16 m2 quadrat of	*Geukensia demissus*
Me (live)	Number per 1/16 m2 quadrat of	*Mytilus edulis*
Me (dead)	Number per 1/16 m2 quadrat of	*Mytilus edulis*
# TAXA	Number of Taxa per 1/16 m2 quadrat	
Molluscs	Number of Molluscs per 1/16 m2 quadrat	
Crustaceans	Number of Crustaceans per 1/16 m2 quadrat	
MarA	Number Marine Animals per 1/16 m2 quadrat	
S/I	Number SPIDERS AND INSECTS per 1/16 m2 quadrat	
L/D Ll	Ratio of live to dead	*Littorina littorea*
*For Anurida	P means Present but not Counted	

UNH-PNS MARSH DATA

MARSH	COM	TRANS	REP	EPA ID#	S ALT	SP	V-S	DS	SE	SM	LN	FV	AN	O VASC	BARE	ALL V	ALGAE	TOTAL	#SPECIES	#VSTEMS SA	#RSTEMS SA	MEAN HT SA	BIOMASS SA	#VSTEMS SP
OPR	SAT	T1	1	112471	70	0	0	0	0	0	0	0	30	0	0	70	30	100	3	71	5	81.20	66.543	0
OPR	SAT	T1	2	112472	35	0	0	0	0	0	0	0	65	0	0	35	65	100	3	36	7	74.70	47.873	0
OPR	SAT	T2	3	112473	60	0	0	0	0	0	0	5	15	0	20	60	20	80	3	74	0	45.70	41.396	0
OPR	SAT	T2	4	112474	65	0	0	0	0	0	0	5	15	0	15	65	20	85	4	91	7	64.30	44.916	0
OPR	SAT	T2	5	112475	70	0	0	0	0	0	0	5	0	0	25	70	5	75	3	25	25	39.20	22.967	0
OPR	SAS	T3	1	112476	75	0	11	0	10	0	1	5	0	0	9	86	5	91	4	67	0	29.50	15.779	0
OPR	SAS	T3	2	112477	55	0	17	0	15	0	2	1	0	0	27	72	1	73	5	68	5	23.90	9.610	0
OPR	SAS	T3	3	112478	45	0	5	0	5	0	0	0	0	0	50	50	0	50	2	142	1	13.30	5.698	0
OPR	SAS	T3	4	112479	40	25	15	0	10	0	5	0	0	0	20	80	0	80	4	96	2	26.20	13.108	88
OPR	SAS	T3	5	112480	30	0	15	0	15	0	0	5	0	0	50	45	5	50	3	34	6	13.80	5.683	0
OPR	SP	T4	1	112481	3	60	27	0	7	0	20	0	0	0	10	90	0	90	6	0	0		0.000	1593
OPR	SP	T4	2	112482	10	85	0	0	0	0	0	0	0	0	5	95	0	95	3	2	0	33.00	0.398	559
OPR	SP	T4	3	112483	0	50	40	0	0	5	30	0	0	5	10	90	0	90	5	0	0		0.000	216
OPR	SP	T4	4	112484	20	70	5	0	5	0	0	0	0	0	5	95	0	95	3	8	0	33.63	2.244	775
OPR	SP	T4	5	112485	0	90	5	0	5	0	0	0	0	0	5	95	0	95	3	0	0		0.000	1247
CICC	SAT	T1	1	112486	80	0	0	0	0	0	0	0	15	0	5	80	15	95	3	39	5	86.50	86.140	0
CICC	SAT	T1	2	112487	45	0	0	0	0	0	0	5	0	0	50	45	5	50	3	26	1	67.50	25.311	0
CICC	SAT	T1	3	112488	55	0	0	0	0	0	0	10	5	0	30	55	15	70	3	38	0	45.30	13.659	0
CICC	SAT	T1	4	112489	75	0	0	0	0	0	0	10	5	0	10	75	15	90	3	108	3	50.10	44.236	0
CICC	SAT	T6	5	112490	55	0	0	0	0	0	0	10	0	0	35	55	10	65	2	116	8	39.10	26.389	0
CICC	SAS	T2	1	112491	50	0	35	0	35	0	0	0	0	0	15	85	0	85	3	192	4	28.99	22.597	0
CICC	SAS	T2	2	112492	45	0	40	0	40	0	0	0	0	0	15	85	0	85	3	272	1	19.30	11.619	0
CICC	SAS	T3	3	112493	45	0	50	0	45	0	0	0	0	5	5	95	0	95	3	307	0	18.10	13.808	0
CICC	SAS	T4	4	112494	55	0	35	0	35	0	0	0	0	0	10	90	0	90	2	211	0	14.60	9.143	0
CICC	SAS	T4	5	112495	55	0	30	0	30	0	0	0	0	0	15	85	0	85	2	53	1	29.60	22.165	0
CICC	SP	T5	1	112496	10	85	5	0	2	0	2	0	0	1	0	100	0	100	5	0	0		0.000	522
CICC	SP	T5	2	112497	0	90	5	0	0	2	0	0	0	3	5	95	0	95	5	0	0		0.000	280
CICC	SP	T5	3	112498	1	90	4	0	3	0	0	0	0	1	5	95	0	95	5	0	0		0.000	281
CICC	SP	T5	4	112499	0	50	30	0	2	25	0	0	0	3	20	80	0	80	6	0	0		0.000	151
CICC	SP	T7	5	112500	0	85	5	0	2	0	3	0	0	0	10	90	0	90	4	0	0		0.000	474
JIBC	SAT	T1	1	112501	40	0	0	0	0	0	0	15	45	0	0	40	60	100	3	11	3	72.80	29.714	0
JIBC	SAT	T1	2	112502	55	0	0	0	0	0	0	20	0	0	25	55	20	75	3	31	6	54.90	26.318	0
JIBC	SAT	T1	3	112503	50	0	0	0	0	0	0	20	20	0	10	50	40	90	3	44	6	60.10	29.788	0
JIBC	SAT	T1	4	112504	60	0	0	0	0	0	0	10	25	0	5	60	35	95	3	57	2	40.90	26.928	0
JIBC	SAT	T1	5	112505	50	0	0	0	0	0	0	25	25	0	0	50	50	100	3	71	0	51.40	31.723	0
BGBC	SAT	T1	1	112506	90	0	1	0	1	0	0	0	0	0	9	91	0	91	2	114	1	25.60	19.554	0
BGBC	SAT	T1	2	112507	55	0	0	0	0	0	0	10	30	0	5	55	40	95	3	49	5	46.60	27.705	0
BGBC	SAT	T1	3	112508	70	8	1	0	1	0	0	0	15	0	6	79	15	94	6	104	18	31.40	19.973	0
BGBC	SAT	T1	4	112509	73	0	0	0	0	0	0	2	10	0	15	73	12	85	3	68	9	28.80	18.950	0
BGBC	SAT	T1	5	112510	60	0	5	0	5	0	0	10	10	0	15	65	20	85	4	26	28	24.80	22.566	0
BGBC	SP	T2	1	112511	0	94	1	0	0	1	0	0	0	0	5	95	0	95	2	0	0		0.000	84
BGBC	SP	T2	2	112512	0	65	25	0	5	20	0	0	0	0	10	90	0	90	3	5	0	24.60	3.045	139
BGBC	SP	T2	3	112513	0	75	20	0	3	15	0	0	0	2	5	95	0	95	5	0	0		0.000	186
BGBC	SP	T2	4	112514	0	88	7	0	5	2	0	0	0	0	5	95	0	95	6	1	0	29.00	0.206	306
BGBC	SP	T2	5	112515	0	75	15	8	2	3	0	0	0	2	10	90	0	90	7	0	0		0.000	526

UNH-PNS MARSH DATA

MARSH	COM	TRANS	REP	EPA ID#	S ALT SP	V-S	DS	SE	SM	LN	FV	AN	O VASC	BARE	ALL V	ALGAE	TOTAL	#SPECIES	#VSTEMS SA	#RSTEMS SA	MEAN HT SA	BIOMASS SA	#VSTEMS SP
SILH	SAT	T1	1	112516	50	5	0	0	0	0	0	5	30	0	10	55	35	90	4	18	27	15.70	46.127	0
SILH	SAT	T1	2	112517	45	0	0	0	0	0	0	25	25	0	5	45	50	95	3	27	5	38.90	21.795	0
SILH	SAT	T1	3	112518	50	5	0	0	0	0	0	5	25	0	15	55	30	85	4	32	6	42.90	28.697	0
SILH	SAT	T1	4	112519	40	0	0	0	0	0	0	15	30	0	15	40	45	85	3	42	11	34.70	36.702	0
SILH	SAT	T1	5	112520	45	5	0	0	0	0	0	10	30	0	10	50	40	90	4	34	1	33.30	26.636	0
SILH	SP	T2	1	112521	2	80	3	0	1	0	2	0	0	0	15	85	0	85	4	1	0	5.00	0.100	77
SILH	SP	T2	2	112522	7	65	3	0	3	0	0	0	0	0	25	75	0	75	3	5	0	24.60	3.045	139
SILH	SP	T2	3	112523	10	65	5	0	5	0	0	0	0	0	20	80	0	80	3	7	0	34.90	5.565	132
SILH	SP	T2	4	112524	1	75	1	0	1	0	0	0	0	0	23	77	0	77	4	0	0		0.000	199
SILH	SP	T2	5	112525	3	80	3	0	3	0	0	0	3	0	11	86	3	89	4	0	0		0.000	152
BNBC	SAT	T1	1	112526	40	0	0	0	0	0	0	5	50	0	5	40	55	95	3	23	0	81.60	19.634	0
BNBC	SAT	T1	2	112527	50	0	0	0	0	0	0	5	40	0	5	50	45	95	3	14	6	91.50	38.468	0
BNBC	SAT	T1	3	112528	55	10	0	0	0	0	0	0	25	0	10	65	25	90	4	3	10	53.70	30.791	0
BNBC	SAT	T1	4	112529	45	5	0	0	0	0	0	3	40	0	7	50	43	93	4	27	0	58.30	32.920	0
BNBC	SAT	T1	5	112530	65	0	0	0	0	0	0	0	5	0	30	65	5	70	2	3	8	119.70	53.124	0
AVSC	SAT	T1	1	112531	50	0	0	0	0	0	0	0	0	0	50	50	0	50	2	76	26	57.50	48.795	0
AVSC	SAT	T1	2	112532	50	0	0	0	0	0	0	0	30	0	20	50	30	80	2	33	0	84.20	29.928	0
AVSC	SAT	T1	3	112533	70	0	0	0	0	0	0	0	15	0	15	70	15	85	2	88	8	47.60	22.847	0
AVSC	SAT	T1	4	112534	60	0	0	0	0	0	0	0	35	0	5	60	35	95	2	33	2	84.20	50.480	0
AVSC	SAT	T1	5	112535	50	0	0	0	0	0	0	0	40	0	10	50	40	90	2	34	11	62.00	36.324	0
AVSC	SP	T2	1	112536	20	70	3	0	0	0	3	0	0	0	7	93	0	93	4	38	0	30.80	5.883	822
AVSC	SP	T2	2	112537	30	40	10	10	0	0	0	0	0	0	20	80	0	80	3	183	2	28.60	15.684	104
AVSC	SP	T2	3	112538	25	50	0	0	0	0	0	0	0	0	25	75	0	75	3	10	4	15.70	8.285	92
AVSC	SP	T2	4	112539	0	95	0	0	0	0	0	0	0	0	5	95	0	95	1	0	0		0.000	457
AVSC	SP	T2	5	112540	0	99	1	0	1	0	0	0	0	0	0	100	0	100	2	0	0		0.000	281
BIYR	SAT	T1	1	112541	55	0	0	0	0	0	0	20	20	0	5	55	40	95	3	43	0	69.60	31.869	0
BIYR	SAT	T1	2	112542	45	0	0	0	0	0	0	20	20	0	15	45	40	85	3	34	0	69.80	25.877	0
BIYR	SAT	T1	3	112543	55	0	0	0	0	0	0	5	35	0	5	55	40	95	3	30	2	76.05	32.976	0
BIYR	SAT	T1	4	112544	65	0	0	0	0	0	0	2	8	0	25	65	10	75	3	41	0	93.80	48.853	0
BIYR	SAT	T1	5	112545	70	0	0	0	0	0	0	7	8	0	15	70	15	85	3	24	0	83.70	29.680	0
BIYR	SAS	T2	1	112546	65	15	0	0	0	0	0	0	5	0	15	80	5	85	3	69	0	35.30	16.161	0
BIYR	SAS	T2	2	112547	60	20	0	0	0	0	0	3	2	0	15	80	5	85	4	96	0	41.20	25.458	0
BIYR	SAS	T2	3	112548	75	0	0	0	0	0	0	2	8	0	15	75	10	85	3	161	0	41.00	30.354	0
BIYR	SAS	T2	4	112549	65	15	0	0	0	0	0	3	2	0	15	80	5	85	5	120	0	35.60	16.453	45
BIYR	SAS	T2	5	112550	70	10	0	0	0	0	0	5	0	0	15	80	5	85	3	91	0	39.50	17.647	0
BIYR	SP	T3	1	112551	0	90	5	5	0	0	0	0	0	0	5	95	0	95	2	0	0		0.000	1129
BIYR	SP	T3	2	112552	0	70	0	0	0	0	0	0	0	0	30	70	0	70	1	0	0		0.000	392
BIYR	SP	T3	3	112553	0	60	0	0	0	0	0	0	0	0	40	60	0	60	1	0	0		0.000	336
BIYR	SP	T3	4	112554	0	58	3	0	1	0	1	0	0	1	39	61	0	61	5	0	0		0.000	445
BIYR	SP	T3	5	112555	0	85	0	0	0	0	0	0	0	0	15	85	0	85	1	0	0		0.000	657

UNH-PNS MARSH DATA

#RSTEMS SP	MEAN HT SP	BIOMASS SP	#VSTEMS SE	MEAN HT SE	BIOMASS SE	#STEMS SM	MEAN HT SM	BIOMASS SM	#STEMS LN	MEAN HT LN	BIOMASS LN	#STEMS SPERGM	MEAN HT SPERGM	BIOMASS SPERGM	#STEMS OVASC	MEAN HT OVASC	BIOMASS OVASC
0		0	0		0.000	0		0.000	0		0.000	0		0.000	0		0.000
0		0	0		0.000	0		0.000	0		0.000	0		0.000	0		0.000
0		0	0		0.000	0		0.000	0		0.000	0		0.000	0		0.000
0		0	0		0.000	0		0.000	0		0.000	0		0.000	0		0.000
0		0	0		0.000	0		0.000	0		0.000	0		0.000	0		0.000
0		0	51	19.00	3.451	0		0.000	0		0.000	0		0.000	0		0.000
0		0	59	13.70	1.838	0		0.000	2	22.50	0.854	0		0.000	0		0.000
0		0	47	10.00	0.946	0		0.000	0		0.000	0		0.000	0		0.000
14	19.20	5.003	72	17.50	3.131	0		0.000	0		0.000	0		0.000	0		0.000
0		0.000	53	9.20	1.518	0		0.000	0		0.000	0		0.000	0		0.000
52	36.10	59.454	91	21.00	5.185	8	15.75	0.384	2	8.00	0.123	3	13.00	0.073	0		0.000
7	34.90	69.106	2	7.50	0.039	0		0.000	0		0.000	0		0.000	0		0.000
0	24.40	10.729	17	7.70	0.220	18	12.90	1.252	3	9.00	0.232	3	4.67	0.042	0		0.000
1	37.10	53.005	14	16.90	0.860	0		0.000	0		0.000	0		0.000	0		0.000
9	33.80	83.235	6	16.00	0.223	0		0.000	0		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.000	0		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	110	19.35	9.633	3	13.80	0.167	0.000		0.000	6	10.00	0.167	0		0.000
0		0.000	144	16.20	7.644	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	94	15.80	8.836	0		0.00	0.000		0.000	13	10.00	0.265	0		0.000
0		0.000	97	15.50	5.711	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	128	24.10	15.123	0		0.00	0.000		0.000	0		0.000	0		0.000
2	40.20	58.543	22	13.00	0.320	0		0.00	0.000		0.000	0		0.000	0		0.000
54	39.90	43.710	9	13.30	0.316	0		0.00	0.000		0.000	0		0.000	0		0.000
45	48.00	50.398	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
24	32.90	16.323	0		0.000	0		0.00	0.000		0.000	33	9.40	0.602	17	25.400	5.201
72	40.80	60.952	4	9.75	0.121	3	14.00	0.155	0.000		0.000	0		0.000	0		0.000
0		0.000	0.000		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	0.000		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	0.000		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	0.000		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	0.000		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0	0.000		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	0.000		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	3	9.70	0.087	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
0		0.000	12	12.70	0.665	0		0.000	0.000		0.000	0		0.000	0		0.000
0	46.13	7.758	0		0.000	0		0.000	0.000		0.000	0		0.000	0		0.000
8	30.80	38.207	17	18.50	0.726	0		0.000	0.000		0.000	0		0.000	0		0.000
3	36.20	20.905	2	28.00	1.426	6	31.70	5.437	0.000		0.000	0		0.000	0		0.000
53	28.20	27.057	4	13.80	0.641	0		0.000	0.000		0.000	0		0.000	0		0.000
19	40.10	94.201	7	11.90	0.496	1	36.00	0.207	0.000		0.000	4	12	0.088	1	39.00	0.626

UNH-PNS MARSH DATA

#RSTEMS SP	MEAN HT SP	BIOMASS SP	#VSTEMS SE	MEAN HT SE	BIOMASS SE	#STEMS SM	MEAN HT SM	BIOMASS SM	#STEMS LN	MEAN HT LN	BIOMASS LN	#STEMS SPERGM	MEAN HT SPERGM	BIOMASS SPERGM	#STEMS OVASC	MEAN HT OVASC	BIOMASS OVASC
0		0.000	0	0.00	0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0	0.00	0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0	0.00	0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0	0.00	0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0	0.00	0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
17	19.00	31.345	13	17.10	0.497	0		0.00	0.000		0.000	0		0.000	0		0.000
8	30.80	38.207	17	18.50	0.726	0		0.00	0.000		0.000	0		0.000	0		0.000
5	30.90	36.872	49	22.60	1.796	0		0.00	0.000		0.000	0		0.000	0		0.000
12	29.30	43.110	17	13.70	0.252	0		0.00	0.000		0.000	0		0.000	0		0.000
35	33.80	42.346	17	18.50	0.596	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
69	24.10	36.273	1	6.00	0.020	0		0.00	0.000		0.000	0		0.000	0		0.000
15	24.70	9.242	0	0.00	0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
87	25.10	20.401	7	15.60	0.486	0		0.00	0.000		0.000	0		0.000	0		0.000
13	37.10	49.768	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
5	37.20	46.649	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
1	29.55	2.479	1		0.022	0		0.00	0.000		0.000	0		0.000	0		0.000
0		0.000	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
0	27.40	52.140	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
4	36.50	19.998	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
1	30.00	26.980	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
1	30.10	28.322	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000
4	34.15	40.055	0		0.000	0		0.00	0.000		0.000	0		0.000	0		0.000

UNH-PNS MARSH DATA

#STEMS OALGAE	MEAN HT OALGAE	BIOMASS OALGAE	#STEMS AN	MEAN HT AN	BIOMASS AN	#STEMS FV	MEAN HT FV	BIOMASS FV	#STEMS ALLALGAE	BIOMASS ALLALGAE	#STEMS OV (w/o S)	BIOMASS OV (w/o S)	#STEMS ALLV	BIOMASS ALLV	#STEMS TOTALM	BIOMASS TOTALM	AMPHIPOD
0		0.000	76	19.30	65.607	1	9.00	0.337	77	65.944	0	0.000	76	81.200	153	147.144	1
0		0.000	97	17.40	110.494	1	12.00	0.783	98	111.277	0	0.000	43	74.700	141	185.977	3
0		0.000	51	16.60	10.076	17	5.90	2.057	68	12.133	0	0.000	74	45.700	142	57.833	0
6	3.67	1.486	25	17.40	39.128	12	15.30	10.046	43	50.66	0	0.000	98	64.300	141	114.960	2
0		0.000	3	4.00	0.150	12	6.30	1.260	15	1.41	0	0.000	50	39.200	65	40.610	1
0		0.000	1	10.00	0.089	0		0.000	1	0.089	51	3.451	169	36.402	170	36.491	1
0		0.000	1	11.00	0.088	2	10.00	0.469	3	0.557	61	2.692	193	28.430	196	28.987	1
0		0.000	0		0.000	0		0.000	0	0	47	0.946	237	15.192	237	15.192	0
0		0.000	0		0.000	0		0.000	0	0	72	3.131	344	51.662	344	51.662	1
0		0.000	0		0.000	1	12.00	0.831	1	0.831	53	1.518	146	16.836	147	17.667	0
0		0.000	0		0.000	0		0.000	0	0	104	5.765	1840	47.050	1840	47.050	0
0		0.000	0		0.000	0		0.000	0	0	2	0.039	572	67.978	572	67.978	0
0		0.000	0		0.000	0		0.000	0	0	41	1.746	274	26.366	274	26.366	0
0		0.000	0		0.000	0		0.000	0	0	14	0.860	812	72.450	812	72.450	0
0		0.000	1	7.00	0.092	0		0.000	1	0.092	6	0.223	1268	34.246	1269	34.338	0
0		0.000	231	13.30	17.009	11	5.70	0.593	242	17.602	0	0.000	44	86.500	286	104.102	0
0		0.000	7	7.70	0.665	14	9.40	3.015	21	3.68	0	0.000	27	67.500	48	71.180	1
0		0.000	5	8.00	0.283	12	7.50	1.811	17	2.094	0	0.000	38	45.300	55	47.394	3
0		0.000	158	15.00	14.921	0		0.000	158	14.921	0	0.000	111	50.100	269	65.021	2
0		0.000	0		0.000	0		0.000	0	0	0	0.000	124	39.100	124	39.100	6
0		0.000	0		0.000	0		0.000	0	0	119	9.967	425	48.590	425	48.590	25
0		0.000	0		0.000	1	4.50	0.059	1	0.059	144	7.644	561	34.588	562	34.647	0
0		0.000	0		0.000	0		0.000	0	0	107	9.101	508	36.037	508	36.037	25
0		0.000	0		0.000	0		0.000	0	0	97	5.711	405	26.022	405	26.022	0
0		0.000	0		0.000	0		0.000	0	0	128	15.123	310	59.846	310	59.846	8
0		0.000	0		0.000	0		0.000	0	0	22	0.320	568	40.840	568	40.840	1
0		0.000	9	13.30	0.316	0		0.000	9	0.316	9	0.316	352	40.532	361	40.848	15
0		0.000	12	18.40	1.259	0		0.000	12	1.259	0	0.000	326	48.000	338	49.259	12
0		0.000	36	24.50	8.194	0		0.000	36	8.194	50	5.803	225	38.703	261	46.897	6
0		0.000	0		0.000	0		0.000	0	0	7	0.276	557	41.197	557	41.197	8
0		0.000	56	29.20	45.997	3	7.00	0.508	59	46.505	0	0.000	14	72.800	73	119.305	1
0		0.000	2	9.00	0.661	3	6.70	1.126	5	1.787	0	0.000	37	54.900	42	56.687	1
0		0.000	18	17.60	11.011	17	21.70	30.189	35	41.2	0	0.000	50	60.100	85	101.300	0
0		0.000	43	20.60	95.512	1	10.00	0.685	44	96.197	0	0.000	59	40.900	103	137.097	3
0		0.000	41	20.40	69.456	17	26.50	45.387	58	114.843	0	0.000	71	51.400	129	166.243	1
0		0.000	0		0.000	0		0.000	0	0	0	0.000	115	25.600	115	25.600	0
0		0.000	11	10.20	7.406	3	5.00	0.279	14	7.685	0	0.000	54	46.600	68	54.285	0
1	1.00	0.307	0		3.555	0		0.887	1	4.749	3	0.087	128	31.574	129	36.323	0
0		0.000	3	9.70	1.812	3	7.70	0.432	6	2.244	0	0.000	77	28.800	83	31.044	0
0		0.000	209	14.20	21.160	0		0.000	209	21.16	12	0.665	78	26.130	287	47.290	0
0		0.000	0		0.000	0		0.000	0	0	0	0.000	84	46.130	84	46.130	0
0		0.000	0		0.000	0		0.000	0	0	17	0.726	186	56.852	186	56.852	0
0		0.000	0		0.000	0		0.000	0	0	8	6.863	199	44.489	199	44.489	1
0		0.000	9	10.20	7.703	7	7.70	0.986	16	8.689	4	0.641	368	58.482	384	67.171	0
0		0.000	0		0.000	0		0.000	0	0	13	1.417	565	42.013	565	42.013	9

UNH-PNS MARSH DATA

#STEMS OALGAE	MEAN HT OALGAE	BIOMASS OALGAE	#STEMS AN	MEAN HT AN	BIOMASS AN	#STEMS FV	MEAN HT FV	BIOMASS FV	#STEMS ALLALGAE	BIOMASS ALLALGAE	#STEMS OV (w/o S)	BIOMASS OV (w/o S)	#STEMS ALLV	BIOMASS ALLV	#STEMS TOTALM	BIOMASS TOTALM	AMPHIPOD
0		0.000	698	13.10	88.905	18	10.70	3.001	716	91.906	0	0.000	45	15.700	761	107.606	3
0		0.000	269	24.70	48.750	27	17.90	9.122	296	57.872	0	0.000	32	38.900	328	96.772	0
0		0.000	608	12.50	38.328	12	5.20	0.175	620	38.503	0	0.000	38	42.900	658	81.403	30
0		0.000	522	19.60	82.357	29	14.60	1.225	551	83.582	0	0.000	53	34.700	604	118.282	0
0		0.000	388	17.50	36.609	131	18.80	10.170	519	46.779	0	0.000	35	33.300	554	80.079	2
0		0.000	0		0.000	0		0.000	0	0	13	0.497	121	24.994	121	24.994	0
0		0.000	0		0.000	0		0.000	0	0	17	0.726	186	56.852	186	56.852	0
0		0.000	0		0.000	0		0.000	0	0	49	1.796	242	69.392	242	69.392	8
0		0.000	0		0.000	3	10.00	0.961	3	0.961	17	0.252	245	29.804	248	30.765	0
0		0.000	0		0.000	0		0.000	0	0	17	0.596	221	34.992	221	34.992	7
0		0.000	43	30.50	146.933	0		0.000	43	146.933	0	0.000	23	81.600	66	228.533	3
0		0.000	427	23.10	107.840	12	13.50	2.528	439	110.368	0	0.000	20	91.500	459	201.868	1
0		0.000	283	22.40	58.865	2	9.50	0.089	285	58.954	0	0.000	13	53.700	298	112.654	6
0		0.000	713	19.80	103.024	0		0.000	713	103.024	0	0.000	27	58.300	740	161.324	2
0		0.000	24	10.00	1.947	0		0.000	24	1.947	0	0.000	11	119.700	35	121.647	0
0		0.000	9	14.10	34.031	0		0.000	9	34.031	0	0.000	102	57.500	111	91.531	3
0		0.000	0		0.000	0		0.000	0	0	0	0.000	33	84.200	33	84.200	1
0		0.000	0		0.000	0		0.000	0	0	0	0.000	96	47.600	96	47.600	6
0		0.000	50	33.20	99.700	0		0.000	50	99.7	0	0.000	35	84.200	85	183.900	30
0		0.000	40	12.90	47.080	0		0.000	40	47.08	0	0.000	45	62.000	85	109.080	1
0		0.000	0		0.000	0		0.000	0	0	1	0.020	931	54.940	931	54.940	1
0		0.000	0		0.000	0		0.000	0	0	0	0.000	304	53.300	304	53.300	0
0		0.000	0		0.000	0		0.000	0	0	7	0.486	207	41.772	207	41.772	9
0		0.000	0		0.000	0		0.000	0	0	0	0.000	470	37.100	470	37.100	7
0		0.000	0		0.000	0		0.000	0	0	0	0.000	286	37.200	286	37.200	2
0		0.000	97	20.50	63.163	71	14.50	8.560	168	71.723	0	0.000	43	69.600	211	141.323	9
0		0.000	226	18.70	55.364	41	19.00	9.251	267	64.615	0	0.000	34	69.800	301	134.415	8
0		0.000	195	18.90	69.231	51	10.40	3.256	246	72.487	0	0.000	32	76.050	278	148.537	11
0		0.000	7	9.00	3.327	12	10.00	9.444	19	12.771	0	0.000	41	93.800	60	106.571	1
0		0.000	7	10.00	1.280	19	11.50	2.410	26	3.69	0	0.000	24	83.700	50	87.390	1
0		0.000	0		0.000	0		0.000	0	0	0	0.000	69	35.300	69	35.300	12
0		0.000	0		0.000	0		0.000	0	0	0	0.000	96	41.200	96	41.200	11
0		0.000	0		0.000	6	12.00	1.068	6	1.068	0	0.000	161	41.000	167	42.068	20
0		0.000	0		0.000	0		0.000	0	0	1	0.022	168	65.194	168	65.194	12
0		0.000	0		0.000	0		0.000	0	0	0	0.000	91	39.500	91	39.500	3
0		0.000	0		0.000	0		0.000	0	0	0	0.000	1129	27.400	1129	27.400	2
0		0.000	0		0.000	0		0.000	0	0	0	0.000	396	36.500	396	36.500	6
0		0.000	0		0.000	0		0.000	0	0	0	0.000	337	30.000	337	30.000	6
0		0.000	0		0.000	1	3.50	0.033	1	0.033	0	0.000	446	30.100	447	30.133	2
0		0.000	0		0.000	0		0.000	0	0	0	0.000	661	34.150	661	34.150	1

UNH-PNS MARSH DATA

ISOPOD	Gcrab	BARNACLE	SPIDER	*Anurida*	ANT	BEETLE	Lo	Ll (live)	Ll (dead)	Mb	Lv	Gd	Me (live)	Me (dead)	# TAXA	Molluscs	Crustaceans	MarA	S/I	L/D	Ll
0	1	0	0	P	0	0	1	5	2	0	0	0	0	0	6	6	2	8	0	2.5	
0	1	0	1	0	0	0	0	0	5	0	0	0	0	0	3	0	4	4	1	0	
0	0	6	0	0	0	0	0	3	2	0	0	0	0	2	2	3	6	9	0	1.5	
0	3	0	0	P	0	0	0	16	8	0	0	0	0	36	4	16	5	21	0	2	
0	0	0	0	0	0	0	0	0	6	0	0	0	0	4	1	0	1	1	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	1	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	10	
0	0	0	0	0	0	0	0	9	5	0	0	0	0	4	1	9	0	9	0	1.8	
0	0	20	0	0	0	0	0	6	20	0	0	0	0	2	3	6	21	27	0	0.3	
0	0	30	0	P	0	0	0	16	50	0	0	0	0	4	4	16	33	49	0	0.32	
0	0	60	0	0	0	0	0	4	20	0	0	0	1	0	4	5	62	67	0	0.2	
0	0	2	0	0	0	0	0	26	19	0	0	0	0	1	3	26	8	34	0	1.368	
0	0	0	1	0	0	0	0	0	4	0	0	0	0	2	3	0	25	25	1	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	25	25	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
0	0	0	0	0	0	0	0	0	8	0	0	0	0	30	1	0	8	8	0	0	
0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	2	0	1	1	0	0	
0	0	0	1	0	6	0	0	0	0	0	0	0	0	0	4	0	15	15	7		
0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	12	12	0	0	
0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	3	0	6	6	3		
0	0	0	0	0	1	1	0	0	3	0	0	0	0	2	3	0	8	8	2	0	
0	0	50	0	0	0	0	0	7	1	0	0	0	0	0	4	7	51	58	0	7	
0	1	16	0	0	0	0	0	18	3	0	0	0	0	1	4	18	18	36	0	6	
0	0	50	0	0	0	0	0	13	5	0	0	0	0	0	3	13	50	63	0	2.6	
0	1	0	0	0	0	0	0	5	10	0	0	0	0	0	4	5	4	9	0	0.5	
0	3	0	0	0	0	0	0	13	17	0	0	0	0	0	4	13	4	17	0	0.765	
0	0	0	0	1	0	0	0	6	3	0	0	0	0	0	3	6	0	6	0	2	
0	0	0	0	1	0	0	0	10	8	0	0	0	0	0	3	10	0	10	0	1.25	
0	1	4	1	1	0	0	0	11	0	0	0	0	0	0	6	11	5	16	1	10	
0	0	2	0	0	0	0	0	6	1	0	0	0	0	0	3	6	2	8	0	6	
0	1	0	0	0	0	0	0	9	3	0	0	0	0	0	3	9	1	10	0	3	
0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	1	0	1	1	0	0	
0	0	0	1	0	0	0	0	5	13	0	0	0	0	0	3	5	0	5	1	0.385	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	9	9	0		

UNH-PNS MARSH DATA

ISOPOD	Gcrab	BARNACLE	SPIDER	*Anurida*	ANT	BEETLE	Lo	Ll (live)	Ll (dead)	Mb	Lv	Gd	Me (live)	Me (dead)	# TAXA	Molluscs	Crustaceans	MarA	S/I	L/D	Ll
0	2	0	0	0	0	0	0	1	1	0	0	1	0	0	5	2	5	7	0		1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	1	0	0	0	0	0	0	2	16	0	0	0	0	0	4	2	31	33	0		0.125
0	4	0	0	0	0	0	1	7	19	0	0	0	0	0	4	8	4	12	0		0.368
0	0	30	0	0	0	0	0	16	7	0	0	0	0	0	4	16	32	48	0		2.286
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	1	0	0	0	0	1	2	0	1	0	0	0	5	2	8	10	1		0.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	0	0	0	50	0	0	0	0	6	0	1	0	0	0	4	1	7	8	0		0
0	4	2	0	0	0	0	0	28	2	0	0	0	2	0	5	30	9	39	0		14
0	1	0	0	0	0	0	1	9	1	0	0	0	0	0	5	10	2	12	0		9
0	1	0	0	0	0	0	0	6	2	0	0	0	0	0	4	6	7	13	0		3
0	1	0	0	0	0	0	1	6	1	0	0	0	0	0	5	7	3	10	0		6
0	0	0	1	0	0	0	0	4	0	0	0	0	0	0	3	4	0	4	1		10
0	0	0	1	0	0	0	0	1	4	0	0	0	0	0	4	1	3	4	1		0.25
0	0	0	0	0	0	0	0	9	2	0	0	0	0	0	2	9	1	10	0		4.5
0	0	0	0	0	0	0	0	4	6	0	0	0	0	0	3	4	6	10	0		0.667
0	1	0	0	1	0	0	0	10	3	0	0	0	0	0	4	10	31	41	0		3.333
0	1	0	0	0	0	0	0	10	3	0	0	0	0	0	3	10	2	12	0		3.333
0	0	0	6	0	0	0	0	0	4	0	0	0	0	0	3	0	1	1	6		0
0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2		
0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	3	1	9	10	0		0.5
0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	3	2	7	9	0		0
0	0	0	0	0	0	0	0		0	0	0	0	0	0	2	0	2	2	0		
1	0	0	0	3	0	0	0	4	2	0	0	0	0	0	4	4	10	14	0		2
0	3	0	1	0	0	0	0	5	0	0	0	0	0	0	4	5	11	16	1		10
0	2	0	1	0	0	0	0	15	9	0	0	0	0	0	4	15	13	28	1		1.667
0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	2	17	1	18	0		10
0	0	0	0 P		0	0	0	14	0	0	0	0	0	0	3	14	1	15	0		10
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	1	12	13	0		10
0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	4	2	11	13	2		10
0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	3	4	20	24	0		4
0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	2	9	12	21	0		10
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	1	3	4	0		10
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	2	2	1		
0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	2	0	6	6	3		
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	6	6	1		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2	0		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0		

Variable Descriptions For Salt Marsh Sediment Data

VARIABLE	VARIABLE DESCRIPTION
MARSH	Code for Salt Marsh (CIPR, CICC, JIBC, BGBC, BNBC, SILH, AVSC, BIYR)
COM	Salt Marsh Community (SAT, SAS or SPN)
TRANS	Transect Within Marsh
EPA ID #	Indentification Number Assigned to Sample
% Moist	Percentage of Soil Moisture on a wet weight basis
% LOI	Percentage of Organic Matter as loss on combustion (LOI)
%GSM	Percentage of Gravel, Sand, and Mud
%SSC	Percentage of Silt, Sand, and Mud
MEAN	Average grain size in Phi units
SORT	Variation in grain size (Sorting)
SKEW	Skewness of grain size distribution
KURT	Kurtosis of grain size distribution

Salt Marsh Sediment Data

MARSH	COM	TRANS	EPA ID #	% Moist	% LOI	%GSM	%SSC	MEAN	SORT	SKEW	KURT
CIPR	SAT	T1	112571	63.27	17.26	59/12/29		-0.03	4.56	0.58	0.67
CIPR	SAT	T1	112572	73.75	34.05						
CIPR	SAT	T2	112573	73.09	31.64						
CIPR	SAT	T2	112574	70.69	28.9						
CIPR	SAT	T2	112575	24.92	3.18						
CIPR	SAS	T3	112576	65.13	31.32	0/29/71	29/48/23	5.95	2.52	0.65	0.99
CIPR	SAS	T3	112577	71.77	39.54						
CIPR	SAS	T3	112578	72.44	43.02						
CIPR	SAS	T3	112579	73.87	52.33						
CIPR	SAS	T3	112580	68.92	29.76						
CIPR	SP	T4	112581	55.24	21.07	18/30/52		3.67	4.4	-0.03	1.34
CIPR	SP	T4	112582	67.12	31.54						
CIPR	SP	T4	112583	47.24	11.1						
CIPR	SP	T4	112584	70.18	37.9						
CIPR	SP	T4	112585	65.11	27.67						
CICC	SAT	T1	112586	69.4	33.05	66/25/9		-1.55	3.42	0.56	0.88
CICC	SAT	T1	112587	31.3	2.96						
CICC	SAT	T1	112588	56.42	15.3						
CICC	SAT	T1	112589	48.58	10.93						
CICC	SAT	T6	112590	26.95	2.8						
CICC	SAS	T2	112591	47.66	11.22	19/43/38		2.87	4.13	0.19	0.94
CICC	SAS	T2	112592	69.5	25.9						
CICC	SAS	T3	112593	50.98	11.03						
CICC	SAS	T4	112594	63.05	20.8						
CICC	SAS	T4	112595	58.96	14.13						
CICC	SP	T5	112596	65.82	27.69	39/48/13		0.4	3.18	-0.1	0.8
CICC	SP	T5	112597	26.76	3.73						
CICC	SP	T5	112598	61.49	19.47						
CICC	SP	T5	112599	52.25	9.58						
CICC	SP	T7	112600	42.38	8.22						
JIBC	SAT	T1	112601	61.08	18.42	11/57/32		2.6	3.05	0.24	1.03
JIBC	SAT	T1	112602	35.32	5.66						
JIBC	SAT	T1	112603	59.12	16.04						
JIBC	SAT	T1	112604	70.64	33.25						
JIBC	SAT	T1	112605	67.48	28.99						
BGBC	SAT	T1	112606	66.24	17.79	23/19/58		3.7	5.26	-0.11	0.91
BGBC	SAT	T1	112607	65.61	22.48						
BGBC	SAT	T1	112608	64.86	24.77						
BGBC	SAT	T1	112609	65.74	17.74						
BGBC	SAT	T1	112610	62.64	13.37						
BGBC	SP	T2	112611	18.82	2.08	48/22/30		0.97	3.86	0.25	0.53
BGBC	SP	T2	112612	48.18	9.14						
BGBC	SP	T2	112613	59.82	12.43						
BGBC	SP	T2	112614	60.12	19.04						
BGBC	SP	T2	112615	51.17	13.58						
SILH	SAT	T1	112616	72.12	37.23	0/0/100	0/45/55	8.78	2.74	0.17	0.77
SILH	SAT	T1	112617	70.57	29.7						
SILH	SAT	T1	112618	74.75	39.54						
SILH	SAT	T1	112619	71.81	36.15						
SILH	SAT	T1	112620	73.03	35.67						
SILH	SP	T2	112621	74.39	45.16	0/18/82	18/48/34	6.97	3.36	0.1	1.16
SILH	SP	T2	112622	75.19	45.31						
SILH	SP	T2	112623	80.86	44.85						
SILH	SP	T2	112624	78.05	55.68						
SILH	SP	T2	112625	71.09	32.14						
BNBC	SAT	T1	112626	32.26	5.6	3/59/38	62/24/14	3.77	3.3	0.59	1.11
BNBC	SAT	T1	112627	73.18	31.04						
BNBC	SAT	T1	112628	69.33	28.8						
BNBC	SAT	T1	112629	70.46	25.29						
BNBC	SAT	T1	112630	75.96	46.57						

UNH-PNS SED DATA

MARSH	COM	TRANS	EPA ID #	% Moist	% LOI	%GSM	%SSC	MEAN	SORT	SKEW	KURT
AVSC	SAT	T1	112631	79.47	31.19	0/9/91	9/43/48	8.2	3.19	0.16	0.74
AVSC	SAT	T1	112632	75.75	27.03						
AVSC	SAT	T1	112633	77.53	29.91						
AVSC	SAT	T1	112634	76.06	17.59						
AVSC	SAT	T1	112635	78.07	28.81						
AVSC	SP	T2	112636	80.86	57.32	0/1/99	1/45/54	8.68	2.89	0.16	0.72
AVSC	SP	T2	112637	82.41	51.91						
AVSC	SP	T2	112638	76.49	41.73						
AVSC	SP	T2	112639	78.43	31.12						
AVSC	SP	T2	112640	79.11	45.54						
BIYR	SAT	T1	112641	72.58	36.68	0/21/79	21/54/25	6.18	3	0.5	1.06
BIYR	SAT	T1	112642	61.29	21.94						
BIYR	SAT	T1	112643	66.65	23.3						
BIYR	SAT	T1	112644	69.09	21.42						
BIYR	SAT	T1	112645	67.65	19.64						
BIYR	SAS	T2	112646	71.59	31.71	0/19/81	19/55/26	6.1	2.53	0.23	0.95
BIYR	SAS	T2	112647	69.05	26.67						
BIYR	SAS	T2	112648	63.57	18.44						
BIYR	SAS	T2	112649	69.91	33.31						
BIYR	SAS	T2	112650	68.63	21.04						
BIYR	SP	T3	112651	75.44	44.09	0/3/97	3/60/37	7.47	2.88	0.44	0.78
BIYR	SP	T3	112652	73.84	30.47						
BIYR	SP	T3	112653	74.89	47.17						
BIYR	SP	T3	112654	76.86	44.52						
BIYR	SP	T3	112655	76.62	47.46						