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WETLAND STUDY REPORT
FOR THE
NEW BEDFORD SUPERFUND SITE

FINAL REPORT

JUNE, 1988

Prepared For:

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New England Division, Corps of Engineers
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DEPARTMENT OF THE ARMY

DATE: 10 AUGUST 1988

TO: Distribution

FROM: Mark J. Otis
Chief, New Bedford Superfund Project Office

SUBJ: Wetland Assessment
Final IEP Contract Report

Although most of our activity is focused on the Pilot Study, work on the Wetland Study continues and is progressing into a final detailed report. One criterion that the alternatives will be assessed against is compliance with the various Wetland Protection Regulations. The use of both the IEP and SES contractor reports should be limited to the raw data. The opinions and analyses are not necessarily reflective of the New England Division. The New England Division will shortly release a final draft report incorporating the work completed to date on the Acushnet River Estuary Wetlands.

Enclosed is the Final IEP Contract Report. If you have any questions or comments please contact Russ Bellmer or myself at (617) 647-8274.

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1.0 INTRODUCTION

1.1 REPORT OBJECTIVES

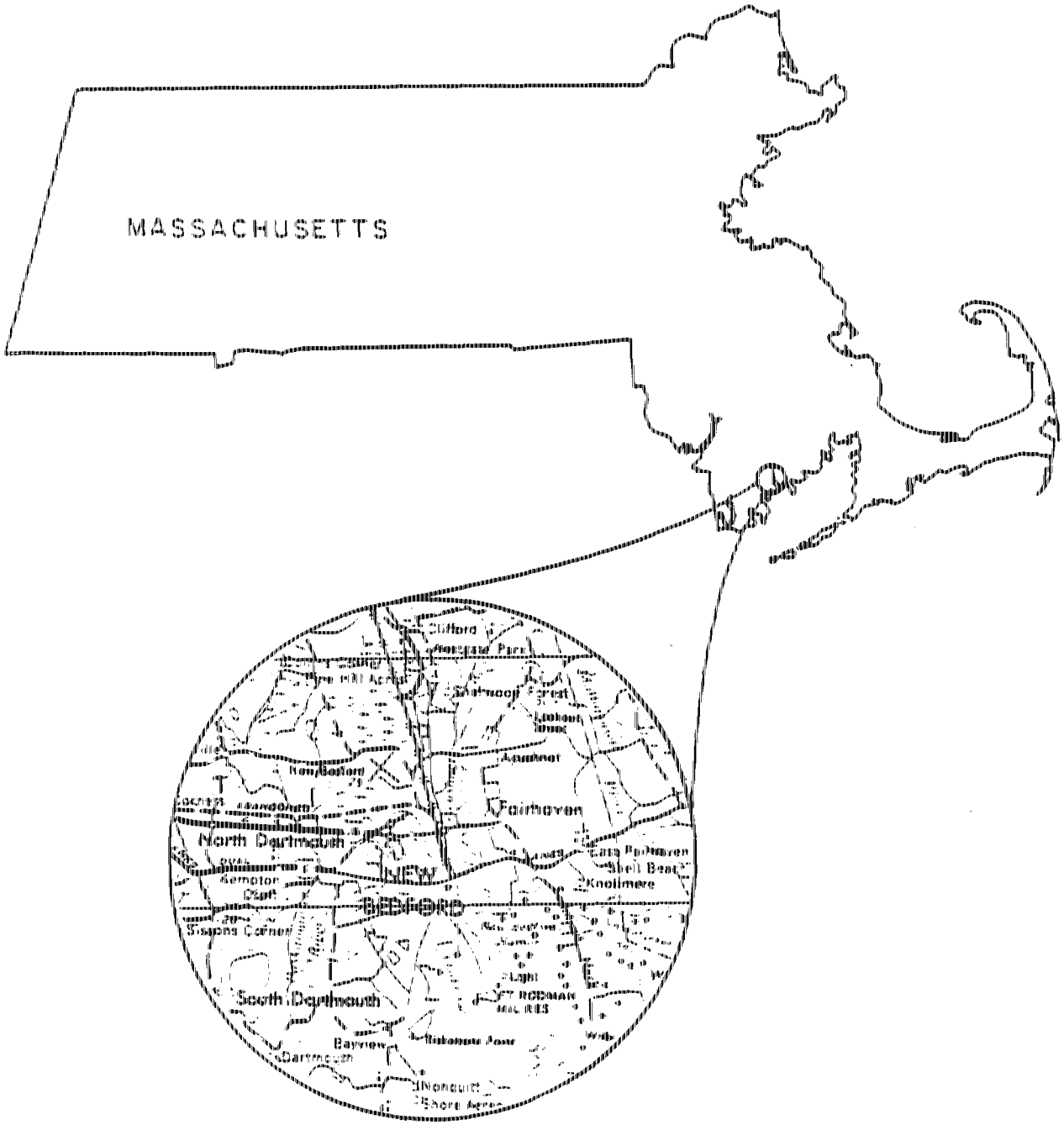
IEP, Inc. has been directed by the U.S. Army Corps of Engineers, New England Division (NED), under Contract DACW33-87-D-0001, and Delivery Order No. 0001 to perform environmental analyses and prepare a wetland study report for the Acushnet River estuary, New Bedford Harbor, Massachusetts (Figure 1-1). The Corps of Engineers is preparing this report to provide technical assistance to the U.S. Environmental Protection Agency for the New Bedford Harbor Superfund Project. The study to concentrate on assessing the present biological conditions of the project area wetlands, their functions and values, contaminant availability, and the effects of contamination on the wetlands. The information gathered would expand upon and complement information collected in previous studies of the Acushnet Estuary wetlands prepared by Sanford Ecological Services. The primary purpose of both studies is to analyze the characteristics of the wetlands relative to alternatives for isolating contaminated sediments of New Bedford harbor. These sediments contain extremely high levels of polychlorinated biphenyls (PCB's) and heavy metals, e.g., copper, chromium, lead and zinc. As part of the current study, IEP was directed to determine existing conditions in order to: (1) assess the overall biological value of the Acushnet Estuary wetlands; (2) compare the Acushnet Estuary wetlands to unpolluted wetlands; (3) provide information on the comparative value of the various Acushnet estuary wetlands; (4) provide information on pollutant export from the wetlands; and (5) provide information to determine potential biological impacts and mitigation measures relative to contaminated sediment isolation alternatives.

1.2 AFFECTED ENVIRONMENT

1.2.1 Location and Setting of Project Area

The Acushnet River estuary is part of the Buzzards Bay coastal drainage area and is one of a series of estuaries and bays along the southern coast of Massachusetts. Although the Acushnet River arises roughly 10 miles north of Buzzards Bay, its estuarine portion is limited to the southern-most four miles below the Tarklin Hill Road/North Main Street crossing. The mouth of the River forms New Bedford Harbor at the confluence with Buzzards Bay. The study area for this project encompasses the entire estuary, and includes portions of the communities of New Bedford, Fairhaven, and Acushnet (Figure 1-2).

North of the Coggeshall Street Bridge, the estuarine Acushnet River is typically less than 1,000 feet wide and covers approximately 220 acres (90 hectacres) of open water/mud flat habitat (NUS 1984). The main channel of the River has a maximum depth of 18 feet (at mean low water) near the Coggeshall Street Bridge, with depths decreasing to six feet, one mile north of the Bridge and to one to two feet at the head of the estuary (NUS 1984). More than one mile of the eastern side of the upper estuary is bordered by a salt marsh community; with an average width of more than 300 feet, this salt marsh comprises more than 45 acres and is the largest vegetated wetland area in the



SCALE:
1" = 2083'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

REGIONAL LOCUS OF
STUDY AREA

JANUARY 1988 FILE No. NECIV-1

FIGURE 1-1

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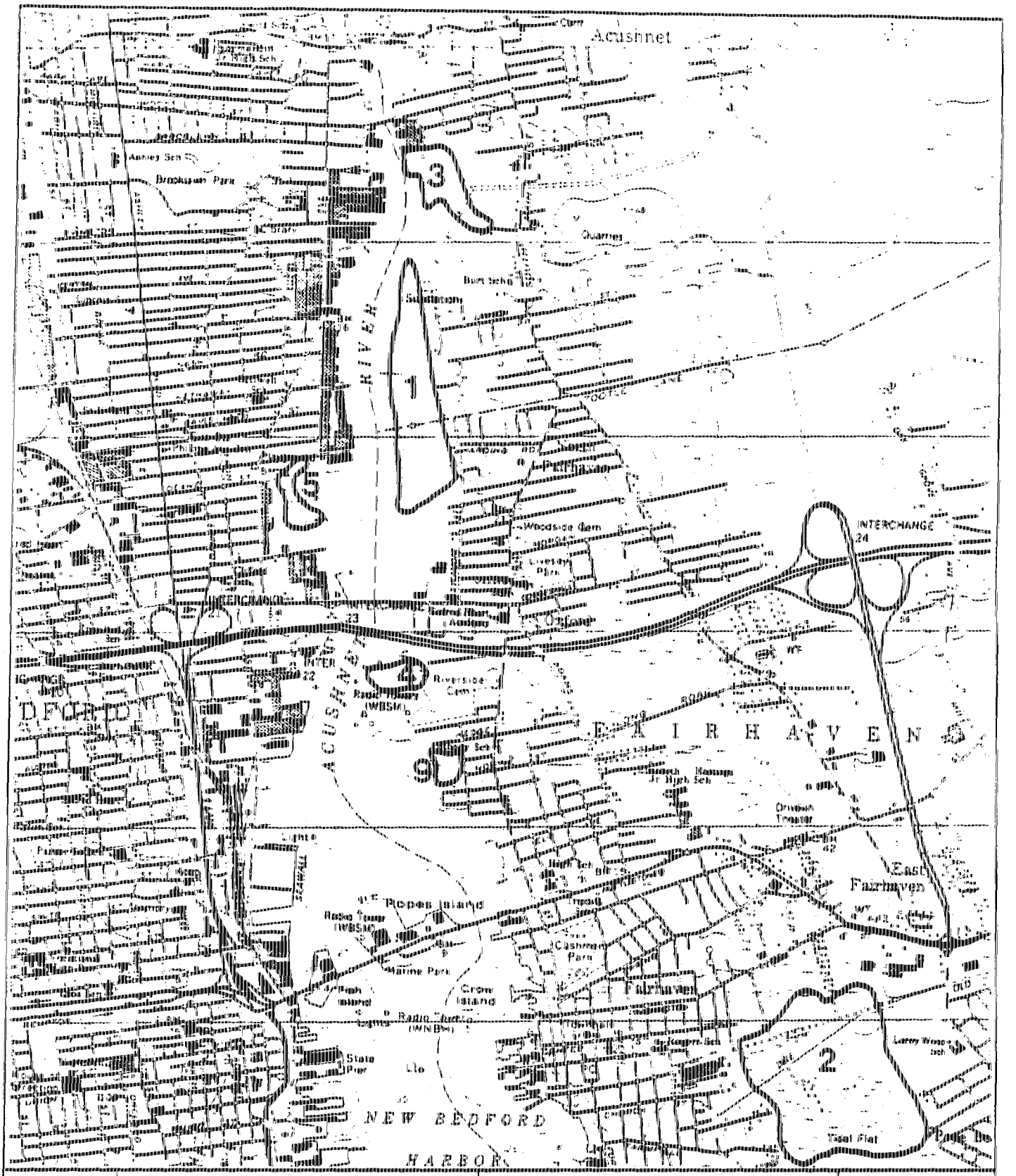


SCALE: 1" = 2150'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

PROJECT AREA AND LOCATION OF WETLAND STUDY SITES

JANUARY 1988 FILE No. NECIV-1

FIGURE 1-2

IEP inc

estuary. For the purposes of this project, this salt marsh and its adjacent mud flats have been separated into two study areas (Wetlands No.1 and 3). Smaller areas of fringing salt marsh occur at three other locations within the estuary, one (Wetland No.5) along the west shore within a prominent cove, and two (Wetlands No.4 and 9) on the east shore south of the Route 195 bridge (Figure 1-2).

These salt marsh areas were the focus of this study; investigations were conducted to examine selected characteristics of the sediments, water chemistry, hydrology, benthic fauna, fisheries, vegetation, and wildlife within these salt marshes. In addition, one salt marsh (Wetland No.2) 3,000 feet east of Acushnet River estuary was selected to receive similar analysis for the purpose of providing comparative data (Figure 1-2).

1.2.2 Environmental Contamination

Previous investigations have documented that the upper estuary, north of the Coggeshall Street Bridge, is severely contaminated with PCB's and heavy metals (NUS 1984, SES 1987). The area of PCB contamination extends from the northern end of the Acushnet estuary to Clark's Point in Buzzards Bay, a distance of over 6 miles (SES 1987). Both PCB and metal concentrations appear to be highest in the upper estuary, apparently as a result of its proximity to industrial discharges over many years. Elevated levels of heavy metals appear to be more widespread through Buzzards Bay than does PCB contamination, however. The present study, along with the recent SES (1987) study, focuses only on defining the extent of PCB and heavy metal contamination within the wetland communities and not the River itself.

1.3 DESCRIPTION OF PROJECT ALTERNATIVES

1.3.1 Cleanup Alternatives

Methods being considered for cleanup of the upper estuary involve either removing the contaminated sediment with a dredge or capping it in place with a layer of clean material. Work would be performed during the spring, summer, and fall; no work is expected to occur in December, January and February.

Dredging Options

The top two feet of sediment in areas below elevation +4.0 Mean Low Water (MLW) is considered to be contaminated. A hydraulic dredge will be used to remove this material. Dredges of this type operate on the principal of the centrifugal water pump. A vacuum is created on the intake side of the pump and atmospheric pressure acts to force water and sediments through the suction pipe. The dredged materials are then hydraulically pumped via pipeline to the disposal site in a slurry consisting of 10 to 40% solids. Two disposal methods are being considered and they are described below.

Confined Disposal Facilities (CDF) Alternatives: Several of these facilities would be constructed to contain the 600,000 cubic yards of contaminated sediment. Their location is shown on Figure 1-3. These sites are currently intertidal and subtidal areas.

The CDF is a large detention pond. A dike is constructed around the perimeter of the site and the dredged material slurry is then pumped into the facility. Within the site the solid material is allowed to settle out and the excess water is drained off the site, treated and released back into the harbor with the contaminants removed. The dike is built out of granular material and has a top elevation of approximately +12' MLW. The contaminated sediments will fill these areas to approximately +8' MLW. Several methods of treating the sediment are being evaluated. The contaminants will either be destroyed or immobilized such that there will be no release of contaminants from these CDF's. After the material has dried out and been treated it will be capped with several feet of clean sediment. This operation will result in the loss of tidal area at the site of the CDF's and the deepening of the upper estuary by approximately two feet.

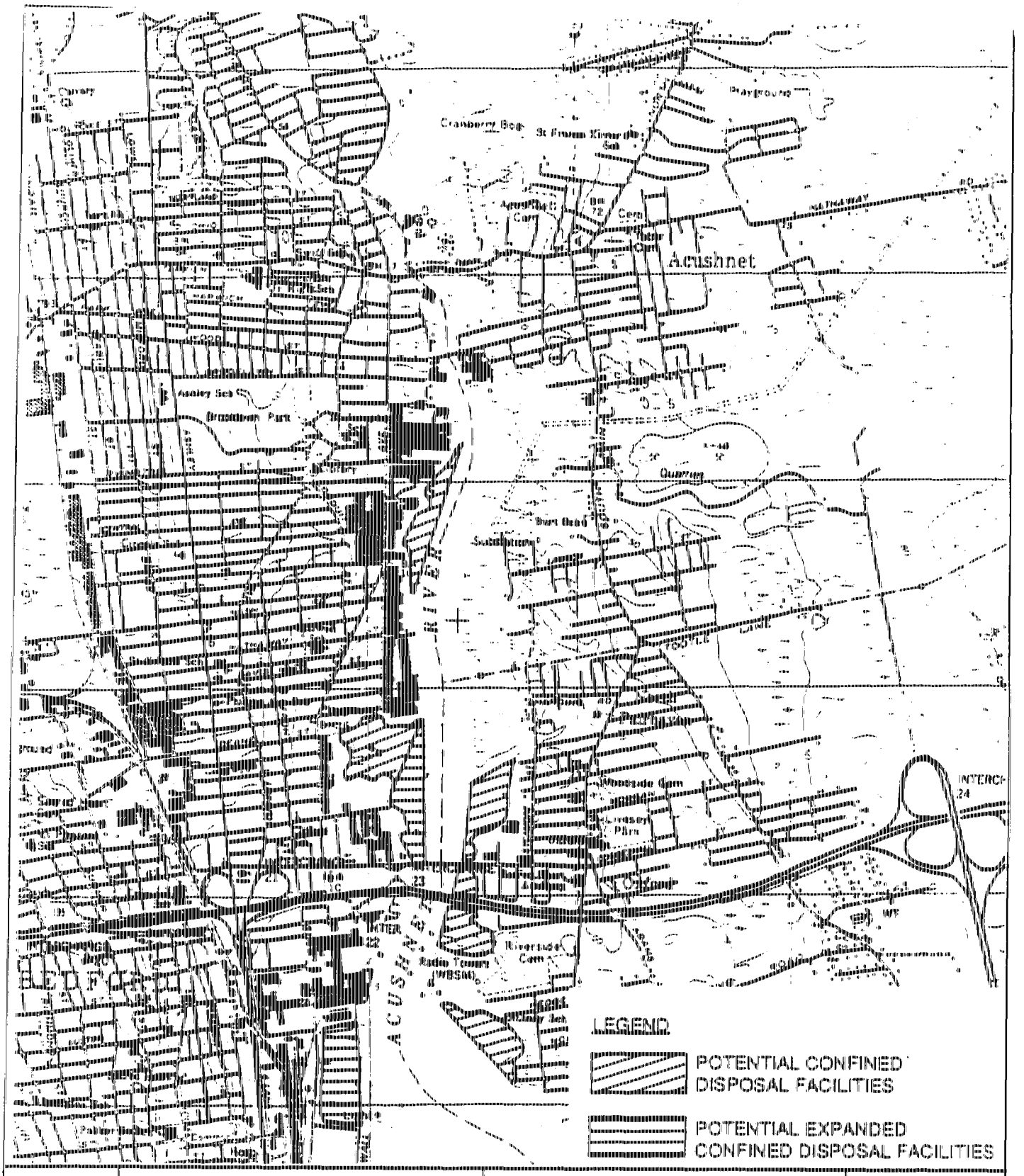
Confined Aquatic Disposal (CAD) Alternatives: This disposal method involves placing the contaminated sediment in pits or cells excavated in the upper estuary and then capping these cells with a layer of clean sediment.

The sequence of this operation involves initially removing contaminated sediment from an area and placing the material in a CDF. This area would then be deepened creating the pit or cell with this clean dredged material also being placed in a CDF. The dredging operation then moves to an adjacent area with the contaminated sediment being placed in the bottom of the cell and then capped with clean sediment which is produced during the excavation of the second cell. This operation continues until all contaminated sediment has been removed. These CAD cells will not be constructed in the main river channel where currents are strong enough to resuspend sediment. They will be constructed in coves and areas along the shoreline. The general areas where CAD cells may be located is shown in Figure 1-4. These areas may be expanded to other non-channel locations if additional capacity is needed to store contaminated material. This disposal method will deepen the main channel in the upper estuary by approximately two feet but will leave depths in other areas essentially unchanged. The number of CDF's will also be reduced.

Capping Option

This alternative requires that the freshwater flows of the Acushnet River be carried through the Upper Estuary. A double embankment channel about 80 feet wide will be constructed over the entire length of the upper estuary as shown on Figures 1-5 and 1-6.

Contaminated sediment in the area of the channel and embankments would be covered by a sand layer. The channel would be covered with rip rap and would be bordered by two 8-foot high embankments constructed out of a glacial till core, a layer of filter fabric and a cover of rip rap. The contaminated



SCALE: 1" = 2083'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

CONFINED DISPOSAL FACILITIES

JANUARY 1988 FILE No. NECIV-1

FIGURE 1-3

IP inc

SCALE: 1" = 2083'

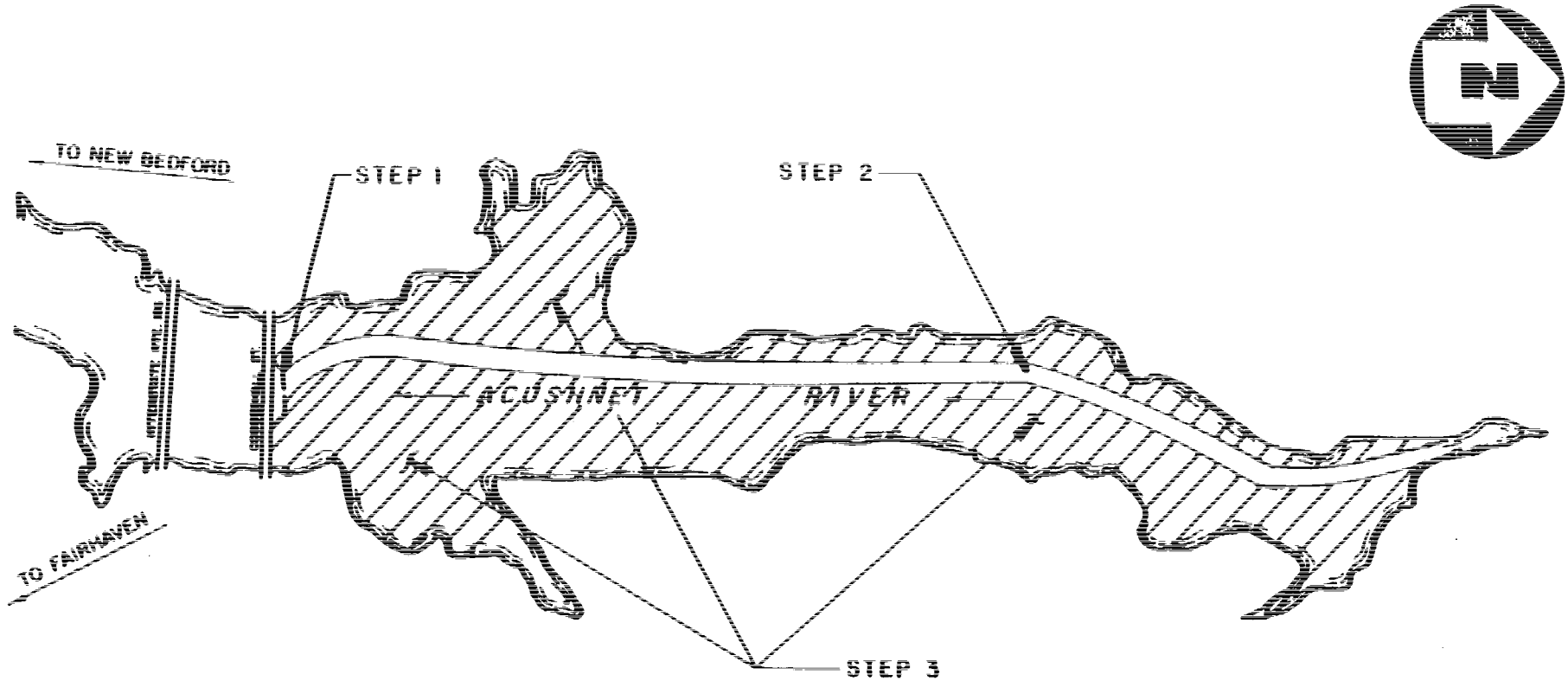
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

CONFINED
AQUATIC DISPOSAL
FACILITIES

JANUARY 1988 FILE No. NECIV-1

FIGURE 1-4

IEP inc



STEP 1- INSTALL SEDIMENT DISPERSAL CONTROL.

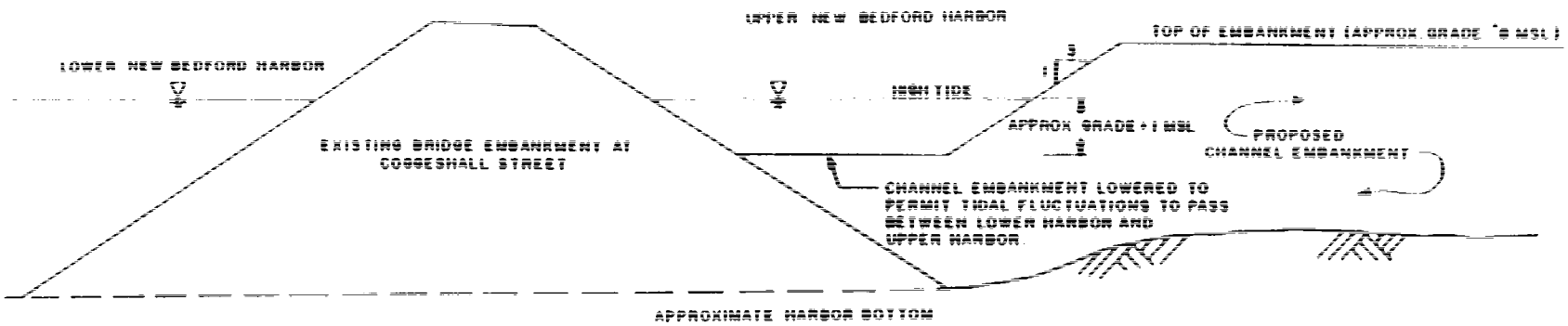
STEP 2- CONSTRUCT DOUBLE EMBANKMENT CHANNEL (APPROXIMATE ALIGNMENT INDICATED).

STEP 3- CAP SEDIMENTS.

0 1000 2000

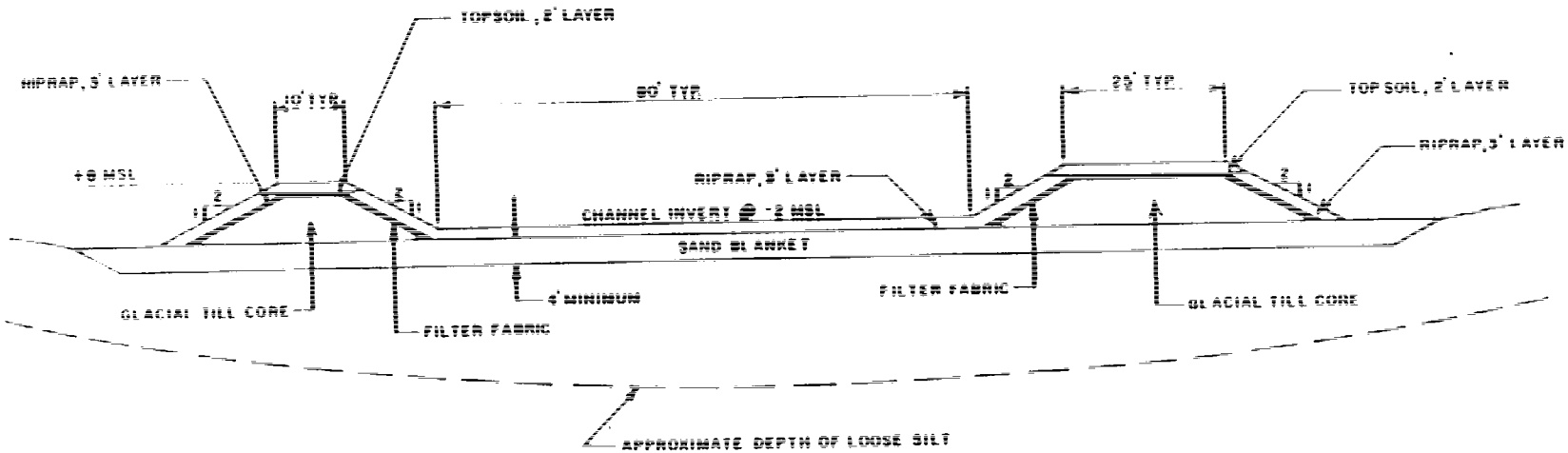
SCALE IN FEET

Figure 1-5. PLAN VIEW OF HARBOR ILLUSTRATING HYDRAULIC CONTROL ALTERNATIVE NEW BEDFORD SITE, NEW BEDFORD, MA



CROSS SECTION
CHANNEL EMBANKMENT AT THE COGGESHALL STREET BRIDGE
NEW BEDFORD HARBOR SITE, NEW BEDFORD, MA

NOT TO SCALE



TYPICAL CROSS-SECTION
DOUBLE EMBANKMENT CHANNEL
NEW BEDFORD HARBOR SITE, NEW BEDFORD, MA

NOT TO SCALE

Figure I-6. TYPICAL CROSS SECTIONS FOR HYDRAULIC CONTROL ALTERNATIVE

sediments located on both sides of the channel would be covered with a 3 to 4 foot layer of clean sediments. Wetlands would not be directly removed or altered. Some tidal flooding would continue to occur but freshwater inflow would be eliminated.

At the southern end of the estuary, sufficient space would be provided between the Coggeshall Street Bridge and the end of the channel embankments to allow tidal flows to the upper estuary.

1.3.2 No Action

Under the no action alternative, existing levels of PCB and heavy metal contamination would be present for an extended period of time in the sediment, water, biota, and air of the Acushnet River Estuary. The migration of contaminants downstream, and the potential for exposing humans and other biotic communities to these contaminants via the food chain would not be eliminated in the near future. Over time some isolation of the contaminated sediments within the estuary would occur due to the deposition of cleaner sediments from the Acushnet River. A substantial amount of cleaner sediment (>9 cm) would have to be deposited before the contaminated sediments were out of the zone of biologically induced sediment mixing (bioturbation) (Whitlach 1982). Bioturbation has the potential to greatly modify the chemical properties of surficial sediments and to re-expose contaminated sediments to the soil/water interface (SES, 1987).

2.0 SEDIMENTS

2.1 SEDIMENT CORE LOCATIONS

Samples for the SES and IEP studies were taken from the New Bedford Estuary from locations shown in Figures 2-1 through 2-5. Samples from Wetland 1 were taken by the New England Division; Corps of Engineers, and described in the SES report. Wetland 1 and 2 samples are not described as being high marsh or low marsh, as are those sampled by IEP for wetlands 4,5,9. All sample locations are approximate as they were not surveyed for horizontal and vertical coordinates.

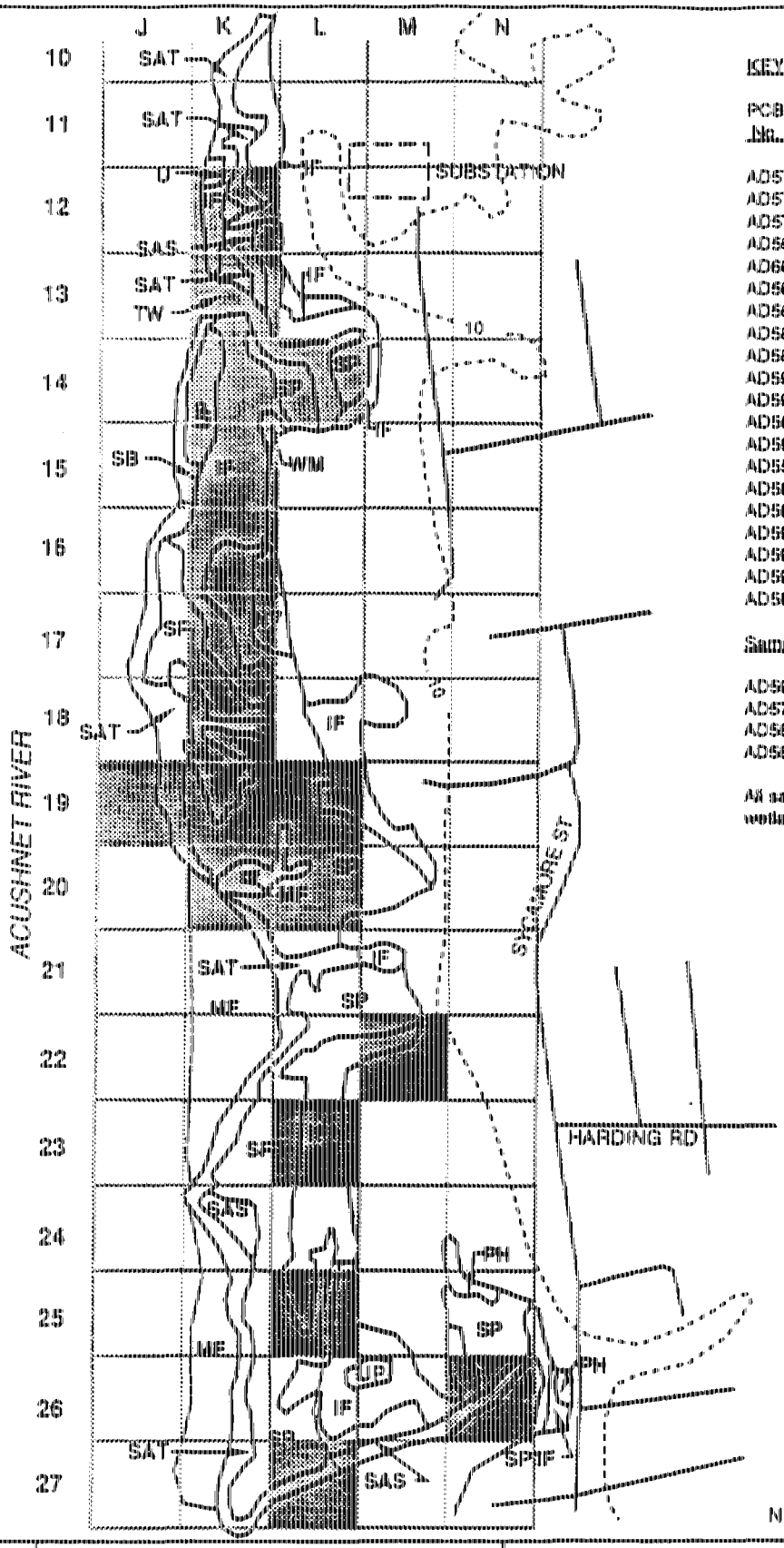
2.2 SEDIMENT COLLECTION METHODOLOGY

The sampling methodology used for Wetland 1 is described in Condike (1986). Wetland 2 was sampled at random using a grid for the placement of the seven samples. Soil cores were collected at two depths, 0-6 inches and 0-12 inches. Only the 0-6 inch deep core samples were analyzed. The upper layer of sediment was collected using a soil auger, and the samples were transferred to clean, teflon-lined glass containers. All samples were labeled and stored at approximately 4°C.

On September 3, 1987 sediment samples were obtained from wetland areas 4, 5 and 9. Within each wetland area three samples were obtained from vegetation mapped as high marsh and three samples from low marsh. Depths varied because of a SOW requirement and physical conditions on the site, i.e., depth of sediments. Six samples were obtained from each of the three wetland areas for a total of 18 samples. The locations of the sampling stations are presented on Figures 2-3 through 2-5. The depth from which the sediment samples were obtained was variable; however, all of the samples were obtained from the 0 to 1.0 foot depth interval. (See Table 6.1 for wetland community types delineated within the study area). The time of sampling, the depth from which each sample was obtained and a description of each sample are presented in Table 2.1.

Samples were obtained at each location using either a soil bucket auger or a trowel. The sampling equipment was decontaminated between each location by washing the equipment with River water, then rinsing the equipment with methanol and wiping the equipment with paper towels. The samples were containerized in 250 ml size glass jars having foil lined lids and then placed in a cooler. Upon return to IEP the samples were refrigerated for overnight storage. On September 4, 1987 the samples were refrigerated in a cooler and shipped under chain-of-custody to ENSECO laboratory.

During the process of placing the sample in the container an attempt was made to as much as possible exclude coarse gravel, stones, living root or stem tissue and large pieces of undecomposed organic material such as sticks from the sample.



KEY:

PCB No.	Inorganic No.	Grid Location
AD570	MAB764	J-19
AD579	MAB773	K-12
AD576	MAB770	K-13
AD592	MAB796	K-14
AD600	MAB794	K-16
AD590	MAB784	K-17
AD565	MAB759	K-18
AD589	MAB783	K-19
AD586	MAB780	K-20
AD595	MAB789	L-5
AD599	MAB793	L-20
AD562	MAB756	L-23
AD598	MAB792	L-25
AD559	MAB753	L-27
AD582	MAB776	M-5
AD567	MAB761	M-8
AD596	MAB790	M-26
AD594	MAB788	N-6
AD583	MAB787	N-7
AD585	MAB779	N-8

Samples with No PCB Data:

AD591	MAB785	K-15
AD573	MAB767	L-14
AD588	MAB782	L-19
AD568	MAB750	M-22

All samples taken from within wetland boundary.

NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 461'

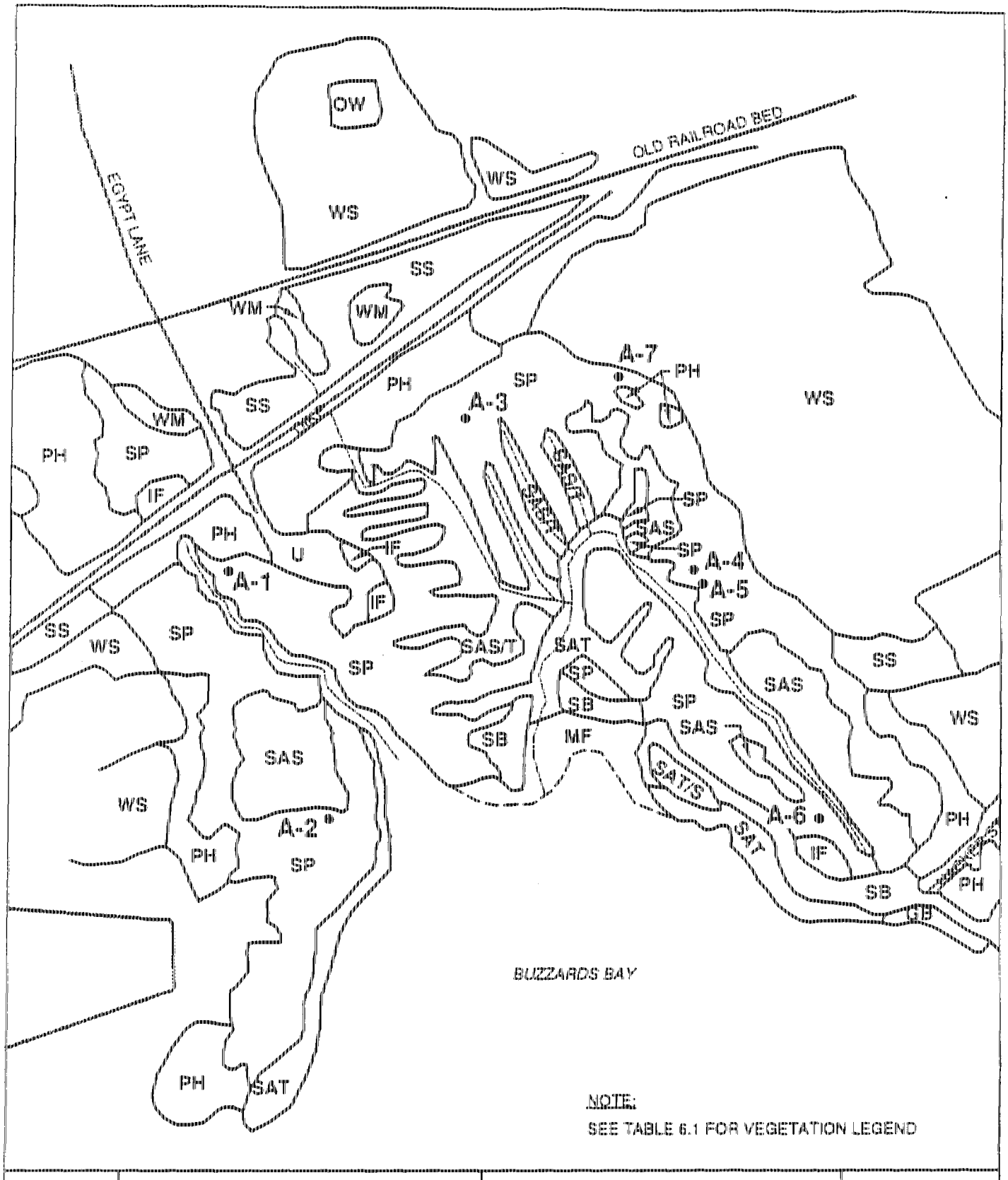
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

SAMPLE SEDIMENT SITES AT WETLAND STUDY AREA NO. 1
(APPROXIMATE)

JANUARY 1988 FILE No. NECIV-1

FIGURE 2-1

FEP inc



NOTE:
SEE TABLE 6.1 FOR VEGETATION LEGEND

SCALE:
1" = 400'

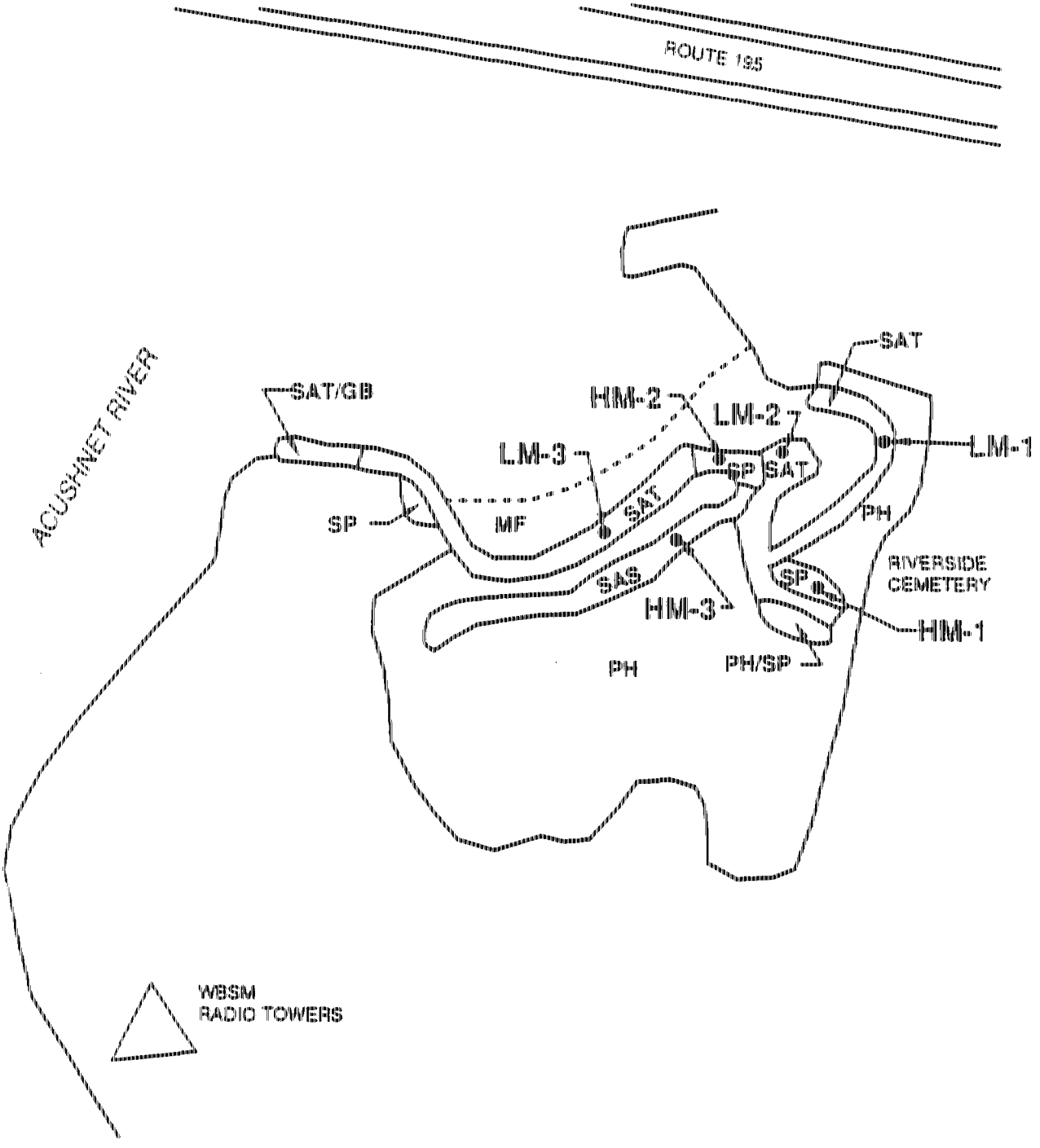
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

SEDIMENT SAMPLE SITES
AT WETLAND STUDY
AREA No. 2
(APPROXIMATE)

JANUARY 1988 FILE No. NECIV-1

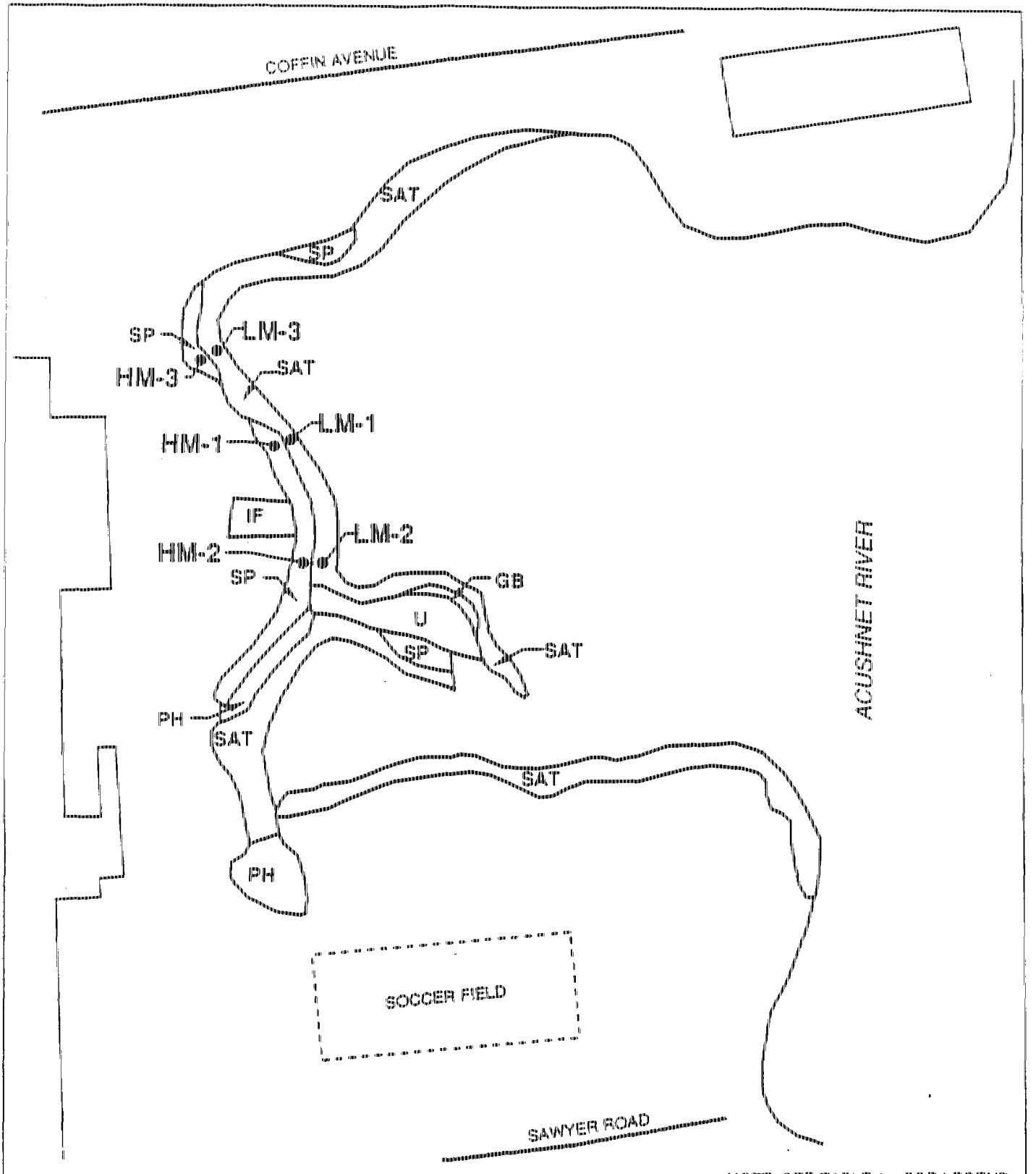
FIGURE 2-2

IEP Inc



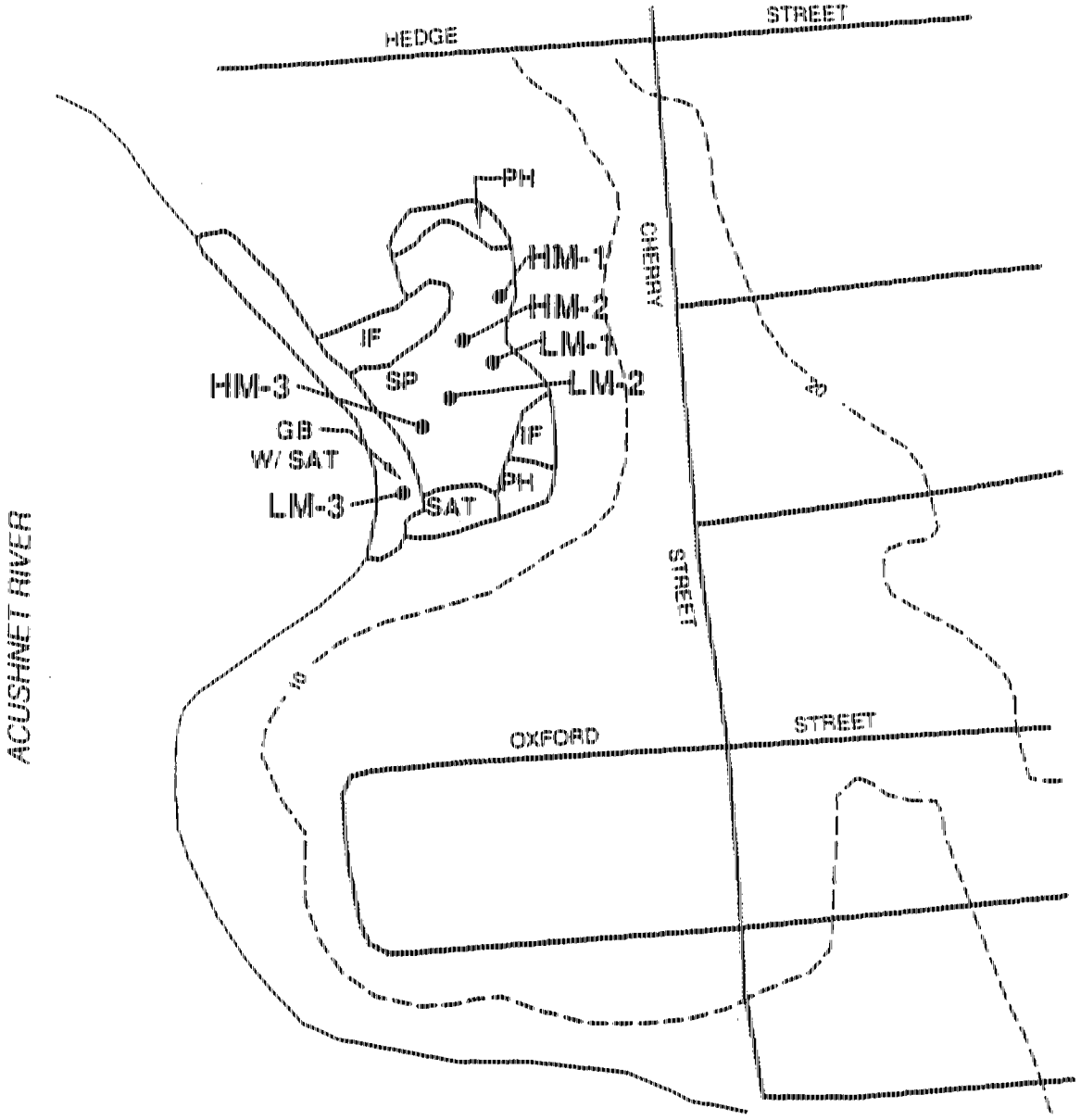
NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	SEDIMENT SAMPLE SITES AT WETLAND STUDY AREA No. 4 JANUARY 1988 FILE No. NECIV-1	FIGURE 2-3 EP inc



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	SEDIMENT SAMPLE SITES AT WETLAND STUDY AREA No. 5 JANUARY 1988 FILE No. NECIV-1	FIGURE 2-4 IEP inc



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	SEDIMENT SAMPLE SITES AT WETLAND STUDY AREA No. 9 JANUARY 1988 FILE No. NECIV-1	FIGURE 2-5 IEP inc

Table 2.1 Description of Sediment Samples, Wetlands 4, 5 & 9*

Location	Time	Depth (Ft.)	Description
AREA 4			
4-HM-1	1609	0.0 - 0.1	Surface scrape of muck from around stems and above root zone. Unvegetated pan area.
4-HM-2	1615	0.0 - 0.2	Surface scrape. Organic muck and detritus. Small unvegetated pan area.
4-HM-3	1630	0.3 - 0.5	No muck layer present. Sand/mineral sediment more/less from below the root zone.
4-LM-1	1545	0.0 - 0.8	Bucket auger used to obtain the sample from beneath 1.5 ft. of water. Muck and some mineral sediment/sand. In root zone.
4-LM-2	1620	0.0 - 0.5	Surface scrape of organic muck.
4-LM-3	1645	0.2 - 0.8	Organic muck and detritus from root zone.
AREA 5			
5-HM-1	1840	0.0 - 0.1	Surface scrape of muck and organic detritus collected from above the root zone.
5-HM-2	1855	0.0 - 0.05	Surface scrape of organic muck and sand. From above the root zone.
5-HM-3	1920	0.0 - 0.1	Mineral sediment/sand and muck.
5-LM-1	1845	0.0 - 0.5	Sample obtained using bucket auger from beneath 1 ft. of water in the River. Coarse sand and gravel having a black organic stain.
5-LM-2	1910	0.4 - 1.0	Organic muck and sand.
5-LM-3	1930	0.4 - 1.0	Organic muck.

* Samples obtained on September 3, 1987

AREA 9

9-HM-1	1726	0.0 - 1.0	Root zone. Detritus and organic muck. No mineral sediment/sand.
9-HM-2	1740	0.0 - 0.4	Detritus, organic muck, moderate roots.
9-HM-3	1800	0.1 - 0.4	Roots, detritus, organic muck.
9-LM-1	1730	0.0 - 0.8	Sample obtained using bucket auger in unvegetated ditch from under 1 ft. of water. Mixed organic mineral sediment with some roots.
9-LM-2	1750	0.0 - 0.8	Sample obtained using bucket auger in ditch from under 0.5 ft. of water. Mostly peat/detritus, organic muck and roots.
9-LM-3	1810	0.0 - 1.0	Sample obtained using bucket auger in River at ditch outlet. Primarily mineral sediment of coarse sand and gravel with a dark organic stain.

Low tides at 0840 EST and 2204 EST

2.3 SEDIMENT ANALYSIS

Samples taken from Wetland 1 and 2 were analyzed using EPA approved methods for copper, chromium, lead, zinc and PCB's. Samples taken from Wetlands 4,5, and 9 by IEP were analyzed for the same chemical parameters and for mercury and cadmium in accordance with current EPA methodology.

2.4 RESULTS

The SES data showed widespread elevated levels of chromium, copper, lead and zinc in wetland 1 (SES Wetland A and B) and Wetland 2 (SES Wetland E,F,G). It was suggested that these data indicate a distribution of metals which may be directly related to chronic disposal of metals in the upper portion of the Acushnet estuary, or may result from widespread distribution of metals from many localities throughout the region. Previous studies demonstrate a substantial PCB content in sediments throughout the upper estuary; approximately 346,000 cubic yards of sediment containing PCB concentrations greater than 50 ppm. An additional 874,000 cubic yards of sediment has concentrations of PCBs between 1-50 ppm. Portions of this contaminant reservoir in the sediment are potentially available for redistribution. The SES and IEP studies were targeted only at defining the PCB content and metals associated with the wetland sediments. The results of COE, SES and IEP sediment sampling efforts are presented in Table 2.1A.

In general, PCB concentrations from Wetland 1 ranged from 0.15-1,500 mg/kg. (SES, 1987). The gridded pattern of the PCB samples shows various potential hot spots of high PCB concentrations, although an accurate placement of the stations within the grids cannot be inferred from the SES report.

The PCB concentrations found in Wetland 2 samples were considerably less than those found in Wetland 1. The maximum concentration (4.1 mg/kg at A-1) location appears to be close to a tidal creek which may influence contaminant levels by allowing transport of PCB's and heavy metals into the wetland. In an apparent reversal of trends noticed in Wetland 1 where the higher levels of contamination were near or adjacent to open water and mudbanks, three sites with low concentrations are close to the open water or mudflats in Wetland 2. The lower PCB concentrations support the use of Wetland 2 as a reference wetland for the upper estuary wetlands.

Data from three contiguous grid stations in Wetland 1 (MAB764, MAB783, MAB782) were compared to determine if the position of the grid with respect to the open water influenced the concentration of metals and/or PCBs (Table 2.2). For metals, the placement of the station apparently did not (for this grid series) influence the trend of metals concentrations. The PCB concentrations

Table 2.1A. Heavy Metal and PCB Concentrations in Salt Marsh Sediments, New Bedford

Wetland(a)	Location(b)	Sample ID. No.	Cadmium(c)	Chromium(c)	Copper(c)	Lead(c)	Mercury(c)	Zinc(c)	Total PCB(d)
1	J-19	AD570/HAB764	*(f)	(j) 23.00	(j)108.00	60.00	*(f)	57.00	39.00
1	K-12	AD579/HAB773	*	(j) 53.00	(r)287.00	162.00	*	(j) 395.00	66.00
1	K-13	AD576/HAB770	*	(j)227.00	(j)557.00	435.00	*	(j) 508.00	1900.00
1	K-14	AD592/HAB786	*	(j) 59.00	(j)338.00	273.00	*	(j) 596.00	161.00
1	K-16	AD600/HAB794	*	5.00	23.00	(j) 15.00	*	298.00	1.53
1	K-17	AD590/HAB784	*	(j) 15.00	(j) 14.00	(j) 14.00	*	(j) 124.00	.15
1	K-18	AD665/HAB759	*	(j) 63.00	(j)172.00	165.00	*	136.00	5.80
1	K-19	AD589/HAB783	*	(j) 25.00	(j) 84.00	75.00	*	(j) 70.00	.69
1	K-20	AD586/HAB780	*	(j)111.00	(r)185.00	95.00	*	(j) 95.00	60.00
1	L-5	AD595/HAB789	*	(j) 46.00	(j)167.00	375.00	*	(j)1290.00	550.00
1	L-20	AD599/HAB793	*	20.00	128.00	(j)154.00	*	199.00	49.40
1	L-23	AD662/HAB756	*	(j)149.00	(j)483.00	275.00	*	92.00	67.00
1	L-25	AD598/HAB792	*	38.00	358.00	(j)316.00	*	79.00	1.50
1	L-27	AD559/HAB753	*	(j)116.00	(j)505.00	128.00	*	100.00	25.60
1	M-5	AD582/HAB776	*	(j) 41.00	(r)306.00	228.00	*	(j) 109.00	440.00
1	M-8	AD667/HAB761	*	(j) 14.00	(j) 76.00	72.00	*	102.00	16.00
1	M-26	AD596/HAB790	*	7.00	39.00	(j) 6.7	*	29.00	.24
1	N-6	AD594/HAB788	*	(j) 22.00	(j)119.00	153.00	*	(j) 79.00	6.81
1	N-7	AD593/HAB787	*	(j) 19.00	(j) 20.00	203.00	*	(j) 117.00	2.57
1	N-8	AD585/HAB779	*	(j)117.00	(r)333.00	227.00	*	(j) 391.00	500.00
1	K-15	AD591/HAB785	*	(j) 4.90	(j) 8.10	(j) 4.80	*	(j) 16.00	ND
1	L-14	AD573/HAB767	*	(j) 7.80	(j) 11.00	24.00	*	24.00	ND
1	L-19	AD588/HAB782	*	(j) 5.60	(r) 9.20	33.00	*	(j) 22.00	ND
1	M-22	AD556/HAB750	*	(j) 36.00	(r)155.00	167.00	*	45.00	ND
2	LM(g)	A-1	*	180.00	1400.00	360.00	*	800.00	4.1
2	HM	A-2	*	31.00	280.00	120.00	*	230.00	1.5
2	HM	A-3	*	63.00	270.00	120.00	*	160.00	1.6
2	HM	A-4	*	67.00	240.00	130.00	*	200.00	2.5
2	HM	A-5	*	24.00	60.00	45.00	*	57.00	1.6
2	LM	A-6	*	3.00	8.00	<5.00	*	26.00	BDL
2	HM	A-7	*	41.00	88.00	430.00	*	130.00	2.9

(Continued on Next Page)

Table 2.1A (Continued)

Wetland(a)	Location(b)	Sample ID. No.	Cadmium(c)	Chromium(c)	Copper(c)	Lead(c)	Mercury(c)	Zinc(c)	Total PCB(d)
4	HM	1	ND(e)	78.00	140.00	130.00	ND	160.00	14.00
4	HM	2	ND	220.00	410.00	300.00	ND	260.00	97.00
4	HM	3	ND	8.00	22.00	19.00	ND	16.00	0.40
4	LM	1	1.7	56.00	110.00	53.00	ND	130.00	10.00
4	LM	2	ND	74.00	160.00	70.00	ND	110.00	26.00
4	LM	3	ND	85.00	330.00	240.00	0.60	110.00	290.00
5	HM	1	ND	270.00	280.00	280.00	0.61	210.00	39.00
5	HM	2	ND	35.00	42.00	66.00	ND	91.00	7.20
5	HM	3	2.1	300.00	310.00	590.00	ND	380.00	50.00
5	LM	1	ND	9.00	7.40	ND	ND	36.00	1.00
5	LM	2	10	340.00	420.00	250.00	0.47	330.00	57.00
5	LM	3	32	540.00	1130.00	390.00	0.93	8780.00	410.00
9	HM	1	ND	54.00	220.00	430.00	0.70	440.00	0.58
9	HM	2	ND	220.00	550.00	370.00	ND	72.00	13.00
9	HM	3	ND	670.00	290.00	1060.00	ND	110.00	44.00
9	LM	1	2.0	130.00	420.00	250.00	0.41	210.00	45.00
9	LM	2	ND	30.00	70.00	42.00	ND	110.00	5.30
9	LM	3	ND	24.00	100.00	100.00	0.23	94.00	12-16.00

(a) See Figure 1.2
(b) HM = High Marsh; LM = Low Marsh
(c) Metal concentrations in mg/kg (dry wt)
(d) PCB concentrations in ug/g
(e) ND = Not detected
(f) * = Not measured in SES study
(j) Value recommended for estimation (see SES Appendix C)
(r) Value recommended for rejection (see SES Appendix C)
(g) HM and LM locations in Wetland 2 estimated by SES (5/20/88)

Table 2.2 Comparison of Metal and PCB Data from Three Contiguous Grid Stations in Wetland #1[1]

PARAMETER	J19 MAB764	K19 MAB783	L19 MAB782
Cr	23	5.6	25
Cu	108	9.2(r)	84
Pb	60	33	75
Zn	57	22	70
PCB	39	0.69	No Data

[1]Source: SES (1987)

decreased from the station most proximate to the open water (39 mg/kg at MAB764) to the next station (0.69 mg/kg at MAB7B3). No PCB data were available for the innermost grid station.

The IEP samples were taken in both high marsh and low marsh areas (see Section 2.2). As the determination of marsh is dependent upon plant species and not located or positioned with respect to open water, some high marsh areas were physically positioned close to open water, mud banks or tidal creeks. All low marsh areas were proximate to open water, mud banks or tidal creeks or ditches.

For each of the IEP-sampled high and low marsh wetlands all parameters were compared and ranked from highest value to lowest. Qualitative site rankings were made based on summary rankings for the individual parameters (Tables 2.3, 2.4 and 2.5).

In Wetland 4, site LM-3 exhibited higher values for all metals except zinc, and was one of the few locations with detectable amounts of mercury (Table 2.3). Qualitatively, metal values at stations LM-1 and LM-2 were equivalent. Station LM-3 is physically closer to the mudflats and open water than are LM-1 and LM-2. In the high marsh areas, site HM-2 clearly had higher values for all detected metals. With all values one to two orders of magnitude greater than HM-3, the sample site with the least elevated chemical values. As for the low marsh, HM-2 is physically closer to mud flats and open water. PCB levels were highest at LM-3 at 290 mg/kg, followed by LM-2 and LM-1 at 26 and 10 mg/kg respectively. In the high marsh, HM-2, which also had the highest metal values, had PCB values of 97 mg/kg. HM-3, the site least exposed to mudflats and tidal waters, had the least PCB concentration at 0.4 mg/kg.

Identical qualitative rankings were performed for Wetlands 5 and 9. In the low marsh samples for Wetland 5, LM-2 and LM-3 exhibited qualitatively similar chemical values, with the exception of zinc which varied by an order of magnitude (Table 2.4). Values for samples taken from LM-1 were lower than LM-2 and LM-3 by one to two orders of magnitude. LM-1 was located in an area of the Wetland 5 cove which could possibly receive less particulate deposition due to reduced current circulation. Both LM-2 and LM-3 had detectable amounts of mercury and cadmium. In the high marsh samples, HM-3 and HM-1 showed qualitatively similar values for all metals except that mercury was detected in HM-1 and not in HM-3, and cadmium was detected in HM-3 and not in HM-1. PCB concentrations followed the same pattern as in Wetland 4. Both the low marsh and high marsh stations with highest metals also exhibited the highest PCB values: LM-3 at 410 mg/kg; HM-3 at 50 mg/kg.

In Wetland 9, metal values in LM-1 consistently exceeded those for LM-2 and LM-3 (Table 2.5). Cadmium and mercury were also detected at this station. LM-2 and LM-3 were qualitatively similar. LM-1 was located in a ditch, and values for chemical parameters for this site may be influenced by tidal sources. In the high marsh stations, high values for metals are distributed among all three stations, although HM-3 had the highest values for chromium and lead. No cadmium was detected at any high marsh station; mercury was

Table 2.3. Comparison and Qualitative Ranking of Metals and PCB Concentrations in Wetland #4

PARAMETER	HIGH MARSH			LOW MARSH		
	HM1	HM2	HM3	LM1	LM2	LM3
Cd	ND	ND	ND	1.7	ND	ND
rank						
Cr	78	220	8.0	56	74	85
rank	2	1	3	2	3	1
Cu	140	410	22	110	160	330
rank	2	1	3	3	2	1
Pb	130	300	19	53	70	240
rank	2	1	3	3	2	1
Hg	ND	ND	ND	ND	ND	0.6
rank						
Zn	160	260	16	130	110	110
rank	2	1	3	1	2	2
PCB	14	97	0.4	10	26	290
rank	2	1	3	3	2	1
OVERALL RANK	2	1	3	3	2	1

Note: All values are mg/kg.

Table 2.4. Comparison and Qualitative Ranking of Metals and PCB Concentrations in Wetlands #5

PARAMETER	HIGH MARSH			LOW MARSH		
	HM1	HM2	HM3	LM1	LM2	LM3
Cd	ND	ND	2.1	ND	10	32
rank					2	1
Cr	270	35	300	9	340	540
rank	2	3	1	3	2	1
Cu	280	42	310	7.4	420	1130
rank	2	3	1	3	2	1
Pb	280	66	590	ND	250	390
rank	2	3	1	--	2	1
Hg	0.61	ND	ND	ND	0.47	0.93
rank					2	1
Zn	210	91	380	36	330	8780
rank	2	3	1	3	2	1
PCB	39	7.2	50	1.0	57	410
rank	2	3	1	3	2	1
Overall Rank	2	3	1	3	2	1

Note: All values are mg/kg.

Table 2.5. Comparison and Qualitative Ranking of Metals and PCB Concentrations in Wetland #9

PARAMETER	HIGH MARSH			LOW MARSH		
	HM1	HM2	HM3	LM1	LM2	LM3
Cd	ND	ND	ND	2.0	ND	ND
rank						
Cr	54	220	670	130	30	24
rank	3	2	1	1	2	3
Cu	220	550	290	420	70	100
rank	3	1	2	1	3	2
Pb	430	370	1060	250	42	100
rank	3	2	1	1	3	2
Hg	0.70	ND	ND	0.41	ND	0.23
rank				1	3	2
Zn	440	72	110	210	110	94
rank	1	3	2	1	2	3
PCB	0.58	13	44	45	5.3	14/12/16
rank	3	2	1	1	3	2
Overall Rank	3	2	1	1	3	2

Note: All values are mg/kg.

detected at HM-1. PCB values for both low and high marsh stations continued the trend shown at Wetland 4 and 5, with high metal stations with high PCB content: LM-1 at 45 mg/kg; HM-3 at 44 mg/kg. Note that the highest PCB values for Wetland 9 is an order of magnitude less than the highest for Wetland 5.

A qualitative ranking between wetlands 4,5 and 9 was performed: the highest values for each site were compared and ranked (Table 2.6). For the low marsh areas, Wetland 5 ranked first with highest overall values for chromium, copper and zinc. In the high marsh, no single wetland exhibited consistent high metal rankings. For PCBs, the low marsh of Wetlands 5 and 4 were high (410 and 290 mg/kg respectively), although the high marsh of Wetland 4 had the highest PCB concentration at 97 mg/kg.

It is not possible to accurately compare metal values between Wetland 1 and 2 and the IEP wetlands, as the SES samples from Wetlands 1 and 2 were taken from a random grid pattern and were not designated as either low or high marsh. The grids were rather large in size, and apparently could have overlapped both high and low marsh wetlands, therefore any attempt to categorize the SES samples as being from low or high marsh could lead to judgmental errors. In order to determine if there was any similarity between Wetlands 1 and 5, qualitative ranking of metal values in Wetland 5 was performed using metal values from the southernmost 12 Wetland 1 sample grids (Table 2.7). The aggregated wetland represented by these 12 grids is physically close to Wetland 5 and north of the bridge: the assumption is that some (but not all) of the physical processes affecting the southern portion of Wetland 1 are similar to those affecting Wetland 5.

Metal content averages for all high and low marsh stations in Wetland 5 were higher than those in Wetland 1, especially for chromium and zinc. The average PCB content was higher in Wetland 5 than Wetland 1. Comparing the PCB data for the entire Wetland 1 with Wetland 5, the values are similar, and, with one single exception, lie within the same order of magnitude.

The combined SES/IEP data clearly support a general trend of decreasing concentrations of metals and PCBs from the upper estuary (Wetlands 1 and 5) south to Wetlands 4 and 9. In addition, there is a clear trend of decreasing concentration laterally into the marsh: stations close to mudflats or tidal waters have higher concentrations of metals and PCBs.

Previous studies (SES, 1987) have demonstrated that much of the metals and PCB contamination is tied to particulate matter in the Acushnet estuary which has been subjected to long term exposure to contaminated effluent from various activities. Although a previous study (Eisenriech, 1980) has indicated a net flow of contaminants south from the upper estuary to the lower portions, depending upon the mass of metals and PCBs released over time, a substantial residual mass of metals and PCBs exist in the sediments of the upper estuary. This large source of material makes potentially available a large mass of

Table 2.6. Comparison and Ranking of Highest Metals and PCB Concentrations at Wetlands 4, 5, and 9

PARAMETER	HIGH MARSH			LOW MARSH		
	#4	#5	#9	#4	#5	#9
Cd	ND	2.1	ND	ND	32	2.0
rank					1	2
Cr	220	300	670	85	540	130
rank	3	2	1	3	1	2
Cu	410	310	290	330	1130	420
rank	1	2	3	3	1	2
Pb	300	590	1060	240	390	250
rank	3	2	1	3	1	2
Hg	ND	ND	ND	0.6	0.93	0.41
rank				2	1	3
Zn	260	380	110	110	8780	210
rank	2	1	3	3	1	2
PCB	97	50	44	290	410	45
rank	1	2	3	2	1	3
Overall Rank	2	1	3	3	1	2

Note: All values are mg/kg.

Table 2.7. Comparison of IEP Wetland #5 Data to 12 Southern Stations of Wetland #1

STATION	Cr	Cu	Pb	Hg	Zn	PCB
K17 MAB784	15	14	14		124	0.15
K18 MAB759	63	172	165		136	5.8
J19 MAB764	23	108	60		57	39.0
K19 MAB783	25	84	75		70	0.69
L19 MAB782	5.6		33		22	0
K20 MAB780	111		95		95	60
L20 MAB793	20	128	154		199	49.4
M22 MAB750	36	155	167		45	0
L23 MAB756	149	483	275		92	67
L25 MAB792	38	358	316		79	1.5
M26 MAB790	7	39	6.7		29	.24
L27 MAB753	116	505	128		100	25.6
AVERAGE	50.7	204.6	124.0		87.3	20.8
HM1	270	280	280		210	39
HM2	35	42	66		91	7.2
HM3	300	310	590		380	50
HM4	9	7.4	ND		36	1.0
LM2	340	420	250		330	57
LM3	540	1130	390		8780	410
AVERAGE	244	364.9	315.2		1630	94.0

Note: All values are mg/kg.

contaminants for redistribution within the estuary by both natural events (Eisenriech, 1980) (estuarine circulation, nutrient cycling) and anthropogenic events (dredging, filling, wetland alteration). These events are similar to those described by Turk (1980) as being responsible for the redistribution of PCBs in the Hudson River.

The combined SES/IEP data show that distribution of PCB's within the entire estuary is likely influenced by estuarine circulation patterns. In all wetland data, the highest concentration of PCBs are found in low marsh stations, which are subjected to daily tidal and circulation patterns and depositional processes. High marsh areas generally have lower PCB concentrations than low marsh areas, with the exception of high marsh areas which are physically closer to the open water. Periodic inundation of the high marsh areas, especially those close to open water, provide these areas with replenishment of contaminants during high water events. Elevated marsh areas are therefore likely to exhibit PCB concentrations which are qualitatively proportional to their elevation and inundation frequency.

Wetlands 1 and 5 demonstrate similar levels of PCB which are probably a reflection of their distance from the original contamination sources and the circulation effects north of the bridge. The low marsh station at Wetland 4 had elevated levels of PCBs, comparable to those in Wetland 1 and 5. These levels are likely due to the Wetland 4 location immediately south of the bridges and its physical intrusion into the central portion of the traditional channel. The physical structure of the bridge pilings and associated appurtances could also affect circulation patterns immediately downstream, which, when combined with the intrusion of the site, could result in depositional patterns leading to increased PCB concentrations. Low marsh PCB concentrations in Wetland 9, which is more physically remote from the centerline of the traditional channel, are an order of magnitude less than those at Wetland 4. Though less than those at Wetland 4, Wetland 9 PCB concentrations are yet an order of magnitude higher than the reference Wetland 2.

There is no exact duplication of the PCB trends for metals. Metal contamination, as noted in the SES report, is widespread through the region. There is a weak upper to lower estuary trend in metals distribution, however there does not appear to be a qualitative difference between low and high marsh metal concentrations. The distribution patterns may result from both physical and biologically mediated processes which act both dependently or independently of each other. Metal contaminants may have been released from industrial activities into the estuary over a longer period of time, and in higher concentrations than PCBs. The sediment-metal reaction kinetics may be such that movement of metals from soluble aqueous forms in association with particulates differs from those for PCBs. Biologically mediated processes leading to the uptake of metals by the entire spectrum of biological systems may affect nutrient cycling rates in the water-mud-wetland system and the residence time within the various biological and physical resource sinks (Eisenreich et al. 1980).

In summary, given that the data from both the SES and IEP studies have limitations for extensive quantitative analyses, only qualitative statements can be made regarding the comparison of the two data sets. However, the qualitative statements are backed by recognizable trends in the concentrations of chemicals in the wetland systems. Further, the combination of the chemical data with typical physical estuarine processes, provides additional insight to the pattern of chemical distribution within the Acushnet estuary. The SES and IEP studies, show a pattern of chemical distribution likely mediated by: the frequency, duration and concentrations of previous contaminant releases; depositional patterns created by the geographic, hydrologic, and circulatory processes specific to the confines of the estuary; and anthropogenic activities such as wetlands alteration, dredging and filling, construction within the estuary, and upland activities which can influence downstream physical, chemical and biological processes.

3.0 SURFACE AND GROUND WATER

3.1 SURFACE WATER

3.1.1. Existing Information - Acushnet River Estuary

A large body of data has been collected on the hydrography, sediments and water quality of the Acushnet River estuary including the studies by Hoff (1973), Summerhayes, et al. (1977), USEPA (1983) and USACE-WES (1986).

The Acushnet River estuary is a shallow estuary characterized by a well defined channel and extensive shoals and tidal flats. Circulation ranges from weakly stratified (Pritchard, 1975) during period of high fresh-water discharge to vertically well mixed (Pritchard type - C estuary) at other times. Water movement in the estuary is constricted at three locations - the Coggeshall Street bridge, Popes Island and the hurricane barrier. Tidal forces control circulation within the estuary under average conditions, although winds, waves and freshwater discharge may dominate during extreme events.

Tides above Coggeshall Bridge are mixed to semi-diurnal with a mean tidal range of 3.8 feet and a spring tidal range of 4.7 feet. A phase difference of 30 minutes has been observed between the areas north and south of the Coggeshall Bridge and the area to the south of the bridge has a recorded tidal range of 3.7 feet, 0.1-foot lower than the tidal range to the north of the bridge (SES, 1987; NOAA, 1981). Tidal current velocities in the upper Acushnet River estuary are generally low, ranging from 0 to 1.2 feet/second with average velocities of approximately 0.4 feet/second (USACE, 1986). Current velocities at the Coggeshall Street Bridge are considerably higher due to the physical constriction at this point. Flow velocities range from 0 to 5.3 feet/second, with average velocities of approximately 1.1 feet/second. Flow through the bridge constriction behaves as uniform turbulent flow, producing a jet-like current with associated eddies. Summerhayes, et al. (1977) found that flood current velocities are generally higher than ebb current velocities in the Acushnet River Estuary.

Suspended sediment concentrations in the Acushnet River estuary were found to be generally low (less than 10 ppm) by Teeter (1987) and increased upstream forming a turbidity maximum in the upper harbor. The net flux of total suspended materials was found to be in an upstream direction, although contaminant transport was found to be in the opposite direction. Summerhayes, et al. (1977), found that, under average conditions, near-bottom concentrations of suspended sediments are generally highest, with peak concentrations occurring during flood tide. Due to the asymmetric current velocities, the silt and clay portions of the suspended load tend to fractionate, resulting in a net import of silt into the Acushnet River estuary and a net export of clay to Buzzards Bay.

Tidal flushing of the upper Acushnet River estuary is estimated at 1.4 tidal cycles or 18.2 hours, based on the Tidal Prism Method (SES, 1987). However, more detailed estimates of tidal flushing based on net flux through the Coggeshall Street Bridge may range from two days under winter conditions (high river discharge, prevailing northwest winds) to eight days under summer conditions (low river discharge, prevailing southwest winds), according to R. Geier, Woods Hole Oceanographic Institute (pers. comm.).

A large salinity data base has been collected by both the EPA and USACE centered primarily in the vicinity of the Coggeshall Street Bridge. Salinities at the bridge range from 10 to 32 0/00 with an average salinity of 30 0/00. The lowest salinity values, 10 0/00 were recorded following a heavy rainfall on ebb tide. To the north of the bridge, salinities range from 7 to 31 0/00 with average values of 30, 29 and 26 proceeding to the north. Vertical salinity gradients varied considerably, however, on average a gradient of only 1 0/00 was measured. The average horizontal salinity gradient between the most northerly sampling station and the bridge was 4 0/00. No existing salinity data exists for the creeks and ditches associated with the tidal marshes.

3.1.2. Existing Information - Acushnet River and other Tributaries

The Acushnet River is the main tributary to the Acushnet River estuary. Its mean annual discharge is estimated at 30 CFS by SES - this volume is only 1% of the average tidal prism (SES). The predicted 10-year low-flow discharge is less than 0.5 cfs; the 100-year flood is estimated at 1,350 cfs (SES, 1987). This low discharge reflects the small size of the drainage basin (9.3 km2). Additional sources of surface water discharge include numerous small streams, primarily located along the eastern side of the estuary. Combined discharge from these streams is estimated at 50,000 cubic feet per day in fall (SES, 1987).

3.1.3. Existing Information - Salt Marsh Surface Water

The salt marshes of the upper Acushnet River estuary consist almost entirely of high marsh communities with a total area of approximately 60 acres (Section 6.0). These marshes have been extensively ditched in the past. No water chemistry data is available for the ditches and pools of the salt marshes.

3.1.4 Salinity Data

In order to provide a more comprehensive understanding of the salinity gradients in and near the salt marshes of the upper Acushnet River estuary, salinity measurements were recorded in the marsh ditches and tidal creeks and in the shallow areas of the estuary adjacent to marshes 1 and 2. Salinity measurements were recorded through two full spring tide cycles (9 July 1987 and 11 September 1987) at 10 locations as indicated in Figure 3-1 . Salinity and temperatures were taken using a YSI Scientific SCT meter. Results are

SCALE: 1" = 2083'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

SALINITY, CONUCTIVITY & TEMPERATURE MEASUREMENT LOCATIONS

JANUARY 1988 FILE No. NECIV-1

FIGURE 3-1

IEP inc

tabulated in Tables 3.1 and 3.2. In general, the salinity data indicates lower salinities during ebb tide, both within the estuary and within the tidal creeks and ditches within the salt marsh. The lowest salinities (less than 15 ppt) were recorded in the brackish creek which discharges to Wetland 1.

3.2 GROUND WATER

The Acushnet River estuary is located in a bedrock valley composed of plutonic intrusive and metamorphic rocks of Proterozoic age (SES, 1987). These moderately deformed and highly faulted rocks are exposed in several areas within the Acushnet River drainage basin, including an abandoned stone quarry located adjacent to Wetland 2. A thin veneer of surficial glacial sediments up to 50 feet in thickness overlies this granitic/gneissic bedrock. These deposits are of Pleistocene age and include kame delta deposits, outwash deposits and till. The upland areas adjacent to the estuary are composed primarily of outwash and kame delta deposits consisting of medium to coarse sand and gravel. According to the USGS Hydrologic Atlas for this area, the salt marshes are underlain by tidal peats, silt and sand less than 30 inches in thickness, however, Soil Conservations Service mapping indicates that the tidal peats belong to the Pawcatuck series and may be thicker (10 to 51 inches deep). Sediments within the upper Acushnet River estuary consist primarily of fine, organic-rich muds. The intertidal zone is characterized by poorly-sorted sand and gravel along exposed shorelines and fine-grained silts and muds on tidal flats and in sheltered shorelines.

Ground-water flows towards the Acushnet River Estuary from both the east and the west, contained primarily within the surficial glacial deposits. The USGS Hydrographic Atlas for this region indicates that the deepest unconsolidated glacial deposits (25 to 50 feet thick) and, therefore, the deepest aquifers are located adjacent to the Acushnet River and estuary (Williams & Tasker, 1978). No public water supplies are located in these aquifers, nor are future public water supplies likely, due to potential salt-water intrusion problems. It is not known if private drinking water wells exist adjacent to the Upper Acushnet River estuary, however, most of this area is served by the New Bedford municipal water supply system, derived from a surface water source to the north.

3.3 SALT MARSH HYDROLOGY AND WATER CHEMISTRY

3.3.1 Salt Marsh Hydrology

Tidal flushing is the dominant hydrologic influence on the salt marshes of the Upper Acushnet River Estuary. A wide range of physiographic, chemical and biological processes are influenced by tidal flushing, including sediment deposition and scouring, import and export of nutrients, organics and toxins and control of sediment redox potential. Different marsh areas are associated with different hydrologic regimes. The upper marsh requires a minimum of ten days of continuous exposure, while the lower marsh is flooded daily. Tidal creeks are also flooded daily and are important conduits of material and energy transfer between the marsh and adjacent water body. Creeks and ditches

Table 3.1

Salinity and Temperature
North Acushnet River Estuary
9 July 1987

Station #		MID - EBB			EBB			MID - FLOOD			FLOOD		
		Time	Temp	Sal	Time	Temp	Sal	Time	Temp	Sal	Time	Temp	Sal
1 (offshore)	S	10:06	22.5	11.7	11:27	24.5	19.1	16:12	30.0	13.8	18:38	27.0	21.2
	B												
2 (creek)	S			T O O	S H A L L O W / E X P O S E D						18:31	27.0	15.9
	B												
3 (creek)	S			T O O	S H A L L O W / E X P O S E D						18:35	27.0	16.4
	B												
4 (offshore)	S	10:17	22.0	17.0	11:39	24.5	11.7	15:55	26.0	23.9	18.49	25.0	25.4
	B											24.0	26.5
5 (creek)	S	10:23	23.5	22.3	11:44	25.0	21.7	16:00	28.0	22.8	18:52	24.0	26.5
	B												
6 (ditch)	S	10:26	22.0	24.3	11:46	23.5	23.9	16:03	28.0	24.3	18:57	24.0	26.5
	B												
7 (offshore)	S	10:40	24.0	21.2	12:01	25.0	19.6	15:33	26.0	26.0	19:09	24.0	27.6
	B												
8 (pool)	S	10:46	23.0	24.3	12:04	24.0	21.2	15:39	29.0	22.8	19:07	24.0	27.6
	B												
9 (ditch)	S	10:52	22.0	24.3	12:10	22.0	21.2	15:46	24.0	24.3	19:12	23.5	27.6
	B												
10 (offshore)	S	11:02	24.0	24.3	12:19	25.0	20.1	15:30	27.0	23.3	19:15	23.5	28.6
	B												

Note: Temperature in °C; Salinity ppt

Table 3.2

Salinity and Temperature
North Acushnet River Estuary
11 September 1987

Station #		MID - EBB			EBB			MID - FLOOD			FLOOD		
		Time	Temp	Sal	Time	Temp	Sal	Time	Temp	Sal	Time	Temp	Sal
1 (offshore)	S	14:08	18*	21.2*	16:10	18*	21.2*	9:30	17*	21.2*	10:45	17*	21.2*
	B												
2 (creek)	S	14:12	17.8	11.7	TOO SHALLOW/EXPOSED			9:40	17*	19.6*	-----	---	----
	B												
3 (creek)	S	TOO SHALLOW/DRY			TOO SHALLOW/DRY			9:45	17*	19.6*	10:50	18*	18.0*
	B												
4 (offshore)	S	14:20	18.2	22.2	16:52	18	22.3	9:12	18.1	20.5	11:00	---	-----
	B												
5 (creek)	S	14:28	21	19.6	16:50	19	22.3	9:18	18.1	20.2	11:05	21.2	21.1
	B												
6 (ditch)	S	14:24	17.2	21.2	16:40	19	21.2	9:25	17*	19.6*	11:10	18*	21.7*
	B												
7 (offshore)	S	14:35	18	22.3	17:00	18	20.1	8:50	18.3	19.2	11:44	18*	21.7*
	B												
8 (pool)	S	14:38	17	20.1	17:02	19	11.7	9:00	16.9	18.6	11:27	18*	23.3*
	B												
9 (ditch)	S	14:43	17.5	22.3	17:07	18	20.7	9:05	16.1	17.5	11:47	17*	23.3*
	B												
10 (offshore)	S	14:50	21.2	21.2	17:14	20	21.2	8:30	18.5	18.7	12:06	18.5	28.6
	B												

Note: Temperature in ˚C ; Salinity ppt

* Equipment problems occurred while taking these measurements. Results have been normalized to account for temperature errors.

are particularly important in marshes with steep, seaward facing banks and a high proportion of high marsh area. Pannes contain standing water at all times. An asymmetric temporal pattern of flow occurs in many marshes in which a briefer period of faster flow characterizes flood tide and longer periods of slower flow occur during ebb tide (Mitch & Gosselink, 1986).

Hydraulic gradients within the marsh water table are governed by the porosity and permeability of the sediments. In permeable sediments, the water table may rise to the surface at high tide; in impermeable sediments, the water table will remain depressed. Permeability may be enhanced by plant roots and animal burrows (Frey and Basan, 1978).

Freshwater/saltwater interactions in salt marshes are poorly understood. Clearly, precipitation and freshwater stream discharge are important components of the freshwater input. In addition, ground water is discharged from the upland and may form springs at the upland/salt marsh border, or may travel in unconsolidated deposits beneath the salt marsh peats. This freshwater rarely discharges into the overlying peats, but may discharge extensively through the pervious, sandy bottoms of tidal creeks (Valiela et al., 1978, Valiela, pers. comm.).

3.3.2 Salinity

Salinity varies both horizontally and vertically within salt marshes. Salinity is generally higher in the low marsh than the high marsh, with salinity fluctuations greatest near mean high water. Salinity within marsh sediments is controlled largely by the frequency and duration of tidal submersion, rainfall, evaporation, vegetation, soil texture and freshwater inflow. Interstitial salinities generally increase from that of the adjacent estuary to a maximum value at the low/high marsh transition and decrease again in a landward direction. Salinity values within low marsh soils are generally fairly constant with depth, whereas in high marsh soils, salinity values fluctuate with depth, depending on seasonal effects (Mitsch & Gosselink, 1986; Frey and Basan, 1978). Salinities within tidal creeks are usually similar to that of the adjacent estuary, although if freshwater input is significant, salinities may be slightly lower during ebb tide. Salt marsh pannes often have very high salinities due to evaporation and limited flushing.

3.3.3 Import/Export of Nutrients, Sediments, Toxins

In most salt marshes, sediment accumulates at a rate of only a few mm/year. Sediment sources may include riverine suspended sediment, landward sediment transport from Buzzards Bay, erosion of subaerial and subaqueious sediments (including salt marsh) within the estuary and organic aggregates and in situ biogenic production. Salt marshes are known to be sinks for nutrients, organic material and toxins, although they also appear to export large quantities of nutrients and detritus on a seasonal basis. Clearly, the marshes of the Upper Acushnet River estuary have trapped large quantities of metals and PCBs. Most of this is associated with the sediment deposition within the accreting portions of the wetlands, as the metals and PCBs are

adsorbed onto the particulates. Although there is debate in the scientific literature regarding the specifics of salt marsh import-export behavior (Nixon 1980), largely because of the difficulties in measuring these processes, a general understanding is possible. Import-export roles are affected by the structure, age, and hydrology of the marsh, and are parameter-specific (i.e., it varies widely between the elements being considered).

Odum et al. (1979) have classified salt marshes into three types according to their flow and tidal exchange characteristics:

1.) Salt marshes with restricted tidal flow, where flow is largely confined within a long, narrow channel by sills or levees or man-made restrictions such as dikes with culverts which regulate flow;

2.) Marshes which are less restricted than the first class, but where most flow is still principally concentrated in channels;

3.) Marshes having completely free flow.

The first class would be expected to have limited export, while the third class would be characterized by a much greater tidal export. Age is also a factor; as the marsh fills its basin to the high tide level it only acts as a sediment sink primarily in relation to sea level rise. The lower metal and PCB concentrations in the high marsh portions of the study wetlands support the notion that sediment accretion rates within these older parts of the marsh is minimal at present. Younger marshes typically have greater accretion rates, and may actually show a net import of particulate organic carbon, while older marshes tend to export carbon through the creek system.

The Acushnet River estuary salt marshes appear to be primarily older marshes, with the exception of site #5 and the cove in site #3, and occur in a setting which is moderately constricted. This indicates that they likely have a net export of organic carbon within or slightly below the normal range determined for east coast marshes of 100-200 g $C/m^2/yr$ (Nixon 1980). The significance of this export in secondary production of adjacent waters is difficult to assess; Nixon 1980 notes that "the path from the emergent marsh to the open coastal water is not through a pipe, but through a complex chain of sub-systems, each of which is characterized by its own internal cycling as well as its own inputs, outputs, transformations and storages." Tidal flats adjacent to the marshes, for example, may be important sites for trapping nutrients leaving the marsh on ebb tides, ultimately converting plant production into animal biomass (Whitlatch 1982).

4.0 BENTHOS

4.1 METHODOLOGY

4.1.1 Quantitative Survey

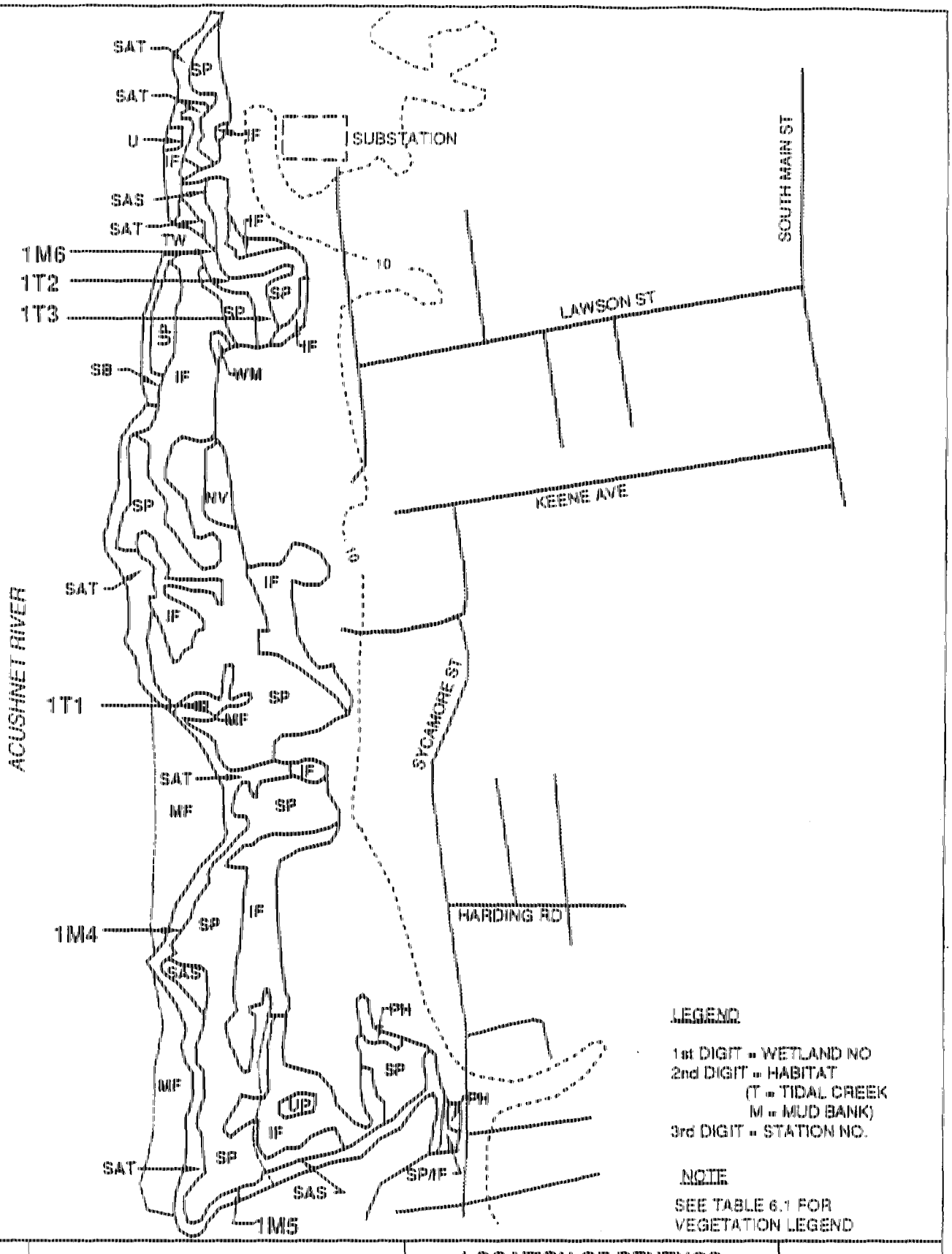
The quantitative survey was conducted to enable the statistical comparison of the benthic fauna (as an indication of secondary production) between a large salt marsh within the sphere of influence of the PCB contaminated sediments of the upper Acushnet River estuary (Wetland 1) and a relatively unpolluted salt marsh outside the boundaries of the estuary (Wetland 2). Sampling took place during two months (June and September) to bracket the summertime recruitment period. Results of this survey were to provide a baseline database against which to assess potential impacts from the alternative cleanup options proposed for New Bedford Harbor sediments.

Quantitative sampling of benthos was conducted on Wetlands 1 and 2 during both June and September 1987 using a stratified random sampling scheme. Mud bank and tidal creek habitats were sampled in three locations on each wetland. Mud banks samples were collected in the area between the tidal flat or creek bed at the base of the vertical bank and the low marsh at the top of the bank. Tidal creek stations were located in the horizontal creek bed of natural creeks. The same stations were occupied in June and September. Random station locations were selected by superimposing a grid on the wetland map and assigning stations from a random numbers table. Station labels identify the wetland (first character), habitat (second character) and station (third character). For field collections, a station was defined as the appropriate habitat within a three-meter diameter of the station marker. Station locations are shown on Figures 4-1 (Wetland 1) and 4-2 (Wetland 2).

Two types of samples were collected at each station. One-liter cores (surface area = 0.0081 m^2; depth = 0.12 m) were collected to evaluate benthic infauna. Three replicate cores were taken at each sampling period. Each replicate was sieved through a 0.5-mm sieve. Animals retained on the sieve were identified to lowest possible taxon and enumerated. Blotted wet weight biomass was determined to 0.01 gram for major taxonomic groupings (Arthropoda, Annelida, Mollusca, Other).

Since infaunal species are frequently associated with specific sediment characteristics, grain-size analysis was conducted on one sample from each station, a fourth 0.0081 m^2 core was collected from each station during June for this analysis. Due to the large amount of peat in the substrate, percent organic material was also measured.

Two-way analysis of variance (ANOVA) was used to determine sampling period and station differences in total infauna abundance (log (x+1)) total annelida abundance (log(x+1)), oligochaete abundance (log(x + 1)), *Polydora ligni* abundance (log (x + 1)), *Mya arenaria* abundance (log (x + 1)) number of taxa and total biomass (square root). Data were transformed prior to analysis to meet the normal-distribution assumption underlying analysis of variance.



SCALE:
1" = 461'

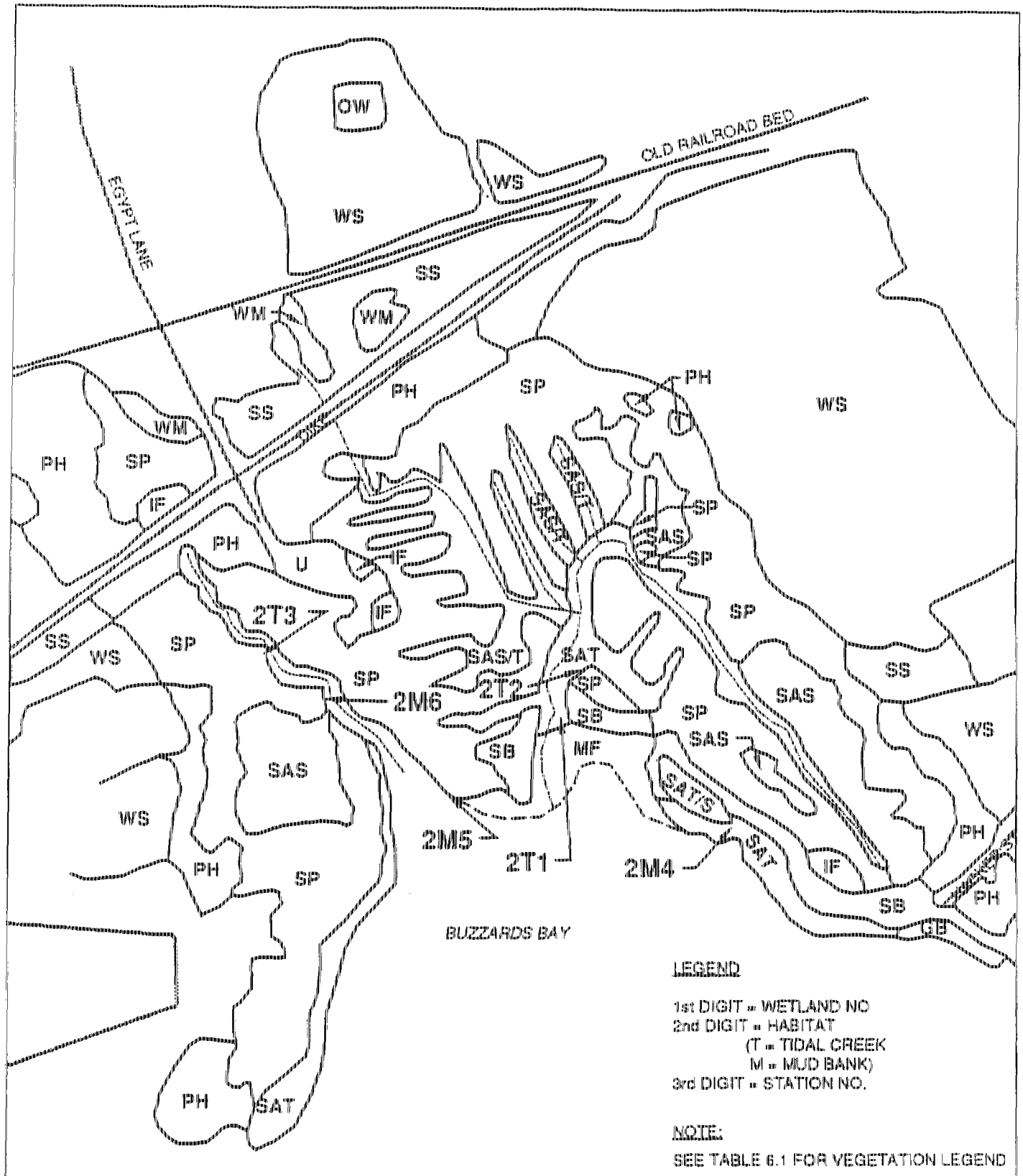
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

LOCATION OF BENTHOS
SAMPLING STATIONS AT
WETLAND STUDY AREA NO. 1,
QUANTITATIVE SURVEY

JANUARY 1988 FILE No. NECIV-1

FIGURE 4-1

EP inc



LEGEND

1st DIGIT = WETLAND NO
2nd DIGIT = HABITAT
(T = TIDAL CREEK
M = MUD BANK)
3rd DIGIT = STATION NO.

NOTE:

SEE TABLE 6.1 FOR VEGETATION LEGEND

SCALE:
1" = 400'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

LOCATION OF BENTHOS
SAMPLING STATIONS AT
WETLAND STUDY AREA No. 2
QUANTITATIVE SURVEY

JANUARY 1988 FILE No. NEC/V-1

FIGURE 4-2

ERT inc

Shannon-Weaver diversity and evenness indices were used to compare wetland habitat and sampling period differences in number of taxa and distribution of abundance among taxa. These indices were computed for each station and date using the mean abundance of each species averaged over three replicate samples. Skewness was calculated for each station and date using the total abundance (sum of all individual species abundances) from each of three replicates.

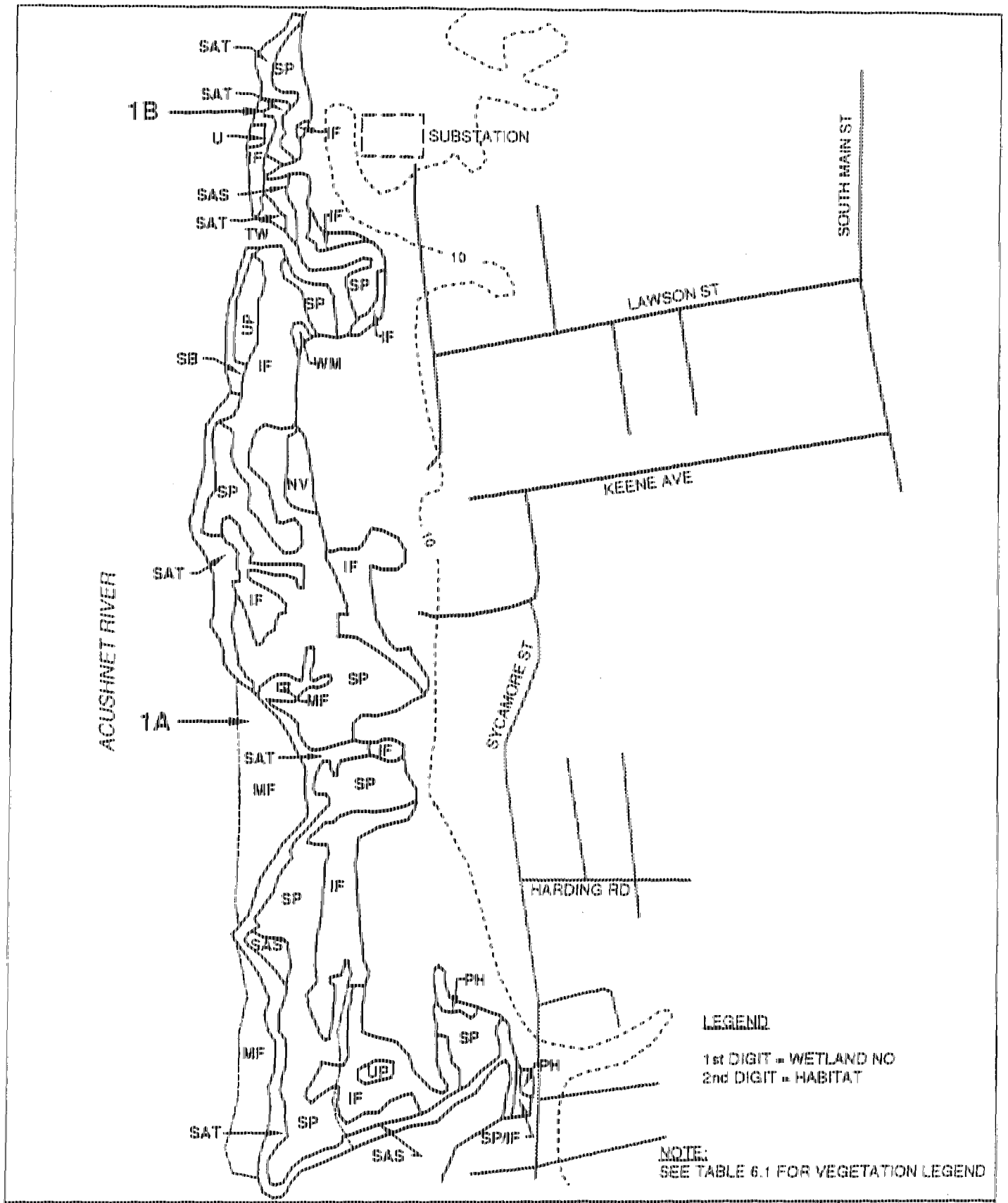
Shellfish were sampled at the same stations and dates as the cores by tossing a 0.25 m^2 frame randomly within the station boundaries to obtain three replicate samples. Material within the frame was excavated to a depth of 0.1 m and washed through a 1-mm sieve on site. Animals retained on sieve were identified and enumerated. Shell length (bivalves) or shell height (gastropods) was measured to the nearest millimeter on all mollusk specimens collected.

Analysis of variance was used to compare sampling periods and stations for total bivalve abundance (log (x +1)), number of bivalve taxa, total gastropod abundance (log (x+1)) and number of gastropod abundance (log (x 1)) and number of bivalve taxa. Abundance data were transformed prior to analysis to normalize the data. One millimeter increments were used to calculate mean size. Length frequency histograms were developed by summing replicate data for each species. For some bivalve species, data were grouped into 5-mm size classes for presentation. Size classes were designated by the maximum size (e.g. 15 mm size class was composed of individuals ranging from 11 to 15 mm).

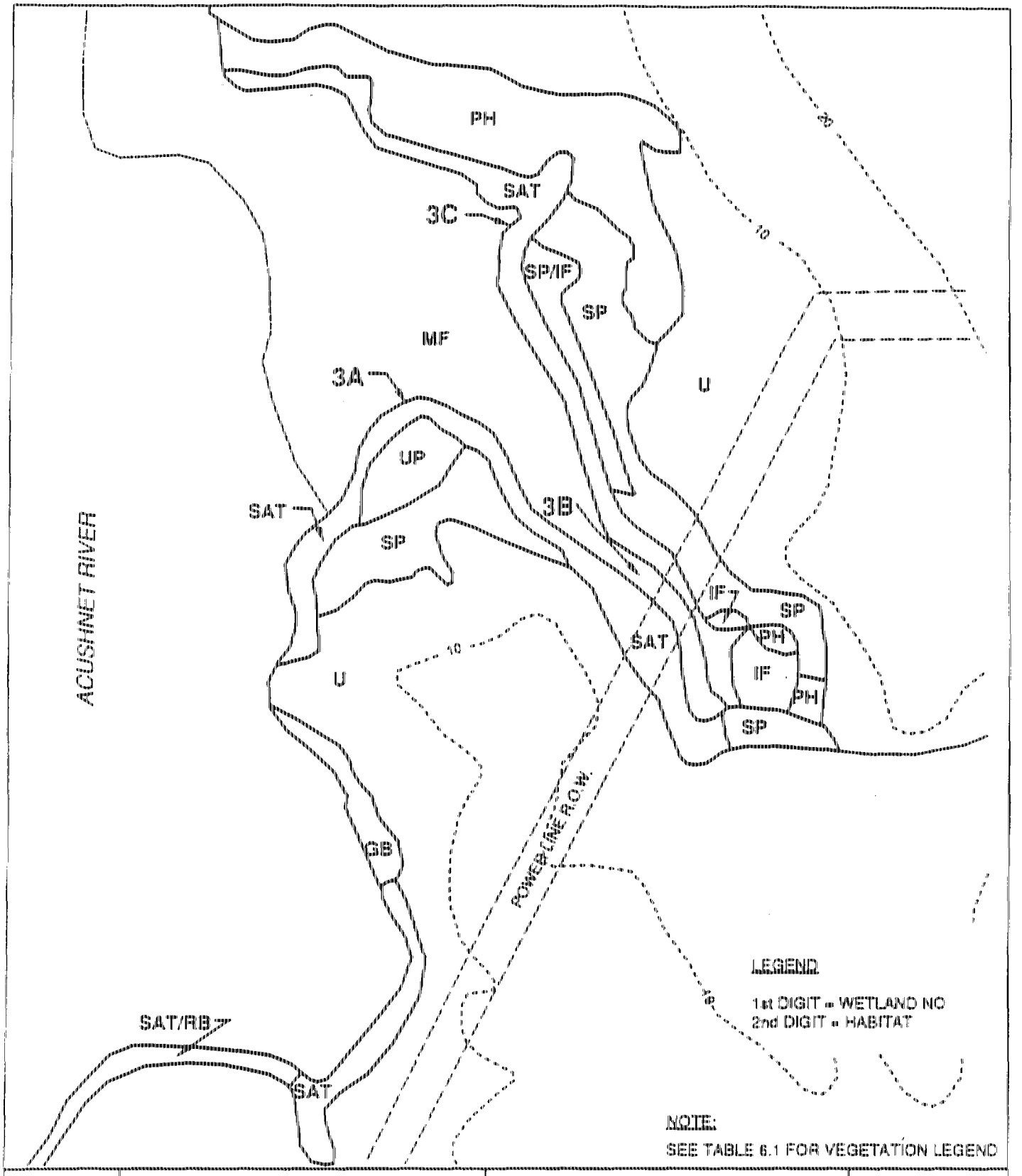
4.1.2 Qualitative Survey

The qualitative evaluation of the five Acushnet River and one Buzzard's Bay salt marsh was intended to compare physical and biological (especially shellfish) characteristics of wetlands 3, 4, 5 and 9 (for which quantitative data has not been collected) to those of wetlands 1 (polluted) and 2 (relatively unpolluted). Each of wetlands 3, 4, 5 and 9 could be impacted by one or more of the cleanup options proposed for the Acushnet River Estuary.

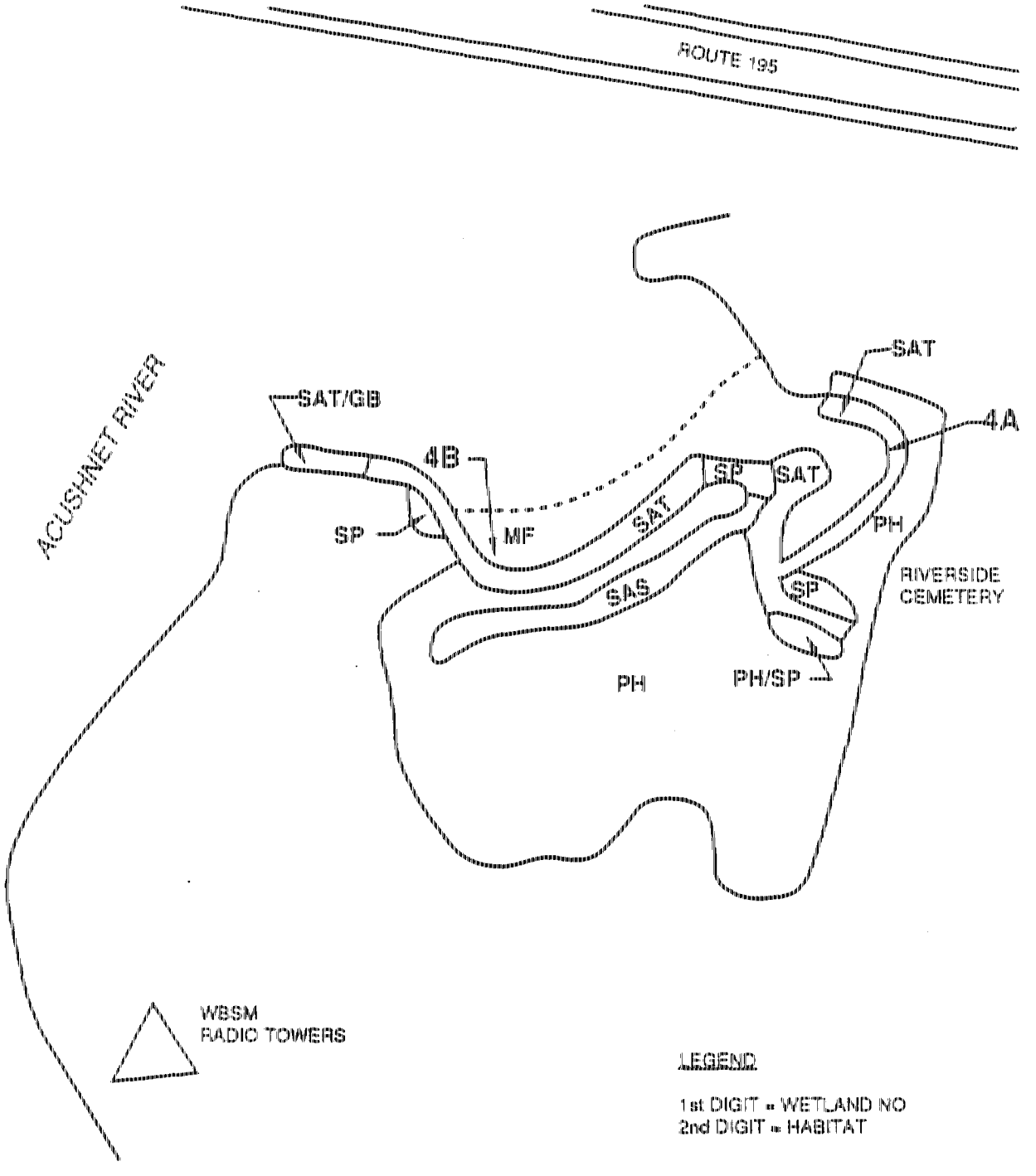
A qualitative comparison of Wetlands 1, 2, 3, 4, 5 and 9 was made in October 1987. Emphasis was placed on the marsh-open water interface to facilitate this comparison. Shellfish samples (using a 0.0625 m^2 frame; no replication) were taken on the wetlands not previously sampled. In addition, because most of the stations on Wetland 1 were in tidal creeks rather than along the marsh-Acushnet River interface additional samples were collected on this site as well. Station locations are indicated on Figures 4-3 through 4-7. Sampling was stratified at the tidal flat-mud bank junction. Samples were seived through a 1.0-mm sieve. Shell length (bivalves) or shell height (gastropods) was measured to the nearest millimeter on all mollusk specimens collected. Comparisons were made using abundance and length frequency data.



SCALE: 1" = 461'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	LOCATION OF SHELLFISH SAMPLING STATIONS AT WETLAND STUDY AREA NO. 1 QUALITATIVE SURVEY JANUARY 1988 FILE No. NEC/V-1	FIGURE 4-3 EP inc



SCALE: 1" = 207'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	LOCATION OF SHELLFISH SAMPLING STATIONS AT WETLAND STUDY AREA No. 3 QUALITATIVE SURVEY JANUARY 1988 FILE No. NEC3V-1	FIGURE 4-4 IEP inc



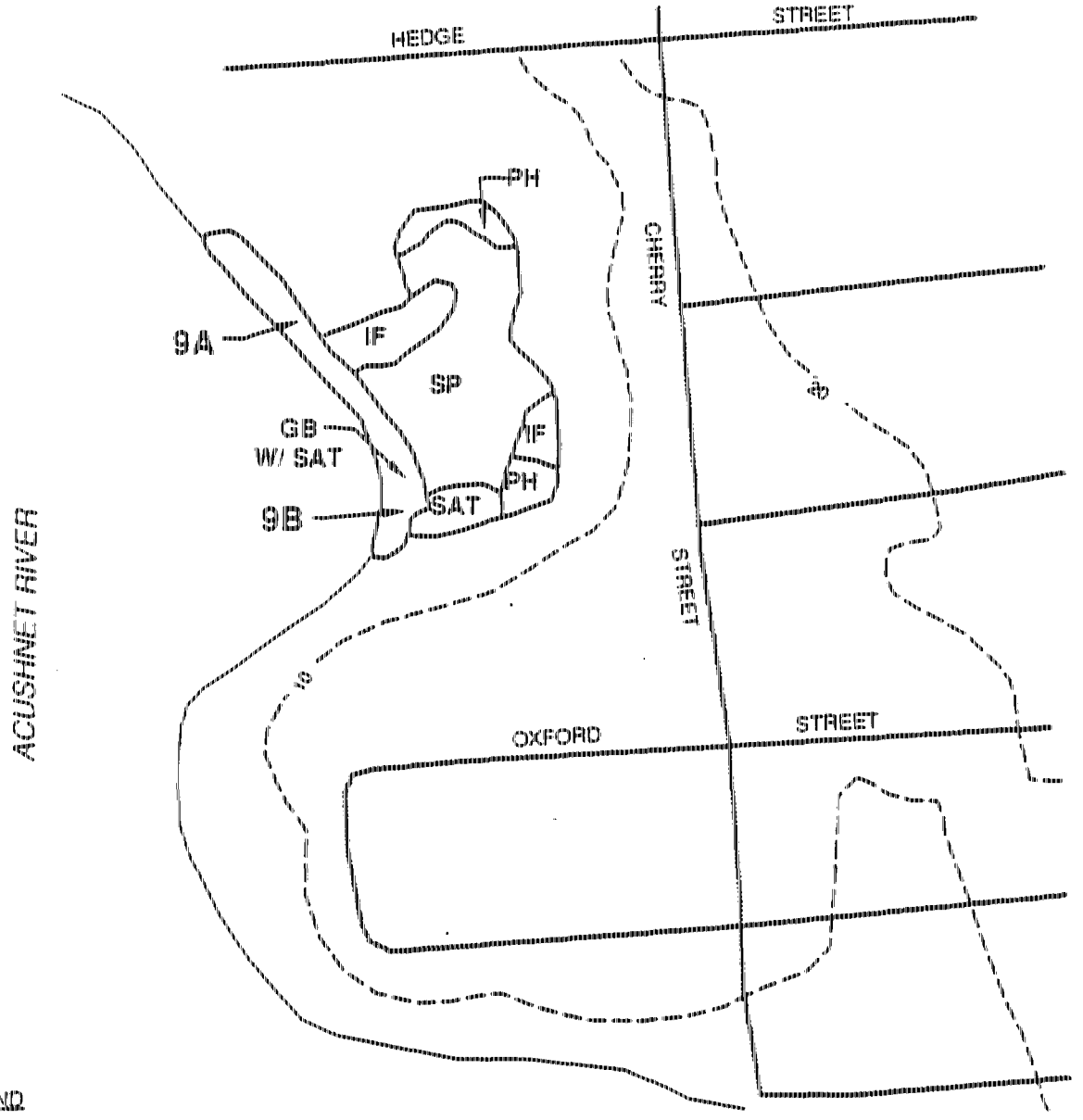
LEGEND

1st DIGIT = WETLAND NO
2nd DIGIT = HABITAT

NOTE:

SEE TABLE 6.1 FOR VEGETATION LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	LOCATION OF SHELLFISH SAMPLING STATIONS AT WETLAND STUDY AREA No. 4 QUALITATIVE SURVEY JANUARY 1988 FILE No. NECIV-1	FIGURE 4-5 inc



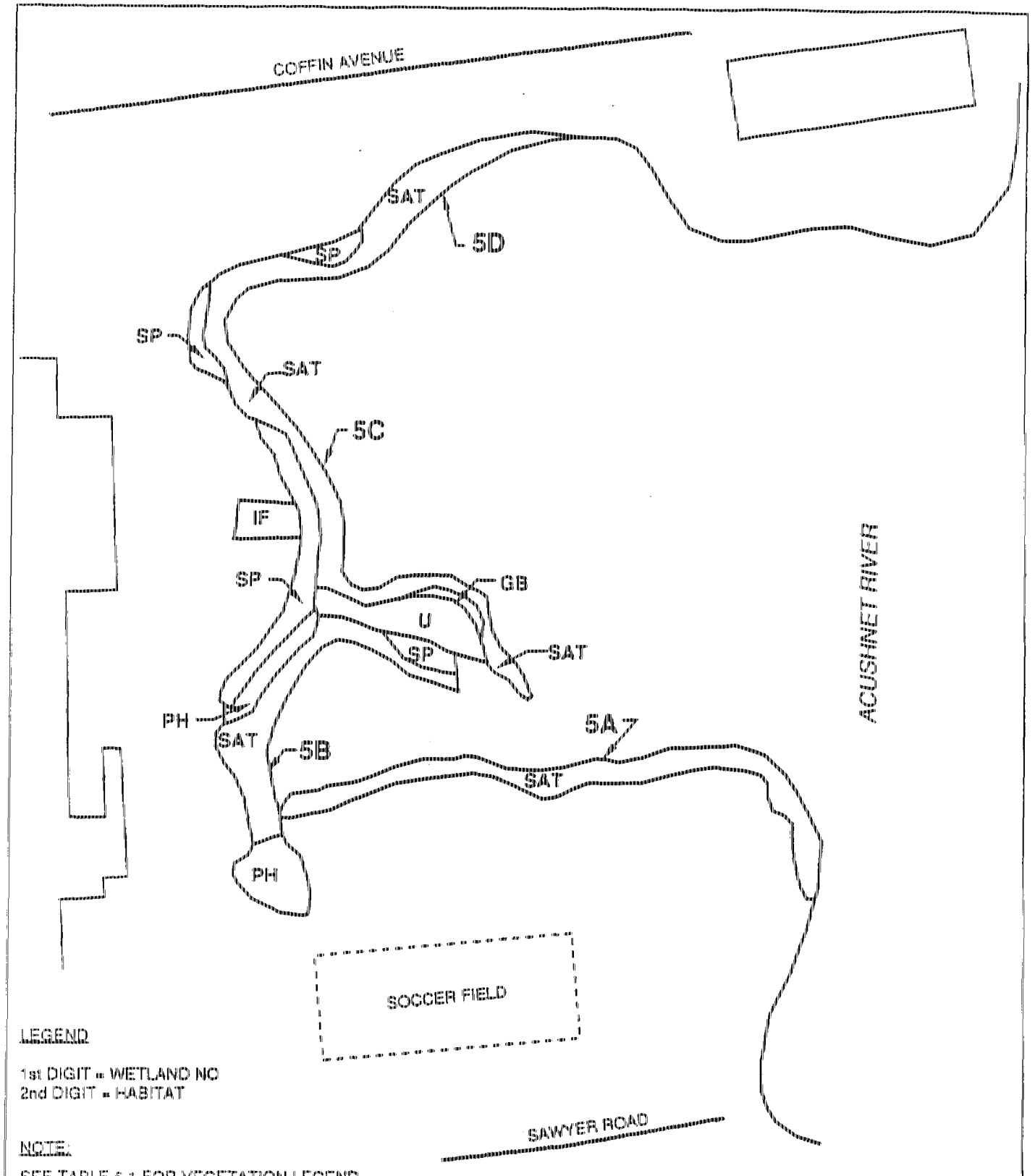
LEGEND

1st DIGIT = WETLAND NO
2nd DIGIT = HABITAT

NOTE:

SEE TABLE 6.1 FOR VEGETATION LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	LOCATION OF SHELLFISH SAMPLING STATIONS AT WETLAND STUDY AREA No. 9 QUALITATIVE SURVEY JANUARY 1988 FILE No. NEC0V-1	FIGURE 4-6 GEI Inc



SCALE:
1" = 200'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

LOCATION OF SHELLFISH SAMPLING STATIONS AT WETLAND STUDY AREA No. 5 QUALITATIVE SURVEY

JANUARY 1988 FILE No. NECIV-1

FIGURE 4-7

IEP inc

4.2 BENTHIC INFAUNAL COMMUNITY

4.2.1 Substrate

Sediment grain-size characteristics for each of the stations sampled for infauna are presented in Table 4.1. The substrate of tidal creek stations 1T1 and 1T3 was silty, as indicated by the median grain size and predominance of (silt and clay, 55-70%) sediments in the creeks on Wetland 2 and at Station 1T2 were coarser, with median grain sizes ranging from medium sand to gravel. These differences in grain size might be attributable to a number of factors such as tidal current speed, exposure to storm generated waves, and potential origin of sediments.

The proportion of organic matter (peat) was typically higher in the mud bank stations than the tidal creek stations. At the mud bank stations on Wetland 2, organic matter composed 21-38% of the sediments. Two of the stations (2M4, 2M6) were coarser, classified as fine sand based on the median grain size, than station 2M5, classified as silty. On Wetland 1, Station 1M4 had the finest sediments, with median grain size in the silt range, while station 1M5 was characterized as fine sand. At Station 1M6, the only mud bank station with a low level of organic matter (<5%), medium sand and was the coarsest of the three stations.

4.2.2 Tidal Creeks

Tidal creek stations on Wetland 1 were dominated by oligochaetes and *Capitella* sp. during both sampling periods (Table 4.1 and Appendix Table 1). Abundances of the spionid *Streblospio benedicti* were also high during September. These three taxa were important numerically in the tidal creek stations of Wetland 2 as well. However, during both sampling periods, numerous other taxa were apparent in moderate ($>10^2/m^2$) to high densities ($>10^3/m^2$) on Wetland 2 (Table 4.2), while the number of abundant taxa on Wetland 1 was limited. The most abundant taxa are typical estuarine species; primarily surface and subsurface deposit feeders. The bivalves collected from tidal creeks in Wetland 2 are filter feeders. Of particular note is the abundance of *Mya arenaria* in Wetland 2 tidal creek stations (Table 4.2) during both sampling periods.

The pattern of community structure was evidenced in the diversity and evenness indices for the six tidal creek stations (Table 4.3). Diversity values varied between wetlands, with Wetland 2 values higher than Wetland 1 values. Only one station x sampling period combination 1.0 (ranged from 0.883-3.098). From Wetland 1, only Station 1T1 data exceeded a value of 1.0 (September), and was close to 1.0 in June. The other stations on Wetland 1 had low diversity values ranging from 0.120 to 0.330. Tidal creek stations on Wetland 2 supported three times as many taxa as the same habitat on Wetland 1 (Table 4.4). The greatest disparity between the two sites was the number of polychaete species. Evenness values were low, indicating that each station had only a few species with high abundances, while the remaining species had low abundances. Only at Stations 2T1 (both months) and 2T2 (June only) was evenness moderately high (>0.6). There was generally no indication of a

TABLE 4.1. SEDIMENT GRAIN SIZE (%) CHARACTERISTICS OF AREAS SAMPLED FOR BENTHOS, NEW BEDFORD WETLANDS STUDY, 1987.

GRAIN SIZE CLASS		STATION 1T1	1T2	1T3	1M4	1M5	1M6
GRAVEL	(2mm)[a]	2.0[b]	1.8	1.5	0.7	0	0
VERY COARSE SAND	(1mm)	1.8	4.5	1.7	1.8	3.0	4.1
COARSE SAND	(.5mm)	4.8	17.3	6.0	3.4	9.7	23.1
MEDIUM SAND	(.25mm)	7.7	28.4	12.6	11.2	15.0	27.5
FINE SAND	(.125mm)	4.2	12.5	5.1	10.0	8.8	16.5
VERY FINE SAND	(.063mm)	4.2	6.6	2.8	6.9	13.6	6.3
SILT	(.03mm)	31.5	23.2	22.1	12.4	4.3	7.6
CLAY	(.004mm)	39.4	1.8	35.9	38.7	16.3	10.1
ORGANIC MATTER	(varies)	4.4	3.9	12.2	15.0	29.3	4.7

GRAIN SIZE CLASS		STATION 2T1	2T2	2T3	2M4	2M5	2M6
GRAVEL	(2mm)	44.0	0.6	1.5	0	0	0.6
VERY COARSE SAND	(1mm)	20.4	4.7	11.8	8.8	1.0	5.5
COARSE SAND	(.5mm)	17.2	15.4	27.9	11.1	4.9	12.5
MEDIUM SAND	(.25mm)	12.0	28.9	26.4	11.9	5.9	14.8
FINE SAND	(.125mm)	2.0	17.9	8.8	8.8	2.4	7.6
VERY FINE SAND	(.063mm)	0.6	19.5	7.9	9.6	4.9	13.7
SILT	(.03mm)	0.1	7.8	7.3	15.4	31.9	18.7
CLAY	(.004mm)	3.6	3.2	1.3	9.6	10.8	5.8
ORGANIC MATTER	(varies)	0	2.0	7.1	24.6	38.2	20.8

[a] minimum size

[b] percentage based on material dried at 105°C

TABLE 4.2. RANKED ABUNDANCE[a] (ORDER OF MAGNITUDE) OF FAUNAL TAXA BY WETLAND AND HABITAT, NEW BEDFORD WETLANDS STUDY, 1987.

JUNE ABUNDANCE[b] (no./m^2)	WETLAND 1 TIDAL CREEK	WETLAND 1 MID BANK	WETLAND 2 TIDAL CREEK	WETLAND 2 MID BANK
$>10^5$		Oligochaeta		Fabricia sabella (10^6)
$>10^4$	Oligochaeta	F. sabella	Oligochaeta	Oligochaeta Polydora ligni
$>10^3$	Capitella capitata	C. capitata Streblospio benedicti	C. capitata Mya arenaria P. ligni S. benedicti	Mya arenaria Nereis succinea
$>10^2$	F. sabella Hydrobia totteni S. benedicti	Gammarus sp. G. palustris Geukensia demissa H. totteni Ilyanassa obsoleta M. arenaria Mytilidae P. ligni	Asabellides oculata Eteone sp. F. sabella Gammarus mucronatus Gastropoda Heteromastus filiformis Littorina littorea Microphthalmus sp. Mytilidae Nereis sp. N. succinea P. elegans Scolecolepides sp. S. viridis Scoloplos fragilis Scoloplos sp. Syllidae Turbellaria	C. capitata Corophium insidiosum Gemma gemma Nereis sp. Polydora websteri Pygospio elegans

TABLE 4.2. (Continued)

SEPTEMBER ABUNDANCE[b] (no./m^2)	WETLAND 1 TIDAL CREEK	WETLAND 1 MUD BANK	WETLAND 2 TIDAL CREEK	WETLAND 2 MUD BANK
$>10^5$	Oligochaeta			F. sabella
$>10^4$		Oligochaeta F. sabella	Oligochaeta C. capitata	Oligochaeta C. insidiosum
$>10^3$	C. capitata S. benedicti	C. capitata S. benedicti	G. gemma Hypaniola florida Mytilidae Rhynocoeela S. fragilis S. benedicti Turtonia minuta	C. capitata Edotea triloba P. ligni Syllis (Typosyllis) sp.
$>10^2$	G. gemma I. obsoleta Orchestia grillus	Anthozoa C. insidiosum G. demissa Microdeutopus sp. O. grillus	Cirratulidae E. triloba E. triloba G. demissa H. totteni Jaera marina M. arenara N. succinea P. ligni Scoloplos sp.	Ampithoidae Arabella iricolor Arabella iricolor Pamida sanguinea G. micronatus G. demissa N. succinea L. littorea Microdeutopus anomalus Nereis sp. N. succinea Petricola pholadiformis P. elegans S. benedicti

[a]Species presented alphabetically within abundance categories.
[b]Based on mean abundance at any of the stations within the habitat. See Appendix Table 1 for abundance data.

TABLE 4.3. DIVERSITY, EVENNESS AND SKEWNESS OF INFAUNA ABUNDANCES (no./m^2; MEAN OF REPLICATES), NEW BEDFORD WETLANDS STUDY, 1987.

SAMPLING PERIOD	STATION	DIVERSITY	EVENNESS	SKEWNESS
JUNE	1T1	0.913	0.457	1.376
	1T2	0.157	0.079	1.999
	1T3	0.330	0.142	2.233
	1M4	0.565	0.158	3.461
	1M5	1.285	0.371	2.506
	1M6	0.544	0.147	3.588
	2T1	3.098	0.651	2.623
	2T2	2.542	0.709	1.236
	2T3	0.883	0.208	4.345
	2M4	0.262	0.063	4.240
	2M5	0.999	0.231	4.288
	2M6	0.457	0.163	2.644
SEPTEMBER	1T1	1.703	0.568	1.792
	1T2	0.232	0.083	2.644
	1T3	0.120	0.035	3.316
	1M4	1.043	0.261	3.589
	1M5	1.025	0.256	3.971
	1M6	1.357	0.392	2.083
	2T1	2.984	0.730	1.633
	2T2	1.336	0.386	3.040
	2T3	1.745	0.436	2.690
	2M4	1.275	0.255	5.275
	2M5	1.093	0.267	3.901
	2M6	1.135	0.404	2.332

TABLE 4.4. COMPARISON OF NUMBER OF TAXA (COLLECTED IN 0.0081 m^2 CORES) BETWEEN HABITATS AT EACH WETLAND AND BETWEEN WETLANDS IN LIKE HABITATS, NEW BEDFORD WETLANDS STUDY, 1987.

	WETLAND					
	1			2		
	TIDAL CREEK	MUD BANK	IN COMMON	TIDAL CREEK	MUD BANK	IN COMMON
All taxa	17	30	13	53	61	29
Amphipoda	4	7	3	5	12	3
Other Arthropoda	2	3	2	4	7	1
Bivalvia	1	5	1	8	10	6
Gastropoda	3	5	2	6	1	1
Polychaeta	7	10	5	22	19	12
Colonials	0	0	0	8	12	6

	HABITAT					
	TIDAL CREEK			MUD BANK		
	1	2	IN COMMON	1	2	IN COMMON
All Taxa	17	53	12	30	61	19
Amphipoda	4	5	3	7	12	3
Other Arthropoda	2	4	1	3	7	2
Bivalvia	1	8	1	5	10	5
Gastropoda	3	6	1	5	1	1
Polychaeta	7	22	6	10	19	8
Colonials	0	8	0	0	12	0

strong difference between sampling periods, suggesting a similar distribution of species abundances in the two months. In June, skewness values for Wetland 2 stations were greater than for Wetland 1, indicating greater within-station (i.e. among replicates) variability in abundance in Wetland 2 than Wetland 1. The reverse was true in September.

These statistics indicate that tidal creek stations on Wetland 2 tend to support a greater variety of infaunal particularly polychaetes and bivalve species than those on Wetland 1, regardless of the month sampled (Table 4.4). There were three to four times as many taxa with abundances greater than $100/m^2$ at Wetland 2 than Wetland 1 during June and September (Table 4.2, Appendix Table 1). Wetland 2 stations are more likely to have several abundant co-dominant species than are Wetland 1 stations. Again, sample period may be less of a contributing factor than location.

The influence of sediment grain size is apparent at Wetland 2 in June, where sediments at station 2T1 (gravel) are much coarser than those at stations 2T2 and 2T3 (medium sand). Taxa such as Mya arenaria, Scoloplos spp., Scolecolepides spp. and syllidae were much more abundant at station 2T1, while Streblospio benedicti was more abundant at stations 2T2 adn 2T3. The presence of herbivores such as Littorina littorea and Gammarus inucronatus at station 2T1 is probably the result of the presence of algae rather than substrate differences.

Wet-weight biomass measurements for major taxa are presented in Appendix Table 2. Stations containing mollusks had the highest biomass values, partially attributable to shell weight.

4.2.3 Mud Banks

The infauna at mud bank stations on Wetland 1 was dominated by Oligochaeta, Fabricia sabella, Capitella sp. and Streblospio benedicti during both sampling periods (Table 4.2, Appendix Table 1). In June, amphipods, bivalves and gastropods were moderately abundant (10^2-$10^3/m^2$) as well. Of these taxa, all but gastropods were also moderately abundant in September. These species encompass several feeding types; filter feeding, surface grazing/scraping, burrowing deposit feeding, and surface deposit feeding. Of the 30 taxa collected from Wetland 1 mud bank stations, ten were polychaetes and seven were amphipods (Table 4.4). Oligochaetes and F. sabella also predominated on Wetland 2 during June and September. The surface deposit feeder Polydora ligni was numerous on this site too. Abundances of Mya arenaria, Nereis succinea (June), Capitella sp., Edotea triloba and Syllis typosyllis sp. (September) exceeded $10^2/m^2$. Moderately abundant (10^2-$10^3/m^2$) taxa represented several major taxonomic (polychaetes, bivalves, amphipods) and feeding (surface deposit feeders, burrowing deposit feeders, carnivores, filter feeders) groups. In all, 61 taxa were recorded from Wetland 2 mud bank stations, predominantly polychaetes, amphipod, and bivalve species (Table 4.4).

The diversity index (Table 4.3) varied more between the two sampling periods than wetlands. For both wetlands, all stations exhibited diversity indices above 1.0 (ranging from 1.025 to 1.357) in September. In June, with the exception of station 1M5 (H'= 1.285) and 2M5 (H'=0.999) values fell below 1.0 (ranging from 0.262 to 1.285). Since H' has no upper limit, no wetlands differences can be inferred from these values. Evenness values (Table 4.3) were highest in September at most mud bank stations, although no value exceeded 0.5. There were no apparent differences between the wetlands. This implies that all mud bank stations had only a few species with high abundances, while the remaining species had low abundances, as indicated by the summary of data in Table 4.2. Skewness (Table 4.3) was affected more by wetland and station than by sampling period. Highest values were observed in Wetland 2, Stations 2M4 and 2M5, indicating greatest within-station variability.

Species distributions appeared to be affected by the presence of mussel clusters (both Mytilidue and Geukensia demissa) which were patchily distributed throughout the mud bank on the sediment surface. These clumps act to provide habitat and refuge for other organisms. This is evident in September at the Wetland 2 mud bank stations. Station 2M4, which had mussel clumps, had more taxa (37) than station 2M5 (26) and 2M6 (12), including infaunal (Neresis succinea, Petricola pholadiformis) as well as epifaunal (Edotea triloba, Hiatella sp.) taxa.

Wet weight biomass is presented in Appendix Table 2. As in the creek samples, those stations containing mollusks had the highest biomass values.

4.2.4 Habitat Comparisons

The most abundant taxa ($>10^4$) were similar in all wetland-habitat groups (Table 4.2). These species are adapted to the stressful intertidal habitat by their burrowing or tube dwelling habits. Abundant ($>10^3$) and moderately abundant ($>10^2$) species were variable between habitats and between wetlands. This can be due partially to the physical differences in the habitats. Mud bank stations provide a somewhat more complex substrate than tidal creeks due to the presence (at most stations) of Spartina alterniflora and large pieces of detritus (seasonally). This provides a niche for grazers (e.g. Littorina littorea, Ilyanassa obsoleta; although both occurred in tidal creeks as well) and detritivores (e.g. Hydrobia totteni, Corophium insidiosum and Gammarus spp.). However, the tidal creek bed may be considered a less stressful habitat because of the duration of exposure during the tidal cycle is shorter than on the banks. In addition, the longer and earlier exposure to flooding tides that the creek beds experience (compared to mud banks) may provide a slight advantage in terms of recruitment from other areas. Within a particular habitat sediment grain size characteristics (Table 4.1) were sufficiently different to account for some of the among-station variability.

Two-way ANOVAs were used to discern sampling period, station, or station x sampling period differences. Results are shown on Table 4.5. In all cases, significant differences were observed among stations and among station x

TABLE 4.5. RESULTS OF TWO-WAY ANOVA AND SIGNIFICANCE TESTS ON VARIOUS PARAMETERS FROM 0.0081 m^2 CORES, NEW BEDFORD WETLANDS STUDY, 1987.

A. ANOVA RESULTS

	PARAMETER							
SOURCE	NO. OF TAXA	TOTAL ABUNDANCE	ANNELIDA ABUNDANCE WITH FABRICIA	ANNELIDA ABUNDANCE WITHOUT FABRICIA	OLIGOCHAETE ABUNDANCE	P. LIGNI ABUNDANCE	H. ARENARIA ABUNDANCE	BIOMASS
MONTH	NS	NS	NS	NS	NS	JUN>SEP	JUN>SEP	SEP>JUN
STATION	*	*	*	*	*	*	*	*
INTERACTION	*	*	*	*	*	*	*	*

(NOTE: ABUNDANCES LOG (X+1) TRANSFORMED; BIOMASS SQUARE ROOT TRANSFORMED; * SIGNIFICANT AT α = 0.05; NS = NO SIGNIFICANT DIFFERENCE).

B. LEAST SQUARES MEANS TESTS ON STATIONS

INCREASING VALUE	NO. OF TAXA	TOTAL ABUNDANCE	ANNELIDA ABUNDANCE WITH FABRICIA	ANNELIDA ABUNDANCE WITHOUT FABRICIA	OLIGOCHAETE ABUNDANCE	P. LIGNI ABUNDANCE	H. ARENARIA ABUNDANCE	BIOMASS
↑	ZM4	ZM4	ZM4	IM6	IM6	ZM5	ZT1	ZT2
	ZT1	ZM5	ZM5	ZT3	ZT3	ZM4	ZM4	ZM4
	ZT3	IM6	IM6	ZM5	ZM5	ZT3	IM5	IM6
	ZM5	IM4	IM4	IT2	IT2	ZT2	IM4	IT2
	IM4	ZT3	ZT3	IM4	IM4	ZT1	IM6	ZT1
	IM5	IT2	IT2	IT3	IT3	ZM6	ZT2	IM5
	ZT2	IT3	IT3	ZM4	IM5	IM6	IT1	ZM5
	IM6	IM5	IM5	IM5	ZM6	IT1	IT2	IM4
	IT3	ZM6	ZM6	ZM6	ZM4	IM4	IT3	IT3
	ZM6	ZT1	ZT2	ZT2	IT1	IM5	ZM5	ZM6
	IT2	ZT2	IT1	IT1	ZT2	IT3	ZM6	ZT3
	IT1	IT1	ZT1	ZT1	ZT1	IT2	ZT3	IT1

(continued)

TABLE 4.5. (Continued)

C. LEAST SQUARES MEANS TESTS ON MONTH X STATION INTERACTIONS

INCREASING VALUE	NO. OF TAXA	TOTAL ABUNDANCE	ANNELIDA ABUNDANCE WITH *FABRICIA*	ANNELIDA ABUNDANCE WITHOUT *FABRICIA*	OLIGOCHAETE ABUNDANCE	*P. LIGNI* ABUNDANCE	*M. ARENARIA* ABUNDANCE	BIOMASS
	S2M4	J2M4	J2M4	J1M6	J1M6	J2M4	J2M4	S2T2
	J2T1	S2M5	S2M5	S1T3	S1T3	J2M5	S2T1	S2M4
	J2T3	S2M4	J2M5	S1T2	S1T2	J2T1	J2T1	S1T2
	J2M4	J2M5	S2M4	J2M5	J2T3	S2M5	J1M5	J1M6
	J2M6	J1M6	J1M6	J2T3	S1M6	J2T2	J2T2	S2T1
	S2M5	S1T3	S1T3	S2T3	J1M4	J2T3	S1M4	S1T3
	S2T1	S1M4	S1M4	S1M6	J2M5	S2M4	S1M6	J1M5
	S2T4	S1M6	S1M6	J1M4	S2M5	S2T3	J1M4	J2M4
	S1M4	S1T2	S1T2	S2M5	S2T3	J2M6	J1M6	J2M5
	S1M5	S2T3	J2T3	J2M4	S1M4	J1T1	J1T1	S2M6
	J1M6	J2T3	S2T3	S1M4	J1M5	J1M6	J1T2	S1M4
	J2T2	J1M4	J1M4	J1M5	S2T2	S2T2	J1T3	S2M5
	S2T2	J1M5	J1M5	S2T2	J1T2	S2M6	J2M5	S1T1
	S1M6	S2T2	S2T2	S2M4	S1M5	J1M4	J2M6	J1M4
	J1M5	J2T1	J1T1	J1T1	J2M6	S1T3	S1M5	J2T1
	J1M4	J1T1	J1T2	J1T2	S2M4	S1M6	S1T1	S1M6
	S1T2	S1M5	J2M6	S1M5	J1T1	S1M5	S1T2	J2T3
	S1T3	J1T2	S1M5	J2M6	S2M6	S2T1	S1T3	S2T3
	S1T1	J2M6	J2T1	J2T1	J1T3	S1T2	S2M5	S1M6
	J2M6	S2M6	S2M6	S2M6	J2M4	S1T1	S2M6	J1T2
	S2M6	S2T1	S1T1	S1T1	J2T1	S1M4	J2T3	J1T1
	J1T3	S1T1	J1T3	J1T3	S1T1	J1T3	S2M4	J2T2
	J1T2	J2T2	J2T2	J2T2	J2T2	J1T2	S2T2	J1T3
	J1T1	J1T3	S2T1	S2T1	S2T1	J1M5	S2T3	J2M6

(NOTE: J = JUNE, S = SEPTEMBER)

sampling period groups. Of the parameters tested statistically, differences between sampling periods were observed only for Polydora ligni, Mya arenaria and biomass.

Four of the six stations on Wetland 2 exhibited a significantly greater number of taxa than all stations on Wetland 1. Tidal creek stations on Wetland 1 contained significantly fewer taxa than the mud bank stations. The significance test on station x season interaction exhibited no strong pattern as evidenced by large numbers of overlapping groups. However, each wetland tended to exhibit differences between the months. On Wetland 2, number of taxa was higher in June than in September. The opposite was true on wetland 1. In addition, on Wetland 1, habitat seemed to affect the number of taxas, with mud banks higher than tidal creeks.

Total abundance and annelida abundance (including Fabricia sabella) paralleled each other (Table 4.5), indicating the dominance of this phylum in the marsh environment. Again, patterns among stations are not clear cut. There is much overlap among station groups and among station x sampling period groups. Generally, though, mud bank stations on Wetland 2 achieved higher abundances than the same habitat on Wetland 1. Tidal creek stations on Wetland 2 exhibited lowest abundances.

Stations 2M4 and 2M5 attained highest abundances during both sampling periods, in large part due to the abundance of Fabricia (Appendix Table 1). Wetland stations sampled in September were next in abundance. Four stations were consistently lower in abundance: 2T1, 2T2, 2M6 and 1T1.

Annelida abundance (excluding F. sabella) and oligochaeta abundance, exhibited very similar patterns (Table 4.5), as anticipated by the predominance of oligochaetes throughout the sampling program (Appendix Table 1). In this case, Wetland 1 tended to rank higher than Wetland 2. Neither habitat nor sampling period seemed to be a major factor influencing the results.

Abundance of Polydora ligni was higher in Wetland 2 than in Wetland 1. Within Wetland 2, abundances tended to be higher in June than September at each station. Abundances at Wetland 1 were very low (Appendix Table 1), so difference between months or habitat patterns were not apparent.

Abundance of Mya arenaria was greater in the June collections than the September collections (Table 4.5). This species was present in cores from six of the twelve stations (1M4, 1M5, 1M6, 2T1, 2T2 and 2M4). Only at Station 2T1 did M. arenaria occur during both sampling periods. The mean abundances at Stations 1M4, 1M6 and 2T2 were quite low as is demonstrated by the fact that these stations were found to be statistically indistinct from those stations where no M. arenaria were collected (Table 4.5, Appendix Table 1). The stations exhibiting the highest abundances were in Wetland 2 (at 2M4 in June and 2T1 during both months; Table 4.5). During June, abundance of M. arenaria at Station 1M5 moderate.

Biomass was higher in September than June, but station and station x sampling period patterns were indistinct. Significant differences were probably due to the presence of large organisms (particularly mollusks) in a few of the samples. A qualitative examination of mean annelid biomass (Appendix Table 2) suggests that the biomass of this group was higher at stations 2M4 and 2M5 (during both sampling periods) and at 1M6 during June than at other stations. The greater abundances of such large species as Nereis succinea, as well as the extremely high abundances of Fabicia sabella, at stations 2M4 and 2M5 than the other stations may partially account for biomass differences (Appendix Table 1). The relatively high annelid biomass observed at 1M6 during June was probably due to high abundances of Streblospio benedicti, Oligochaeta and Capitella sp. (Appendix Table 1).

Among the tidal creek stations annelid biomass showed no patterns (Appendix Table 2). Although the mean values at stations 1T2 and 1T3 were relatively high in September, the high standard deviations indicated that the mean was strongly influenced by one or two replicates. Of the annelids at these stations, oligochaetes were the most abundant and exhibited variability among the replicates (Appendix Table 1).

4.3 SHELLFISH COMMUNITY

Mean abundance (over replicates) of organisms collected in 0.25 m^2 quadrats is presented by station and sampling period in Appendix Table 3. Twenty-three species were collected in total, only ten of which were mollusks. Non-molluscan species are not treated quantitatively because the sampling procedure was designed to sample sessile macrofauna. However, the presence of these other species is at least indicative of their distribution on the study marshes. The omnivorous burrowing polychaete Nereis succinea was collected from the banks of both marshes. Xanthid crabs, Rhithropanopeus harrisii and Neopanope sayi were collected from Wetland 2. The marsh crab Sesarma reticulatum, whose burrows generally occur in the Spartina alterniflora zone (Daiber 1982) was collected on Wetland 1 as was the fiddler crab Uca pugnax. Absence of any of these species from the collections in a particular area could as easily be an artifact of sampling as a true absence of the species.

4.3.1 Tidal Creeks

The most abundant molluscan taxa within each habitat on each wetland are reported by sampling period in Table 4.6.

Sampling the tidal creek habitat at Wetland 1 revealed only very low abundances of bivalves (Appendix Table 3) represented by only one species, Geukensia demissa (Appendix Table 3). Only the mud snail Ilyanassa obsoleta, a typical inhabitant of salt marsh creeks (Daiber 1982) ever reached even moderate densities. As this species feeds on benthic unicellular algae, its presence in September suggests that the sediment surface of Wetland 1 tidal creeks is suitable to support microfloral production.

TABLE 4.6. RANKED ABUNDANCE (ORDER OF MAGNITUDE) OF MOLLUSCAN TAXA BY WETLAND AND HABITAT, NEW BEDFORD WETLANDS STUDY, 1987.

ABUNDANCE[a] (no./m^2)	WETLAND 1		WETLAND 2	
	TIDAL CREEK	MUD BANK	TIDAL CREEK	MUD BANK
JUNE				
$>10^2$		*Geukensia demissa* *Ilyanassa obsoleta*		*Geukensia demissa*
>10			*I. obsoleta* *L. littorea* *Mercenaria mercenaria* *Mya arenaria*	*Littorina littorea*
SEPTEMBER				
$>10^2$	*I. obsoleta*	*G. demissa*		
>10			*G. demissa* *Macoma balthica* *M. arenaria*	*Bittium alternatum* *G. demissa* *L. littorea*

[a]Based on mean abundance at any of the stations within the habitat. See Appendix Table 3 for abundance data. Species presented alphabetically within abundance categories.

The tidal creeks on Wetland 2 supported populations of filter feeding bivalves (Mya arenaria and Mercenaria) as well as the deposit feeding Macoma balthica. Mya and Macoma are often associated with salt marsh creeks (MacDonald 1969 a,b). Sediment-grazing gastropods were in evidence during June. Three bivalve and two gastropod species were collected from Wetland 2 tidal creeks (Appendix Table 4).

Sediment textural differences between the two marshes (Table 4.1) is likely one factor affecting the diversity of their respective molluscan faunas. The two stations, 2T1 and 2T3, that contained the highest proportion of coarse sediments, also exhibited the highest number of bivalve species. Geukensia demissa was the only bivalve collected at any of the other stations. The presence of Littorina littorea at station 2T1 may have been related to its exposed location and secondarily, to its coarse substrate since this species is generally associated with rocky intertidal areas. Ilyanassa obsoleta, present in all sampling of Wetland 1 tidal creeks, occurred only occasionally at Wetland 2. In this case, the finer sediments occurring at Wetland 1 probably influenced the distribution.

4.3.2 Mud Banks

Geukensia demissa, the ribbed mussel, was the predominant member of the molluscan assemblage in the mud bank habitat on both wetlands (Table 4.6). This species has been reported to have a mutualistic relationship with Spartina alterniflora (Bertness 1984). The cordgrass provides an attachment surface for the mussel's byssal threads and Geukensia deposits fecal material providing a nitrogen source for plant growth. In addition, aggregations of the mussel help to stabilize the seaward edge of the marsh, reducing erosion from wave action.

Mya arenaria occurred in low numbers on both wetlands. Other than G. demissa and M. arenaria no other bivalves were collected from Wetland 1 mud bank stations. In addition to the two species occurring on Wetland 1, Macoma balthica, Mytilus edulis (blue mussels), Mercenaria mercenaria (hard clams) and Petricola pholadiformis (false angel wings) were found on Wetland 2. Differences in sediment grain size distribution between the two wetlands may contribute to the observed differences in species composition. Water quality characteristics (salinity and temperature) may also play a role in these differences.

Gastropods were present on mud bank stations on both wetlands. Ilyanassa obsoleta was abundant on Wetland 1 in June. Littorina littorea was abundant during both collection periods on Wetland 2. Its presence on Wetland 2 might be influenced by higher energy there than at Wetland 1. Bittium alternatum occurred on Wetland 2 in September.

4.3.3 Habitat Comparisons

Analysis of variance was conducted to assess differences among stations, between sampling periods and among station sampling period groups on four parameters - number of bivalve taxa, total bivalve abundance, number of gastropod taxa and total gastropod abundance (Table 4.7). The number of bivalve taxa was significantly different among stations but the groups of similar stations were not distinct from one another. Several Site 2 stations (2T1, 2M4, 2T3) had the largest number of taxa, followed by the mud bank stations from Wetland 1. Tidal creek stations from Wetland 1 had the lowest number of taxa - one (Geukensia) or zero. The six stations with the smaller numbers of taxa were also those with the lowest abundances (Table 4.7). Site 1 mud bank stations had the highest bivalve abundances since random sampling fell within patches of ribbed mussels.

Only four gastropod species were collected in the shellfish quadrats. Tidal creek stations never contained more than one species in any collection. Three mud bank stations (2M4, 2M5, 1M5), however, were inhabited by two or more gastropod species in at least one sampling period.

Gastropod abundance station groupings fell in roughly the same order as a number of taxa. Significant differences in station x sampling period groups were detected (Table 4.7). Highest abundances in occurred in September Wetland 1 tidal creek stations and June mud bank samples (stations from both sites).

4.3.4 Population Size Structure

Shell length data were obtained for all bivalve individuals collected as part of the current study. Mean length and size class distribution for the dominant bivalve, Geukensia demissa and the commercially valuable Mya arenaria are presented in Table 4.8 and Figures 4-8, 4-9 and appendix figures.

The mean size of ribbed mussels (Table 4.8) was probably not different among stations or wetlands since the means generally fall within one standard deviation of each other. Apparent differences might be attributable to a number of factors. For instance, the number of individuals varied widely among the samples. Location within a patch of mussels can affect the size of the individuals. Mussels on the edge of the aggregate could potentially be larger, since they are less crowded and have less competition for food than those in the center. Since some of the mussel patches observed in the study area were up to two meters across, it is quite possible that the random sampling did not evenly sample different locations in the patches. Finally, there may be real environmental differences (e.g., salinity, temperature, grain size, turbidity, contaminants) that affect the growth of mussels at the various sites sampled. Hampson and Moul (1978) observed that Geukensia was virtually the only species to recover within a few years fromthe effects of a

TABLE 4.7. RESULTS OF TWO-WAY ANOVAS AND SIGNIFICANCE TESTS ON VARIOUS PARAMETERS FROM 0.25 m^2 QUADRATS, NEW BEDFORD WETLANDS STUDY, 1987.

A. ANOVA RESULTS

	BIVALVES		GASTROPODS	
SOURCE	NO. OF TAXA	LOG ABUNDANCE	NO. OF TAXA	LOG ABUNDANCE
MONTH	NS	NS	NS	NS
STATION	*	*	*	*
INTERACTION	NS	NS	NS	*

B. LEAST SQUARES MEANS TEST ON STATIONS

	BIVALVES		GASTROPODS	
	NO. OF TAXA	LOG ABUNDANCE	NO. OF TAXA	LOG ABUNDANCE
INCREASING ABUNDANCE	2T1	1M6	2M4	2M4
	2M4	2M4	2M5	1T2
	2T3	1M5	1M5	2M5
	1M5	1M4	1T1	1M5
	1M4	2T1	1T2	1T3
	1M6	2T3	2T1	1T1
	2M6	2M6	1M4	2T1
	2T2	2T2	1M6	1M6
	2M5	2M5	1T3	1M4
	1T2	1T2	2M6	2T2
	1T1	1T1	2T2	2M6
	1T3	1T3	2T3	2T3

C. LEAST SQUARES MEANS TEST ON MONTH X STATION GASTROPOD ABUNDANCE

S	S	S	J	J	J	S	S	S	J	J	J	S	S	J	J	S	S	J	J	J	J	S	S
2	2	1	2	2	1	1	2	1	1	2	1	2	2	1	2	2	1	1	2	1	2	1	1
T	T	M	M	T	T	M	M	M	T	T	T	T	M	M	T	M	T	M	M	M	M	T	T
3	2	6	6	3	3	4	6	5	2	2	1	1	5	4	1	4	1	6	5	5	4	3	2

INCREASING ABUNDANCE

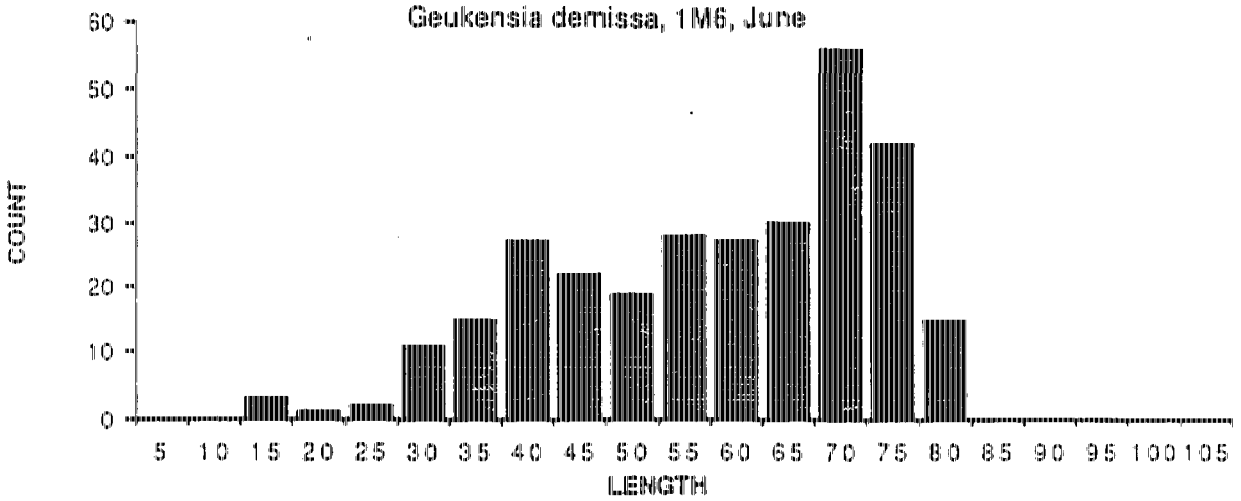
TABLE 4.8. MEAN (mm) AND STANDARD DEVIATION OF SHELL LENGTH OF *GEUKENSIA DEMISSA* AND *MYA ARENARIA* AND NUMBER COLLECTED (REPLICATES SUMMED), NEW BEDFORD WETLANDS STUDY, 1987.

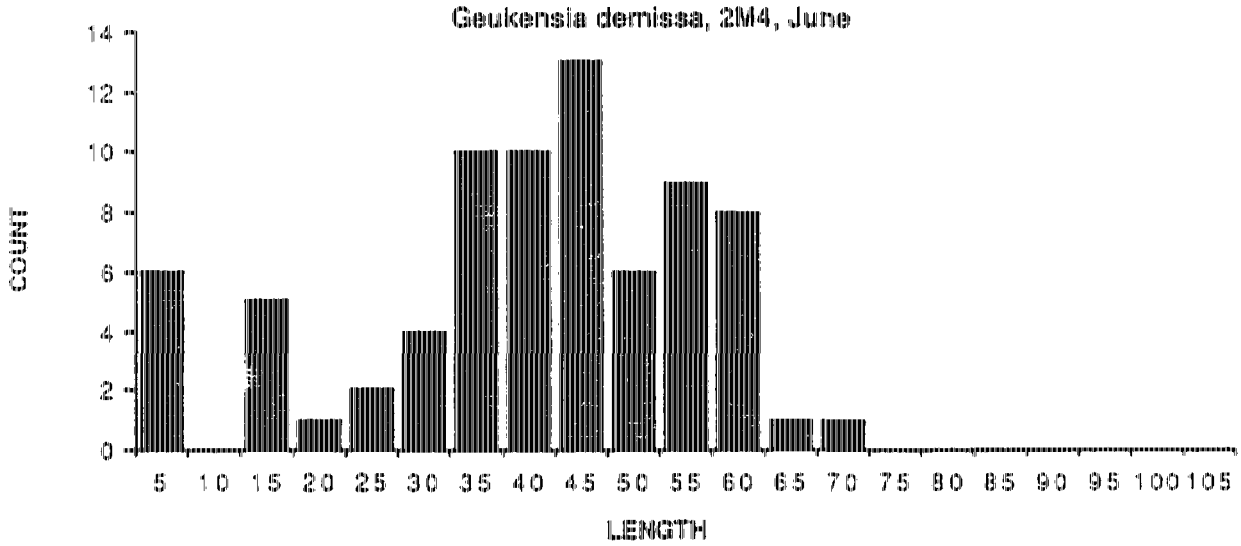
GEUKENSIA DEMISSA

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1	54	(-)	1	--		
1T2	58	(-)	1	--		
1T3	--			--		
1M4	29.4	(17.78)	10	37.1	(16.20)	47
1M5	44.1	(16.70)	55	29.8	(14.84)	8
1M6	56.4	(15.26)	299	65.4	(15.21)	125
2T1	58.5	(3.54)	2	58	(-)	1
2T2	72	(-)	1	73.3	(14.11)	12
2T3	--			54.0	(40.26)	3
2M4	37.9	(15.91)	76	42.0	(9.78)	19
2M5	--			--		
2M6	66.6	(28.17)	7	72.1	(11.42)	9

MYA ARENARIA

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1	--			--		
1T2	--			--		
1T3	--			--		
1M4	--			40	(-)	1
1M5	9.0	(2.00)	3	19	(-)	1
1M6	--			--		
2T1	33.8	(21.02)	16	39.7	(12.47)	11
2T2	--			--		
2T3	--			19.5	(14.85)	2
2M4	13.5	(7.78)	2	1	(-)	1
2M5	--			9	(-)	1
2M6	--			--		





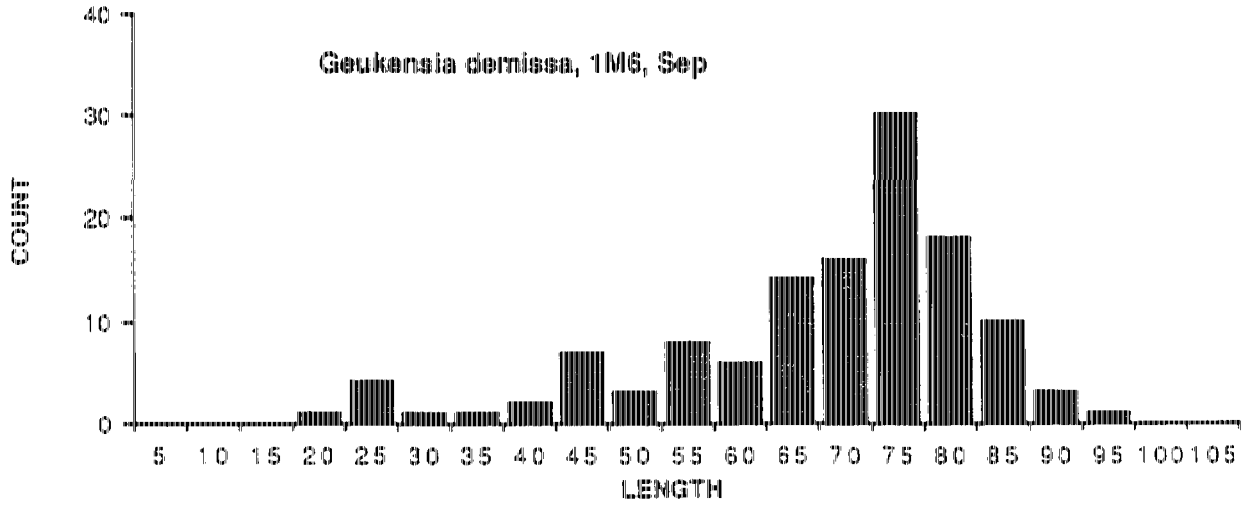


Figure 4-8. Shell length (mm) frequency distribution of Geukensia demissa collected at Stations 1M6 and 2M4 in June and 1M6 in September (replicates summed), New Bedford Wetlands Study, 1987.

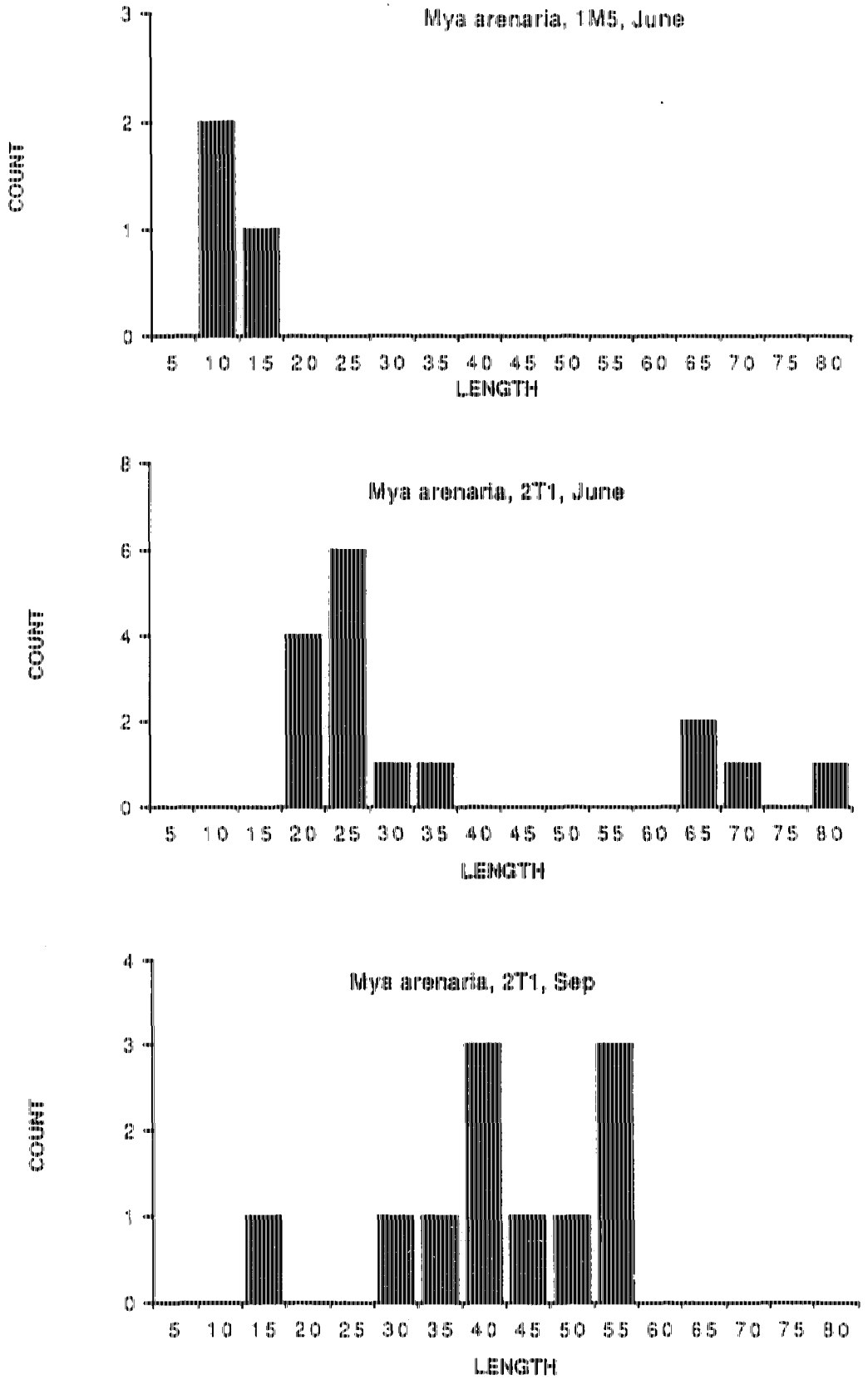


Figure 4-9. Shell length (mm) frquency distribution of Mya arenaria collected at Stations 2T1 in June and September and 1M5 in June (replicates summed), New Bedford Wetlands Study, 1987.

spill of Bunker C oil. If ribbed mussel populations experienced mortalities from exposure to PCBs, a comparison of length data between wetlands 1 and 2 suggests that the effects are no longer manifested in population structure, despite continued uptake of PCBs (see Section 10.2).

Rough age groups can be ascribed only to small mussels: one year old mussels - up to 10 mm; two year old mussels - up to 40 mm; three-four year old mussels - up to 60 mm. Older mussels may grow more slowly, depending on environmental conditions. This species is capable of surviving 10-20 years. Thus, stability of an aggregate or population of ribbed mussels is not dependent on frequent input of juveniles. Relatively low numbers of small Geukensia may be attributable to several factors such as preferential predation on small individuals, low recruitment rates, or intraspecific competition (crowding).

Few Mya arenaria were collected. Most of those occurred at Station 2T1 (Table 4.8, Figure 4-9). Shell lengths ranged from 10-80 mm. Based on growth rates observed in this species in Cape Ann, Massachusetts (Brousseau 1978), this indicates that recruitment occurred over a number of years. Growth rates immediately north and south of Cape Cod are likely to be similar since Massachusetts is approximately the middle of this species range. The smallest clams (10-15 mm) are probably young-of-the-year clams. Few Mya were collected from Wetland 1, none in the tidal creeks. Most were collected from Station 1M5, possibly because of the relatively large proportion of sand in the sediment there. Mya was found to be tolerant of moderate levels of PCB's (0.05-0.16 ppm) and metals in the ranges observed at the New Bedford Wetlands (SES 1988, and, Dec. 24) (Tsai, et al. 1979). However, the concentrations of PCBs observed in New Bedford Harbor are much higher than Tsai, et al. tested and they may reduce the success of recruitment of Mya to Wetland 1.

Collection of other bivalve species was sparse and was restricted to Wetland 2 as discussed earlier. Length frequency information for these species is presented in Appendix Tables 4 and 5 and appendix figures. These data are too limited to elucidate strong patterns.

The gastropods Littorina littorea and Ilyanassa obsoleta both distribute their larvae planktonically (Yamada 1987; Gooch et al. 1972). Thus, within an ecosystem such as the Acushnet River estuary - Buzzards Bay complex, it would be expected that population size class structures are similar throughout. This appeared not to be the case for Ilyanassa collected on Wetland 1 versus Wetland 2 (Table 4.9, Figure 4-10, appendix figures), although data from Site 2 may be less representative of the overall population due to the relatively low numbers of specimens collected. As suggested previously, sediment textural characteristics varied between the two wetlands, potentially contributing to the disparity in occurrence. Other environmental factors affecting growth could include sediment-borne contaminants either directly ingested by the gastropods or which inhibit production of benthic microalgae or salinity. PCBs, for example, are more concentrated at Wetland 1 and Wetland 2.

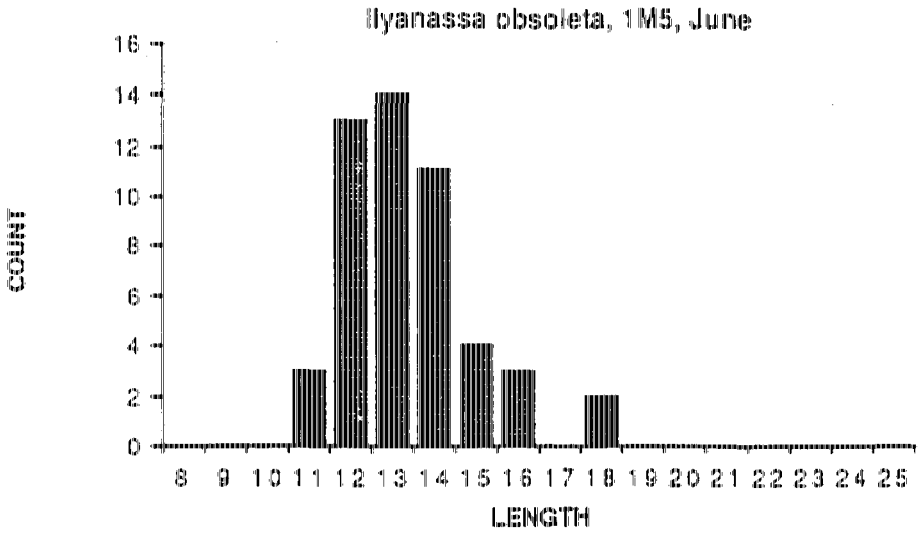
TABLE 4.3. MEAN (mm) AND STANDARD DEVIATION OF SHELL HEIGHT OF *ILYANASSA OBSOLETA* AND *LITTORINA LITTOREA* AND NUMBER COLLECTED (REPLICATES SUMMED), NEW BEDFORD WETLANDS STUDY, 1987.

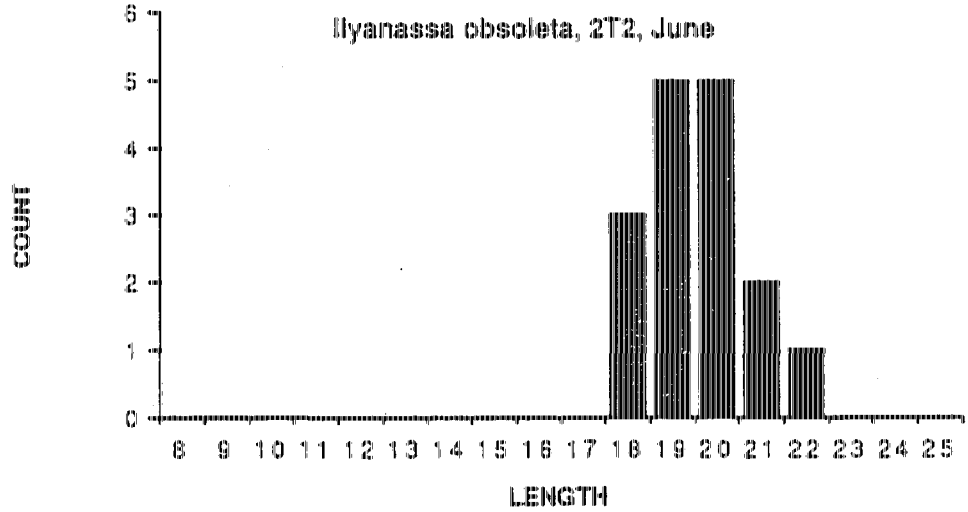
ILYANASSA OBSOLETA

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1	14.8	(1.48)	5	14.7	(1.34)	24
1T2	16.2	(1.28)	4	17.0	(1.36)	95
1T3	16.0	(-)	1	17.1	(1.99)	68
1M4	14.4	(1.17)	17	12	(-)	1
1M5	13.4	(1.58)	50		--	
1M6	15.5	(1.50)	192		--	
2T1		--		23.0	(1.41)	6
2T2	19.6	(1.15)	16		--	
2T3		--			--	
2M4	20.5	(1.87)	6		--	
2M5	20.5	(0.71)	2		--	
2M6		--			--	

LITTORINA LITTOREA

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1		--			--	
1T2		--			--	
1T3		--			--	
1M4	13.3	(1.37)	6		--	
1M5	15.0	(0)	3	11.5	(0.71)	2
1M6		--			--	
2T1	14.3	(2.61)	11		--	
2T2		--			--	
2T3		--			--	
2M4	15.1	(3.89)	57	16.9	(2.97)	21
2M5	16.8	(3.03)	32	17.0	(1.73)	3
2M6		--			--	





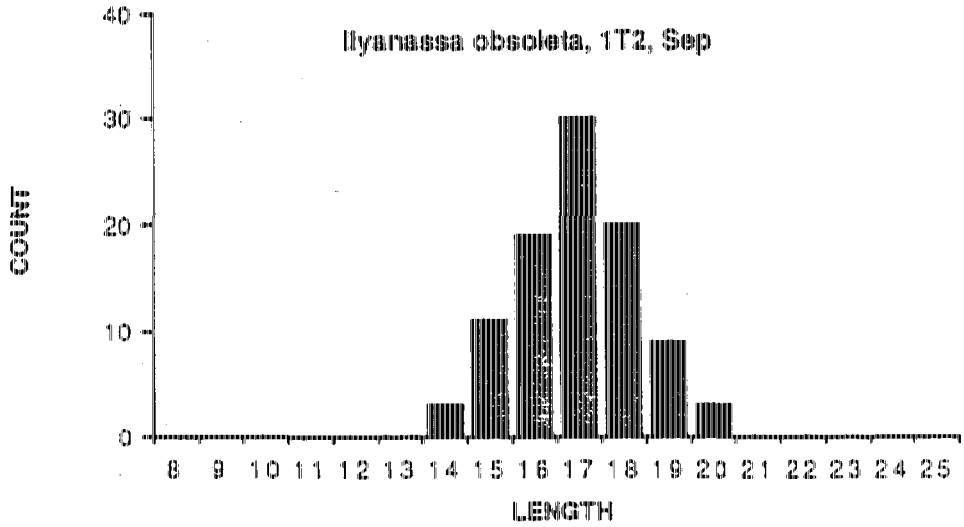


Figure 4-10. Shell height (mm) frequency distribution of *Ilyanassa obsoleta* collected at Stations 1M5 and 2T2 in June and 1T2 in September (replicates summed), New Bedford Wetlands Study, 1987.

Littorina littorea occasionally occurred in moderate numbers, particularly at mud bank stations 2M4 and 2M5. Size class structure exhibited no differences between these stations or between sampling periods (Table 4.9, Figure 4-11, appendix figures).

The size class data collected on other gastropods is presented in Appendix Table 7 appendix Figures. The collection of Melampus bidentatus was incidental, since this species generally resides in the Spartina patens zone. The small size of the Bittium alternatum collected suggests recent recruitment. Absence of larger specimens may indicate that the marsh environment, in general, provides unsuitable habitat for this species.

4.4 QUALITATIVE ASSESSMENT OF WETLANDS 1, 2, 3, 4, 5 AND 9

4.4.1 Wetland 1

Wetland 1 is located along the eastern shoreline of the upper Acushnet River estuary, extending more than 1 km in length. All typical salt marsh vegetative zones are represented on this wetland. There is one major tidal creek dissecting the northern end of the marsh. Depth of the creek is about 2 m, width at the mouth is greater than 5 m. The marsh is extensively ditched laterally and longitudinally, but openings to the river are generally narrow (<0.5 m). One ditch, however, widens to form a small mud flat (location of Station 1T1, Figure 4-1) behind a Spartina alterniflora bed, in the shadow of an intertidal sandbar. The southern boundary of the marsh is an arm of the Acushnet River.

The seaward edge of the marsh is generally marked by a peat bank rising from 15-30 cm above the intertidal flat along its face. Dense aggregates of ribbed mussels (Geukensia demissa) are present intermittently along this bank, as indicated by the quantitative sampling. Uca pugnax (fiddler crab) burrows were observed in the S. alterniflora zone, particularly in the creeks and ditches. In some cases, S. alterniflora grows down the bank to the tidal flat, although generally the slope is bare of grass.

The character of the sediments of the intertidal flat seaward of the marsh varied substantially along the marsh. In several areas, including north of the tidal creek, the flat just seaward of Station 1T1 and along the southern periphery of the marsh, the flat was unconsolidated mud covered extensively (in October) with Ulva lactuca (sea lettuce). This macroalga is typically grazed upon by such species as Littorina littorea, the black duck and the brant goose. Ulva can also enhance the mud flat environment for amphipod production. The area north of the creek was sampled for mollusks (Figure 4-3), but none were recovered (Table 4.10). In a Salem Massachusetts mud flat of similar textural characteristics, the area occupied by Ulva exhibited low infaunal abundances (NAI 1987). Intertidal Ulva production is usually seasonal since the species is easily subject to desiccation from high temperatures or extended day length.

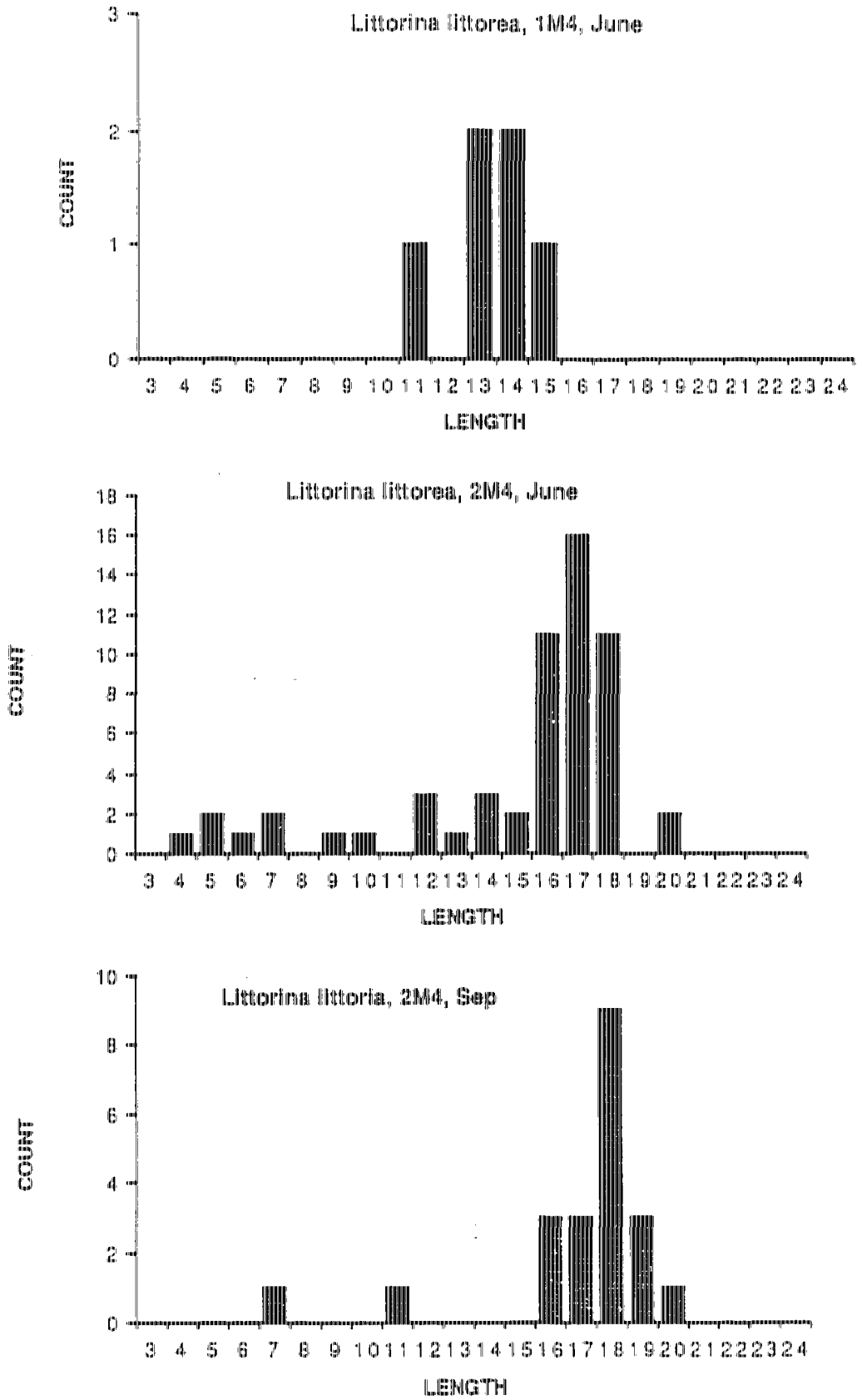


Figure 4-11. Shell height (mm) frequency distribution of *Littorina littoria* collected at Stations 1M4 and 2M4 in June and 2M4 in September (replicates summed), New Bedford Wetlands Study, 1987.

Sediments at the mouth of the tidal creek and the flat about 100 m south of the creek were predominantly sandy with noticeable gravel mixed in. There were few mussels along the bank in this area. The mud flat off of 1T1 is buffered to the seaward side with a sand bar. Empty sand tubes of Pectinaria and hinged Mya shells were scattered on the sand surface. A sample collected near the marsh on this sand (Figure 4-3) revealed the presence of living Mya arenaria, Mercenaria mercenaria and Macoma balthica. Abundance and shell-length data are presented in Tables 4.10, 4.11 and Figure 4-12. Sandy patches also occurred along the southern periphery of the marsh. Approximately 30-40% of the flat could be characterized as predominantly sandy. Sediments in the remaining flat area (circa 30%) represented a gradation between the unconsolidated mud and the sand habitats. This type of substrate is probably more conducive to support of shellfish populations than the unconsolidated mud.

A portion (about 20% of the marsh bank along the river-marsh interface shows signs of erosion - a stepped effect. This was much more evident in the southern third of the marsh and was particularly obvious in areas where intertidal flat sediments tended towards coarse material. Storm events or ice rafting may have been responsible for this effect. Sediments on or adjacent to Wetland 1 contained PCBs ranging from 0.15-1900 ppm (SES 1987), among the highest in the estuary.

4.4.2 Wetland 2

Wetland 2 is located outside of the estuary, to the east in Buzzard's Bay and is oriented so that the marsh-open water interface faces south. This location and orientation make it the most exposed marsh encompassed by this study. Although its total area is similar to that of Wetland 1, the linear extent of the marsh-open water interface is less on Wetland 2 than Wetland 1 if tidal creek lengths are excluded. Two major creeks trisect Wetland 2. Both have mouths 6-7 m across; depths may vary from 1-2.5 m along the length. This marsh is extensively ditched. Like Wetland 1, Wetland 2 supports all typical vegetation of a fully developed saltmarsh.

The exposure of the marsh is evident in a number of features of the marsh-open water interface. The tidal flat is predominantly sandy rather than muddy. Coarse sediments extend well into the tidal creeks. Marsh banks facing Buzzard's Bay are severely eroded in places. Many areas of peat along the bank are unvegetated. Like Wetland 1, the marsh bank is scattered with dense aggregates of ribbed mussels. Littorina littorea was abundant along the marsh face.

The varying sediment conditions in the tidal creeks were probably a key factor in the enhanced diversity of macrobenthic species observed at Wetland 2 compared to Wetland 1 (Tables 4.2, 4.6). Additional shellfish samples were not collected at this wetland because the randomized quantitative sampling had

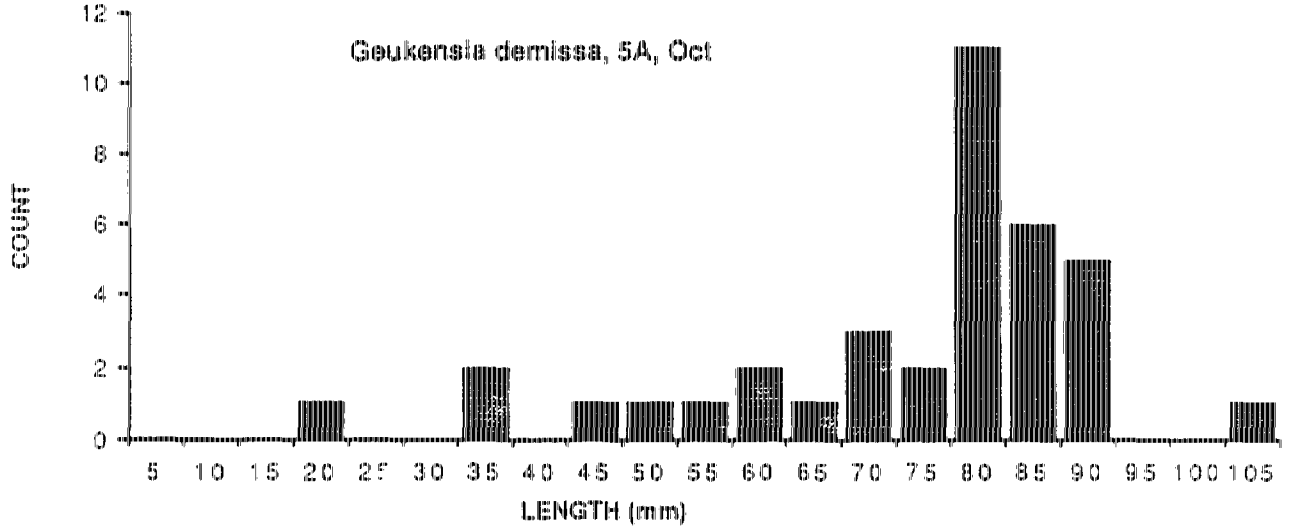
TABLE 4.10. ABUNDANCE (no./m^2) OF MOLLUSKS COLLECTED IN 0.0625m^2 QUADRAT DURING QUALITATIVE MARSH ASSESSMENT, NEW BEDFORD WETLANDS STUDY, 1987.

SPECIES	STATION 1A	1B	3A	3B	3C	4A	4B	5A	5B	5C	5D	9A	9B
Geukensia demissa						416		592			32	384	512
Mya arenaria	176									128			16
Mercenaria mercenaria	16												
Macoma balthica	32												
Littorina littorea										160		96	80
Ilyanassa obsoleta								64	560	128			
TOTAL BIVALVES	224	0	0	0	0	416	0	592	0	128	32	384	528
TOTAL GASTROPODS	0	0	0	0	0	0	0	64	560	288	0	96	80

TABLE 4.11. MEAN (mm) AND STANDARD DEVIATION OF SHELL LENGTH (BIVALVES) OR HEIGHT (GASTROPODS) AND NUMBER COLLECTED DURING QUALITATIVE MARSH SURVEY, NEW BEDFORD WETLANDS STUDY, 1987.

SPECIES		STATION[a] 1A	4A	5A	5B	5C	5D	9A	9B
Geukensia demissa	x		66.3	72.2			74.5	64.7	66.5
	SD		12.47	17.83			7.78	9.92	7.63
	n		26	37			2	24	32
Mya arenaria	x	24.0				30.7			33
	SD	8.81				10.09			—
	n	11							
Mercenaria mercenaria	x	45							
	SD	—							
	n	1							
Macoma balthica	x	21.0							
	SD	0.00							
	n	2							
Littorina littorea	x					12.2		20.2	20.2
	SD					3.74		3.71	3.19
	n					10		6	5
Ilyanasa obsoleta	x			15.0	16.5	15.4			
	SD			0.00	1.63	2.07			
	n			4	35	8			

[a]No mollusks occurred in samples from Stations 1B, 3A, 3B, 3C, 4B.



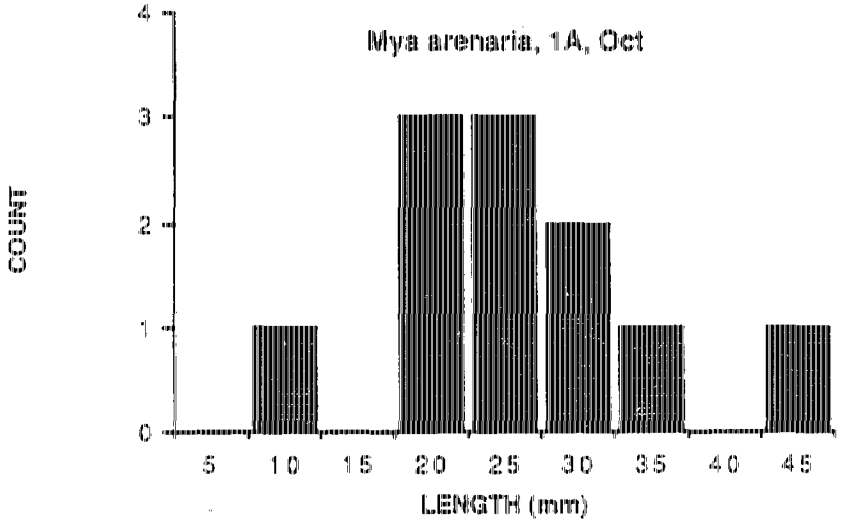
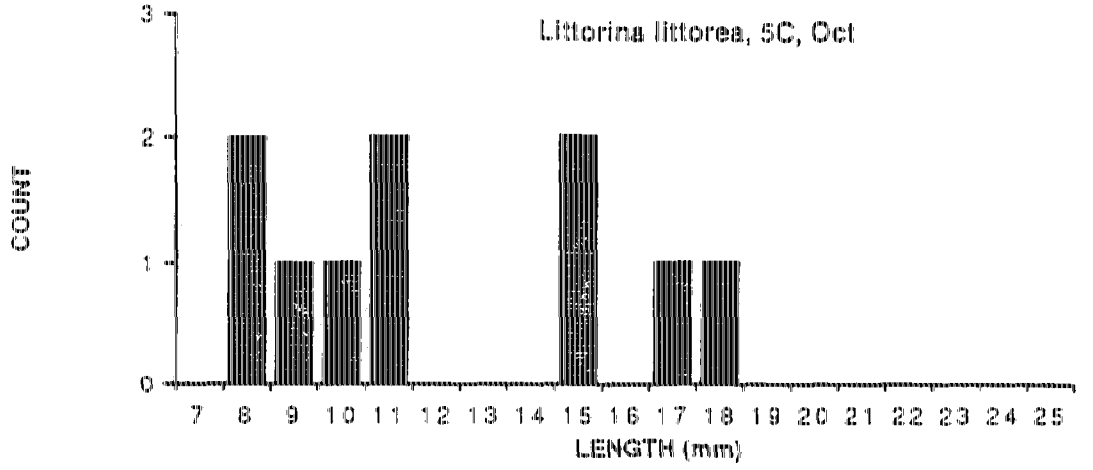
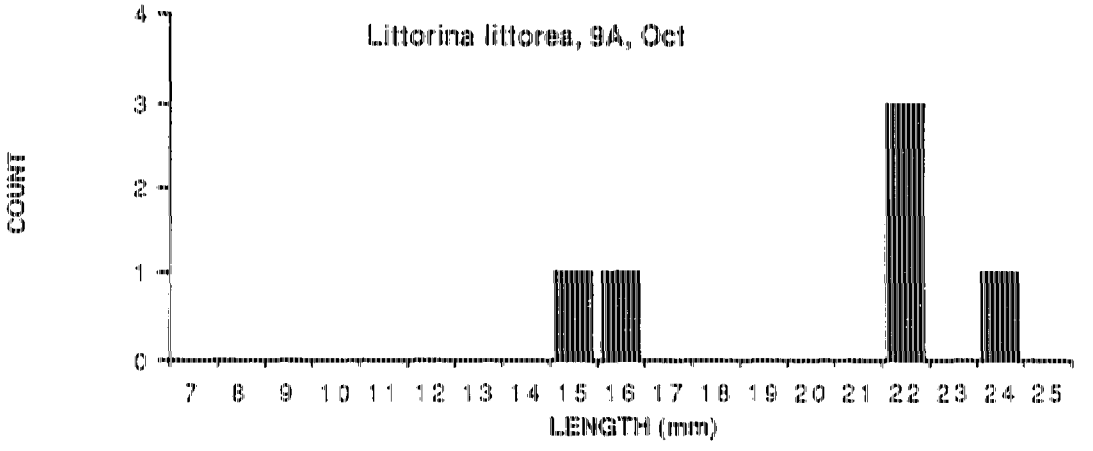


Figure 4-12. Shell length distribution of Geukensia demissa from station 5A and Mya arenaria from station 1A collected in October, New Bedford Wetlands Study, 1987.





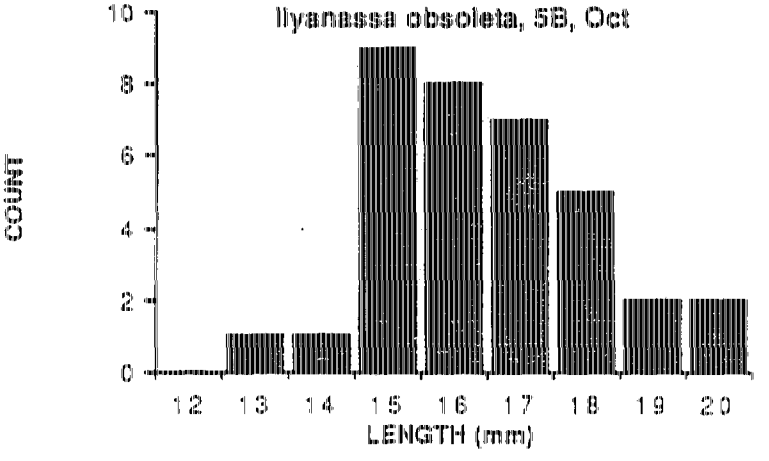


Figure 4-13. Shell height distribution of *Littorina littorea* from stations 5C and 9A and *Ilyanassa obsoleta* from station 5B collected in October, New Bedford Wetlands Study, 1987.

revealed a more extensive species composition than at Site 1. Fiddler crabs were very abundant in parts of the Spartina alterniflora zone up in the creeks. Wetland 2 sediments contained the lowest levels of PCBs among the study of marshes.

4.4.3 Wetland 3

Wetland 3 is located directly north of Wetland 1 (Figure 4-4). The marsh fringes a southerly-directed arm of the river, connected landside to a drainage ditch and is protected from any storm-induced wave action by this orientation. On the day of the visit, water flowed in the stream bed even at dead low water due to flow from the drainage ditch. The greatest width separating the two sides of the marsh is 300 m. Depth from the creek bed to the Spartina alterniflora zone is 1-2 m.

The area between the arms of the marsh is an unconsolidated mud flat. Much of it was heavily vegetated with Ulva. Swans were observed offshore of this flat on several visits. The mud smelled and looked oily. The marsh and associated mud flat contained highlevels of PCBs (SES 1987, stations L5, M5, N7), undoubtedly a significant factor in the biological conditions.

Several areas were sampled for shellfish (Figure 4-4) but no mollusks were recovered (Table 4.9). The difficulty in obtaining sufficient biomass of ribbed mussels for body burden analysis supports an assessment of extremely low molluscan productivity. Fiddler crabs were not observed on this site either.

Although invertebrate production associated with Wetland 3 appears to be low, the Ulva production on the mud flat this marsh surrounds might support invertebrate and avian faunas.

4.4.4 Wetland 4

Wetland 4 (Figure 4-5) is located on the eastern shoreline of the river just south of the Route I-195 bridge in the lee of a point of land extending into the river. The narrow band of salt marsh on Wetland 4 surrounds a cove. Sediments in the cove were unconsolidated mud. There was scattered Ulva cover on the mud flat.

Ribbed mussels were abundant throughout the tall Spartina alterniflora zone Station 4A; Table 4.10). At the intersection of the marsh and mud flat, however, no evidence of other molluscan fauna was observed (Station 4B; Table 4.10). Fiddler crab burrows were not observed on this marsh. PCB concentrations in the low marsh ranged from 10 to 290 ppm and may have reduced the potential molluscan diversity.

4.4.5 Wetland 9

Wetland 9 (Figure 4-6) is a small stand of Spartina on a gravel beach, south of the prominence protecting Wetland 4. Although Wetland 9 maybe shadowed by the downstream Popes Island, substrate textural characteristics suggest that it is likely this wetland is exposed to the effects of most significant storm events. Because of its coarse sediments and distance from the source, this site contains relatively low levels of PCB. Fauna is affected by the grain size rather than contaminants.

Ribbed mussels are uniformly distributed throughout the tall Spartina alterniflora and the gravel areas between the stands of cord grass. Littorina littorea was also uniformly scattered in the gravel (Tables 4.10, 4.11). These species predominated in the samples collected. The intertidal flat below the marsh was sandy mud-potentially good habitat for other mollusk species.

4.4.6 Wetland 5

Wetland 5 (Figure 4-7) is located on the western side of the Acushnet River across from the southern section of Wetland 1. Spartina alterniflora forms a narrow fringe around a cove with a few isolated clumps in the cove. Substrate in the cove is predominately unconsolidated mud. A spit of land extends into the cove in the southern portion of the gravel.

Several areas along the edge of the marsh were sampled (Figure 4-7) for shellfish. Ribbed mussels were abundant in one sample (Table 4.10) and were observed throughout the Spartina alterniflora. Sizes of the mussels fell within the range observed in the quantitative sampling of Wetlands 1 and 2. Mya arenaria was abundant in the sandy intertidal area. The size range suggests that these specimens had been recruited more than a year before sampling. Littorina littorea and Ilyanassa obsoleta were also abundant on the flat and marsh. Uca burrows were common in the Spartina.

Like the other in-harbor wetlands, much of the unconsolidated tidal flat at Site 5 supported Ulva lactuca. Unique to this site though was the presence of Fucus in the southern area. Gammarid amphipods were observed among these algae. Level of PCBs varies within the site, but can be nearly as high as values recorded at Wetland 1.

4.5 DISCUSSION

4.5.1 Wetlands 1 and 2

A comparison of the benthic communities between Wetland 1 and Wetland 2 is complicated by physical differences of the Wetlands as described in Sections 4.2.1, 4.4.1 and 4.4.2. Most striking are the differences in sediment characteristics among the stations (Table 4.1), often a major determining factor in species distribution. The array of sediment particles resuspended by the local currents will also differ. Based on the relationship of particle

size and current speed (Hjulstrom 1939), sediment particles at Wetland 2 measuring less than 4.5 mm, at least 98% of the surface sediments at all stations except 2T1, could be resuspended by the estimated 0.6 K current speed (SES 1988). Current speeds at Wetland 1, estimated at 0.2 K (SES 1988) could potentially transport particles measuring less than 1.4 mm, or an average 96% of all surface sediments. Another potential, although untested, difference might be differences in contaminant levels between the two wetlands. Wetland 1 is located just downstream from the PCB hot spots in the Acushnet River (SES 1987), while Wetland 2 is located more than 6 km from this area. In addition, fine grained sediments tend to have a higher affinity for contaminants than coarse grained sediments do. Wetland 1 tidal creek stations exhibited a higher proportion of fine grained sediments compared to the same habitat on Wetland 2, suggesting a greater potential for contaminant concentration at Wetland 1. As indicated in Section 2.4, PCB levels are substatially higher on and around Wetland 1 then Wetland 2.

There were marked differences in infauna between tidal creeks on Wetlands 1 and 2. Dominant species on Wetland 1 were similar to those dominating the mean low water zone near the salt marsh in Hampton Harbor, New Hampshire (NAI 1985). Many of the taxa at Wetland 1 were surface deposit feeders and burrowing deposit feeders. The dominant taxa (Oligochaeta, Capitella sp., Streblospio benedicti) are generally considered to be opportunistic, resistant to pollutants (Grassle and Grassle 1974). Diversity was low, indicative of a stressed environment, as estuaries generally are (Rhoads et al. 1978). The shellfish fauna, too, was depauperate in Wetland 1 tidal creeks. Only two species were represented.

There were three times as many infaunal species in the creeks on Wetland 2 than at Wetland 1 (Table 4.4), with particular differences in polychaetes and bivalves. Although deposit feeders still predominated, many species encountered at Wetland 2 are suspension feeders. Resuspended sediments at Wetland 2 are likely to be coarser, and remain in suspension for a shorter period of time than sediments at Wetland 1. This situation would be advantageous to filter feeders as chances for clogging filter apparatus with fine particles would be decreased (Sanders, 1958).

A greater variety of mollusks (Table 4.5) occurred at Wetland 2 than at Wetland 1. Most of the bivalves occurring in this habitat at Wetland 2 but not Wetland 1 are filter feeders, again suggesting that differences in turbidity or sediment texture affected species composition.

The same taxa dominating tidal creek fauna at Wetland 1 were also numerical dominants in the mud banks. Several amphipod species were also moderately abundant in the mud banks. These species generally have a strong association with the marsh grasses, either as detritivores or grazers of microorganisms associated with the plants (Daiber 1982).

Species composition in Wetland 2 mud banks varied from that observed at Wetland 1. Like tidal creeks, mud banks on Wetland 2 exhibited higher diversity, particularly among polychaetes, bivalves and amphipods. The higher

proportion of organic material and fine grained sediments at Wetland 2 may offer an enhanced habitat value for deposit feeders and detritivores over Wetland 1. In addition, several filter feeders not present on Wetland 1 were present Wetland 2.

Mud banks on neither wetland support a wide array of mollusks. The dominant bivalve, Geukensia demissa, is especially adapted to existence in and near the Spartina alterniflora zone by its ability to "air gape" (Daiber 1982). Air-gaping increases the efficiency of aerial respiration. This was the only species collected in sufficient numbers to make comparisons of size distributions feasible. It is unlikely that size differences existed in Geukensia populations on the two wetlands.

The higher diversity at Wetland 2 compared to Wetland 1 suggests that the Buzzard's Bay marsh provides a more conducive environment for benthic fauna than the Acushnet River site. As indicated in the results section and preceding discussion, several characteristics contribute to these differences. Wetland 2 exhibited a greater variety of substrates (as evidenced in grain size values) than Wetland 1. This provides greater opportunities for species which are sediment-specific. PCBs are considerably lower at Wetland 2. Wetland 2 is subject to stronger currents and more wave action.

4.5.2 Wetlands 1, 2, 3, 4, 5 and 9

The qualitative and quantitative surveys conducted on the Acushnet River salt marshes and Wetland 2 in Buzzard's Bay provide a means for assessing ecological value of these wetlands. Part of the ecological value of Wetlands 1 and 2 derives from the areal extent of these marshes. In addition, both include a variety of intertidal habitats which contribute to the potential primary and secondary (invertebrate) production. As indicated in earlier sections, some of the biological differences in the sites should be ascribed to physical differences in the sites - e.g., location in or out of the estuary, exposure to high energy environment, and the sedimentary environment.

The size of the marsh and abundance and diversity of fauna combine to indicate that Wetland 2 has the potential for contributing a high level of secondary production to the ecosystem. Although diversity is greatly reduced at Wetland 1, due to sediment characteristics, contaminants and current regime, the size (especially linear distance of marsh-open water interface) and elevated abundances of a few taxa suggest that invertebrate production on this wetland could make a substantial contribution to the system.

Wetlands 4 and 5 are both small fringing marshes associated with very soft mud flats. Ribbed mussels are prominent features of both sites. Wetland 5 offered a greater variety of microhabitats (determine by grain size) than Wetland 4, and consequently supported a greater variety of shellfish. No shellfish species were observed on Wetland 5 that weren't also observed at Wetlands 1 and 2, however.

Wetland 9 is located on a gravel beach. Although ribbed mussels and periwinkles were abundant, the gravel substrate is not especially conductive for benthic infauna. Coupled with its small size, the biological and physical characteristics of this site provide little feeding habitat for demersal fish and little likelihood of export of primary and secondary production.

Wetland 3 exhibited extremely low invertebrate production and very low diversity of shellfish compared to Wetlands 1 and 2. Although this marsh is large, it does not provide good feeding habitat for species feeding on benthic marine invertebrates.

5.0 FISHERIES

5.1 METHODOLOGY

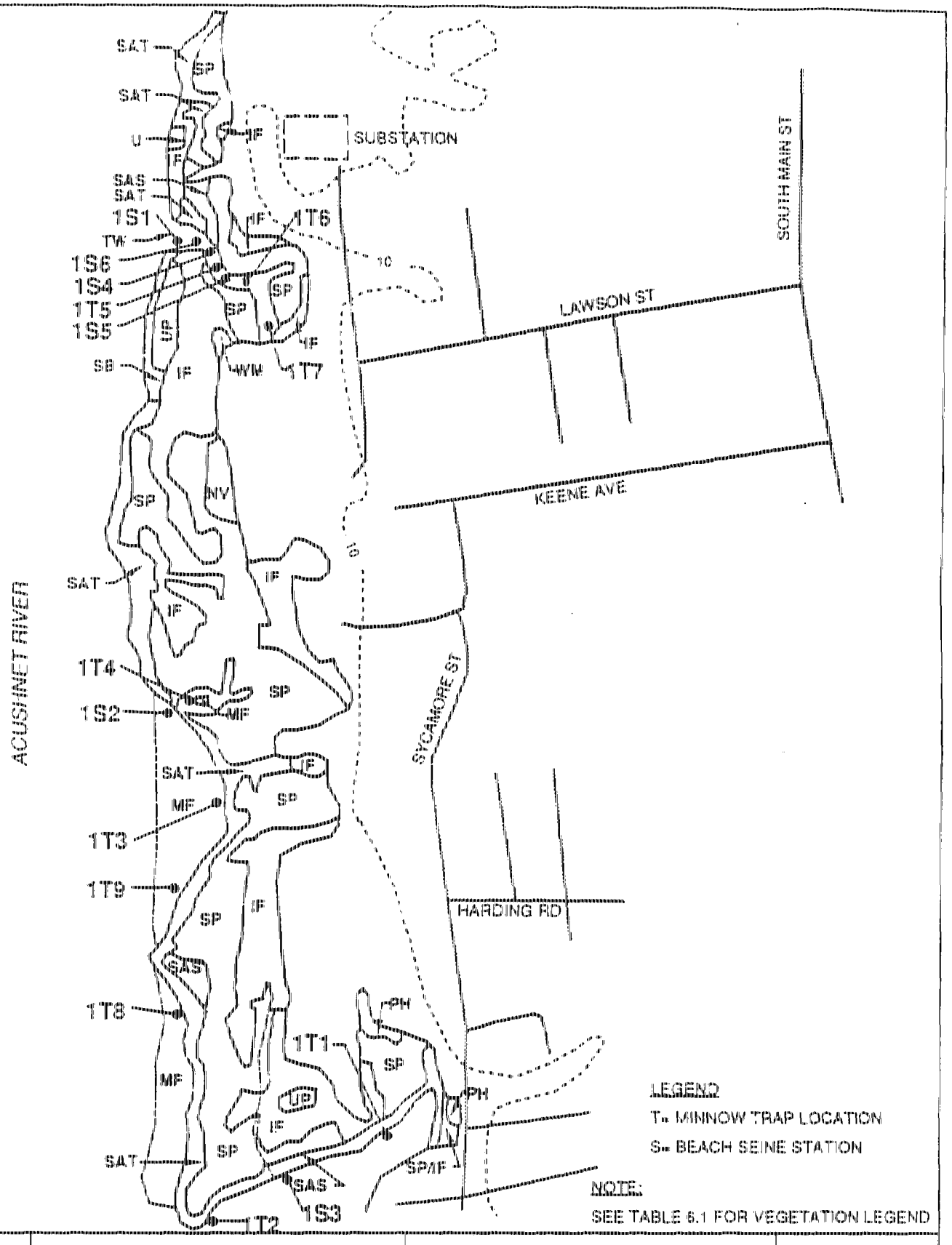
Fish populations were sampled in midsummer (28-30 July) at six salt marshes in the Acushnet River estuary study area (Wetlands 1, 2, 3, 4, 5, and 9, Figure 1-2). Sampling was conducted with beach seines and minnow traps in tidal creeks and along the edge of the salt marshes in order to determine the kinds and relative numbers of fishes utilizing the saltmarsh habitat, and to obtain specimens to be analyzed for gut contents and for concentrations of PCBs and heavy metals.

Commercially available minnow traps (1/4-inch mesh) were baited and set at from three to nine sites at each of the six marshes (a total of 34 stations; Figures 5-1 through 5-6). Each trap was set for two consecutive tidal cycles for a total of approximately 24 hours.

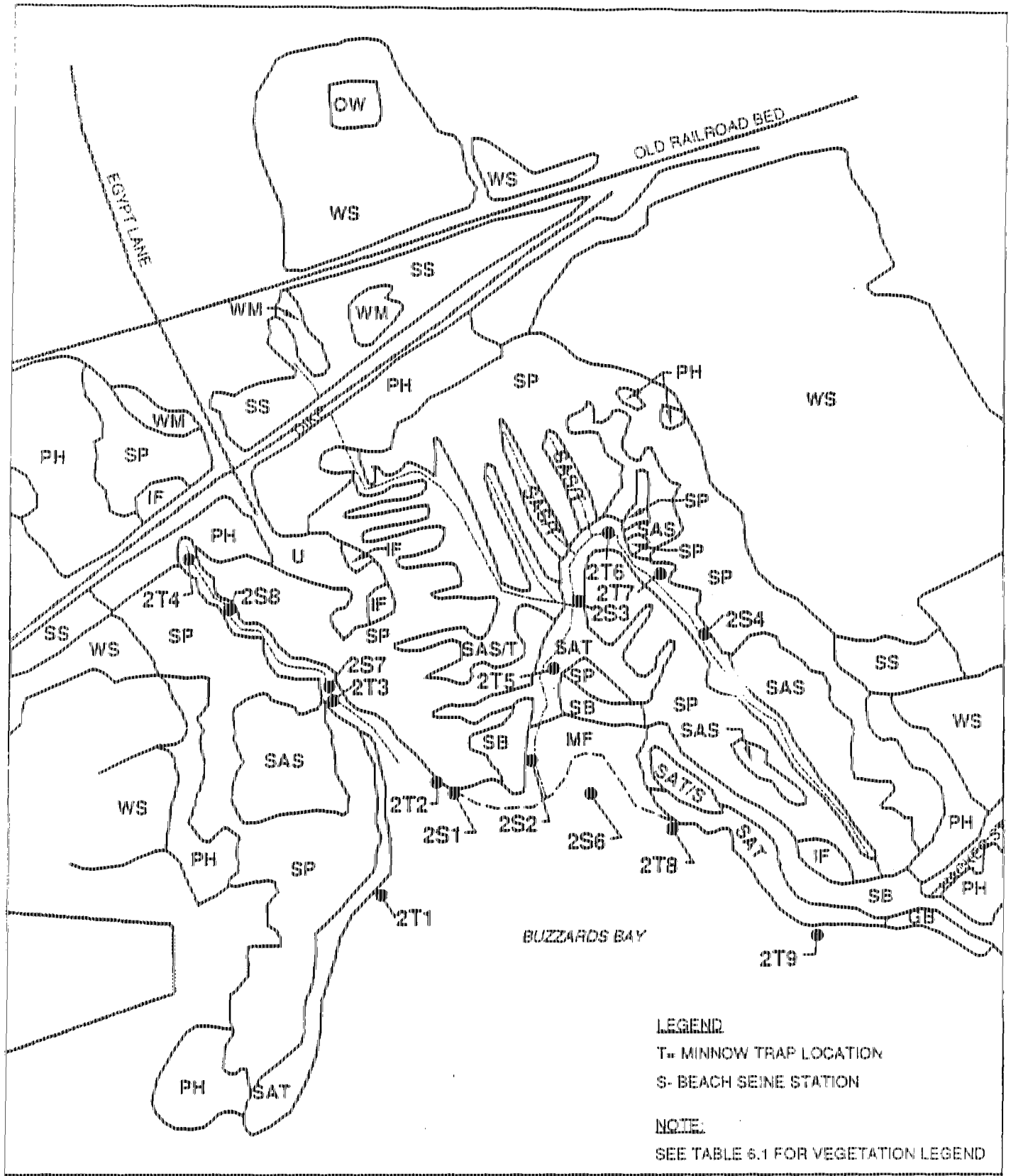
Seining was conducted with 3/8-inch mesh beach seines with overall dimensions of 50 by 6 feet or 25 by 4 feet. From three to eight seine hauls were taken at five of the six marshes, depending on the overall size of each marsh. Seining sites within each marsh were distributed at representative locations (Figures 5-1, 5-2, 5-3, 5-5, and 5-6). Method of deployment and choice of net size varied depending on the constraints of the individual site of a haul. Generally, the larger net was used along the edge of a marsh when there was a sufficiently wide area to work in. The smaller net was used in restricted inlets and tidal creeks. In very small areas in some cases the 25-foot seine was shortened by rolling part of it up on the pole at one end. The usual method of deployment was to hold one end at the shore while the other end was hauled out from shore and then around in an arc back to the shore. In some cases a larger area was sampled by hauling both ends in a parallel direction for some distance before hauling the net up onto the shore. The effort was directed at samping a variety of locations as effectively as possible rather than maintaining a rigidly uniform procedure.

As each seine or trap sample was collected, the fish were identified and counted in the field. Up to 20 specimens per species from each 12-hour trap sample and 50 specimens per species from each seine haul were preserved in formalin and returned to the laboratory for length and weight measurements. Length was measured as total length to the nearest millimeter, weight as wet weight to the nearest 0.1 gram.

Stomach contents were analyzed for the two key species, mummichog (*Fundulus heteroclitus*) and winter flounder (*Pseudopleuronectes americanus*). A total of ten full stomachs were examined for each species. Specimens of mummichogs for gut contents analysis were selected from a number of different samples to provide representatives of several different locations and sizes. For winter



SCALE: 1"= 461'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	FISH SAMPLING STATIONS AT WETLAND STUDY AREA NO. 1 JANUARY 1988 FILE No. NECIV-1	FIGURE 5-1 RES inc



SCALE:
1"= 400'

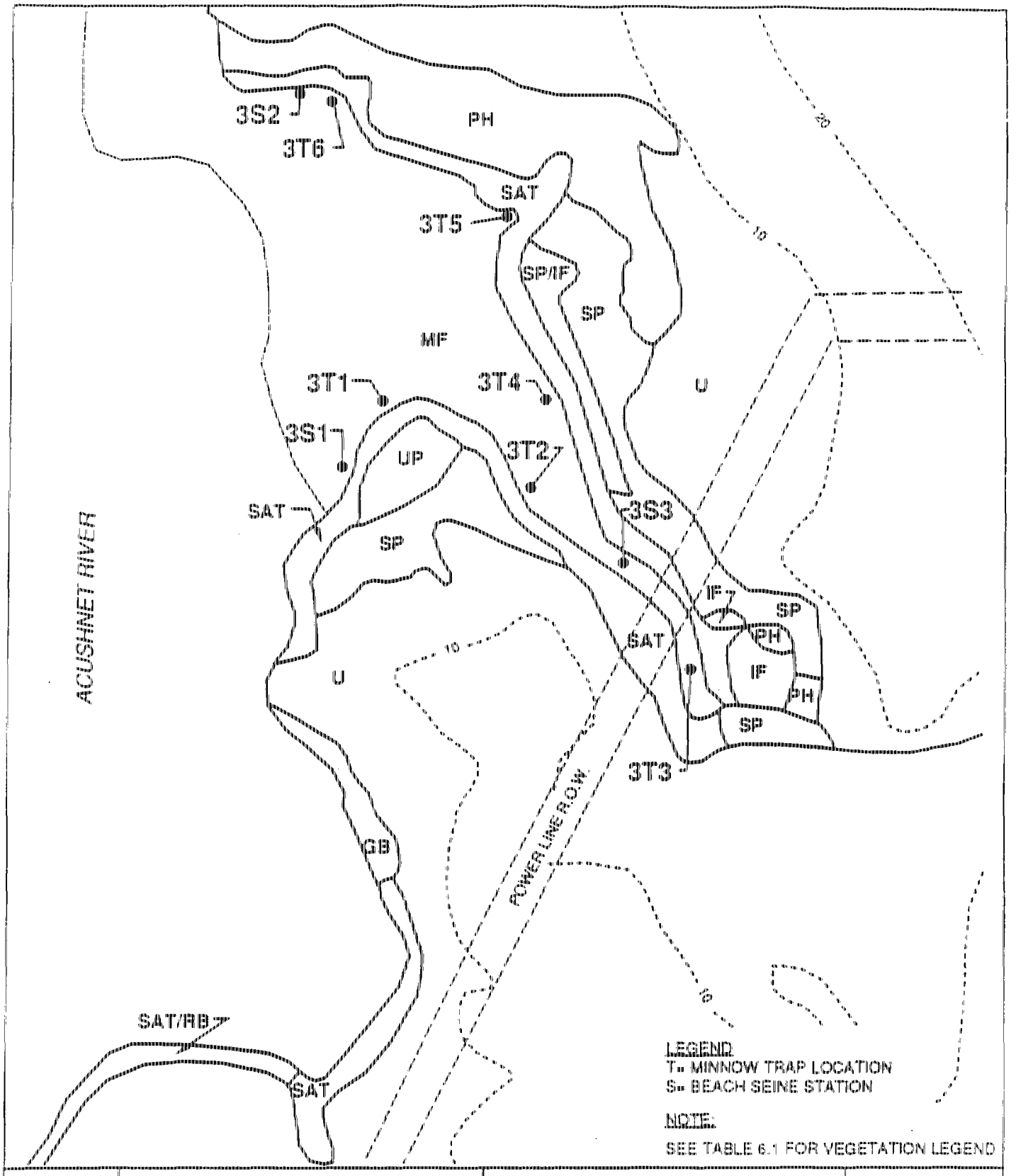
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

FISH SAMPLING STATIONS
AT WETLAND STUDY
AREA No. 2

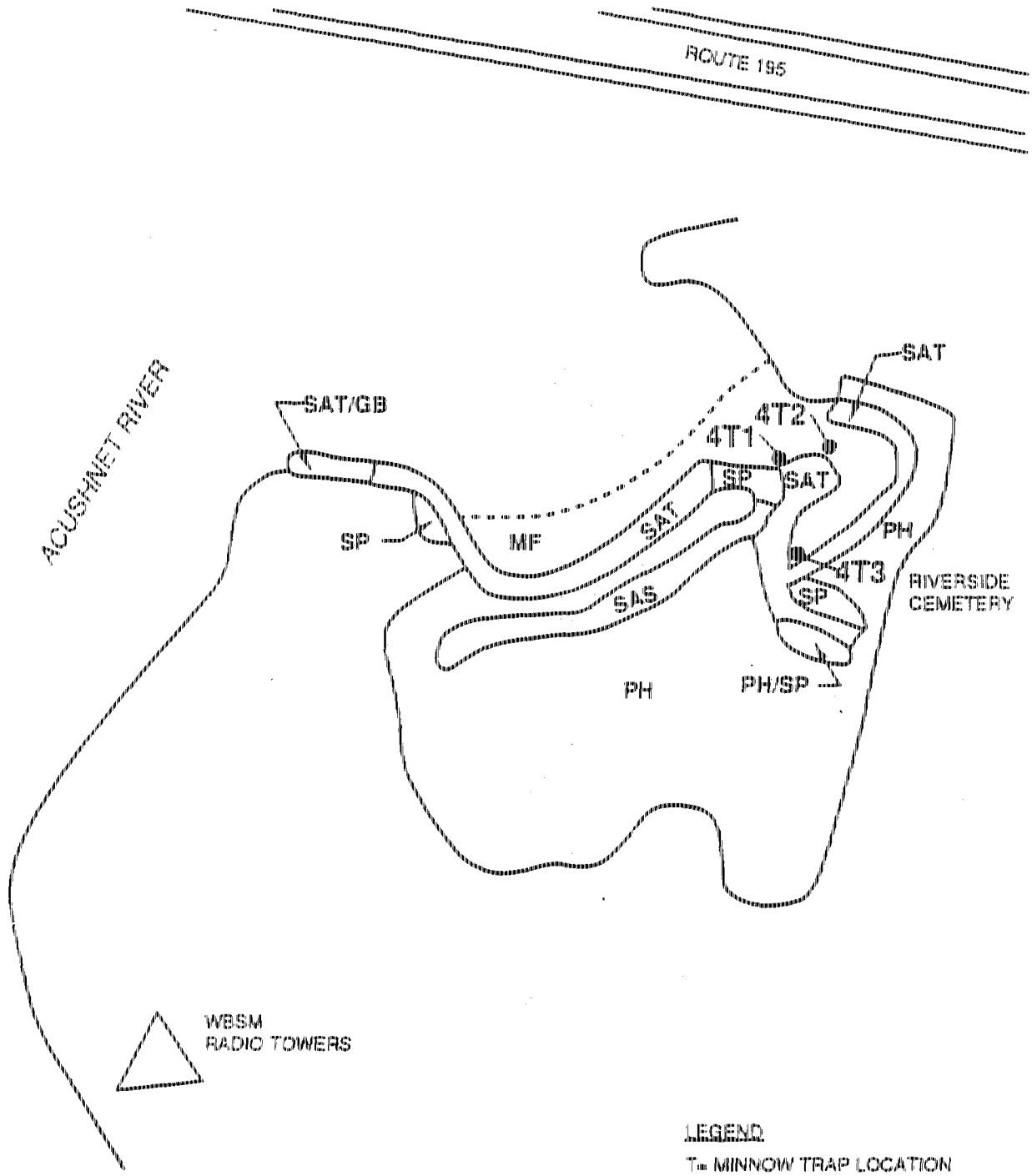
JANUARY 1988 FILE No. NECIV-1

FIGURE 5-2

NEP inc



SCALE: 1" = 207'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	FISH SAMPLING STATIONS AT WETLAND STUDY AREA No. 3 JANUARY 1988 FILE No. NECIV-1	FIGURE 5-3 GP inc



LEGEND

T= MINNOW TRAP LOCATION

NOTE:

SEE TABLE 6.1 FOR VEGETATION LEGEND

SCALE:
1"= 200'

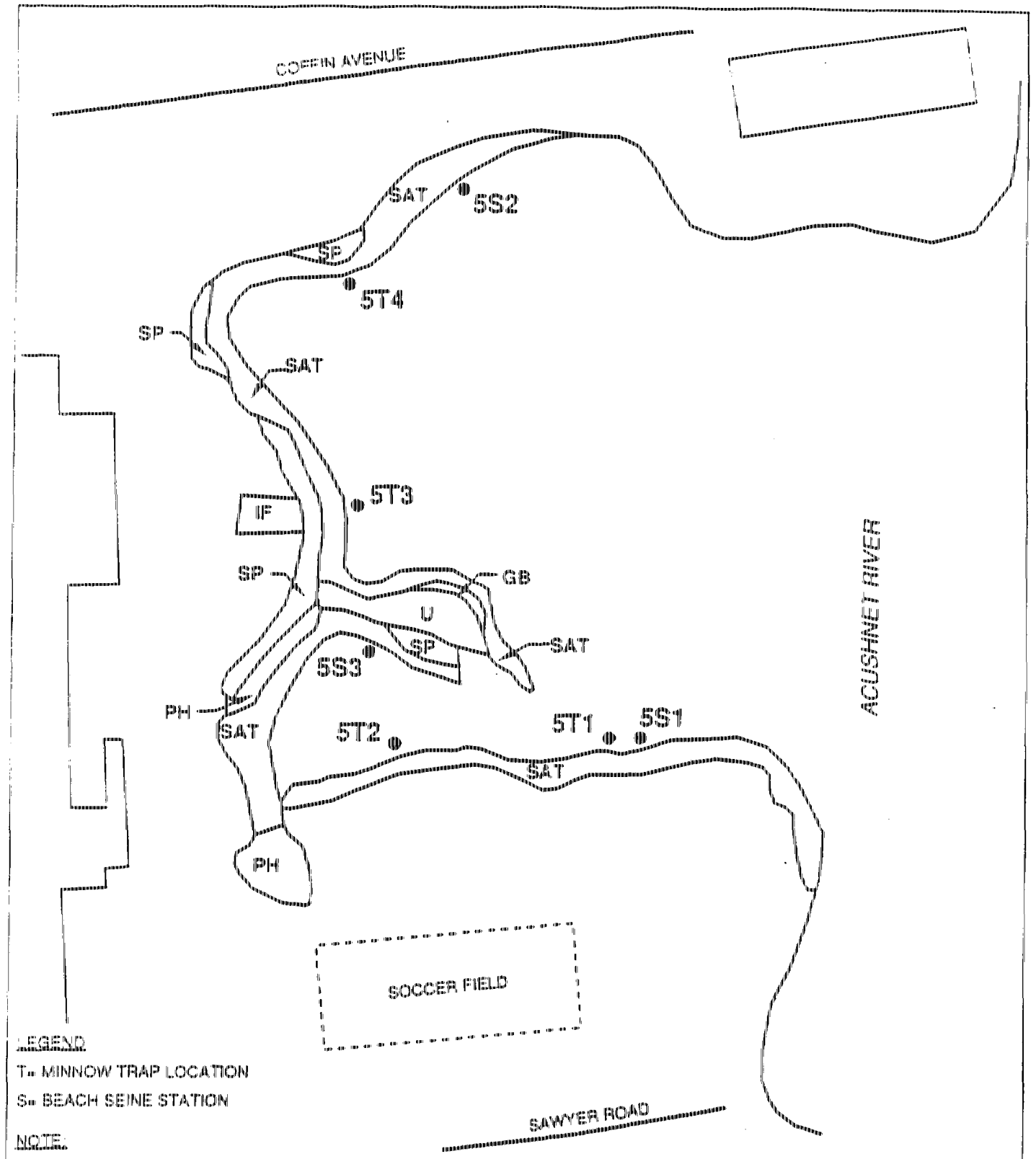
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

FISH SAMPLING STATIONS
AT WETLAND STUDY
AREA No. 4

JANUARY 1988 FILE No. NECIY-1

FIGURE 5-4

EP inc



LEGEND

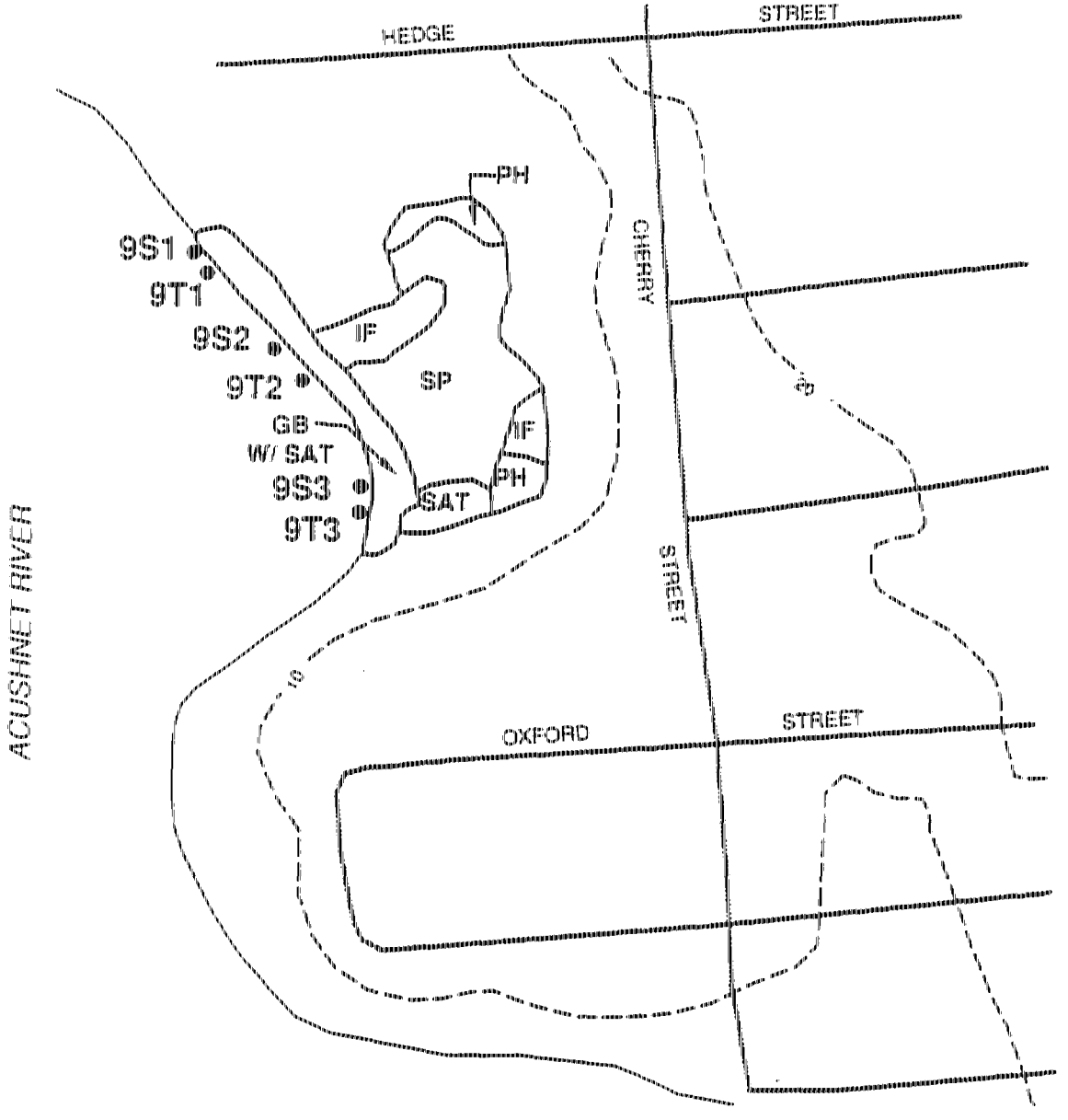
T= MINNOW TRAP LOCATION

S= BEACH SEINE STATION

NOTE:

SEE TABLE 6.1 FOR VEGETATION LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	FISH SAMPLING STATIONS AT WETLAND STUDY AREA No. 5 JANUARY 1994 FILE No. NECIV-1	FIGURE 5-5 IEP Inc



LEGEND

T= MINNOW TRAP LOCATIONS

S= BEACH SEINE STATIONS

NOTE:

SEE TABLE 6.1 FOR VEGETATION LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	FISH SAMPLING STATIONS AT WETLAND STUDY AREA No. 9 JANUARY 1988 FILE No. NECIV-1	FIGURE 5-6 ICF inc

flounder, all available specimens were used, and these were all young-of-the-year fish from Wetland 2. The contents were identified to the lowest practical taxon and each category was weighed to the nearest 0.01 g (blotted wet weight).

5.2 RESULTS

5.2.1 Species and Numbers Collected

A total of 16 species of fish were collected or observed in the waters bordering the salt marshes of this study (Table 5.1).

Beach Seines

The beach seine catches were characterized by large numbers of Atlantic silverside (*Menidia menidia*), which accounted for 76.8% of the total catch at all wetlands combined (Table 5.2). Atlantic silversides were the most numerous fish caught by far in the middle estuary and Buzzards Bay marshes making up 97.7% and 88.6% of the catch in Wetlands 9 and 2, respectively. In the upper estuary (Wetlands 1, 3, and 5), Atlantic silversides accounted for 74.7% of the fish caught. The second most numerous fish species caught, mummichog, was present in greater numbers in the upper estuary than in the middle estuary or in Buzzards Bay. In the upper estuary mummichogs accounted for 24.4% of the fish caught, compared to 0.7% and 3.0% in the middle estuary and in Buzzards Bay, respectively. The striped killifish (*Fundulus majalis*) exhibited the reverse situation accounting for only 0.2% of the fish caught in the upper estuary compared to 1.4% and 7.5% in the middle estuary and Buzzards Bay, respectively. Of the other eight species caught, none contributed even 1% of the total of all fish caught.

TABLE 5.1. FISH SPECIES PRESENT IN OR NEAR SALT MARSHES, NEW BEDFORD WETLANDS STUDY, 1987.

SCIENTIFIC NAME	COMMON NAME	BEACH SEINES	MINNOW TRAPS	OTHERa
Alosa pseudoharengus	alewife	Ob		
Alosa sapidissima	American shad	C	O	
Anguilla rostrata	American eel			O
Apeltes quadracus	fourspine stickleback	C		
Caranx hippos	crevalle jack	O		
Cyprinodon variegatus	sheepshead minnow			O
Fundulus heteroclitus	mummichog	A	A	
Fundulus majalis	striped killifish	C	C	
Menidia menidia	Atlantic silverside	A	O	
Mugil cephalus	striped mullet	C		
Pomatomus saltatrix	bluefish	C		
Pseudopleuronectes americanus	winter flounder	O		
Scophthalmus aquosus	windowpane			O
Sphoeroides maculatus	northern puffer			O
Stenotomus chrysops	scup			O
Tautoga onitis	tautog	O		

a Observed during bioaccumulation or benthic sampling
b A = abundant, C = common, O = occasional

TABLE 5.2. NUMBERS OF FISH CAUGHT IN BEACH SEINES BY SPECIES AND WETLAND, ON 29-30 JULY 1987. NEW BEDFORD WETLANDS STUDY.

	UPPER ACUSHNET RIVER ESTUARY			MIDDLE ACUSHNET RIVER ESTUARY	BUZZARDS BAY	
	WETLANDS			WETLAND	WETLAND	TOTAL NUMBER
SPECIES	1	3	5	9	2	CAUGHT
Menidia menidia	19,274	599	2,071	1,889	1,496	25,329
Fundulus heteroclitus	6,739	230	207	14	51	7,241
Fundulus majalis	58	1	6	28	126	219
Alosa sapidissima	20	29	8	1	2	60
Apeltes quadracus	75	0	0	0	3	78
Mugil cephalus	5	0	23	1	0	29
Pomatomus saltatrix	11	0	0	0	8	19
Tautoga onitis	1	0	0	0	0	1
Caranx hippos	0	0	0	0	1	1
Pseudopleuronectes americanus	0	0	0	0	1	1
Alosa pseudoharengus	0	0	1	0	0	1

Minnow Traps

There were four fish species caught in the minnow traps (Table 5.3). Fundulus heteroclitus, the most numerous, accounted for 95.5% of the total catch from all wetlands. This species made up 98.9% of the catch in the upper estuary, 95.8% in the middle estuary and 87.0% in Buzzards Bay. Fundulus majalis, the second most abundant of the four species caught, accounted for 12.9% of the catch in Buzzards Bay and only 4.1% of the total number of fish caught. The two remaining species combined contributed less than 1% of the catch in any wetland or for the total number of fish.

5.2.2 Length and Weights

Beach Seines

Length and weight measurements were obtained from 1781 specimens of eleven species from five wetlands (Table 5.4). Lengths for Menidia menidia, the most numerous species caught, ranged from 22 mm to 132 mm, 95.3% of them measuring less than 80 mm. The larger specimens (89-132 mm) were only caught at Wetland 2 (Figure 5-7) and Wetland 9.

Weights ranged from 0.1 to 13.6 grams, most of them measuring from 0.1 to 3.0 grams. Menidia were caught at all five wetlands. Fundulus heteroclitus lengths ranged from 22 mm to 100 mm, with 66.7% of the specimens measuring from 30 to 50 mm (Figure 5-8). Weights for F. heteroclitus ranged from 0.1 to 17.5 grams, 68.5% of them below 1.5 grams. Fundulus heteroclitus was caught at all wetlands. Fundulus majalis lengths ranged from 26 to 131 mm, 98.1% of which were under 60 mm (Figure 5-9). Weights ranged from 0.1 to 33.3 grams, with almost all of the fish less than 3.0 grams. Fundulus majalis was also caught at all wetlands. Length for Alosa sapidissima, also caught at all wetlands, ranged from 33 mm to 57 mm. All of the weights were less than or equal to 2.5 grams. Apeltes quadracus, caught only at Wetlands 1 and 2, had very narrow length and weight ranges. Length ranged from 27 mm to 39 mm, and weight only fluctuated 0.2 grams (from 0.1 to 0.3 grams). The length range for Mugil cephalus was from 54 mm to 113 mm, while the weight measured from 1.1 grams to 17.7 grams. This species was caught at only three wetlands (1, 5, and 9). The last species present in any number, Pomatomus saltatrix, was caught at Wetlands 1 and 2. Length ranged from 107 to 139 mm; weight from 12.0 grams to 21.3 grams. For the remaining four species (Tautoga onitis, Caranx hippos, Pseudopleur-onectes americanus and Alosa pseudoharengus) only one specimen of each was caught.

TABLE 5.3. NUMBERS OF FISH CAUGHT IN MINNOW TRAPS, BY SPECIES AND WETLAND, 28-30 JULY 1987. NEW BEDFORD WETLANDS STUDY.

	UPPER ACUSHNET RIVER ESTUARY			MIDDLE ACUSHNET RIVER ESTUARY		BUZZARDS BAY	
	WETLANDS			WETLANDS		WETLAND	TOTAL NUMBER
SPECIES	1	3	5	4	9	2	CAUGHT
Fundulus heteroclitus	934	507	248	420	257	615	2,981
Fundulus majalis	8	0	0	0	28	91	127
Menidia menidia	4	4	3	0	1	3	15
Alosa sapidissima	0	0	0	1	0	0	1

TABLE 5.4. LENGTH AND WEIGHT RANGES FOR SPECIES CAUGHT IN BEACH SEINES, NEW BEDFORD WETLANDS STUDY, 29-30 JULY 1987.

SPECIES	LENGTH (mm)	WEIGHT (g)	COLLECTED FROM WETLAND	NUMBER OF FISH MEASURED
Menidia menidia	22 - 132	0.1 - 13.6	1,2,3,5,9	771
Fundulus heteroclitus	22 - 100	0.1 - 17.5	1,2,3,5,9	615
Fundulus majalis	26 - 131	0.1 - 33.3	1,2,3,5,9	206
Alosa sapidissima	33 - 57	0.2 - 2.5	1,2,3,5,9	60
Apeltes quadracus	27 - 39	0.1 - 0.3	1,2	63
Mugil cephalus	52 - 113	1.1 - 17.7	1,5,9	29
Pomatomus saltatrix	107 - 139	12.0 - 21.3	1,2	19
Tautoga onitis	34	0.7	1	1
Caranx hippos	44	1.5	2	1
Pseudopleuronectes americanus	46	0.9	2	1
Alosa pseudoharengus	50	1.5	5	1

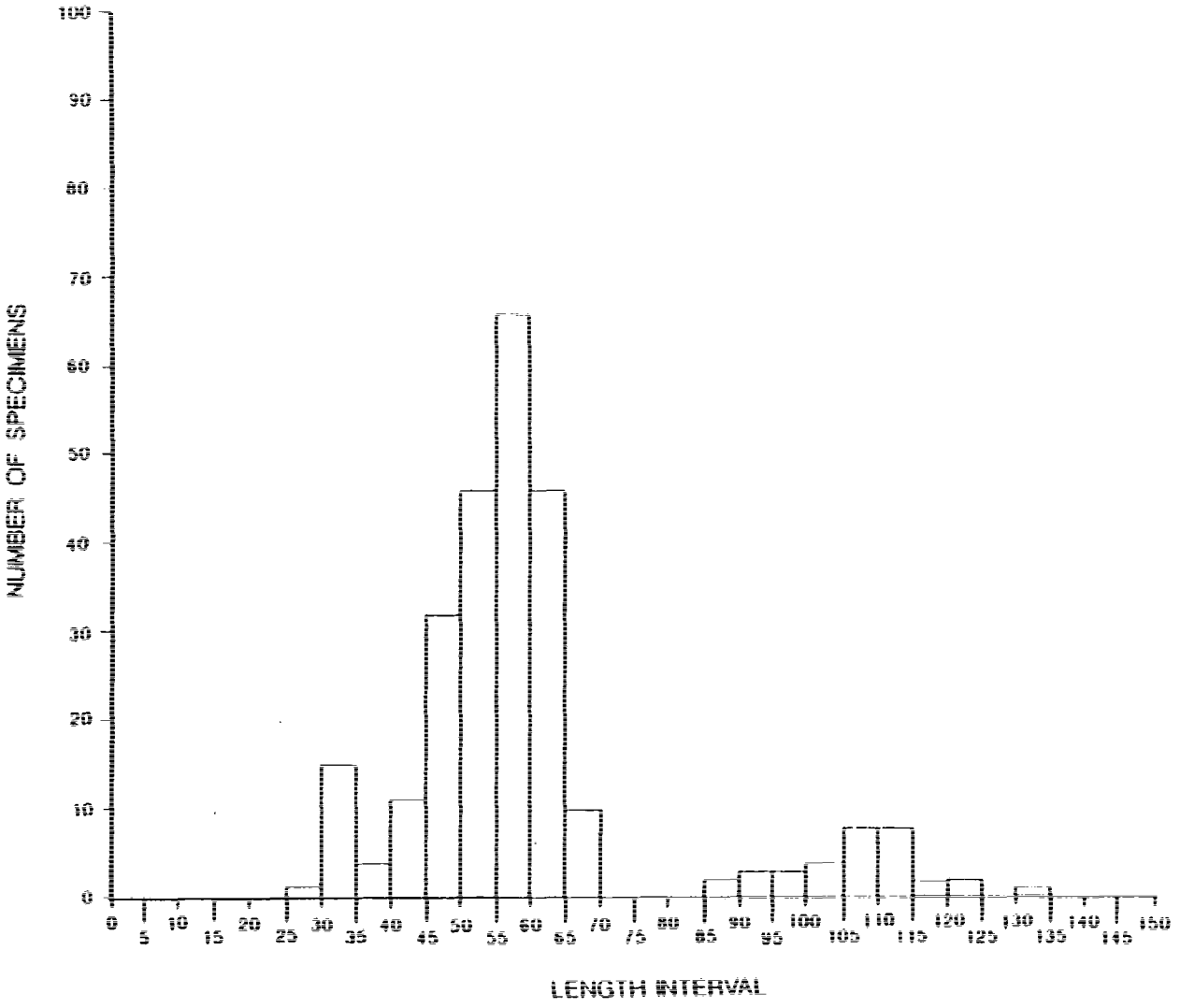


Figure 5-7. Length frequency histogram for *Menidia menidia* at Wetland 2 collected with beach seines, New Bedford Wetlands Study, 29-30 July 1987.

Minnow Traps

A total of 1318 fish from four species were measured and weighed from six wetlands (Table 5.5). Fundulus heteroclitus, the most numerous, accounted for 91.7% of that number. Its lengths ranged from 33 mm to 112 mm with weights ranging from 0.5 grams to 26.7 grams. This is the only species of the four to be caught at all wetlands. The next species, Fundulus majalis, accounted for only 7.2% of the fish measured, and ranged in length from 37 to 56 mm and in weight from 0.5 to 2.3 grams. This species was collected from only three of the six wetlands.

Menidia menidia, the most numerous in the seines, accounted for only 1% of the fish measured from the minnow traps. This species was caught at Wetlands 1, 2, 3 and 5. Lengths ranged from 52 to 70 mm and the weights from 0.9 grams to 2.3 grams. There was only one specimen of Alosa pseudoharengus caught in the minnow traps. The fish was caught at Wetland 4.

5.2.3 Gut Contents

Fundulus heteroclitus

Seventeen specimens of Fundulus heteroclitus were examined for gut contents in the New Bedford Harbor area (Table 5.6), ten of which contained food. All fish ranged from 70-75 mm in length and were collected from various stations in the sampling area.

Gut contents included seven major groups of organisms. Bivalve mollusks, the group with the largest number of individuals, accounted for 53% of the total number of animals found. Fish and fish eggs, decapod crustaceans, and worms, the next three most numerous groups, accounted for 17.8%, 13.3%, and 11.1%, respectively. Chordates and gastropods each accounted for 2.2%. Plant material, which was found in three of the ten stomachs, was only noted as present.

Biomass (blotted wet weight in grams) was measured for each prey category. Bivalves comprised 44% of the total biomass found in the guts. Fish and fish eggs and decapods, the next two groups, accounted for 29% and 14%, respectively. Plant material accounted for 13% of the total biomass present. The remaining three groups each accounted for less than 1% of the biomass: worms, chordates, and gastropods.

TABLE 5.5. LENGTH AND WEIGHT RANGES FOR SPECIES CAUGHT IN MINNOW TRAPS, NEW BEDFORD WETLAND STUDY, 28-30 JULY 1987.

SPECIES	LENGTH (mm)	WEIGHT (g)	COLLECTED FROM WETLAND	NUMBER OF FISH MEASURED
Fundulus heteroclitus	33 - 112	0.5 - 26.7	1,2,3,4,5,9	1,209
Fundulus majalis	37 - 56	0.5 - 2.3	1,2,9	95
Menidia menidia	52 - 70	0.9 - 2.3	1,2,3,5	13
Alosa sapidissima	39	0.2	4	1

TABLE 5.6. ANALYSIS OF GUT CONTENTS OF FUNDULUS HETEROCLITUS IN THE ACUSHNET RIVER ESTUARY AND BUZZARDS BAY SALT MARSHES. NEW BEDFORD WETLANDS STUDY.

SPECIMEN	PREY COUNT	PREY SPECIES	BIOMASS (grams)
1	1	Palaemonetes pugio	0.04
	4	Eggs (anchovy)	<0.01
2	3	Hiatella sp.	0.08
	1	Gemma gemma	
	3	Nematoda	<0.01
	1	Fundulus sp.	0.13
	1	Turbellaria	<0.01
3	1	Palaemonetes sp.	0.07
	1	Molgula sp.	<0.01
4	3	Fundulus sp.	0.23
	7	Mya arenaria	0.23
	P	Seedpod; plant material	<0.01
5	1	Nematoda	<0.01
	1	Decapoda (crab)	0.01
	P	Plant material	0.14
6	P	Plant material	0.02
7	1	Palaemonetes sp.	0.03
8	13	Mya arenaria	0.25
	1	Hydrobia totteni	<0.01
9	1	Palaemonetes sp.	0.02
10	1	Caridea	0.01

P = present in gut (nonquantifiable)

Pseudopleuronectes americanus

Analysis of the contents of the guts were performed on ten fish collected in th New Bedford Harbor area (Table 5.7). All the fish analyzed were between 50 and 60 mm in length and were caught on the beach at Wetland 2 (Buzzards Bay). All ten stomachs examined contained food.

Only two groups of invertebrates were found frequently in the guts of these fish: isopods and polychaetes. Isopods, the most numerous, comprised 63.8% of the total number of organisms, but only accounted for 21% of the total biomass. Polychaetes, which accounted for only 31.9% of the total number of organisms, made up the greater portion of the biomass at 73%. The only other prey categor present in these ten stomachs was amphipods, accounting for 4.3% of the total number and 6% of the biomass.

5.3 DISCUSSION

5.3.1 Characterization of Saltmarsh Fish Community

Species composition for the Acushnet River estuary is comparable to that in other estuaries in the general area (Curley et al. 1971, 1974; Nixon and Oviatt 1973). Differences in composition can be attributed to the extent of sampling. In the other estuaries, samples were taken throughout the year, while sampling for this study was confined to two days at the end of July. More species are caught with year-round sampling because of various species of migrating fish which arrive at different times of the year. The dominant species in the Acushnet River estuary (Menidia menidia, Fundulus heteroclitus, and Fundulus majalis) were also dominant in the other estuaries of south-eastern Massachusetts. These species are characteristic of the shore zone and can be expected to comprise a large portion of any beach seine or minnow trap catch. M. menidia, the most abundant species collected, accounted for 76.8% of the total catch in the Acushnet River estuary. This percent was similar to that reported by Curley et al. (1974) for the Taunton River and Mount Hope Bay estuary where Menidia made up 66.6% of the total catch. Sanford Ecological Services (1987) listed eight fish species commonly found in the Acushnet River estuary. Those species were rare or absent in this wetlands study because they are demersal species likely to be found on the bottom in the deeper channel areas rather than in the shallow shoreline and marsh areas.

The four dominant species in the beach seines (Menidia menidia, Fundulus heteroclitus, Fundulus majalis, and Alosa sapidissima) were caught at all five wetlands (Table 5.2). This is consistent with McHugh's (1967) classification, of fishes based on their estuarine dependence: the first three species are considered to be general estuarine residents, while Alosa sapidissima is an anadromous species (one which passes through the estuary to reach freshwater spawning areas). Menidia menidia was the most abundant species in beach seines at each of the five wetlands sampled. Menidia enter the shallows and tidal creeks of the upper estuary to feed and breed. The length

TABLE 5.7. ANALYSIS OF GUT CONTENTS OF PSEUDOPLEURONECTES AMERICANUS IN THE ACUSHNET RIVER ESTUARY AND BUZZARDS BAY SALT MARSHES. NEW BEDFORD WETLANDS STUDY.

SPECIMEN	PREY COUNT	PREY SPECIES	BIOMASS (grams)
1	P	Polychaeta fragments	0.02
	2	Edotea triloba	<0.01
2	1	Spio setosa	
	2	Polydora ligni	0.01
	P	Nereis sp. fragments	
3	2	Edotea triloba	<0.01
	2	Nereis sp.	0.10
	P	Plant material	<0.01
4	1	Polydora ligni	0.01
	1	Edotea triloba	<0.01
5	4	Polydora ligni	0.01
	1	Edotea triloba	<0.01
6	2	Polydora ligni	<0.01
	1	Gammarus mucronatus	0.01
7	P	Nereis sp. fragments	0.02
	1	Polydora ligni	
	12	Edotea triloba	0.06
	1	Isopoda	
8	P	Polychaeta fragments	<0.01
	3	Edotea triloba	<0.01
	1	Isopoda	
	1	Gammarus mucronatus	0.01
9	5	Edotea triloba	0.01
	1	Nereis succinea	0.07
10	2	Edotea triloba	<0.01
	1	Polydora ligni	<0.01

P = Present in the gut (nonquantifiable)

TABLE 5.8. CATCH PER UNIT EFFORT FOR FISH CAUGHT BY MINNOW TRAPS, 28-30 JULY 1987. NEW BEDFORD WETLANDS STUDY. (Average catch per trap by species and wetland.)

WETLAND	F. HETEROCLITUS	F. MAJALIS	M. MENIDIA	A. SAPIDISSIMA
1	104	<1	<1	0
2	68	10	<1	0
3	84	0	<1	0
4	140	0	0	<1
5	62	0	<1	0
9	86	9	<1	0

frequency distribution of Menidia at Wetland 2 (Figure 5-7) exhibited a bimodal pattern indicating the presence of two distinct size groups. Wetland 9 in the middle estuary also had fish of the larger size group, but these were only isolated individuals and there were not enough data from Wetland 9 for a valid comparison with the other areas. In the upper estuary (Wetlands 1, 3, 5) the larger size group was not present. This might be indicative of one of two things: either the larger fish had already spawned and moved out of the upper estuary, or they had not yet moved into the estuary to spawn.

Percent composition of F. heteroclitus was higher at Wetland 1 than at any other wetland and exhibited a general decrease moving down the estuary toward a marine environment. This might indicate a preference of F. heteroclitus to a more brackish environment. As was the case with Menidia the length frequencies of F. heteroclitus caught with beach seines exhibited a bimodal distribution (Figure 5-8) indicating the presence of two distinct size groups. However unlike Menidia, both size groups were present at all wetlands, not just one or two. Percent composition of F. majalis was highest at Wetland 2 and decreased with increasing distance up the estuary, indicating a possible preference for a more marine environment. Although only a few specimens of larger fish were caught, there are also indications of a bimodal distribution in the length frequencies of F. majalis (Figure 5-9). Alosa sapidissima and Mugil cephalus, both migratory species, appeared to be more abundant in the upper estuary (Wetlands 1, 3, 5). These two species utilize estuaries during spawning migrations or as nursery areas, in this case the latter is likely based on the size of the fish caught. Length ranges for these two species (Table 5.4) indicate that these specimens were all young-of-the-year. Apeltes quadracus was restricted almost entirely to Wetland 1, with only three specimens caught at Wetland 2. A. quadracus has also been categorized as an estuarine resident. Pomatomis saltatrix was found only at Wetlands 1 and 2, occurring in comparable numbers in those two areas. This species, a top predator, usually enters estuaries in pursuit of migratory planktivores such as A. sapidissima and M. cephalus. Caranx hippos and Pseudopleuronectes americanus, primarily marine species, were only caught along the shore of Buzzards Bay (Wetland 2).

There were only four species of fish caught with minnow traps in the Acushnet River estuary (Table 5.3). Of these species only two, F. heteroclitus and F. majalis, were caught in any concentrations. The other two, M. menidia and A. sapidissima, swim and feed in the middle to upper areas of the water column. Their presence in the minnow traps, which were set on the bottom sediment, is probably only a chance occurrence. As was the case in the beach seines, F. heteroclitus was present at all wetlands and was more abundant in the estuary than at Wetland 2 in Buzzards Bay. Length frequencies from minnow traps showed a bimodal distribution, though less distinctly than in the beach seine data (Appendix Table 10). F. majalis was caught at only three wetlands (1, 2, and 9), one wetland in the upper and middle estuaries each and the one in Buzzards Bay. The number of specimens increased moving closer to the open coast similar to observations in the beach seine collections.

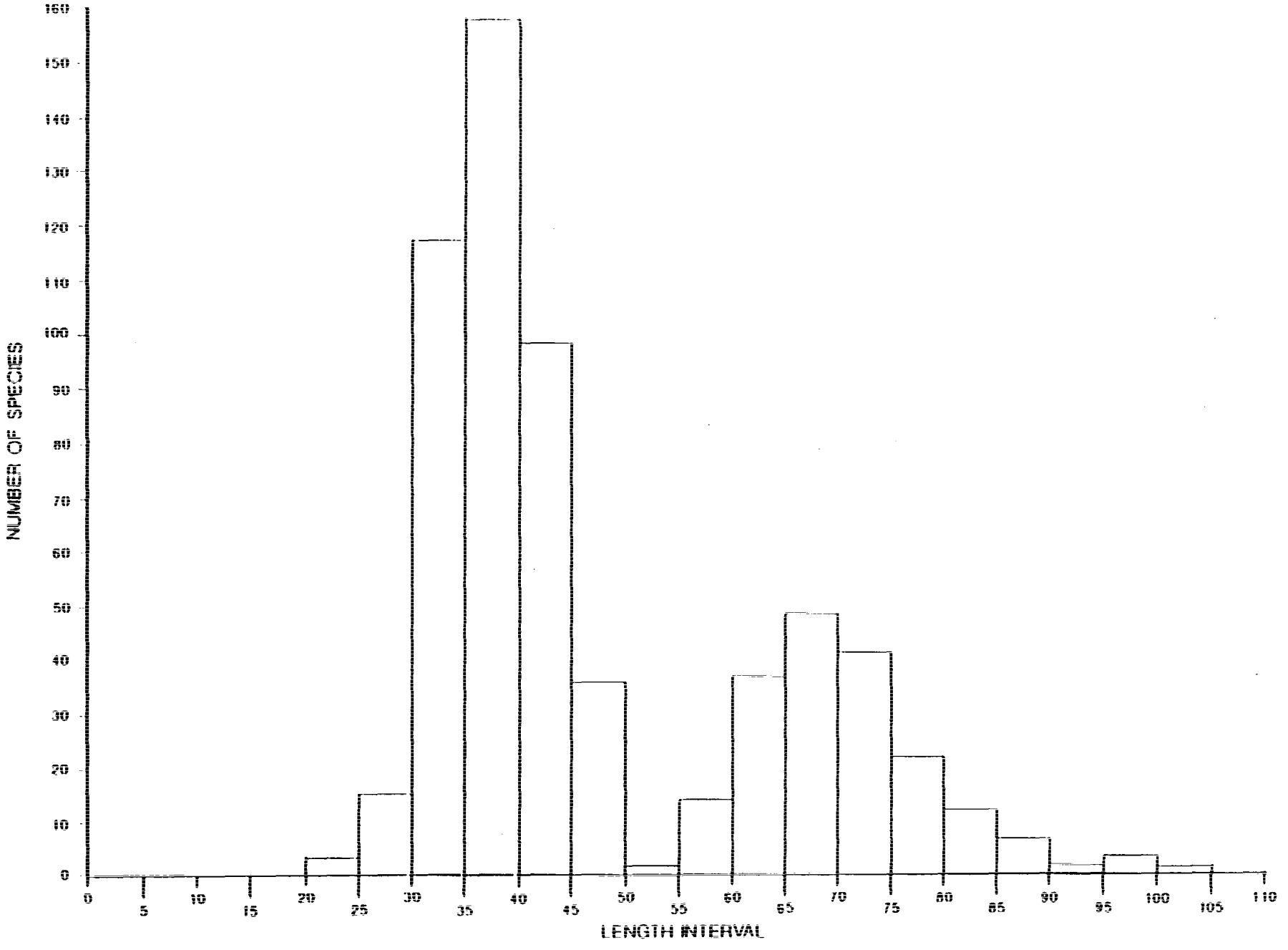


Figure 5-8. Length frequency histogram for *Fundulus heteroclitus* at all wetlands collected with beach seines, New Bedford Wetlands Study, 29-30 July 1987.

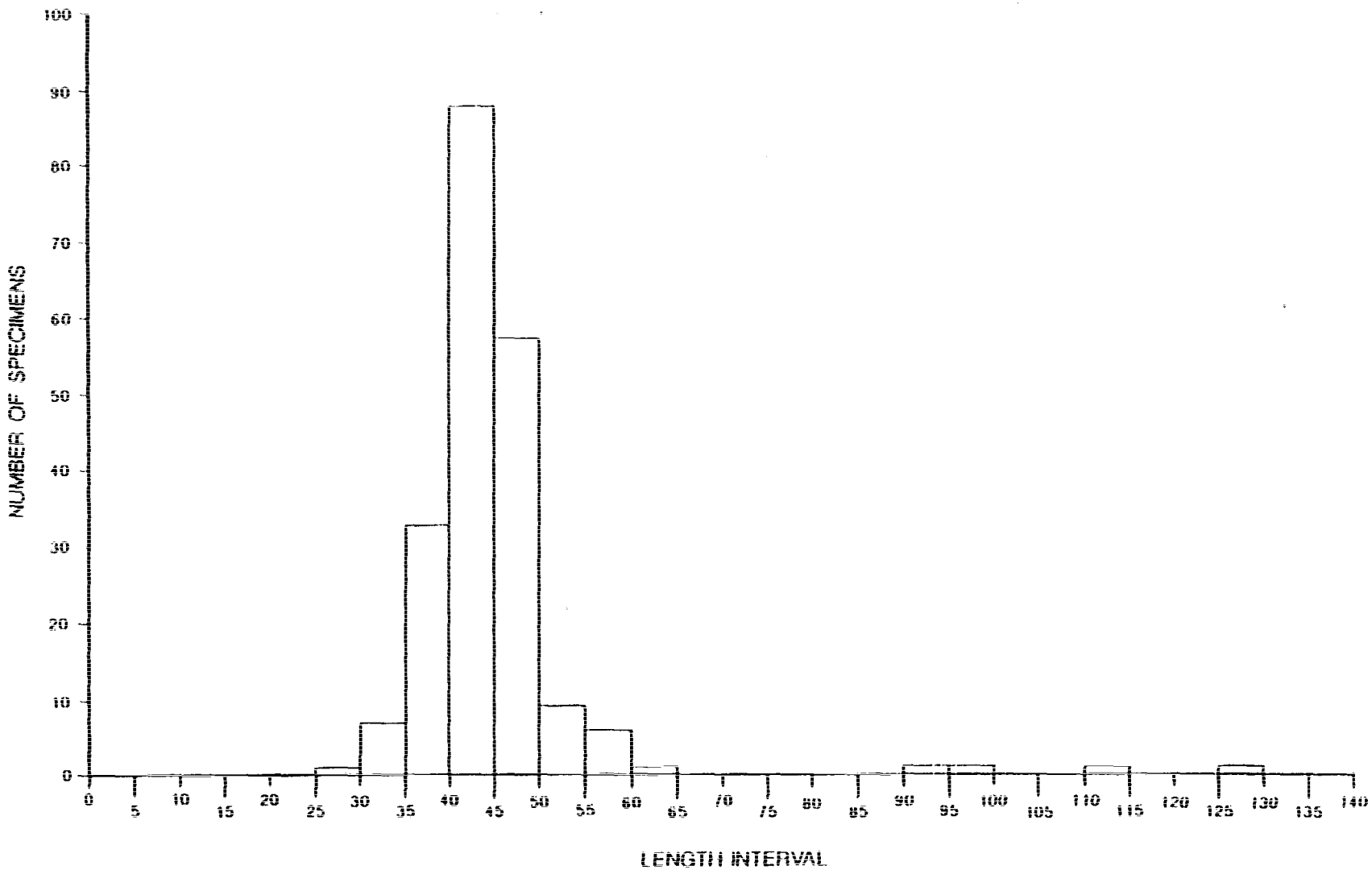


Figure 5-9. Length frequency histogram for *Fundulus majalis* at all wetlands collected with beach seines, New Bedford Wetlands Study, 29-30 July 1987.

Areas of high PCB and heavy metal concentration were identified by Sanford Ecological Services (1987) in the upper Acushnet River estuary where Wetlands 1 3 and 5 are located. They reported high concentrations not only in the sediments but also in the water column, primarily bound to particulate matter. The average number of Fundulus heteroclitus caught by minnow traps did not differ substantially among the six wetlands (Table 5.8), showing that comparable concentrations of this species are present in suitable habitat throughout the estuary regardless of level of contamination in the sediments. The higher the contamination in a wetland, the greater the total amount of contamination is likely to be in the fish biomass in that area. Fundulus heteroclitus would come into contact with contaminants associated with particulate matter in the water column as well as the sediments since they tend to burrow in the soft mud to over-winter (Chidester 1920). F. heteroclitus also tend to stay in the same general area throughout the year, moving very little within an estuary (Lotrich 1975). Fundulus majalis would exhibit the same general behavior as F. heteroclitus, but F. majalis is a smaller component of the fish fauna in the areas of high contamination. The plankton feeding species Menidia menidia and Alosa sapidissima might come into contact with the contaminants bound to the particulate matter in the water column either through ingestion or physical contact.

5.3.2 Food Chain Links

The diet of Fundulus heteroclitus in the Acushnet River estuary consists of (1) benthic organisms which live either on or in the bottom sediment, (2) decapods and other crustaceans which can live on the bottom or in the water column, and (3) plant material which is either attached to the bottom or is free floating. Comparison of the diets between fish caught in the Acushnet estuary and other estuaries shows little or no variation in the composition of their diets. There is a difference however, in the percent occurrence of various groups in their diets. Fundulus heteroclitus usually consume prey items in proportion to their occurrence in the environment (Fraser 1973). Concentrations of PCBs in the tissues of F. heteroclitus were approximately four times higher in the middle estuary (Wetland 9) than they were in the fish caught at Buzzards Bay (Wetland 2). The upper estuary (Wetland 5) had concentrations approximately five times higher than the middle estuary. There was approximately twenty times as much PCB contamination in the fish from the upper estuary compared to the fish from Buzzards Bay. Concentrations of two heavy metals (copper and lead) from the fish in the upper estuary were higher than the concentrations in fish from Buzzards Bay. F. heteroclitus, because of its diet preferences, would be susceptible to PCB and heavy metal contamination from prey living in or on the contaminated sediments.

The diet of Pseudopleuronectes americanus consists of organisms which live either in or on the bottom sediments. All of the fish analyzed however, were caught at Buzzards Bay (Wetland 2) which presumably has little or no contamination. Analysis of tissue from P. americanus from Wetland 2 showed much lower concentrations of copper, lead, and zinc than the concentrations found in F. heteroclitus from the upper (Wetland 1) and middle (Wetland 4) estuary. Concentrations from P. americanus and F. heteroclitus caught at Wetland 2 were almost identical. As previously mentioned PCB concentrations for F. heteroclitus at Wetland 2 were 5% of the concentrations found in fish from Wetland 1. Analysis of tissue from P. americanus caught at Wetland 2 showed roughly half the concentration of PCBs in F. heteroclitus caught at the same wetland. If the high levels of PCBs and metals in Fundulus in the upper estuary are a result of its diet, then Pseudopleuronectes would also be expected to contain higher contaminant levels than in the fish sampled from Buzzards Bay.

6.0 VEGETATION

6.1 WETLAND VEGETATION CHARACTERIZATION

6.1.1 Description of Community Types

The community-types defined and delineated for the cover maps of the project area wetlands primarily reflect the hydrologic regime and vegetative species composition which dominate within each wetland. As outlined in Table 6.1, the initial classification relates to the water regime of the wetland as defined by Cowardin et al. (1979). All wetland portions of the study area are considered tidal, with distinctions made as follows:

- irregularly exposed (land surface is exposed by tides less often than daily),
- regularly flooded (tidal water alternately floods and exposes the surface at least once daily); or
- irregularly flooded (tidal water floods the land surface less often than daily).

The dominant vegetative species within the regularly flooded and irregularly flooded zones have been delineated. Contiguous seasonally-flooded freshwater wetland habitats have also been delineated. Brief descriptions of the various community-types delineated on the cover maps and listed in Table 6.1 are provided below:

6.1.1.1 Irregularly Exposed Habitats

These are areas where the land is exposed by tides less often than daily, and include Tidal Water (TW), which is represented by tidal creeks and some (larger) mosquito ditches, Rocky Beaches (RB), and mudflats (MF) which lie below mean low water (MLW). The U.S.G.S. topographic maps were frequently used to supplement the delineation of mudflats, since they designate such areas; for the most part, however, the delineations were based upon tonal patterns on the photographs which appeared to differentiate deepwater areas from irregularly exposed habitat.

6.1.1.2 Regularly Flooded Habitats

Areas delineated within this zone are exclusively dominated by *Spartina alterniflora* (saltwater cordgrass), and comprise the traditional "low salt marsh" of the northeast coast. These areas are delineated as "SAT" on the cover maps, distinguishing the tall form of *S. alterniflora* (> 1m) from less frequently flooded shorter forms. Soils within the low marshes of the project area typically consist of highly decomposed (sapric) organic soils formed from the remains of previous salt marsh vegetation and mineral alluvial sediment. Less sheltered areas often have more of a mucky silt substrate.

Table 6.1. Wetland Community Types Delineated Within the Study Area.

Irregularly Exposed Habitats

MF: Mud Flat (in part)
RB: Rock Beach (in part)
TW: Tidal Water

Regularly Exposed Habitats

GB: Gravel Beach
MF: Mud Flat (in part)
RB: Rock Beach (in part)
SAT: Spartina alterniflora, tall form (> 1m) dominates
SB: Sand Beach (in part)

Irregularly Flooded Habitats

IF: Iva frutescens dominates
NV: Non-vegetated
PH: Phragmites australis dominates
SAS: Spartina alterniflora, short form (< 1m) dominates
SB: Sand Beach (in part)
SP: Spartina patens dominates
SP-I: Spartina patens/Iva frutescens co-dominates

Seasonally Flooded Freshwater Habitats

OW: Open Water
SS: Shrub Swamp
WM: Wet Meadow
WS: Wooded Swamp

UP: Upland

6.1.1.3 Irregularly Flooded Habitats

These habitats are typically at or slightly above the elevation of mean high tide, such that tidal water floods the land less often than daily. This zone encompasses the traditional "high salt marsh" most often dominated by Spartina patens (saltmeadow cordgrass). Much of this community type within the project area has been ditched extensively in the past.

Within the irregularly flooded high salt marsh portions of the study area, the following cover or dominance types have been delineated:

SP: These are areas of the high marsh where S. patens clearly comprises a major proportion of the vegetative cover, such that it is considered to dominate the area. This dominance type is by far the most extensive within the high marsh portions of the project areas. In some of the study area wetlands, however, co-dominates do occur within this cover type; the most common associates are Distichlis spicata (spikegrass) and Juncus gerardi (black rush).

SAS: These are portions of the irregularly flooded salt marsh where the short form of S. alterniflora is dominant. For the purposes of this report, such areas are where the cordgrass is predominantly less than 1m tall. In the project area wetlands this community is dominated by cordgrass which is, typically, less than 30cm in height. However, since covertype mapping was conducted in June, when the short and commonly recognized medium height forms (30 - 80cm) cannot yet be differentiated, all areas that were dominated by irregularly flooded cordgrass were designated as the short form. Such areas are typically associated with slightly lower elevations than the S. patens dominance type, and where surface drainage is impeded; in the project area wetlands, this community is commonly found lining the banks of mosquito ditches which bisect the high marsh. This community-type has been associated with higher interstitial salinities and more reduced soil conditions than regularly flooded zones of S. alterniflora (Teal 1986; Neiring and Warren 1980; Nixon 1982).

IF: Iva frutescens (marsh elder or high-tide bush) is a woody shrub, normally 1.0 - 1.5m tall, most often found at the highest elevations of the salt marsh edges or on spoil mounds along mosquito ditches. This community-type is restricted to the marsh/upland edge in all of the project area wetlands except for wetland site 1, where extensive Iva dominant communities occur mixed within more typical high marsh communities, and at wetland site 3 where a sparse stand occurs within a S. patens dominant community.

NV: One non-vegetated area was delineated within the project area wetlands which, until recently, was occupied by auto salvage. No vegetation colonized this area during the period encompassed by this investigation.

In addition to the true salt marsh habitats of the irregularly flooded zone, some units delineated are comprised of non-halophytes which are subject to tidal inundation on an irregular basis. These areas were dominated by Phragmites australis (reedgrass) and are designated as "PE".

6.1.1.4 Seasonally Flooded Freshwater Habitats

Occasionally bordering the wetlands which were irregularly flooded by tidal waters are freshwater wetland habitats dominated by herbaceous or woody vegetation. These areas are classified as wet meadow (WM) where the vegetation is predominantly herbaceous, shrub swamp (SS) where the vegetation is predominantly woody and less than 20 ft. tall, and wooded swamp (WS) where it is taller than 20 ft.

6.1.2 Vegetation Zonation Within Each Wetland

Table 6.2 presents the acreages of the various community cover-types for the 6 wetland sites which were characterized during this study. The cover-type composition for each wetland is briefly described below.

Wetland Site 1 (38.1 acres): Situated on the east side of the Acushnet River Estuary just north of the Coggeshall Street Bridge, site 1 is nearly 7/8 of mile in length and 600 ft. wide at its widest point (Figure 6-1). This site is dominated by two covertypes, S. patens, and Iva frutescens, which cover 80% of the vegetated wetland (Figure 6-2). These communities occur in large, near monotypic stands, and as a result, zonation is distinct. The high marsh cover-type, S. patens, covers 48% of the vegetated wetland and occurs in large patches throughout the interior of this site; Distichlis spicata is often co-dominant in this community. Iva frutescens occurs in broad bands within or adjacent to high marsh grass communities and covers 32% of the vegetated wetland. Diversity and density of understory plants in this community are low due to the height and shading effect of the Iva. The tall form of S. alterniflora covers 18% of the vegetated wetland and grows in a narrow (<50m) band along the entire marsh/river border. In this low marsh zone, S. alterniflora grows in pure stands.

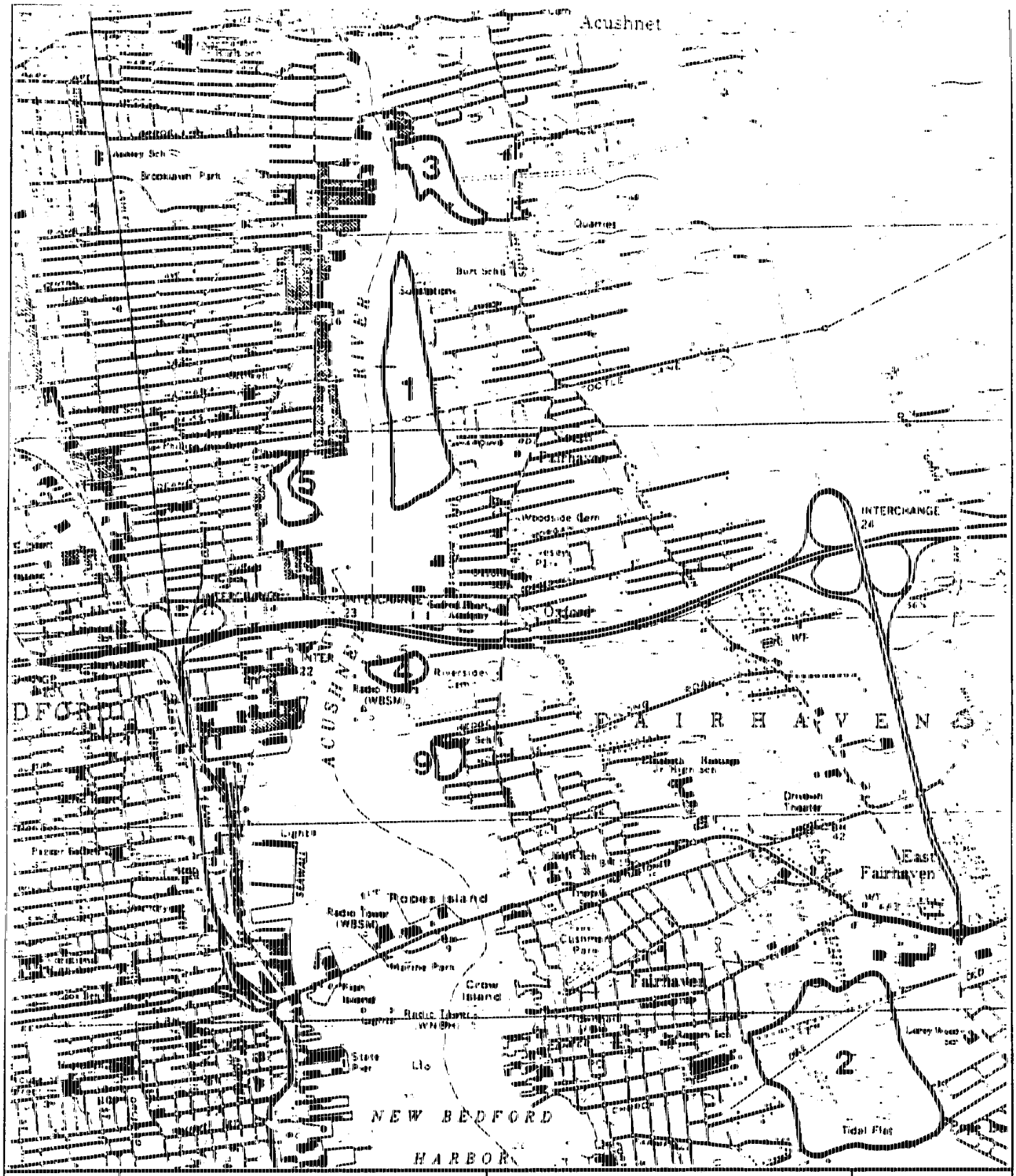
Several factors have apparently contributed to the widespread distribution and dominance of the S. patens and Iva frutescens covertypes, neither of which typically grow in areas innumdated daily by tidal waters. Parallel, evenly spaced mosquito ditches occurring at intervals of 200 ft. increase the drainage rate of tidal water, reducing salinity levels and hydroperiod; freshwater run-off from upland areas can penetrate throughout this relatively narrow wetland thereby reducing interstitial salinity levels; high marsh communities have colonized areas of the wetland that have been raised slightly by filling, increasing the total area of high marsh.

Wetland Site 2 (121 acres): The only site situated outside of the New Bedford Hurricane Dike and exposed to Buzzards Bay, site 2 lies east of New Bedford Harbor and Fort Phoenix State Reservation in Fairhaven (Figure 6-1). Although

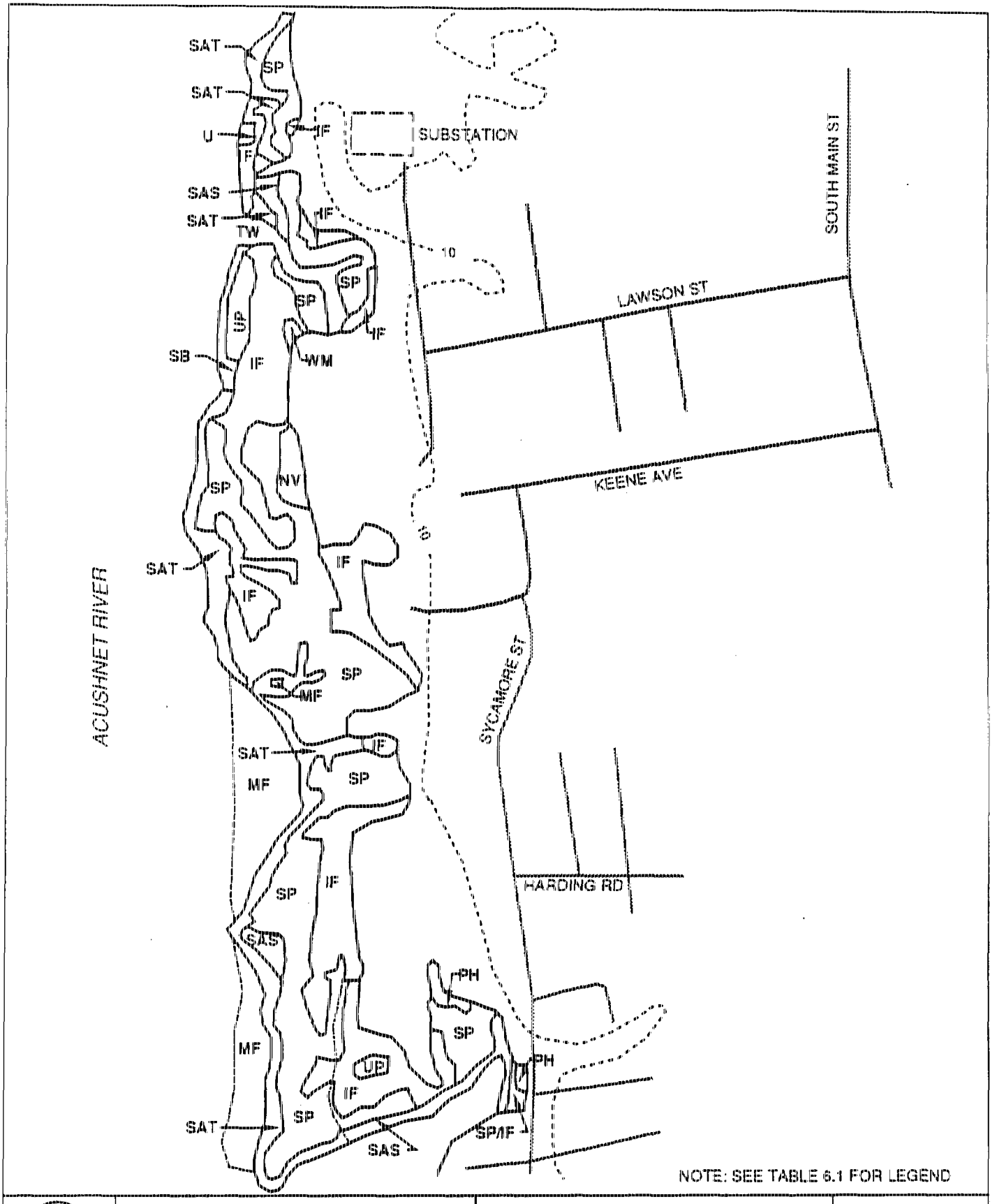
Table 6.2. Wetland Cover-type Acreages[1].

Covertypes	Covertype Codes	Wetland Site 1	2	3	4	5	9
Spartina alterniflora shrt	(SAS)	0.5	6.4	-	0.3	-	-
Spartina alterniflora tall	(SAT)	6.8	1.9	2.1	0.9	2.4	-
S. alterniflora short/tall	(SAS/T)	-	4.8	-	-	-	-
Spartina patens	(SP)	18.1	38.2	2.1	0.2	0.8	0.9
S. patens/Iva frutescens	(SP-I)	-	-	0.4	-	-	-
Iva frutescens	(IF)	11.9	0.9	0.4	-	0.1	0.2
Phragmites australis	(PH)	0.2	15.6	2.1	8.0	0.2	0.2
Phragmites/S. patens	(PH/SP)	-	-	-	0.1	-	-
Shrub swamp	(SS)	-	7.3	-	-	-	-
Wooded swamp	(WS)	-	40.7	-	-	-	-
Wet Meadow	(WH)	-	1.3	-	-	-	-
No vegetation	(NV)	0.6	-	-	-	-	-
Mudflat	(MF)	4.7	1.7	6.2	1.1	-	-
Open water	(OW)	-	0.9	-	-	-	-
Sand beach	(SB)	-	3.0	-	-	-	-
Gravel beach/SAT	(GB/SAT)	-	-	-	-	-	0.4
Total acreage		42.8	122.7	13.3	10.6	3.5	1.7
No. of covertypes		7	12	6	6	4	4
No. of vegetated covertypes		5	9	5	5	4	4

[1] SS, WH, and WS are freshwater wetlands.



SCALE: 1" = 2150'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	PROJECT AREA AND LOCATION OF WETLAND STUDY SITES JANUARY 1988 FILE No. NECIV-1	FIGURE 6-1 IEP inc



SCALE: 1" = 461'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

COVER-TYPES DELINEATED
AT WETLAND STUDY
AREA NO. 1

JANUARY 1988 FILE No. NECIV-1

FIGURE 6-2

IEP inc

seasonally flooded freshwater habitats are contiguous with the estuarine wetlands on the north and east sides, estuarine wetlands comprise 70.8 acres of the total area (Figure 6-3). Due to the widespread distribution of tidal creeks and mosquito ditches at site 2, which carry tidal water throughout the marsh, zonation patterns are complex. Cover types are patchily distributed and, with the exception of the regularly flooded low marsh zone, high marsh communities are co-dominated and often contain a variety of species.

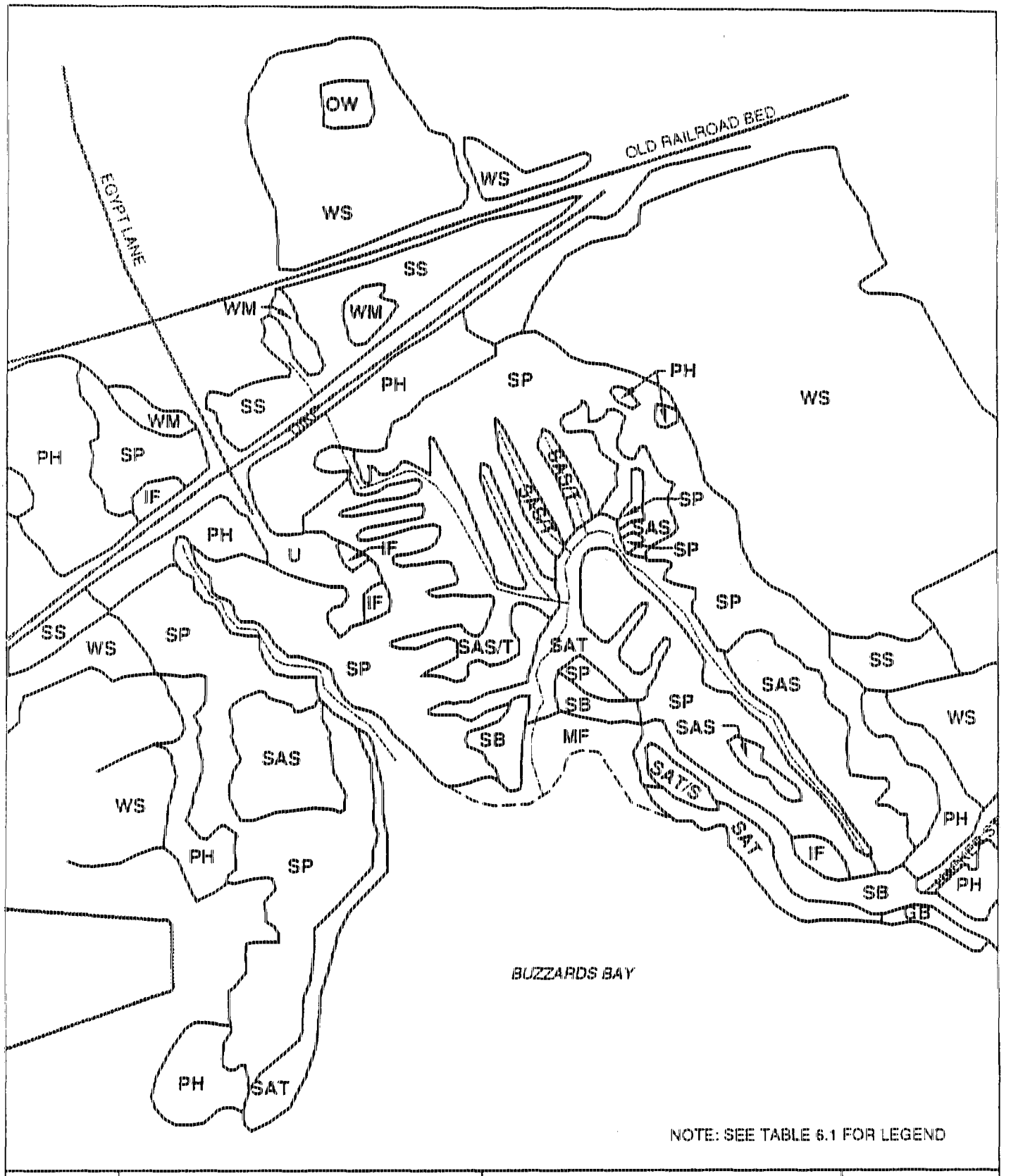
The estuarine wetland at site 2 is dominated (55%) by the high marsh covertype, S. patens. Pure stands of tall S. alterniflora cover 3% of the vegetated wetland and occur along the marsh/bay edge. A mixture of the tall and short forms of S. alterniflora occur in approximately 1m wide strips adjacent to tidal creeks and mosquito ditches. The short form also occurs in the irregularly flooded high marsh adjacent to more typical high marsh communities (e.g., S. patens, D. spicata). Stands of Phragmites australis, which are limited to the marsh/upland edge in the main section of the wetland, but dominate the wetland sections north of the floodgate, cover 23% of the vegetated wetland.

Wetland Site 3 (7.1 acres): Situated in a cove on the east side of the Acushnet River Estuary between wetland site 1 and the Wood Street Bridge (Figure 6-1), a variety of species occur at this site, but community size is limited by the narrow width and small size of the wetland. Tall S. alterniflora, S. patens high marsh communities, and Phragmites stands are the dominant cover-types, all occupying 30% of the vegetated wetland. A sparse stand of Iva frutescens, S. patens, and forbs such as Aster tenufolia (salt marsh aster) covers 6% of the study area (Figure 6-4).

Wetland Site 4 (9.5 acres): Situated on the east side of the Acushnet River Estuary just south of route 195 (Figure 6-1), this site has been altered considerably and as a result, Phragmites now covers 84% of the wetland (Figure 6-5). A narrow band of tall S. alterniflora covering 9% lines the edge of the wetland. Short S. alterniflora covering 3% and S. patens covering 2% occur in small patches.

Wetland Site 5 (3.5 acres): This site is located across from site 1 on the west bank of the Acushnet River Estuary (Figure 6-1). Steep banks support only a narrow band of tall S. alterniflora covering 68% of the wetland, S. patens covering 26%, and small patches of Iva and Phragmites (Figure 6-6). Old foundations and various types of fill occupy parts of both the regularly and irregularly flooded zones.

Wetland Site 9 (1.7 acres): The smallest of the project area wetlands in this study, site 9 occurs as a pocket marsh on the east side of the Acushnet River Estuary just south of wetland site 4 (Figure 6-1). This site is dominated (53%) by S. patens (Figure 6-7). A small patch of tall S. alterniflora occurs on the gravel beach and patches of Iva and Phragmites occur at the marsh/upland edge.



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 400'

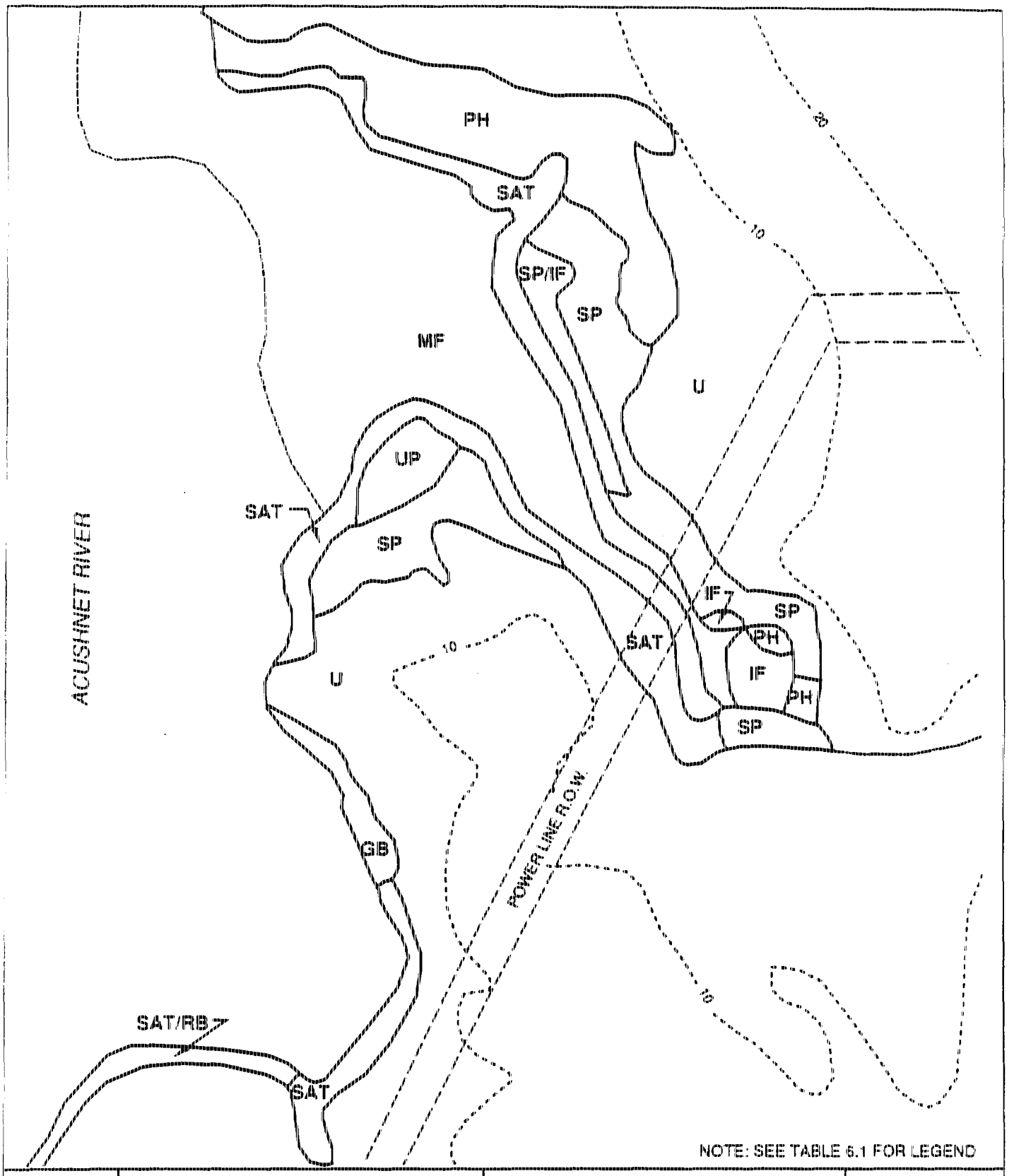
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

COVER-TYPES DELINEATED
AT WETLAND STUDY
AREA NO. 2

JANUARY 1988 FILE No. NECIV-1

FIGURE 6-3

IEP inc



SCALE: 1" = 207'

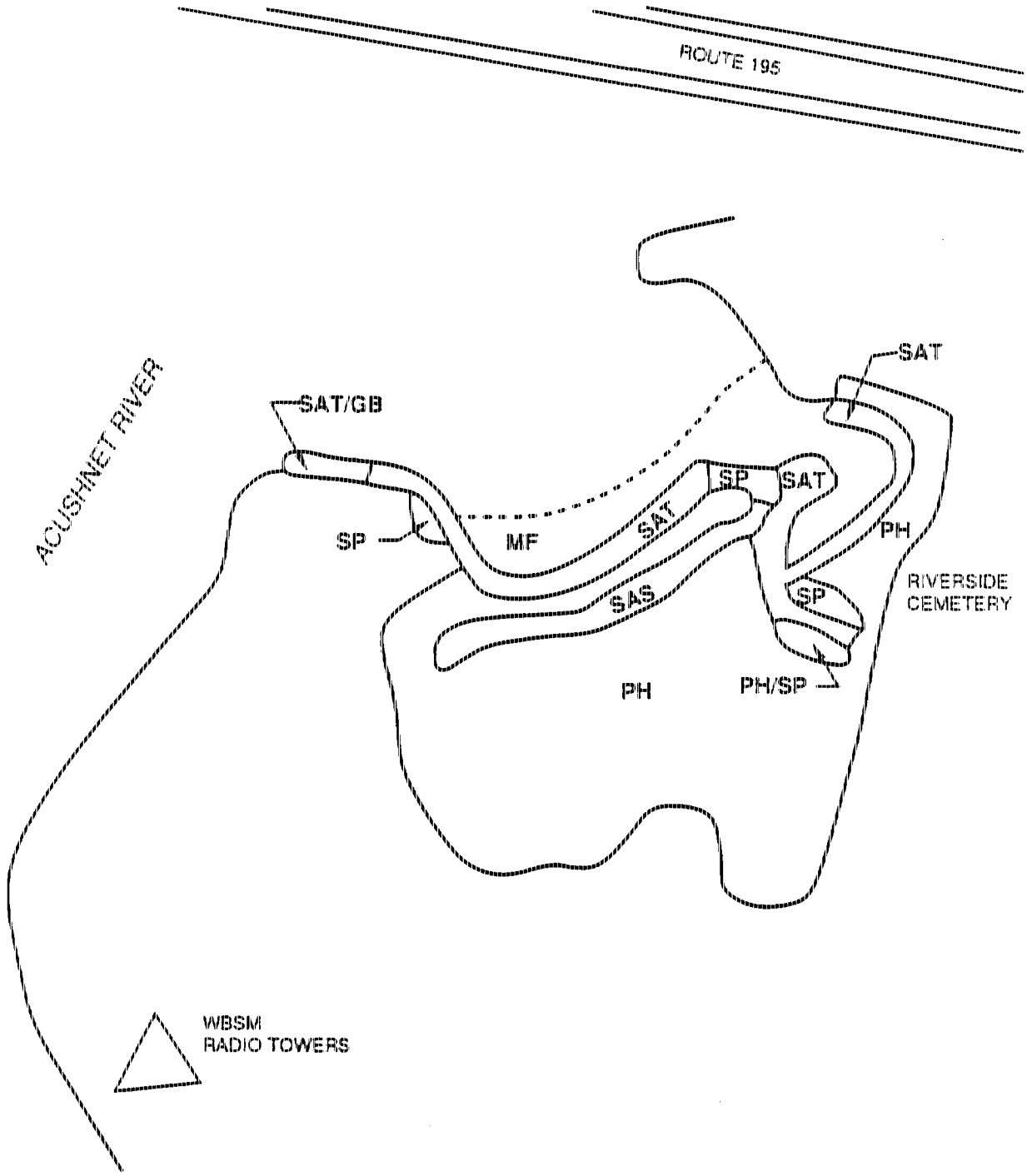
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

COVER-TYPES
DELINEATED AT WETLAND
STUDY AREA NO. 3

JANUARY 1988 FILE No. NECIV-1

FIGURE 6-4

IEP inc



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE:
1" = 200'

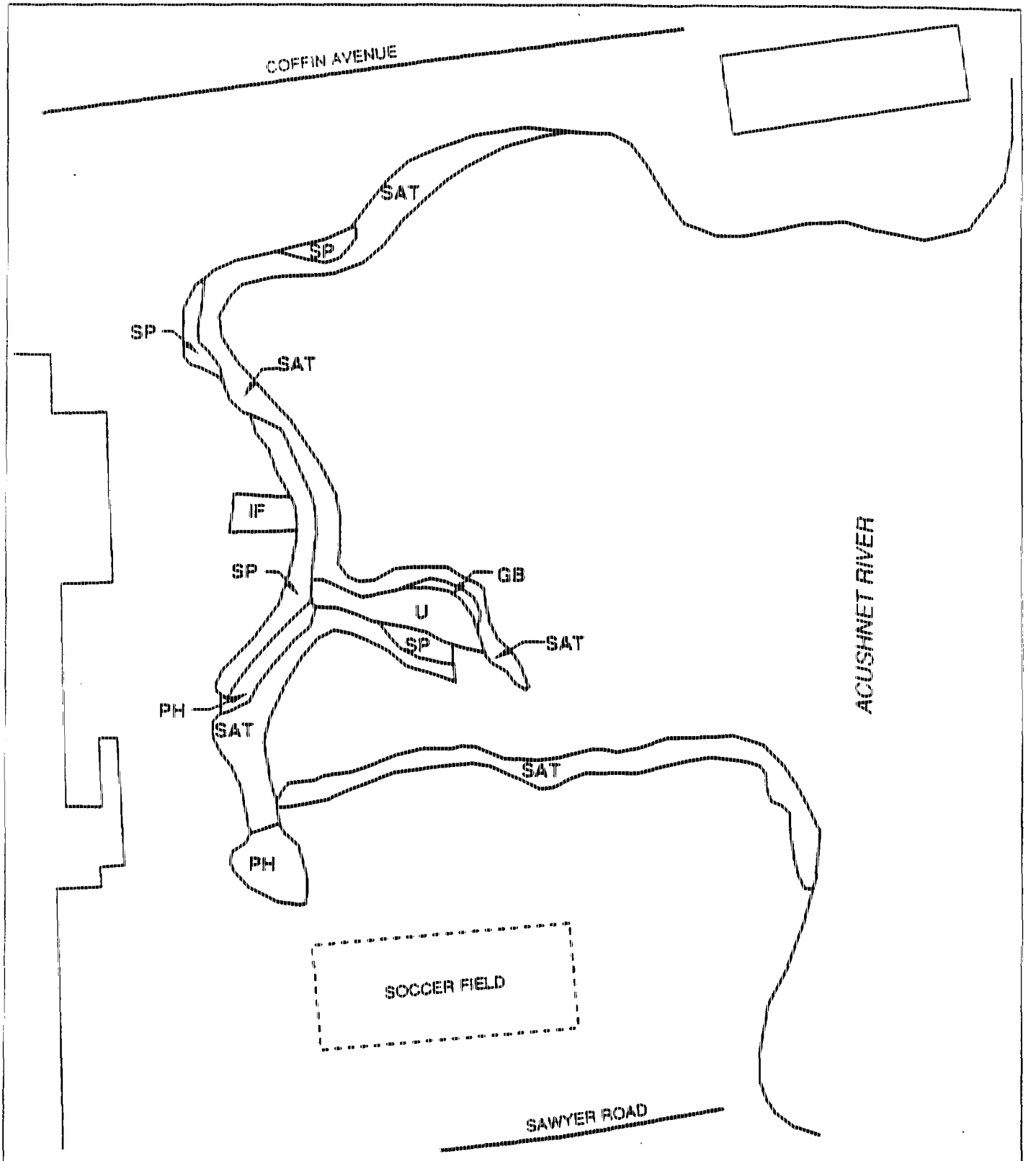
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

COVER-TYPES
DELINEATED AT WETLAND
STUDY AREA No. 4

JANUARY 1988 FILE No. NECIV-1

FIGURE 6-5

IEP inc



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 200'

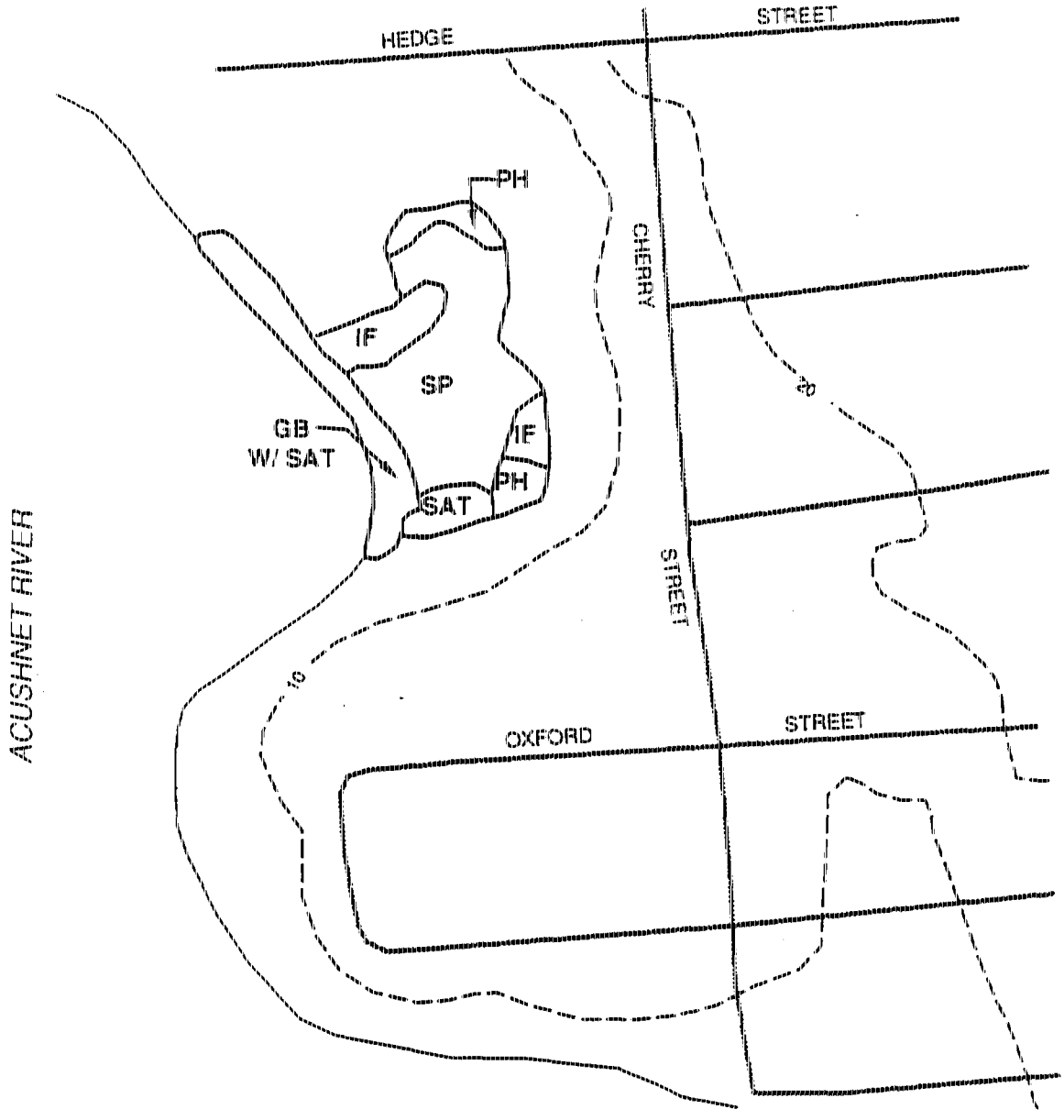
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

COVER-TYPES
DELINEATED AT WETLAND
STUDY AREA No. 5

JANUARY 1988 FILE No. NECIV-1

FIGURE 6-6

ICF inc



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	COVER-TYPES DELINEATED AT WETLAND STUDY AREA No. 9 JANUARY 1988 FILE No. NECIV-1	FIGURE 6-7 IEP inc

6.2 VEGETATION PRODUCTIVITY

6.2.1 Indirect Indices of Productivity

6.2.1.1 Methods

In order to assess productivity and characterize the composition of plant communities of the project area wetlands, indirect indices of vegetation productivity were measured for wetland sites 1, 2, 3, 5, and 9 between 20 July and 31 August 1987. Vegetation was sampled along evenly spaced (100m intervals) transects established perpendicular to the river and randomly at each site. One hundred and fifty (150) sample plots were distributed proportionately among the 5 sites according to the size of each wetland. All communities bisected by transects were sampled at least once; communities which were bisected for more than 50 ft. were sampled twice. Sample $1m^2$ plots within communities were established randomly. Percent cover and height were measured for all species encountered which covered greater than 5% of each plot. In addition, mean stem density was measured for all species occurring in a $0.1m^2$ (0.2 m x 0.5 m) sub-plot located in the northeast corner of the main plot.

6.2.1.2 Results

Tables 6.3 through 6.7 present the results of the vegetation sampling for each wetland site; percent cover, height and stem density and the standard error of the mean are given for each. In addition, the frequency with which a species occurs at each site as well as the distribution of each species relative to all species encountered is given. Since the sampling methodology was community biased (sample plots were based on community changes rather than by regular interval or random designation) measures of percent cover, mean height, and mean stem density characterize the composition of the communities in which the species were found rather than characteristics of all marsh vegetation inclusive. Brief descriptions of the compositional characteristics of the species which make up the salt marsh communities are given below.

6.2.1.3 Wetland Site 1

Sixty-three (63) sample plots were distributed among 10 transects in the salt marsh habitats at site 1 (Figure 6-8). Sample-plot data for this site correspond well with the data obtained from the cover-type mapping. Analysis of sample-plot data reflects a marsh dominated by the high marsh grasses S. patens, which occurred in 50.8% of the plots, and D. spicata which occurred in 49.2% of the plots (Table 6.3). For plots in which it occurred, the mean percent cover of S. patens was 77.6 and the mean stem density 259.1 stems/$0.1m^2$. The percent cover of D. spicata, with a mean of 54.4%, varied considerably; mean stem density for plots in which this species occurred was 72.8 stems/$0.1m^2$. Iva frutescens was the third most abundant species at this site, occurring in 28.6% of the plots; mean stem density in this community was 28.6 stems/$0.1m^2$. Table 6.3 presents complete results of the sample-plot measures.

Table 6.3. Occurrence, Distribution and Species Characteristics[1] for Vegetation Sampled at Wetland Site 1[2].

	Percent Frequency of Occurrence[3]	Relative Frequency Distribution[4]	Mean Percent Cover[5]	Mean Height (cm)[5]	Mean Stem Density[6]
Spartina patens	50.8	22.4	77.6 ± 6.2	29.7 ± 3.1	259.1 ± 39.3
Distichlis spicata	49.2	21.7	54.4 ± 32.3	31.5 ± 1.9	72.8 ± 22.8
Iva frutescens	28.6	12.6	64.4 ± 6.6	87.8 ± 5.6	28.6 ± 9.6
Spartina alterniflora (shrt[7])	19.0	8.4	74.5 ± 9.1	73.4 ± 4.1	33.4 ± 7.7
Juncus gerardii	19.0	8.4	83.6 ± 8.0	41.6 ± 4.0	327.3 ± 72.5
Spartina alterniflora (tall[8])	14.3	6.3	89.4 ± 5.4	133.1 ± 9.0	27.5 ± 3.5
Atriplex patula	12.7	5.6	5.0 -	47.0 -	5.0 -
Salicornia europaea	11.1	4.9	95.0 -	27.0 -	245.0 -
Suaeda linearis	4.8	2.1	5.0 -	17.0 -	1.0 -
Aster tenifolius	4.8	2.1	20.0 -	40.0 -	20.0 -
Spergularia marina	4.8	2.1	30.0 -	10.0 -	9.0 -
Elymus virginicus	1.6	0.7	- -	- -	- -
Solidago sempervirens	1.6	0.7	5.0 -	21.0 -	5.0 -

1 Reported with standard error of the mean.

2 Total number of sample plots = 63.

3 Percentage of plots in which species was found.

4 Measure of distribution, or chance of finding species in random selection.

5 Derived only from plots in which species occurred; measure of community characteristics.

6 No. of stems/ $0.1m^2$.

7 < 1 m tall.

8 > 1 m tall.

Table 6.4. Occurrence, Distribution and Species Characteristics[1] for Vegetation Sampled at Wetland Site 2[2].

	Percent Frequency of Occurrence[3]	Relative Frequency Distribution[4]	Mean Percent Cover[5]	Mean Height (cm)[5]	Mean Stem Density[6]
Spartina patens	51.0	19.5	63.9 ± 7.1	34.3 ± 1.5	244.4 ± 33.2
Distichlis spicata	49.0	18.8	53.1 ± 7.6	34.8 ± 1.8	59.5 ± 10.7
Spartina alterniflora (shrt[7])	43.1	16.5	79.5 ± 22.4	43.2 ± 4.3	91.4 ± 14.7
Limonium nashii	23.5	9.0	17.1 ± 6.2	30.4 ± 2.6	40.0 ± 15.4
Juncus gerardii	21.6	8.3	62.8 ± 10.8	41.9 ± 3.4	264.1 ± 80.0
Salicornia europaea	15.7	6.0	5.0 -	- -	9.0 -
Solidago sempervirens	9.8	3.8	7.5 -	40.0 -	- -
Spartina alterniflora (tall[8])	7.8	3.0	80.0 ± 5.4	105.5 ± 2.0	30.0 ± 1.0
Gerardia maritima	5.8	2.2	35.0 -	15.0 -	56.0 -
Iva frutescens	5.8	2.2	48.3 ± 13.6	77.0 ± 4.4	2.0 ± 57.7
Ammophila breviligulata	3.9	1.5	52.5 ± 7.5	50.0 ± 0.0	45.5 ± 1.5
Atriplex patula	3.9	1.5	- -	- -	- -
Elymus virginicus	3.9	1.5	- -	- -	- -
Triglochin maritima	3.9	1.5	10.0 -	57.0 -	- -
Suaeda maritima	2.0	0.8	- -	- -	- -
Convolvulus sp.	2.0	0.8	10.0 -	- -	2.0 -
Plantago sp.	2.0	0.8	65.0 -	15.0 -	56.0 -

1 Reported with standard error of the mean.

2 Total number of sample plots = 51.

3 Percentage of plots in which species was found.

4 Measure of distribution, or chance of finding species in random selection.

5 Derived only from plots in which species occurred; measure of community characteristics.

6 No. of stems/ $0.1m^2$

7 < 1m tall.

8 > 1m tall.

Table 6.5. Occurrence, Distribution and Species Characteristics[1] for Vegetation Sampled at Wetland Site 3[2].

	Percent Frequency of Occurrence[3]	Relative Frequency Distribution[4]	Mean Percent Cover[5]	Mean Height (cm)[5]	Mean Stem Density[6]
Spartina alterniflora (tall[7])	53.3	21.6	94.3 ± 2.8	127.6 ± 6.2	31.1 ± 3.2
Juncus gerardii	40.0	16.2	66.7 ± 12.8	35.5 ± 5.1	227.5 ± 159.8
Solidago sempervirens	40.0	16.2	26.0 ± 8.9	47.2 ± 8.9	7.3 ± 4.1
Distichlis spicata	33.3	13.5	36.0 ± 13.7	38.8 ± 5.7	164.5 ± 109.3
Iva frutescens	33.3	13.5	31.0 ± 14.7	96.2 ± 8.3	11.0 ± 5.8
Spartina patens	20.0	8.1	75.0 ± 25.0	33.0 ± 1.7	274.5 ± 22.5
Phragmites australis	6.7	2.7	- -	- -	- -
Atriplex patula	6.7	2.7	- -	- -	- -
Aster tenifolius	6.7	2.7	- -	- -	- -

1 Reported with standard error of the mean.

2 Total number of sample plots = 15.

3 Percentage of plots in which species was found.

4 Measure of distribution, or chance of finding species in random selection.

5 Derived only from plots in which species occurred; measure of community characteristics.

6 No. of stems/ $0.1m^2$

7 > 1m tall.

Table 6.6. Occurrence, Distribution and Species Characteristics[1] for Vegetation Sampled at Wetland Site 5[2].

	Percent Frequency of Occurrence[3]	Relative Frequency Distribution[4]	Mean Percent Cover[5]	Mean Height (cm)[5]	Mean Stem Density[6]
Spartina alterniflora (tall[7])	83.3	66.7	96.5 ± 1.7	150.0 ± 3.6	32.3 ± 3.4
Iva frutescens	8.3	6.7	80.0 -	110.0 -	17.0 -
Elymus virginicus	8.3	6.7	- -	- -	- -
Atriplex patula	8.3	6.7	- -	- -	- -
Salicornia europaea	8.3	6.7	50.0 -	27.0 -	20.0 -

1 Reported with standard error of the mean.

2 Total number of sample plots = 12.

3 Percentage of plots in which species was found.

4 Measure of distribution, or chance of finding species in random selection.

5 Derived only from plots in which species occurred; measure of community characteristics.

6 No. of stems/ $0.1m^2$.

7 > 1m tall.

Table 6.7. Occurrence, Distribution and Species Characteristics[1] for Vegetation Sampled at Wetland Site 9[2].

	Percent Frequency of Occurrence[3]	Relative Frequency Distribution[4]	Mean Percent Cover[5]	Mean Height (cm)[5]	Mean Stem Density[6]
Distichlis spicata	50.0	21.2	40.7 ± 14.4	31.3 ± 3.6	76.1 ± 45.1
Spartina patens	42.8	18.2	66.7 ± 13.3	32.8 ± 5.7	237.8 ± 58.1
Juncus gerardii	21.4	9.1	86.7 ± 7.3	49.0 ± 5.8	330.0 ± 85.0
Spartina alterniflora (tall[7])	21.4	9.1	61.7 ± 6.0	125.7 ± 11.9	14.3 ± 6.3
Iva frutescens	21.4	9.1	27.5 ± 2.5	83.0 ± 3.0	13.5 ± 2.5
Spartina alterniflora (shrt[8])	14.3	6.1	20.0 -	58.0 -	9.0 -
Salicornia virginica	7.1	3.0	- -	- -	- -
Salicornia europaea	7.1	3.0	- -	- -	- -
Limonium nashii	7.1	3.0	- -	- -	- -
Solidago sempervirens	7.1	3.0	20.0 -	50.0 -	6.0 -

1 Reported with standard error of the mean.

2 Total number of sample plots = 14.

3 Percentage of plots in which species was found.

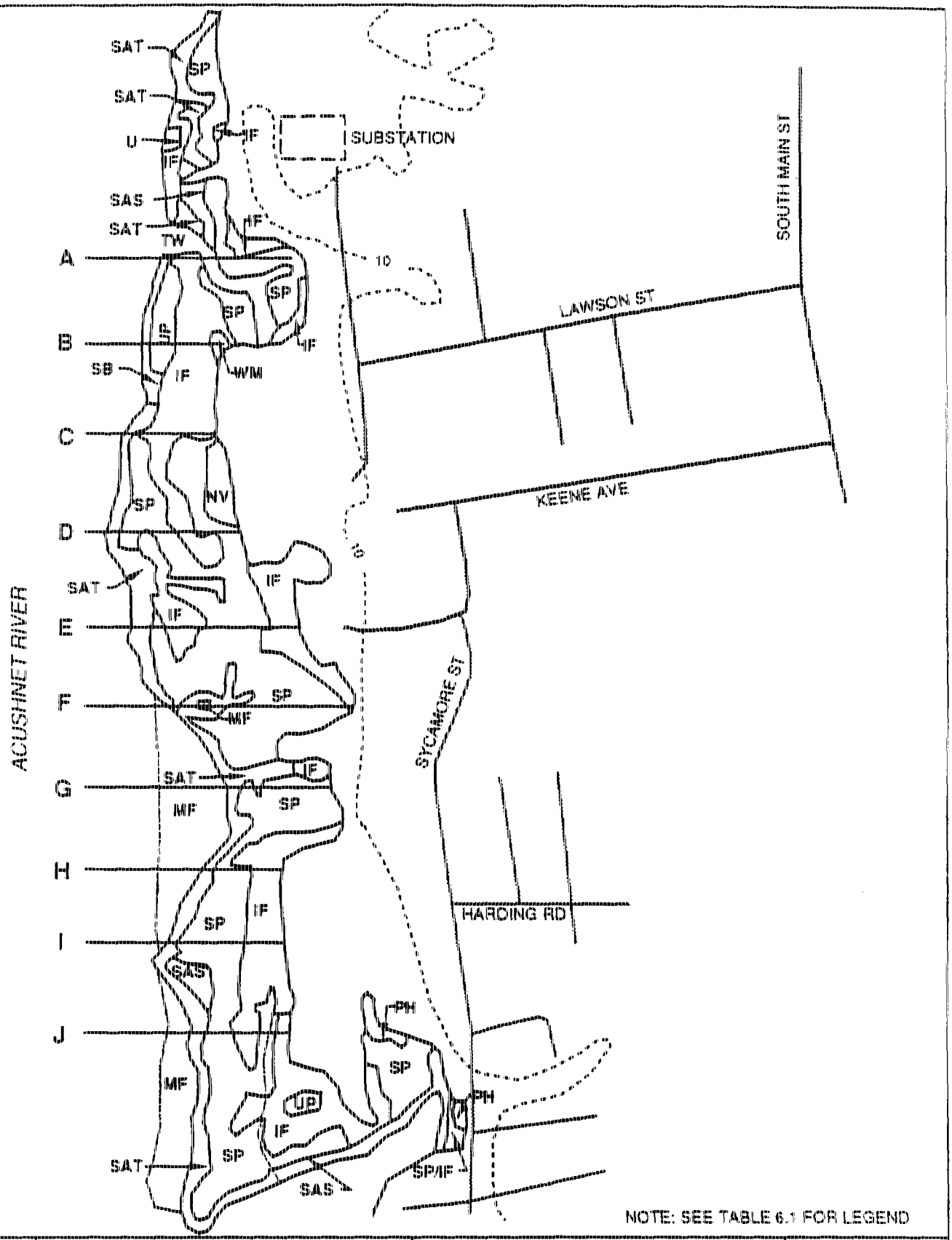
4 Measure of distribution, or chance of finding species in random selection.

5 Derived only from plots in which species occurred; measure of community characteristics.

6 No. of stems/ $0.1m^2$.

7 > 1m tall.

8 < 1m tall.



SCALE: 1" = 461'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

LOCATION OF TRANSECTS
FOR VEGETATION SAMPLING
AT WETLAND STUDY
AREA NO. 1

JANUARY 1988 FILE No. NECIV-1

FIGURE 6-8

ICF inc

6.2.1.4 Wetland Site 2

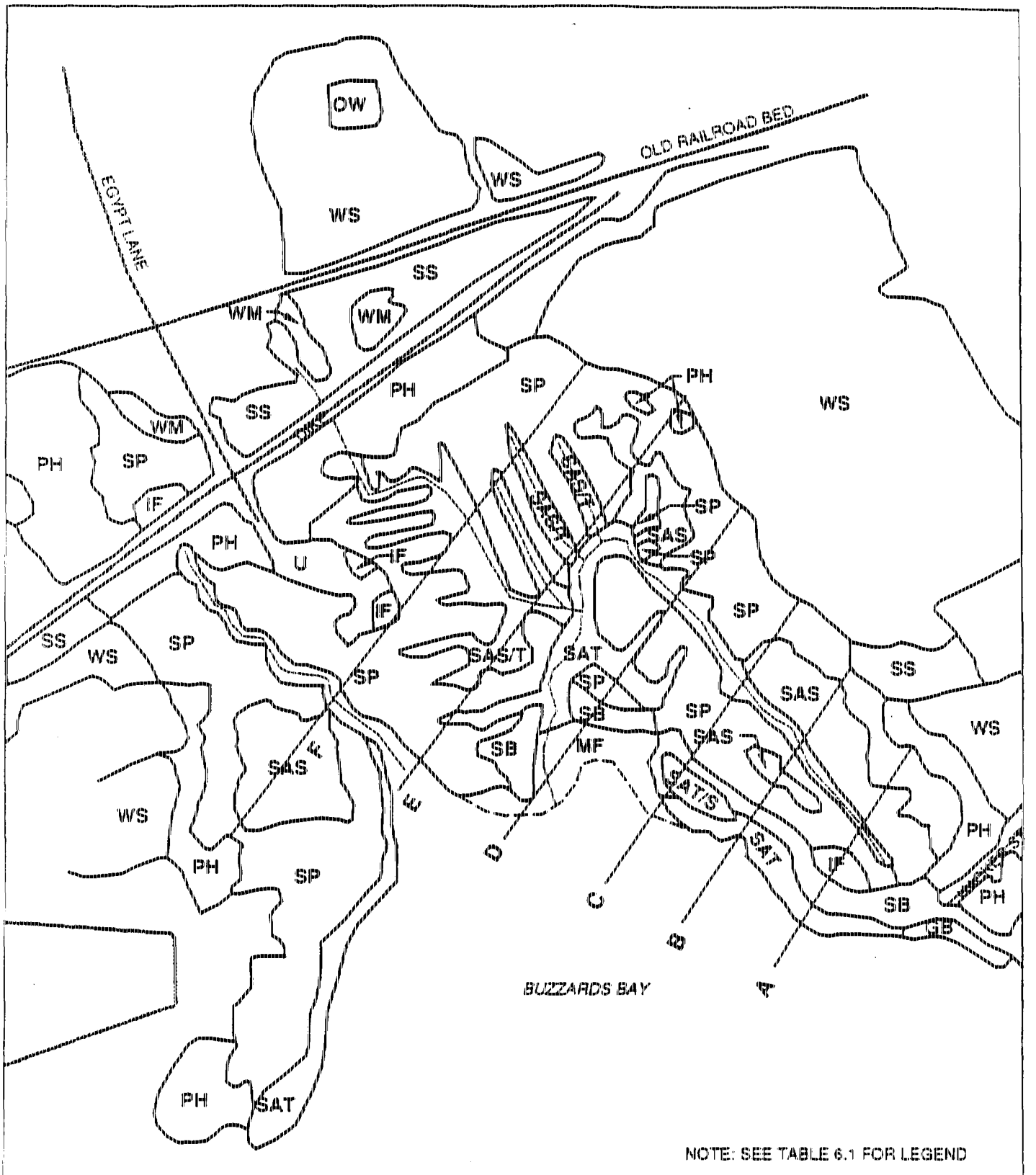
Fifty-one (51) sample plots were distributed among the 6 transects which were established in the estuarine wetlands at site 2 (Figure 6-9). Seventeen (17) species were encountered during sampling efforts, which was the highest number of species recorded in all of the project areas. Spartina patens had the highest (51%) frequency of occurrence; the mean percent cover in S. patens communities was 63.9 and the mean stem density was 244.4 stems/0.1m^2. Distichlis spicata, which occurred in 47% of the plots, was often co-dominant in the high marsh communities and had a mean stem density of 59.5 stems/0.1m^2. Five (5) species occurred in more than 20% of the plots at this site making community composition fairly complex. The short form of S. alterniflora, occurring in 43.1% of the plots, had the highest mean percent cover (79.5%) and a relatively high stem density of 91.4 stems/0.1m^2. Limmonium nashii (seaside lavender) occurred in 23.5% of the plots and had a typically low percent cover of 17%. Juncus gerardi occurred in 21.6% of the plots and had a mean percent cover of 62.8%; although stem densities for this species varied considerably, the mean stem density for plots in which this species occurred was 264 stems/0.1m^2. The tall form of S. alterniflora occurred in only 7.8% of the plots, but had the highest mean percent cover (80%). Table 6.4 presents complete results of the sample-plot data collected at this site.

6.2.1.5 Wetland Site 3

Fifteen (15) sample plots were distributed among 4 transects at this site (Figure 6-10). Tall S. alterniflora (mean height = 126.7cm) occurred in 53.3% of the plots and was the sole inhabitant of the low marsh zone. For plots in which this species occurred the mean percent cover was 94.3 and mean stem density 31.1 stems/0.1m^2. High marsh communities were co-dominated by up to 5 species, a complexity in community composition that could not be delineated in the cover-type mapping. Juncus gerardi occurred in 40% of the plots; its mean percent cover was 66.7 and mean stem density 22.7 stems/0.1m^2. Solidago sempervirens (seaside goldenrod) also occurred in 40% of the plots, but had an expected low percent cover (26%) and stem density (7 stems/0.1m^2). Distichlis spicata and Iva frutescens both occurred in 33.3% of the plots. Spartina patens, which occurred in 20% of the plots had a relatively high percent cover (75%) and stem density (274.5 stems/0.1m^2). See table 6.5 for complete results of sample-plot data.

6.2.1.6 Wetland Site 5

Twelve (12) sample-plots were distributed among 9 transects along the narrow wetland band at site 5 (Figure 6-11). Tall S. alterniflora dominates this low marsh wetland and occurred in 83.3% of the sample plots. The S. alterniflora at this site was the densest (mean percent cover = 96.5; mean stem density = 32.3 stems/0.1m^2) and tallest (mean height = 150cm) found in all of the project areas. The four other species encountered in the sample plots, which included



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 400'

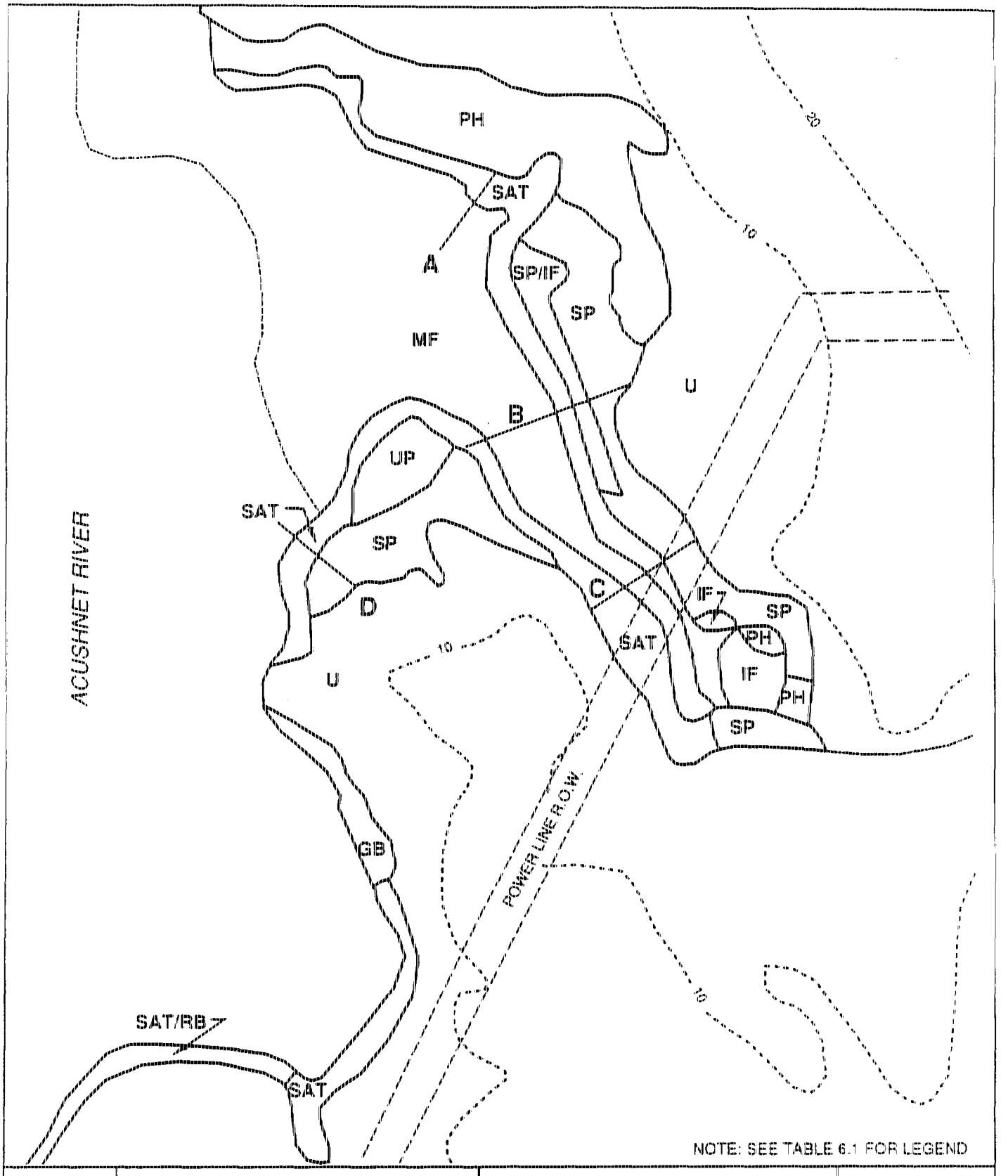
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

LOCATION OF TRANSECTS FOR VEGETATION SAMPLING AT WETLAND STUDY AREA No. 2

JANUARY 1988 FILE No. NECIV-1

FIGURE 6-9

IEP inc



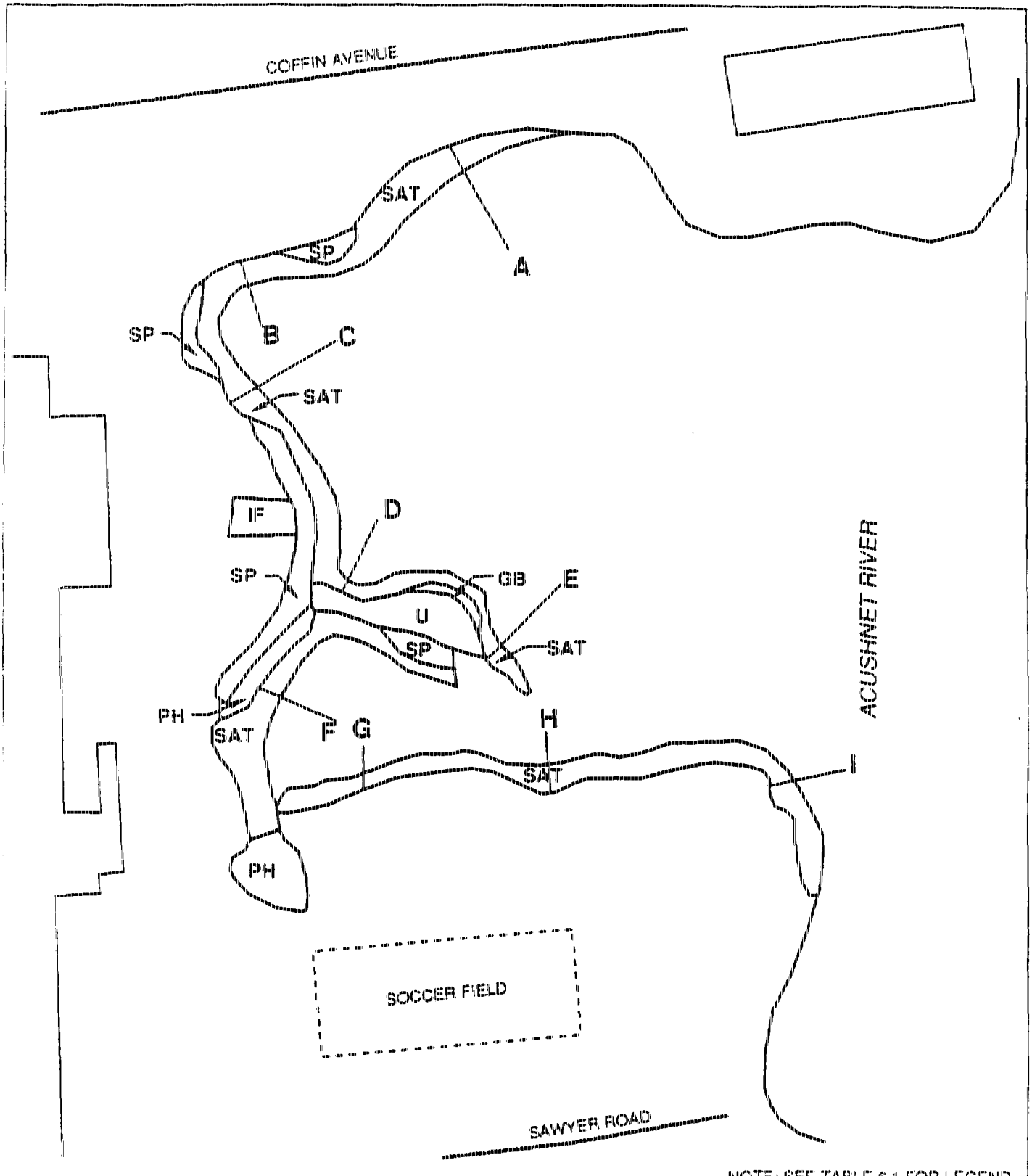
SCALE: 1" = 207'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

LOCATION OF TRANSECTS
FOR VEGETATION SAMPLING
AT WETLAND STUDY
AREA No. 3

JANUARY 1988 FILE No. NECIV-1

FIGURE 6-10



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	LOCATION OF TRANSECTS FOR VEGETATION SAMPLING AT WETLAND STUDY AREA No. 5 JANUARY 1988 FILE No. NECIV-1	FIGURE 6-11 IEP inc

Iva frutescens, Elymus virginicus (seaside rye), Atriplex patula (orach), and Salicornia europaea (glasswort), all occurred in only 8.3% of the plots. Sample-plot results substantiate the cover-types delineated for this wetland. See Table 6.6 for complete results of sample-plot data.

6.2.1.7 Wetland Site 9

Two (2) transects and 14 sample-plots were established at this site in order to characterize the composition of vegetation communities (Figure 6-12). This site is predominantly high marsh; the three most frequently encountered species were D. spicata, S. patens, and J. gerardi. Distichlis spicata occurred in the greatest number of plots (50%), but had a relatively low mean percent cover (40.7%) and stem density (76.1 stems/0.1m^2) when compared to Spartina patens, which occurred in 42.8% of the sample-plots and had a mean percent cover of 66.7% and mean stem density of 237.8 stems/0.1m^2, and Juncus gerardi, which occurred in 21.4% of the plots and had the highest percent cover (86.7) and stem density (330 stems/0.1m^2) of all species encountered at this site. Iva frutescens, which lines the marsh/upland edge, occurred in 21.4% of the plots and had a mean percent cover of 27.5. Table 6.7 gives complete results of the sample-plot data for this site.

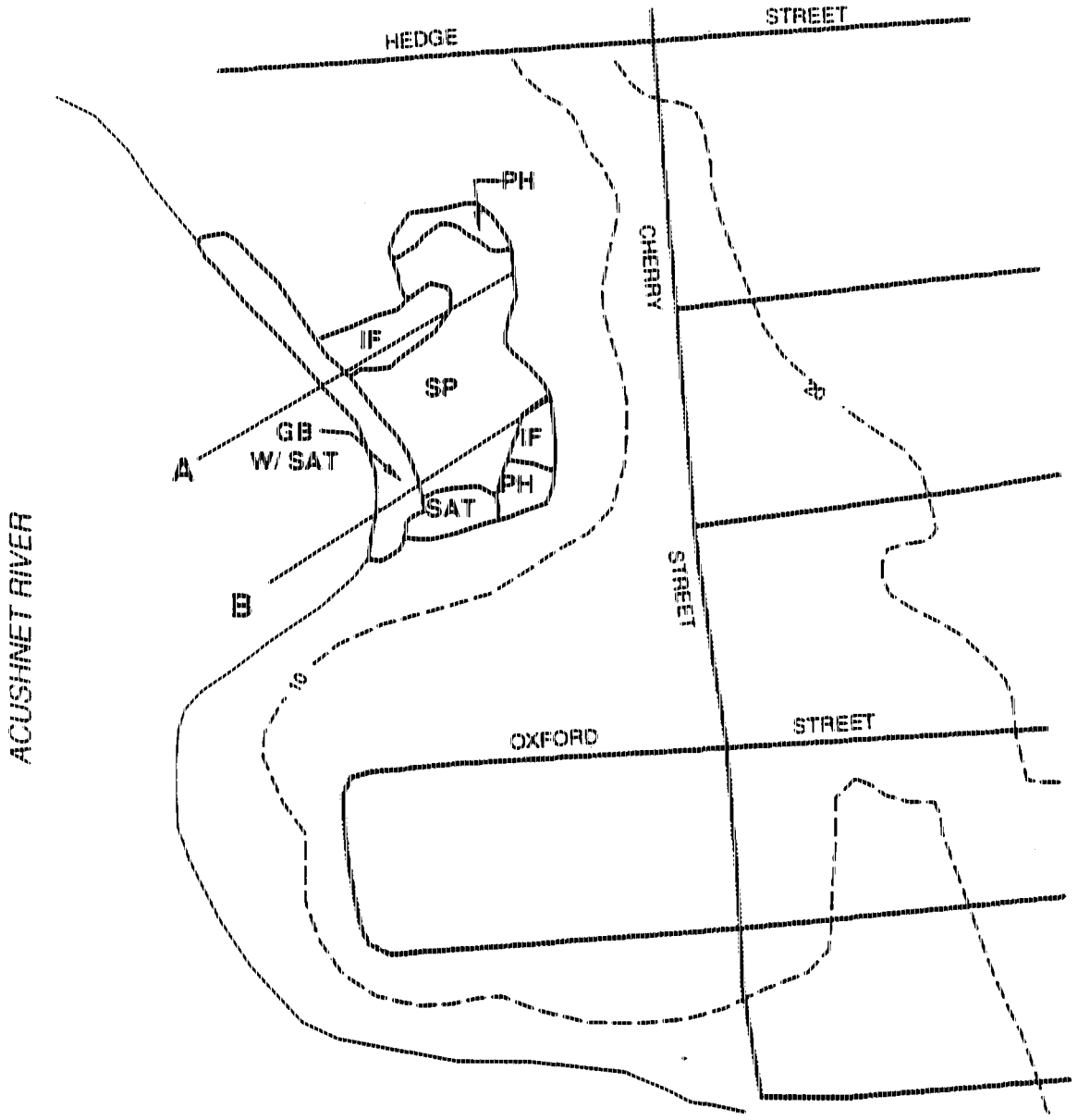
6.2.2 Above-Ground Primary Productivity

6.2.2.1 Methods

Above-ground primary productivity was measured at wetland sites 1, 2, 5 and 9 during September 1987 by collecting all above-ground vegetation within 0.1 m^2 plots. Three (3) samples were taken in all of the major estuarine wetland vegetation communites mapped at the wetland sites: 12 samples were taken from four communities at sites 1, and 2; nine samples were taken from three communities at site 9; and three samples were taken from one community at site 5 for a total of 36 samples collected from the four wetlands. All vegetation was cut to within 1" of the substrate. Ten (10) percent of each sample was dried at 105° C for 48 hours to determine dry weight.

6.2.2.2 Results

Estimates of net marsh productivity derived solely from above-ground plant harvesting are known to underestimate the total energy within a marsh system (Nixon 1982; Teal 1986); leaf fall, grazing, and exudation of organic material all contribute to loss of biomass, and research has shown that more than half of all S. alterniflora biomass is found in below-ground roots and rhizomes (Teal 1986). However, net above-ground productivity values for S. alterniflora have been correlated with below-ground production (Nixon 1982; Teal 1986) providing comparative data for studies in which only above-ground data has been collected. Teal (1986) reports ratios of above/below - ground productivity in Massachusetts of 2.5 for stands of tall S. alterniflora and 8.3 for stands of short S. alterniflora. Nixon (1982) reports a ratio of 4.0 for high marsh communities in a Massachusetts marsh.



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 200'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	LOCATION OF TRANSECTS FOR VEGETATION SAMPLING AT WETLAND STUDY AREA No. 9 JANUARY 1988 FILE No. NECIV-1	FIGURE 6-12 IEP inc

Table 6.8 gives the estimates of above-ground primary productivity for the project areas in which this data was collected and comparison values from other studies conducted in southern New England. Values for tall S. alterniflora correspond well with both data from Teal (1986) and with the indirect indices data collected in this study. In the four project areas where samples of tall S. alterniflora were collected, above-ground primary productivity values ranged from 1023 g dry wt./m^2/yr (site 1) to 1800 g dw/m^2/yr (site 5). In comparison, Teal (1986) reports a value of 1320 g dw/m^2/yr for tall S. alterniflora communities in the Great Sippewissett marsh in Falmouth, MA. The high productivity value for tall S. alterniflora at site 5 can be expected based on the height and density values obtained in the collection of indirect indices data (see Table 6.4). These values may be due, in part, to the high degree of tidal flushing this community receives (Teal 1986); tall S. alterniflora at site 5 occurs in a very narrow (< 5m) band along steep banks which are completely flooded and exposed twice daily, thus facilitating constant nutrient exchange and oxidation of soils.

On the high marsh productivity values for S. patens communities ranged from 935 g dw/m^2/yr (site 2) to 1040 g dw/m^2/yr (site 9). In comparison, Nixon (1982) reports a value of 1100 g dw/m^2/yr for a Massachusetts marsh, and a value of 430 g dw/m^2/yr for a Rhode Island marsh (Table 6.8). Using the ratios given Teal (1986) for below-ground productivity of S. alterniflora communities, and that given by Nixon (1982) for below-ground productivity of high marsh communities, estimates of total marsh productivity for those communities range from 2557 g dw/m^2/yr (site 1) to 4500 g dw/m^2/yr (site 5) for tall S. alterniflora communities, and from 2874 g dw/m^2/yr (site 2) to 4220 g dw/m^2/yr (site 9) for high marsh communities (includes S. patens, short S. alterniflora, and high marsh mix communities).

6.3 DISCUSSION

The salt marsh communities within the project area are quite typical of salt marshes along the southern New England coast. The plant species composition of the vegetated marshes (Tables 6-3 to 6-7) are representative of those found in the region, as referenced in the community profiles of the regularly flooded marshes (Teal 1986) and high salt marshes (Nixon 1982) of New England. The most unusual feature with respect to vegetative composition is the relative abundance of Iva frutescens throughout much of wetland 1; this is probably related to the hydrologic regime which has developed along this stretch subsequent to the installation of the hurricane barrier.

There are no obvious indications of damage or stress to salt marsh macrophytes which might be related to chemical contamination. There are no signs of abnormal rates of plant mortality or stress as might be reflected in chlorosis or other color or morphological aberrations. The above-ground standing crop data (Table 6-8) suggest that vascular plant productivity of the marshes is well within the range of reported values for other salt marshes in southern New England.

Table 6.8. Estimates of Above-ground Primary Productivity (g dw/m2/yr)[a] of Vascular Plants at the Project Area Wetlands[b] and Comparison Values from Other Southern New England Salt Marshes.

VEGETATION	Wetland Site 1	2	5	9	Teal (1986)	Nixon (1982) MA	RI
Spartina alterniflora (short[c])	-	410	-	-	420	480	430
Spartina alterniflora (tall[d])	1023	1153	1800	1240	1320	-	-
Spartina patens	957	935	-	1040	-	1100	430
High Marsh[e]	933	811	-	1070	-	-	680
Iva frutescens	5286	-	-	-	-	-	-

a Grams of dry weight per square meter per year; values represent mean of 3 samples taken at each community.

b Productivity values represent the mean of 3 samples taken in each community; see text.

c < 1m in height.

d > 1m in height.

e Predominantly S. patens/D. spicata mix.

The highest biomass of herbaceous vegetation was recorded for tall Spartina alterniflora in the regularly flooded zone of wetland 5; this wetland is relatively close to a principal source of contamination, yet no indication of reductions in plant productivity are observed as a result of this proximity.

There is little available data on what levels of contaminants such as heavy metals or PCBs are damaging to salt marshes (Teal 1986). Existing studies are limited to examining the effects of long-term (12 years) experimental application of sewage sludge containing heavy metals at levels nine times higher than those normally used in upland sludge disposal (Giblin 1982), or the impacts from a major oil spill on a marsh in Buzzards Bay (Hampson and Moul 1978). While the latter found reductions in biomass, height and density of vegetation, the former research has revealed no indication that the marsh ecosystem has been damaged by the long-term sewage sludge application, and no clearly detrimental effects of the sludge on marsh plants were demonstrated in spite of the heavy metals in the sludge (Teal 1986). Observable effects of elevated metal concentrations in the New Bedford marshes would not be expected given these findings. Since PCBs are not known to accumulate in Spartina tissues, it may not be surprising that no visible impacts to the vegetation of the New Bedford salt marshes are evident.

7.0 SALT MARSH INSECTS

7.1 FIELD OBSERVATIONS

Incidental observations of insects in the project area wetlands were recorded while performing other study tasks. Due to the greater effort involved in performing project tasks at wetland sites 1 and 2 the majority of insect observations were taken from these wetlands.

The most common insects found in all of the salt marsh habitats include the salt marsh mosquito (Aedes solicitans) and the green-headed fly (Chloropidae). The salt marsh mosquito was observed from early June though mid September, with population eruptions occurring within a few days of heavy rains or flooding of the marsh by spring tides. The green-headed fly was not observed until mid July and was most prevalent at site 2. Other insects commonly observed on the high marsh include crickets, grasshopers, and praying mantids. Spiders, mainly jumping spiders and wolf spiders, were also commonly observed in the high marsh habitats.

Additional insect occurrences reported by SES (1987) for the project area wetlands include katydids (Tettigoniidae), casebearers (Coleoptera sp.), mantids (Tenodera aridifolia) and mirids (Miridae).

8.0 WILDLIFE

8.1 AVIFAUNA

8.1.1 Census Methodology

To document the abundance and diversity of birds resident during the breeding season, surveys were conducted at the Acushnet River Estuary (wetland site 1) and Pope Beach (wetland site 2) (Figure 8-1) on 10 dates between 9 June 1987 and 20 July 1987. All surveys were begun within 1 hour after sunrise, a period of increased activity (e.g. singing, foraging) especially among terrestrial, territorial birds.

Three habitats were censused at each site, tidal open water, salt marsh and salt marsh/upland edge. Only birds observed using the habitat being surveyed were included in the analysis; use included foraging, resting, preening, and courtship display.

All confirmed and suspected breeding species were noted; breeding status was confirmed by finding a nest, or observing one or more of the following behaviors: copulation, parent with food in bill, and parent feeding newly fledged young.

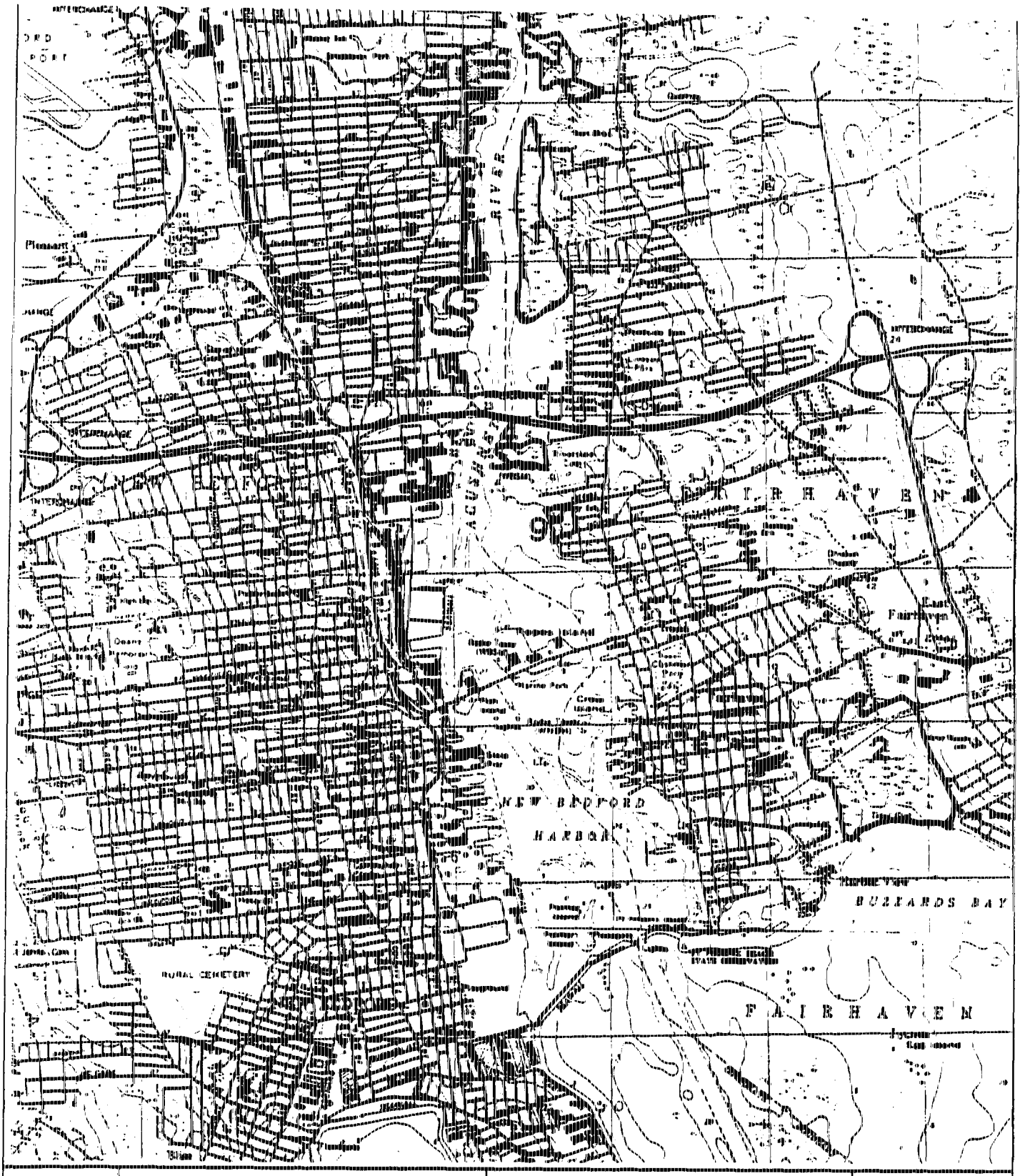
To avoid possible sources of variability, surveys were not conducted during rain or flood tides when the marsh was not easily accessible. Both sites 1 and 2 were in the flight path of the New Bedford Airport, and low flying aircraft.

At the Acushnet River Estuary (wetland site 1), surveys of the open water habitat were conducted from two points on the edge of the salt marsh (Figure 8-2). These points offered unobstructed views of the survey area which included all tidal open water, mudflat, and shore habitats between the Coggesshall and Wood street bridges; the tidal creek extending into wetland 3 was not surveyed. Birds were enumerated in the open water habitat by scanning pre-established segments of the study area and recording individuals and/or groups as encountered.

The area encompassed in the open water surveys of Pope Beach (wetland site 2) include the shoreline extending east from Pope Beach to Silver Shell Beach, swinging out into Buzzards Bay to Little Egg Island, and then to the eastern end of Fort Phoenix State Reservation (Figure 8-3). All tidal open water, mudflat, and shore habitats were surveyed from the parking lot at Pope Beach with the aid of a 20 x 60 spotting scope (Figure 8-3).

8.1.2 Transect Methodology and Location

The salt marsh and marsh/upland edge habitats were censused using the variable-strip method, Emlen (1971), whereby an observer walks an established trail (transect) and records all individual birds observed and the distance, perpendicular to the transect, at which individual birds were first detected.



SCALE:
1" = 2083'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

PROJECT AREA
AND LOCATION OF
WETLAND STUDY SITES

JANUARY 1988 FILE No. NECIV-1

FIGURE 8-1

IEP inc

SCALE:
1" = 1100'

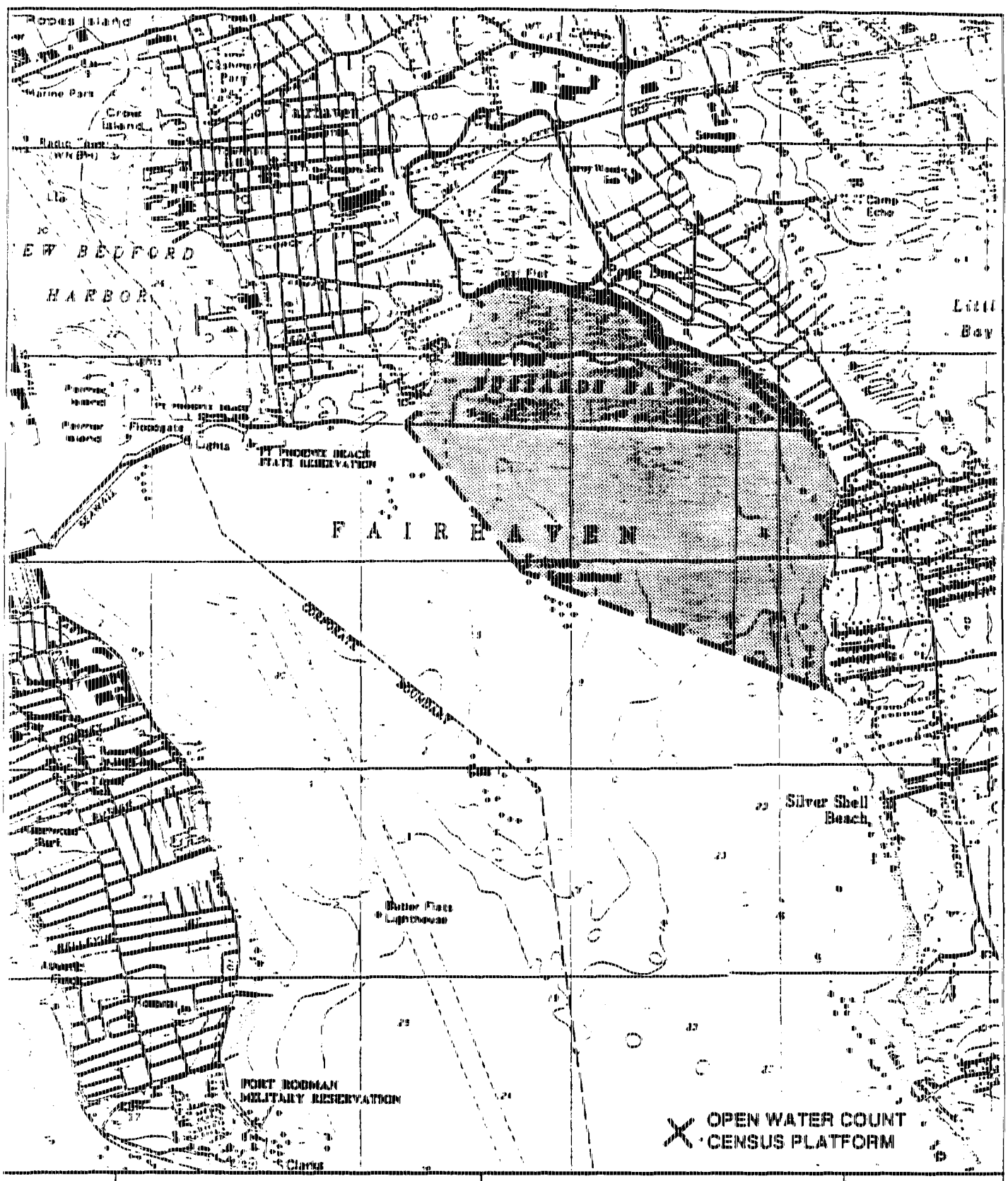
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

AREA COVERED BY AVIAN CENSUS OF OPEN WATER HABITATS AT WETLAND STUDY AREA NO. 1

JANUARY 1988 FILE No. NECIV-1

FIGURE 8-2

IEP inc



SCALE: 1" = 2083'

ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

AREA COVERED BY AVIAN CENSUS OF OPEN WATER HABITATS AT WETLAND STUDY AREA NO. 2

JANUARY 1988 FILE No. NECIV-1

FIGURE 8-3

IEP inc

Near complete detection of all birds within the basal strip (the first 15m on both sides of the transect) is assumed. A ratio is derived from the proportion of the total number of a species observed within the basal strip to that observed outside the basal strip, and is used to extrapolate the density of a species for a given area.

The positioning of the salt marsh and marsh/upland edge transects follows those used by SES (1987) (Figures 8-2, 8-4), except at site 2 where no transect was established on the north side of the hurricane dike. This highly disturbed portion of the marsh is dominated by Phragmites, and offered little value in terms of habitat/species comparison with site 1.

Transects were staked at 100m intervals, allowing the observer to concentrate on detecting birds, rather than on trying to follow the same path traversed in previous census efforts.

At site 1, a continuous transect of 800m was established on the salt marsh, and a 900m transect, split in 2 sections, was established in the marsh/upland edge (Figure 8-4). At site 2, an 800m transect was established in three sections on the salt marsh, and a single transect 800m in length was established on the marsh/upland edge (Figure 8-4).

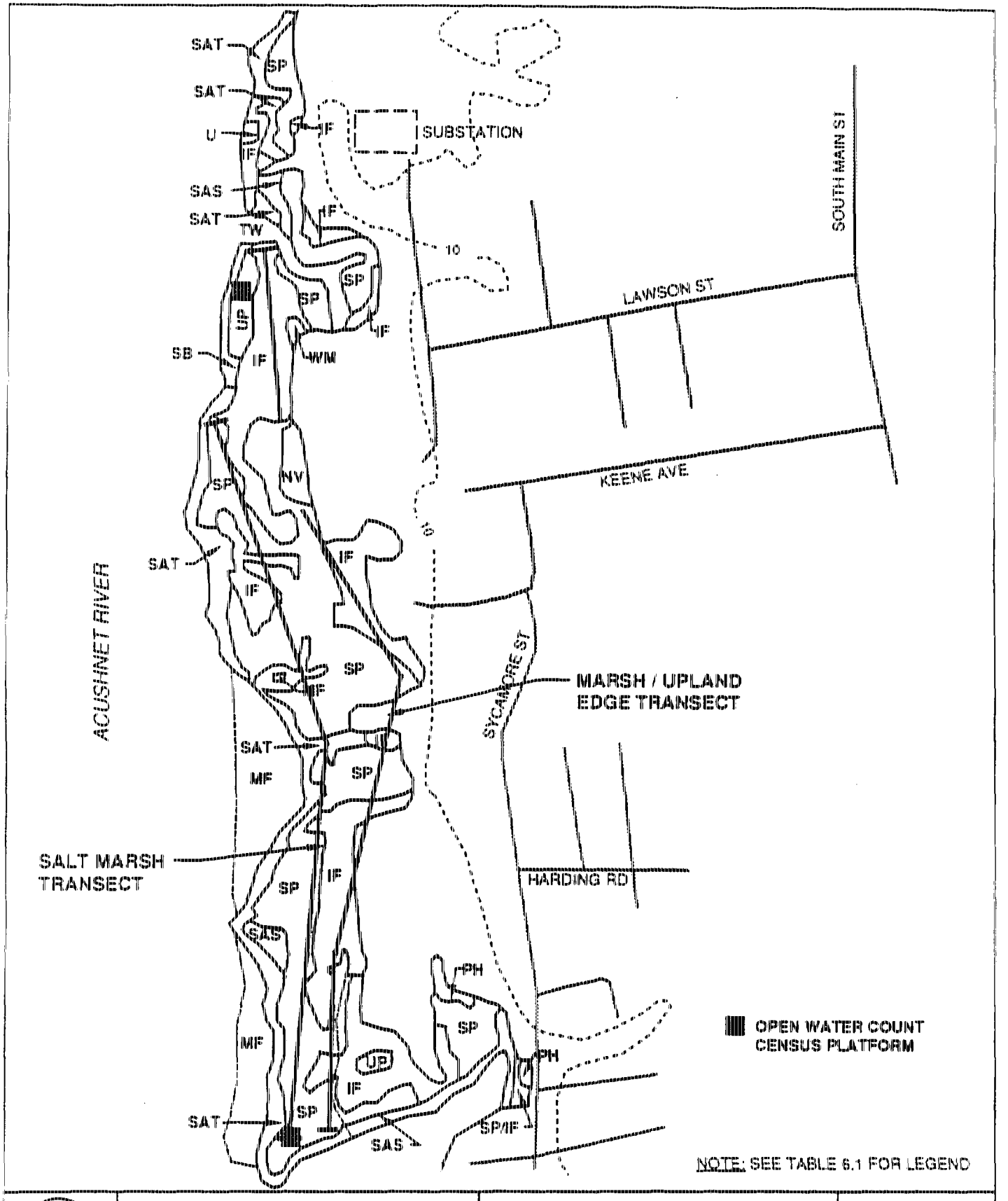
8.1.3 Avian Usage within each Wetland by Habitat Type

8.1.3.1 Open Water Habitat

Differences in several aspects of the open water habitats at wetland sites 1 and 2 warrant careful interpretation of the open water counts. The size and exposure of both sites differ markedly, with site 1 abutting protected, relatively shallow estuary, whereas site 2 abuts deep water marine habitats lying outside the New Bedford hurricane barrier. Intertidal flats are virtually absent at site 2, whereas at site 1 there is an extensive area of mud flats just south of the Wood Street bridge and adjacent to wetland site 3, which are exposed during most low tides. Wetland site 2 is adjacent to fisheries traffic of New Bedford and Fairhaven; the development patterns along its shoreline vary from dense residential developments to relatively undeveloped beach, salt marsh, and forest. The eastern shoreline of wetland site 1 is dominated by salt marsh and shrub communities, whereas its western side is heavily industrialized.

Accurate comparisons of use by species and groups at these dissimilar sites requires a combination of quantitative measures and knowledge of how site differences might affect bird use. Thus, in addition to presenting avian denstities at each site, the total number of a species observed, and the frequency in which a species occurred at each site are also given (Table 8.1).

A total of 16 species was observed in the tidal open water habitat at wetland site 1, for a total density of 13.0 birds/100acres, and 24 species at wetland site 2, for a total density of 12.8 birds/100 acres (Table 8.1). Five species were common (observed >50% of the time) to both sites including: Herring



SCALE: 1" = 461'

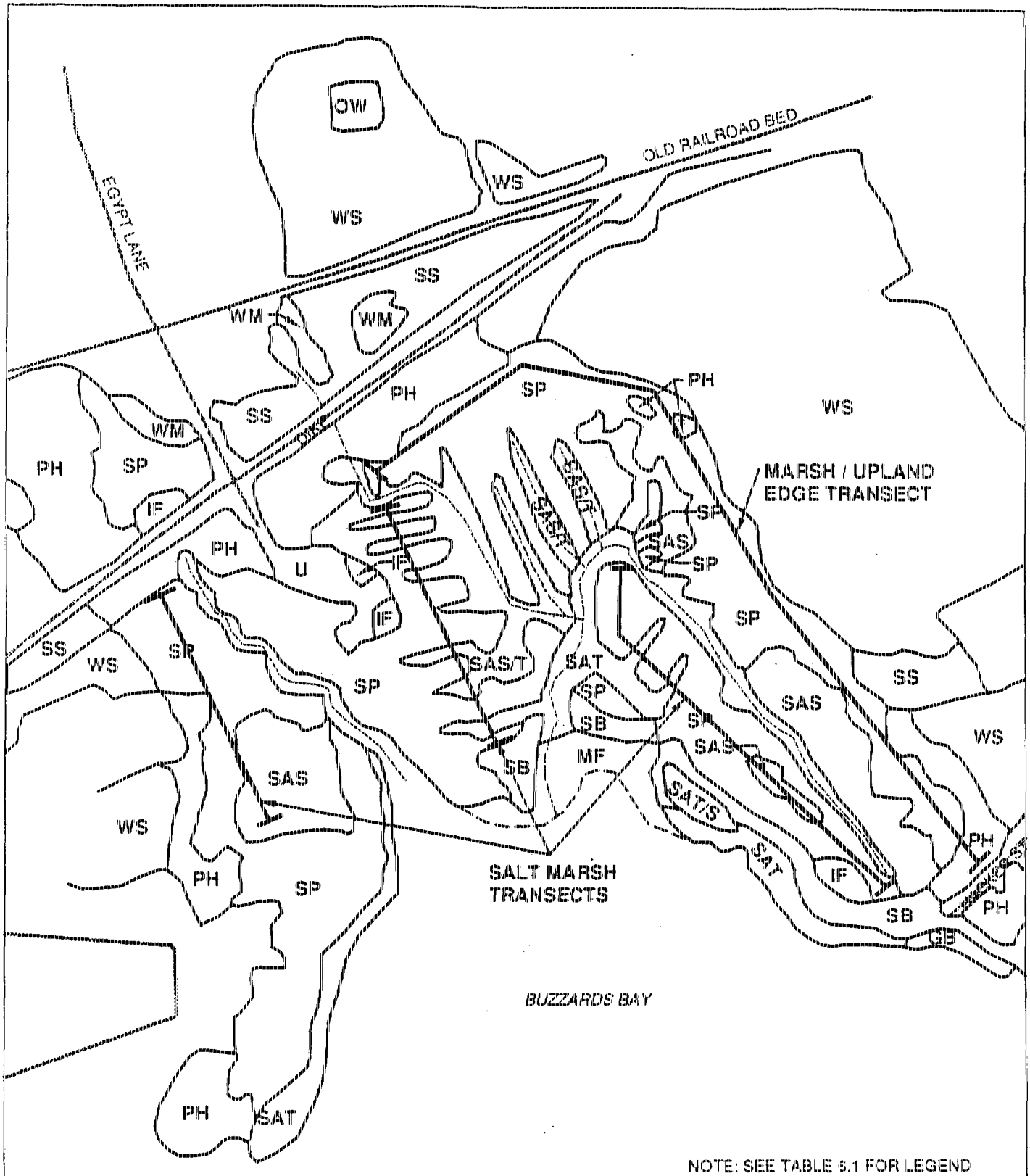
ACUSHNET RIVER ESTUARY
NEW BEDFORD HARBOR
SUPERFUND PROJECT

LOCATION OF AVIAN CENSUS TRANSECTS AND OPEN WATER COUNT PLATFORMS AT WETLAND STUDY AREA NO. 1

JANUARY 1988 FILE No. NECIV-1

FIGURE 8-4

IEP inc



NOTE: SEE TABLE 6.1 FOR LEGEND

SCALE: 1" = 400'	ACUSHNET RIVER ESTUARY NEW BEDFORD HARBOR SUPERFUND PROJECT	LOCATION OF AVIAN CENSUS TRANSECT AT WETLAND STUDY AREA NO. 2 JANUARY 1988 FILE No. NECIV-1	FIGURE 8-5 ICF inc

Table 8.1. Total Counts (no.) and Percent Frequency of Occurrence (%) of Birds Observed Within Open Water and Mud/sandflat Habitats Censused between 9 June and 20 July 1987.

	Acushnet River Estuary Site 1		Pope Beach Site 2	
Species	no.	%	no.	%
Horned Grebe	-	-	7	70
Double-crested Cormorant	7	60	186	100
Great Blue Heron	-	-	3	10
Green-backed Heron	-	-	3	30
Black-crowned Night Heron	2	20	-	-
Great Egret	2	20	-	-
Snowy Egret	3	30	6	50
American Black Duck	5	20	12	40
Mallard Duck	28	60	33	70
Mute Swan	13	40	-	-
Osprey	-	-	1	10
American Kestrel	-	-	1	10
Killdeer	1	10	14	60
Lesser Yellowlegs	-	-	1	10
Greater Yellowlegs	-	-	1	10
Spotted Sandpiper	-	-	6	30
Peep sp.	-	-	3	10
Herring Gull	134	100	412	90
Great Black-backed Gull	31	90	17	80
Ring-billed Gull	5	30	10	30
Laughing Gull	-	-	1	10
Gull sp.	4	20	57	50
Least Tern	2	10	-	-
Common Tern	-	-	13	80
Rock Dove	15	60	55	70
Mourning Dove	2	10	1	10

Table 8.1. Birds Observed Within Open Water and Mud/sandflat Habitats Censused between 9 June and 20 July 1987.

	Acushnet River Estuary Site 1		Pope Beach Site 2	
Species	no.	%	no.	%
American Crow	1	10	14	60
European Starling	1	10	4	30
Common Grackle	-	-	4	20
Total: Birds Enumerated	254		865	
Species	16		24	
Density	13.0/40 ha (100 acres)		12.8/40 ha (100 acres)	

Gull, Double-crested Cormorant, Mallard Duck, Great Black-backed Gull and Rock Dove. Four species were unique to site 1 and these included: Mute Swan, Black-crowned Night Heron, Great Egret, and Least Tern. The Least Tern is a species of special concern of the Massachusetts Natural Heritage Program. This species nests primarily on mainland beaches in variable sized colonies and feeds on minnows in shallow water. Observed on one occasion during the study period, Least Terns were observed incidentally foraging in the waters adjacent to wetland site 1 throughout August and early September.

Twelve species were unique to wetland site 2 including: Horned Grebe, Great Blue Heron, Green-backed Heron, Lesser Yellowlegs, Spotted Sandpiper, peep sp. (one or more of the small calidrid sandpipers including the Least and Semi-palmated Sandpipers), Laughing Gull, Common Tern, Common Grackle, Osprey, and American Kestrel. Both the Osprey and Common Tern are special concern species of the Massachusetts Natural Heritage Program.

Wetland sites 1 and 2 received the greatest use by gulls. Of this group, the Herring Gull was the most abundant and most frequently observed. The greater number of Herring Gulls observed at site 2 reflects the greater size of the study area as well as its proximity to fisheries traffic; gulls often were observed following fishing vessels at site 2. Although this group was frequently observed, greater abundance may be expected at both sites in the fall/winter (SES 1987) when post-breeding gulls come inshore. Although not abundant during the study period, Common Terns were observed frequently at site 2, and were observed incidentally throughout August at sites 1 and 2.

Shorebird numbers were low and reflect trends observed throughout the region (Lloyd Center 1986) during this part of the year when the vast majority of shorebirds are on their breeding ground to the north. Except for the Killdeer, a confirmed breeder at site 2, and Spotted Sandpiper, a suspected breeder at site 2, the few shorebirds observed were recorded at site 2 near the end of the census period and probably represented the first migrants of the fall. These early migrants included the Lesser Yellowlegs, Greater Yellowlegs, and peep sp. The Killdeer was the only shorebird observed at site 1 during the study period. However, an incidental sighting on 18 August of 10 Greater Yellowlegs foraging on the exposed flats adjacent to wetland site 3, and subsequent incidental sightings throughout August and September of Yellowlegs, Spotted Sandpipers, and peep sp., suggest that the tidal open water habitat of the Acushnet River Estuary receive increased use by shorebirds as fall migration progresses.

The Mallard Duck was common at wetland sites 1 and 2, and was a confirmed breeder at site 2; 10 juveniles (ca. 3 weeks old) with a hen Mallard were observed in the open water at site 2 on 9 June. The American Black Duck was less common at both sites, but was a suspected breeder in the marsh at wetland site 3. Incidental sightings of up to 25 Black Ducks were recorded throughout August and September in the upper reaches of the tidal creek at wetland site 3.

Although not abundant, herons and egrets were observed throughout the study period. The Snowy Egret was the most frequently observed wader at both sites. Incidental sightings at site 1 throughout August and September show a much greater abundance of this group, especially immature birds, in the post-breeding season which foraged in the shallow water adjacent to wetland site 3.

One other incidental sighting should be noted. On 9 July a Least Bittern was observed foraging at the edge of a Phragmites community just north of the Wood Street bridge (wetland site 3). The Least Bittern is currently listed as a threatened species by the Mass. Natural Heritage program.

The doves and passerines observed at both sites used the intertidal habitat for foraging.

SES (1987) also censused the open water/mud flat habitats from Tarklin Hill Road to the estuary mouth during late winter/early spring of 1985 and late summer of 1986 (Table 8.2). Based on trends reported by the Lloyd Center (1986) and SES (1987), the abundance of the various bird groups reported in this study are within the expected range for this region during the spring/summer. Although SES (1987) did not conduct surveys during June, data for their April and May surveys show a decrease in the numbers of bird species and densities as summer approaches, a trend confirmed in this study.

Heron, egret, and tern numbers at both sites were lower than those reported by the Lloyd Center (1986). However, this is most likely due to the proximity of the study areas under investigation here, to breeding grounds. Both the Common and Least Tern are known to breed in the Plymouth County region of Buzzards Bay (east of the study sites) and to the west at Allens Pond (Lloyd Center 1986). Furthermore, the broad, shallow lagoon, along with the undeveloped and undisturbed shoreline characteristic of the Lloyd Center (1986) study site, offers favorable foraging and resting areas for long-legged waders and terns, and nesting habitat for the latter group. This, alone, may account for the overall greater abundance of these groups reported by the Lloyd Center (1986).

Although species diversity was greater at site 2, densities between sites 1 and 2 were nearly equal. Differences in the abundance of certain species between project area locations can be expected based on site locations. Wetland site 2 is more centrally located with respect to nesting grounds of colonial nesters such as terns and long-legged waders. Greater use of site 2 by these groups can be expected, as birds commuting to and from coastal foraging areas are more likely to encounter wetland site 2 than wetland site 1.

Trends observed at wetland site 1 in August and September suggest that the tidal open water habitat at this site become more important during fledgling dispersion and migration, when terns and long-legged waders are not restricted in their foraging range, and when shorebirds pass through the region on their journey south.

Table 8.2. RESULTS OF SES (1987)
Open Water/Mudflat Bird Censuses-Acushnet River Estuary

	Late Winter / Early Spring (1985)					Late Summer (1986)
	22 FEB	08 APR	14 APR	04 MAY	19 MAY	18,19 SEPT
Double-crested Cormorant	---	2	1	8	9	3
Great Egret	---	---	1	---	---	1
Mute Swan	6	6	4	7	6	1
Canada Goose	---	2	2	2	2	---
American Black Duck	24	11	---	---	---	---
Mallard	22	2	---	---	---	---
American Wigeon	23	---	4	---	---	---
Canvasback	4	---	---	---	---	---
Greater Scaup	10	5	119	---	---	---
Common Goldeneye	---	---	---	1	---	---
Bufflehead	14	60	13	2	---	---
Peregrine Falcon	1	---	---	---	---	---
Black-bellied Plover	---	---	---	---	2	---
Killdear	---	---	2	---	---	---
Greater Yellowlegs	---	2	---	13	6	---
Spotted Sandpiper	---	---	---	---	1	1
Laughing Gull	---	---	---	2	---	25
Common Black-headed Gull	---	1	---	---	---	---
Ring-billed gull	266	8	53	36	42	2
Herring Gull	295	14	11	20	2	9
Iceland Gull	1	---	---	---	---	---
Great Black-backed Gull	40	10	16	9	33	9
Least Tern	---	---	---	8	---	---
Rock Dove	3	---	---	2	10	+
Mourning dove	---	---	---	---	2	---
Tree Swallow	---	---	---	2	---	---
American Robin	---	---	---	---	1	---
European Starling	---	---	7	8	2	---
Song Sparrow	---	---	---	2	1	---
Common Grackle	---	---	---	---	8	---
House Sparrow	---	---	8	---	---	---
Great Blue Heron	---	---	---	---	---	10
Snowy Egret	---	---	---	---	---	8

Table 8.2 RESULTS OF SES (1987)
continued Open Water/Mudflat Bird Censuses - Acushnet River Estuary

	22 FEB	08 APR	14 APR	04 MAY	19 MAY	18,19 SEPT
Lesser Yellowlegs	---	---	---	---	---	6
Forster's Tern	---	---	---	---	---	1
Belted Kingfisher	---	---	---	---	---	2
TOTALS #	849	533	241	122	127	78+
SPECIES	13	12	13	15	15	14

8.1.3.2 Salt Marsh Habitat

Table 8.3 presents species densities recorded in the salt marsh habitats at sites 1 and 2. Twelve (12) species for a total density of 276 birds/100 acres were recorded in the salt marsh habitat at site 1. Eighteen (18) species for a total density of 305.4 birds/100 acres were recorded in the salt marsh habitat at site 2. The densities are within typically reported values for southern New England salt marshes (Reinert and Kilpatrick 1986; Reinert et al 1981).

The American Black Duck was unique to site 1, and was suspected breeding in the northern end of site 1. Seven (7) species were unique to site 2, however, only 2, the Clapper Rail and Spotted Sandpiper, had densities greater than 1.9 birds/100 acres. The Clapper Rail was a confirmed nesting species at site 2 within a creekside stand of tall Spartina alterniflora in the southeast part of the study area; an adult incubating 10 eggs was discovered on 16 June, and both parents were observed near the nest with at least 2 young (1-2 days old) on 8 July. The nest was placed in a stand of short (<40cm) Spartina alterniflora 2m from a mosquito ditch. The Spotted Sandpiper was suspected to be nesting at site 2, and was most frequently observed on the exposed bottoms of mosquito ditches and tidal creeks.

The salt marsh habitat at sites 1 and 2 received the greatest use by passerines (i.e. perching birds; sparrows, blackbirds, starling, etc.). Passerine densities were very similar (231 birds/40 ha, site 1; 236.3 birds/40 ha, site 2), but use of the salt marsh habitat between sites differed considerably. Salt marsh use at site 1 was dominated by birds nesting in the marsh/upland edge that commuted out to the marsh to forage. This use was most evident by Red-winged Blackbirds which were confirmed breeders in the marsh/upland edge habitats and Song Sparrows which were confirmed nesting in Iva frutescens, but only one salt marsh obligative - the Sharp-tailed Sparrow - was recorded at this site. The Sharp-tailed was a confirmed nesting species and had a density of 22.6 birds/100 acres - low compared to site 2 which had a Sharp-tail density of 143.0 birds/100 acres. The greater diversity and more highly interspersed nature of the cover types at site 2 may contribute to the higher densities there.

At site 2, salt marsh use was dominated by an obligative salt marsh nester, the Sharp-tailed Sparrow (Table 8.2). This species was abundant and distributed throughout the marsh as it was found on all 3 sections of the salt marsh transect. Red-winged Blackbirds, European Starlings, and Song Sparrows nesting in the marsh/upland edge habitats also commuted out to the marsh to forage, but to a lesser degree than recorded at site 1.

Both sites 1 and 2 received irregular use by American Kestrels, and regular, similar use by Mourning Doves and aerial insectivores (e.g. Chimney Swifts, Barn Swallows, and Tree Swallows). Shorebirds observed at site 2 (Killdeer and Spotted Sandpiper) were resident and suspected breeders. Prior to the beginning of census efforts (May), Greater Yellowlegs and Black bellied Plovers were observed on the marsh at site 2.

Table 8.3. Species Densities (birds/40 ha, 100 acres) of Birds Using Salt Marsh Habitat between 9 June and 20 July 1987.

Acushnet River Estuary Site 1		Pope Beach Site 2	
American Black Duck 1	2.1	Snowy Egret	1.9
American Kestrel	1.4	American Kestrel	2.8
Mourning Dove	7.5	Clapper Rail *1	19.4
Chimney Swift	9.4	Killdeer	1.4
Barn Swallow	9.4	Spotted Sandpiper 1	4.3
Tree Swallow	15.2	Mourning Dove	7.5
American Crow	1.9	Chimney Swift	11.5
European Starling	74.7	Barn Swallow	18.9
Red-winged Blackbird 1	103.6	Tree Swallow	1.4
Common Grackle	1.4	American Crow	3.8
Song Sparrow *1	24.0	Northern Mockingbird	0.9
Sharp-tailed Sparrow *1	22.6	European Starling	52.5
Sparrow Sp. 1	2.8	Common Yellowthroat	0.9
		Red-winged Blackbird 1	29.8
		Common Grackle	4.2
		Brown-headed Cowbird	0.9
		Song Sparrow 1	0.3
		Sharp-tailed Sparrow *1	143.0
Total: Species	12		18
Density	276.0/40 ha (100 acres)		305.4/40 ha (100 acres)

* confirmed nesting

1 for suspected and confirmed nesting species, a correction factor of 1.5 was applied to compensate for the inactivity of nesting individuals (Emlen 1971).

Numbers of species using salt marsh habitats reported by SES (1987) are similar to those found in this study, but bird densities reported by SES are much lower (Table 8.4) and reflect the timing of their censusing efforts, which were begun a month before most estuarine breeding species arrive in this region (Lloyd Center 1986). The trends recorded in the salt marsh habitat at wetland sites 1 and 2 reflect differences in habitat features. Site 1 is dominated by high marsh grasses (Spartina patens, Distichlis spicata, Juncus gerardi) and the shrub Iva frutescens. The widespread distribution of these communities in combination with few natural tidal creeks and steep-sided mosquito ditches leave the habitat largely unsuitable for obligative nesting marsh birds. However, Sharp-tailed Sparrows and Song Sparrows do find nesting sites on the marsh, and a few Red-winged Blackbirds were suspected nesting on the marsh. The narrow width of site 1 allows marsh/upland nesting species easy access to foraging areas in the Spartina alterniflora habitat lining the shore, and these sites also provide suitable foraging areas for the Sharp-tailed Sparrow. Access to these estuarine foraging areas may, in part, allow for the relatively dense association of nesting species found in the marsh/upland edge (see section 8.1.1.3).

The vegetation communities at site 2 are much more heterogeneous providing different habitats for foraging, nesting, and mating activities of marsh nesting birds. This is most evident in the abundance of nesting Sharp-tailed Sparrows and the Clapper Rail which find suitable nest cover in Spartina alterniflora habitat, and foraging areas along sloped, partially filled mosquito ditches and natural tidal creeks. Other suspected nesting species as well as birds nesting in the marsh/upland edge habitats were also recorded using these foraging areas.

Winter 1985 and fall 1986 observations of bird use at sites 1 and 2 were conducted by SES (1987); results are provided in Table 8.5.

8.1.3.3 Marsh/Upland Edge Habitat

The marsh/upland edge habitat at site 1 is dominated by Iva frutescens and Panicum virgatum on the marsh side, and by tall (>1.3m) shrubs mixed with deciduous and evergreen trees on the upland side. Shrub communities up to 75m wide form a broad transition zone between the salt marsh and forested upland habitat; this transition zone supported the highest density of birds (531.0 birds/100 acres) found on any of the transects in this study.

Table 8.6 presents species densities recorded in the marsh/upland edge habitat at sites 1 and 2. Twenty-seven (27) species were recorded at site 1. Five (5) species were confirmed breeding with 17 additional species suspected breeding (Table 8.6). The 5 dominant species at this site - Red-winged Blackbird, European Starling, Northern Mockingbird, Song Sparrow, and American Robin - account for 66% of the total density of birds recorded in this habitat; their relatively high densities reflect the heterogeneity of vegetation communities in this transect, for the Red-winged Blackbird and Song Sparrow are commonly found in wetland edge habitats, whereas the European

Table 8.4. SES (1987) Data on Saltmarsh Bird Densities (#/40 ha) recorded during Early Spring 1985 Transects

Acushnet River Estuary Site 1		Pope Beach Site 2	
American Black Duck	1.4	Great Blue Heron	0.5
American Kestrel	0.3	American Black Duck	0.4
Killdeer	0.6	Mallard	0.5
Greater Yellowlegs	0.9	American Kestrel	1.1
Mourning Dove	0.3	Killdeer	1.4
Tree Swallow	0.3	Greater Yellowlegs	0.4
American Crow	1.7	Ring-billed Gull	0.2
Savannah Sparrow	0.6	Herring Gull	1.4
Song Sparrow	4.0	Mourning Dove	0.2
Sparrow sp.	0.3	American Crow	1.3
Common Grackle	0.6	Savannah Sparrow	0.4
Eastern Meadowlark	0.6	Song Sparrow	4.3
	---	Northern Mockingbird	0.2
		Sparrow sp.	0.4

TOTAL: 13 species	12.2/40 ha	TOTAL: 15 species	12.9/40 ha

Table 8.5. Winter and Fall Bird Sightings of Salt Marsh Habitat at the Acushnet and Pope Beach Sites.

	Acushnet River Site 1		Pope Beach Site 2
	February 1985	September 1986	September 1986
Great Blue Heron	-	-	2
Green-backed Heron	-	1	-
Black Duck	-	4	-
Red-tailed Hawk	1	-	-
Peregrine Falcon	1	-	-
Merlin	-	-	1
Osprey	-	1	-
American Kestrel	-	1	-
Laughing Gull	-	12	13
Herring Gull	-	-	1
Rock Dove	3	-	-
Belted Kingfisher	-	-	1
Northern Flicker	-	3	1
Tree Swallow	-	-	2
Barn Swallow	-	-	2
Blue Jay	-	-	1
American Crow	2	-	5
Northern Mockingbird	-	-	1
Gray Catbird	-	-	1
European Starling	-	80	1
House Finch	-	-	1
Savannah Sparrow	-	4	-
Song Sparrow	-	5	-
Red-winged Blackbird	5	-	-
Total # individuals	12	111	33
Species number	5	9	14

Table 8.6. Species Densities (birds/40ha, 100 acres) of Birds Using Marsh/Upland Edge Habitat between 9June and 20 July 1987.

Acushnet River Estuary Site 1		Pope Beach Site 2	
American Kestrel 1	5.6	American Black Duck	0.9
Mourning Dove 1	9.9	Mallard Duck *	14.3
Chimney Swift	6.2	American Kestrel 1	1.4
Common Flicker 1	3.7	Clapper Rail 1	2.2
Great-crested Flycatcher2	2.5	Killdeer 1	2.2
Barn Swallow	8.2	Mourning Dove 1	2.8
Tree Swallow	7.4	Chimney Swift	5.6
Blue Jay 1	7.5	Common Flicker 1	1.4
American Crow	6.2	Barn Swallow	15.7
Northern Mockingbird *2	52.2	Tree Swallow	5.7
Gray Catbird 1	11.2	Blue Jay	4.7
American Robin *1	41.1	American Crow	1.9
Cedar Waxwing	2.5	Black-capped Chickadee1	2.9
European Starling *1	86.9	Tufted Titmouse 1	2.2
Yellow Warbler 2	18.2	House Wren 2	18.9
Common Yellowthroat 2	29.7	Northern Mockingbird 2	11.3
Red-winged Blackbird *1	116.9	Gray Catbird 1	25.8
Common Grackle 1	20.6	American Robin 1	21.5
Brown-headed Cowbird 1	2.5	European Starling *1	29.8
Northern Oriole 1	1.9	White-eyed Vireo 2	5.7
Northern Cardinal 2	1.6	Yellow Warbler 2	28.4
House Finch 1	15.0	Common Yellowthroat 2	54.9
American Goldfinch	6.2	House Sparrow 1	1.4
Rufous-sided Towhee 2	2.5	Red-winged Blackbird*1	83.4
Song Sparrow *1	52.9	Common Grackle 1	19.4
Sharp-tailed Sparrow 1	1.2	Brown-headed Cowbird 1	6.4
Field Sparrow 2	6.6	Northern Oriole *1	14.9
Sparrow sp. 1	2.5	Northern Cardinal 2	5.7
		American Goldfinch	1.4
		Rufous-sided Towhee 2	2.9

Table 8.6. Marsh/upland Bird Densities (birds/40ha, 100 acres) (Continued)

Acushnet River Estuary Site 1			Pope Beach Site 2	
			Song Sparrow *1	49.6
			Sharp-tailed Sparrow*1	36.9
			Sparrow sp. 1	2.5
Total:	Species	27		32
	Density	531.0/40 ha (100 acres)		484.4/40 ha (100 acres)

* confirmed nesting species

1 for suspected and confirmed nesting species, a correction factor of 1.5 was applied to compensate for the inactivity of nesting individuals (Emlen 1971).

2 for species in which the male's song was the only detection cue used, a correction factor of 2.0 was applied to compensate for the inactivity of nesting individuals (Emlen 1971).

Starling, Northern Mockingbird, and American Robin are more often found in upland habitats. Red-winged Blackbirds, European Starlings, and Song Sparrows nesting in the edge habitats were observed making frequent trips to the salt marsh to forage.

At site 2, the marsh/upland edge habitat is dominated by Phragmites australis which occurs in narrow (<50m) strips. Shrub communities are sparsely distributed and the transition from salt marsh to oak-hickory forest is abrupt; in some places scrub oak defines the marsh/upland border. The influence of forest associated species (e.g. Black-capped Chickadee, Tufted Titmouse, House Wren, and White-eyed Vireo) at this site contributed to the, overall, highest species diversity (32 species) recorded during this study. These species were observed singing and foraging at the wetland edge and made up 6% of the total density found in this habitat.

The 5 dominant species (Red-winged Blackbird, Common Yellowthroat, Song Sparrow, and European Starling) made up 50% of the total species density; all, except the European Starling, are commonly found nesting in wetland or wetland edge habitat. Dominance by this group of primarily wetland associated species indicates a greater homogeneity of habitat at site 2. Other wetland species including the Mallard Duck, a confirmed nesting species, the Killdeer, a suspected nesting species, the American Black Duck and the Clapper Rail were recorded in this habitat.

Differences in the species composition and relative densities between sites 1 and 2 can be attributed, in part, to the composition, abundance, and distribution of the vegetation communities found within the marsh/upland edge transects. The relatively high density of both wetland associated and upland associated species at site 1 reflect the heterogeneity of the vegetation communities as well as the proximity of this habitat to wetland foraging areas. Broad shrub zones mixed with forested habitat provide cover for a variety of nesting species, while the Spartina alterniflora habitat lining the shore of wetland 1 provides additional, and, for some species (e.g. Red-winged Blackbird), primary foraging habitat.

The edge habitat at site 2 is much narrower, bordered on the marsh side by Phragmites with few shrub communities, and on the upland side by forested habitat. As a result, the dominant species in this habitat were wetland associated species that nested in Phragmites or adjacent shrub communities. Species more often associated with forested habitat were observed at the wetland edge and contributed to the high species diversity recorded on this transect.

The number and relative abundance of species found in this study are similar to those reported by SES (1987) during early spring 1985 (Table 8.7). However, marsh/upland edge bird densities found in this study are higher than those reported by SES and reflect the close timing of this study with the breeding season of estuarine wetland birds. SES results from censusing bird use along the salt marsh edges during winter 1985 and late summer 1986 are presented in Table 8.8.

Table 8.7. Marsh/Upland Edge Bird Densities (#/40 ha) Recorded During Early Spring 1985 Transects (from SES 1987)

Acushnet River Site 1		Pope Beach Site 2	
American Kestrel	0.4	Rock Dove	0.2
Rock Dove	4.9	Downy Woodpecker	4.7
Mourning Dove	2.0	Northern Flicker	6.4
Downy Woodpecker	0.8	Tree Swallow	0.9
Hairy Woodpeckier	0.6	Blue Jay	1.0
Northern Flicker	3.4	American Crow	6.8
Blue Jay	12.8	Black-capped Chickadee	11.0
American Crow	2.9	Tufted Titmouse	9.2
Black-capped Chickadee	1.0	Carolina Wren	4.1
Tufted Titmouse	2.9	American Robin	15.9
Carolina Wren	6.2	Gray Catbird	7.3
American Robin	33.1	Northern Mockingbird	4.1
Northern Mockingbird	17.6	European Starling	15.1
European Starling	44.6	Yellow-rumped Warbler	18.6
Yellow-rumped Warbler	10.5	Northern Cardinal	7.5
Northern Cardinal	6.5	Field Sparrow	0.6
American Tree Sparrow	3.2	Savannah Sparrow	0.7
Field Sparrow	3.6	Song Sparrow	27.8
Savannah Sparrow	0.7	Swamp Sparrow	2.1
Song Sparrow	35.9	White-throated Sparrow	13.1
Swamp Sparrow	1.4	Red-winged Blackbird	6.5
White-throated Sparrow	14.5	Common Grackle	5.1
Red-winged Blackbird	13.1	Brown-headed Cowbird	5.3
Common Grackle	40.8	House Finch	13.1
Brown-headed Cowbird	3.3	American Goldfinch	23.1
House Finch	5.2	House Sparrow	1.4
American Goldfinch	4.1		
House Sparrow	5.4		
TOTAL:	281.4/40 ha 28 species		211.6/40 ha 26 species

Table 8.8. Salt Marsh/Upland Edge - Bird Data from the Winter (February 1985) and Late Summer (September 1986) survey (From SES 1987).

	Acushnet Study Area		Reference Site
	February 1985	September 1986	September 1986
Osprey	-	present	-
Northern Harrier	-	present	-
American Kestrel	1	present	1
Sharp-shinned Hawk	1	-	-
Rock Dove	-	present	+
Mourning Dove	5	present	-
Blue Jay	-	present	5
Common Crow	2	present	-
Black-capped Chickadee	-	present	1
Tufted Titmouse	1	-	5
House Wren	-	present	1
Carolina Wren	-	present	2
Northern Mockingbird	1	present	3
Gray Catbird	-	present	11
American Robin	-	present	3
European Starling	-	present	-
Tennessee Warbler	-	present	-
Bay-breasted Warbler	-	present	-
Blackpoll Warbler	-	present	1
Connecticut Warbler	-	present	-
Yellow-rumped Warbler	3	-	-
Common Yellowthroat	-	present	3
American Redstart	-	-	2
Northern Cardinal	-	present	6
Rose-breasted Grosbeak	-	present	-
Song Sparrow	11	present	4
Common Grackle	-	present	-
House Finch	-	present	-
American Goldfinch	-	present	+
Red-eyed Vireo	-	-	1
White-eyed Vireo	-	-	1
Solitary Vireo	-	-	1
Total # individuals	25	dozens of individuals of each species	33+
Species number	8	25	21

8.2 MAMMALS

8.2.1 Mammals Observed Directly and By Signs

Each of the wetland sites (#1, 2, 3, 4, 5, and 9) were visited on several occasions to conduct a qualitative wildlife assessment of mammalian use of the wetlands. In addition, each of the wetlands were visited in association with other project tasks, such as during bird censuses, vegetation sampling, etc., and a record was kept of all incidental wildlife observations at each wetland. Mammal use was documented by direct observation or from signs of activity such as tracks, scat, scrapes, nests, dens, burrows, and signs of foraging activity.

A second task involved attracting mammals to scent posts so that their occurrences could be documented and quantified. This work was conducted on four days in September 1987. Scent posts which consisted of hardwood posts measuring approximately 3cm x 3cm x 150cm were established at 500 yard intervals along the wetland/upland boundary on wetlands 1, 3, 4, 5, and 9. Approximately 100 cm of the post was left protruding above the ground level.

On wetlands 5 and 9 where there was less than 500 yards of available edge, a minimum of at least two scent posts were used at a placement of less than 500 yards apart.

The methodology used was to clear an area of bare ground at the base of the scent post so that tracks and sign could be readily observed. The post was scented with a commercially available Fox Urine scent and the posts revisited within 3 days to observe any activity around the posts. The use of Fox urine was considered to be ideal for attracting all carnivores which may be found on the site. While food baits appeal to mammals only when they are hungry, the sense of smell, which is acute in mammals, will often appeal to a mammal's sex interest, antagonism, or it's curiosity. Because mammals use scent to communicate territories and sexual readiness, scent should be an attraction at all times while food bait may only be an attraction occasionally (Taber and Cowan 1969). The scent posts were used to mimic the mammalian behavior of marking their home ranges with urine, feces, or glandular secretions.

8.2.1.1 Species and Numbers Observed

The species observed from both incidental and scentpost observations on the study area wetlands are presented in Table 8.9. Table 8.10 lists those species which DeGraaf and Rudis (1986) report as occurring in salt marsh habitats within this region . The occurrence of domestic mammals (dogs and cats) was documented as these animals were thought to be of importance given the nature of the contaminants on the site and the potential movement of contaminants via these mammals. In April, 1985 field personnel from Sanford Ecological Services placed 206 snap-traps randomly along the eastern edge of wetland site 1 as part of the effort to collect small mammals for bioaccumulation studies. Traps were placed along the salt marsh upland border of grass and shrubs. The 206 trap night effort yielded the following; House

Table 8.9. Occurrence of Mammals On Project Area Wetlands.

	Incidentally Observed		Scentpost Sampling	
	I.D.	Habitat	I.D.	Habitat
Site 1				
Eastern Cottontail	visual	high marsh	scat	high marsh
Woodchuck	burrow	*I. frutescens*	-	-
Meadow Vole	nest	*S. patens*	-	-
Muskrat	scat	high marsh	-	-
Dog	visual	all	-	-
Cat	visual	high marsh	-	-
Raccoon	tracks	non-vegetated	-	-
Site 2				
Eastern Cottontail	scat	high marsh	-	-
Muskrat	scat	creek-bank	-	-
Dog	visual	all	-	-
Cat	visual	high marsh	-	-
Raccoon	tracks	*S. alterniflora*	-	-
Site 3				
Eastern Cottontail	scat	high marsh	scat[a]	high marsh
Muskrat	visual	tidal creek	-	-
Red Fox	den	upland	scat[a]	high marsh
Dog	scat	high marsh	-	-
Site 4				
Eastern Cottontail	visual	*Ammophila*	-	-
Woodchuck	visual	upland edge	-	-
House Mouse	visual	*Phragmites*		
Dog	visual	all	-	-
Raccoon	-	-	tracks	*Phragmites*
Site 5				
Eastern Cottontail	scat	upland edge	-	-
Norway Rat	visual	*S. alterniflora*	-	-
Site 9				
Eastern Cottontail	scat	high marsh	-	-
Gray Squirrel	visual	high marsh	-	-
Dog	visual	all	-	-

a Scat found 10m from scent post.

Table 8.10 Mammalian Species Found in Salt Marsh Habitats in This Region.

DIDELPHIDAE	
Virginia Opossum	Didelphis virginiana
TALPIDAE	
Masked Shrew	Sorex cinereus
Short-tailed Shrew	Blarina brevicauda
Star-nosed Mole	Scalopus cristata
CHIROPTERA	
Little Brown Myotis	Myotis lucifugus
Keen's Myotis	Myotis keenii
Silver-haired Bat	Lasinycteris noctivagans
Eastern Pipistrelle	Pipistrllus subflavus
Big Brown Bat	Eptesticus fuscus
Red Bat	Lasiurus borealis
Hoary Bat	Lasiurus cinereus
LAGOMORPHA	
New England Cottontail	Sylvilagus transitionalis
CRICETIDAE	
White-footed Mouse	Peromyscus leucopus
ZAPODIDAE	
Meadow Jumping Mouse	Zapus hudsonius
Mustelidae	
Long-tailed Weasel	Mustela frenata
Mink	Mustela vison
Striped Skunk	Mephitis mephitis

mouse (Mus musculus) 3, Norway Rat (Rattus norvegicus) 1 and White-Footed Mouse (Peomyscus leucopus) 15. The trapping success for small mammals was 9.2 percent (19/206). Based on the above success, data collected incidentially, wetland site characteristics which include abundant upland islands and fill areas within or adjacent to the wetland study areas, and literature sources (e.g., DeGraaf and Rudis, 1986), it is likely that small mammals are the most abundant resident vertebrates found on these wetlands.

8.2.1.2 **Location and Habitat Type**

Direct observations and signs of mammal use were observed in all the habitat types represented on the study area wetlands. Dogs, cats and rabbits comprised the majority of direct observations, while scat, tracks, small mammal nests and clippings, burrows and dens of medium sized mammals were the most frequently observed signs on the salt marsh and marsh/upland edge habitats. Brief descriptions of the mammal observations recorded for each site are given below:

Wetland Site 1 - At wetland site 1 the eastern cottontail was the only mammal, besides dogs and cats, that was observed directly. Cottontail scat, however, was found throughout the high marsh habitats. Two (2) apparently active woodchuck burrows were found in the extensive area of Iva frutescens at the northern end of the wetland, a meadow vole nest and system of runways was found in S. patens, muskrat scat was found on the high marsh, and raccoon tracks were observed in the non-vegetated portion of the wetland that is adjacent to the auto salvage yard. SES (1987) wildlife observations in this site included eastern cottontail, skunk, meadow vole, and white-footed mice.

Wetland Site 2 - Dogs and cats, which roamed throughout this entire system, were the only mammals observed directly at this site. Raccoon tracks and muskrat scat were found in the regularly flooded zone, and eastern cottontail scat was found on the high marsh. SES (1987) observed use of the wooded swamp in the northeast part of site 2 by gray squirrels, opposum, and eastern chipmunks.

Wetland Site 3 - A muskrat was observed swimming in the main tidal creek at this site on 9 July. A large fox compound with at least 10 burrows, some of which were active, was found on an upland knoll directly adjacent to the estuarine wetlands at this site; on 25 September fox scat was found approximately 10m from a scent post placed in the high marsh. Cottontail and dog scat were found in the high marsh.

Wetland Site 4 - Eastern cottontails were observed foraging in Ammophila breviligulata habitats, a woodchuck was observed at the upland edge, a house mouse was observed in Phragmites, and dogs were observed regularly in all habitats. Raccoon tracks were present at a scent post placed adjacent to a stand of Phragmites.

Wetland Site 5 - A norway rat was observed foraging in the tall S. alterniflora habitat and cottontail scat was littered throughout the upland/edge portions of this site.

Wetland Site 9 - Dogs were observed throughout this wetland, a gray squirrel was observed foraging on the high marsh and cottontail scat was found on the high marsh.

8.2.2 Results of Scent Post Observations for Upland Edges of Saltmarsh Habitats

Scent post sampling yielded only 3 additional observations to sightings and/or sign observed incidentally (Table 8.9). At site 1 rabbit scat was found at a post placed in S. patens, and at site 4 raccoon and dog tracks were found at a post adjacent to a stand of Phragmites. At site 3, however, fox and rabbit scat were found approximately 10m from a post placed in S. patens.

8.2.3 Habitat Descriptions

Differences in the size and compositional characteristics of the project area wetland habitats will affect mammal diversity and abundance among the wetland sites. Because the majority of mammal use of salt marshes is foraging by animals living in marsh edge or upland habitats, the wetland sites containing large transition zones from marsh to upland are expected to have the greatest diversity and abundance of small and medium sized mammals.

Wetland sites 1 and 3 are connected and form an uninterrupted wetland/upland system with a variety of marsh, marsh/upland edge, and upland habitats. The extensive area of salt marsh habitats in the project areas provides suitable habitat for the Meadow Vole, which builds its nest in Spartina patens (sometimes in Spartina alterniflora) and feeds exclusively on salt marsh plants, as well as foraging areas for larger mammals such as: the Eastern Cottontail, Muskrat, Raccoon, Opossum, Skunk, Weasel, and Red Fox which live in upland areas but feed on vegetation, insects, marine invertebrates, bird eggs and small mammals found in the marsh. In addition, the extensive transition zone from marsh to upland and upland islands that occur within this wetland system provide suitable habitat for burrowing mammals such as the Masked and Short-tailed Shrew, Woodchuck, and for seed eaters such as the White-footed and Meadow Jumping Mouse which build nests in old logs or tufts of grass.

Although wetland site 2 has less transitional marsh/upland edge habitat, adjacent shrub and forested areas provide suitable habitat for small mammals such as shrews and White-footed Mice, and larger mammals such as Weasels, Mink, Skunk, Oppossum, and Raccoon. The extensive area of salt marsh at this site having high interspersion of cover types provides rich foraging areas for the species living in adjacent upland areas, as well as for wetland nesting species such as the Muskrat and Meadow Vole.

The small area of salt marsh at wetland site 4 is probably not inhabitated by mammals, rather it is most likely used by mammals living in the adjacent stand of Phragmites and upland areas. Mammals that might occupy these areas include seed eaters such as the White-footed Mouse, herbivores such as the Eastern Cottontail, and omnivores such as the Raccoon, Oppossum, and Skunk.

There is little habitable salt marsh at wetland site 5 since this wetland is dominated by the intertidal form of Spartina alterniflora. As a result, mammal density and diversity is expected to be low in the wetland proper. However, adjacent upland areas contain much fill and rubble providing habitat for the Norway Rat and House Mouse, both of which will exclude habitation of the area by other small mammals.

The small size of wetland site 9 and its proximity to dense development precludes extensive use of this wetland by mammals; mammal use of this wetland is expected by some small mammals such as the Meadow Vole and White-footed Mouse, and by domestic dogs and cats.

8.2.3 Discussion - Mammal Use of the Wetlands

Signs of mammal activity or direct observation of mammals were observed on all of the project area wetlands. Despite the lack of results from scent post sampling, over 35 days of incidental observations provided extensive data on mammal species occurrences in tidal water, salt marsh and marsh/upland edge habitats. Domestic dogs and cats, and cottontail rabbits were the most frequently observed mammals. Medium-sized mammals such as the woodchuck, muskrat, and raccoon were found at the larger wetlands and based on the discovery of a large system of burrows in a relatively undisturbed portion of wetland site 3, it apears that red fox have inhabited this area for some time. Although few small mammals were observed directly, the diversity of habitat types, both natural and human created, and observation of small mammal sign suggest that this group of mammals is abundant on all of the project area wetlands. Small mammal diversity and abundance is probably the lowest on the marsh proper where only the meadow vole, and occasionally, the white-footed mouse are known to nest. In the marsh/upland edge, however, one would expect to find a much greater abundance and diversity of species including the masked shrew, short-tailed shrew, star-nosed mole, house mouse and meadow jumping mouse (Table 8.5). In addition, species from the mustelid family (e.g., weasel, mink, skunk) are also expected to frequent the wetlands in some of the larger and relatively more remote sites.

Many dogs were observed traveling through study area wetlands and were observed within ditches and other contaminated areas. The potential for migration of PCB contaminated substrate on the fur of dogs into the living rooms of adjacent residents is, potentially, quite high. While domestic cats may also transfer contaminated materials into homes, cats were most often observed in the high marsh and marsh/upland edge habitats and are not as likely as dogs to become covered with contaminated muck.

9.0 RARE AND ENDANGERED SPECIES

9.1 SPECIES AND LOCATION

No species listed as endangered or threatened by the U.S. Fish and Wildlife Service (Department of the Interior) were observed during the study period. A peregrine falcon, however, was observed in the vicinity of wetland site 1 on 22 February 1985 (SES 1987). In addition, the Massachusetts Natural Heritage Program (MNHP) has no records of any rare or endangered fauna or flora in the study area wetlands.

Species listed as threatened or of special concern by the MNHP were observed throughout the study period. On 9 July a least bittern, which is listed as threatened by the MNHP, was observed foraging adjacent to a stand of Phragmites on the east side of the Acushnet River Estuary just north of the Wood Street Bridge. This sighting was subsequently reported to the MNHP. Least terns, listed as a species of special concern, were observed throughout August and early September foraging in the waters adjacent to wetland sites 1 and 3. These were also observed in May of 1985 (SES 1987); SES observations also included a single sharp-shinned (special concern species) hawk in February 1985. Both the osprey and common tern, listed as species of special concern, were observed at wetland site 2 in July and during July and August for the latter species.

10.0 BIOACCUMULATION

10.1 COLLECTION AND ANALYSIS METHODOLOGIES

10.1.1 Ribbed Mussels

To determine the bioaccumulation of PCB's, copper, chromium, mercury, lead, zinc, cadmium, and aromatic hydrocarbons (PHC's), the ribbed mussel (*Geukensia demissa*) were collected during mid-April from five stations at wetland 2 and two (2) stations at 3,4,5, and 9. All mussels were collected at random locations along a 15m transect located within the salt marsh cordgrass (*Spartina alterniflora*) zone, and placed in hexane rinsed glass jars. These specimens were transported back to the lab on ice. Replicates from one (1) station at each wetland were analyzed. The remainder were archived (frozen) for future use. On the remaining mussels whole wet weight, shell weight, meat wet weight and length were measured. Shells were scrubbed clean of any debris before weighing. Shell length was measured. Meats were placed on filter paper for 2 minutes before weighing. Within each station, sufficient tissue weight were pooled to form three replicate samples according to the methods outlined in the SOW.

10.1.2 Grass Shrimp

Grass shrimp of one species (*Palaemonetes pugio*) were collected from the salt marsh sediments of the project area wetlands (1,2,3,4,5,9) during mid-late summer for body burden analysis. These specimens were collected from randomly generated locations. Sufficient biomass was obtained to conduct three replicate analyses for each constituent to be measured (copper, chromium, lead, zinc, cadmium, iron, mercury, and PCB). Standard EPA analysis methods (Appendix 10.1) were used to determine concentrations.

10.1.3 Fish

10.1.3.1 Fish Sampling

Fish specimens were collected and analyzed for body burdens of PCB, copper, chromium, mercury, lead, zinc, and cadmium. Mummichogs and winter flounder were collected in sufficient quantities for site specific (3 sites: site 1 = wetlands 1,3,5; site 2 = wetlands 4 and 9; site 3 = wetland 2) pooled analysis of 3 replicates per site and each species was analyzed separately to establish invertebrate-fish food chain, bioaccumulation links, for a total of 18 replicates. Tissue collected in excess of that required for this analysis was archived for possible future analysis. Standard EPA methods (Appendix 10.1) for PCB and metals analysis were used to measure concentrations.

10.1.3.2 Results of Visual Inspection for Neoplasms or Tumors in Fish Livers

The livers of winter flounder (*Pseudopleuronectes americanus*) were collected and visually surveyed for neoplasms. Flounder were collected only at Site 2. Individuals obtained from that site and intended for PCB analyses (placed in

aluminum foil) were dissected and examined in the laboratory for liver neoplasms and tumors. (Examinations were not performed on flounder intended for metal analyses since dissection with metal utensils could have contaminated the samples). A total of 13 flounder were examined for neoplasms and tumors. Examination occurred on September 14, 1987. No neoplasms or tumors were observed on livers of the examined fish. During the course of the internal examination, remains of small crustaceans were occasionally noted in the stomach of the fish.

Neoplasms have been found in soft shell clams from New Bedford Harbor (Reinisch et al. 1984). Cell extracts from the tumors showed detectable levels of PCB congeners which suggest an association between the high prevalence of diseased tissue (10-90%) and the presence of contaminated sediment. In another study (Brown et al. 1977) soft shell clam neoplasms were common (12.5%) in New England sites with varying degrees of hydrocarbon contamination. Hydrocarbon levels in clam tissue were related to sediment hydrocarbon concentrations.

10.2 DISCUSSION OF PREVIOUS AND PRESENT STUDIES

10.2.1 Previous Studies

Fish and other aquatic organisms accumulate PCBs and metals both by direct water intake and absorption through gills (SES, 1987) and the ingestion of other aquatic organisms lower in their food chain (Swartz and Lee, 1980). Because PCBs and some other chemicals are persistent in the body tissues of both the food source and the organisms, magnification occurs in organisms which are higher in the food chain, and can result in contaminant concentrations one or several orders of magnitude higher than concentrations in the water or sediment. Larger fish, bottom feeders, and carnivores tend to accumulate (biomagnify) higher levels of contaminants (Swartz and Lee, 1980). Humans exposed to contaminated materials from the Acushnet estuary, as from ingestion of contaminated shellfish, finfish and shorebirds, could accumulate body burdens of metals and PCBs.

Many other studies have documented the presence of contaminated materials in the Acushnet estuary (NUS, 1984; Battelle, 1985; SES, 1987; Reinisch et. al, 1984; Genest and Hatch, 1981). Many of the fish and shellfish in the estuary exceed the FDA limit of 2 ppm PCBs in the edible portion, while several others have concentrations near that limit (NUS, 1984). Species residing in or feeding in those areas noted for their elevated PCB content (the upper estuary wetlands and open channel benthic areas) can be expected to accumulate metals and PCBs. As massive volumes of sediment contaminated with PCB occur in the upper estuary, normal biological and abiotic forces (Eisenreich, 1980) will continue to make a portion of the PCBs and metals in the sediment sink available for bioaccumulation. Even as normal sedimentation in the estuary would eventually isolate some contaminated benthic areas with layers of non-contaminated material (NUS, 1984), the length of time required for this to occur is likely not to be acceptable as a treatment alternative.

Studies were completed by SES (1987) to determine the levels of PCB and metals in various organisms in the Acushnet estuary and to determine whether there was evidence of bioconcentration within two specific food chains (ribbed mussel - salt marsh snail - ring-billed gull; arthropods, seeds, nuts - white-footed mice) within the estuary. A number of ribbed mussels (Geukensia demissa) were collected from Wetlands 1 and 3 and analyzed for contaminants, along with samples of the salt marsh snail (Melampus bidentatus), and the amphipod (Orchestia grillus). Individuals of the ring-billed gull (Larus Delawarensis) were also collected. This set of samples was intended to be representative of the ring-billed gull food chain. Ring-billed gulls exhibit strong site tenacity and seldom, if ever, feed at nearby landfills. Thus, the likelihood of PCB contamination in gulls from other sources was minimized by selecting this species.

A second set of samples were collected to approximate the food chain of a small mammal known to use the wetlands, the white footed mouse (Peromyscus leocopus). Food items from the varied diet of the mouse, including vegetative matter from bayberry, acorns, horse briar, black grass shoots, insects, isopods and millipedes, were similarly sampled and analyzed.

Elevated levels of PCBs were found in nearly all samples, indicating an uptake of this contaminant at all the trophic levels in the wetland system. Arcolors 1242 and 1254 were detected in all of the ribbed mussel, amphipod, and snail samples which comprise the lower trophic level of the mussel - ring-billed gull food chain, as well as in selected fruit, composite animal food samples, and the amphipod and snail which comprise the base of the arthropod, nut, fruit - white footed mice food chain. The highest levels of PCBs were found in fat samples from ring billed gulls, and a single sample of a white footed mouse. In general, the data show a gradual increase in the order of magnitude of the PCB concentration, from vegetative matter to herbivore/filter feeder to the gull. The data do not support a comparison between different wetland sites for different PCB uptake rates. Data from the metals analyses are less indicative of biomagnification (SES,1987), although elevated levels of metals were found in most samples.

These data clearly indicate a PCB bioaccumulation/biomagnification trend in the Acushnet estuary. Other studies have documented the occurrence of bioaccumulation in similar species in similar environments. Although PCBs are not known to accumulate in live Spartina alterniflora tissue, they have been shown to accumulate in decomposing S. alterniflora tissue (Marinucci, 1981). PCB concentrations were three to four times higher in decomposing cordgrass detritus than in the sediment. This has obvious implications for detritivore based food chains. Lobsters have been shown to accumulate PCBs from the ingestion of contaminated mussels, and hard shelled clams have been shown to accumulate amounts of PCBs from contaminated sediment (Battelle, 1984). Bioaccumulation of PCBs by sandworms, grass shrimp and hard clams was demonstrated in four sites in New York Harbor (Rubinstein, et al., 1983). Uptake was highest for the sandworms and was affected by the organic content of the substrate, with higher tissue concentrations occurring in low organic sediment. These results stress that sediment concentration alone does not

reflect bioavailability, and that biassays and field monitoring are necessary for estimating bioaccumulation potential of sediment-bound contaminants.

More controlled laboratory studies were conducted to determine the uptake and depuration of various metals in winter flounder, lobster, sandworms and hard clams, Appendix 10.2. These data show a rapid uptake of lead, copper, and cadmium over a forty-two day period followed by a depuration period. The rates of depuration varied between species and metal. Since the organisms sampled in sites in the Acushnet River estuary are living at equilibrium with the environmental conditions present and continue to show elevated levels of metals (i.e., depuration is not occurring), a continued availability of metals is indicated.

Other studies (Black et al, 1987) have been conducted to determine if the accumulation of PCBs has an effect on the growth and survival of the winter flounder (Pseudopleuronectes americanus). Eggs of the winter flounder taken from New Bedford Harbor contained significantly higher levels of PCBs than reference populations, and larvae hatched from these eggs were significantly smaller than reference larvae. The ultimate impact of these physiological responses to future population trends is difficult to predict, as subsequent (eight weeks) growth of these smaller larvae was such to eliminate the differences between New Bedford and control fish. Although this particular study demonstrated no significant differences between embryo survival, larval survival or percent metamorphosis, other studies have demonstrated the detrimental impacts of PCBs on these biological attributes in other fish species. Appendix 10.3 contains annotated bibliographies of a number of other studies demonstrating bioaccumulation rates in various estuarine species.

10.2.2. Results of Current Study

The data collected for the present (IEP) sampling effort were geared to determine if similar bioaccumulation/bioconcentration patterns are indicated in food chains between detrital sediments - grass shrimp (Palaemonetes pugio) - mummichog (Fundulus heteroclitus), and between these lower trophic levels and winter flounder or other sport finfish. Additional data on metal and PCB levels in the ribbed mussel were also obtained.

Data from the metals and PCB bioaccumulation portion of this study are shown in Tables 10.1-10.3. Detailed statistical analyses cannot be done on these data due to the insufficient number of samples and subsamples. Evaluation of the concentrations of metals and PCBs taken from samples of the grass shrimp (Palaemonetes pugio) show a continuation of the trend demonstrated in the sediment samples. Metal concentrations from shrimp taken near the upper, more contaminated wetlands are more elevated than Wetland 9 or 2. Using a qualitative ranking of averages, shrimp from wetland 1 exhibited the highest levels for chromium, copper, and iron. The highest PCB values were found in shrimp taken near Wetland 3 (25.3 mg/kg), the northernmost wetland in the study: Shrimp PCB values were 7.63 mg/kg from Wetland 1. Shrimp taken near wetland 2, the SES reference wetland (SES, 1987), ranked last with the least average concentrations for chromium, copper, PCB and iron. No clear ranking was evident

Table 10.1. Metal and PCB Concentrations (mg/kg)Found in the Grass Shrimp (*Palaemonetes pugio*)

WETLAND/REPLICATE	Cd	Cr	Cu	Pb	Hg	Zn	PCB	Fe
1-1	ND	0.97	42	0.87	ND	20	9.2	73
1-2	ND	1.1	43	0.91	ND	20	6.9	73
1-3	ND	0.83	47	0.91	ND	21	6.8	71
Average	---	0.97	44	0.90	---	20.3	7.63	72.3
Rank		1	1	2			2	1
2-1	ND	ND	32	0.85	ND	19	0.45	38
2-2	ND	ND	33	1.2	ND	21	0.23	46
2-3	ND	ND	34	0.50	ND	20	0.37	40
Average	---		33	.85	---	20	.33	41.3
Rank		6	6	3			6	5
3-1	ND	0.53	41	0.80	ND	20	20	42
3-2	ND	ND	41	0.92	ND	20	33	39
3-3	ND	0.54	38	0.76	ND	20	23	43
Average	---	.36	40	.83	---	20	25.3	41.3
Rank		4	2	4			1	5
4-1	ND	0.50	37	ND	ND	15	2.7	49
4-2	ND	ND	35	ND	ND	16	2.6	50
4-3	ND	ND	33	0.66	ND	15	1.9	51
Average	---	.50	35	.66	---	15.3	2.4	50
Rank		3	5	5			4	3
5-1	ND	0.80	36	1.1	ND	20	3.8	74
5-2	ND	0.79	35	1.2	ND	20	3.5	78
5-3	ND	0.85	38	1.2	ND	20	3.5	76
Average	---	.81	36.3	1.17	---	20	3.6	76
Rank		2	4	1			3	2
9-1	ND	ND	38	0.62	ND	17	1.2	42
9-2	ND	ND	37	0.59	ND	17	1.8	46
9-3	ND	ND	41	0.65	ND	18	2.0	41
Average	---	---	38.7	.61	---	17.3	1.7	43
Rank		6	3	6			5	4

Table 10.2. Metals and PCB Concentrations (mg/kg) Found in the Ribbed Mussel (*Geukensia demissa*)

WETLAND/REPLICATE	Cd	Cr	Cu	Pb	Hg	Zn	PCB	Fe
2-3	0.29	ND	3.8	0.40	0.010	6.7	0.38	9.2
2-3 DUP	0.28	ND	3.9	0.62	0.0094	6.7	0.50	12
2-3 Trip	0.28	ND	3.8	0.44	0.0087	6.1	0.90	11
2-5	0.34	0.55	6.9	0.60	0.0079	7.6	0.47	33
2-5 DUP	0.36	0.59	6.6	0.59	0.0075	8.0	0.77	31
2-5 Trip	0.37	0.58	7.7	0.73	0.0079	7.9	0.80	31
Average	0.32	0.57	5.5	0.56	.0086	7.17	.64	21.2
Rank	3	4	1	4			4	
3-1								
3-2								
3-3								
Average								
Rank								
4-1	0.26	0.67	5.1	0.91	ND	9.6	10	94
4-2 DUP	0.22	0.63	4.1	0.85	ND	9.2	10	61
4-3 Trip	0.29	0.56	5.3	0.85	ND	9.3	11	60
Average	.26	.62	4.8	.87	---	9.4	10.3	72
Rank	4	3	2	2		2	2	
5-2	0.34	0.64	2.8	0.78	ND	8.9	14	65
5-2 DUP	0.31	0.67	2.9	0.76	ND	11	16	74
5-3	0.33	0.69	2.7	0.84	ND	9.7	12	72
Average	.33	.67	2.8	.79	---	9.9	14	71
Rank	2	2	3	3		1	1	1
9-2	1.1	0.80	2.2	1.0	0.0084	6.4	2.7	15
9-2 DUP	1.1	0.87	2.2	0.92	0.0096	6.8	1.7	13
9-2 Trip	0.92	0.78	1.9	0.83	0.0087	6.5	2.2	12
Average	1.04	.82	2.1	.92	.0089	6.6	2.2	13
Rank	1	1	4	1			3	

Table 10.3. Metals and PCB Concentrations (mg/kg) Found in the Mummichog (*Fundulus heteroclitus*) and Winter Flounder (*Pseudopleuronectes americanus*)

WETLAND/REPLICATE	Cd	Cr	Cu	Pb	Hg	Zn	PCB
Mummichog							
Site 1	ND	0.85	4.3	0.90	0.0099	32	
Site 1 DUP	ND	0.86	4.3	1.1	0.0099	35	
Site 1 Trip	ND	0.92	4.4	1.2	0.0099	35	
Average	---	0.88	4.3	1.1	0.0099	34	
Rank			1	1	3	2	
Site 2	ND	ND	2.5	0.30	0.020	29	
Site 2 DUP	ND	ND	2.4	ND	0.017	31	
Site 2 Trip	ND	ND	2.0	ND	0.018	29	
Average			2.5		0.018	30	
Rank			3		2	3	
Site 4	ND	ND	2.7	0.40	0.016	38	
Site 4 DUP	ND	ND	3.2	0.29	0.016	34	
Site 4 Trip	ND	ND	2.7	0.35	0.015	38	
			2.9	0.35	0.016	37	
Flounder			2	2	1	1	
Site 2	ND	ND	1.7	0.32	0.0056	26	
Site 2 DUP	ND	ND	1.8	0.33	0.0061	33	
Site 2 Trip	ND	ND	1.6	0.31	0.0051	34	
			1.7	0.32	0.0056	31	
Mummichog							
Site 2							2.9
Site 2 DUP							2.4
Site 2 Trip							3.6
Average							3.0
Site 5							33
Site 5 DUP							51
Site 5 Trip							48
Average							44
Site 9							2.3
Site 9 DUP							12
Site 9 Trip							10
Average							8.1
Flounder							
Site 2 DUP							1.2
Site 2 Trip							1.5
Average							1.4

for concentrations of zinc: no detectable amounts of cadmium or mercury were found in any of the shrimp samples. The ranking is most evident with PCBs, with a two order of magnitude drop between the highest PCB content from shrimp taken near Wetland 3 (25.3 mg/kg) and that from Wetland 2 (0.33 mg/kg).

Mussels were taken near Wetlands 2,3,4,5 and 9. Metal and PCB concentrations from mussel tissue taken near Wetland 5 were generally higher than other stations, followed by decreasing concentrations from Wetlands 4,9 to 2. The PCB, total aromatic hydrocarbons and zinc concentrations were highest in tissue from Wetland 5. Copper and mercury concentrations were high from tissue from Wetland 2, and cadmium was highest at Wetland 2.

Samples of mummichog (Fundulus heteroclitus) were taken using beach seines just off the beaches at Wetlands 1,2 and 4. Flounder was only taken off of Wetland 2, making comparisons with this species impossible. With the exception of chromium and lead concentrations found in fish tissue from Wetland 1, there are no real major differences between contaminant values from the various wetland stations. PCB analyses were performed on fish taken off of wetlands 2,5 and 9. Fish samples taken from Wetland 5 exhibited PCB values an order of magnitude higher (44 mg/kg) than all other stations. PCB concentrations at Wetlands 9 and 2 were 8.1 mg/kg and 3.0 mg/kg respectively. Studies by Batelle (1987) have shown a general decrease in tissue levels of PCBs in flounder from the upper estuary south to Buzzard's Bay; all (8) fish sampled in the upper estuary exceeded the FDA limit of 2 ppm PCB. The levels in flounder off wetland 2 determined during this study are all below this limit (Table 10.3).

10.3 FOOD CHAIN IMPLICATIONS OF PRESENT AND PAST STUDIES

PCBs enter the aquatic environment primarily by deposition from aerial sources or from contaminated effluent disposal. Movement of PCBs and metals through the various food chains (webs) in the New Bedford estuary is accomplished via direct uptake across dermal and gill tissues, ingestion of contaminated sediment or consumption of contaminated food items. Ingestion of sediment can be direct, through grazing or filter feeding, or indirect, ingestion of food items coated with sediment. Food web transfer through the trophic levels occurs primarily from direct ingestion of contaminated prey (Swartz and Lee, 1980).

The SES study sampled various members of the New Bedford food chain(s), as described in Section 10.2. Their data clearly suggest the movement of PCBs through two food chains (sediment--mussels--snails--ring billed gull and vegetative matter--white footed mice); metal movement is less defined (Tables 10.4, 10.5). Additional food chain studies with sea lettuce (Ulva lactuca) and the black duck (Anas rubripes) need to be undertaken.

The SES PCB data indicate that PCB materials are incorporated into the tissue of the selected organisms from all trophic levels. Concentrations of Aroclor 1254 exceeded FDA levels in mussel meat, ring billed gull muscles, the salt marsh snail and the white footed mouse, indicating that "...biomagnification of PCBs

Table 10.4. PCBs in Plant and Animal Tissues (From SES 1987)

Sample Designation (Collected 15, 19, 20, 29 April 1985)	PCB Aroclors PCB 1242 (ug/g wet wt)	PCB 1254 (ug/g wet wt)
Ring-billed Gulls #1 Muscles	BDL	2.00
Ring-billed Gulls #2 Muscles	BDL	1.00
Ring-billed Gulls #3 Muscles	BDL	9.30
Ring-billed Gulls #4 Muscles	BDL	4.60
Ring-billed Gulls #5 Muscles	BDL	12.00
Ring-billed Gulls #6 Muscles	BDL	0.96
Ring-billed Gulls #7 Muscles	BDL	25.00*
Ring-billed Gulls #8 Muscles	BDL	27.00*
Ring-billed Gulls #9 Muscles	BDL	20.00
Ring-billed Gulls #10 Muscles	BDL	38.00
Ring-billed Gulls Composite #1-5 fat	BDL	88.00
Ring-billed Gulls Composite #6-7 fat	BDL	33.00
Ring-billed Gulls Composite #8-10 fat	BDL	340.00
Mussel Meat Stn 1-M Rep. 1	14.00	7.60
Mussel Meat Stn 1-M Rep. 2	20.00	10.00
Mussel Meat Stn 2-M Rep. 1	21.00*	11.00*
Mussel Meat Stn 2-M Rep. 2	20.00*	9.00*
Mussel Meat Stn 3-M Rep. 1	24.00	8.10
Mussel Meat Stn 3-M Rep. 2	17.00	6.20
Mussel Meat Stn 4-M Rep. 1	18.00	5.70
Mussel Meat Stn 4-M Rep. 2	24.00	8.40
Mussel Meat Stn 4a-M Rep. 1	69.00	23.00
Mussel Meat Stn 4a-M Rep. 2	58.00	17.00
Amphiphods Orchestia Composite #1A-5A	17.00	29.00
Melampus Stn #4	2.40	3.20
White-footed Mice Stn 2-WFM Composite of 3	BDL	17.00
White-footed Mice Stn 3-WFM Composite of 4	BDL	11.00*
White-footed Mice Stn 4-WFM Composite of 6	BDL	5.30
White-footed Mice Stn 5 Single Individual	BDL	56.00
Mouse Food Bayberry Fruits Stn #2	0.08	0.05
Mouse Food Bayberry Fruits Stn #4	0.25	0.08
Mouse Food Acorns Stn #2	BDL	BDL
Mouse Food Smilax Fruits Stn #2	BDL	0.05
Mouse Food Black Grass Stn #4	BDL	BDL
Mouse Food Composite of Isopods, Millipedes, Weevil, Hemipteran Stn #2	BDL	1.90
Mouse Food Composite of 10 Orthopteran and Isopods Stn #4	1.40	4.40

* = Average of duplicate vaues (See Appendix F).

Table 10.4. PCBs in Plant and Animal Tissues (From SES 1987), (Continued)

Sample Designation (Collected 20, 23 March 1987)	PCB Aroclors PCB 1242 (ug/g wet wt)	PCB 1254 (ug/g wet wt)
Black Duck (breast muscle)	0.58	100.00
Black Duck (subcutaneous fat)	42.00	5000.00
Black Duck (liver)	5.10	420.00
Mussel Meat Stn #1A	10.00	5.50
Mussel Meat Stn #1B	7.30	3.80
Mussel Meat Stn #2A	7.20	4.20
Mussel Meat Stn #2B	5.80	3.70
Mussel Meat Stn #3A	17.00	9.50
Mussel Meat Stn #3B	21.00	14.00
Mussel Meat Stn #4A	28.00	10.00
Mussel Meat Stn $4B	3.90	1.50
Mussel Meat Stn #5A	40.00	14.00
Mussel Meat Stn #5B	47.00	17.00
Sea Lettuce Stn #1-1	1.90	0.81
Sea Lettuce Stn #1-2	2.20	1.00
Sea Lettuce Stn #1-3	1.20	0.51
Sea Lettuce Stn #2-1	0.76	0.35
Sea Lettuce Stn #2-2	0.93	0.43
Sea Lettuce Stn #3-1	1.70	0.68
Sea Lettuce Stn #3-2	2.10	0.94
Sea Lettuce Stn #4-1	0.44	0.24
Sea Lettuce Stn #4a-1	2.10	1.00
Sea Lettuce Stn #4-2	2.20	0.70
Sea Lettuce Stn #5-1	40.00	8.80

Table 10.5. Metals in Plant and Animal Tissues (From SES 1987)

Field Identification (Collected 15, 19, 20, 29 April 1985)	Chromium	Copper	Lead	Zinc
	in ug/g wet weight			
Ring-billed Gulls #1 Muscles	1.1	5.1	0.8	24
Ring-billed Gulls #2 Muscles	3.1	5.6	1.3	86
Ring-billed Gulls #3 Muscles	1.7	5.2	0.6	26
Ring-billed Gulls #4 Muscles	3.1	5.4	3.0	78
Ring-billed Gulls #5 Muscles	2.8	5.9	0.8	20
Ring-billed Gulls #6 Muscles	2.8	5.0	0.6	26
Ring-billed Gulls #7 Muscles	2.0	6.7	1.2	22
Ring-billed Gulls #8 Muscles	1.5	6.3	1.7	20
Ring-billed Gulls #9 Muscles	1.7	4.6	0.9	68
Ring-billed Gulls #10 Muscles	2.5	5.0	5.0	42
Ring-billed Gulls Composite #1-5 fat	2.9	3.0	2.9	130
Ring-billed Gulls Composite #6-7 fat	1.8	2.3	1.1	60
Ring-billed Gulls Composite #8-10 fat	4.0	3.5	1.3	110
Mussel Meat Stn 1-M Rep. 1	3.7	8.8	1.9	24
Mussel Meat Stn 1-M Rep. 2	2.1	6.0	1.1	140
Mussel Meat Stn 2-M Rep. 1	3.5	5.3	1.1	36
Mussel Meat Stn 2-M Rep. 2	2.2	6.5	0.9	130
Mussel Meat Stn 3-M Rep. 1	2.5	5.8	1.1	110
Mussel Meat Stn 3-M Rep. 2	4.1	6.8	1.0	25
Mussel Meat Stn 4-M Rep. 1	2.7	5.8	1.7	60
Mussel Meat Stn 4-M Rep. 2	2.3	5.8	1.1	52
Mussel Meat Stn 4a-M Rep. 1	2.6	4.9	0.6	22
Mussel Meat Stn 4a-M Rep. 2	2.5	6.0	1.1	23
Amphipods Orchestia Composite #1A-5A	2.8	36.0	1.3	140
Melampus Station #4	2.5	25.0	9.0	630
White-footed Mice Stn 2-WFM Composite of 3	2.7	8.4	2.1	91
White-footed Mice Stn 3-WFM Composite of 4	3.7	6.9	3.9	49
White-footed Mice Stn 4-WFM Composite of 6	2.5	8.3	1.5	33
White-footed Mice Stn 5 Single Individual	3.0	5.5	1.5	56
Mouse Food Bayberry Fruits Stn #2	2.4	3.4	3.5	42
Mouse Food Acorns Stn #2	3.5	8.5	3.8	40
Mouse Food Black Grass Stn #4	2.2	6.8	0.7	37

Table 10.5. Metals in Plant and Animal Tissues (From SES 1987), (Continued)

Field Identification (Collected 20, 23 March 1987)	Chromium	Copper	Lead	Zinc
	in ug/g wet weight			
Black Duck (breast muscle)	0.2	5.7	0.9	10
Black Duck (liver)	0.2	2.3	0.7	15
Mussel Meat Stn #1A	0.4	3.8	1.1	11
Mussel Meat Stn #1B	0.3	.42	1.5	12
Mussel Meat Stn #2A	0.4	4.8	1.7	19
Mussel Meat Stn #2B	0.3	4.7	1.2	11
Mussel Meat Stn #3A	0.3	3.5	1.2	13
Mussel Meat Stn #3B	0.2	2.9	0.7	13
Mussel Meat Stn #4A	0.3	3.5	1.0	13
Mussel Meat Stn #4B	0.2	2.9	0.8	12
Mussel Meat Stn #5A	0.3	3.1	0.9	11
Mussel Meat Stn #5B	0.3	4.0	0.9	13
Sea Lettuce Stn #1-1	3.6	24.0	18.0	87
Sea Lettuce Stn #1-2	3.9	26.0	21.0	110
Sea Lettuce Stn #1-3	3.0	22.0	17.0	80
Sea Lettuce Stn #2-1	2.4	7.8	6.1	27
Sea Lettuce Stn #2-2	3.3	18.0	9.3	28
Sea Lettuce Stn #3-1	4.2	20.0	17.0	49
Sea Lettuce Stn #3-2	3.7	18.0	11.0	23
Sea Lettuce Stn #4-1	3.3	27.0	12.0	45
Sea Lettuce Stn #4a-1	1.1	3.2	5.3	37
Sea Lettuce Stn #4-2	4.5	21.0	14.0	48
Sea Lettuce Stn #5-1	4.6	10.0	10.0	38

may be taking place within the mussel-ring billed gull food chain." (SES, 1987). The data for the vegetation and mouse system "...suggest that biomagnification of PCBs may be taking place within this food chain as well."

Biomagnification of metals in the New Bedford food chain(s) is less well defined. This present inability to document metal biomagnification may be due to a number of factors: the ubiquitous and chronic nature of metals contamination in the region leading to constant elevated levels of metals in water and sediment; differential metal uptake rates in the various biological systems sampled; lack of statistical power to mathematically describe uptake trends between the various trophic levels.

The IEP data contained in this report continues to support the suggested trend of bioaccumulation within the New Bedford estuary. The recent IEP data indicate that movement of PCBs through food chains other than the two examined by SES is also occurring. Elevated levels of PCBs in sediments (Section 2.0) appear to be reflected in elevated levels in grass shrimp, with concentrations in both decreasing north to south through the estuary. The grass shrimp is generally a deposit feeder, ingesting the substrate over which it moves along with detrital matter with their microbial populations as well as small invertebrates (Daiber, 1982; Whitlach, 1982).

Similarly, PCB concentrations in mummichogs from the upper estuary (wetland 5) were five times higher than levels in the middle estuary (wetland 9) and 20 times higher than those in Buzzard's Bay (wetland 2). The mummichog is omnivorous, feeding on detrital material, eelgrass, diatoms, forams, shrimp, small crustaceans, molluscs, and fish fry; the mummichog appears to be preferentially an active predator, however, having to ingest sizeable amounts of food to meet metabolic needs (Daiber, 1982; Whitlach, 1982). PCB and metal ingestion by mummichogs, therefore, is probably related more to its predation on consumer organisms such as shrimp. The mummichog, in turn, serves as a food source for several species of larger finfish as well as predatory wading birds. PCB transfer to these trophic levels is therefore likely. The winter flounder is also omnivorous, feeding on isopods, copepods, amphipods, shrimp, crabs, worms, molluscs, and some seaweed (Whitlach, 1982); PCB ingestion through any of these sources is possible. Bioaccumulation of PCBs through these food chains is indicated by the data, and there are definite trends showing the gradual decrease in concentrations of PCBs from the northern wetlands to the southern wetlands. The data lack the power to discriminate statistically significant differences between species, trophic levels, or locations, or interpret linear (or nonlinear) relationships between the above.

10.4 GENERAL CONCLUSIONS ON WETLAND VALUES AND BIOACCUMULATION

1. Sediments in the Northern end of the Acushnet River estuary, between the Tarklin Hill bridge and Popes Island, are contaminated with PCB's and heavy metals which include chromium, zinc, mercury, lead, cadmium and copper.

2. The most contaminated portions of the wetlands are generally those where sediment deposition (accretion) continues to occur; these include the mud flats, tidal creeks, and low salt marsh habitat, although high marsh areas in proximity to these areas may also be significantly contaminated. Elevated levels of PCBs and metals in these sediments appears to be reflected in detritivores, which directly ingest the sediments and contaminated detrital matter. Similar trends are indicated for consumers of the detritivores and higher level biota.

3. Biomagnification of PCB's is apparent in several of the food chains investigated and suggests a widespread condition throughout the Achushnet River estuary and Buzzards Bay. The trend being one of decreased levels from the sources in the estuary to more distant areas in the bay.

4. Despite very heavy levels of contaminants as well as evidence of bioaccumulation, the project area wetlands continue to function as effective systems and have high values. The wetlands continue to support and produce biota representative of estuaries in southeastern New England. Plant biomass, benthic and fish community composition and structure, and avian and mammal use are all typical of estuarine wetlands of the region, although elements of the benthic community indicate the influence of pollutants. The overall effect of the PCB and metal contamination and bioaccumulation on the biological systems in the estuary is not readily apparent.

11.0 BIOLOGICAL EFFECTS OF PROJECT ALTERNATIVES

The various alternatives presently being considered within the Acushnet River estuary have been summarized in Section 1.3; they include: 1) no action; 2) dredging with in-harbor disposal and containment within either Confined Disposal Facilities (CDF) or through a Confined Aquatic Disposal (CAD) method; and 3) a hydraulic-control and capping option. In this section, the short- and long-term effects of the various alternatives are characterized, with particular emphasis placed upon the biological effects on the wetland communities described through the course of this report.

11.1 NO ACTION ALTERNATIVE

The New Bedford Harbor estuary has a unique physical and hydrological environment which exists in spite of numerous man-made alterations to the environment. The estuary has proved to be a viable buffer to episodic events such as flooding and would continue to do so under the no-action alternative. Erosion is not clearly evident, and the general area may be considered slightly depositional with respect to bottom sediment. Since the construction of the hurricane barrier accretion rates in the upper Acushnet River estuary have ranged from 1.7 cm - 4 cm/year (NUS 1984). Based on these rates of accretion, in ten years 17 cm (0.6 ft) - 40 cm (1.3 ft) of sediment would accumulate on the bottom of the estuary barring any major storm-driven, erosional forces. Biologically induced sediment mixing (bioturbation) has the potential to modify the chemical properties of surficial sediments and re-expose contaminated sediments to the soil/water interface. This zone of bioturbation is primarily within the top 9 cm although sediment turnover to a depth of 20 cm has been reported (Whitlach 1982). Therefore, in ten years, time most of the contaminated bottom sediments could potentially be effectively isolated. It is not known to what extent the contaminated sediments mix with cleaner sediments during deposition. Some of the newly accreted cleaner sediments could be colonized and stabilized by encroaching salt marsh vegetation, although the present salt marshes do not appear to be rapidly accreting.

The salt marsh and reed marsh sediments are also contaminated with PCBs and heavy metals (SES, 1987) and there is evidence of bioaccumulation of these contaminants amongst the various trophic levels using the wetlands (Section 10). The net accumulation of sediment in a Massachusetts salt marsh was 31 cm/100 yrs for the low marsh and 2-8 cm/100 yrs in the high marsh (Chapman 1960), however the average accretion rate for salt marshes in the northeast is 45 cm/100 yrs (Nixon and Lee, 1986). These sediment accumulation rates are substantially lower than for the adjacent bottom of the estuary. It would take on the order of one hundred years to partially isolate the contaminated surficial marsh sediments from biotic activity. If the roots of salt marsh vegetation are within contaminated sediments the plants can accumulate some heavy metals (Kelly, Harwell and Giblin 1982) and excrete them along with salts from their leaves (Kraus, Weis and Crow 1986). Rain or tidal waters wash the metals from the leaves and return them to the waters or sediments of the estuary. The transformation of PCBs is promoted under anaerobic

conditions (EPA 1983) which prevail in salt marshes. However, transformations of PCBs may lead first to more toxic compounds prior to degradation to innocuous chemicals. The rate of PCB mobilization by vegetative uptake, translocation, and release is not known. However, under the no action alternative the contaminated marshland would continue to be a source of pollutants for years to come.

During this period, however, the wetlands (particularly areas 1 and 3) will continue to support a diversity of biological organisms and provide a wide array of functions and values. With the existing data, it is difficult to assess the significance of the apparent bioaccumulation to local biota, and it is not possible at present to relate the effects in terms of estuarine and offshore dynamics on a long-term basis. A number of studies have indicated or demonstrated a decrease in reproductive success in higher-level biota exposed to excessive levels of PCBs (e.g., Linzey 1987: white-footed mice; Koval et al. 1987: mourning dove; Rattner et al. 1984: avian species; Eisler 1986: fish and wildlife; Wren et al. 1987: mink). Linzey (1987) found impaired reproductive success in white-footed mice (Peromyscus leucopus) exposed to food treated at a rate of 10 ppm (ug/g); SES (1987) data from Peromyscus at wetland #1 found comparable levels (5.3-17 ppm), while one sample from wetland #3 registered a level of 56.0 ppm. This suggests that concentrations of PCBs in higher-level biota in the Acushnet River wetlands may be sufficient to affect reproductive success, and could eventually disrupt the population structure of susceptible species. The benthos data presented in Section 4.0 of this report noted generally fewer taxa and lower diversity of benthic species at wetland 1 (high in the estuary) than at wetland 2 (in Buzzard's Bay), although it is cautioned that numerous physical and chemical factors may contribute to such differences. The dominant taxa at wetland 1 (Oligochaeta, capitella sp., Streblospio benedicti) are generally considered to be opportunistic and resistant to pollutants, further suggestive of an influence from contamination. No such obvious effects to fish, vegetation, birds, or mammals in the estuary exists. As discussed in Section 10, however, additional studies are necessary to derive data sufficient to allow modeling of the food chain to better assess PCB cycling, bioaccumulation, and the effects on the biological systems in the New Bedford estuary and associated areas.

11.2 DREDGING WITH IN-HARBOR DISPOSAL

The two options for dredging the contaminated sediments with disposal and containment in the estuary were described in Section 1.3; Figures 1-3 and 1-4 showing the locations of the containment areas which could be used under each option. Both options present similar potentials for short-term water quality degradation resulting from increased turbidity and contaminant mobilization during dredging and movement of sediments. Sediment control and methods for treating effluent from dewatering processes would need to be carefully analyzed. The potential temporary effects extend from water degradation and contaminant mobilization to smothering of benthic organisms and the departure of more mobile fish and wildlife. Re-colonization of the benthic community

will depend upon the sediment, water quality, and hydrologic characteristics which develop as well as available recruitment populations (Rhoads et al 1978; Whitlach 1982).

Both options will result in the direct filling of salt marsh and mudflat habitat. The CDF option would eliminate wetlands #4 and 5, and either fill or completely isolate wetland #9 from the River. This would amount to a loss of approximately 6.0 acres of vegetated salt marsh as well as 8.0 acres of Phragmites habitat. The CAD option would result in the filling of wetland #5 (3.5 acres) and could potentially impact wetlands #3 and 4 depending upon final design configurations of the CADs. Both options offer considerably less direct wetland impacts than did previous alternatives which entailed creating a permanent containment site over all of wetland #3 and the northern one-half of wetland #1 (SES 1987). Of the two present options, the CAD method appears to have less direct wetland impact and has the potential of maintaining the existing amount of tidal flats, versus the CDF method which will eliminate (by deepening) most intertidal flats. The concerns noted in the previous section regarding bioaccumulation within salt marsh biota apply equally to the dredging options, since most of the salt marsh area will be preserved.

The CDF alternative will result in the deepening of the upper estuary by approximately two feet. This has the potential of inducing minor changes in water circulation patterns in the estuary and could have a small affect on tides in New Bedford inner harbor. In addition, dredging along the edges of the salt marshes to a final depth two-feet below existing grades could increase currents and wave action at the salt marsh face. Erosion and slumping of the salt marsh peat could be accelerated until a new equilibrium is established. Concern would then exist for mobilization of contaminants, previously adsorbed or retained within the wetland soils. More detailed data would be required to assess the hydraulic changes induced by CDF option, including bathymetry of the lower estuary, water current and pressure measurements at key locations, and modeling of tidal response for different geometric configurations in relation to potential CDFs (SES 1987). The CAD option would be expected to have less hydraulic effects, since only the main channel of the upper estuary would be deepened by two feet while depths in other areas will be largely unchanged. Nevertheless, hydraulic changes induced by the channel deepening requires more assessment.

Assessing the biological effects of the alternatives also requires referencing data generated on the sediment, benthos, fish, vegetation, and wildlife composition of each wetland which could be impacted. Both the CDF and CAD options will directly impact only the relatively small, disjunct areas of marsh in the upper estuary. Wetlands 4 and 5 would be filled by either option, while wetlands 9 and 3 will be affected by the CDF and CAD options, respectively. Wetlands 5 and 3 have high levels of PCB and metals in the sediments (Section 2.0; SES, 1987), and availalbe data indicate that benthos and fish populations also reflect this contamination. Wetlands 4 and 9 show less, but still significant levels of contamination. For example, PCB concentrations in mummichog at wetland 9 were four times higher than the fish at wetland 2 (Buzzard's Bay), but five times lower than the fish caught at

wetland 5. Despite this, vegetative composition and productivity, as well as wildlife use, do not appear to reflect excessive contamination. For example, above-ground biomass of tall Spartina alterniflora was greatest at wetland 5, exceeding the recorded values from wetland 2. Wildlife use of the wetlands appears to be more a function of habitat variables than contamination levels. Thus, the small, disjunct wetlands 4, 5, and 9 with lower diversity and interspersion of cover types appear to have less habitat value than the larger, more diverse wetlands (1, 2, and 3). Although elevated levels of PCBs and metals were recorded in higher-level biota (ring-billed gull and white-footed mice; SES, 1987), there is no obvious effect on the populations of the birds and mammals using the wetlands.

Given the considerations discussed above, biological impacts associated with the loss of wetlands 4, 5, and 9 are indicated to be minimal, and the likelihood of mitigating for the impacts is good. Biological impacts resulting from filling at wetland 3 vary; while the wetland offers good habitat for a number of wildlife species, contamination levels in the mud flat, creek, and low salt marsh portions are excessive and generate concern for long-term transfer through the food chain. The CAD option will cover the more contaminated portions with fill; impacts to the unfilled marsh portions are uncertain, but it could encourage the invasion of Phragmites already apparent along the north side.

Overall, the CDF and CAD options offer minimal direct biological impacts due to filling of wetland habitats, and will remove most of the more contaminated sediments from the biologically active zone.

11.3 HYDRAULIC-CONTROL AND CAPPING ALTERNATIVE

As described in Section 1.3, this option requires that the freshwater flows of the Acushnet River be carried through the upper estuary within an 80-foot wide channel bounded by two 8-foot high embankments. Contaminated sediment in the area of the channel and embankments would be covered by a sand layer. Contaminated sediments located outside of the channel would be covered with a 3 to 4 foot layer of clean sediments. Figure 1-5 shows the conceptual plan view of this method.

Short-term impacts associated with the capping alternative are similar to those previously cited for the dredging options, and include water quality degradation (turbidity, contaminant suspension and mobility) during construction of the channel and the initial stages of capping. Again, the details of the sediment dispersal control method would need to be established to assess this.

Tidal currents in the proposed channel would be much less than presently exist in the estuary due to the reduced volume of water that would flow into the channel. The river discharge into the proposed channel would be the same, and, thus the lower salinity gradients between the river water and harbor water would move southward, decreasing the salinity in the area near the Coggeshall Street Bridge. The local wind-driven circulation and waves would

be greatly reduced due to the reduction in surface areas of the exposed water in the estuary. It is also important to note that, by changing the geometry of the Acushnet River estuary, the tidal currents and elevations in the inner New Bedford Harbor are also expected to change. Whether the effect would be to increase the tidal range and currents, or to reduce them in the inner harbor, is not known without a predictive physical model, but the amplitude change is expected to be less than 0.5 feet of elevation. The tidal currents in the immediate vicinity of the Coggeshall Street Bridge would be reduced. These reduced currents would create a depositional environment for suspended sediments transported by the Acushnet River (SES 1987).

Although vegetated wetlands would not be directly filled by the capping option, it would appear that the 8-foot high embankments along the channel and the resulting altered hydraulics would severely curtail or eliminate the present tidal flushing. The existing vegetative characteristics of wetland #1, with an unusually extensive cover of marsh elder, indicates that the hydrologic regime of the wetland is presently near the upper range or limit for salt marshes of the region (i.e., marsh elder grows at the upper elevations of salt marshes). Additional constricted tidal inundation from the embankments may accelerate vegetative changes; the likely change would be toward a Phragmites marsh. In any event, decreased coupling between the marshes and the estuary is probable, inferring a loss (import and/or export) of exchange between these resources; it is noted, however, that there is debate in the scientific community concerning the significance of such exchanges (Nixon 1980). In the present case, reduced interaction may be desirable considering the levels of contamination. Nevertheless, it is likely that the present salt marshes will change considerably in character.

The capping option will fill roughly 72 acres of tidal flat habitat and 130 acres of subtidal habitat (SES 1987). What is established in their place depends upon numerous factors, including: 1) final elevations of the fill; 2) the microtopography of the fill; 3) the physical properties of the fill; and 4) the freshwater/saltwater balance. The proposed thickness of fill (3-4 feet) will apparently bring final grades to between 1-5 feet above MLW. These elevations could support habitats ranging from tidal flats to Phragmites marsh. It is likely that flats and Phragmites habitat will be the most common condition which will develop without careful design considerations, proper construction, and active management. This is discussed in more detail in Section 12.

Additional biological effects of the capping option relate to direct habitat changes in the area of filling. Benthic fauna, fish (including migratory alewives and blue-back herring), and avian use of the open water subtidal and intertidal habitat would be virtually eliminated on at least a temporary basis. The long-term impacts to these communities will depend upon the conditions which are created in the upper estuary. While the potential exists for some creative habitat development and management, the risks associated with the uncertainties of this type of endeavor are substantial, and the potential of establishing a monotypic Phragmites stand is high.

11.4. EVALUATION OF REMEDIAL ACTION PROJECT ALTERNATIVES WITH RESPECT TO WILDLIFE IN THE UPPER ESTUARY

With respect to wildlife, project alternatives should be evaluated from the standpoint of minimizing habitat alteration. Primary biological effects in the upper estuary that could impact the estuarine wetland habitats include destruction of the wetland habitats, lowering of salinity levels, changes in the tidal amplitude, and changes in current velocities.

Despite the levels of contamination in the upper estuary weltands by PCB's, a diverse bird and mammal community exists in wetlands 1 and 3. As documented in earlier sections (4.0, 5.0) lower, supporting trophic levels in these wetlands are representative of estuaries of the area and contribute to the productivity of the bird and mammal components. Project alternatives should be aimed at maintaining or enhancing the structure of the marsh and marsh/upland edge habitats in these wetlands.

Aside from removing the wetlands altogether, the most detrimental primary effect with respect to wildlife habitat would be a lowering of salinity levels which would undoubtedly lead to colonization of any remaining wetland by Phragmites. Encroachment by Phragmites would represent a severe degradation of wildlife habitat. The potential for this to occur is high under the hydraulic control alternative since tidal flow would be reduced considerably. There appears to be little potential for Phragmites encroachment under the CAD alternative, and some potential under the CFD alternative if freshwater runoff is increased.

Changes in tidal amplitude could also impact wetland habitat and are identified below based on 3 possible conditions: 1) tidal amplitude remains unchanged - If the tidal amplitude remains unchanged then the structure of the present wetlands should also remain the same in the short term. However, deepening of the upper estuary will result in an increased tidal prism and higher current velocities (SES 1987) which could inhibit further growth of intertidal Spartina alterniflora habitats and possibly lead to erosion; 2) tidal amplitude decreases - A decrease in tidal amplitude would result in a decrease in intertidal Spartina alterniflora in areas that are no longer exposed daily. With respect to the biotic community this would be undesirable for intertidal Spartina alterniflora provides foraging habitat for terrestrial and estuarine animals, serves as a nursery for marine organisms, and is thought to play a major role in the detritus based estuarine food web; 3) tidal amplitude increases - An increase in the tidal range in the upper estuary could lead to an increase in the area of intertidal Spartina alterniflora as more tidal flat is exposed on a daily basis.

11.5 SECTION 404 (b)(1) GUIDELINES

The Section 404 (b)(1) guidelines under the Clean Water Act essentially mandate that no discharge of fill material may occur within waters (including wetlands) of the United States when there is a practicable, less damaging alternative, and require that all practicable steps to minimize impacts are

taken, and finally that steps are taken to mitigate for unavoidable impacts. An initial criterion in the process of satisfying the guidelines is establishing the need for the project. The need for remedial action in the Acushnet River to mitigate for PCB and heavy metal contamination has been known and documented for years (NUS 1984; Batelle 1985; Genest and Hatch 1981; Reinisch et al 1984; SES 1987).

The available data strongly indicate that bioaccumulation and biomagnification is occurring through the trophic levels which exist in the estuary (Section 10.0). The potential health and environmental risks to the aquatic food chain from continued exposure of the biological systems in the estuary to PCBs and metals have been discussed in most of the reports cited above; these risks, as well as those to humans are outlined in Section 10 of this report. A more definitive assessment of the short- and long-term food chain impacts from taking no action (as well as from the various alternatives) is being generated through development of a food chain mathematical model.

Given the need for remedial action, the three alternatives proposed in this report have reduced direct wetland impacts considerably over previously proposed options (NUS 1984; SES 1987). All three proposals have attempted to minimize direct filling of vegetated wetlands to the extent practicable; one result of this is the potential for continued contaminant availability and cycling within the wetlands.

Of the three alternatives, the CDF option entails the greatest direct impacts to vegetated wetlands, and it is likely that much of the estuary will be too deep to support tidal flat habitat in the near future. The more valuable salt marsh areas from bird and mammal habitat perspectives (wetlands 1 and 3), however,will be least impacted by the CDF option.

The capping option offers potentially extreme indirect impacts to these two wetlands (Section 11.3), although the direct filling is largely eliminated. It would also appear that contaminant mobility out of the marshes into the estuary would be minimized by the capping option. The net impact to tidal flat habitat is unknown, being dependent upon the conditions described in Section 11.3.

The CAD option entails less direct salt marsh filling than the CDF method (3.5 vs 6.0 acres), and has the potential to replace all tidal flat habitat in a much shorter time frame. As with the CDF option, however, contaminant availability and cycling between wetland and open water will continue under the CAD option.

In summary, the three options are an attempt to compromise between the goals of maintaining viable wetland habitat in the estuary while minimizing the contaminant availability and cycling. The CDF and CAD options appear to more strongly favor the former goal, while the capping option more strongly meets the latter goal. The third component of the 404 (b)(1) guidelines, mitigation for unavoidable impacts, is most critical for successful implementation of the capping option; this is discussed in Section 12.

12.0 MITIGATION

12.1 FUNCTIONAL ATTRIBUTES OF PROJECT AREA WETLANDS

In order to supplement the understanding of wetland functions in the estuary, a published wetland evaluation method has been employed which assesses relative wetland significance for 15 functions. The Wetland Evaluation Technique (WET) developed by the Corps of Engineers (1987), in operational computerized draft, has been employed for this purpose.

The WET method assumes that wetland characteristics in combination contribute certain functions, and therefore rating those characteristics can provide a relative assessment of how well a particular wetland functions for certain interests. The evaluation method is not intended to provide definitive answers to the questions of wetland significance. It is intended to provide a documented, standardized means of assessment which requires an inventory of wetland characteristics and an understanding of how those characteristics may contribute to function. The assessment may also provide a basis for judging the degree of mitigation necessary to compensate for unavoidable impacts.

WET is based on the premise that the functions and values of a wetland can be identified and evaluated in terms of social significance, effectiveness, and opportunity. The social significance evaluation assesses whether the wetland has important natural features or economic value. The effectiveness evaluation assesses the potential capability of a wetland to perform a function or value because of its physical, chemical, or biological attributes. The opportunity evaluation assesses the potential opportunity a wetland has to perform a function or value because of its location in the watershed or other factors that influence opportunity.

WET evaluates functions and values by characterizing the wetland in terms of its physical, chemical, and biological processes or attributes. This characterization is accomplished by asking a series of questions concerning predictors. Predictors are simple, or integrated, variables that reflect the physical, chemical, and biological processes or attributes of the wetland and its surroundings. Responses to the characterization questions are interpreted in a series of "keys" that define the relationship between predictors and wetland functions and values. The relationships defined in the interpretation keys are based on the technical literature. The interpretation results in a qualitative probability ratings of HIGH, MODERATE, or LOW being assigned to functions and values in terms of social significance, effectiveness, and opportunity.

Table 12.1 presents the compiled results of the WET assessment for the six project area wetlands. Tables 12.2 through 12.7 present the individual results for each wetland, showing the ratings for social significances, effectiveness, and opportunity of each area as well as probable use assessments for 14 waterfowl groups.

Table 12.1. Functional Significance Ratings[1] of Project Area Wetlands

	Wetland Area					
Function	1	2	3	4	5	9
Ground Water Recharge	L	L	L	L	L	L
Ground Water Discharge	M	L	M	M	M	M
Floodflow Alteration	L	L	L	L	L	L
Sediment Stabilization	H	H	H	H	H	H
Sediment/Toxic Retention	H	H	H	H	H	H
Nutrient Removal/Trans.	H	M	H	H	H	H
Production Export	M	M	M	M	M	M
Aquatic Diversity/Abundance	H	H	H	H	H	H
General Fish Habitat	H	H	H	H	H	H
General Wildlife Habitat	H	H	H	H	H	H
Wildlife D/A Breeding	L	L	L	L	L	L
Wildlife D/A Migration	H	H	H	H	H	H
Wildlife D/A Wintering	M	H	H	M	M	M
Uniqueness/Heritage	H	H	H	H	H	H
Active Recreation	L	L	L	L	L	L

[1]As derived from Wetland Evaluation Technique (WET), April 1987 Operational Draft, U.S. Army Corps of Engineers.

L = Low M = Moderate H = High

Table 12.2. Evaluation Summary - Wetland Area 1

	Significance	Effectiveness	Opportunity	Combined
Ground Water Recharge	M	L	*	L
Ground Water Discharge	M	M	*	M
Floodflow Alteration	M	L	L	L
Sediment Stabilization	H	H	*	H
Sediment/Toxic Retention	H	H	H	H
Nutrient Removal/Trans.	H	L	H	H
Production Export	*	M	*	M
Aquatic Diversity/Abundance	M	H	*	H
General Fish Habitat	M	M	*	H
General Wildlife Habitat	H	*	*	H
Wildlife D/A Breeding	*	L	*	L
Wildlife D/A Migration	*	H	*	H
Wildlife D/A Wintering	*	M	*	M
Uniqueness/Heritage	H	*	*	H
Active Recreation	L	*	*	L

W = potentially High if watershed changes, I = potentially high if improved

Probable Use Assessments

Warmwater Fish	M
Coldwater Fish	L
Coldwater Riverine Fish	L
Northern Lake Fish	H

	Breeding	Migration	Wintering
Waterfowl Group 1	L	L	L
Waterfowl Group 2	L	H	L
Waterfowl Group 3	L	L	L
Waterfowl Group 4	L	L	L
Waterfowl Group 5	L	L	L
Waterfowl Group 6	L	M	L
Waterfowl Group 7	L	L	L
Waterfowl Group 8	L	L	L
Waterfowl Group 9	L	M	L
Waterfowl Group 10	L	M	L
Waterfowl Group 11	M	L	L
Waterfowl Group 12	L	H	H
Waterfowl Group 13	L	M	L
Waterfowl Group 14	L	L	H

Table 12.3. Evaluation Summary - Wetland Area 2

	Significance	Effectiveness	Opportunity	Combined
Ground Water Recharge	M	L	*	L
Ground Water Discharge	M	L	*	L
Floodflow Alteration	M	L	L	L
Sediment Stabilization	M	H	*	H
Sediment/Toxic Retention	M	H	H	H
Nutrient Removal/Trans.	M	L	H	M
Production Export	*	M	*	M
Aquatic Diversity/Abundance	M	L	*	L
General Fish Habitat	M	M	*	H
General Wildlife Habitat	H	*	*	H
Wildlife D/A Breeding	*	L	*	L
Wildlife D/A Migration	*	H	*	H
Wildlife D/A Wintering	*	H	*	H
Uniqueness/Heritage	H	*	*	H
Active Recreation	L	*	*	L

W = potentially High if watershed changes, I = potentially high if improved

Probable Use Assessments

Warmwater Fish	M
Coldwater Fish	L
Coldwater Riverine Fish	L
Northern Lake Fish	H

	Breeding	Migration	Wintering
Waterfowl Group 1	L	L	L
Waterfowl Group 2	L	L	L
Waterfowl Group 3	L	L	L
Waterfowl Group 4	L	L	L
Waterfowl Group 5	L	L	L
Waterfowl Group 6	L	L	L
Waterfowl Group 7	L	L	L
Waterfowl Group 8	L	L	L
Waterfowl Group 9	L	L	L
Waterfowl Group 10	L	L	L
Waterfowl Group 11	M	L	L
Waterfowl Group 12	L	L	L
Waterfowl Group 13	L	L	L
Waterfowl Group 14	L	L	L

Table 12.4. Evaluation Summary - Wetland Area 3

	Significance	Effectiveness	Opportunity	Combined
Ground Water Recharge	M	L	*	L
Ground Water Discharge	M	M	*	M
Floodflow Alteration	M	L	L	L
Sediment Stabilization	H	H	*	H
Sediment/Toxic Retention	H	L	H	H
Nutrient Removal/Trans.	H	L	H	H
Production Export	*	M	*	M
Aquatic Diversity/Abundance	M	H	*	H
General Fish Habitat	M	M	*	H
General Wildlife Habitat	H	*	*	H
Wildlife D/A Breeding	*	L	*	L
Wildlife D/A Migration	*	H	*	H
Wildlife D/A Wintering	*	H	*	H
Uniqueness/Heritage	H	*	*	H
Active Recreation	L	*	*	L

W = potentially High if watershed changes, I = potentially high if improved

Probable Use Assessments

Warmwater Fish	M
Coldwater Fish	L
Coldwater Riverine Fish	L
Northern Lake Fish	H

	Breeding	Migration	Wintering
Waterfowl Group 1	L	L	L
Waterfowl Group 2	L	H	L
Waterfowl Group 3	L	L	L
Waterfowl Group 4	L	L	L
Waterfowl Group 5	L	L	L
Waterfowl Group 6	L	M	L
Waterfowl Group 7	L	L	L
Waterfowl Group 8	L	M	L
Waterfowl Group 9	L	M	L
Waterfowl Group 10	L	M	L
Waterfowl Group 11	L	M	M
Waterfowl Group 12	L	H	H
Waterfowl Group 13	L	M	L
Waterfowl Group 14	L	L	H

Table 12.5. Evaluation Summary - Wetland Area 4

	Significance	Effectiveness	Opportunity	Combined
Ground Water Recharge	M	L	*	L
Ground Water Discharge	M	M	*	M
Floodflow Alteration	M	L	L	L
Sediment Stabilization	H	H	*	H
Sediment/Toxic Retention	H	L	H	H
Nutrient Removal/Trans.	H	L	H	H
Production Export	*	M	*	M
Aquatic Diversity/Abundance	M	H	*	H
General Fish Habitat	M	M	*	H
General Wildlife Habitat	H	*	*	H
Wildlife D/A Breeding	*	L	*	L
Wildlife D/A Migration	*	H	*	H
Wildlife D/A Wintering	*	M	*	M
Uniqueness/Heritage	H	*	*	H
Active Recreation	L	*	*	L

W = potentially High if watershed changes, I = potentially high if improved

Probable Use Assessments

Warmwater Fish	M
Coldwater Fish	L
Coldwater Riverine Fish	L
Northern Lake Fish	H

	Breeding	Migration	Wintering
Waterfowl Group 1	L	L	L
Waterfowl Group 2	L	H	L
Waterfowl Group 3	L	L	L
Waterfowl Group 4	L	L	L
Waterfowl Group 5	L	L	L
Waterfowl Group 6	L	M	L
Waterfowl Group 7	L	L	L
Waterfowl Group 8	L	L	L
Waterfowl Group 9	L	M	L
Waterfowl Group 10	L	M	L
Waterfowl Group 11	M	L	L
Waterfowl Group 12	L	H	H
Waterfowl Group 13	L	M	L
Waterfowl Group 14	L	L	H

Table 12.6. Evaluation Summary - Wetland Area 5

	Significance	Effectiveness	Opportunity	Combined
Ground Water Recharge	M	L	*	L
Ground Water Discharge	M	M	*	M
Floodflow Alteration	M	L	L	L
Sediment Stabilization	H	H	*	H
Sediment/Toxic Retention	H	L	H	H
Nutrient Removal/Trans.	H	L	H	H
Production Export	*	M	*	M
Aquatic Diversity/Abundance	M	H	*	H
General Fish Habitat	M	M	*	H
General Wildlife Habitat	H	*	*	H
Wildlife D/A Breeding	*	L	*	L
Wildlife D/A Migration	*	H	*	H
Wildlife D/A Wintering	*	M	*	M
Uniqueness/Heritage	H	*	*	H
Active Recreation	L	*	*	L

W = potentially High if watershed changes, I = potentially high if improved

Probable Use Assessments

Warmwater Fish	M
Coldwater Fish	L
Coldwater Riverine Fish	L
Northern Lake Fish	H

	Breeding	Migration	Wintering
Waterfowl Group 1	L	L	L
Waterfowl Group 2	L	M	L
Waterfowl Group 3	L	L	L
Waterfowl Group 4	L	L	L
Waterfowl Group 5	L	L	L
Waterfowl Group 6	L	L	L
Waterfowl Group 7	L	L	L
Waterfowl Group 8	L	L	L
Waterfowl Group 9	L	M	L
Waterfowl Group 10	L	M	L
Waterfowl Group 11	M	L	L
Waterfowl Group 12	L	M	H
Waterfowl Group 13	L	L	L
Waterfowl Group 14	L	L	H

Table 12.7. Evaluation Summary - Wetland Area 9

	Significance	Effectiveness	Opportunity	Combined
Ground Water Recharge	M	L	*	L
Ground Water Discharge	M	M	*	M
Floodflow Alteration	M	L	L	L
Sediment Stabilization	H	H	*	H
Sediment/Toxic Retention	H	L	H	H
Nutrient Removal/Trans.	H	L	H	H
Production Export	*	M	*	M
Aquatic Diversity/Abundance	M	H	*	H
General Fish Habitat	M	M	*	H
General Wildlife Habitat	H	*	*	H
Wildlife D/A Breeding	*	L	*	L
Wildlife D/A Migration	*	H	*	H
Wildlife D/A Wintering	*	H	*	H
Uniqueness/Heritage	H	*	*	H
Active Recreation	L	*	*	L

W = potentially High if watershed changes, I = potentially high if improved

Probable Use Assessments

Warmwater Fish	M
Coldwater Fish	L
Coldwater Riverine Fish	L
Northern Lake Fish	H

	Breeding	Migration	Wintering
Waterfowl Group 1	L	L	L
Waterfowl Group 2	L	H	L
Waterfowl Group 3	L	L	L
Waterfowl Group 4	L	L	L
Waterfowl Group 5	L	L	L
Waterfowl Group 6	L	M	L
Waterfowl Group 7	L	L	L
Waterfowl Group 8	L	M	L
Waterfowl Group 9	L	M	L
Waterfowl Group 10	L	M	L
Waterfowl Group 11	M	L	L
Waterfowl Group 12	L	H	H
Waterfowl Group 13	L	M	L
Waterfowl Group 14	L	L	H

Overall, the wetlands were rated quite similarly for the functions evaluated. This demonstrates the importance of setting (physiographic, hydrologic, juxtaposition, etc.) in influencing value, at least as perceived by this assessment method. The functions generally rated as most strongly provided by the project area wetlands include sediment stabilization, sediment/toxic retention, nutrient removal or transformation, and biological habitat and diversity. The lowest rated functions were for ground water recharge, flood flow alteration, and as breeding areas for designated waterfowl.

The inability of WET to distinguish differences in functional values between most of the six wetlands underscores questions pertaining to the sensitivity of such evaluation techniques. Intuitively, the larger size and more diversity of vegetative types within Wetland 2 infers greater potential to provide a wider array of functions to a degree which has more local significance than the smaller, less diverse marshes (wetland sites 4, 5, and 9). Similarly, Wetlands 1 and 3, which may be considered together due to their proximity and undeveloped shoreline and upland habitat in between, offer a relatively large area (56 acres) of a diversity of coastal wetland cover types. In contrast, Wetlands 4, 5, and 9 are relatively small, disjunct marshes. In looking at the distribution of certain cover type, particularly the regularly flooded tall Spartina alterniflora marsh (which is often considered the most productive coastal wetland type), it should be noted that Wetlands 1 and 3 provide the greatest area (8.9 acres) of this habitat type. The tall S. alterniflora cover in Wetlands 1 and 3 also have considerable areas of adjacent mud flats, often considered to be the principal site for the conversion of plant production into animal biomass (Whitlatch 1982). Wetland 5, despite its' small size (3.5 acres), is predominantly (69%) tall S. alterniflora, whereas the extensive Wetland 2 has slightly less cover of tall S. alterniflora. Alternatively, Wetland 4 is predominantly (75%) Phragmites cover; from a wildlife habitat perspective this cover is probably the least valuable of those occurring in the project area wetlands. In considering the range of factors which, in combination, determine overall wetland value, the following ranking of the project area wetlands (from highest to lowest) is suggested: 2, 1, 3, 5, 4, 9. The first three areas would be logically grouped together in a "higher value" assessment versus the latter three in a "lower value" category. Again, this ranking is intended only to provide guidance in determining the level of mitigation which may be appropriate in the eventual disturbance of the various wetland areas.

12.2 Minimizing, Rectifying, Compensating for Biological Effects

In line with the definitions used by the Council on Environmental Quality (40 CFR 1508.20), mitigation includes:

- avoiding adverse impacts to wetlands altogether by not taking a certain action;

- minimizing impacts by limiting the degree or magnitude of action;

- rectifying the impact by repairing, rehabilitating, or restoring the affected environment;

- reducing or eliminating the impact on wetlands by preservation and maintenance operations during the life of the project; and

- compensating for the wetland losses by replacing or providing substitute resources or environments."[10]

The aspects of avoiding taking remedial action steps in the Acushnet River estuary, as well as those of minimizing direct wetland impacts by modifying the proposed locations of containment areas, have been discussed in Section 11.0. Table 12.8 summarizes the probable unavoidable impacts associated with the three remedial action alternatives and outlines potential mitigation strategies which might be considered to offset the impacts.

For all three remedial action alternatives, erosion and sediment control measures are considered an important initial component to mitigate (minimize) biological impacts.

The principal strategy to mitigate for the direct loss of vegetated wetland under both the CDF and CAD options is the potential for establishing fringing salt marsh areas at several locations within the estuary. This would necessitate using clean sediments to raise the elevation of intertidal flats or subtidal habitat to grades which will support regularly flooded low salt marsh. Plugs of Spartina alterniflora would be planted in the deposited sediments. Measures to reduce surface water flow velocities would be required during the period of vegetation establishment to prevent sediment erosion and loss of plant plugs. This technique has been implemented in numerous instances by the Corps of Engineers throughout the east coast under their Dredged Material Research Program (DMRP). The final locations for such areas would require additional assessment of existing and proposed conditions. The actual need for such mitigation is also questionable, considering that the direct wetland losses are confined to the three wetland areas indicated to have lower value in the estuary. Given the scarcity of vegetated wetland in the estuary, however, any efforts to maintain or increase the extent of wetland may be warranted.

The loss of tidal flat habitat under the CDF option (as much as 72 acres lost by excavation) would be extremely difficult to compensate for in the near future. The volume of sediment necessary to re-establish grades necessary to become intertidal flat is considerable. Natural deposition would, over time (tens of years) likely accomplish this. Recolonization is dependent principally upon substrate conditions and proximity/availability of recruitment areas. The disturbance of a much smaller area (~10 acres) of tidal flat under the CAD option, with artificial re-establishment of grades and substrate suitable for intertidal flats, greatly reduces the impacts over the CDF option.

Table 12-8. Probable Wetland Impacts and Potential Mitigation Strategies for Three Remedial Action Alternatives

Alternative	Probable Direct Wetland Impact	Probable Indirect Wetland Impact	Potential Mitigation for Wetland Impact
Confined Disposal Facilities	Filling of 6 acres of salt marsh, 8 acres of *Phragmites* marsh. Loss by excavation of much of the 72 acres of tidal flat.	Increase currents and wave action along salt marsh edges leading to possible erosional losses	Possible creation of fringing salt marsh at several locations using clean dredged sediments.
Confined Aquatic Disposal	Filling of 3.5 acres of salt marsh and ~10 acres of tidal flat.	Hydrologic changes in wetlands 3 and 4 adjacent to CAD's.	Probable natural re-establishment of most tidal flat areas. Possible creation of fringing salt marsh using clean sediments.
Hydraulic-Control and Capping	Filling of ~72 acres of tidal flat.	Hydrologic changes in all wetland areas resulting in a likely increase of *Phragmites* cover.	Creation of diverse wetland habitat over the capped sediments, although with high risk of creating *Phragmites* cover.

The hydraulic-control with capping alternative, while essentially eliminating direct impacts to vegetated wetlands, will require placement of fill over the entire 72 acres of tidal flat and has potentially major indirect effects on adjacent wetlands (Section 11). The actual effects on the adjacent salt marshes are difficult to predict, being dependent primarily upon the hydrologic flushing which remains after construction of the embankments. If the flushing is significantly diminished, there is a high probability of expanded Phragmites growth in the high salt marsh areas. It is unlikely that the high marsh would succeed to upland, given the organic soils, physiographic setting, and climate of the area.

The thickness of fill (3-4 feet) proposed to be placed over subtidal (open water) and intertidal habitats between the channel embankments and the salt marshes will apparently bring final grades in these areas to between 1-5 feet above MLW. These elevations could support habitats ranging from tidal flats to Phragmites marsh. There is, therefore, a potential of creating diverse wetland and upland habitats which may mitigate for the impacts of placement of fill associated with the capping. As noted earlier, it will require detailed design measures, proper construction, and possibly active management to establish habitat other than shallow open water/flats and Phragmites cover. It may be feasible, however, to create a diverse mosaic of shallow water, flats, brackish marsh, and upland islands which could attract and support a number of wildlife species. Impacts to shellfish and marine fisheries would not be mitigated by this proposal, however. Designing such habitat will require detailed understanding of the hydrologic regime which will develop after the embankments and capping are completed, knowledge of the sediment characteristics to be used in the capping, probable water chemistry (of parameters likely to influence plant composition, e.g., pH and salinity), and better understanding of final grades in relation to water levels. Identification of certain targeted wildlife species may also be warranted to direct the type of habitat which is designed for.

Ms. Farah Courtney 2/25/88
Massachusetts Coastal Zone Management
(617) 283-0598

Not in.

Mr. Richard Quateman 2/25/88
Massachusetts Audubon Society
(617) 283-0598

No longer works for MAS. No information on current work address.

Mr. Jeff Benoit 2/25/88
Massachusetts Coastal Zone Management
(617) 727-9530

Not in.

Ms. Susan Moore 2/25/88
Massachusetts Coastal Zone Management
(617) 994-9728

Forwarded technical report completed in 1985 and suggested that Judy Peterson be contacted.

Mr. Jan Smith 2/25/88
Massachusetts Coastal Zone Management
(617) 727-9530

Could not comment on New Bedford project and suggested that Susan Moore be contacted.

Ms. Judy Peterson 2/25/88
Massachusetts Coastal Zone Management
(617) 727-9530

Offered to send technical report completed in 1985, but could not comment on project proposals.

Mr. H.W. Heusmann 2/25/88
Massachusetts Division of Fisheries & Wildlife
(617) 366-4470

Not in.

Mr. Jay Copeland 2/25/88
Massachusetts Natural Heritage and Endangered Species Program
(617) 727-9194

Requested that a locus map be forwarded to the MNHESP office so that records of species occurrences could be referenced more accurately. Map forwarded on same date.

Mr. Chris Manzaras 3/30/88
National Marine Fisheries Service
(617) 281-3600

Needed to see proposed plans before his agency could comment on any current or proposed work. Suggested that Sue Mello at Woods Hole and Ed Reiner at EPA be contacted.

Ms. Sue Mello 3/30/88
National Marine Fisheries Service
(617) 548-5123

Concerned that dredging is being considered without adequate data on resuspension. Cannot comment until results of the pilot dredging program are available, but will forward comments given in past and suggested that she be contacted after review of those comments.

Mr. H.W. Heusmann 3/31/88
Massachusetts Division of Fisheries and Wildlife
(617) 366-4470

Regional data has been collected on wintering waterfowl, but has no specific data on waterfowl in the Acushnet River Estuary System. Suggested that Ward Stone of New York Department of Environmental Conservation be contacted for information on bio-accumulation of PCB's and heavy metals in ducks wintering on contaminated rivers.

Mr. Ward Stone 3/31/88
New York Department of Environmental Conservation
(518) 439-8017

Not in.

Mr. Rocky Guyer 3/31/88
Woods Hole Oceanographic Institute
(617) 548-1400

Not in.

Mr. Lee Bridges 3/31/88
Massachusetts Division of Marine Fisheries

(617) 727-3193

Does not have first hand knowledge of project, but offered to make available extensive data on PCB contamination in the Acushnet River Estuary, which staff from his agency have been collecting since 1977. Data may be obtained from Jack Schwartz at the MDMF Salem Lab.

Ms. Sue Morrison 3/31/88
Massachusetts Department of Environmental Quality Engineering
(617) 935-2160

Does not work for DEQE any longer, and DEQE, at the moment, has no shellfish department.

Mr. Frank Germano 3/31/88
Massachusetts Division of Marine Fisheries
(617) 888-4043

Not in.

Mr. Mike Hickey 3/31/88
Massachusetts Division of Marine Fisheries
(617) 888-4043

Not in.

Mr. Randall Fairbanks 3/31/88
Massachusetts Division of Marine Fisheries
(617) 727-3193

Is not familiar with specifics of project and did not feel it would be appropriate for field personnel to be contacted since they are already overloaded with work. However, the MDMF Boston office does have information on sport fisheries in the Acushnet River Estuary which would be made available to IEP. The director, Philip Coates, should be contacted first and made aware that this has been cleared by Mr. Fairbanks.

Ms. Farah Courtney 3/31/88
Massachusetts Coastal Zone Management
(617) 283-0598

Suggested that Richard Quateman of ICF Inc. be contacted.

Mr. Richard Quateman 3/31/88
ICF Inc.
(617) 723-3860

Mr. Quateman coordinates community relations in his new position. He has not had time to review project alternatives and therefore could not comment.

He suggested that Ed Reiner at the EPA be contacted.

Mr. Ed Reiner 3/31/88
EPA Wetlands Division
(617) 565-3347

Not in.

Mr. Rocky Guyer 4/1/88
Woods Hole Oceanographic Institute
(617) 548-1400

Flow is weak in the upper estuary due to the constriction at the Coggeshall St. Bridge, which he believes caused a decrease of a few inches in the tidal amplitude of the upper estuary. As a result, there should be little (negligible) change in both the tidal prism and amplitude if the estuary was deepened by up to two feet. A dramatic change in the tidal amplitude would result, however, from drastic changes of the shoreline characteristics, or if the hydraulic control alternative was implemented. Deepening of the upper estuary would result in an increased flushing rate and, possibly, higher salinities further up the estuary; this, in turn, might effect migratory fish that require brackish conditions. After deepening the estuary, the system would become depositional as it moved toward equilibrium.

Mr. Ed Reiner 4/1/88
EPA Wetlands Division
(617) 565-3347

Not in.

Mr. Frank Germano 4/1/88
Massachusetts Division of Marine Fisheries
(617) 888-4043

Not in.

Mr. Mike Hickey 4/1/88
Massachusetts Division of Marine Fisheries
(617) 888-4043

Not in.

Mr. Ward Stone 4/1/88
New York Department of Environmental Conservation
(518) 439-8017

Not in.

Mr. Jim Fair 4/1/88
Massachusetts Division of Marine Fisheries
(617) 727-3193

Most significant resource in the estuary/bay are shellfish, which cannot be taken now. Anything that causes resuspension of contaminated sediments would pose a major problem for shellfish in the outer harbor, which are already plagued by problems with coliform. Prognosis for the health of the shellfish in the outer harbor looks good, and anything that will contain contaminated sediment will help shellfish resources tremendously. PCB's do not pose a problem for shellfish. Shellfish purge themselves yearly during spawning, and then PCB levels may build back up to 1 part per million during the rest of the year.

Massachusetts
Natural Heritage
Program

18 April 1988

Mr. Dennis Lowry
IEP, Inc.
6 Maple Street
P.O. Box 780
Northborough, MA 01532

Re: Acushnet River Wetlands
New Bedford, Fairhaven,
Acushnet

Dear Mr. Lowry:

Thank you for contacting the Massachusetts Natural Heritage Program regarding rare species and ecologically significant natural communities in the vicinity of the Acushnet River Wetlands shown on the map contained in your 3 March 1988 letter.

At this time, we are not aware of any rare plants or animals or natural communities in the area of these wetlands.

If your project plans change, or if additional fieldwork and research results in an update of our database, this evaluation may require reconsideration.

Sincerely,

Jay Copeland
Environmental Reviewer

JC/jc:ER/New Bedford, et al/Lowry

cc: New Bedford town file, chrono file, notes in Fairhaven and Acushnet town files

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APPENDICES

4.1 FISHERIES DATA

APPENDIX TABLE 1. NUMBERS OF FISH CAUGHT IN BEACH SEINES, 29-30 JULY 1987, NEW BEDFORD WETLANDS STUDY.

	STATIONS										
	1S1	1S2	1S3	1S4	1S5	1S6	2S1	2S2	2S3	2S4	2S5
Menidia menidia	12800	378	6078	15	1	2	287	654	318	15	0
Fundulus heteroclitus	1070	0	33	118	189	5329	0	8	0	6	1
Fundulus majalis	48	8	1	0	1	0	1	13	0	13	1
Alosa sapidissima	6	0	12	1	0	1	0	0	0	1	0
Apeltes quadracus	5	0	69	0	0	1	0	0	0	0	0
Mugil cephalus	3	0	0	0	0	2	0	0	0	0	0
Pomatomus saltatrix	0	0	11	0	0	0	1	1	0	0	0
Tautoga onitis	0	0	1	0	0	0	0	0	0	0	0
Caranx hippos	0	0	0	0	0	0	0	1	0	0	0
Pseudopleuronectes americanus	0	0	0	0	0	0	0	0	0	0	0
Alosa pseudoharengus	0	0	0	0	0	0	0	0	0	0	0

(continued)

APPENDIX TABLE 1. (cont)

	STATIONS											
	2S6	2S7	2S8	3S1	3S2	3S3	5S1	5S2	5S3	9S1	9S2	9S3
Menidia menidia	167	55	0	389	208	2	1954	52	65	855	316	718
Fundulus heteroclitus	0	2	34	137	46	47	4	43	160	6	2	6
Fundulus majalis	36	5	57	1	0	0	0	0	6	17	8	3
Alosa sapidissima	1	0	0	0	29	0	0	3	5	0	1	0
Apeltes quadracus	0	0	3	0	0	0	0	0	0	0	0	0
Mugil cephalus	0	0	0	0	0	0	23	0	0	1	0	0
Pomatomus saltatrix	6	0	0	0	0	0	0	0	0	0	0	0
Tautoga onitis	0	0	0	0	0	0	0	0	0	0	0	0
Caranx hippos	0	0	0	0	0	0	0	0	0	0	0	0
Pseudopleuronectes americanus	0	0	1	0	0	0	0	0	0	0	0	0
Alosa pseudo-harengus	0	0	0	0	0	0	0	1	0	0	0	0

APPENDIX TABLE 2. NUMBERS OF FISH CAUGHT IN MINNOW TRAPS, 28-30 JULY 1987, NEW BEDFORD WETLANDS STUDY. DAY TOTALS FOR STATION 2T4 ARE COMBINED TOTALS FOR NIGHT AND DAY.

	F. heteroclitus		F. majalis		M. menidia		A. sapidissima	
STATION	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY
1T1	7	105	0	0	0	0	0	0
1T2	6	26	0	0	0	0	0	0
1T3	0	71	0	0	0	0	0	0
1T4	46	108	0	0	0	0	0	0
1T5	23	94	0	0	3	0	0	0
1T6	29	93	0	0	1	0	0	0
1T7	20	90	0	0	0	0	0	0
1T8	38	60	5	2	0	0	0	0
1T9	29	87	0	1	0	0	0	0
2T1	30	19	0	9	0	0	0	0
2T2	94	11	7	1	0	0	0	0
2T3	36	7	3	0	1	0	0	0
2T4	N/A	21	N/A	0	N/A	0	N/A	0
2T5	32	57	52	11	0	1	0	0
2T6	45	86	0	0	0	0	0	0
2T7	31	92	0	0	0	0	0	0
2T8	7	21	0	3	0	0	0	0
2T9	26	0	0	5	1	0	0	0
3T1	29	54	0	0	0	1	0	0
3T2	19	58	0	0	0	0	0	0
3T3	7	45	0	0	2	0	0	0
3T4	59	40	0	0	1	0	0	0
3T5	19	97	0	0	0	0	0	0
3T6	22	58	0	0	0	0	0	0
4T1	71	46	0	0	0	0	0	0
4T2	89	44	0	0	0	0	0	0
4T3	83	87	0	0	0	0	1	0
5T1	2	63	0	0	2	0	0	0
5T2	7	44	0	0	0	0	0	0
5T3	2	52	0	0	0	0	0	0
5T4	17	61	0	0	1	0	0	0
9T1	0	54	0	2	0	0	0	0
9T2	58	18	2	1	0	0	0	0
9T3	101	26	23	0	1	0	0	0

APPENDIX TABLE 3. FREQUENCY DISTRIBUTION OF LENGTH AND WEIGHT DATA MENIDIA MENIDIAFOR COLLECTED IN BEACH SEINES, NEW BEDFORD WETLANDS STUDY, 29-30 JULY 1987.

APPENDIX TABLE 3. FREQUENCY DISTRIBUTION OF LENGTH AND WEIGHT DATA MENIDIA MENIDIAFOR COLLECTED IN BEACH SEINES, NEW BEDFORD WETLANDS STUDY, 29-30 JULY 1987.

TOTAL LENGTH (mm)	WETLAND 1	2	3	5	9
20-24	2	0	0	0	0
25-29	0	1	0	0	0
30-34	4	15	0	1	2
35-39	7	4	2	12	2
40-44	14	11	8	29	3
45-49	27	32	16	38	9
50-54	31	43	17	20	14
55-59	38	69	15	19	11
60-64	31	47	23	16	13
65-69	16	9	16	13	7
70-74	8	0	5	4	3
75-79	5	0	1	0	0
80-84	1	0	0	0	0
85-89	0	2	0	0	0
90-94	0	3	0	0	0
95-99	0	3	0	0	1
100-104	0	4	0	0	1
105-109	0	8	0	0	0
110-114	0	8	0	0	0
115-119	0	2	0	0	0
120-124	0	2	0	0	1
130-134	0	1	0	0	0

(continued)

APPENDIX TABLE 3. (Cont)

WET WEIGET (g)	WETLAND 1	2	3	5	9
<0.5	28	20	19	33	4
0.5-0.9	54	59	26	62	19
1.0-1.4	35	106	29	25	17
1.5-1.9	39	40	21	20	16
2.0-2.4	14	6	6	12	5
2.5-2.9	5	0	2	0	3
3.0-3.4	7	0	0	0	0
3.5-3.9	2	1	0	0	0
4.0-4.4	0	1	0	0	0
4.5-4.9	0	3	0	0	0
5.0-5.4	0	1	0	0	1
5.5-5.9	0	3	0	0	0
6.0-6.4	0	2	0	0	1
6.5-6.9	0	3	0	0	0
7.0-7.4	0	6	0	0	0
7.5-7.9	0	3	0	0	0
8.0-8.4	0	4	0	0	0
8.5-8.9	0	1	0	0	0
9.0-9.4	0	2	0	0	0
9.5-9.9	0	0	0	0	1
11.0-11.4	0	1	0	0	0
13.0-13.4	0	1	0	0	0
13.5-13.9	0	1	0	0	0

APPENDIX TABLE 4. FREQUENCY DISTRIBUTIONS OF LENGTH AND WEIGHT DATA FOR FUNDULUS HETEROCLITUS COLLECTED IN BEACH SEINES, NEW BEDFORD WETLANDS STUDY, 29-30 JULY 1987.

TOTAL LENGTH (mm)	WETLAND 1	2	3	5	9
20-24	1	0	2	0	0
25-29	15	0	2	0	0
30-34	76	28	3	9	0
35-39	93	12	39	9	3
40-44	43	1	45	8	1
45-49	16	0	15	3	2
50-54	2	0	0	0	0
55-59	5	2	6	1	0
60-64	16	4	12	5	0
65-69	13	2	10	17	5
70-74	14	0	2	24	1
75-79	5	0	4	14	0
80-84	4	0	2	5	1
85-89	3	1	1	1	0
90-94	1	0	1	0	0
95-99	2	0	0	0	1
100-104	1	0	0	0	0

WET WEIGHT (g)	WETLAND 1	2	3	5	9
<0.5	130	28	12	15	1
0.5-0.9	92	13	58	11	2
1.0-1.4	18	1	33	3	3
1.5-1.9	3	0	4	0	0
2.0-2.4	2	2	2	0	0
2.5-2.9	5	0	3	0	0
3.0-3.4	7	2	10	2	0
3.5-3.9	9	1	5	5	2
4.0-4.4	6	1	5	6	2
4.5-4.9	6	2	1	11	1
5.0-5.4	4	0	2	5	1
5.5-5.9	6	0	1	14	0

(continued)

APPENDIX TABLE 4. (Cont)

WET WEIGHT (g)	WETLAND 1	2	3	5	9
6.0-6.4	4	0	2	8	0
6.5-6.9	5	0	3	5	0
7.0-7.4	2	0	0	2	0
7.5-7.9	2	0	0	3	0
8.0-8.4	0	0	1	1	0
8.5-8.9	0	0	0	1	0
9.0-9.4	2	0	0	2	1
10.0-10.4	1	0	1	0	0
10.5-10.9	2	1	1	2	0
13.0-13.4	0	0	0	0	1
15.0-15.4	3	0	0	0	0
17.5-17.9	1	0	0	0	0

APPENDIX TABLE 5. FREQUENCY DISTRIBUTIONS OF LENGTH AND WEIGHT DATA FOR FUNDULUS MAJALIS COLLECTED IN BEACH SEINES, NEW BEDFORD WETLANDS STUDY, 29-30 JULY 1987.

TOTAL LENGTH (mm)	WETLAND 1	2	3	5	9
25-29	1	0	0	0	0
30-34	0	6	0	1	0
35-39	4	27	0	2	0
40-44	15	63	1	2	7
45-49	33	12	0	1	11
50-54	3	1	0	0	5
55-59	2	0	0	0	4
60-64	0	0	0	0	1
90-94	0	1	0	0	0
95-99	0	1	0	0	0
110-114	0	1	0	0	0
130-134	0	1	0	0	0

WET WEIGHT (g)	WETLAND 1	2	3	5	9
<0.5	2	5	0	1	0
0.5-0.9	16	60	1	3	3
1.0-1.4	32	42	0	2	14
1.5-1.9	8	2	0	0	5
2.0-2.4	0	0	0	0	4
2.5-2.9	0	0	0	0	2
10.0-10.4	0	1	0	0	0
13.5-13.9	0	1	0	0	0
20.5-20.9	0	1	0	0	0
33.0-33.4	0	1	0	0	0

APPENDIX TABLE 6. FREQUENCY DISTRIBUTIONS OF LENGTH AND WEIGHT DATA FOR ALOSA SAPIDISSIMA COLLECTED IN BEACH SEINES, NEW BEDFORD WETLANDS STUDY, 29-30 JULY 1987.

TOTAL LENGTH (mm)	WETLAND 1	2	3	5	9
33	1	0	0	0	0
34	0	0	0	0	0
35	1	0	1	1	0
36	1	0	0	1	0
37	1	1	2	0	0
38	1	0	1	0	0
39	1	0	3	0	0
40	4	0	1	0	1
41	1	1	1	1	0
42	1	0	4	2	0
43	0	0	2	1	0
44	1	0	2	0	0
45	2	0	4	0	0
46	0	0	0	0	0
47	2	0	1	0	0
48	1	0	2	0	0
49	0	0	2	0	0
50	1	0	1	1	0
51	0	0	1	0	0
52	0	0	1	0	0
57	1	0	0	0	0

WET WEIGHT (g)	WETLAND 1	2	3	5	9
0.2	1	0	0	0	0
0.3	2	0	0	0	0
0.4	1	0	4	1	0
0.5	6	0	4	1	0
0.6	2	1	3	0	1
0.7	0	0	6	2	0
0.8	2	0	4	2	0
0.9	4	0	2	0	0
1.0	1	1	2	0	0
1.1	0	0	3	0	0
1.2	0	0	0	0	0
1.3	0	0	1	2	0
2.5	1	0	0	0	0

APPENDIX 4G. FREQUENCY DISTRIBUTIONS OF LENGTH AND WEIGHT DATA FOR APELTES QUADRACUS COLLECTED IN BEACH SEINES, NEW BEDFORD WETLANDS STUDY, 29-30 JULY 1987. NONE WERE CAUGHT AT WETLANDS 3, 5, OR 9.

TOTAL LENGTH (mm)	WETLAND 1	WETLAND 2
27	1	0
28	1	0
29	1	0
30	4	1
31	2	0
32	3	2
33	6	0
34	6	0
35	18	0
36	6	0
37	10	0
38	1	0
39	1	0

WET WEIGHT (g)	WETLAND 1	WETLAND 2
0.1	5	3
0.2	16	0
0.3	39	0

APPENDIX 4H. FREQUENCY DISTRIBUTIONS OF LENGTH AND WEIGHT DATA FOR MUGIL CEPHALUS COLLECTED IN BEACH SEINES, NEW BEDFORD WETLANDS STUDY, 29-30 JULY 1987. NONE WERE CAUGHT AT WETLANDS 2 OR 3.

TOTAL LENGTH (mm)	WETLAND 1	5	9
45-49	1	0	0
50-54	2	0	1
55-59	0	0	0
60-64	1	0	0
65-69	0	1	0
70-74	0	10	0
75-79	0	7	0
80-89	0	3	0
85-89	0	2	0
110-114	1	0	0

WET WEIGHT (g)	WETLAND 1	2	9
1.0-1.4	1	0	0
1.5-1.9	2	0	1
2.0-2.4	0	0	0
2.5-2.9	1	0	0
3.0-3.4	0	0	0
3.5-3.9	0	0	0
4.0-4.4	0	3	0
4.5-4.9	0	3	0
5.0-5.4	0	4	0
5.5-5.9	0	3	0
6.0-6.4	0	3	0
6.5-6.9	0	2	0
7.0-7.4	0	3	0
7.5-7.9	0	0	0
8.0-8.4	0	1	0
8.5-8.9	0	1	0
17.5-17.9	1	0	0

APPENDIX 4I. FREQUENCY DISTRIBUTIONS OF LENGTH AND WEIGHT DATA FOR POMATOMUS SALTATRIX COLLECTED IN BEACH SEINES, NEW BEDFORD WETLANDS STUDY, 29-30 JULY 1987. NONE WERE CAUGHT AT WETLANDS 3, 5, OR 9.

TOTAL LENGTH (mm)	WETLAND 1	WETLAND 2
105-109	1	0
110-114	0	1
115-119	1	0
120-124	5	0
125-129	3	5
130-134	1	0
135-139	0	2

WET WEIGHT (g)	WETLAND 1	WETLAND 2
12.0-12.4	1	0
12.5-12.9	0	0
13.0-13.4	1	0
13.5-13.9	1	1
14.0-14.4	0	0
14.5-14.9	1	0
15.0-15.4	2	0
15.5-15.9	1	1
16.0-16.4	1	2
16.5-16.9	0	1
17.0-17.4	0	0
17.5-17.9	0	1
18.0-18.4	1	0
18.5-18.9	1	1
19.0-19.4	1	0
21.0-21.4	0	1

APPENDIX 4J. FREQUENCY DISTRIBUTIONS OF LENGTH AND WEIGHT DATA FOR FUNDULUS HETEROCLITUS COLLECTED IN MINNOW TRAPS, NEW BEDFORD WETLANDS STUDY, 28-30 JULY 1987.

TOTAL LENGTH (mm)	WETLAND 1	2	3	4	5	9
30-39	26	29	15	1	3	4
40-49	54	46	34	7	12	13
50-59	39	32	8	42	5	6
60-69	92	60	33	29	42	18
70-79	93	76	79	18	40	38
80-89	30	29	51	7	8	9
90-99	14	9	19	4	4	3
100-109	1	7	7	5	3	2
110-119	0	0	3	0	0	0

WET WEIGHT (g)	WETLAND 1	2	3	4	5	9
<2.0	84	77	50	11	14	17
2.0-3.9	61	50	9	64	9	17
4.0-5.9	94	53	47	13	46	23
6.0-7.9	56	51	60	12	27	21
8.0-9.9	27	25	37	2	12	8
10.0-11.9	9	10	18	2	2	2
12.0-13.9	7	9	13	2	1	3
14.0-15.9	5	5	2	3	1	1
16.0-17.9	4	1	3	3	1	0
18.0-19.9	1	2	3	1	1	0
20.0-21.9	1	3	4	0	0	1
22.0-23.9	0	2	2	0	2	0
24.0-25.9	0	0	0	0	0	0
26.0-27.9	0	0	1	0	0	0

APPENDIX 4K. FREQUENCY DISTRIBUTIONS OF LENGTH AND WEIGHT DATA FOR FUNDULUS MAJALIS COLLECTED IN MINNOW TRAPS, NEW BEDFORD WETLANDS STUDY, 28-30 JULY 1987. NONE WERE CAUGHT AT WETLANDS 3, 4 OR 5.

TOTAL LENGTH (mm)	WETLAND 1	2	9
35-39	0	15	2
40-44	2	40	8
45-49	3	4	10
50-54	2	0	7
55-59	1	0	1

WET WEIGHT (g)	WETLAND 1	2	9
0.5	0	2	0
0.6	0	16	0
0.7	1	12	1
0.8	1	5	1
0.9	0	11	1
1.0	0	9	4
1.1	0	3	2
1.2	0	1	5
1.3	1	0	1
1.4	0	0	2
1.5	1	0	1
1.6	2	0	3
1.7	1	0	0
1.8	0	0	3
1.9	1	0	0
2.0	0	0	1
2.1	0	0	1
2.2	0	0	0
2.3	0	0	2

APPENDIX 4L. FREQUENCY DISTRIBUTIONS OF LENGTH AND WEIGHT DATA FOR MENIDIA MENIDIA COLLECTED IN MINNOW TRAPS, NEW BEDFORD WETLANDS STUDY, 28-30 JULY 1987.

TOTAL LENGTH (mm)	WETLAND 1	2	3	4	5	9
50-54	0	1	0	0	1	0
55-59	2	1	1	0	1	0
60-64	1	1	0	0	1	0
65-69	1	0	1	0	0	0
70-74	0	0	1	0	0	0

WET WEIGHT (g)	WETLAND 1	2	3	4	5	9
0.9	0	0	0	0	1	0
1.0	0	0	0	0	0	0
1.1	0	0	0	0	0	0
1.2	2	0	0	0	0	0
1.3	0	1	0	0	1	0
1.4	0	1	1	0	1	0
1.5	0	0	0	0	0	0
1.6	1	0	0	0	0	0
1.7	0	0	0	0	0	0
1.8	0	0	0	0	0	0
1.9	1	0	0	0	0	0
2.0	0	1	0	0	0	0
2.1	0	0	0	0	0	0
2.2	0	0	1	0	0	0
2.3	0	0	1	0	0	0

5.1 BENTHIC DATA

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

JUNE

	STATION											
	1T1		1T2		1T3		1M4		1M5		1M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ACHELIA SPINOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AMPHIPODA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AMPITHOIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANTHOZOA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ARABELLA TRICOLOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASABELLIDES OCULATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BIVALVIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOWERBANKIA GRACILIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BRACHYURA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BUCCINUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAMPANULARIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPITELLA SP.	4890.9	4287.8	452.1	466.8	41.1	71.2	0.0	0.0	1808.4	1165.4	4438.8	2746.0
CAPRELLA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPRELLIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAULLERIELLA SP. B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CERASTODERMA PINNULATUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CIRRATULIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COROPHIUM INSIDIOSUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COROPHIUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRANGON SEPTEMSPINOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CREPIDULA FORNICATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CREPIDULA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DYNAMENA PUMILA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EDOTEA TRILOBA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2
ELASMOPUS LEVIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELECTRA PILOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETEONE HETEROPODA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETEONE SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	41.1	71.2
EUDENDRIUM DISPAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUDENDRIUM RUGOSUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUDENDRIUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUMIDA SANGUINEA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FABRICIA SABELLA	0.0	0.0	0.0	0.0	164.4	71.2	575.4	792.7	10563	9030.7	493.2	123.3
GAMMARUS MUCRONATUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAMMARUS PALUSTRIS	0.0	0.0	0.0	0.0	0.0	0.0	575.4	466.8	0.0	0.0	41.1	71.2
GAMMARUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	287.7	498.3	41.1	71.2	82.2	142.4
GASTROPODA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GEMMA GEMMA	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4	0.0	0.0	0.0	0.0
GEUKENSIA DEMISSA	0.0	0.0	0.0	0.0	0.0	0.0	123.3	213.6	41.1	71.2	41.1	71.2
HETEROMASTUS FILIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HIATELLA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

JUNE

	STATION											
	1T1		1T2		1T3		1M4		1M5		1M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
HIPPOTHOA HYALINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYALE PLUMOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROBIA TOTTENI	123.3	213.6	164.4	142.4	82.2	71.2	863.1	1067.8	82.2	142.4	452.1	582.7
HYPANIOLA FLORIDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ILYANASSA OBSOLETUS	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4	41.1	71.2	164.4	142.4
JAERA MARINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LACUNA VINCTA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LITTORINA LITTOREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MACOMA BALTHICA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MARINOGAMMARUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MEDIOMASTUS AMBISETA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELAMPUS BIDENTATUS	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
MELITA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELITIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICRODEUTOPUS ANOMALUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICRODEUTOPUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICROPHTHALMUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICROPROTOPUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYA ARENARIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	164.4	188.3	0.0	0.0
MYTILIDAE	0.0	0.0	0.0	0.0	0.0	0.0	123.3	213.6	0.0	0.0	41.1	71.2
NEOMYSIS AMERICANA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS PELAGICA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS SUCCINEA	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4	0.0	0.0	0.0	0.0
NUCULA PROXIMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OBELIA DICHOTOMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OLIGOCHAETA	13974	8571.2	39415	34002	15084	21786	39415	21523	23180	18417	140726	73285
ORCHESTIA GRILLUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PETRICOLA PHOLADIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHYLLODOCE MACULATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHYLLODOCE MUCOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHYLLODOCIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PODARKE OBSCURA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLYDORA CAULLERYI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLYDORA LIGNI	82.2	71.2	0.0	0.0	0.0	0.0	123.3	213.6	0.0	0.0	82.2	71.2
POLYDORA WEBSTERI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PYGOSPIO ELEGANS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PYROSOMA ATLANTICUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PYROSOMIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RHYNCHOCOELA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCOLECOLEPIDES SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

JUNE

	STATION											
	1T1		1T2		1T3		1M4		1M5		1M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
SCOLECOLEPIDES VIRIDIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCOLOPLOS FRAGILIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCOLOPLOS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEMIBALANUS BALANOIDES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERTULARELLA RUGOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERTULARIA CUPRESSINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERTULARIA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SMITTINIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
STREBLOSPIO BENEDICTI	0.0	0.0	123.5	213.6	411.0	608.2	0.0	0.0	123.3	123.3	6534.9	5118.1
SYLLIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYLLIS (TYPOSYLLIS) SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TANAIDACEA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TELLINA AGILIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TONICELLA RUBRA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
TURBELLARIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURTONIA MINUTA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UCA PUGNAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UCA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XANTHIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

JUNE

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ACHELIA SPINOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AMPHIPODA	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
AMPITHOIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANTHOZOA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ARABELLA IRICOLOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASABELLIDES OCULATA	0.0	0.0	0.0	0.0	328.8	71.2	0.0	0.0	0.0	0.0	0.0	0.0
BIVALVIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
BOWERBANKIA GRACILIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BRACHYURA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BUCCINUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAMPANULARIDAE	P	P	0.0	0.0	P	P	P	P	0.0	0.0	P	P
CAPITELLA SP.	2671.5	1762.5	369.9	123.3	1685.1	1655.8	205.5	71.2	452.1	582.7	287.7	256.7
CAPRELLA SP.	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPRELLIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAULLERIELLA SP. B	41.1	71.2	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
CERASTODERMA PINNULATUM	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
CIRRATULIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COROPHIUM INSIDIOSUM	41.1	71.2	0.0	0.0	0.0	0.0	534.3	433.0	246.6	427.1	82.2	142.4
COROPHIUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRANGON SEPTEMSPINOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CREPIDULA FORNICATA	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CREPIDULA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DYNAMENA PUMILA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EDOTEA TRILOBA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELASMOPUS LEVIS	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
ELECTRA PILOSA	0.0	0.0	0.0	0.0	P	P	P	P	0.0	0.0	0.0	0.0
ETEONE HETEROPODA	41.1	71.2	82.2	142.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETEONE SP.	123.3	213.6	82.2	71.2	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
EUDENDRIUM DISPAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUDENDRIUM RUGOSUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUDENDRIUM SP.	P	P	0.0	0.0	P	P	0.0	0.0	0.0	0.0	P	P
EUMIDA SANGUINEA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FABRICIA SABELLA	0.0	0.0	246.6	0.0	205.5	142.4	1019E3	469078	219762	197447	328.8	188.3
GAMMARUS MUCRONATUS	534.3	498.3	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
GAMMARUS PALUSTRIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAMMARUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
GASTROPODA	123.3	123.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GEMMA GEMMA	41.1	71.2	41.1	71.2	0.0	0.0	0.0	0.0	246.6	427.1	0.0	0.0
GEUKENSIA DEMISSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HETEROMASTUS FILIFORMIS	0.0	0.0	123.3	213.6	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
HIATELLA SP.	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.008M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

JUNE

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
HIPPOTHOA HYALINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYALE PLUMOSA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	41.1	71.2
HYDROBIA TOTTENI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYPANIOLA FLORIDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ILYANASSA OBSOLETUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JAERA MARINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LACUNA VINCTA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LITTORINA LITTOREA	123.3	213.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MACOMA BALTHICA	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
MARINOGAMMARUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MEDIOMASTUS AMBISETA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELAMPUS BIDENTATUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELITA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELITIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICRODEUTOPUS ANOMALUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICRODEUTOPUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICROPHTHALMUS SP.	123.3	213.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICROPROTOPUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYA ARENARIA	2507.1	2359.9	41.1	71.2	0.0	0.0	2096.1	1712.9	0.0	0.0	0.0	0.0
MYTILIDAE	123.3	213.6	616.5	1067.8	411.0	498.3	739.8	1176.2	4767.6	4022.6	0.0	0.0
NEOMYSIS AMERICANA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS PELAGICA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
NEREIS SP.	123.3	123.3	0.0	0.0	41.1	71.2	82.2	71.2	123.3	123.3	0.0	0.0
NEREIS SUCCINEA	534.3	310.3	0.0	0.0	41.1	71.2	1068.6	142.4	369.9	326.2	0.0	0.0
NUCULA PROXIMA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
OBELIA DICHOTOMA	0.0	0.0	0.0	0.0	P	P	0.0	0.0	0.0	0.0	0.0	0.0
OLIGOCHAETA	5548.5	4625.0	1767.3	1887.5	43360	22254	9206.4	11361	35880	9849.3	15043	9314.7
ORCHESTIA GRILLUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PETRICOLA PHOLADIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
PHYLLODOCE MACULATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
PHYLLODOCE MUCOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHYLLODOCIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PODARKE OBSCURA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLYDORA CAULLERYI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
POLYDORA LIGNI	3863.4	3122.5	1931.7	582.7	1027.5	874.8	18783	11599	9576.3	7092.0	123.3	123.3
POLYDORA WEBSTERI	0.0	0.0	0.0	0.0	0.0	0.0	369.9	644.6	493.2	565.0	0.0	0.0
PYGOSPIO ELEGANS	123.3	123.3	0.0	0.0	452.1	376.7	0.0	0.0	164.4	284.7	82.2	71.2
PYROSOMA ATLANTICUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PYROSOMIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	P	P
RHYNCHOCOELA	41.1	71.2	0.0	0.0	0.0	0.0	41.1	71.2	41.1	71.2	0.0	0.0
SCOLECOLEPIDES SP.	287.7	188.3	0.0	0.0	82.2	142.4	0.0	0.0	41.1	71.2	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

JUNE

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
SCOLECOLEPIDES VIRIDIS	534.3	376.7	0.0	0.0	82.2	142.4	0.0	0.0	0.0	0.0	0.0	0.0
SCOLOPLOS FRAGILIS	205.5	142.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCOLOPLOS SP.	369.9	123.3	41.1	71.2	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
SEMIBALANUS BALANOIDES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERTULARELLA RUGOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERTULARIA CUPRESSINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERTULARIA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SMITTINIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
STREBLOSPIO BENEDICTI	82.2	71.2	2219.4	2250.0	863.1	495.2	41.1	71.2	0.0	0.0	0.0	0.0
SYLLIDAE	164.4	142.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYLLIS (TYPOSYLLIS) SP.	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TANAIDACEA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TELLINA AGILIS	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
TONICELLA RUBRA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURBELLARIA	0.0	0.0	0.0	0.0	246.6	246.6	0.0	0.0	0.0	0.0	0.0	0.0
TURTONIA MINUTA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UCA PUGNAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UCA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XANTHIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

SEPTEMBER

	STATION											
	1T1		1T2		1T3		1M4		1M5		1M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ACHELIA SPINOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AMPHIPODA	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
AMPITHOIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANTHOZOA	0.0	0.0	0.0	0.0	0.0	0.0	246.6	213.6	0.0	0.0	0.0	0.0
ARABELLA IRICOLOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASABELLIDES OCULATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BIVALVIA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
BOWERBANKIA GRACILIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BRACHYURA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BUCCINUM SP.	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
CAMPANULARIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPITELLA SP.	1520.7	1048.7	287.7	310.3	41.1	71.2	4315.5	3638.9	82.2	71.2	1315.2	1216.4
CAPRELLA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPRELLIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAULLERIELLA SP. B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CERASTODERMA PINNULATUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CIRRATULIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
COROPHIUM INSIDIOSUM	0.0	0.0	0.0	0.0	41.1	71.2	205.5	256.7	82.2	71.2	82.2	142.4
COROPHIUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRANGON SEPTEMSPINOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CREPIDULA FORNICATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CREPIDULA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DYNAMENA PUMILA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EDOTEA TRILOBA	82.2	142.4	0.0	0.0	41.1	71.2	41.1	71.2	0.0	0.0	0.0	0.0
ELASMOPUS LEVIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELECTRA PILOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETEONE HETEROPODA	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETEONE SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUDENDRIUM DISPAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUDENDRIUM RUGOSUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUDENDRIUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUMIDA SANGUINEA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FABRICIA SABELLA	0.0	0.0	123.3	0.0	0.0	0.0	89475	73734	41.1	71.2	35962	39799
GAMMARUS MUCRONATUS	0.0	0.0	41.1	71.2	82.2	142.4	41.1	71.2	0.0	0.0	0.0	0.0
GAMMARUS PALUSTRIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAMMARUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GASTROPODA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GEMMA GEMMA	123.3	123.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2
GEUKENSIA DEMISSA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	328.8	355.9	0.0	0.0
HETEROMASTUS FILIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HIATELLA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

SEPTEMBER

	STATION											
	1T1		1T2		1T3		1T4		1T5		1T6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
HIPPOTHOA HYALINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYALE PLUMOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROBIA TOTTENI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4
HYPANIOLA FLORIDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ILYANASSA OBSOLETUS	0.0	0.0	452.1	376.7	164.4	284.7	0.0	0.0	0.0	0.0	0.0	0.0
JAERA MARINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LACUNA VINCTA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LITTORINA LITTOREA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	41.1	71.2	41.1	71.2
MACOMA BALTHICA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MARINOGAMMARUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4	0.0	0.0
MEDIOMASTUS AMBISETA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELAMPUS BIDENTATUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELITA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELITIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICRODEUTOPUS ANOMALUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICRODEUTOPUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	328.8	569.5
MICROPHTHALMUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICROPROTOPUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYA ARENARIA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	41.1	71.2
MYTILIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
NEOMYSIS AMERICANA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS PELAGICA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS SP.	41.1	71.2	0.0	0.0	0.0	0.0	41.1	71.2	41.1	71.2	0.0	0.0
NEREIS SUCCINEA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NUCULA PROXIMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OBELIA DICHOTOMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OLIGOCHAETA	4233.3	3576.4	97037	104787	155276	101313	24454	5057.3	14097	5067.8	52320	42843
ORCHESTIA GRILLUS	0.0	0.0	0.0	0.0	246.6	427.1	0.0	0.0	657.6	498.3	0.0	0.0
PETRICOLA PHOLADIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHYLLODOCE MACULATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHYLLODOCE MUCOSA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
PHYLLODOCIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PODARKE OBSCURA	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLYDORA CAULLERYI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLYDORA LIGNI	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	41.1	71.2	41.1	71.2
POLYDORA WEBSTERI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PYGOSPIO ELEGANS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PYROSOMA ATLANTICUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PYROSOMIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RHYNCHOCOELA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
SCOLECOLEPIDES SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

SEPTEMBER

	STATION											
	1T1		1T2		1T3		1M4		1M5		1M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
SCOLECOLEPIDES VIRIDIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCOLOPLOS FRAGILIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCOLOPLOS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEMIBALANUS BALANOIDES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERTULARELLA RUGOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERTULARIA CUPRESSINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SERTULARIA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SMITTINIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
STREBLOSPIO BENEDICTI	1726.2	1009.3	1931.7	1034.1	1191.9	256.7	164.4	188.3	780.9	1145.7	4315.5	5545.8
SYLLIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYLLIS (TYPOSYLLIS) SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TANAIDACEA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TELLINA AGILIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TONICELLA RUBRA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURBELLARIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURTONIA MINUTA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UCA PUGNAX	41.1	71.2	0.0	0.0	0.0	0.0	82.2	71.2	41.1	71.2	0.0	0.0
UCA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4	0.0	0.0
XANTHIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

SEPTEMBER

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ACHELIA SPINOSA	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AMPHIPODA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
AMPITHOIDAE	0.0	0.0	0.0	0.0	0.0	0.0	205.5	355.9	0.0	0.0	0.0	0.0
ANTHOZOA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
ARABELLA IRICOLOR	0.0	0.0	0.0	0.0	0.0	0.0	123.3	213.6	0.0	0.0	0.0	0.0
ASABELLIDES OCULATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BIVALVIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOWERBANKIA GRACILIS	0.0	0.0	0.0	0.0	0.0	0.0	P	P	P	P	0.0	0.0
BRACHYURA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
BUCCINUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAMPANULARIDAE	P	P	P	P	P	P	P	P	0.0	0.0	0.0	0.0
CAPITELLA SP.	411.0	711.9	739.8	444.6	17098	10002	328.8	466.8	123.3	0.0	2959.2	1176.2
CAPRELLA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPRELLIDAE	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
CAULLERIELLA SP. B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CERASTODERMA PINNULATUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CIRRATULIDAE	123.3	123.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COROPHIUM INSIDIOSUM	41.1	71.2	0.0	0.0	0.0	0.0	39867	25522	43689	37340	0.0	0.0
COROPHIUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	411.0	188.3	205.5	188.3	0.0	0.0
CRANGON SEPTEMSPINOSA	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4	0.0	0.0	0.0	0.0
CREPIDULA FORNICATA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CREPIDULA SP.	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DYNAMENA PUMILA	P	P	P	P	P	P	0.0	0.0	P	P	P	P
EDOTEA TRILOBA	82.2	71.2	41.1	71.2	205.5	188.3	2055.0	3041.1	0.0	0.0	0.0	0.0
ELASMOPUS LEVIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELECTRA PILOSA	0.0	0.0	0.0	0.0	0.0	0.0	P	P	0.0	0.0	0.0	0.0
ETEONE HETEROPODA	41.1	71.2	205.5	355.9	123.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETEONE SP.	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
EUDENDRIUM DISPAR	0.0	0.0	P	P	P	P	0.0	0.0	P	P	0.0	0.0
EUDENDRIUM RUGOSUM	0.0	0.0	0.0	0.0	P	P	0.0	0.0	0.0	0.0	0.0	0.0
EUDENDRIUM SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	P	P
EUMIDA SANGUINEA	0.0	0.0	0.0	0.0	0.0	0.0	123.3	123.3	246.6	246.6	0.0	0.0
FABRICIA SABELLA	41.1	71.2	0.0	0.0	0.0	0.0	188197	78124	266081	104848	123.3	213.6
GAMMARUS MUCRONATUS	0.0	0.0	0.0	0.0	0.0	0.0	287.7	284.7	0.0	0.0	0.0	0.0
GAMMARUS PALUSTRIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAMMARUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GASTROPODA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GEMMA GEMMA	2260.5	933.6	123.3	213.6	41.1	71.2	82.2	142.4	41.1	71.2	0.0	0.0
GEUKENSIA DEMISSA	0.0	0.0	164.4	142.4	0.0	0.0	164.4	284.7	0.0	0.0	0.0	0.0
HETEROMASTUS FILIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HIATELLA SP.	0.0	0.0	0.0	0.0	0.0	0.0	123.3	213.6	0.0	0.0	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

SEPTEMBER

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
HIPPOTHOA HYALINA	0.0	0.0	0.0	0.0	0.0	0.0	P	P	0.0	0.0	0.0	0.0
HYALE PLUMOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROBIA TOTTENI	205.5	142.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYPANIOLA FLORIDA	0.0	0.0	0.0	0.0	1027.5	310.3	0.0	0.0	0.0	0.0	0.0	0.0
ILYANASSA OBSOLETUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JAERA MARINA	0.0	0.0	0.0	0.0	205.5	355.9	0.0	0.0	0.0	0.0	0.0	0.0
LACUNA VINCTA	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
LITTORINA LITTOREA	0.0	0.0	0.0	0.0	0.0	0.0	123.3	123.3	0.0	0.0	0.0	0.0
MACOMA BALTHICA	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
MARINOGAMMARUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MEDIOMASTUS AMBISETA	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0
MELAMPUS BIDENTATUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELITA SP.	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	41.1	71.2	0.0	0.0
MELITIDAE	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICRODEUTOPUS ANOMALUS	0.0	0.0	0.0	0.0	0.0	0.0	205.5	355.9	0.0	0.0	0.0	0.0
MICRODEUTOPUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICROPHTHALMUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MICROPROTOPUS SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
MYA ARENARIA	287.7	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYTILIDAE	0.0	0.0	0.0	0.0	1561.8	2705.1	82.2	142.4	0.0	0.0	0.0	0.0
NEOMYSIS AMERICANA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0
NEREIS PELAGICA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS SP.	82.2	142.4	0.0	0.0	0.0	0.0	287.7	142.4	205.5	355.9	0.0	0.0
NEREIS SUCCINEA	82.2	71.2	534.3	310.3	82.2	142.4	575.4	310.3	493.2	444.6	0.0	0.0
NUCULA PROXIMA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OBELIA DICHOTOMA	0.0	0.0	P	P	P	P	P	P	P	P	P	P
OLIGOCHAETA	1109.7	978.7	14796	3082.5	25235	5114.1	15454	9020.6	27455	9366.2	11097	10020
ORCHESTIA GRILLUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PETRICOLA PHOLADIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	328.8	466.8	0.0	0.0	0.0	0.0
PHYLLODOCE MACULATA	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
PHYLLODOCE MUCOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHYLLODOCIDAE	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4	0.0	0.0	0.0	0.0
PODARKE OBSCURA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLYDORA CAULLERYI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLYDORA LIGNI	0.0	0.0	82.2	71.2	534.3	433.0	945.3	802.2	2794.8	2079.1	164.4	284.7
POLYDORA WEBSTERI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PYGOSPIO ELEGANS	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	411.0	711.9
PYROSOMA ATLANTICUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	P	P
PYROSOMIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RHYNCHOCOELA	2096.1	3419.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4
SCOLECOLEPIDES SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(CONTINUED)

APPENDIX TABLE 1. ABUNDANCE (NO./M2; MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLAND STUDY, 1987.

SEPTEMBER

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
SCOLECOLEPIDES VIRIDIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCOLOPLOS FRAGILIS	1315.2	513.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCOLOPLOS SP.	575.4	256.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEMIBALANUS BALANOIDES	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0
SERTULARELLA RUGOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	P	P	0.0	0.0
SERTULARIA CUPRESSINA	0.0	0.0	0.0	0.0	P	P	0.0	0.0	0.0	0.0	P	P
SERTULARIA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SMITTINIDAE	0.0	0.0	0.0	0.0	0.0	0.0	P	P	0.0	0.0	0.0	0.0
STREBLOSPIO BENEDICTI	0.0	0.0	3493.5	1997.1	575.4	679.1	246.6	427.1	0.0	0.0	0.0	0.0
SYLLIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYLLIS (TYPOSYLLIS) SP.	0.0	0.0	0.0	0.0	0.0	0.0	1191.9	556.0	1356.3	978.7	0.0	0.0
TANAIDACEA	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TELLINA AGILIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TONICELLA RUBRA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TURBELLARIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.2	142.4	0.0	0.0
TURTONIA MINUTA	0.0	0.0	0.0	0.0	1438.5	2491.6	0.0	0.0	41.1	71.2	0.0	0.0
UCA PUGNAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.2	71.2
UCA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XANTHIDAE	0.0	0.0	0.0	0.0	0.0	0.0	41.1	71.2	0.0	0.0	0.0	0.0

APPENDIX TABLE 2 - BIOMASS(GM/CORE;MEAN AND STANDARD DEVIATION OF REPLICATES) OF BENTHIC INFAUNA COLLECTED IN 0.0081M2 CORES, NEW BEDFORD WETLANDS STUDY.

JUNE

	STATION											
	1T1		1T2		1T3		1M4		1M5		1M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ARTHROPODA	.	.	.	.	.	.	0.04	0.04	0.00	.	0.00	0.00
MOLLUSCA	0.00	.	0.01	0.01	0.00	0.00	0.29	0.43	1.65	2.46	3.06	2.40
OTHER	.	.	.	.	.	.	.	.	.	.	.	.
POLYCHAETA	0.02	0.03	0.03	0.04	0.01	0.01	0.04	0.04	0.01	0.02	0.39	0.19

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ARTHROPODA	0.00	0.00	.	.	0.00	.	0.02	0.03	0.00	0.00	0.00	0.00
MOLLUSCA	0.49	0.85	0.02	0.03	0.17	0.21	0.13	0.21	0.31	0.32	0.00	.
OTHER	0.00	0.00	.	.	0.00	0.00	0.00	0.00	.	.	0.01	0.01
POLYCHAETA	0.02	0.01	0.00	0.00	0.04	0.04	0.71	0.38	0.25	0.19	0.00	0.00

SEPTEMBER

	STATION											
	1T1		1T2		1T3		1M4		1M5		1M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ARTHROPODA	0.64	0.87	0.00	.	0.00	.	0.50	0.59	0.41	0.70	0.00	.
MOLLUSCA	0.03	0.04	3.44	2.76	3.61	.	0.04	0.04	0.05	0.09	0.03	0.04
OTHER	.	.	.	.	.	.	0.00	0.00	.	.	.	.
POLYCHAETA	0.02	0.02	0.21	0.25	0.34	0.28	0.02	0.02	0.01	0.01	0.09	0.09

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ARTHROPODA	0.01	0.01	0.00	.	0.01	0.02	0.07	0.12	0.06	0.04	0.94	0.62
MOLLUSCA	3.70	6.32	53.05	7.95	0.04	0.06	5.09	5.85	0.00	.	.	.
OTHER	0.01	0.02	0.44	0.35	0.03	0.01	0.01	0.01	0.07	0.07	0.11	0.13
POLYCHAETA	0.02	0.02	0.03	0.03	0.06	0.08	0.24	0.13	0.33	0.23	0.00	0.00

APPENDIX TABLE 3 - ABUNDANCE (NO./M2;MEAN AND STANDARD DEVIATION OF REPLICATES)
OF BENTHOS COLLECTED IN 0.25M2 QUADRATS, NEW BEDFORD WETLANDS STUDY.

JUNE

	STATION											
	1T1		1T2		1T3		1M4		1M5		1M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ANTHOZOA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BITTIUM ALTERNATUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPITELLA SP.	1.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CARCINUS MAENAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAMMARUS PALUSTRIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	4.6
GEUKENSIA DEMISSA	1.3	2.3	1.3	2.3	0.0	0.0	13.3	8.3	73.3	40.3	398.7	98.8
HYALE PLUMOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ILYANASSA OBSOLETUS	6.7	8.3	5.3	6.1	1.3	2.3	22.7	39.3	66.7	36.1	256.0	439.9
LIMULUS POLYPHEMUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LITTORINA LITTOREA	0.0	0.0	0.0	0.0	0.0	0.0	8.0	8.0	4.0	6.9	0.0	0.0
MACOMA BALTHICA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELAMPUS BIDENTATUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.3
MERCENARIA MERCENARIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYA ARENARIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	6.9	0.0	0.0
MYTILUS EDULIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEOPANOPE SAYI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS SUCCINEA	2.7	4.6	0.0	0.0	0.0	0.0	1.3	2.3	2.7	4.6	0.0	0.0
PALAEMONETES PUGIO	0.0	0.0	1.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PETRICOLA PHOLADIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RHITHROPANOPEUS HARRISII	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEMIBALANUS BALANOIDES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SESARMA RETICULATUM	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	1.3	2.3	0.0	0.0
UCA PUGNAX	0.0	0.0	0.0	0.0	0.0	0.0	41.3	8.3	25.3	16.7	0.0	0.0

APPENDIX TABLE 3 - ABUNDANCE (NO./M2;MEAN AND STANDARD DEVIATION OF REPLICATES)
OF BENTHOS COLLECTED IN 0.25M2 QUADRATS, NEW BEDFORD WETLANDS STUDY.

JUNE

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ANTHOZOA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BITTIUM ALTERNATUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPITELLA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CARCINUS MAENAS	1.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAMMARUS PALUSTRIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GEUKENSIA DEMISSA	2.7	2.3	1.3	2.3	0.0	0.0	101.3	104.1	0.0	0.0	9.3	6.1
HYALE PLUMOSA	0.0	0.0	0.0	0.0	0.0	0.0	64.0	73.3	0.0	0.0	0.0	0.0
ILYANASSA OBSOLETUS	0.0	0.0	21.3	37.0	0.0	0.0	8.0	8.0	2.7	4.6	0.0	0.0
LIMULUS POLYPHEMUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LITTORINA LITTOREA	14.7	11.5	0.0	0.0	0.0	0.0	76.0	60.4	42.7	25.7	0.0	0.0
MACOMA BALTHICA	0.0	0.0	0.0	0.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
MELAMPUS BIDENTATUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MERCENARIA MERCENARIA	12.0	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYA AREMARIA	22.7	29.5	0.0	0.0	0.0	0.0	2.7	4.6	0.0	0.0	0.0	0.0
MYTILUS EDULIS	0.0	0.0	0.0	0.0	0.0	0.0	2.7	4.6	0.0	0.0	0.0	0.0
NEOPANOPE SAYI	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	1.3	2.3	0.0	0.0
NEREIS SUCCINEA	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.3	0.0	0.0	0.0	0.0
PALAEMONETES PUGIO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PETRICOLA PHOLADIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	2.7	4.6	0.0	0.0
RHITHROPANOPEUS HARRISII	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEMIBALANUS BALANOIDES	0.0	0.0	0.0	0.0	0.0	0.0	3192.0	3363.4	6.7	11.5	0.0	0.0
SESARMA RETICULATUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UCA PUGNAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX TABLE 3 - ABUNDANCE (NO./M2;MEAN AND STANDARD DEVIATION OF REPLICATES)
OF BENTHOS COLLECTED IN 0.25M2 QUADRATS, NEW BEDFORD WETLANDS STUDY.

SEPTEMBER

	STATION											
	1T1		1T2		1T3		1M4		1M5		1M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ANTHOZOA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BITTIUM ALTERNATUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPITELLA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	6.1
CARCINUS MAENAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAMMARUS PALUSTRIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GEUKENSIA DEMISSA	0.0	0.0	0.0	0.0	0.0	0.0	62.7	53.7	10.7	11.5	166.7	171.1
HYALE PLUMOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ILYANASSA OBSOLETUS	32.0	17.4	126.7	30.3	90.7	28.1	1.3	2.3	0.0	0.0	0.0	0.0
LIMULUS POLYPHEMUS	0.0	0.0	1.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LITTORINA LITTOREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.3	0.0	0.0
MACOMA BALTHICA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MELAMPUS BIDENTATUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MERCENARIA MERCENARIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYA ARENARIA	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	1.3	2.3	0.0	0.0
MYTILUS EDULIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEOPANOPE SAYI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS SUCCINEA	0.0	0.0	0.0	0.0	0.0	0.0	2.7	4.6	0.0	0.0	0.0	0.0
PALAEMONETES PUGIO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PETRICOLA PHOLADIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RHITHROPANOPEUS HARRISII	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEMIBALANUS BALANOIDES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SESARMA RETICULATUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	0.0	0.0
UCA PUGNAX	1.3	2.3	1.3	2.3	0.0	0.0	25.3	4.6	18.7	11.5	2.7	4.6

APPENDIX TABLE 3 - ABUNDANCE (NO./M2;MEAN AND STANDARD DEVIATION OF REPLICATES)
OF BENTHOS COLLECTED IN 0.25M2 QUADRATS, NEW BEDFORD WETLANDS STUDY.

SEPTEMBER

	STATION											
	2T1		2T2		2T3		2M4		2M5		2M6	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ANTHOZOA	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	0.0	0.0	0.0	0.0
BITTIUM ALTERNATUM	0.0	0.0	0.0	0.0	0.0	0.0	12.0	10.6	9.3	16.2	1.3	2.3
CAPITELLA SP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CARCINUS MAENAS	0.0	0.0	1.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAMMARUS PALUSTRIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GEUKENSIA DEMISSA	1.3	2.3	16.0	17.4	4.0	4.0	25.3	28.4	0.0	0.0	12.0	10.6
KYALE PLUMOSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ILYANASSA OBSOLETUS	8.0	10.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIMULUS POLYPHEMUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LITTORINA LITTOREA	0.0	0.0	0.0	0.0	0.0	0.0	28.0	35.6	4.0	4.0	0.0	0.0
MACOMA BALTHICA	0.0	0.0	0.0	0.0	16.0	14.4	0.0	0.0	0.0	0.0	0.0	0.0
MELAMPUS BIDENTATUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MERCENARIA MERCENARIA	1.3	2.3	0.0	0.0	0.0	0.0	2.7	4.6	0.0	0.0	0.0	0.0
MYA ARENARIA	14.7	18.5	0.0	0.0	2.7	4.6	1.3	2.3	1.3	2.3	0.0	0.0
MYTILUS EDULIS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEOPANOPE SAYI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEREIS SUCCINEA	0.0	0.0	0.0	0.0	1.3	2.3	14.7	6.1	14.7	16.2	0.0	0.0
PALAEMONETES PUGIO	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	0.0	0.0	0.0	0.0
PETRICOLA PHOLADIFORMIS	0.0	0.0	0.0	0.0	0.0	0.0	5.3	9.2	5.3	9.2	0.0	0.0
RHITHROPANOPEUS HARRISII	1.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	2.7	4.6	0.0	0.0
SEMIBALANUS BALANOIDES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SESARMA RETICULATUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UCA PUGNAX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.3	16.7

APPENDIX TABLE 4. MEAN (mm) AND STANDARD DEVIATION OF SHELL LENGTH OF *MERCENARIA MERCENARIA* AND *MACOMA BALTHICA* AND NUMBER COLLECTED (REPLICATES SUMMED), NEW BEDFORD WETLANDS STUDY, 1987.

MERCENARIA MERCENARIA

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1		--			--	
1T2		--			--	
1T3		--			--	
1M4		--			--	
1M5		--			--	
1M6		--			--	
2T1	18.4	(8.72)	9	8	(-)	1
2T2		--			--	
2T3		--			--	
2M4		--		2.5	(0.71)	2
2M5		--			--	
2M6		--			--	

MACOMA BALTHICA

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1		--			--	
1T2		--			--	
1T3		--			--	
1M4		--			--	
1M5		--			--	
1M6		--			--	
2T1		--			--	
2T2		--			--	
2T3	17.7	(2.08)	3	11.3	(2.10)	12
2M4		--			--	
2M5		--			--	
2M6		--			--	

APPENDIX TABLE 5. MEAN (mm) AND STANDARD DEVIATION OF SHELL LENGTH OF *PETRICOLA PHOLADIFORMIS* AND *MYTILUS EDULIS* AND NUMBER COLLECTED (REPLICATES SUMMED), NEW BEDFORD WETLANDS STUDY, 1987.

PETRICOLA PHOLADIFORMIS

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1		--			--	
1T2		--			--	
1T3		--			--	
1M4		--			--	
1M5		--			--	
1M6		--			--	
2T1		--			--	
2T2		--			--	
2T3		--			--	
2M4	12	(-)	1	4.0	(0.82)	4
2M5	14	(-)	1	5.2	(1.50)	4
2M6		--			--	

MYTILUS EDULIS

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1		--			--	
1T2		--			--	
1T3		--			--	
1M4		--			--	
1M5		--			--	
1M6		--			--	
2T1		--			--	
2T2		--			--	
2T3		--			--	
2M4	19	(24.04)	2		--	
2M5		--			--	
2M6		--			--	

APPENDIX TABLE 6. MEAN (mm) AND STANDARD DEVIATION OF SHELL HEIGHT OF *MELAMPUS BIDENTATUS* AND *BITTIUM ALTERNATUM* AND NUMBER COLLECTED (REPLICATES SUMMED), NEW BEDFORD WETLANDS STUDY, 1987.

MELAMPUS BIDENTATUS

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1		--			--	
1T2		--			--	
1T3		--			--	
1M4		--			--	
1M5		--		6	(-)	1
1M6	9.0	(1.41)	2		--	
2T1		--			--	
2T2		--			--	
2T3		--			--	
2M4		--			--	
2M5		--			--	
2M6		--			--	

BITTIUM ALTERNATUM

	JUN			SEP		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1T1		--			--	
1T2		--			--	
1T3		--			--	
1M4		--			--	
1M5		--			--	
1M6		--			--	
2T1		--			--	
2T2		--			--	
2T3		--			--	
2M4		--		1.8	(0.44)	9
2M5		--		2.1	(0.69)	7
2M6		--		3	(-)	1

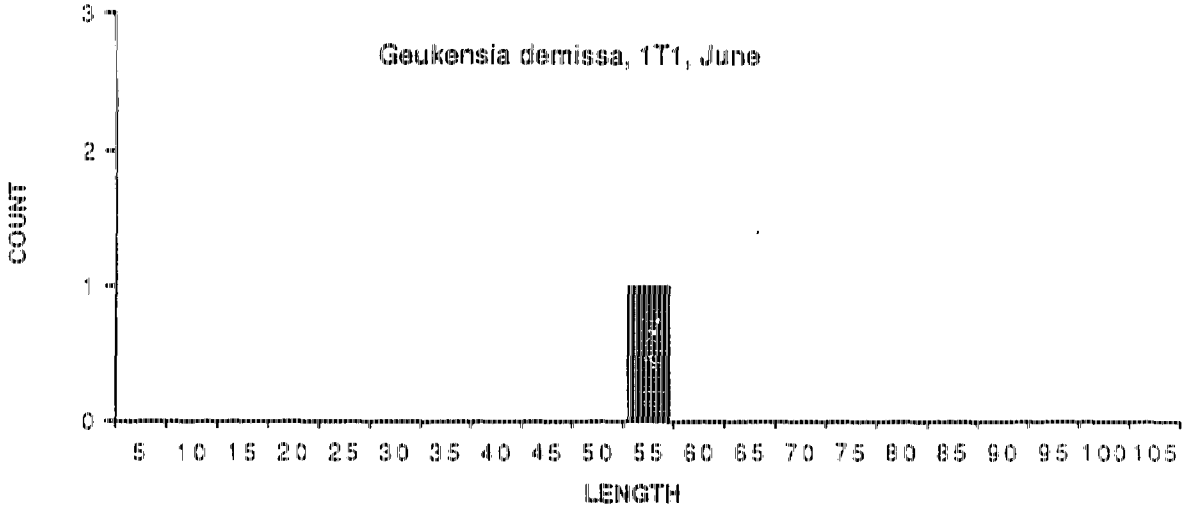
APPENDIX FIGURES:

Shell length (mm) frequency distributions (replicates summed) for Geukensia demissa, Mya arenaria, Mercenaria mercenaria, Macoma balthica, Mytilus edulis and Petricola pholandiformis, New Bedford Wetlands Study, 1987.

Shell height (mm) frequency distributions (replicates summed) for Ilyanassa obsoleta, Littorina littoria, Melampus bidentatus and Bittium alternatum, New Bedford Wetlands Study, 1987.

Shell length distributions of Geukensia demissa, Mya arenaria, Mercenaria mercenaria and Macoma balthica collected during October, New Bedford Wetlands Study, 1987.

Shell height distributions of Littorina littorea and Ilyanassa obsolata collected during October, New Bedford Wetlands Study, 1987.


Geukensia demissa, 1T1, June
COUNT
LENGTH
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1
2
3
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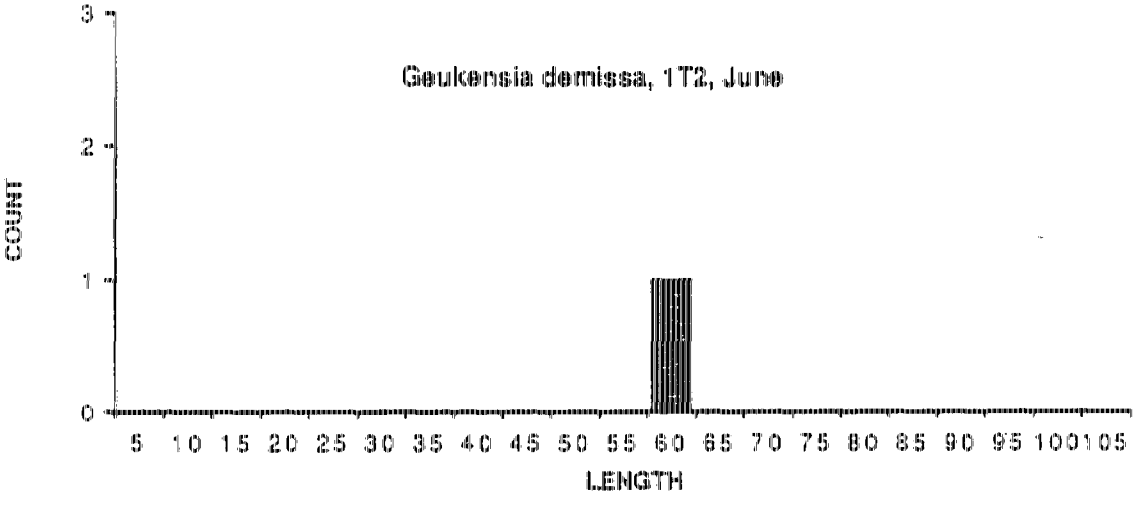
Geukensia demissa, 1T2, June
COUNT
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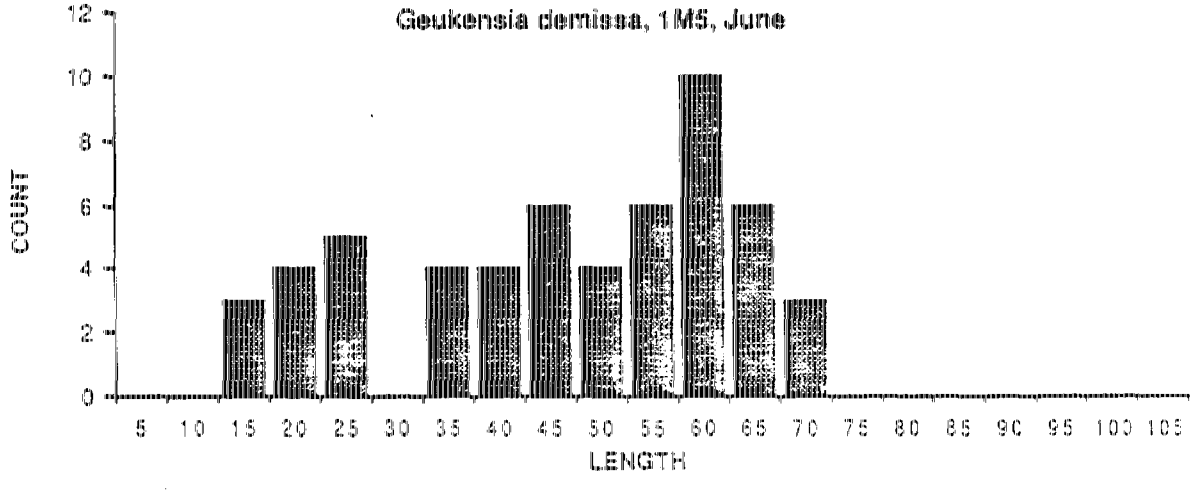
Geukensia demissa, 1M5, June
COUNT
LENGTH
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12
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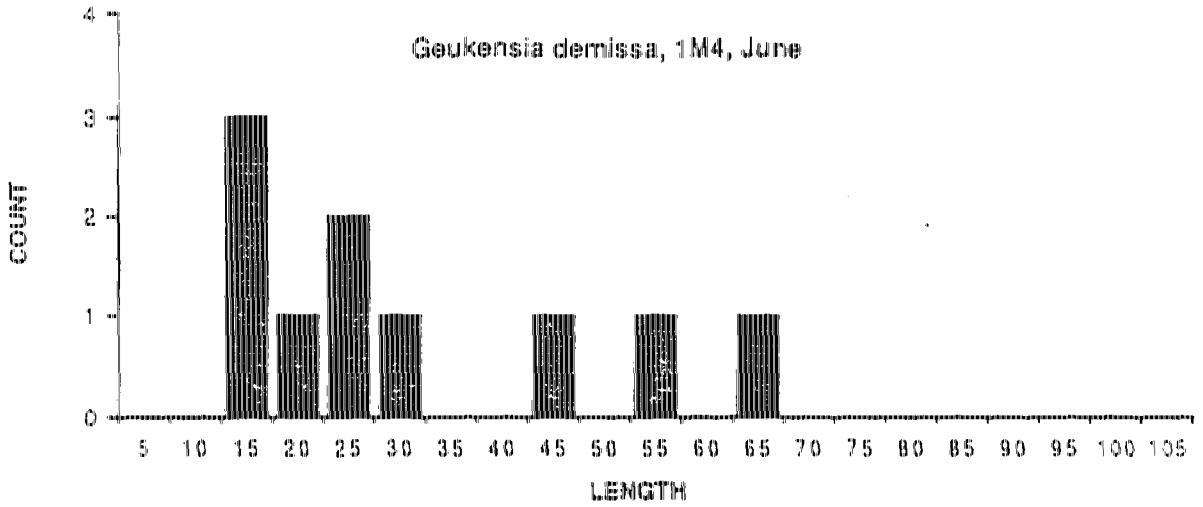
Geukensia demissa, 1M4, June
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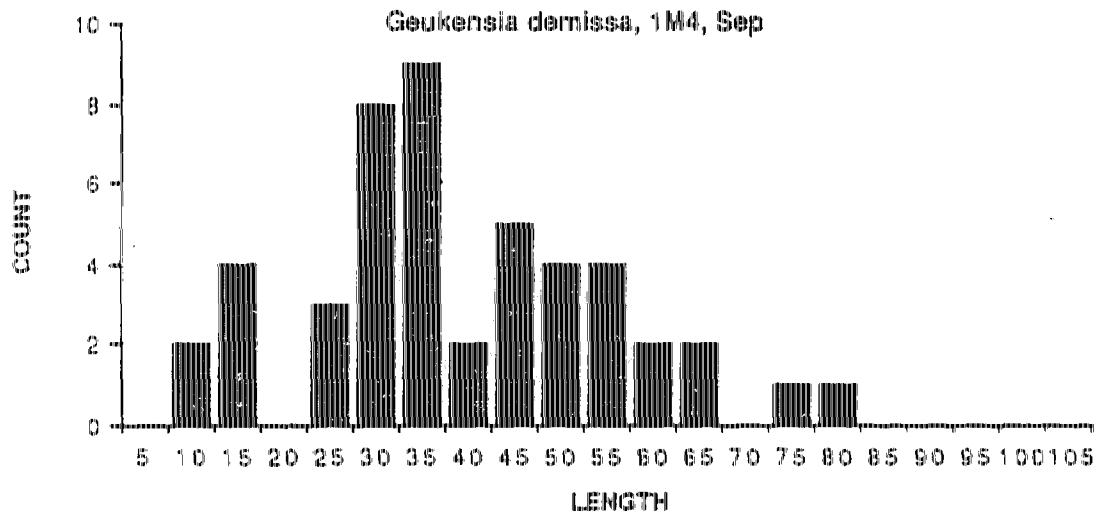
LENGTH


Geukensia demissa, 1M4, Sep
COUNT
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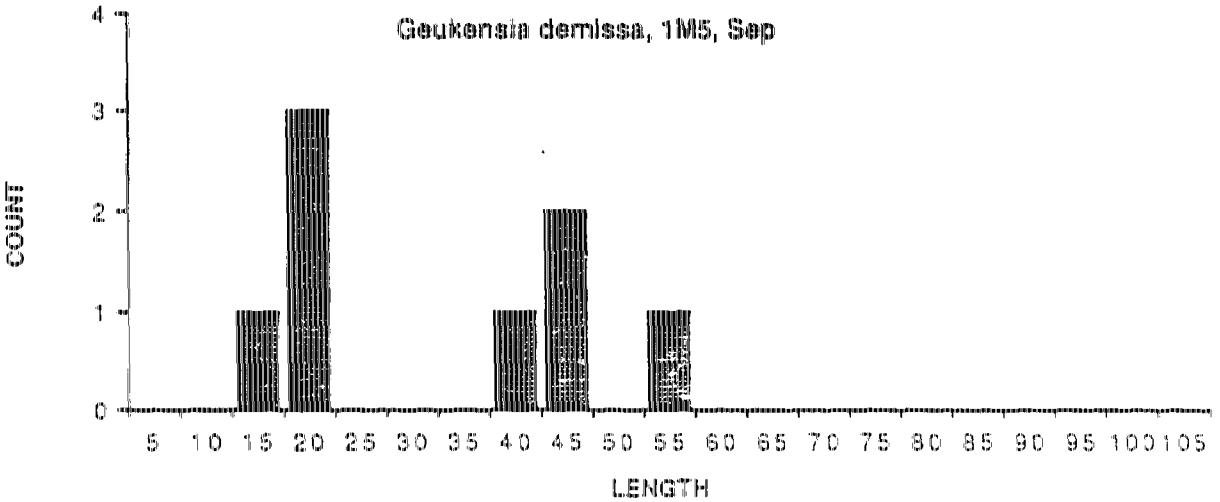
LENGTH


Geukensia demissa, 1M5, Sep
COUNT
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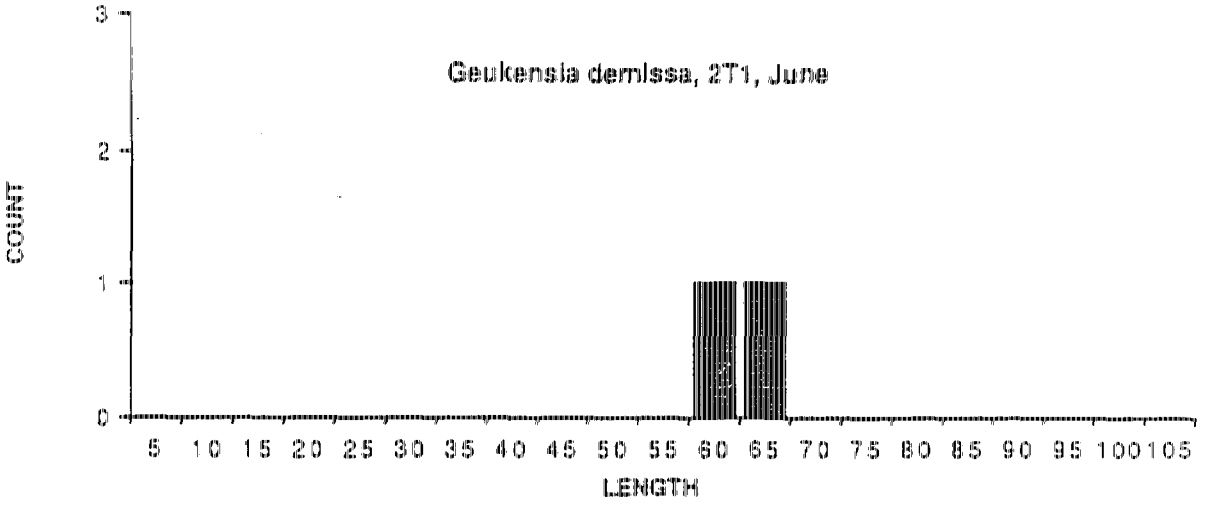
Geukensia demissa, 2T1, June
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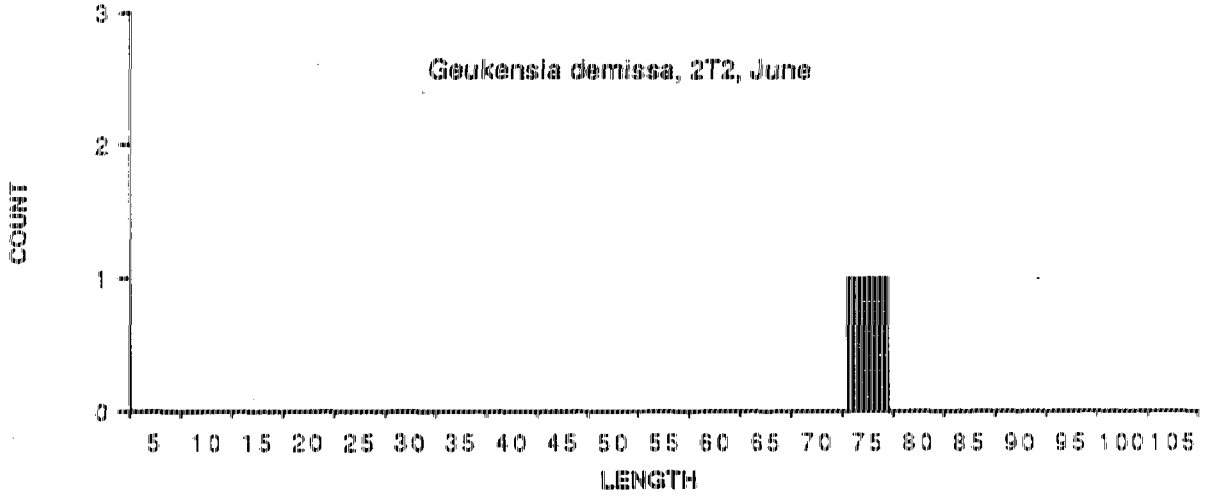
LENGTH


Geukensia demissa, 2T2, June
COUNT
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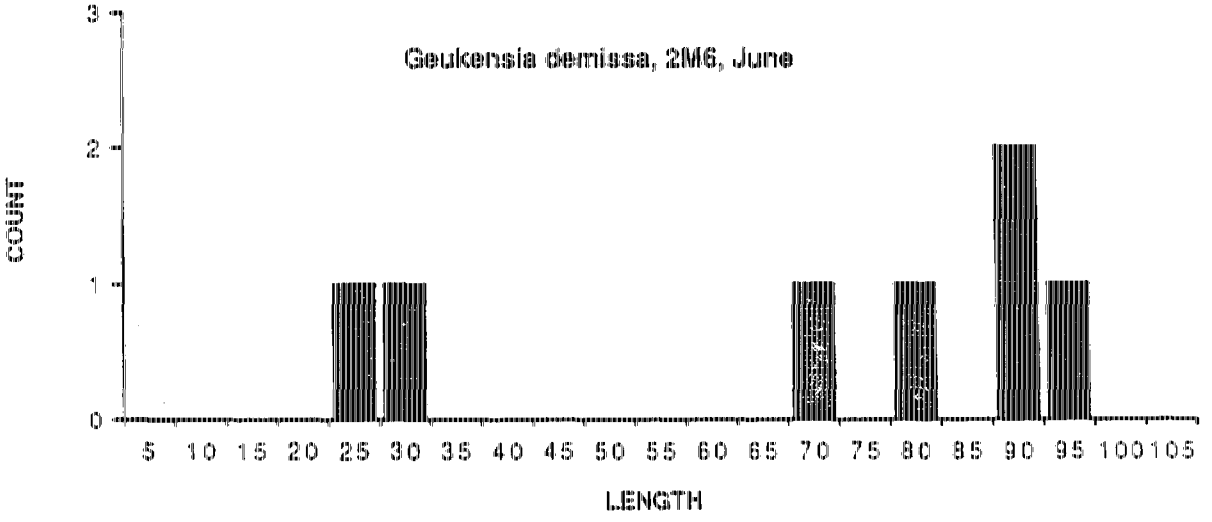
LENGTH


Geukensia demissa, 2M6, June
COUNT
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2
3
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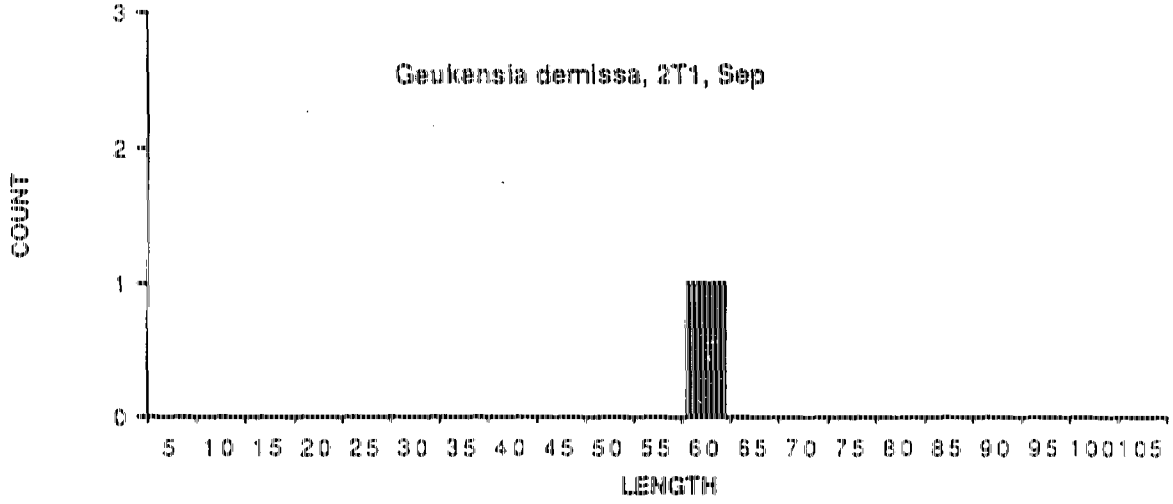
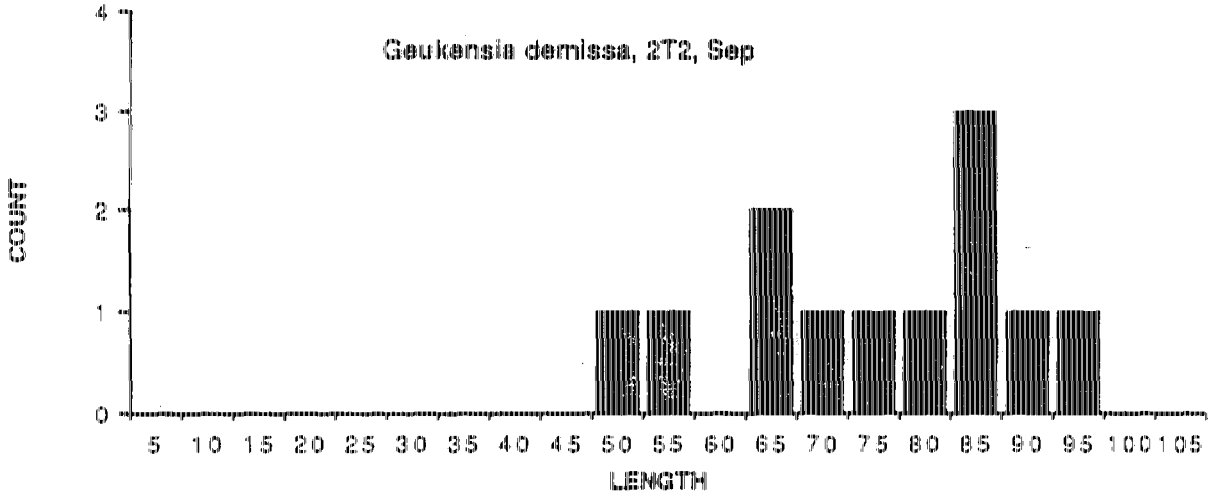

Geukensia demissa, 2T1, Sep
COUNT
LENGTH


Geukensia demissa, 2T2, Sep
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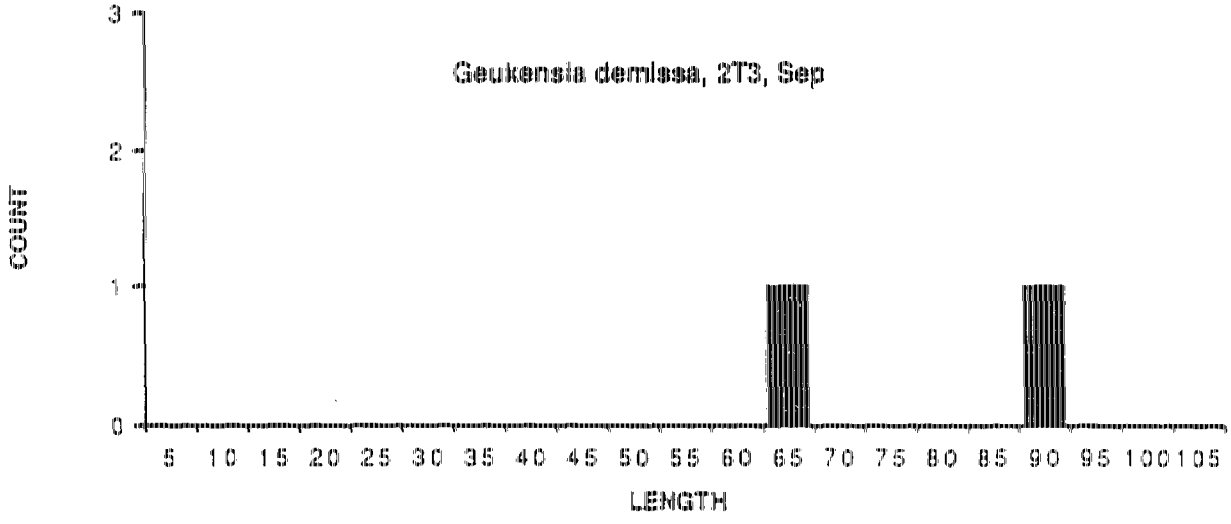
Geukensia demissa, 2T3, Sep
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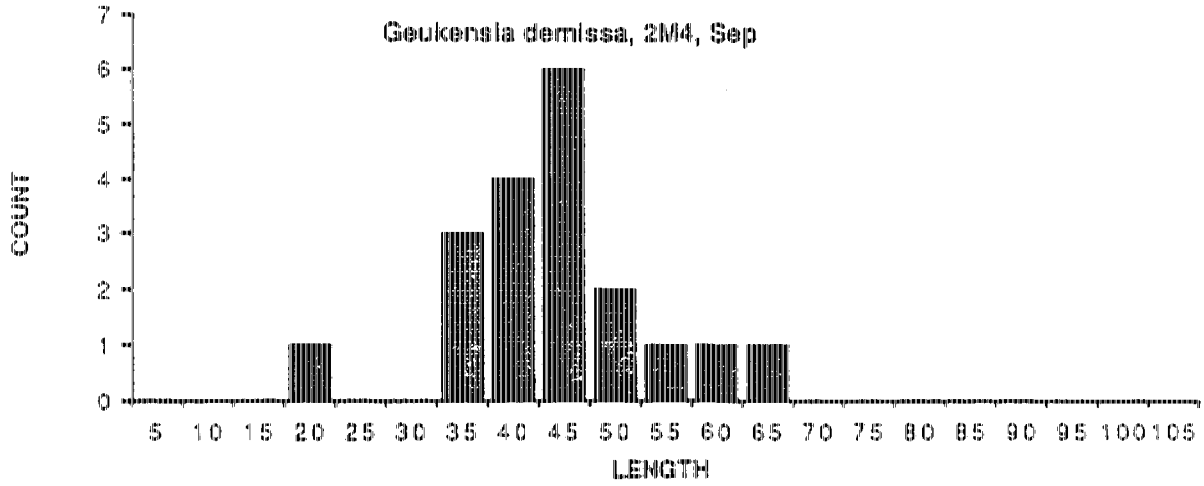
Geukensia demissa, 2M4, Sep
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4
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6
7
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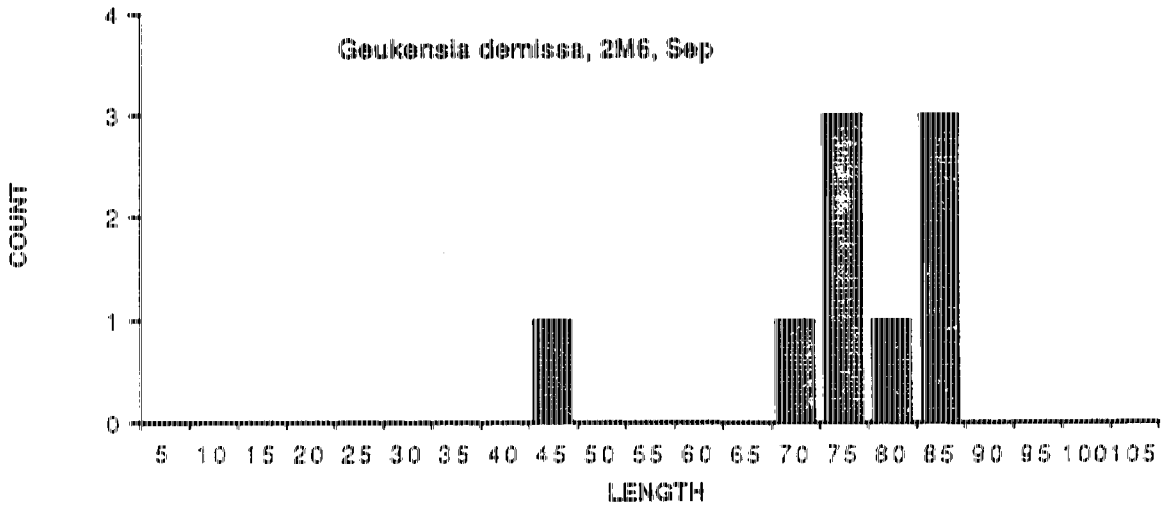
LENGTH


Geukensia demissa, 2M6, Sep
COUNT
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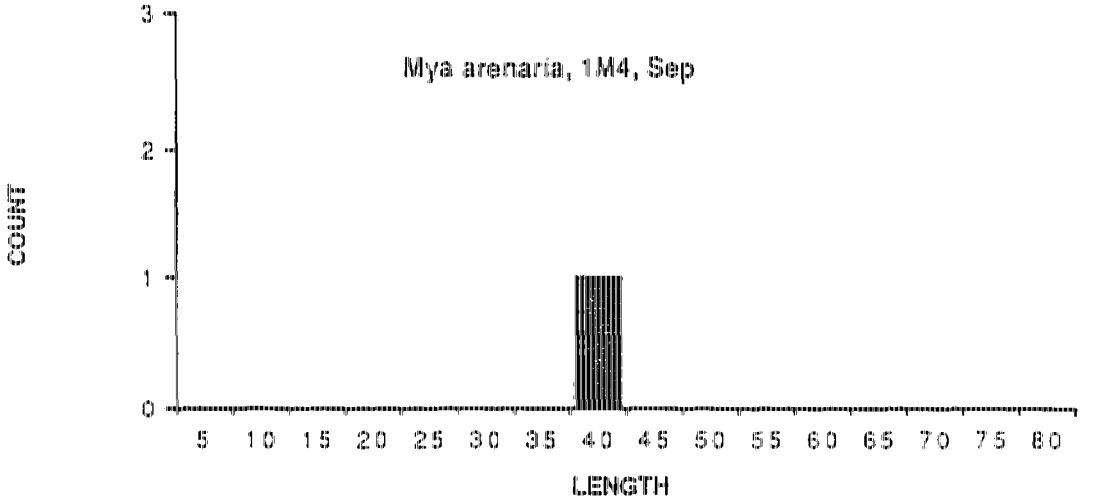
LENGTH


Mya arenaria, 1M4, Sep
COUNT
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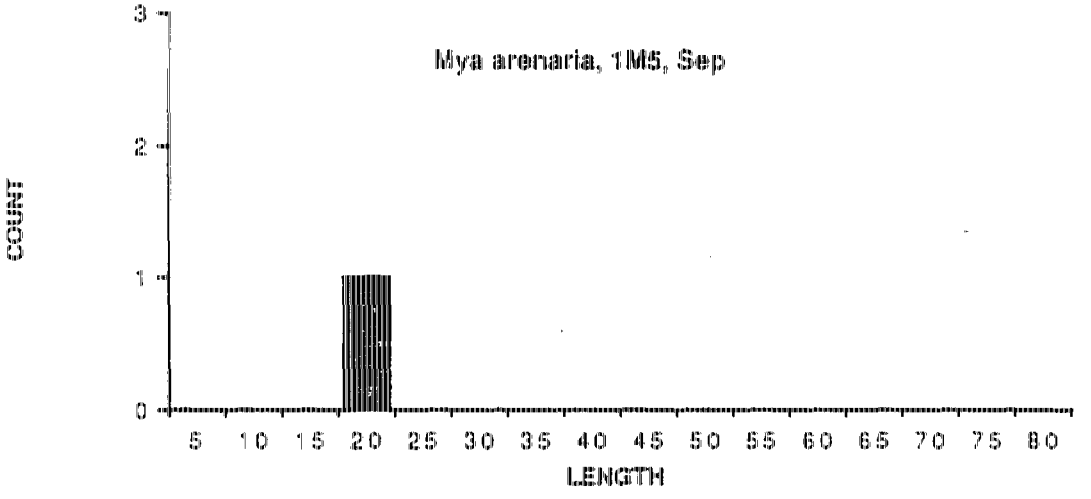
LENGTH


Mya arenaria, 1M5, Sep
COUNT
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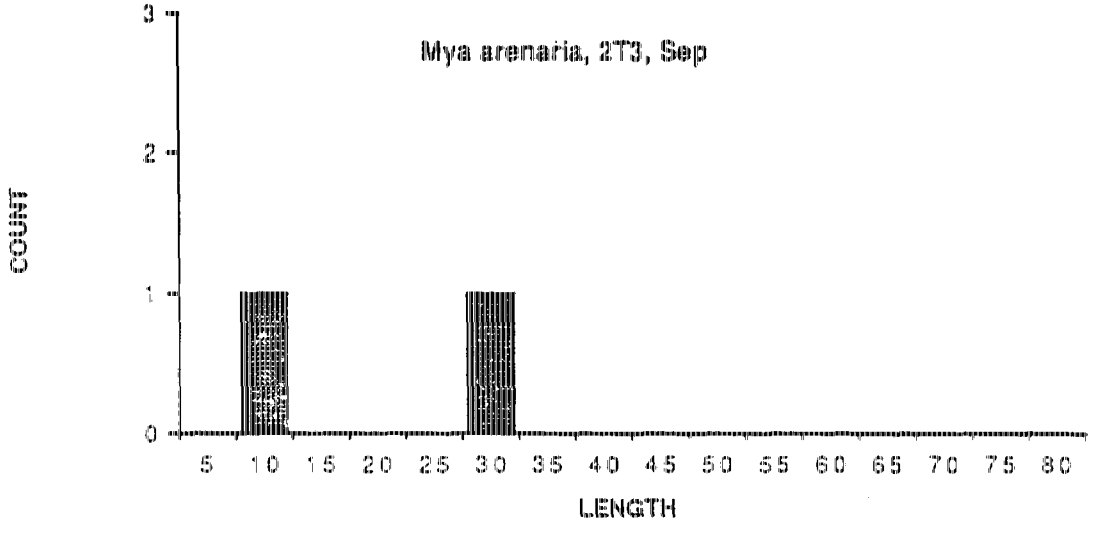
Mya arenaria, 2T3, Sep
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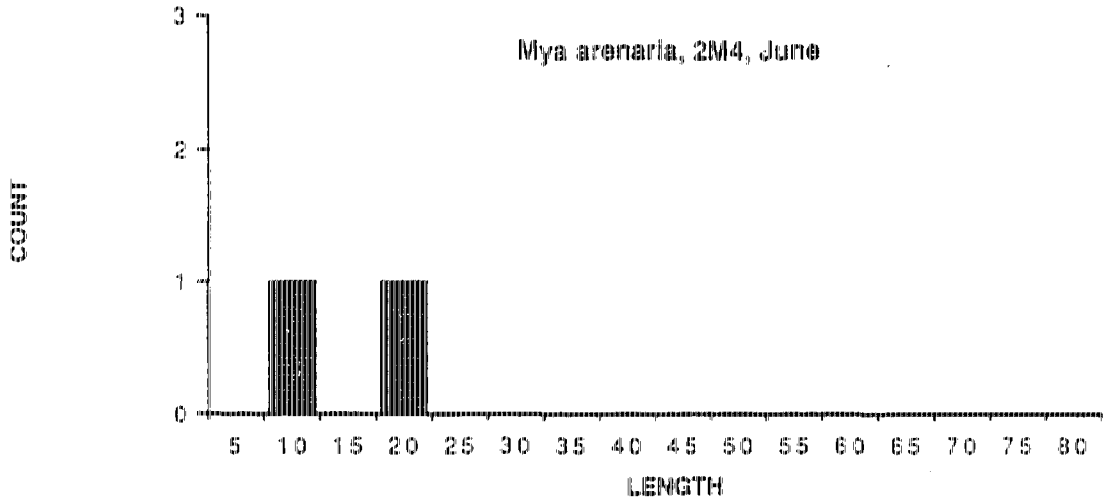
Mya arenaria, 2M4, June
COUNT
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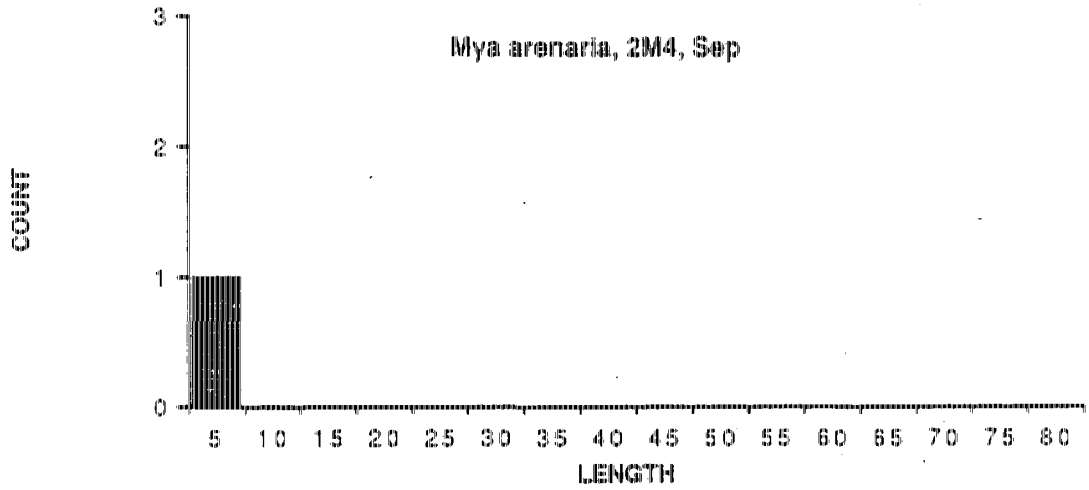
LENGTH


Mya arenaria, 2M4, Sep
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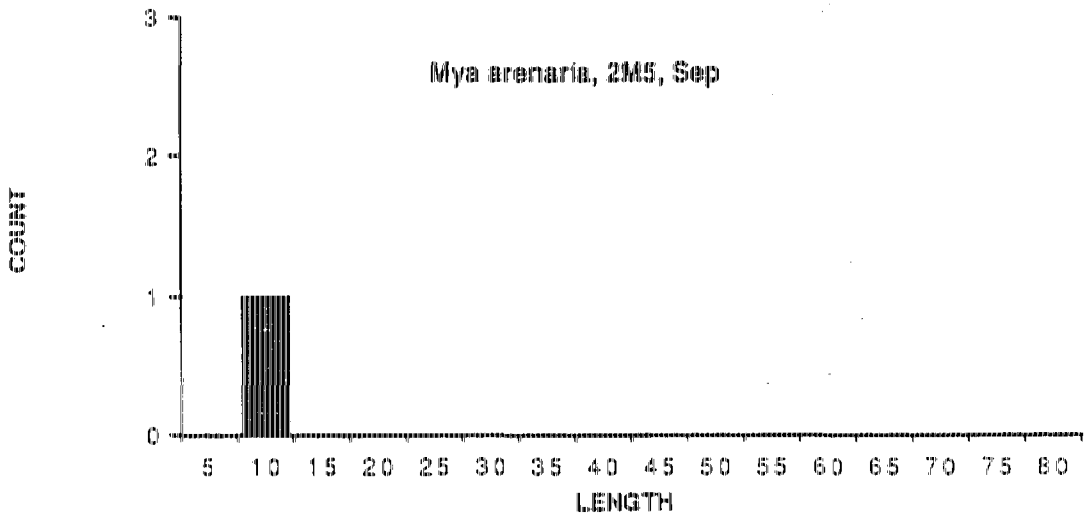
LENGTH


Mya arenaria, 2M5, Sep
COUNT
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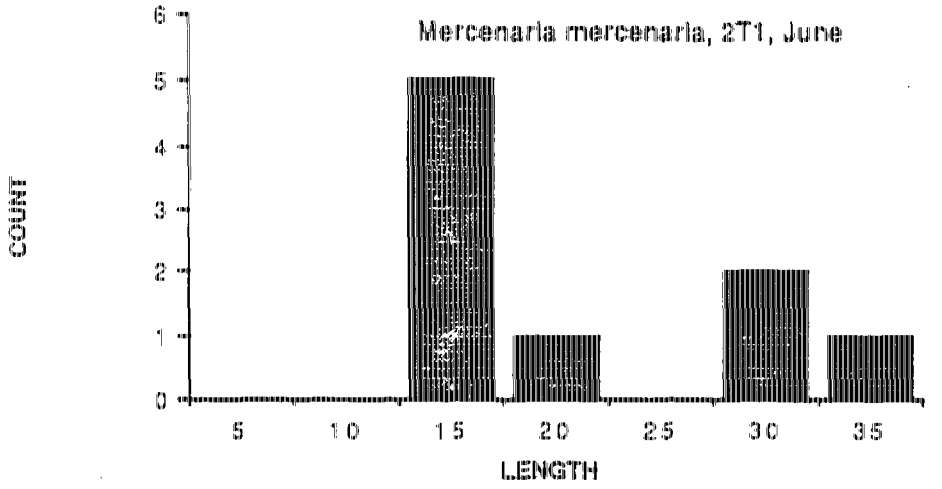
LENGTH

A-46


Mercenaria mercenaria, 2T1, June
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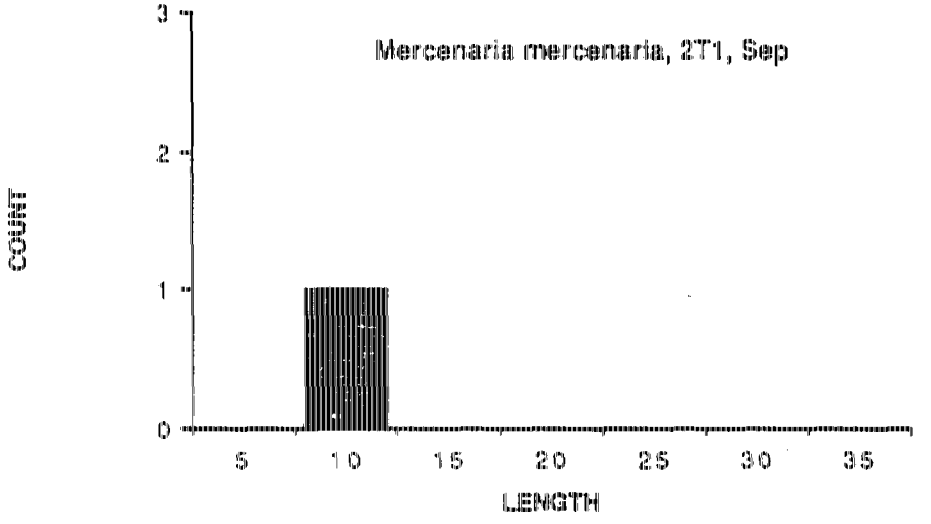
Mercenaria mercenaria, 2T1, Sep
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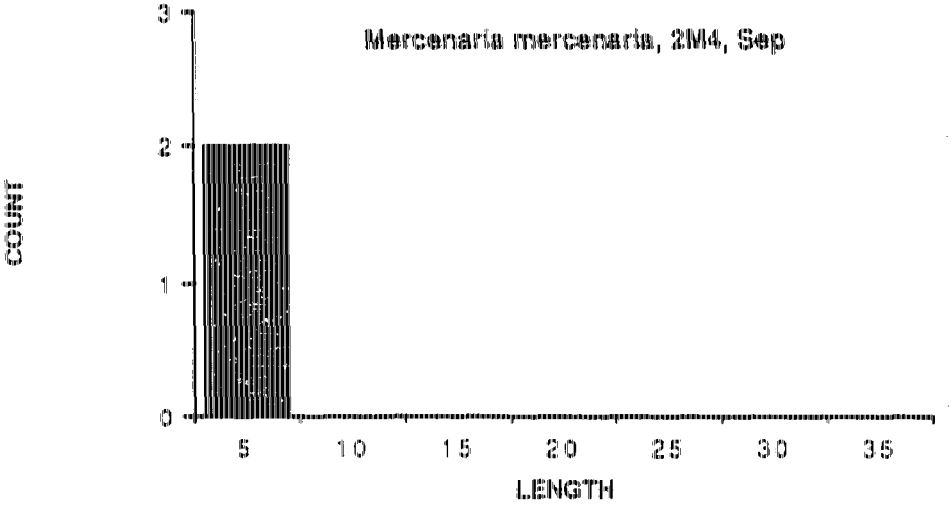
Mercenaria mercenaria, 2M4, Sep
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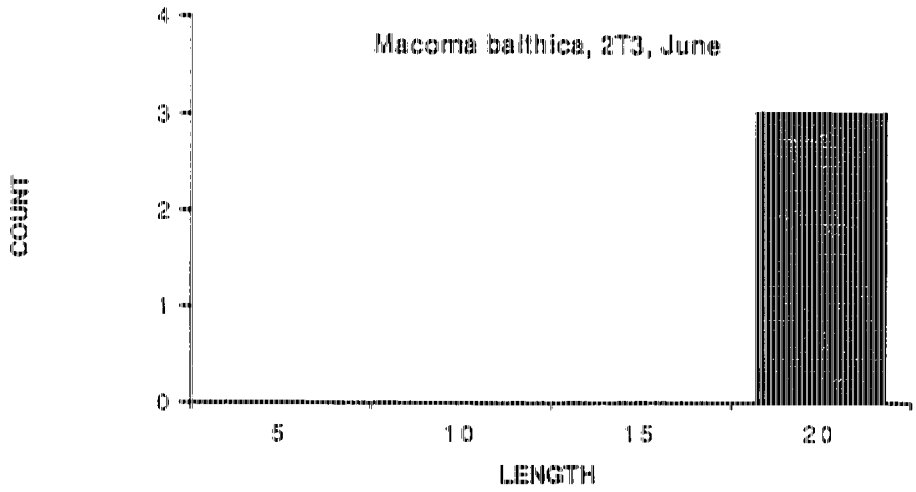
Macoma balthica, 2T3, June
COUNT
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4
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10
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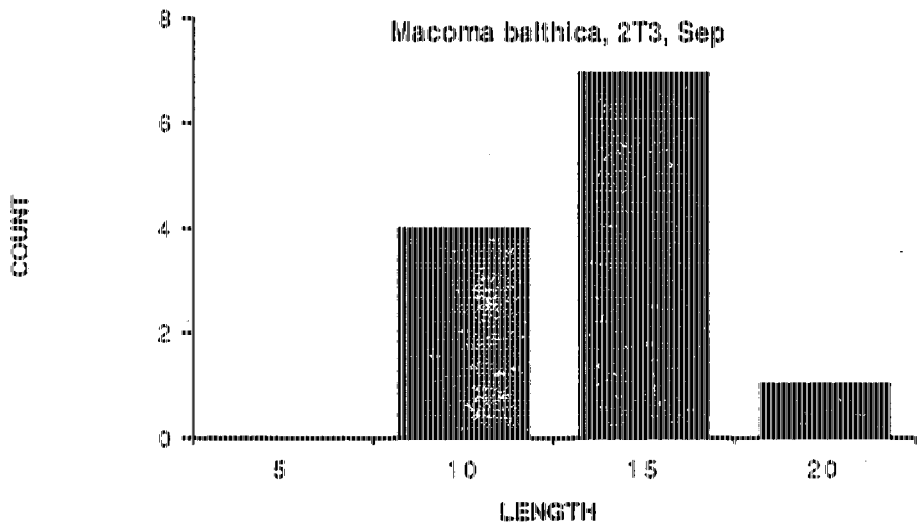
20
LENGTH


Macoma balthica, 2T3, Sep
COUNT
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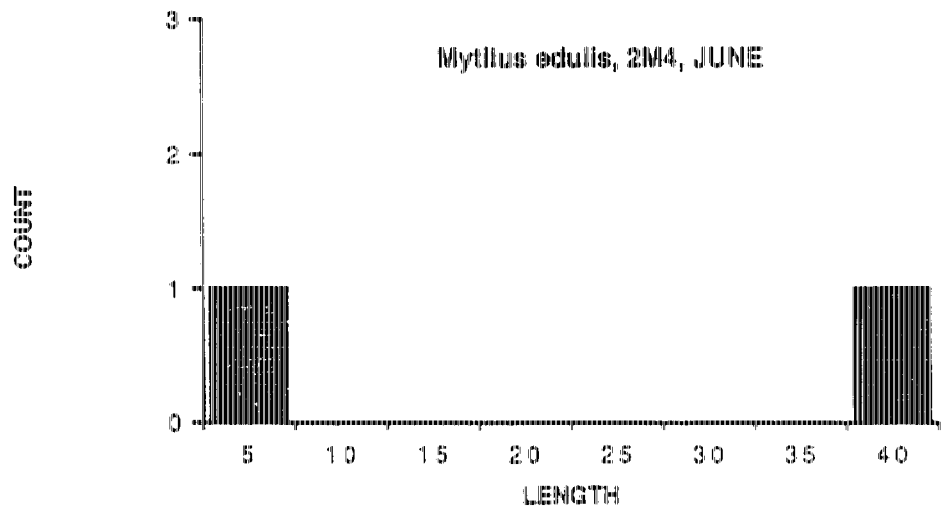
Mytilus edulis, 2M4, JUNE
COUNT
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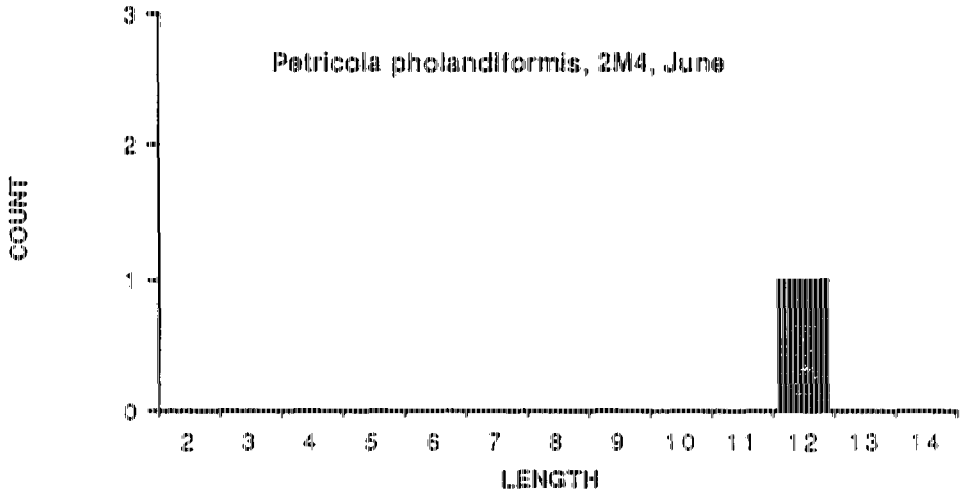
40
LENGTH


Petricola pholandiformis, 2M4, June
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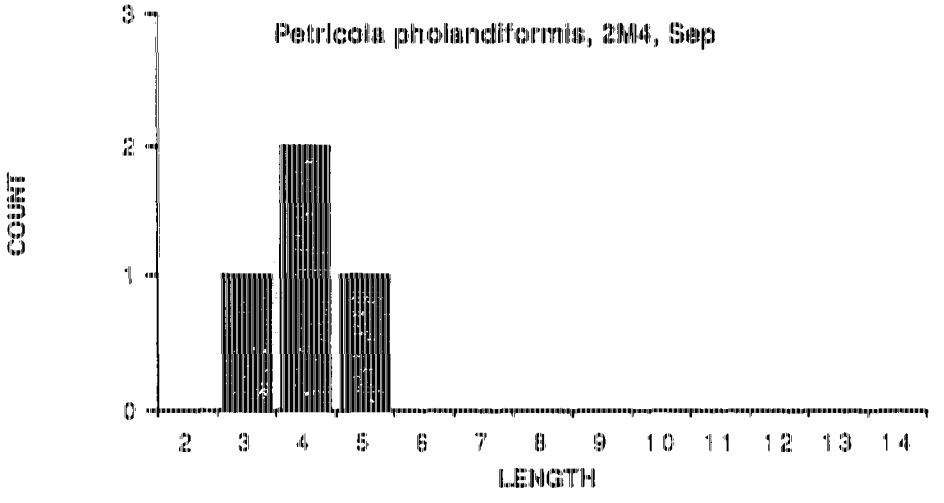
Petricola pholandiformis, 2M4, Sep
COUNT
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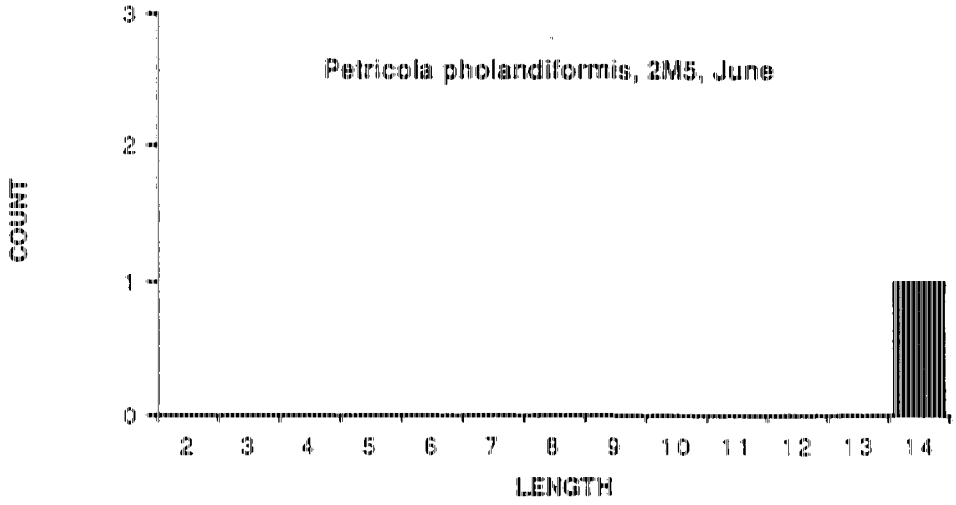
LENGTH


Petricola pholandiformis, 2M5, June
COUNT
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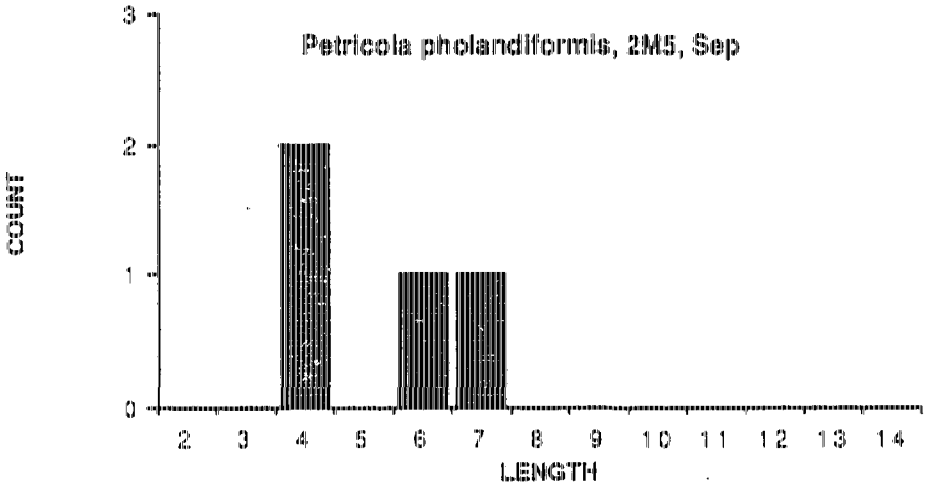
LENGTH


Petricola pholandiformis, 2M5, Sep
COUNT
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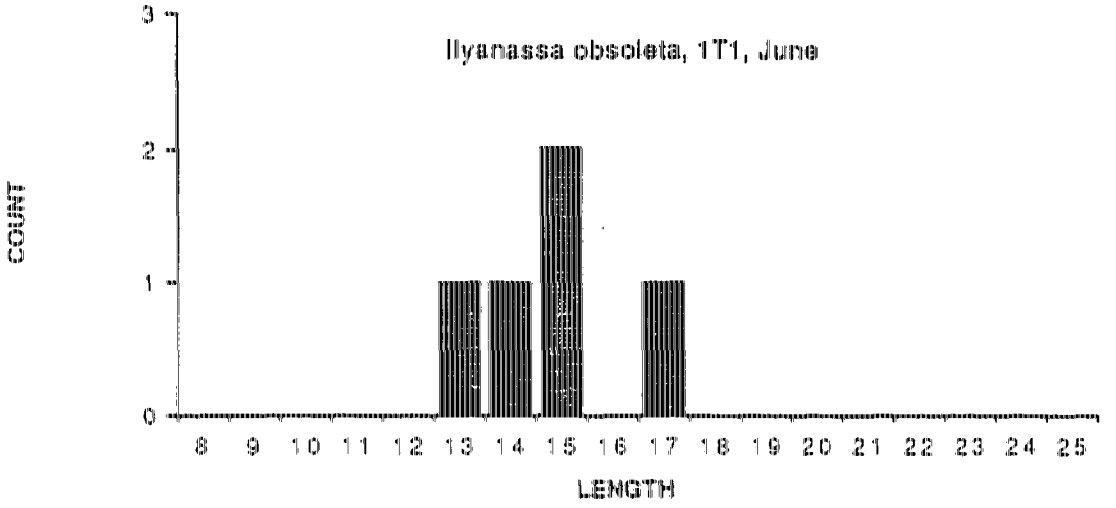
Ilyanassa obsoleta, 1T1, June
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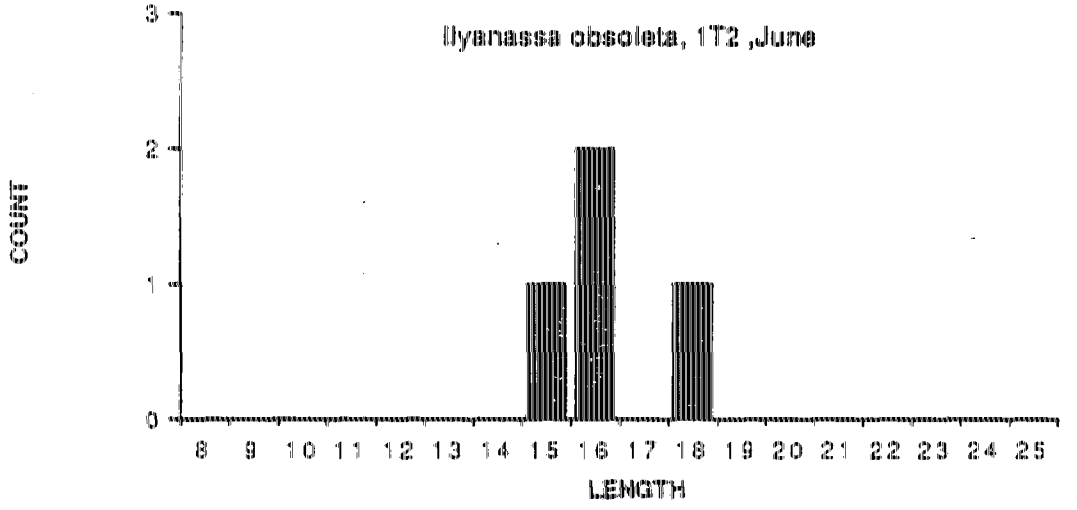
Ilyanassa obsoleta, 1T2 ,June
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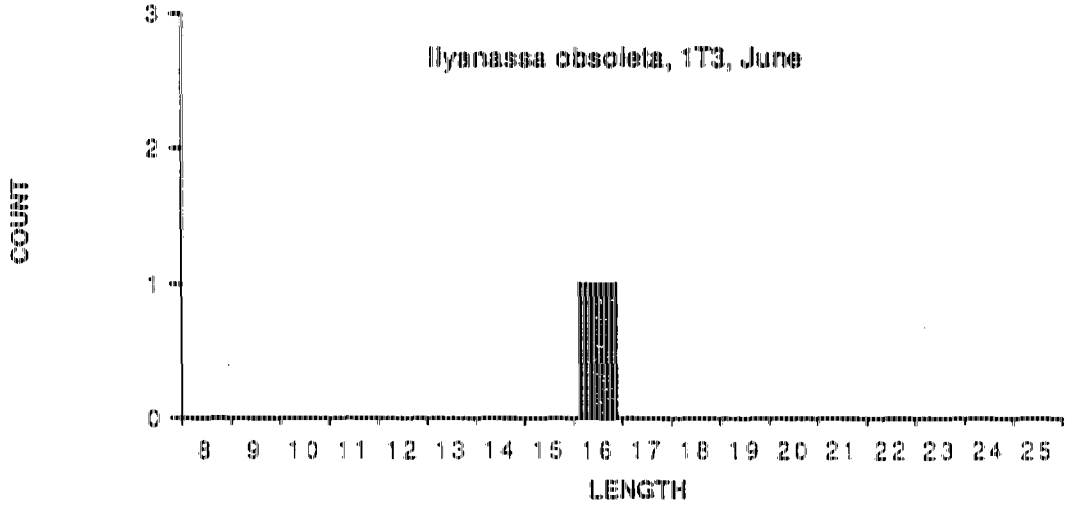
Ilyanassa obsoleta, 1T3, June
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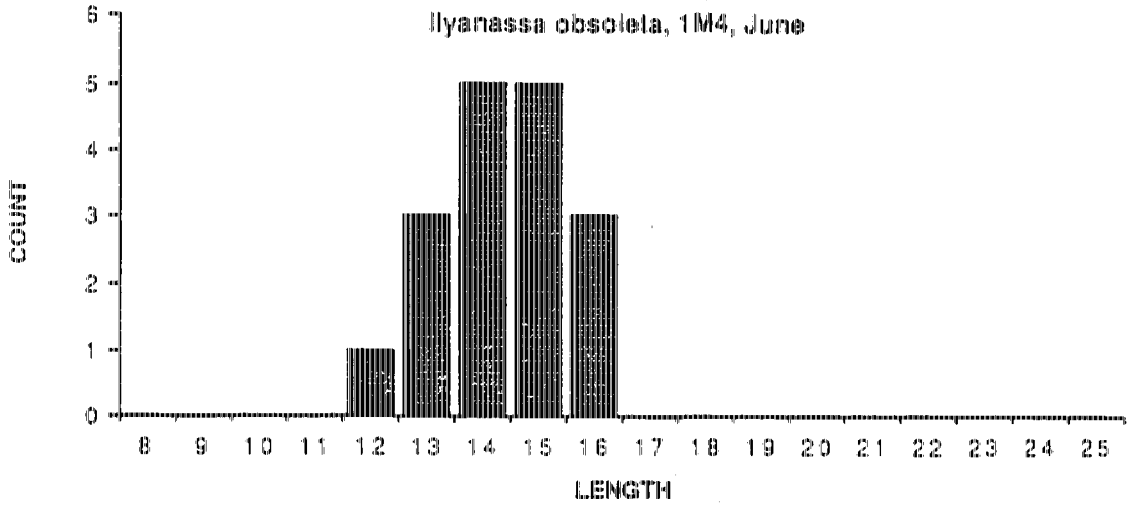
Ilyanassa obsoleta, 1M4, June
COUNT
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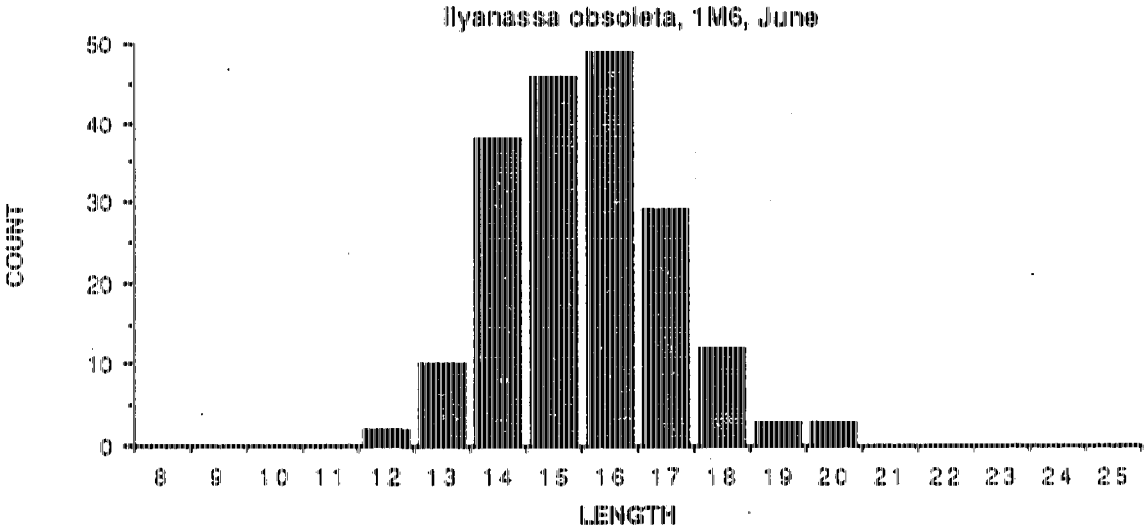
LENGTH


Ilyanassa obsoleta, 1M6, June
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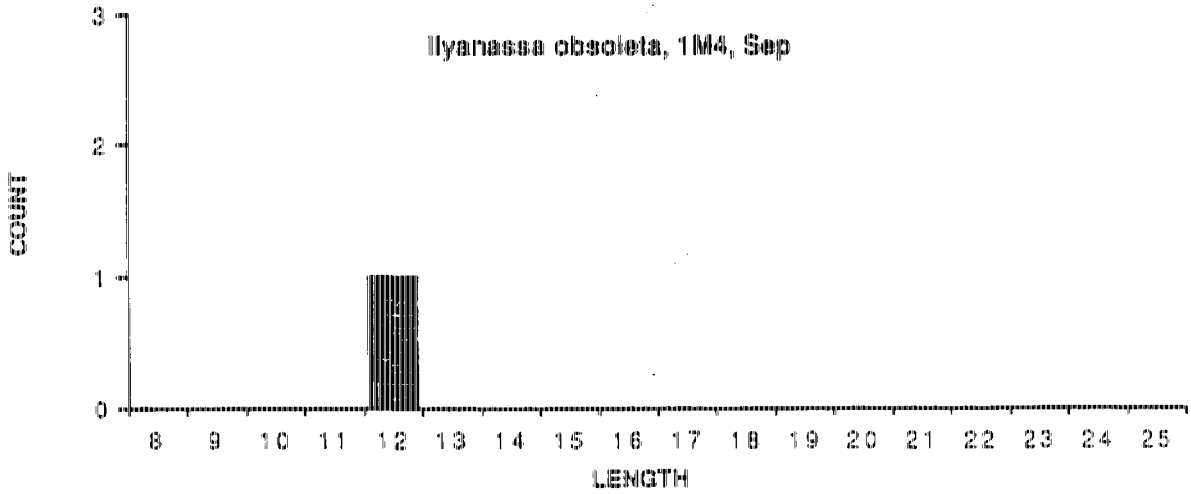
LENGTH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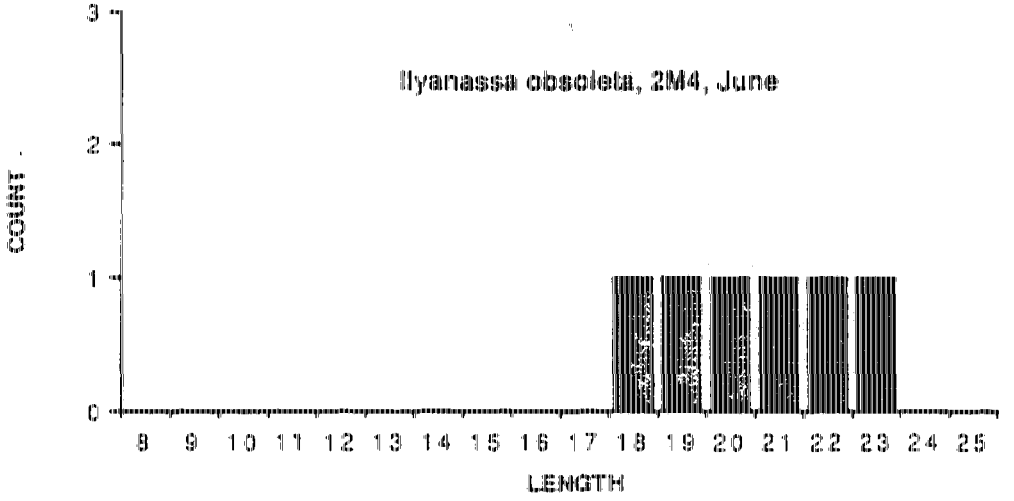
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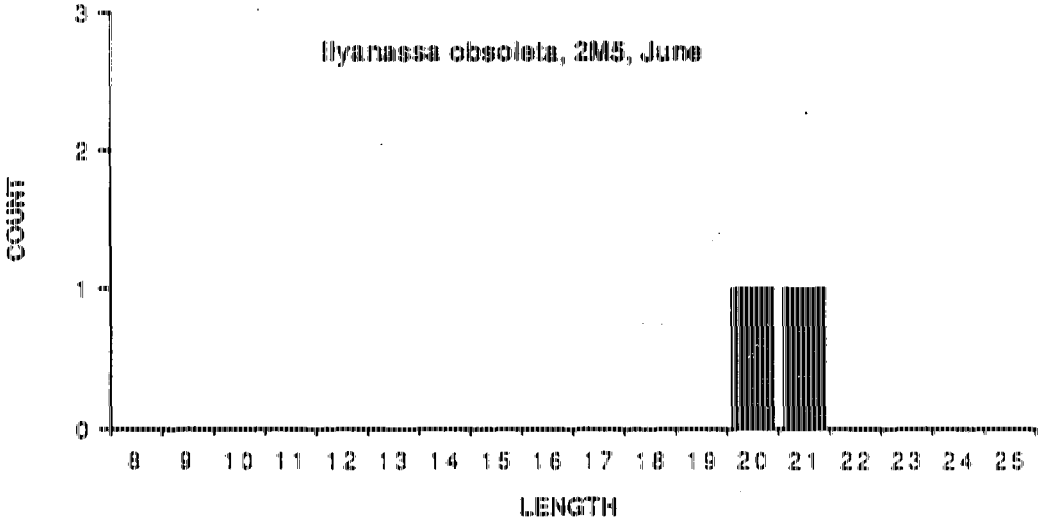
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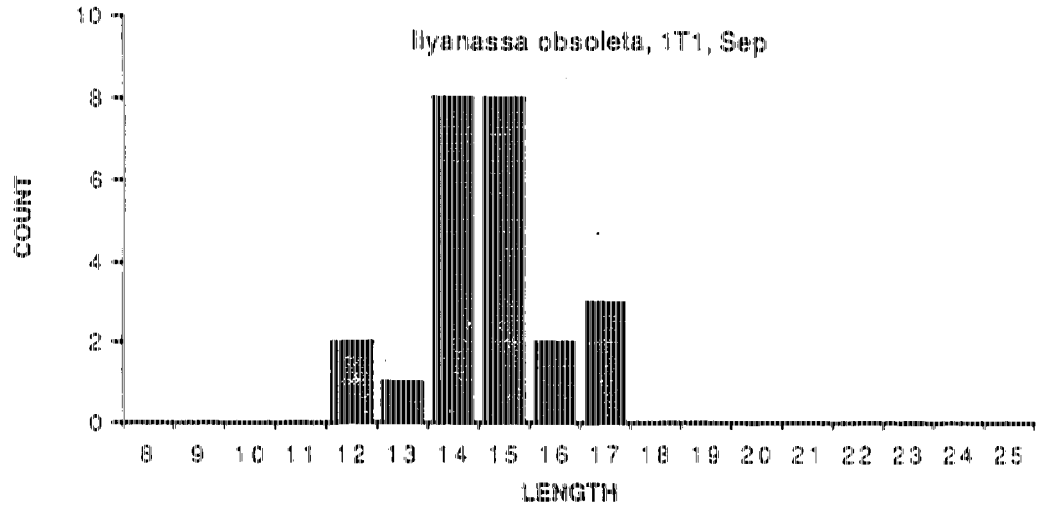
Ilyanassa obsoleta, 1T1, Sep
COUNT
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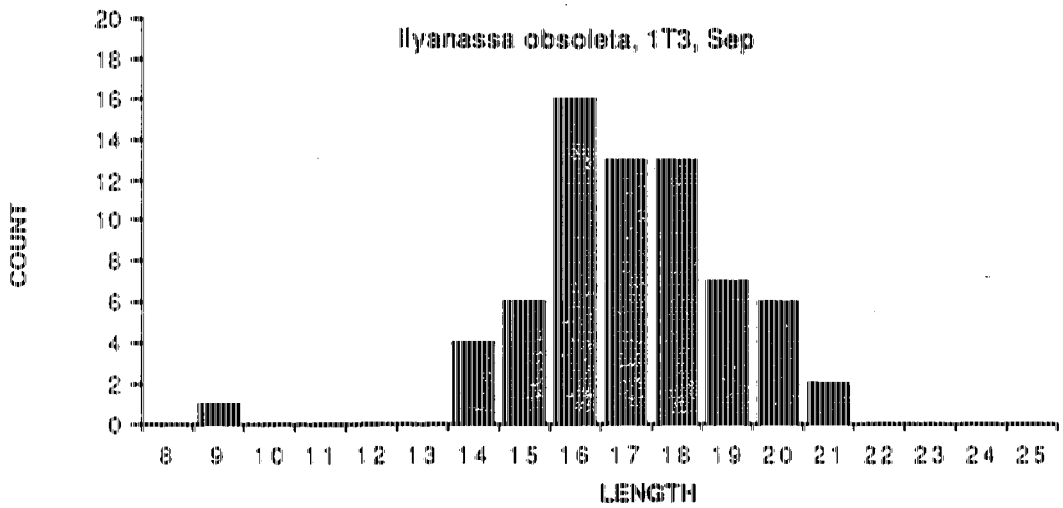
Ilyanassa obsoleta, 1T3, Sep
COUNT
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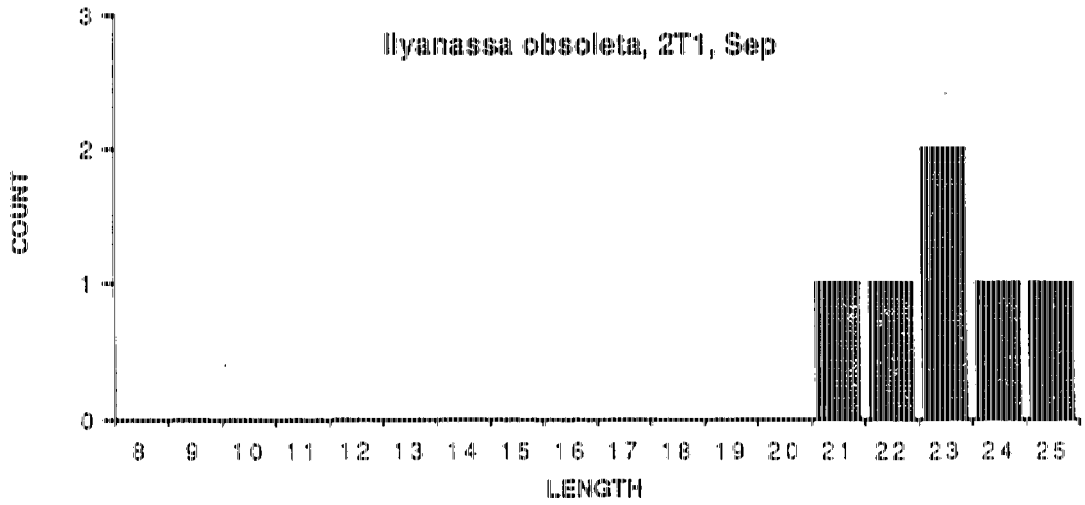
Ilyanassa obsoleta, 2T1, Sep
COUNT
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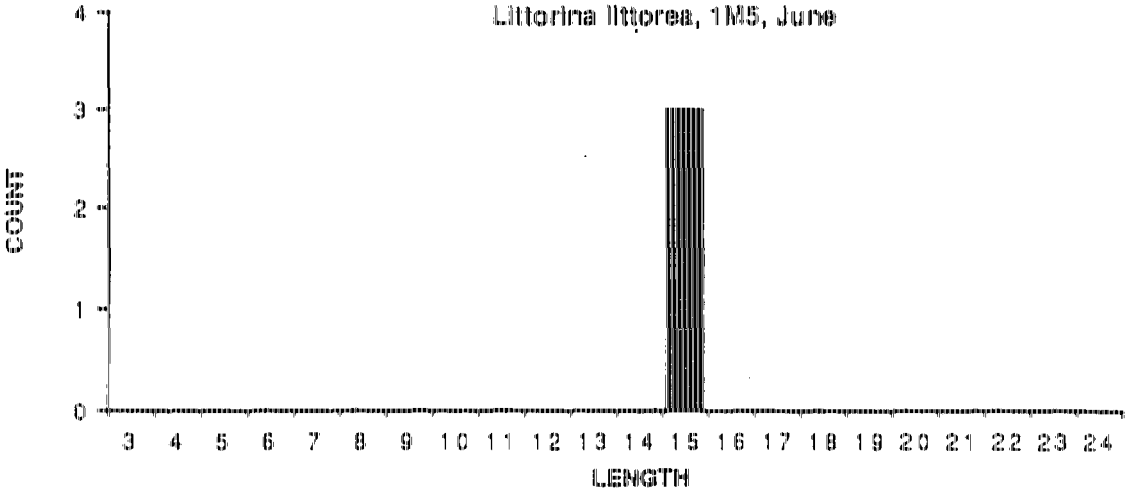
Littorina littorea, 1M5, June
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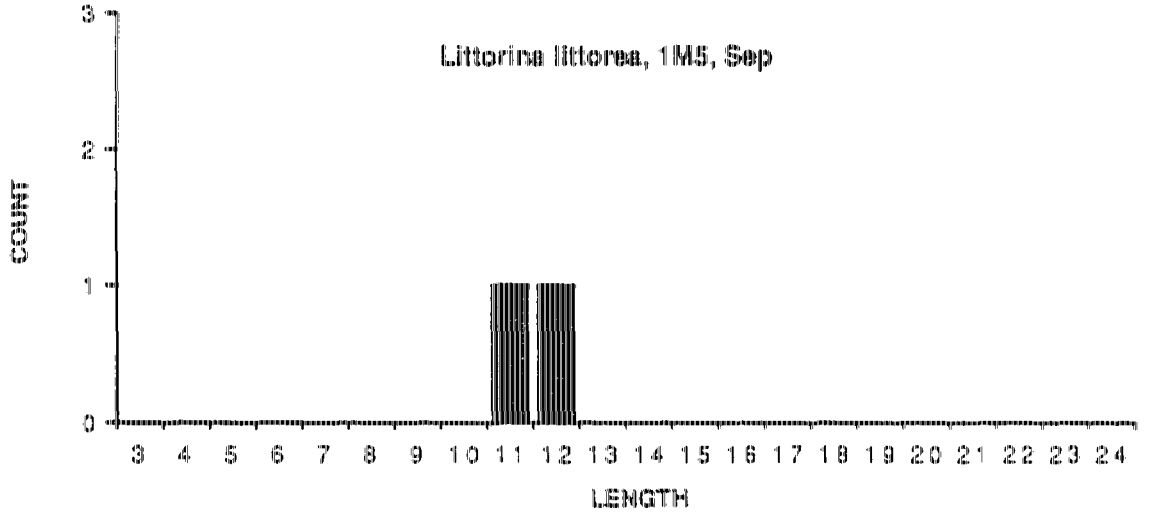
LENGTH


Littorina littorea, 1M5, Sep
COUNT
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2
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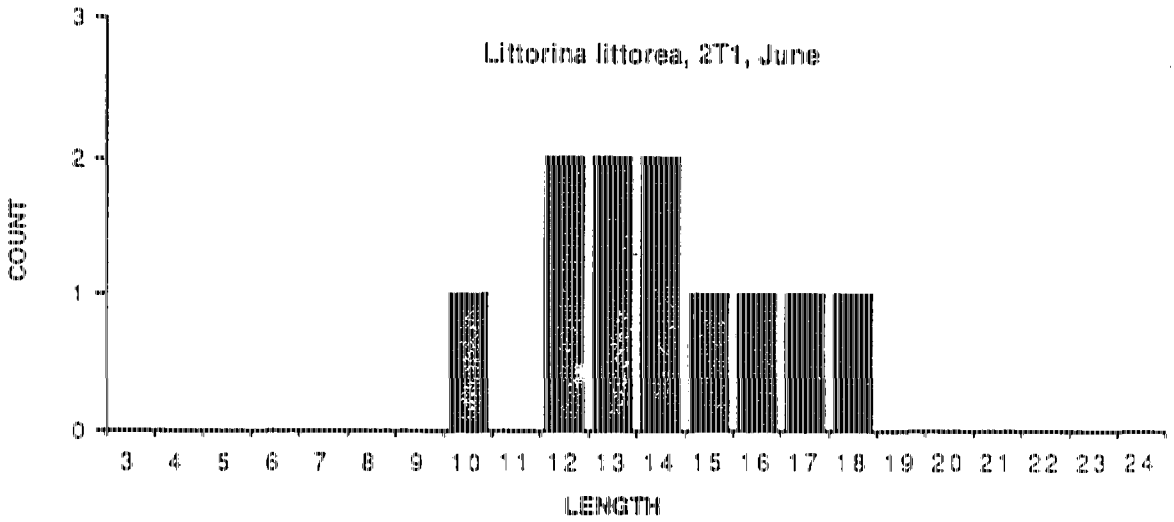
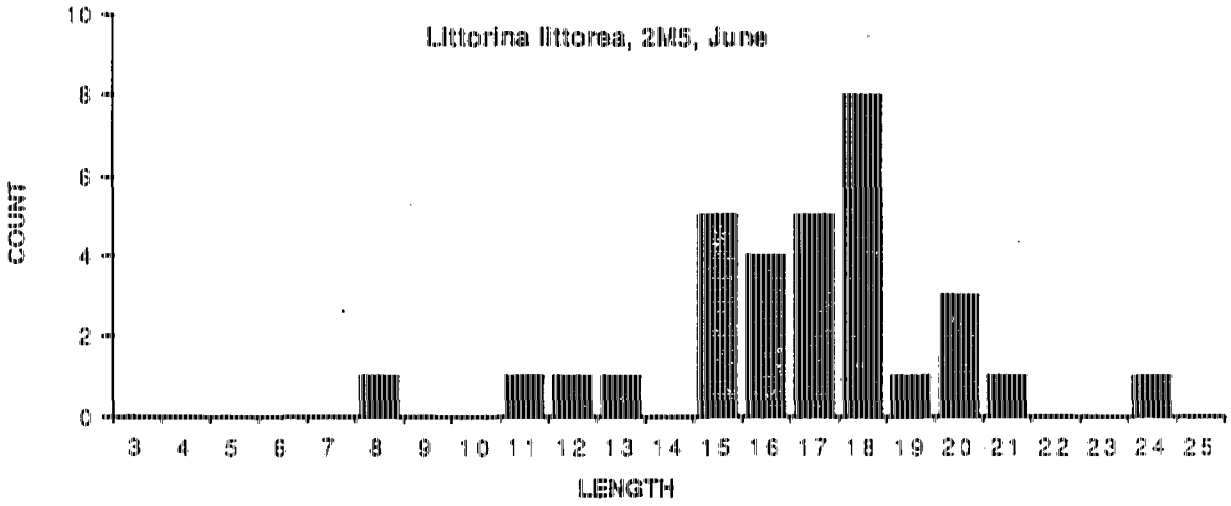
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
LENGTH


Littorina littorea, 2T1, June
COUNT
LENGTH


Littorina littorea, 2M5, June
COUNT
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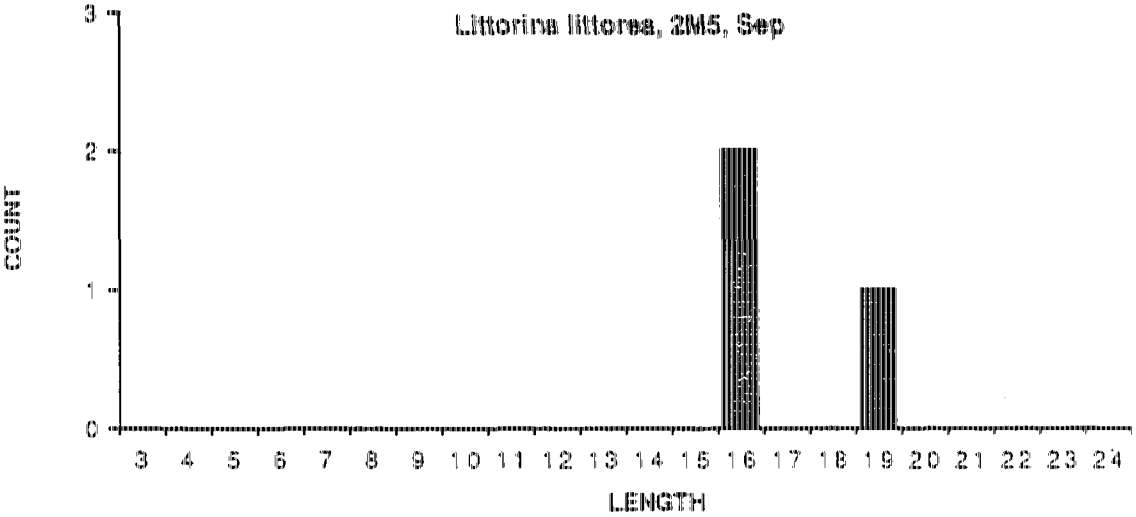
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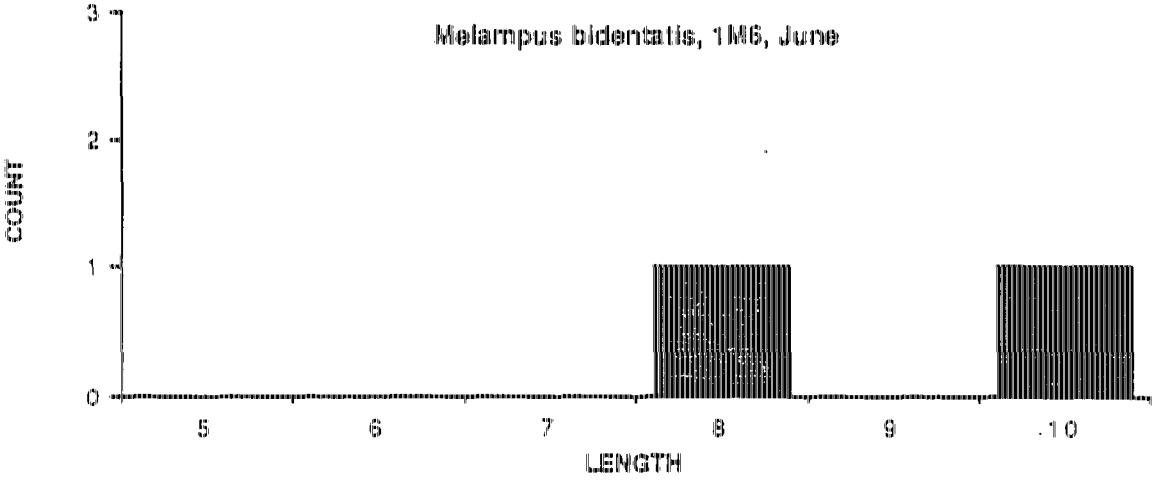
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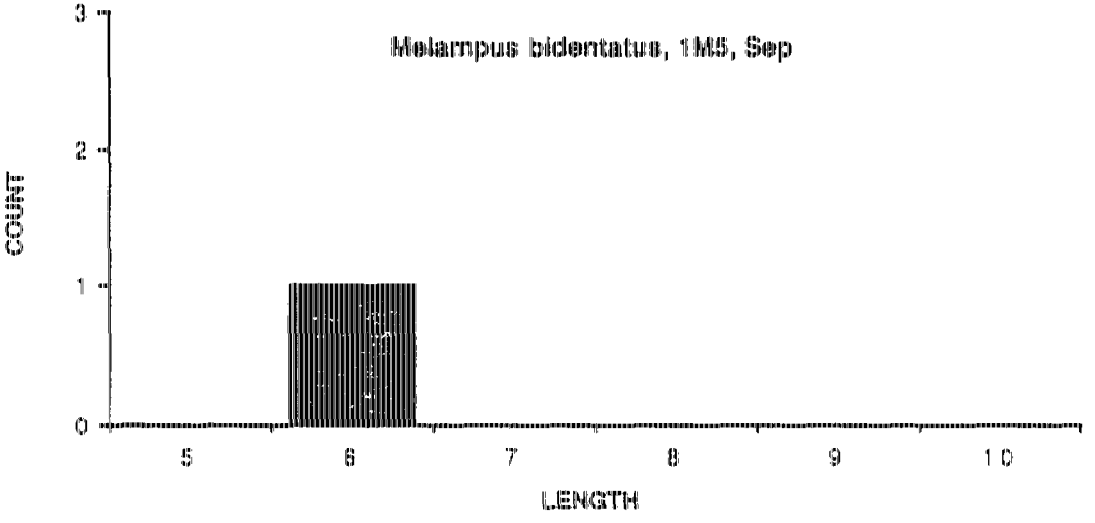
LENGTH


Melampus bidentatus, 1M5, Sep
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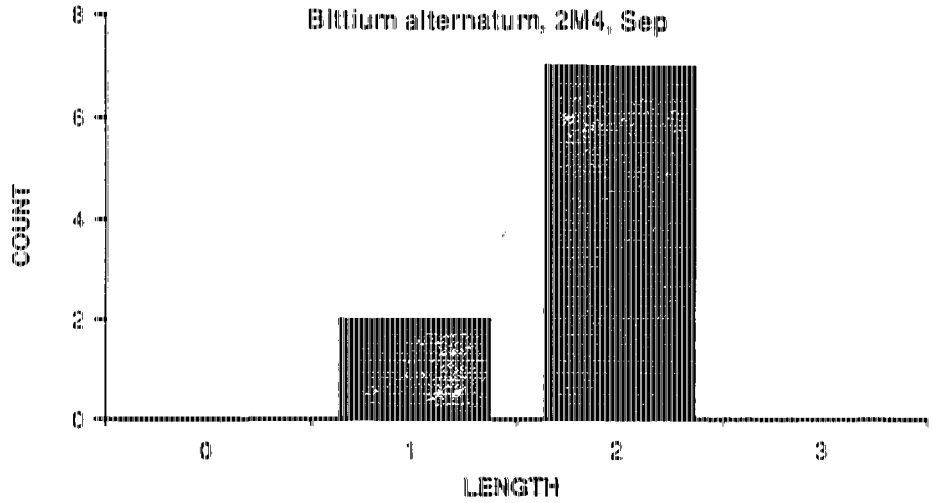
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2
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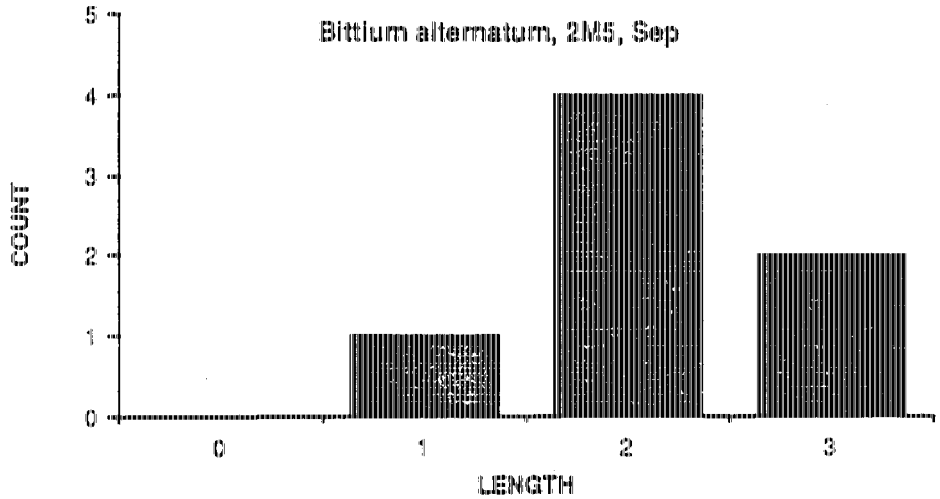
Bittium alternatum, 2M5, Sep
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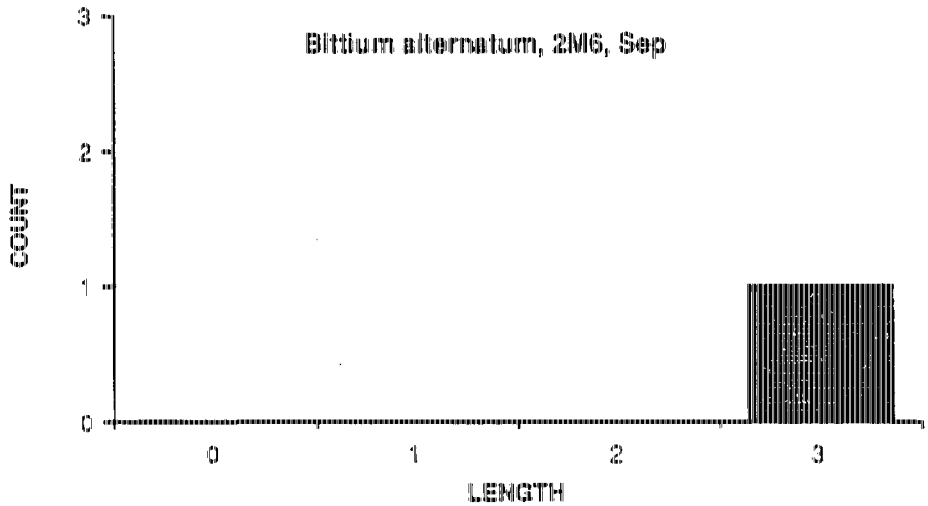
Bittium alternatum, 2M6, Sep
COUNT
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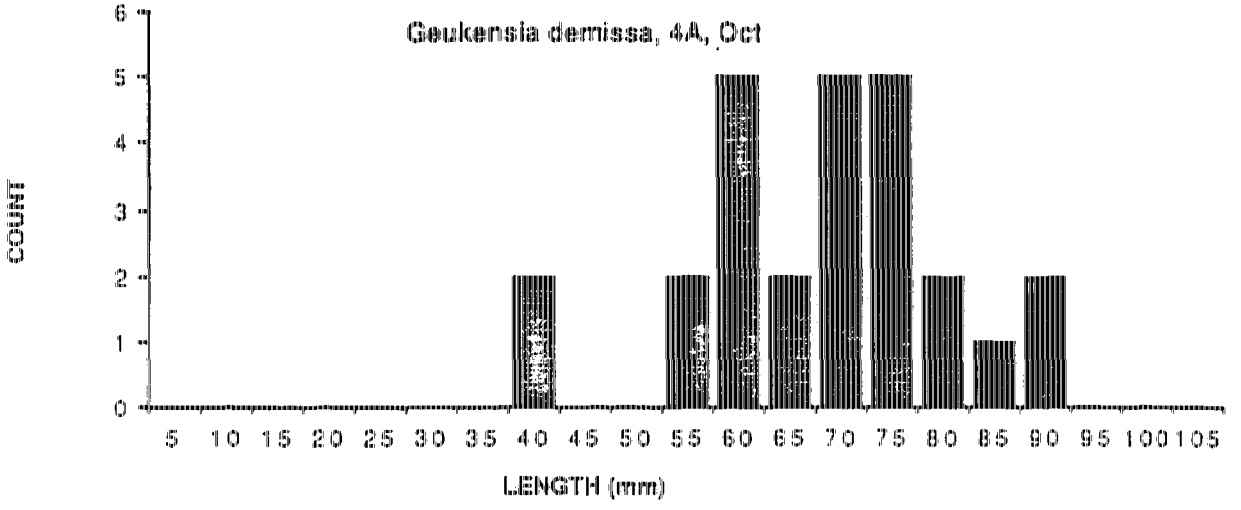
Geukensia demissa, 4A, Oct
COUNT
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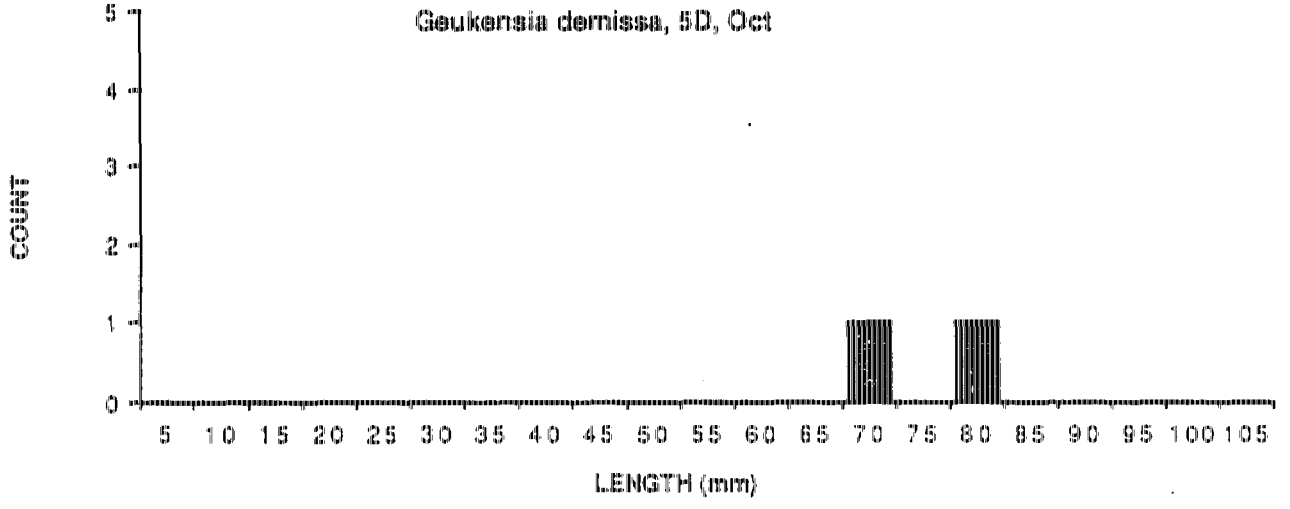
LENGTH (mm)


Geukensia demissa, 5D, Oct
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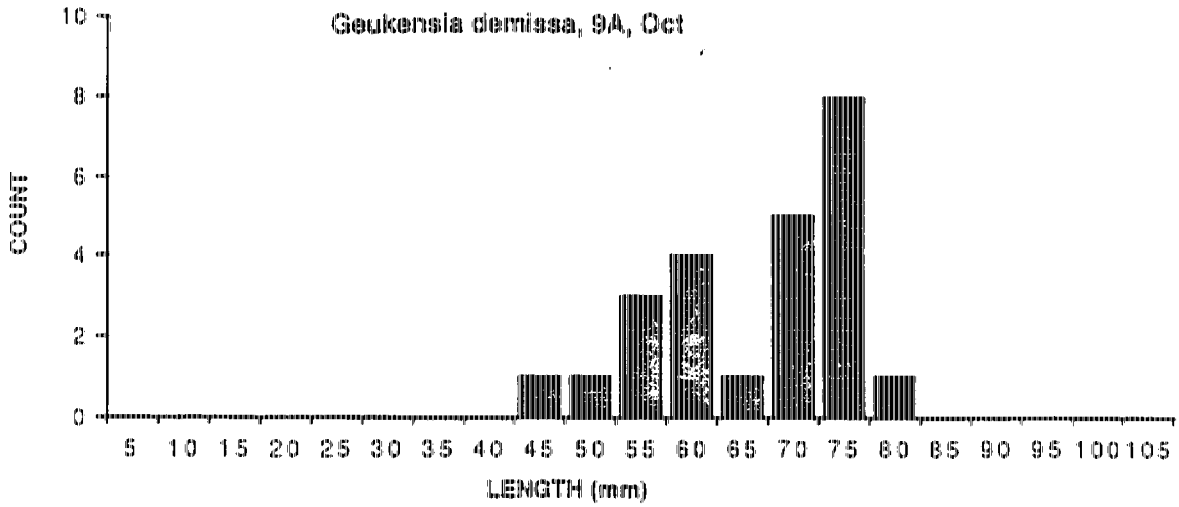
LENGTH (mm)


Geukensia demissa, 9A, Oct
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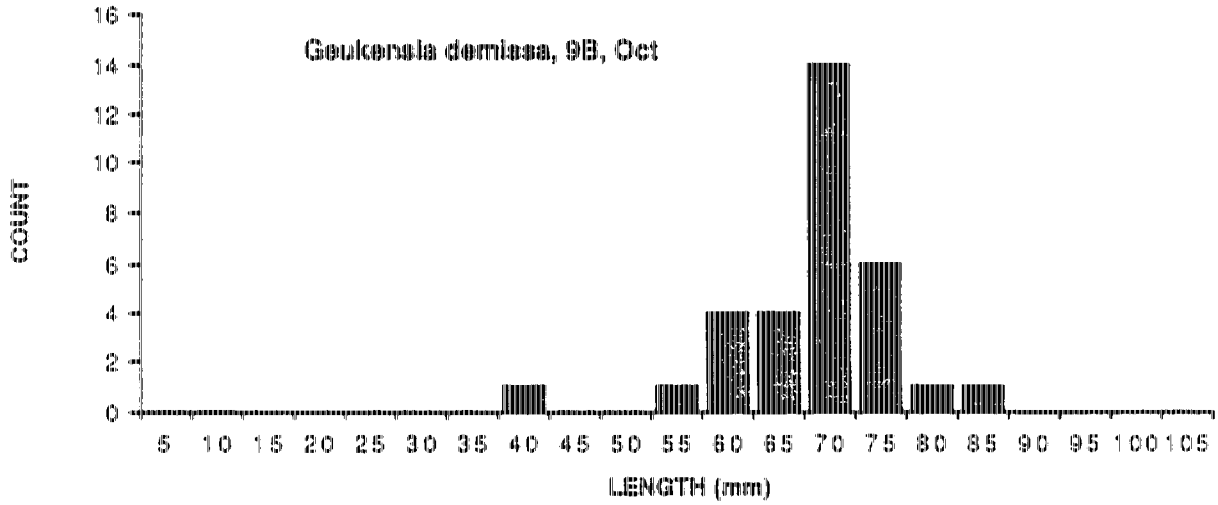
LENGTH (mm)


Geukensia demissa, 9B, Oct
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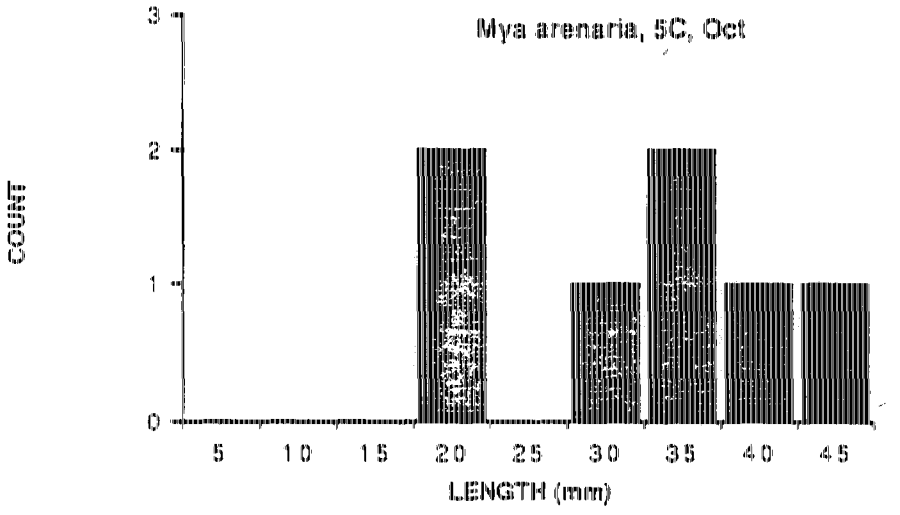
LENGTH (mm)


Mya arenaria, 5C, Oct
COUNT
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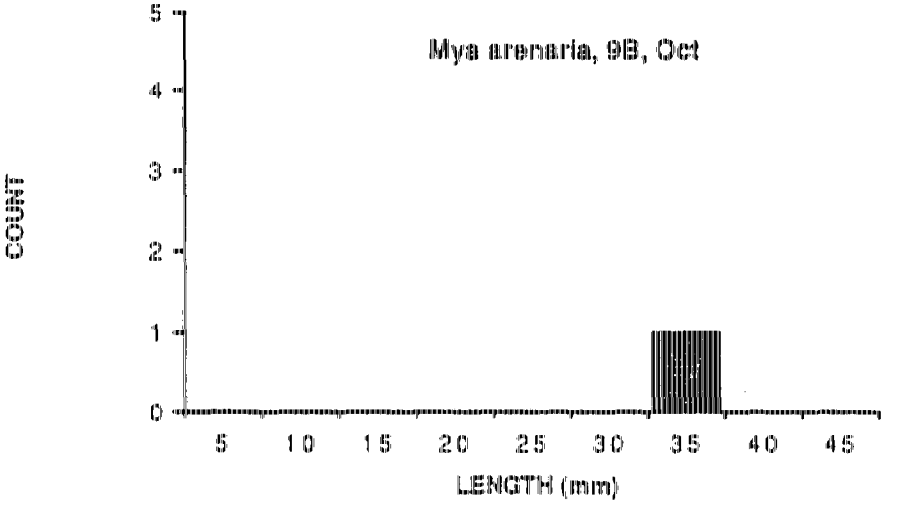
LENGTH (mm)


Mya arenaria, 9B, Oct
COUNT
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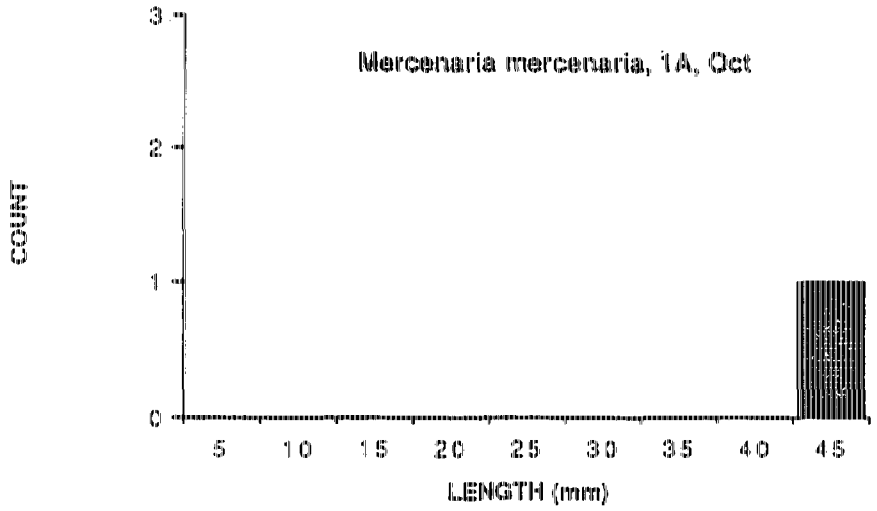
LENGTH (mm)


Mercenaria mercenaria, 1A, Oct
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30
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40
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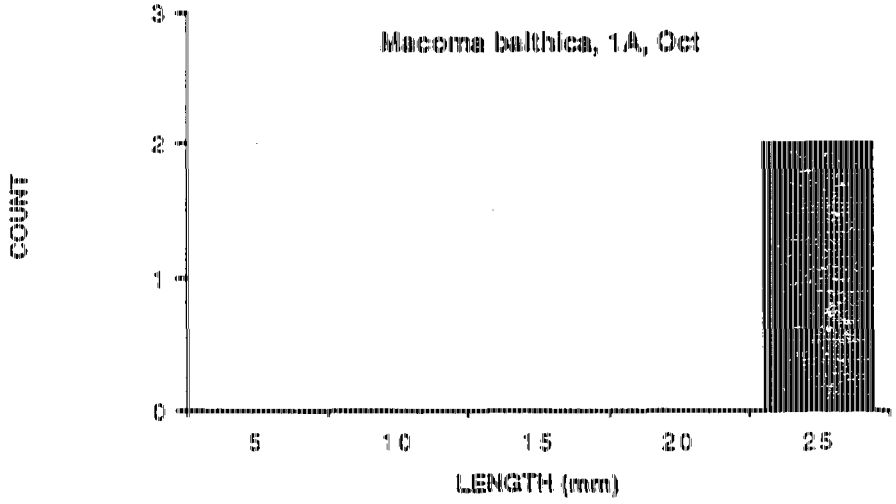
LENGTH (mm)


Macoma balthica, 1A, Oct
COUNT
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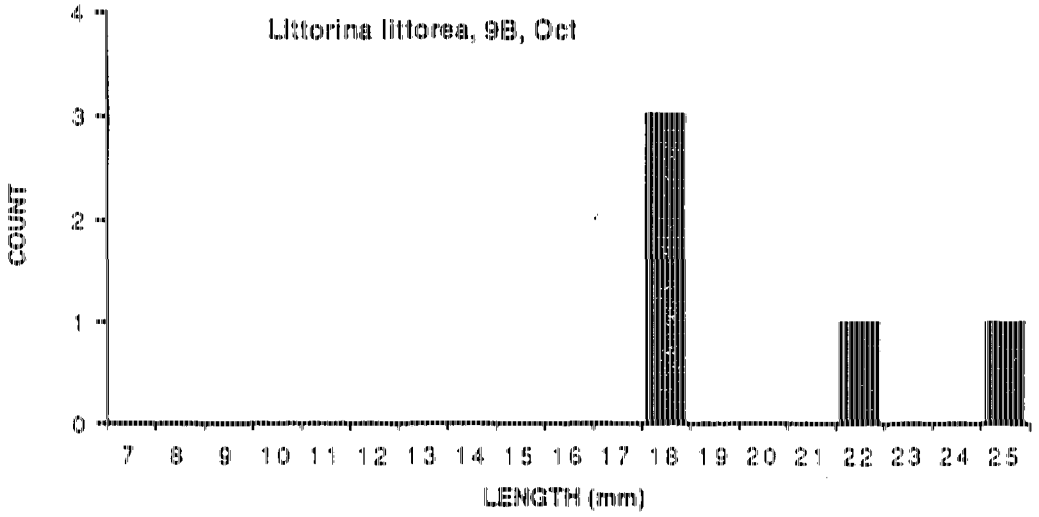
Littorina littorea, 9B, Oct
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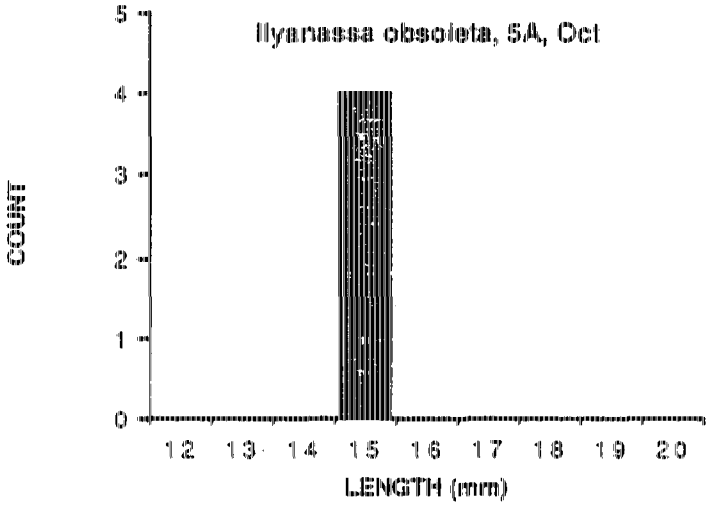
LENGTH (mm)


Ilyanassa obsoleta, 5A, Oct
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4
5
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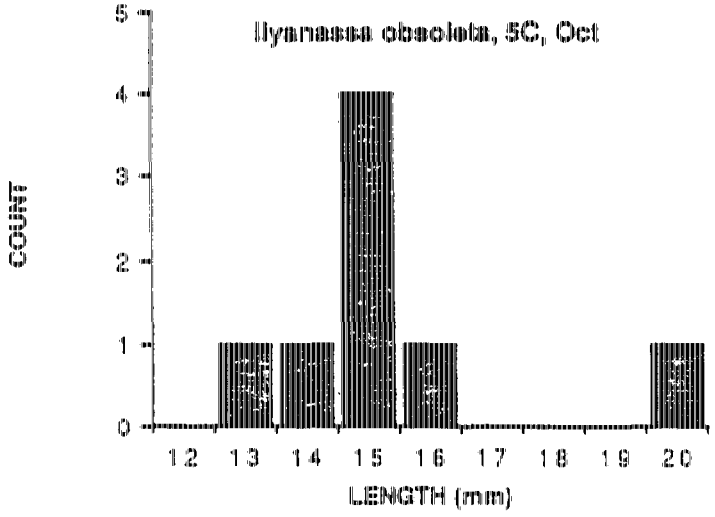
LENGTH (mm)


Ilyanassa obsoleta, 5C, Oct
COUNT
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4
5
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LENGTH (mm)

6.1 SCIENTIFIC AND COMMON NAMES OF PLANTS

IEP inc.

APPENDIX 6A. SCIENTIFIC AND COMMON NAMES OF PLANT SPECIES.

Ammophila breviligulata	American Beach Grass
Aster tenifolius	Salt Marsh Aster
Atriplex patula	Marsh Orach
Convolvulus sp	Bindweed
Distichlis spicata	Spike Grass
Elymus virginicus	Seaside Rye
Gerardia maritima	Seaside Gerardia
Iva frutescens	High Tide Bush
Juncus gerardii	Black Rush
Limonium nashii	Sea Lavender
Phragmites australis	Common Reed
Plantago sp	Seaside Plantain
Salicornia europaea	Glasswort
Salicornia virginica	Glasswort
Solidago sempervirens	Seaside Goldenrod
Spartina alterniflora	Salt Water Cordgrass
Spartina patens	Salt Meadow Cordrass
Spergularia marina	Seaside Spurge
Suaeda linearis	Sea Blite
Suaeda maritima	Sea Blite
Triglochin maritima	Seaside Arrow Grass

8.1 SCIENTIFIC AND COMMON NAMES OF BIRDS AND MAMMALS

APPENDIX 8A. SCIENTIFIC NAMES OF BIRD SPECIES.

Horned Grebe	Podiceps auritus
Double-crested Cormorant	Phalacrocorax auritus
Great Blue Heron	Ardea herodias
Green-backed Heron	Butorides striatus
Black-crowned Night Heron	Nycticorax nycticorax
Great Egret	Casmerodius albus
Snowy Egret	Egretta thula
American Black Duck	Anas rubripes
Mallard	Anas platyrhynchos
Canada Goose	Branta canadensis
Mute Swan	Cygnus olor
Northern Harrier	Circus cyaneus
Osprey	Pandion haliaetus
American Kestrel	Falco sparverius
Ring-necked Pheasant	Phasianus colchicus
Clapper Rail	Rallus longirostris
Black-bellied Plover	Pluvialis squatarola
Killdeer	Charadrius vociferus
Spotted Sandpiper	Actitus macularia
Least Sandpiper	Calidris minutilla
Semi-palmated Sandpiper	Calidris pusilla
Lesser Yellowlegs	Tringa flavipes
Greater Yellowlegs	Tringa melanoleuca
Greater Black-backed Gull	Larus marinus
Herring Gull	Larus argentatus
Ring-billed Gull	Larus delawarensis
Laughing Gull	Larus atricilla
Common Tern	Sterna hirundo
Least Tern	Sterna antillarum
Chimney Swift	Chaetura pelagica
Belted Kingfisher	Ceryle alcyon
Common Flicker	Colaptes auratus

APPENDIX Continued.

Barn Swallow.....Hirundo rustica
Tree Swallow.....Tachycineta bicolor
Eastern Kingbird.....Tyrannus tyrannus
Blue Jay.....Cyanocitta cristata
Common Crow.....Corvus brachyrhynchos
Black-capped Chickadee.....Parus atricapillus
Tufted Titmouse.....Parus bicolor
House Wren.....Troglodytes aedon
Northern Mockingbird.....Mimus polyglottos
Gray Catbird.....Dumetella carolinensis
American Robin.....Turdus migratorius
Cedar Waxwing.....Bombycilla cedrorum
European Starling.....Sturnus vulgaris
White-eyed Vireo.....Vireo griseus
Yellow Warbler.....Dendroica petechia
Common Yellowthroat.....Geothlypsis trichas
Red-winged Blackbird.....Agelaius phoenicieus
Brown-headed Cowbird.....Molothrus ater
Common Grackle.....Quiscalus quiscala
Northern Oriole.....Icterus galbula
Rufous-sided Towhee.....Pipilo erythrophthalmus
Northern Cardinal.....Cardinalis cardinalis
House Finch.....Carpodacus mexicanus
Purple Finch.....Carpodacus purpureus
Field Sparrow.....Spizella pusilla
Song Sparrow.....Melospiza melodia
Swamp Sparrow.....Melospiza georgiana
Sharp-tailed Sparrow.....Ammodramus caudacutus
American Goldfinch.....Carduelis tristis
House Sparrow.....Passer domesticus

APPENDIX 8B. SCIENTIFIC NAMES OF MAMMALIAN SPECIES.

Meadow Vole	Microtus pennsylvanicus
Norway Rat	Rattus norvegicus
Gray Squirrel	Sciurus carolinensis
Raccoon	Procyon lotor
Woodchuck	Marmota monax
Muskrat	Ondatra zibethica
Eastern Cottontail	Sylvilagus floridanus
Red Fox	Vulpes vulpes

10.1 LABORATORY ANALYSIS DATA FOR SEDIMENT, MUSSELS, SHRIMP AND FISH

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254-9149

REPLY TO
ATTENTION OF

December 22, 1987

Planning Division
Impact Analysis Branch

Mr. Lester Garvin
IEP, Inc.
6 Maple Street
P.O. Box 780
Northborough, Massachusetts 01532

Dear Mr. Garvin:

We have completed a preliminary review of the "New Bedford Superfund Site Bioaccumulation Study - Sediment, Mussels, Shrimp, and Fish" prepared by your subcontractor Enseco Inc. as part of the New Bedford Superfund Site Wetland Study, Contract No. DACW33-87-D-0001, Delivery Order No. 0001.

We noted from our review that tissue PCB spike recovery percentages for shrimp were very low (e.g. 5270-19S at 61% and 5270-20SD at 35%). It is questionable whether results in this range are acceptable. Please explain the reason for these low percentages. How do these low recoveries affect confidence in the accuracy and precision of the sample results?

Please also explain the excessive matrix levels for spike recovery in mussel PCB samples (5270-37S and 5270-38SD) and winter flounder sample (5270-43S). It appears that a new QA/QC will need to be performed.

If you have any questions concerning these comments please contact Mr. Larry Oliver of my staff at (617)647-8347.

Sincerely,

Joseph L. Ignazio
Chief, Planning Division

Enseco

January 11, 1988

Mr. Lester Garvin
IEP, Inc.
6 Maple Street
P.O. Box 780
Northborough, MA 01532

Dear Lester:

The major problem with the spike recovery values is that the samples were spiked with a moderate level of PCB-1254 as per our Standard Operating Procedures. However, the samples also contained considerable amounts of PCB-1254. This was corrected for in the spike recovery calculation. Unfortunately, the greater the difference between the spiking level and the matrix contribution, the greater the variability is in spike recoveries.

In a recent performance evaluation study, conducted by the New York State Department of Environmental Protection (NYDEP), the 95% confidence limit for the recovery of PCB-1254 in water ranged from 57% to 143%. Our range is reasonable considering the fact that tissue is a far more difficult matrix to extract than water. If a spike recovery falls within a reasonable range (e.g., Shrimp 5270-19S, 20SD), we report it. If a spike recovery falls outside that range and the matrix contribution is excessive (Mussels 5270-37S, 38SD; Winter Flounder 5270-43S) (>2 x spiking level), we comment that the matrix contribution was excessive compared to the spiking level.

I believe that in all cases the observed spike recoveries were influenced by the natural variability of PCB-1254 in the samples. The preferred spiking compound is one which does not occur in the natural environment (i.e., ortho terphenyl for hydrocarbon analyses). Unfortunately, such a compound is not currently available for PCBs.

Doaks Lane at Little Harbor
Marblehead, Massachusetts 01945
617 639-2695 Facsimile 617 639-2637

I have enclosed a table of the EPA Contract Laboratory Program's (CLP's) criteria for pesticide spike recoveries in soil samples (a chemical substance and medium not too dissimilar from those addressed in our study). Spike recoveries of from 23 to 134% are identified as being acceptable.

If you have further questions, please do not hesitate to call.

Sincerely,

Curt D. Rose
Senior Technical Specialist

Enclosure
CDR/hmd

SOIL MATRIX SPIKE/MATRIX SPIKE DUPLICATE RECOVERY

Case No. _____ Contractor Enseco - Erco Laboratory Contract No. _____

Low Level _____ Medium Level _____

FRACTION	COMPOUND	CONC. SPIKE ADDED (ug/Kg)	SAMPLE RESULT	CONC. MS	% REC	CONC. MSD	% REC	RPD	QC LIMITS* RPD	QC LIMITS* RECOVERY
VOA SMO SAMPLE NO. _____	1,1-Dichloroethene								22	59-172
	Trichloroethene								24	62-137
	Chlorobenzene								21	60-133
	Toluene								21	59-139
	Benzene								21	66-142
B/N SMO SAMPLE NO. _____	1,2,4-Trichlorobenzene								23	39-107
	Acenaphthene								19	31-137
	2,4-Dinitrotoluene								47	28-89
	Pyrene								36	35-142
	N-Nitroso-di-n-Propylamine								38	41-126
	1,4-Dichlorobenzene								27	28-104
ACID SMO SAMPLE NO. _____	Pentachlorophenol								47	17-109
	Phenol								35	26-90
	2-Chlorophenol								40	25-102
	4-Chloro-3-Methylphenol								33	26-103
	4-Nitrophenol								50	11-114
PEST SMO SAMPLE NO. _____	Lindane								50	46-127
	Heptachlor								31	35-130
	Aldrin								43	34-132
	Dieldrin								38	31-134
	Endrin								45	42-139
	4,4'-DDT								50	23-134

*ASTERISKED VALUES ARE OUTSIDE QC LIMITS.

RPD: VOAs _____ out of _____; outside QC limits
B/N _____ out of _____; outside QC limits
ACID _____ out of _____; outside QC limits
PEST _____ out of _____; outside QC limits

RECOVERY: VOAs _____ out of _____; outside QC limits
B/N _____ out of _____; outside QC limits
ACID _____ out of _____; outside QC limits
PEST _____ out of _____; outside QC limits

Comments: _____

7/85

FORM III

JAN 11 '88 15:10 ERCO 908 .02

TABLE OF CONTENTS

Section[a]

1. SEDIMENT (ACCUMULATION OF Cd, Cr, Cu, Pb, Hg, Zn, AND PCBs)

2. SHRIMP (BIOACCUMULATION OF Cd, Cr, Cu, Fe, Pb, Hg, Zn, AND PCBs)

3. RIBBED MUSSELS (BIOACCUMULATION OF Cd, Cr, Cu, Pb, Hg, Zn, PCBs, AND TOTAL AROMATIC HYDROCARBONS; ALSO, SHELL AND MEAT CHARACTERISTICS OF EVALUATED ORGANISMS)

4. FISHES -- FLOUNDERS AND MUMMICHOGS (BIOACCUMULATION OF Cd, Cr, Cu, Pb, Hg, Zn, AND PCBs; ALSO, LIVER NEOPLASMS AND TUMORS IN FLOUNDERS)

[a]Each section contains main analytical data followed by QA/QC data. In the case of all bioaccumulation data (Section 2, 3, and 4), concentrations of constituents are reported on a wet-weight basis.

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 4-HM-1

Laboratory ID: 5269-07

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	78	mg/kg (dry wt)	1	6010
Copper	140	mg/kg (dry wt)	1	6010
Lead	130	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	160	mg/kg (dry wt)	1	6010

Solid content = 17.4%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 4-HM-2

Laboratory ID: 5269-08

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	220	mg/kg (dry wt)	1	6010
Copper	410	mg/kg (dry wt)	1	6010
Lead	300	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	260	mg/kg (dry wt)	1	6010

Solid content = 26.6%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 4-HM-3

Laboratory ID: 5269-09

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	8.0	mg/kg (dry wt)	1	6010
Copper	22	mg/kg (dry wt)	1	6010
Lead	19	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	16	mg/kg (dry wt)	1	6010

Solid content = 78.8%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 4-LM-1

Laboratory ID: 5269-10

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	1.7	mg/kg (dry wt)	0.5	6010
Chromium	56	mg/kg (dry wt)	1	6010
Copper	110	mg/kg (dry wt)	1	6010
Lead	53	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	130	mg/kg (dry wt)	1	6010

Solid content = 63.9%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 4-LM-2

Laboratory ID: 5269-11

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	74	mg/kg (dry wt)	1	6010
Copper	160	mg/kg (dry wt)	1	6010
Lead	70	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	110	mg/kg (dry wt)	1	6010

Solid content = 48.1%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 4-LM-3

Laboratory ID: 5269-12

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	85	mg/kg (dry wt)	1	6010
Copper	330	mg/kg (dry wt)	1	6010
Lead	240	mg/kg (dry wt)	5	6010
Mercury	0.60	mg/kg (dry wt)	0.1	7471
Zinc	110	mg/kg (dry wt)	1	6010

Solid content = 33.2%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by /45 Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 5-HM-1

Laboratory ID: 5269-01

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	270	mg/kg (dry wt)	1	6010
Copper	280	mg/kg (dry wt)	1	6010
Lead	280	mg/kg (dry wt)	5	6010
Mercury	0.61	mg/kg (dry wt)	0.1	7471
Zinc	210	mg/kg (dry wt)	1	6010

Solid content = 26.5%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 5-HM-2

Laboratory ID: 5269-02

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	35	mg/kg (dry wt)	1	6010
Copper	42	mg/kg (dry wt)	1	6010
Lead	66	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	91	mg/kg (dry wt)	1	6010

Solid content = 79.1%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 5-HM-3

Laboratory ID: 5269-03

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	2.1	mg/kg (dry wt)	0.5	6010
Chromium	300	mg/kg (dry wt)	1	6010
Copper	310	mg/kg (dry wt)	1	6010
Lead	590	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	380	mg/kg (dry wt)	1	6010

Solid content = 23.9%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 5-LM-1

Laboratory ID: 5269-04

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	9.0	mg/kg (dry wt)	1	6010
Copper	7.4	mg/kg (dry wt)	1	6010
Lead	ND	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	36	mg/kg (dry wt)	1	6010

Solid content = 68.0%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 5-LM-2

Laboratory ID: 5269-05

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	10	mg/kg (dry wt)	0.5	6010
Chromium	340	mg/kg (dry wt)	1	6010
Copper	420	mg/kg (dry wt)	1	6010
Lead	250	mg/kg (dry wt)	5	6010
Mercury	0.47	mg/kg (dry wt)	0.1	7471
Zinc	330	mg/kg (dry wt)	1	6010

Solid content = 29.3%

*Reporting limit based on 100% solid.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 5-LM-3

Laboratory ID: 5269-06

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	32	mg/kg (dry wt)	0.5	6010
Chromium	540	mg/kg (dry wt)	1	6010
Copper	1,130	mg/kg (dry wt)	1	6010
Lead	390	mg/kg (dry wt)	5	6010
Mercury	0.93	mg/kg (dry wt)	0.1	7471
Zinc	8,780	mg/kg (dry wt)	1	6010

Solid content = 28.7%

*Reporting limit based on 100% solid.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 9-HM-1

Laboratory ID: 5269-13

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	54	mg/kg (dry wt)	1	6010
Copper	220	mg/kg (dry wt)	1	6010
Lead	430	mg/kg (dry wt)	5	6010
Mercury	0.70	mg/kg (dry wt)	0.1	7471
Zinc	440	mg/kg (dry wt)	1	6010

Solid content = 26.3%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 9-HM-2

Laboratory ID: 5269-14

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	220	mg/kg (dry wt)	1	6010
Copper	550	mg/kg (dry wt)	1	6010
Lead	370	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	72	mg/kg (dry wt)	1	6010

Solid content = 15.6%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 9-HM-3

Laboratory ID: 5269-15

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	670	mg/kg (dry wt)	1	6010
Copper	290	mg/kg (dry wt)	1	6010
Lead	1,060	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	110	mg/kg (dry wt)	1	6010

Solid content = 18.0%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 9-LM-1

Laboratory ID: 5269-16

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	2.0	mg/kg (dry wt)	0.5	6010
Chromium	130	mg/kg (dry wt)	1	6010
Copper	420	mg/kg (dry wt)	1	6010
Lead	250	mg/kg (dry wt)	5	6010
Mercury	0.41	mg/kg (dry wt)	0.1	7471
Zinc	210	mg/kg (dry wt)	1	6010

Solid content = 38.0%

*Reporting limit based on 100% solid.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 9-LM-2

Laboratory ID: 5269-17

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	30	mg/kg (dry wt)	1	6010
Copper	70	mg/kg (dry wt)	1	6010
Lead	42	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	110	mg/kg (dry wt)	1	6010

Solid content = 14.7%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 9-LM-3

Laboratory ID: 5269-18

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	24	mg/kg (dry wt)	1	6010
Copper	100	mg/kg (dry wt)	1	6010
Lead	100	mg/kg (dry wt)	5	6010
Mercury	0.23	mg/kg (dry wt)	0.1	7471
Zinc	94	mg/kg (dry wt)	1	6010

Solid content = 73.2%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Erco Blank

Laboratory ID: 5269-21

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	ND	mg/kg (dry wt)	0.5	6010
Chromium	ND	mg/kg (dry wt)	1	6010
Copper	ND	mg/kg (dry wt)	1	6010
Lead	ND	mg/kg (dry wt)	5	6010
Mercury	ND	mg/kg (dry wt)	0.1	7471
Zinc	ND	mg/kg (dry wt)	1	6010

Solid content = 100%

*Reporting limit based on 100% solid.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 9-LM-3 Matrix Spike

Laboratory ID: 5269-19

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	6.8 (100)	mg/kg (dry wt)	0.5	6010
Chromium	56 (118)	mg/kg (dry wt)	1	6010
Copper	210 (331)	mg/kg (dry wt)	1	6010
Lead	170 (101)	mg/kg (dry wt)	5	6010
Mercury	1.9 (100)	mg/kg (dry wt)	0.1	7471
Zinc	190 (146)	mg/kg (dry wt)	1	6010

Solid content = 73.2%

*Reporting limit based on 100% solid.

Reported by LAS Approved by CAK

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: 9-LM-3 Matrix Spike Dup.

Laboratory ID: 5269-20

Matrix: Solid Sampled: 09/03/87 Received: 09/04/87

Authorized: 09/10/87 Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Theoretical Reporting Limit*	Analytical Method
Cadmium	6.1 (90)	mg/kg (dry wt)	0.5	6010
Chromium	51 (101)	mg/kg (dry wt)	1	6010
Copper	120 (51)	mg/kg (dry wt)	1	6010
Lead	130 (44)	mg/kg (dry wt)	5	6010
Mercury	1.4 (98)	mg/kg (dry wt)	0.1	7471
Zinc	150 (78)	mg/kg (dry wt)	1	6010

Solid content = 73.2%

*Reporting limit based on 100% solid.

Reported by LAS Approved by CAK

METALS QC

Laboratory ID: Blank

Matrix: Sediment Received: 09/04/87

Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Result	Units	Reporting Limit	Analytical Method
Aluminum	ND	mg/kg	5	6010
Antimony	ND	mg/kg	5	6010
Arsenic	†	mg/kg	0.3	7060
Barium	ND	mg/kg	0.5	6010
Beryllium	ND	mg/kg	0.1	6010
Cadmium	ND	mg/kg	0.5	6010
Calcium	ND	mg/kg	20	6010
Chromium	ND	mg/kg	1	6010
Cobalt	ND	mg/kg	1	6010
Copper	ND	mg/kg	1	6010
Iron	ND	mg/kg	5	6010
Lead	ND	mg/kg	5	6010
Magnesium	ND	mg/kg	10	6010
Manganese	ND	mg/kg	0.5	6010
Mercury	ND	mg/kg	0.10	7471
Nickel	ND	mg/kg	4	6010
Potassium	ND	mg/kg	500	6010
Selenium	†	mg/kg	0.2	7740
Silver	ND	mg/kg	0.5	6010
Sodium	ND	mg/kg	50	6010
Thallium	†	mg/kg	0.4	7841
Tin	ND	mg/kg	10	6010
Vanadium	ND	mg/kg	1	6010
Zinc	ND	mg/kg	1	6010

†Not analyzed.

ND = Not detected.

Reported by LAS Approved by CAK

Enseco

METALS QC

Laboratory ID: Spike

Matrix: Sediment Received: 09/04/87

Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Spike Added	% Recovery	Units	Reporting Limit	Analytical Method
Aluminum	*	*	mg/L	5	6010
Antimony	0.500	89	mg/L	5	6010
Arsenic	0.040	†	mg/L	0.3	7060
Barium	2.0	88	mg/L	0.5	6010
Beryllium	0.050	78	mg/L	0.1	6010
Cadmium	0.050	88	mg/L	0.5	6010
Calcium	*	*	mg/L	20	6010
Chromium	0.200	89	mg/L	1	6010
Cobalt	0.500	82	mg/L	1	6010
Copper	0.250	90	mg/L	1	6010
Iron	*	*	mg/L	5	6010
Lead	0.50	87	mg/L	5	6010
Magnesium	*	*	mg/L	10	6010
Manganese	0.500	87	mg/L	0.5	6010
Mercury	0.0025	108	mg/L	0.10	7471
Nickel	0.500	86	mg/L	4	6010
Potassium	*	*	mg/L	500	6010
Selenium	0.010	†	mg/L	0.2	7740
Silver	0.050	74	mg/L	0.5	6010
Sodium	*	*	mg/L	50	6010
Thallium	0.050	†	mg/L	0.4	7841
Tin	0.500	95	mg/L	10	6010
Vanadium	0.500	83	mg/L	1	6010
Zinc	0.500	86	mg/L	1	6010

†Not analyzed.

*Element spike not required by CLP method.

Reported by LAS Approved by CAK

Enseco

METALS QC

Laboratory ID: Spike Dup.

Matrix: Sediment Received: 09/04/87

Prepared: 10/05/87 Analyzed: 10/21/87

Parameter	Spike Added	% Recovery	Units	Reporting Limit	Analytical Method
Aluminum	*	*	mg/L	5	6010
Antimony	0.500	85	mg/L	5	6010
Arsenic	0.040	†	mg/L	0.3	7060
Barium	2.0	85	mg/L	0.5	6010
Beryllium	0.050	76	mg/L	0.1	6010
Cadmium	0.050	80	mg/L	0.5	6010
Calcium	*	*	mg/L	20	6010
Chromium	0.200	85	mg/L	1	6010
Cobalt	0.500	82	mg/L	1	6010
Copper	0.250	87	mg/L	1	6010
Iron	*	*	mg/L	5	6010
Lead	0.50	82	mg/L	5	6010
Magnesium	*	*	mg/L	10	6010
Manganese	0.500	84	mg/L	0.5	6010
Mercury	0.0025	108	mg/L	0.10	7471
Nickel	0.500	83	mg/L	4	6010
Potassium	*	*	mg/L	500	6010
Selenium	0.010	†	mg/L	0.2	7740
Silver	0.050	70	mg/L	0.5	6010
Sodium	*	*	mg/L	50	6010
Thallium	0.050	†	mg/L	0.4	7841
Tin	0.500	90	mg/L	10	6010
Vanadium	0.500	80	mg/L	1	6010
Zinc	0.500	83	mg/L	1	6010

†Not analyzed.

*Element spike not required by CLP method.

Reported by LAS Approved by CAK

TOTAL POLYCHLORINATED BIPHENYLS (PCBS)

Client Name: ENSECO-Marblehead (IEP)
Matrix: Sediments Sampled: 09/03/87 Received: 09/04/87
Authorized: 09/10/87 Prepared: 09/16-9/17/87 Analyzed: 9/25-9/29/87

Erco ID	Client ID	Total PCBs	Units*	Reporting Limit
5269-07	4-HM-1	14	ug/g	1.0
5269-08	4-HM-2	97	ug/g	1.0
5269-09	4-HM-3	0.4	ug/g	0.03
5269-10	4-LM-1	10	ug/g	0.27
5269-11	4-LM-2	26	ug/g	0.56
5269-12	4-LM-3	290	ug/g	4.7
5269-01	5-HM-1	39	ug/g	1.1
5269-02	5-HM-2	7.2	ug/g	0.35
5269-03	5-HM-3	50	ug/g	1.0
5269-04	5-LM-1	1.0	ug/g	0.07
5269-05	5-LM-2	57	ug/g	1.4
5269-06	5-LM-3	410	ug/g	5.8
5269-13	9-HM-1	0.58	ug/g	0.05
5269-14	9-HM-2	13	ug/g	0.46
5269-15	9-HM-3	44	ug/g	1.6
5269-16	9-LM-1	45	ug/g	0.53
5269-17	9-LM-2	5.3	ug/g	0.23
5269-18	9-LM-3	14	ug/g	0.44
5269-18D	9-LM-3	12	ug/g	0.44
5269-18T	9-LM-3	16	ug/g	0.37
5269-21B	Erco Blank	ND	ug/g	0.01

Spike recovery (%) **

5269-19 spike	5-LM-1	87
5269-19 spike	5-LM-1 (dup)	130

* Dry weight
** Sample was spiked with 1000 ug of Aroclor 1260.
NA = Not applicable
ND = Not detected

Reported by LAS (co MMA) Approved by ESC (co MMA)

A-101

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 1

Laboratory ID: 5270-04

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	0.97	mg/kg	0.5	7191
Copper	42	mg/kg	10	7210
Iron	73	mg/kg	10	7380
Lead	0.87	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	20	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 1 Dup.

Laboratory ID: 5270-05

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Uni	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	1.1	mg/kg	0.5	7191
Copper	43	mg/kg	10	7210
Iron	73	mg/kg	10	7380
Lead	0.91	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	20	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 1 Trip

Laboratory ID: 5270-06

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	0.83	mg/kg	0.5	7191
Copper	47	mg/kg	10	7210
Iron	71	mg/kg	10	7380
Lead	0.91	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	21	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 2

Laboratory ID: 5270-16

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	32	mg/kg	10	7210
Iron	38	mg/kg	10	7380
Lead	0.85	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	19	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 2 Dup.

Laboratory ID: 5270-17

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	33	mg/kg	10	7210
Iron	46	mg/kg	10	7380
Lead	1.2	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	21	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 2 Trip

Laboratory ID: 5270-18

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	34	mg/kg	10	7210
Iron	40	mg/kg	10	7380
Lead	0.50	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	20	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LPS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 3

Laboratory ID: 5270-01

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	0.53	mg/kg	0.5	7191
Copper	41	mg/kg	10	7210
Iron	42	mg/kg	10	7380
Lead	0.80	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	20	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 3 Dup.

Laboratory ID: 5270-02

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	41	mg/kg	10	7210
Iron	39	mg/kg	10	7380
Lead	0.92	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	20	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 3 Trip

Laboratory ID: 5270-03

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	0.54	mg/kg	0.5	7191
Copper	38	mg/kg	10	7210
Iron	43	mg/kg	10	7380
Lead	0.76	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	20	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LRS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 4

Laboratory ID: 5270-10

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	0.50	mg/kg	0.5	7191
Copper	37	mg/kg	10	7210
Iron	49	mg/kg	10	7380
Lead	ND	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	15	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LBS Approved by SDC

A-111

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 4 Dup.

Laboratory ID: 5270-11

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	35	mg/kg	10	7210
Iron	50	mg/kg	10	7380
Lead	ND	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	16	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 4 Trip

Laboratory ID: 5270-12

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	33	mg/kg	10	7210
Iron	51	mg/kg	10	7380
Lead	0.66	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	15	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LPS Approved by SDS

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 5

Laboratory ID: 5270-07

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	0.80	mg/kg	0.5	7191
Copper	36	mg/kg	10	7210
Iron	74	mg/kg	10	7380
Lead	1.1	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	20	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 5 Dup.

Laboratory ID: 5270-08

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	0.79	mg/kg	0.5	7191
Copper	35	mg/kg	10	7210
Iron	78	mg/kg	10	7380
Lead	1.2	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	20	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 5 Trip

Laboratory ID: 5270-09

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	0.85	mg/kg	0.5	7191
Copper	38	mg/kg	10	7210
Iron	76	mg/kg	10	7380
Lead	1.2	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	20	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LPS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 9

Laboratory ID: 5270-13

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	38	mg/kg	10	7210
Iron	42	mg/kg	10	7380
Lead	0.62	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	17	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 9 Dup.

Laboratory ID: 5270-14

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	37	mg/kg	10	7210
Iron	46	mg/kg	10	7380
Lead	0.59	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	17	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAO Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 9 Trip

Laboratory ID: 5270-15

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	41	mg/kg	10	7210
Iron	41	mg/kg	10	7380
Lead	0.63	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	18	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - Blank

Laboratory ID: 5270-21

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.1	7131
Chromium	ND	mg/kg	0.5	7191
Copper	ND	mg/kg	10	7210
Iron	ND	mg/kg	10	7380
Lead	ND	mg/kg	0.5	7421
Mercury	ND	mg/kg	0.01	††
Zinc	ND	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 5 Matrix Spike

Laboratory ID: 5270-19

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result**	Units	Reporting Limit	Analytical Method*
Cadmium	41 (96)	mg/kg	0.1	7131
Chromium	4.5 (86)	mg/kg	0.5	7191
Copper	122 (99)	mg/kg	10	7210
Iron	79 (†††)	mg/kg	10	7380
Lead	4.7 (83)	mg/kg	0.5	7421
Mercury	0.22 (95)	mg/kg	0.01	††
Zinc	103 (97)	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

**Value in parentheses represents percent spike recovery.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

†††Spike concentration less than 10% of sample concentration.

Reported by LPS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Shrimp - 5 Matrix Spike Dup.

Laboratory ID: 5270-20

Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result**	Units	Reporting Limit	Analytical Method*
Cadmium	42 (97)	mg/kg	0.1	7131
Chromium	5.3 (101)	mg/kg	0.5	7191
Copper	125 (100)	mg/kg	10	7210
Iron	77 (†††)	mg/kg	10	7380
Lead	5.2 (91)	mg/kg	0.5	7421
Mercury	0.20 (92)	mg/kg	0.01	††
Zinc	104 (96)	mg/kg	2	7950

*Method 3050 from SW-846 used on all elements except for mercury.

**Value in parentheses represents percent spike recovery.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

†††Spike concentration less than 10% of sample concentration.

Reported by LBS Approved by SDC

TOTAL POLYCHLORINATED BIPHENYLS (PCBS)

Client Name: ENSECO-Marblehead (IEP)
Matrix: Tissue Sampled: 09/09/87 Received: 09/15/87
Authorized: 09/17/87 Prepared: 10/05-10/13/87 Analyzed: 10/16-10/19/87

Erco ID	Client ID	Total PCBs	Units*	Reporting Limit
5270-04	shrimp 1	9.2	ug/g	0.28
5270-05	shrimp 1 dup	6.9	ug/g	0.27
5270-06	shrimp 1 trip	6.8	ug/g	0.27
5270-16	shrimp 2	0.45	ug/g	0.07
5270-17	shrimp 2 dup	0.23	ug/g	0.03
5270-18	shrimp 2 trip	0.37	ug/g	0.06
5270-01	shrimp 3	20	ug/g	1.4
5270-02	shrimp 3 dup	33	ug/g	1.4
5270-03	shrimp 3 trip	23	ug/g	1.4
5270-10	shrimp 4	2.7	ug/g	0.26
5270-11	shrimp 4 dup	2.6	ug/g	0.27
5270-12	shrimp 4 trip	1.9	ug/g	0.33
5270-07	shrimp 5	3.8	ug/g	0.26
5270-08	shrimp 5 dup	3.5	ug/g	0.27
5270-09	shrimp 5 trip	3.5	ug/g	0.27
5270-13	shrimp 9	1.2	ug/g	0.26
5270-14	shrimp 9 dup	1.8	ug/g	0.26
5270-15	shrimp 9 trip	2.0	ug/g	0.24
5270-21B	Erco Blank	ND	ug/g	0.01

		Spike Recovery (%)
5270-19S	shrimp 2 spike	61
5270-20SD	shrimp 2 spike (dup)	35

NA = Not applicable
ND = Not detected
* wet weight

Reported by CDS (c HMD) Approved by Sx (c HMD)

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 2-3

Laboratory ID: 5270-25

Matrix: Tissue Sampled: 06/16/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.29	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	3.8	mg/kg	0.5	7210/7211
Lead	0.40	mg/kg	0.25	7421
Mercury	0.010	mg/kg	0.005	††
Zinc	6.7	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 2-3 Dup.

Laboratory ID: 5270-26

Matrix: Tissue Sampled: 06/16/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.28	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	3.9	mg/kg	0.5	7210/7211
Lead	0.62	mg/kg	0.25	7421
Mercury	0.0094	mg/kg	0.005	††
Zinc	6.7	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAB Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 2-3 Trip

Laboratory ID: 5270-27

Matrix: Tissue Sampled: 06/16/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.28	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	3.8	mg/kg	0.5	7210/7211
Lead	0.44	mg/kg	0.25	7421
Mercury	0.0087	mg/kg	0.005	††
Zinc	6.1	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 2-5

Laboratory ID: 5270-22

Matrix: Tissue Sampled: 06/16/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.34	mg/kg	0.05	7131
Chromium	0.55	mg/kg	0.5	7191
Copper	6.9	mg/kg	0.5	7210/7211
Lead	0.60	mg/kg	0.25	7421
Mercury	0.0079	mg/kg	0.005	††
Zinc	7.6	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 2-5 Dup.

Laboratory ID: 5270-23

Matrix: Tissue Sampled: 06/16/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.36	mg/kg	0.05	7131
Chromium	0.59	mg/kg	0.5	7191
Copper	6.6	mg/kg	0.5	7210/7211
Lead	0.59	mg/kg	0.25	7421
Mercury	0.0075	mg/kg	0.005	††
Zinc	8.0	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

Reported by LDB Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 2-5 Trip

Laboratory ID: 5270-24

Matrix: Tissue Sampled: 06/16/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.37	mg/kg	0.05	7131
Chromium	0.58	mg/kg	0.5	7191
Copper	7.7	mg/kg	0.5	7210/7211
Lead	0.73	mg/kg	0.25	7421
Mercury	0.0079	mg/kg	0.005	††
Zinc	7.9	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

Reported by LAB Approved by SJC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 4-1 Trip

Laboratory ID: 5270-33

Matrix: Tissue Sampled: 06/17/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.29	mg/kg	0.05	7131
Chromium	0.56	mg/kg	0.5	7191
Copper	5.3	mg/kg	0.5	7210/7211
Lead	0.85	mg/kg	0.25	7421
Mercury	ND	mg/kg	0.005	††
Zinc	9.3	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 5-2

Laboratory ID: 5270-28

Matrix: Tissue Sampled: 06/16/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.34	mg/kg	0.05	7131
Chromium	0.64	mg/kg	0.5	7191
Copper	2.8	mg/kg	0.5	7210/7211
Lead	0.78	mg/kg	0.25	7421
Mercury	ND	mg/kg	0.005	††
Zinc	8.9	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 5-2 Dup.

Laboratory ID: 5270-29

Matrix: Tissue Sampled: 06/17/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.31	mg/kg	0.05	7131
Chromium	0.67	mg/kg	0.5	7191
Copper	2.9	mg/kg	0.5	7210/7211
Lead	0.76	mg/kg	0.25	7421
Mercury	ND	mg/kg	0.005	††
Zinc	11	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SJC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 5-2 Trip

Laboratory ID: 5270-30

Matrix: Tissue Sampled: 06/17/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.33	mg/kg	0.05	7131
Chromium	0.69	mg/kg	0.5	7191
Copper	2.7	mg/kg	0.5	7210/7211
Lead	0.84	mg/kg	0.25	7421
Mercury	ND	mg/kg	0.005	††
Zinc	9.7	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 9-2

Laboratory ID: 5270-34

Matrix: Tissue Sampled: 06/17/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	1.1	mg/kg	0.05	7131
Chromium	0.80	mg/kg	0.5	7191
Copper	2.2	mg/kg	0.5	7210/7211
Lead	1.0	mg/kg	0.25	7421
Mercury	0.0084	mg/kg	0.005	††
Zinc	6.4	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 9-2 Dup.

Laboratory ID: 5270-35

Matrix: Tissue Sampled: 06/17/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	1.1	mg/kg	0.05	7131
Chromium	0.87	mg/kg	0.5	7191
Copper	2.2	mg/kg	0.5	7210/7211
Lead	0.92	mg/kg	0.25	7421
Mercury	0.0096	mg/kg	0.005	††
Zinc	6.8	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

Reported by LPS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 9-2 Trip

Laboratory ID: 5270-36

Matrix: Tissue Sampled: 06/17/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	0.92	mg/kg	0.05	7131
Chromium	0.76	mg/kg	0.5	7191
Copper	1.9	mg/kg	0.5	7210/7211
Lead	0.83	mg/kg	0.25	7421
Mercury	0.0087	mg/kg	0.005	††
Zinc	6.5	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels - Blank

Laboratory ID: 5270-39

Matrix: Tissue Sampled: 06/17/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	ND	mg/kg	0.5	7210/7211
Lead	ND	mg/kg	0.25	7421
Mercury	ND	mg/kg	0.005	††
Zinc	ND	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LCS Approved by SDC

Ensec

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 4-1 Matrix Spike

Laboratory ID: 5270-37

Matrix: Tissue Sampled: 06/17/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result**	Units	Reporting Limit	Analytical Method*
Cadmium	23 (97)	mg/kg	0.05	7131
Chromium	2.6 (90)	mg/kg	0.5	7191
Copper	49 (95)	mg/kg	0.5	7210/7211
Lead	2.7 (79)	mg/kg	0.25	7421
Mercury	0.13 (104)	mg/kg	0.005	††
Zinc	54 (98)	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

**Value in parentheses represents percent spike recovery.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

Reported by LDS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Mussels 4-1 Matrix Spike Dup.

Laboratory ID: 5270-38

Matrix: Tissue Sampled: 06/17/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result**	Units	Reporting Limit	Analytical Method*
Cadmium	21 (92)	mg/kg	0.05	7131
Chromium	2.3 (77)	mg/kg	0.5	7191
Copper	46 (92)	mg/kg	0.5	7210/7211
Lead	2.8 (90)	mg/kg	0.25	7421
Mercury	0.13 (106)	mg/kg	0.005	††
Zinc	50 (93)	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

**Value in parentheses represents percent spike recovery.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

Reported by LAS Approved by SDC

TOTAL POLYCHLORINATED BIPHENYLS (PCBS)

Client Name: ENSECO-Marblehead (IEP)
Matrix: Tissue Sampled: 06/16/87 Received: 09/15/87
Authorized: 09/17/87 Prepared: 10/05-10/13/87 Analyzed: 10/16-10/19/87

Erco ID	Client ID	Total PCBs	Units*	Reporting Limit
5270-25	mussel 2-3	0.38	ug/g	0.20
5270-26	mussel 2-3 dup	0.50	ug/g	0.20
5270-27	mussel 2-3 trip	0.90	ug/g	0.20
5270-22	mussel 2-5	0.47	ug/g	0.20
5270-23	mussel 2-5 dup	0.77	ug/g	0.20
5270-24	mussel 2-5 trip	0.80	ug/g	0.20
5270-31	mussel 4-1	10	ug/g	1.0
5270-32	mussel 4-1 dup	10	ug/g	1.0
5270-33	mussel 4-1 trip	11	ug/g	1.0
5270-28	mussel 5-2	14	ug/g	1.0
5270-29	mussel 5-2 dup	16	ug/g	1.0
5270-30	mussel 5-2 trip	12	ug/g	1.0
5270-34	mussel 9-2	2.7	ug/g	0.21
5270-35	mussel 9-2 dup	1.7	ug/g	0.19
5270-36	mussel 9-2 trip	2.2	ug/g	0.19

Spike Recovery (%)

5270-37S	mussel 4-1 spike	Excessive matrix level compared to spiking level
5270-38SD	mussel 4-1 spike (dup)	Excessive matrix level compared to spking level

NA = Not applicable
ND = Not detected
* wet weight

Reported by LMS (to MMD) Approved by SDL (to MMD)

TOTAL AROMATIC HYDROCARBONS

Client Name: ENSECO-Marblehead (IEP)
Matrix: Tissue Sampled: 06/16-6/17/87 Received: 09/15/87
Authorized: 09/17/87 Prepared: 10/06-10/08/87 Analyzed: 10/13-10/16/87

Erco ID	Client ID	Aromatic Hydrocarbons	Units*	Reporting Limit
5270-25	mussel 2-3	9.2	ug/g	0.1
5270-26	mussel 2-3 dup	12	ug/g	0.1
5270-27	mussel 2-3 trip	11	ug/g	0.1
5270-22	mussel 2-5	33	ug/g	0.1
5270-23	mussel 2-5 dup	31	ug/g	0.1
5270-24	mussel 2-5 trip	31	ug/g	0.1
5270-31	mussel 4-1	94	ug/g	0.1
5270-32	mussel 4-1 dup	61	ug/g	0.1
5270-33	mussel 4-1 trip	60	ug/g	0.1
5270-28	mussel 5-2	65	ug/g	0.1
5270-29	mussel 5-2 dup	74	ug/g	0.1
5270-30	mussel 5-2 trip	72	ug/g	0.1
5270-34	mussel 9-2	15	ug/g	0.42
5270-35	mussel 9-2 dup	13	ug/g	0.38
5270-36	mussel 9-2 trip	12	ug/g	0.38
5270-39B	Erco Blank	<0.1	ug/g	0.1
5270-72B	Erco Blank	<0.1	ug/g	0.1
5270-37S**	mussel 4-1 quad	70	ug/g	0.1
5270-38SD**	mussel 4-1 quint	63	ug/g	0.1

Spike Recovery (%): samples unrelated to project

Tissue matrix spike A (clam)	93
Tissue matrix spike B (clam)	84
Tissue matrix spike C (shrimp)	94
Tissue matrix spike D (shrimp)	87
Tissue matrix spike E (worm)	110
Tissue matrix spike F (worm)	90

* wet weight
** Matrix contribution was excessive compared to spiking level. Samples were treated as replicates

NA = Not applicable
ND = Not detected

Reported by CTS (w MMD) Approved by SDK (w MMD)

SHELL AND MEAT CHARACTERISTICS OF
EVALUATED ORGANISMS

Laboratory ID (Client ID)	Length (mm)	Total Weight (g, wet wt)	Tissue Weight (g, wet wt)	Shell Weight
		Organic Analyses		
5270-25/26/27 (2-3)	98	66.30	20.46	34.98
	104	77.89	29.00	34.70
	91	51.93	18.66	22.17
	84	45.83	30.78	21.20
	75	38.79	16.88	14.81
	73	24.36	4.90	11.47
	81	37.96	15.41	16.70
	74	36.24	11.97	17.29
	75	28.09	8.06	12.87
		Metal Analyses		
5270-25/26/27 (2-3)	93	48.37	18.64	22.38
	97	61.45	18.78	28.54
	89	39.32	11.54	18.13
	83	36.37	12.94	16.11
	63	13.65	3.36	7.19
	74	22.25	7.12	9.11
	53	10.23	2.19	4.99
	56	12.33	2.20	6.93
	47	7.30	1.42	3.36
	43	5.93	1.23	3.26

SHELL AND MEAT CHARACTERISTICS OF
EVALUATED ORGANISMS

Laboratory ID (Client ID)	Length (mm)	Total Weight (g, wet wt)	Tissue Weight (g, wet wt)	Shell Weight
		Organic Analyses		
5270-22/23/24 (2-5)	95	58.37	22.49	25.96
	100	64.32	23.20	29.35
	97	51.97	22.02	20.65
	98	60.43	24.91	25.13
	92	52.32	18.37	23.53
	87	41.16	11.11	21.02
	92	46.80	14.28	18.97
	90	51.33	14.29	22.96
	69	19.33	6.81	10.40
		Metal Analyses		
5270-22/23/24 (2-5)	92	48.48	22.90	21.47
	99	54.68	18.98	24.79
	91	40.60	18.53	17.06
	85	42.56	15.36	18.45
	90	37.78	13.89	16.25
	85	40.90	16.59	16.62
	85	47.48	19.31	20.04
	97	52.60	17.15	23.14

SHELL AND MEAT CHARACTERISTICS OF
EVALUATED ORGANISMS

Laboratory ID (Client ID)	Length (mm)	Total Weight (g, wet wt)	Tissue Weight (g, wet wt)	Shell Weight
		Organic Analyses		
5270-31/32/33 (4-1)	68	18.30	3.21	10.56
	73	25.53	4.08	14.15
	65	15.53	2.03	9.56
	60	13.16	1.71	8.03
	64	13.01	2.31	6.83
	55	9.92	1.75	5.29
	62	14.43	2.02	8.75
	60	11.98	2.10	7.69
	60	14.16	1.31	9.24
	59	12.83	1.46	7.35
		Metal Analyses		
5270-31/32/33 (4-1)	60	10.55	2.07	7.32
	67	14.97	2.52	9.66
	62	12.16	2.27	7.34
	57	8.43	1.58	5.85
	59	13.23	2.81	6.89
	60	11.25	1.73	7.69
	57	10.55	2.05	6.46
	56	12.10	1.55	6.82
	55	11.28	2.23	6.92
	62	14.38	1.85	7.98
	56	11.79	2.29	6.43
	55	10.53	1.71	6.83
	40	3.39	Deac, no tissue	1.84

SHELL AND MEAT CHARACTERISTICS OF
EVALUATED ORGANISMS

Laboratory ID (Client ID)	Length (mm)	Total Weight (g, wet wt)	Tissue Weight (g, wet wt)	Shell Weight
		Organic Analyses		
5270-28/29/30 (5-2)	79	30.28	14.11	13.70
	75	24.56	9.89	11.06
	77	27.78	12.66	11.88
	80	28.35	10.54	13.31
	75	27.87	9.76	12.56
	71	23.23	9.63	9.55
	86	39.04	16.31	14.36
	79	32.01	15.26	12.39
	87	43.48	12.29	17.88
	82	33.07	9.65	12.72
	71	21.76	7.88	10.95
	76	21.40	7.61	11.71
	68	21.93	8.42	10.66
	70	24.72	7.85	11.46
	47	7.25	2.80	3.56
		Metal Analyses		
5270-28/29/30 (5-2)	75	27.06	10.26	9.83
	70	24.68	9.57	11.14
	75	22.29	8.51	12.94
	70	22.30	9.46	11.12
	70	22.12	8.17	9.97
	76	30.34	12.30	12.61
	68	24.79	8.08	10.19
	75	30.86	11.20	11.96
	60	16.05	5.66	7.06
	76	28.63	8.82	12.11
	76	32.96	11.23	12.71
	80	33.87	10.89	12.85
	66	12.29	5.20	6.71
	77	33.62	11.74	13.23
	75	21.23	15.55	11.79
	60	15.42	5.88	6.79
	67	19.92	6.47	7.66

SHELL AND MEAT CHARACTERISTICS OF
EVALUATED ORGANISMS

Laboratory ID (Client ID)	Length (mm)	Total Weight (g, wet wt)	Tissue Weight (g, wet wt)	Shell Weight
		Organic Analyses		
5270-34/35/36 (9-2)	76	32.41	10.91	14.39
	82	35.10	12.47	17.83
	77	32.84	9.74	15.43
	92	37.39	14.23	21.72
	77	42.36	13.63	15.66
	72	21.96	6.14	14.42
	88	35.23	12.19	19.62
	85	37.37	12.83	20.70
	73	22.47	8.18	13.01
	70	24.95	8.32	10.13
	78	33.68	10.37	16.74
	85	40.54	10.90	17.57
	57	13.54	Dead, no tissue	5.45
		Metal Analyses		
5270-34/35/36 (9-2)	90	46.13	17.57	22.30
	93	57.40	22.26	23.46
	83	47.70	30.27	22.22
	80	31.32	11.92	16.56
	99	58.82	29.57	24.28
	90	51.06	21.72	26.04
	87	38.23	16.82	19.06
	75	34.15	12.43	15.25
	82	31.85	13.06	18.47
	86	54.07	21.54	23.65
	70	29.91	11.53	11.80
	95	58.48	19.51	26.12
	80	42.52	15.24	18.83

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 1

Laboratory ID: 5270-66

Matrix: Tissue Sampled: 07/29/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	0.85	mg/kg	0.5	7191
Copper	4.3	mg/kg	0.5	7210/7211
Lead	0.90	mg/kg	0.25	7421
Mercury	0.0099	mg/kg	0.005	††
Zinc	32	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 1 Dup.

Laboratory ID: 5270-67

Matrix: Tissue Sampled: 07/29/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	0.86	mg/kg	0.5	7191
Copper	4.3	mg/kg	0.5	7210/7211
Lead	1.1	mg/kg	0.25	7421
Mercury	0.0099	mg/kg	0.005	††
Zinc	35	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LPS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 1 Trip

Laboratory ID: 5270-68

Matrix: Tissue Sampled: 07/29/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	0.92	mg/kg	0.5	7191
Copper	4.4	mg/kg	0.5	7210/7211
Lead	1.2	mg/kg	0.25	7421
Mercury	0.0099	mg/kg	0.005	††
Zinc	35	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LBB Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Flounder - Site 2

Laboratory ID: 5270-56

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	1.7	mg/kg	0.5	7210/7211
Lead	0.32	mg/kg	0.25	7421
Mercury	0.0056	mg/kg	0.005	††
Zinc	26	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LPS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Flounder - Site 2 Dup.

Laboratory ID: 5270-57

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	1.8	mg/kg	0.5	7210/7211
Lead	0.33	mg/kg	0.25	7421
Mercury	0.0061	mg/kg	0.005	††
Zinc	33	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Flounder - Site 2 Trip

Laboratory ID: 5270-58

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	1.6	mg/kg	0.5	7210/7211
Lead	0.31	mg/kg	0.25	7421
Mercury	0.0051	mg/kg	0.005	††
Zinc	34	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 2

Laboratory ID: 5270-61

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	2.5	mg/kg	0.5	7210/7211
Lead	0.30	mg/kg	0.25	7421
Mercury	0.020	mg/kg	0.005	††
Zinc	29	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 2 Dup.

Laboratory ID: 5270-62

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	2.9	mg/kg	0.5	7210/7211
Lead	ND	mg/kg	0.25	7421
Mercury	0.017	mg/kg	0.005	††
Zinc	31	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 2 Trip

Laboratory ID: 5270-63

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	2.0	mg/kg	0.5	7210/7211
Lead	ND	mg/kg	0.25	7421
Mercury	0.018	mg/kg	0.005	††
Zinc	29	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDS

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 4

Laboratory ID: 5270-69

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	2.7	mg/kg	0.5	7210/7211
Lead	0.40	mg/kg	0.25	7421
Mercury	0.016	mg/kg	0.005	††
Zinc	38	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 4 Dup.

Laboratory ID: 5270-70

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	3.2	mg/kg	0.5	7210/7211
Lead	0.29	mg/kg	0.25	7421
Mercury	0.016	mg/kg	0.005	††
Zinc	34	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 4 Trip

Laboratory ID: 5270-71

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	2.7	mg/kg	0.5	7210/7211
Lead	0.35	mg/kg	0.25	7421
Mercury	0.015	mg/kg	0.005	††
Zinc	38	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LDS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Blank

Laboratory ID: 5270-72

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result	Units	Reporting Limit	Analytical Method*
Cadmium	ND	mg/kg	0.05	7131
Chromium	ND	mg/kg	0.5	7191
Copper	ND	mg/kg	0.5	7210/7211
Lead	ND	mg/kg	0.25	7421
Mercury	ND	mg/kg	0.005	††
Zinc	ND	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

ND = Not detected.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Flounder - Site 2 Matrix Spike

Laboratory ID: 5270-59

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result**	Units	Reporting Limit	Analytical Method*
Cadmium	20 (93)	mg/kg	0.05	7131
Chromium	2.1 (98)	mg/kg	0.5	7191
Copper	43 (96)	mg/kg	0.5	7210/7211
Lead	2.2 (86)	mg/kg	0.25	7421
Mercury	0.12 (90)	mg/kg	0.005	††
Zinc	69 (81)	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

**Value in parentheses represents percent spike recovery.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Flounder - Site 2 Matrix Spike Dup.

Laboratory ID: 5270-60

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result**	Units	Reporting Limit	Analytical Method*
Cadmium	20 (90)	mg/kg	0.05	7131
Chromium	2.3 (102)	mg/kg	0.5	7191
Copper	43 (93)	mg/kg	0.5	7210/7211
Lead	2.3 (90)	mg/kg	0.25	7421
Mercury	0.11 (97)	mg/kg	0.005	††
Zinc	72 (86)	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

**Value in parentheses represents percent spike recovery.

Reported by LAS Approved by SDC

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 2 Matrix Spike

Laboratory ID: 5270-64

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result**	Units	Reporting Limit	Analytical Method*
Cadmium	23 (95)	mg/kg	0.05	7131
Chromium	2.1 (90)	mg/kg	0.5	7191
Copper	48 (97)	mg/kg	0.5	7210/7211
Lead	2.3 (86)	mg/kg	0.25	7421
Mercury	0.13 (91)	mg/kg	0.005	††
Zinc	75 (97)	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

**Value in parentheses represents percent spike recovery.

Reported by LAS Approved by SDC

Enseco

METALS

Client Name: Enseco - Marblehead

Client ID: Fish - Mum - Site 2 Matrix Spike Dup.

Laboratory ID: 5270-65

Matrix: Tissue Sampled: 07/30/87 Received: 09/15/87

Authorized: 09/17/87 Prepared: 10/12/87 Analyzed: 10/27/87

Parameter	Result**	Units	Reporting Limit	Analytical Method*
Cadmium	22 (93)	mg/kg	0.05	7131
Chromium	2.2 (92)	mg/kg	0.5	7191
Copper	48 (96)	mg/kg	0.5	7210/7211
Lead	2.4 (90)	mg/kg	0.25	7421
Mercury	0.12 (91)	mg/kg	0.005	††
Zinc	77 (100)	mg/kg	1	7950

*Method 3050 from SW-846 used on all elements except for mercury.

††Interim methods for the sampling and analysis of priority pollutants in sediments and fish tissue -- EPA (600/4-81-055).

**Value in parentheses represents percent spike recovery.

Reported by LPS Approved by SDC

TOTAL POLYCHLORINATED BIPHENYLS (PCBS)

Client Name: ENSECO-Marblehead (IEP)
Matrix: Tissue Sampled: 07/29-7/30/87 Received: 09/15/87
Authorized: 09/17/87 Prepared: 10/05-10/13/87 Analyzed: 10/16-10/19/87

Erco ID	Client ID	Total PCBs	Units*	Reporting Limit
5270-41	flounder 2 dup	1.2	ug/g	0.21
5270-42	flounder 2 trip	1.5	ug/g	0.23
5270-45	fish-mum 2	2.9	ug/g	0.59
5270-46	fish-mum 2 dup	2.4	ug/g	0.58
5270-47	fish-mum 2 trip	3.6	ug/g	0.54
5270-50	fish-mum 5	33	ug/g	2.7
5270-51	fish-mum 5 dup	51	ug/g	2.7
5270-52	fish-mum 5 trip	48	ug/g	2.6
5270-53	fish-mum 9	2.3	ug/g	1.0
5270-54	fish-mum 9 dup	12	ug/g	1.0
5270-55	fish-mum 9 trip	10	ug/g	1.0
5270-72B	Erco blank	ND	ug/g	0.01

Spike Recovery (%)

5270-43S	Flounder 2 spike	**
5270-44SD	Flounder 2 spike (dup)	110
5270-48S	Fish-mum 2 spike	120
5270-49SD	Fish-mum 2 spike (dup)	120

NA = Not applicable
ND = Not detected
* wet weight
** matrix contribution was excessive compared to spiking level

Reported by _____ Approved by _____

TOTAL POLYCHLORINATED BIPHENYLS (PCBS)

Client Name: ENSECO-Marblehead (IEP)
Matrix: Tissue Sampled: 07/29-7/30/87 Received: 09/15/87
Authorized: 09/17/87 Prepared: 10/05-10/13/87 Analyzed: 10/16-10/19/87

Erco ID	Client ID	Total PCBs	Units*	Reporting Limit
5270-41	flounder 2 dup	1.2	ug/g	0.21
5270-42	flounder 2 trip	1.5	ug/g	0.23
5270-45	fish-mum 2	2.9	ug/g	0.59
5270-46	fish-mum 2 dup	2.4	ug/g	0.58
5270-47	fish-mum 2 trip	3.6	ug/g	0.54
5270-50	fish-mum 5	33	ug/g	2.7
5270-51	fish-mum 5 dup	51	ug/g	2.7
5270-52	fish-mum 5 trip	48	ug/g	2.6
5270-53	fish-mum 9	2.3	ug/g	1.0
5270-54	fish-mum 9 dup	12	ug/g	1.0
5270-55	fish-mum 9 trip	10	ug/g	1.0
5270-72B	Erco blank	ND	ug/g	0.01

Spike Recovery (%)

5270-43S	Flounder 2 spike	**
5270-44SD	Flounder 2 spike (dup)	110
5270-48S	Fish-mum 2 spike	120
5270-49SD	Fish-mum 2 spike (dup)	120

NA = Not applicable
ND = Not detected
* wet weight
** matrix contribution was excessive compared to spiking level

Reported by _____ Approved by _____

LIVER NEOPLASMS AND TUMORS IN FLOUNDERS

Flounder were collected only at Site 2. Individuals obtained from that site and intended for PCB analyses (placed in aluminum foil) were dissected and examined in the laboratory for liver neoplasms and tumors. (Examinations were not performed on flounder intended for metal analyses since dissection with metal utensils could have contaminated the samples.) A total of 13 flounder were examined for neoplasms and tumors. Examination occurred on September 14, 1987.

No neoplasms or tumors were observed on livers of the examined fish. During the course of the internal examination, remains of small crustacerns were occasionally noted in the stomachs of the fish.

10.2 GRAPHS AND FORMULAE FOR UPTAKE AND DEPURATION OF HEAVY METALS IN LOBSTER, WINTER FLOUNDER, SANDWORMS AND HARD CLAMS

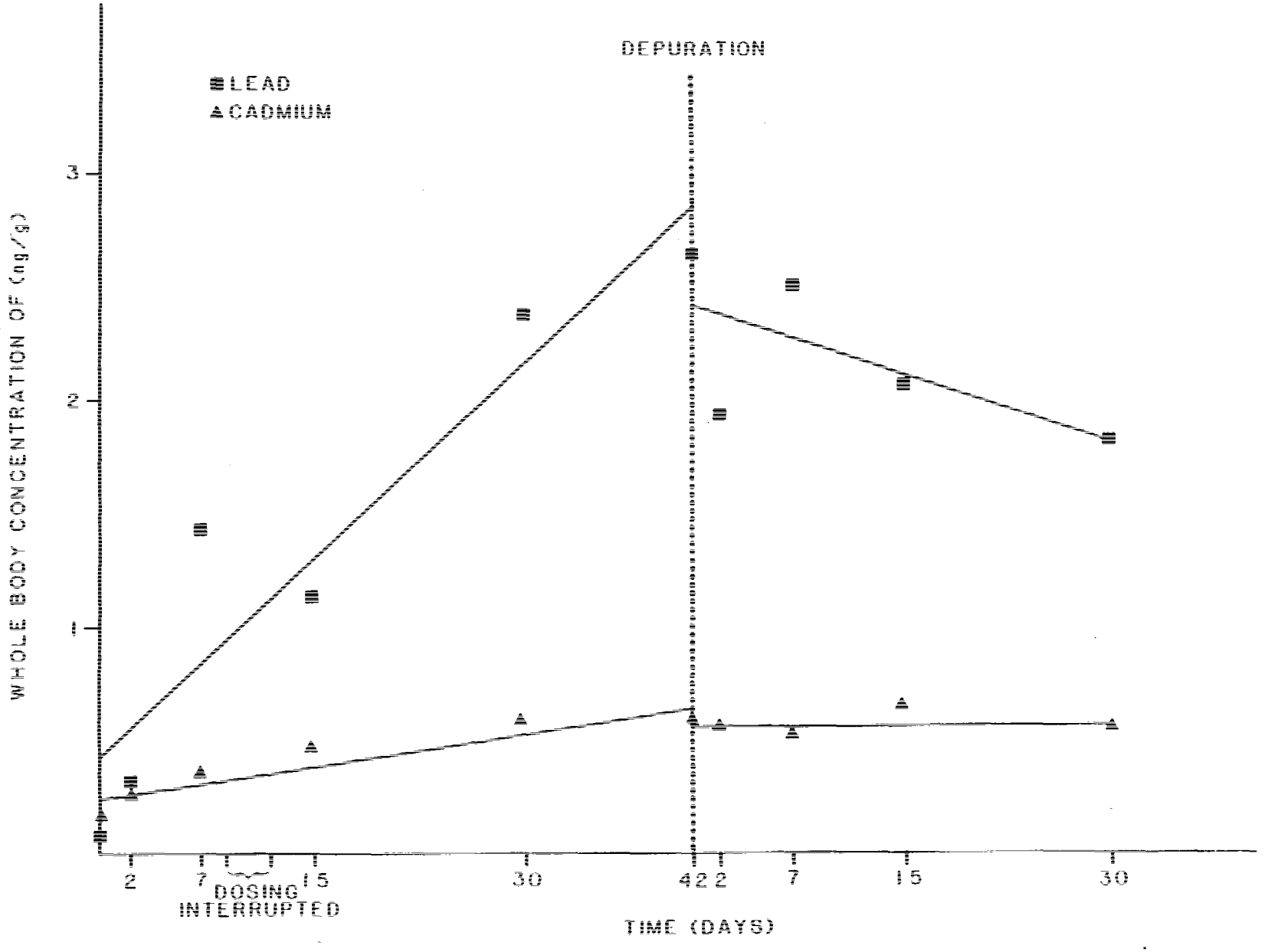

Figure 1. Linear Regressions for Uptake and Depuration of Cadmium

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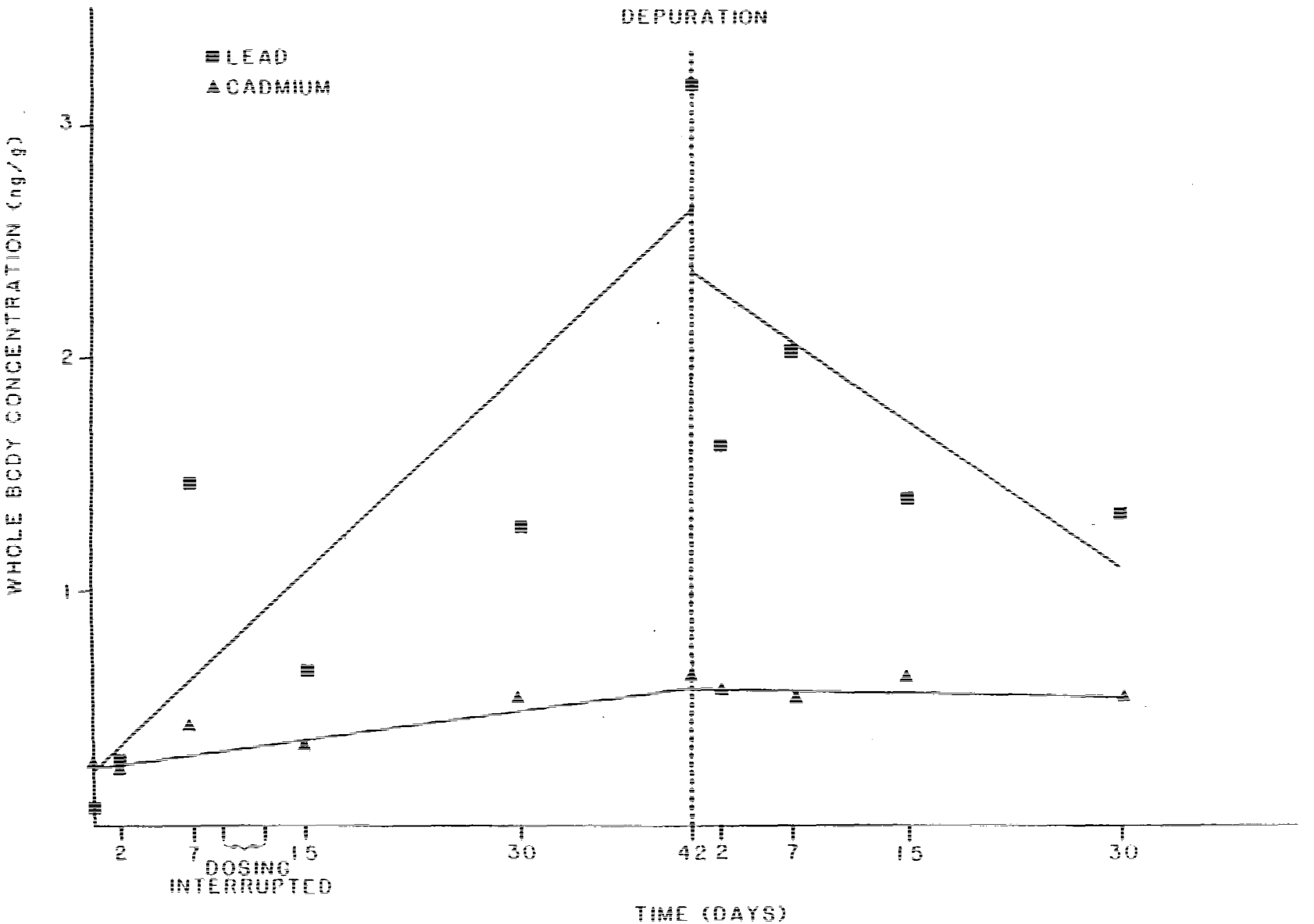

Figure 2. Linear Regressions for Uptake and Depuration of Cadmium and Lead for Juvenile Lobster

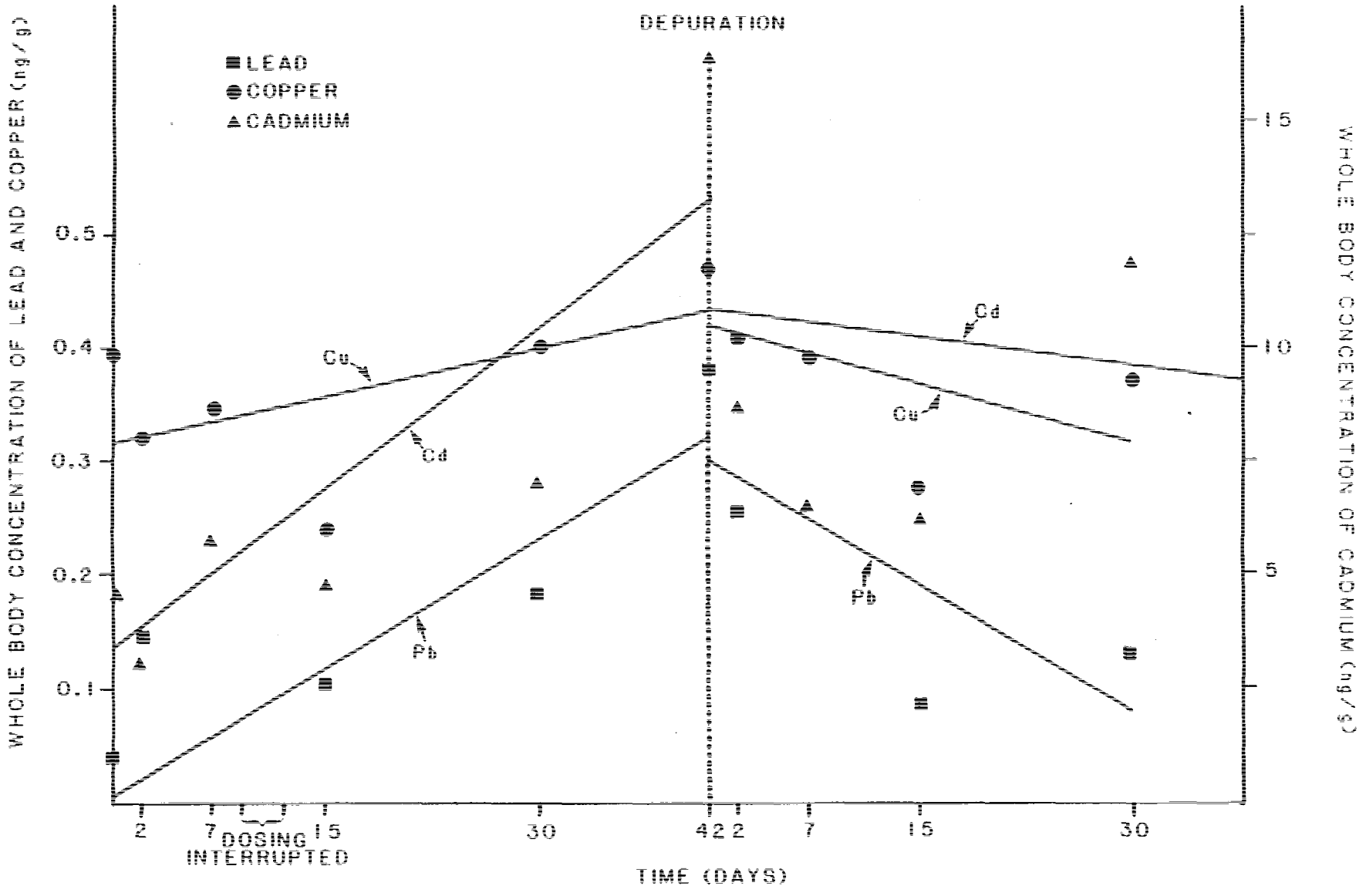

Figure 3. Linear Regressions for Uptake and Depuration of Lead, Copper and Cadmium for Adult Winter Flounder

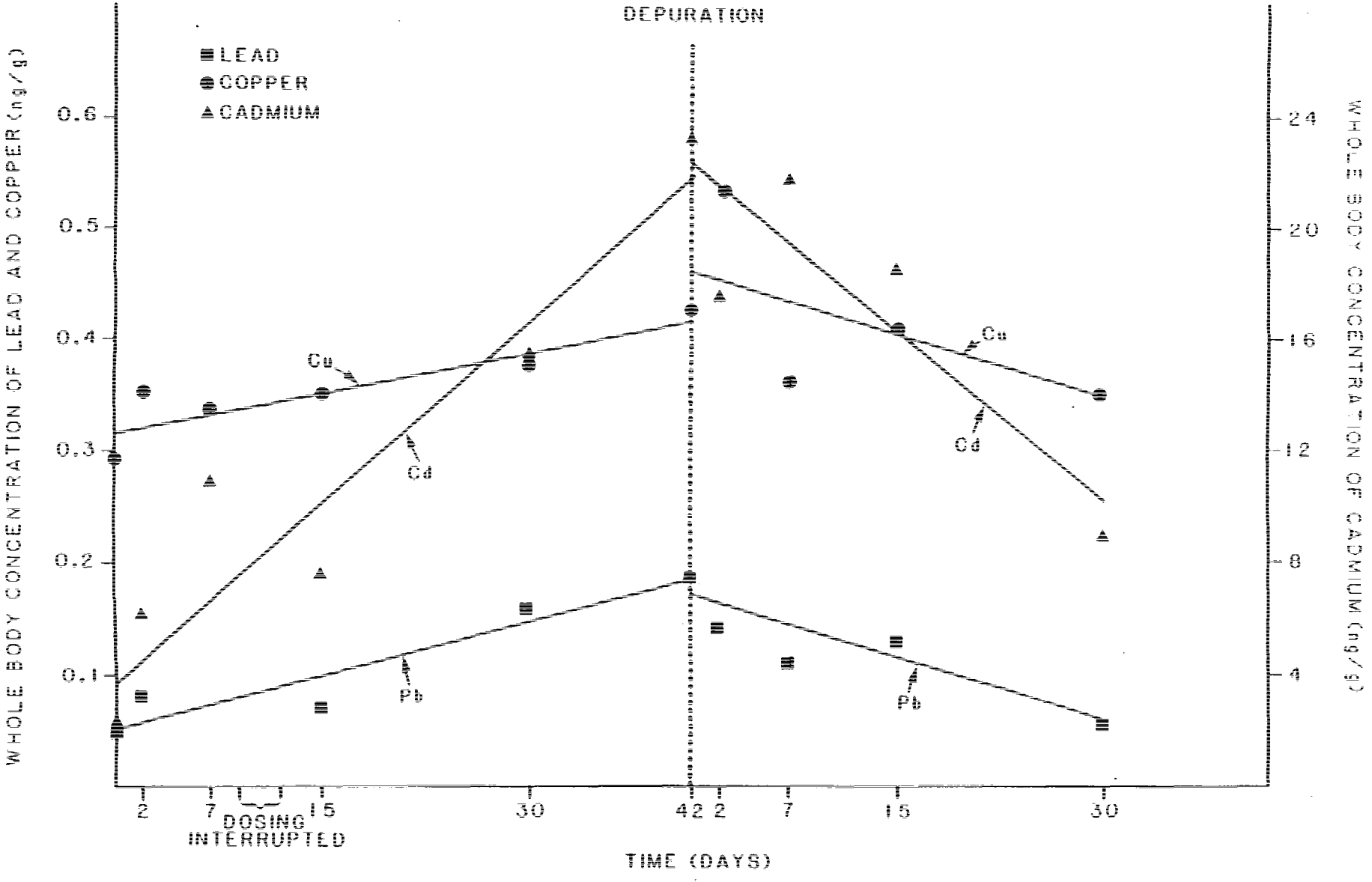

Figure 4. Linear Regressions for Uptake Depuration of Lead, Copper, Cadmium for Juvenile Winter Flounder

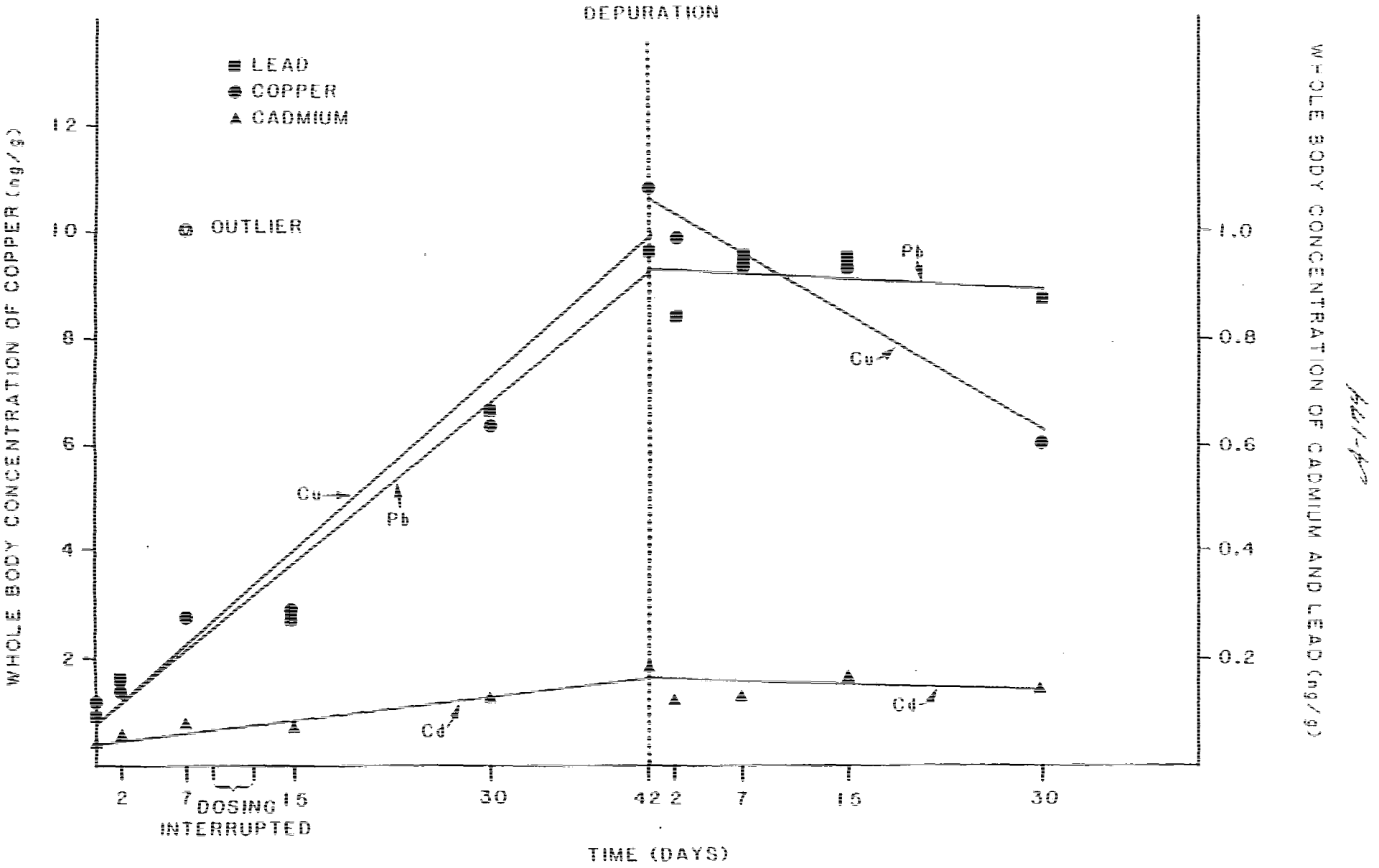

Figure 5. Linear Regressions for Uptake and Depuration of Copper, Cadmium and Lead for Sandworms

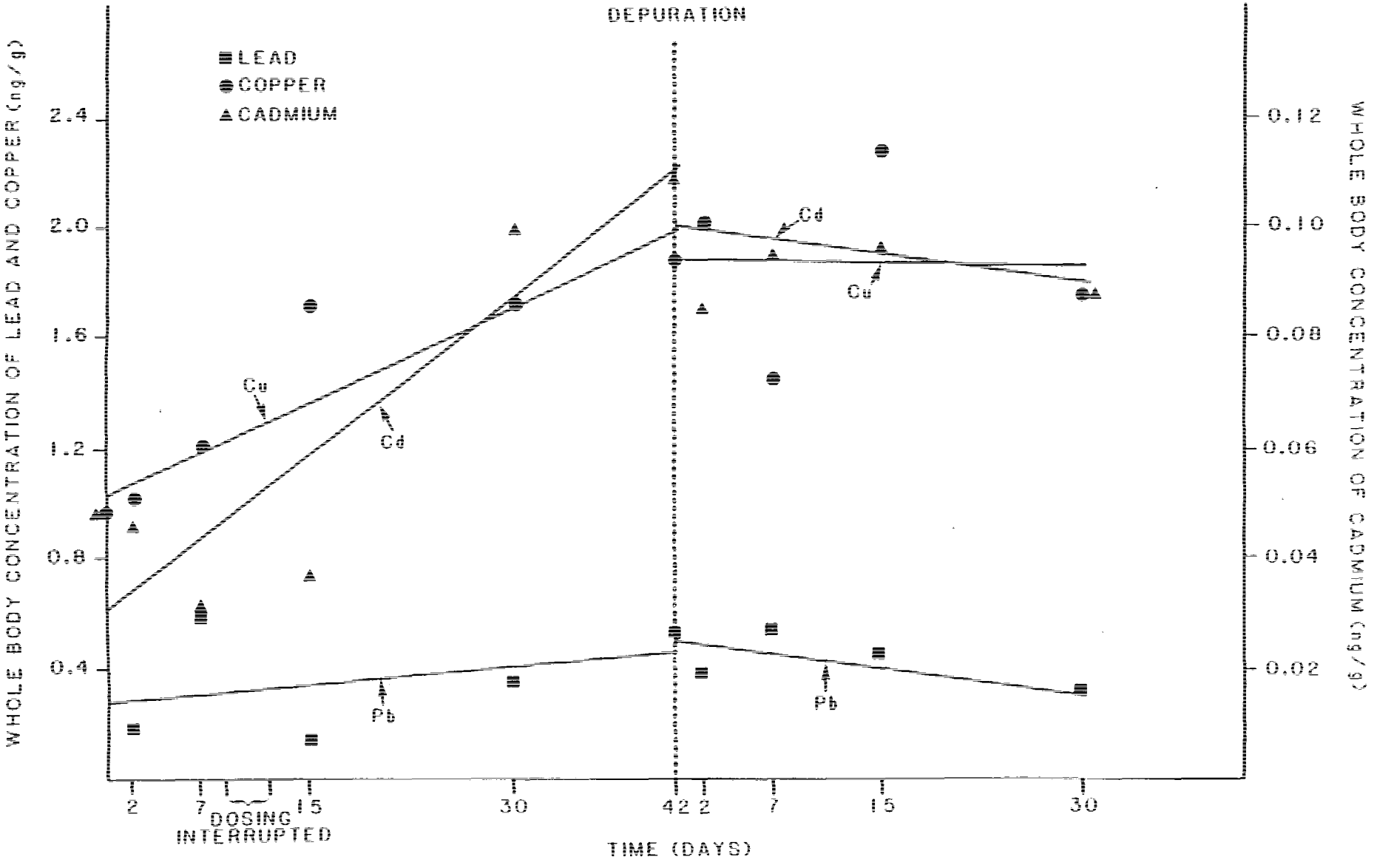

Figure 6. Linear Regressions for Uptake and Depuration of Copper, Cadmium and Lead for Hard Clams

TABLE 9. REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS FOR UPTAKE AND DEPURATION OF CADMIUM AND LEAD FOR ADULT AND JUVENILE LOBSTER

Metal	Type of Regression Equation	Adult Lobster		Juvenile Lobster	
		Uptake	Depuration	Uptake	Depuration
Cadmium	Linear	$Y = 0.01X + 0.25$ $R_2 = 0.85$	$Y = -0.0006X + 0.57$ $R_2 = 0.02$	$Y = 0.01X + 0.25$ $R_2 = 0.90$	$Y = -0.0014X + 0.59$ $R_2 = 0.09$
Lead	Linear	$Y = 0.06X + 0.38$ $R_2 = 0.89$	$Y = -0.02X + 2.41$ $R_2 = 0.44$	$Y = 0.06X + 0.21$ $R_2 = 0.74$	$Y = -0.04X + 2.38$ $R_2 = 0.45$
Lead	Power				$Y = 1.67X^{-0.03}$ $R_2 = 0.82$

TABLE 10. REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS FOR UPTAKE AND DEPURATION OF CADMIUM, LEAD AND COPPER FOR ADULT AND JUVENILE WINTER FLOUNDER

Metal	Type of Regression Equation	Adult Winter Flounder		Juvenile Winter Flounder	
		Uptake	Depuration	Uptake	Depuration
Cadmium	Linear	$Y = 0.24X + 3.38$ $R_2 = 0.74$	$Y = -0.05X + 10.85$ $R_2 = 0.02$	$Y = 0.43X + 3.85$ $R_2 = 0.92$	$Y = -0.4X + 22.4$ $R_2 = 0.78$
Cadmium	Power		$Y = 8.99X^{-0.03}$ $R_2 = 0.58$		
Lead	Linear	$Y = 0.01X + 0.06$ $R_2 = 0.76$	$Y = -0.01X + 0.3$ $R_2 = 0.61$	$Y = 0.003X + 0.05$ $R_2 = 0.89$	$Y = -0.003X + 0.17$ $R_2 = 0.79$
Copper	Linear	$Y = 0.003X + 0.32$ $R_2 = 0.30$	$Y = -0.003X + 0.42$ $R_2 = 0.30$	$Y = 0.0025X + 0.32$ $R_2 = 0.82$	$Y = -0.004X + 0.46$ $R_2 = 0.38$
Copper	Power		$Y = 0.36X^{-0.01}$ $R_2 = 0.41$		

TABLE 11. REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS FOR UPTAKE AND DEPURATION OF CADMIUM, LEAD AND COPPER FOR SANDWORMS AND HARD CLAMS

Metal	Type of Regression Equation	Sandworms		Hard Clams	
		Uptake	Depuration	Uptake	Depuration
Cadmium	Linear	$Y = 0.003X + 0.04$ $R_2 = 0.89$	$Y = -0.0006X + 0.16$ $R_2 = 0.06$	$Y = 0.002X + 0.03$ $R_2 = 0.78$	$Y = -0.0004X + 0.1$ $R_2 = 0.21$
Cadmium	Power				$Y = 0.09X^{-0.01}$ $R_2 = 0.68$
Lead	Linear	$Y = 0.02X + 0.07$ $R_2 = 0.92$	$Y = -0.001X + 0.93$ $R_2 = 0.10$	$Y = 0.005X + 0.27$ $R_2 = 0.18$	$Y = -0.01X + 0.5$ $R_2 = 0.45$
Copper	Linear	$Y = 0.22X + 0.76$ $R_2 = 0.95$	$Y = -0.14X + 10.7$ $R_2 = 0.91$	$Y = 1.07 + 0.02X$ $R_2 = 0.82$	$Y = -0.00045X + 1.88$ $R_2 = 0.00031$
Copper	Power				$Y = 1.85X^{-0.0006}$ $R_2 = 0.00143$

TABLE 9. REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS FOR UPTAKE AND DEPURATION OF CADMIUM AND LEAD FOR ADULT AND JUVENILE LOBSTER

Metal	Type of Regression Equation	Adult Lobster		Juvenile Lobster	
		Uptake	Depuration	Uptake	Depuration
Cadmium	Linear	$Y = 0.01X + 0.25$ $R_2 = 0.85$	$Y = -0.0006X + 0.57$ $R_2 = 0.02$	$Y = 0.01X + 0.25$ $R_2 = 0.90$	$Y = -0.0014X + 0.59$ $R_2 = 0.09$
Lead	Linear	$Y = 0.06X + 0.38$ $R_2 = 0.89$	$Y = -0.02X + 2.41$ $R_2 = 0.44$	$Y = 0.06X + 0.21$ $R_2 = 0.74$	$Y = -0.04X + 2.38$ $R_2 = 0.45$
Lead	Power				$Y = 1.67X^{-0.03}$ $R_2 = 0.82$

TABLE 10. REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS FOR UPTAKE AND DEPURATION OF CADMIUM, LEAD AND COPPER FOR ADULT AND JUVENILE WINTER FLOUNDER

Metal	Type of Regression Equation	Adult Winter Flounder		Juvenile Winter Flounder	
		Uptake	Depuration	Uptake	Depuration
Cadmium	Linear	$Y = 0.24X + 3.38$ $R_2 = 0.74$	$Y = -0.05X + 10.85$ $R_2 = 0.02$	$Y = 0.43X + 3.85$ $R_2 = 0.92$	$Y = -0.4X + 22.4$ $R_2 = 0.78$
Cadmium	Power		$Y = 8.99X^{-0.03}$ $R_2 = 0.58$		
Lead	Linear	$Y = 0.01X + 0.06$ $R_2 = 0.76$	$Y = -0.01X + 0.3$ $R_2 = 0.61$	$Y = 0.003X + 0.05$ $R_2 = 0.89$	$Y = -0.003X + 0.17$ $R_2 = 0.79$
Copper	Linear	$Y = 0.003X + 0.32$ $R_2 = 0.30$	$Y = -0.003X + 0.42$ $R_2 = 0.30$	$Y = 0.0025X + 0.32$ $R_2 = 0.82$	$Y = -0.004X + 0.46$ $R_2 = 0.38$
Copper	Power		$Y = 0.36X^{-0.01}$ $R_2 = 0.41$		

TABLE 11. REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS FOR UPTAKE AND DEPURATION OF CADMIUM, LEAD AND COPPER FOR SANDWORMS AND HARD CLAMS

Metal	Type of Regression Equation	Sandworms		Hard Clams	
		Uptake	Depuration	Uptake	Depuration
Cadmium	Linear	$Y = 0.003X + 0.04$ $R_2 = 0.89$	$Y = -0.0006X + 0.16$ $R_2 = 0.06$	$Y = 0.002X + 0.03$ $R_2 = 0.78$	$Y = -0.0004X + 0.1$ $R_2 = 0.21$
Cadmium	Power				$Y = 0.09X^{-0.01}$ $R_2 = 0.68$
Lead	Linear	$Y = 0.02X + 0.07$ $R_2 = 0.92$	$Y = -0.001X + 0.93$ $R_2 = 0.10$	$Y = 0.005X + 0.27$ $R_2 = 0.18$	$Y = -0.01X + 0.5$ $R_2 = 0.45$
Copper	Linear	$Y = 0.22X + 0.76$ $R_2 = 0.95$	$Y = -0.14X + 10.7$ $R_2 = 0.91$	$Y = 1.07 + 0.02X$ $R_2 = 0.82$	$Y = -0.00045X + 1.88$ $R_2 = 0.00031$
Copper	Power				$Y = 1.85X^{-0.0006}$ $R_2 = 0.00143$

10.3 ANNOTATED BIBLIOGRAPHY OF BIOACCUMULATION STUDIES IN CONTAMINATED MARINE ENVIRONMENTS

Effects of environmental contaminants on snapping turtles of a tidal wetland

Albers, P.H.; Sileo, L.; Mulhern, B.M.

USFWS, Patuxent Wildl. Res. Cent., Laurel, MD 20708, USA

ARCH. ENVIRON. CONTAM. TOXICOL., VOL. 15, NO. 1, pp. 39-49, 1986

To determine the effects of environmental contaminants on a resident wetland species, snapping turtles (Chelydra serpentina) were collected from a brackish-water and nearly freshwater area in the contaminated Hackensack Meadowlands of New Jersey and an uncontaminated freshwater area in Maryland. Snapping turtles from the brackish-water area had an unusually low lipid content of body fat and reduced growth compared to turtles from the fresh-water areas in New Jersey and Maryland. Despite the serious metal contamination of the Hackensack Meadowlands, the metal content of kidneys and livers from New Jersey turtles was low and not greatly different from that of the Maryland turtles. Organochlorine pesticide concentrations in body fat were generally low at all three study areas. Polychlorinated biphenyls (PCBs) concentrations in fat were highest in male turtles from the New Jersey brackish-water area.

Temporal variations of heavy metals in Mercenaria mercenaria

Behrens, W.J.; Duedall, I.W.

Oceanogr. Sci. Div., Brookhaven Nat. Lab., Upton, NY

J. CONSEIL., VOL. 39, NO. 3, pp. 219-222, 1981

Simultaneous analyses of changes in dry body weight, heavy metal concentrations, and total body burden of heavy metals in Mercenaria indicated that temporal variations in metal levels were associated with biological processes of the organism. Changes in Ni, Pb, and Cu levels in hard clams were related to the spawning cycle while Cd, Cr, and Zn levels were not. The interpretation of fluctuations in metal concentrations may be misleading unless considered with respect to seasonal variations in body weight.

Behavior of heavy metals in transplanted hard clams, *Mercenaria mercenaria*

Behrens, W.J.; Duedall, I.W.

Ecosys. Ctr., Marine Biolog. Lab., Woods Hole, MA

J. CONSEIL., VOL. 39, NO. 3, pp. 223-230, 1981

An area in Great South Bay, NY which has been closed to shellfishing on the basis of coliform bacteria standards was shown to have elevated levels of heavy metals in hard clams, *Mercenaria mercenaria*, and sediments. Clams from this area were transplanted into the central portion of the Bay, an area which is open to shellfishing. The heavy metal concentrations in the transplanted clams was primarily affected by long-term trends based on seasonal fluctuations in the organisms. While these clams were being depurated of bacteria, no depuration of any heavy metal analyzed (Cd, Cr, Cu, Ni, Pb, and Zn) was noted over the 50-day duration of this study.

Trace element enrichments in decomposing litter of *Spartina alterniflora*

Breteler, R.J.; Teal, J.M.; Giblin, A.E.; Valiela, I.

Battelle New England Mar. Res. Lab., 397 Washington St., Duxbury, MA 02332, USA

AQUAT. BOT; VOL. 11, NO. 2, pp. 111-120, 1981

Concentrations of mercury, copper, zinc, chromium, iron, and manganese were measured in *S. alterniflora* during different stages of decomposition. Samples were collected from a salt marsh treated with a metal-containing sewage sludge and from a control marsh area. Substantial increases were found in the concentrations of Hg, Cu, Fe, and Zn in all the *Spartina* litter samples collected. The trace-metal enrichment in the decaying *Spartina* grass was best explained by the adsorption of metal-enriched organic substances during tidal flooding of the marsh surface.

Retention and fate of experimentally added mercury in a Massachusetts salt marsh treated with sewage sludge

Breteler, R.J.; Teal, J.M.; Valiela, I.

Battelle New England Mar. Res. Lab., 397 Washington St., P.O. Drawer AM, Duxbury, MA 02332, USA

MAR. ENVIRON. RES., VOL. 5, NO. 3, pp. 211-225, 1981

A simple, rapid, precise and reproducible procedure is described for sample preparation, extraction and measurement of total mercury in peaty sediments, plants, and animal tissues. Various amounts of dried sewage sludge containing heavy metals were applied to experimental plots in a New England salt marsh. This treatment resulted in elevation of mercury levels in the surface 5 cm of the soil. Discrepancies in the bulk density of marsh sediments corresponded with interparticle spaces and detritus/mineral ratios in the peat matrix. Mass balance calculations showed that wetlands covered with tall Spartina alterniflora lost mercury considerably faster than higher marsh locations which retained virtually all mercury added.

Hydrocarbon pollution and the prevalence of neoplasia in New England soft-shell clams (Mya arenaria)

Brown R.S.; Wolke, R.E.; Brown, C.W.; Saila, S.B.

Rhode Island Univ., Dep. Anim. Pathol., Chem. & Oceanogr., Kingston, RI 02881, USA

Symposium on Pathobiology of Environmental Pollutants: Animal Models and Wildlife as Monitors, Storrs, CT (USA), 1977

ANIMALS AS MONITORS OF ENVIRONMENTAL POLLUTANTS. SYMPOSIUM ON PATHOBIOLOGY OF ENVIRONMENTAL POLLUTANTS: ANIMAL MODELS AND WILDLIFE AS MONITORS, pp. 41-51, 1979

NATIONAL ACADEMY OF SCIENCES, WASHINGTON, DC (USA)

Ecological, chemical, and pathological analyses were conducted on soft-shell clams from ten New England sites of varying types and degrees of hydrocarbon pollution (e.g., oil spill, industrial sewage, and domestic sewage). To date, over 1,300 clams have been histopathologically examined. Of these, 162 had neoplastic lesions. Clams from one site had predominately gonadal neoplasms, while the majority were of hematopoietic origin. Cells of both types were markedly anaplastic, invasive, and apparently metastatic. Hydrocarbon levels in clam tissues were related to sediment hydrocarbon concentrations.

Pesticide residues in estuarine mollusks, 1977 versus 1972 -- National Pesticide Monitoring Program

Butler, P. A.; Kennedy, C. D.; Schutzmann, R. L.

EPA, Technical Services Div., Ecological Monitoring Branch, Gulf Breeze, FL 32561

PESTICIDES MONITORING JOURNAL, 12(3), 99-101, Dec. 1978

Bivalve mollusks (the oysters Crassostrea virginica and C. gigas, the mussel Geukensia demissa, the quahog Mercenaria mercenaria, the clam Mya arenaria, the mussel Mytilus edulis, and the freshwater clam Corbicula manilensis) were monitored for residues of 20 organochlorine and organophosphate pesticides and PCBs during spring, 1977. Eighty-seven of the 181 estuaries were routinely monitored on a monthly basis during 1965 through 1972. DDT, the only pesticide detected in 1977, occurred at low levels in one estuary each on the Atlantic and Pacific coasts.

Effects of cadmium, mercury, and silver on marine animals

Calabrese, A.; Thurberg, F. P.; Gould, E.

NMFS, Middle Atlantic Coastal Fisheries Center, Milford Lab., Milford, CT 06460

MARINE FISHERIES REVIEW, 39(4), 5-11, Apr. 1977

Test animals were acclimated in the laboratory for at least two weeks prior to heavy metal exposure. Exposures were either short, static tests or long-term continuous-flow tests. At the end of each exposure period, or at intervals during that time, animals were removed for evaluation of metal stress. Short-term tests were designed to measure mortality rates, determine tolerance ranges, and discover those metabolic systems most sensitive to metal stress. Long-term tests were designed primarily to study the physiological and biochemical effects of sublethal metal stress. Metal exposure tests on mollusks (Crassostrea virginica, Argopecten irradians, and Nassarius obsoletus) included evaluation of larval and juvenile mortality and O5 consumption of adult animals. Different species of decapod crustaceans (Carcinus maenas, Cancer irroratus, Eurypanopeus depressus, and Homarus americanus) showed the same diversity of physiological response to metal exposure as did the mollusks. Three teleost species -- the cunner (Tautogolabrus adspersus), striped bass (Morone saxatilis), and winter flounder (Pseudopleuronectes americanus) -- were also examined.

4-194

Metals in the molluscan kidney: uptake and subcellular distribution of ^{109}Cd, ^{54}Mn and ^{65}Zn by the clam, Mercenaria mercenaria

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COMPARATIVE BIOCHEMISTRY AND PHYSIOLOGY, A 65A(2), 203-206, 1980

The relative tissue distribution of Cd, Mn, and Zn accumulated by M. mercenaria from seawater was assessed using ^{109}Cd, ^{54}Mn, and ^{65}Zn. The kidney accumulated all 3 metals most extensively with Cd in particular showing the greatest degree of renal concentration. Subcellular fractionation of the kidney showed that 34.3% of the Mn, 5.6% of the Zn, and 1.3% of the Cd was incorporated into mineral concretions present in kidney cells. Gel permeation chromatography of renal cytosol fractions showed the isotopes to be bound to macromolecules with molecular weights of 60,000, 12,000, and 7,500.

A review of the evidence supporting a viral agent causing a hematopoietic neoplasm in the soft-shelled clam, Mya arenaria

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3rd Int. Colloq. on Invertebrate Pathology/15th Annual Meeting of the Society for Invertebrate Pathology, Brighton (UK), 6-10 Sep 1982

INVERTEBRATE PATHOLOGY AND MICROBIAL CONTROL, pp. 271-272, 1982

SOCIETY FOR INVERTEBRATE PATHOLOGY, (UK)

Field studies that examined a total of 4,053 soft-shelled clams from 17 sites along the United States East Coast were conducted from 1976 to 1979. From these studies it was shown that the occurrence of a gonadal and a hematopoietic neoplasia was highest in Southern New England clam populations and the prevalence decreased to zero in areas both north and south of this area. A hematopoietic neoplasm was the most frequently observed lesion. There was no correlation between the area of collection based on pollutant type (hydrocarbon, domestic sewage, heavy metal) and prevalence of the hematopoietic neoplasm. The gonadal neoplasm was observed only at three sites; the highest prevalence occurred at Long Cove, Searsport, Maine. The percentage of gonadal and hematopoietic neoplasms in the Searsport site was 50%. A biphasic increase in the prevalence of both neoplasms was observed. The prevalence and severity of the disease increased in the spring (May) and fall (October) and decreased during the summer and winter months. Similar findings have been reported for other molluscan species with neoplastic lesions. These data presented support a viral etiology for a hematopoietic neoplasm in Mya arenaria.

A new syndrome of intensively cultured sea bass (Dicentrarchus labrax)

Doimi, M.; Bovo, G.; Ceschia, G.; Giorgetti, G.; Saroglia, M.; Ellis, A.E. (ed.)

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1st International Conference of the European Assoc. of Fish Pathologists, Plymouth (UK), 20-23 Sep 1983

FISH AND SHELLFISH PATHOLOGY, pp. 231-240, 1985

ACADEMIC PRESS, ORLANDO, FL (USA)

The authors conclude that the cause of the disease observed is the anomalous presence of heavy metals in the feed (Pb, Zn, Cr, Cu) together with a deficiency of vitamin C. Intoxication is chronic (approximately 3 months) and is probably due to the combined action of various metals. Hypovitaminosis, a possible cause of slow mortality, follows progressive intoxication. Symptoms observed are similar to those of scurvy. Treatment with multivitamins, particularly vitamin C, is recommended.

Heavy metals in relation to the biology of the mummichog Fundulus heteroclitus

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JOURNAL OF FISH BIOLOGY, 14(3), 309-328, Mar 1979

Heavy metal levels of Cd, Cu, Hg, Mn, and Zn were studied in the mummichog F. heteroclitus from industrialized and nonindustrialized environments (Timber Island, Great South Bay; Garvey's Point, Hempstead Harbor, and Hamilton Beach, Jamaica Bay, New York). With one exception, the environment with the highest trace metal in its waters, had the fish with the highest metal concentration. Except for Hg, the concentration factor varied inversely with the metal concentrations of the fish and water, indicating a possible regulatory mechanism for the metals in the tissues of mummichogs from environments with high metal concentrations. There was an inverse relationship between SL and concentrations of Zn, Mn, Cu, and Cd in whole male and female fish. The viscera contained significantly greater concentrations of these metals than somatic muscle tissue. There were significant differences between males and females with respect to whole-body Zn and Cu concentrations, but no sex differences for Mn and Cd.

A-189

Geographic variability in trace element levels in Spartina alterniflora

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ESTUAR. COAST. SHELF SCI., VOL. 13, NO. 6, pp. 209-716, 1981

Significant ($P < 0.05$) differences were observed in Mn, Fe, Cu, Zn, and Ni levels in live S. alterniflora from six marshes along the salinity gradient of the York River estuary. Levels of these metals did not correlate strongly with the salinity of either river or sediment pore water. Concentrations of these metals in standing dead S. alterniflora from these six marshes were significantly higher than levels in the live plants but did not show site specific differences. Significant ($P < 0.005$) differences were found between 16 different marshes along the Atlantic Coast, in the Fe, Cu, Zn, but not Mn, content of live S. alterniflora, respectively.

Organochlorine residues analyzed in invertebrates of the Dutch Wadden Sea by two methods

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NETH. J. SEA RES., VOL. 15, NO. 1, pp. 78-87, 1981

Two laboratories analyzed 12 organochlorine compounds in the same and parallel samples of 3 invertebrate species (Cerastoderma edule, Mya arenaria, Crangon crangon) obtained from the western Dutch Wadden Sea in 1976. The two different analytical methods used resulted in very similar mean residue levels. These levels deviated in only 2 out of 16 cases by more than 50%. The PCB levels predominated with 20 to 100 ng/g, and were higher than those of the same species from the Weser estuary, Germany. The other compounds ranged generally below 6 ng/g.

Trace metal residues in shellfish from Maryland waters, 1976-1980

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J. ENVIRON. SCI. HEALTH, PART B, VOL. 19B, NO. 7, pp. 649-672

Levels of seven heavy metal residues, arsenic, cadmium, chromium, copper, lead, mercury, and zinc were monitored in samples of the American oyster (Crassostrea virginica), the soft shell clam (Mya arenaria), the hard shell clam (Mercenaria mercenaria) and the blue crab (Callinectes sapidus). Samples were taken from the Maryland section of the Chesapeake Bay and its tributaries over a five year period (1976-80). This study was undertaken to provide estimated baseline values of trace heavy metals. Also, the oyster, a non-mobile filter feeder, provides information regarding the level of metal residues in its environment (water and sediment), because heavy metal uptake is related to the surrounding metal concentrations. Results of the study are consistent with data from previous years. No statistically significant year-to-year trends were observed over the period of the investigation.

Trace metal-binding proteins in marine mollusks and crustaceans

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7th International Estuarine Research Conference, Virginia Beach, VA (USA), 22-26 Oct 1983

MAR. ENVIRON. RES., VOL. 13, NO. 3, pp. 177-194, 1984

Some marine invertebrates, such as the American oyster, Crassostrea virginica, the blue crab, Callinectes sapidus, and the American lobster, Homarus americanus, concentrate trace metals in their tissues. The occurrence of metallothionein, a low molecular weight, sulfur-containing, metal-binding protein, has been correlated with elevated levels of trace metals in these organisms. It has been hypothesized that, while metallothioneins are involved in the sequestration of elevated levels of trace metals, they primarily function in regulating normal metal metabolism. The authors describe recent field and laboratory experiments designed to examine how oysters, blue crabs and lobsters manage accumulated cadmium, copper and zinc. The possible roles of metallothionein, as well as the tissue distribution of metals, are emphasized.

Heavy metals in Mercenaria mercenaria and sediments from the New Bedford Harbor Region of Buzzard's Bay, Massachusetts

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BULL. ENVIRON. CONTAM. TOXICOL., VOL. 26, NO. 1, pp. 124-130, 1981

The presence of manufacturing facilities engaged in the use of heavy metals combined with the existence of a local fishery suggested the importance of studying the distribution and accumulation of metals in bivalves in the New Bedford, Massachusetts area. This study employed one of the edible clams, Mercenaria mercenaria (L), as an indicator. M. mercenaria and sediments from the New Bedford region were analyzed for cadmium, copper, iron, lead, and zinc to investigate some of the relationships between environmental and organismal levels.

Uptake and losses of heavy metals in sewage sludge by a New England salt marsh

Giblin, A.E.; Valiela, I.; Teal, J.M.; Bourg, A.

WHOI Inst., MA, 1980

NTIS, SPRINGFIELD, VA

PB81-127920

As part of an investigation on the potential of salt marshes to act as natural waste treatment systems, the cycling of heavy metals in Great Sippewissett Marsh, Massachusetts was studied. For the last seven years, varying doses of fertilizer containing sewage sludge have been added to experimental plots. Changes in metal levels in the sediment, grasses, and animals have been monitored. These levels are given in this report.

The fate of metals introduced into a New England salt marsh

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WATER AIR SOIL POLLUT., VOL. 20, NO. 1, pp. 81-98, 1983

As part of a study to investigate the effect of chronic eutrophication on salt marshes, a sewage sludge fertilizer has been applied to experimental plots in Great Sippewissett Marsh, MA, since 1974. The fertilizer contains substantial amounts of heavy metals. Sediments from fertilized plots contain elevated levels of Cu, Cd, Zn, Fe, Mn, Cr, and Pb. The above- and below-ground portions of the dominant grass, Spartina alterniflora, contain significantly higher levels of Cd, Cr, Cu, and Zn when compared to control plots. The mussel, Modiolus demissus, from fertilized plots contains elevated levels of Cu, Cd, and Cr. The fiddler crab, Uca pugnax contains more Cu and Cd than control animals. Low marsh sediments fertilized for 8 years retained 15% Cd, 24% Fe, 27% Mn, 28% Zn, 45% Cr, 49% Cu, and 60% of the Pb in the fertilizer. Plots which had only received fertilizer for one year retained a higher percentage of the metals which had been added. The differential solubilization of metals from the fertilizer appear to be one factor influencing metal retention on the plots although changes in sediment chemistry due to nutrient addition are also a factor.

Seasonal and environmental variation in Mn, Fe, Cu, and Zn content of Spartina alterniflora

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AQUATIC BOTANY, 7(4), 385-392, Dec 1979

Manganese, Fe, Cu, and Zn in S. alterniflora shoot tissues were analyzed for seasonal trends and relationships to dry matter standing crop. Two brackish marshes in Virginia were sampled four times between April and September, 1975. Between early April and late May, shoots accumulated Mn, Cu, and Zn at a faster rate than dry matter standing crop increased. Iron followed this trend at Bennett's Marsh but matched standing crop increase at Taskinas Marsh. Tissue concentrations of Mn, Cu, and Zn declined over the growing season at both marshes; Fe declined at Bennett's Marsh and increased at Taskinas Marsh.

Organochlorine pesticides and polychlorinated biphenyls on sediments from a subarctic salt marsh, James Bay, Canada -- 1976

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PESTICIDES MONITORING JOURNAL, 12(2), 94-95, Sept. 1978

Sediment samples collected from a subarctic salt marsh on James Bay, Ontario (May 1976) were analyzed by high-pressure liquid chromatography. Of 15 organochlorine compounds analyzed, trace amounts, mainly of p,p-DDE and PCBs were detected, but could not be quantified.

Patterns of organochlorine residues in animals of different trophic levels from the Weser estuary

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MARINE POLLUTION BULLETIN, 10(5), 127-132, May 1979

The cockle Cerastoderma edule, the clam Mya arenaria, the bristle worm Arenicola marina, the shrimp Crangon crangon, and the sole Solea solea from a single area of the German Wadden Sea were investigated for concentrations of 10 organochlorine pollutants in 1976. PCB concentrations were predominant with 10-200 ng/g. p,p-DDD, dieldrin, a-HCH, c-HCH, and p,p-DDE generally ranged between 1 and 10 ng/g. Values of a-endosulfan were even lower; p,p-DDT, endrin, and heptachlor epoxide could not be detected. Residue levels in shrimps were close to the lower range of values which have been found in this species from other areas of the North Sea since 1974. The patterns of residue concentrations in the 5 aquatic species were remarkably different indicating species- and compound-specific bioaccumulation. Trophic level and lipid content were shown to be responsible for PCB concentrations increasing from bivalves to fish.

Short-term low-salinity response in lead-exposed lobsters, *Homarus americanus* (Milne Edwards)

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J. EXP. MAR. BIOL. ECOL., VOL. 69, NO. 3, pp. 283-295, 1983

The only effect attributable solely to lead exposure (50 mcg/l for 30 days) in lobsters, *H. americanus* (Milne Edwards), was decreased pentose shunt activity (G6PDH) in the antennal gland. This gland contained the greatest concentration of lead taken up by the tissues analyzed. In lobsters similarly exposed and subsequently held for 2 days in clean, aerated sea water at either ambient or low salinity (27 or 17 ppt, respectively), lead concentration in the antennal gland dropped by one-third and G6PDH returned to control values. Low-salinity effects far outnumbered lead-induced effects and were found primarily in the tail muscle, corroborating findings in an earlier study with cadmium.

In situ striped bass (*Morone saxatilis*) contaminant and water quality studies in the Potomac River

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AQUATIC TOXICOLOGY, VOL. 10, pp. 73-99, 1987

The objectives of this study were to evaluate survival of striped bass (*Morone saxatilis*) prolarvae and yearlings in the Potomac River by using *in situ* test chambers; correlate survival of both striped bass life stages with the presence of water quality conditions, inorganic contaminants, and organic contaminants and conduct histological examinations of surviving yearling striped bass. Survivial of striped bass prolarvae ranged from 4.5-22% at three field locations during three 96-hour experiments; control survival was $\geq$81%. Yearling survival ranged from 0-77.5% at three river stations during two 7-day experiments; highest mortality occurred at the upriver station. Control survival was 100%. Poor survival of striped bass prolarvae was likely related to the presence of inorganic contaminants (monomeric aluminum, cadmium, and copper) acting singly or synergistically and sudden decreases in water temperature (<11°C). Yearling mortality at the upriver station was likely correlated with high pH conditions from a point source discharge and perhaps inorganic contaminants. Histological examinations of yearlings suggested that test organisms exposed to Potomac River water exhibited adverse changes in the kidney.

Rainfall input of toxaphene to a South Carolina estuary

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ESTUARIES, VOL. 3, NO. 2, pp. 142-147, 1980

Toxaphene concentrations in rainfall over a South Carolina salt marsh were monitored from 1976 through 1978. This insecticide is toxic to some organisms in the low mcg/kg range and causes sublethal effects in the very low ng/kg range. Rainfall was sampled by both continuously exposed collectors and by collectors which were exposed only during actual precipitation. Toxaphene concentrations in individual rainstorms showed a high day-to-day variation, and in general were 10-100 times higher than PCB and DDT levels. Washout ratios for toxaphene were higher than those reported for other chlorinated hydrocarbons, but lower than those of trace metals.

Lead-bacterial interactions in an estuarine salt marsh microlayer

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DISS. ABST. INT., PT. B - SCI. & ENG, VOL. 42, NO. 5, 1981

The 300-mcm-deep surface layer at the estuarine air-water interface frequently contains elevated concentrations of toxic heavy metals such as lead relative to subsurface waters, yet serves as habitat for a substantial population of metabolically active bacteria. The likelihood for interactions between bacteria and lead in the surface layer of a contaminated urban estuary has important environmental considerations and is evaluated in this study. In addition, the effects of abiotic particulates upon these interactions are also assessed. Enrichments, calculated as surface-layer concentrations/subsurface concentrations, and particulate associations for surface-layer bacteria (bacterioneuston) were determined at two ecologically different salt marshes located near Falmouth, MA and Palo Alto, CA. The effect of particulate material upon lead enrichment in the surface layer and correlations between lead and bacteria in this microenvironment were assessed at the Palo Alto site. The likelihood and nature of specific lead-bacterioneuston interactions were examined in laboratory experiments.

Bioassay of Baltimore Harbor sediments

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ESTUARIES, 2(3), 141-153, Sep 1979

Baltimore Harbor has received and is receiving large quantities of chemical pollutants. Gross bioassay analyses were performed for sediments using two species of fish -- mummichogs or killifish (Fundulus heteroclitus) and spot (Leiostomus xanthurus) -- and one mollusk, the soft-shell clam (Mya arenaria). Acclimated organisms were exposed in static systems to a series of concentrations of suspended sediment from each station, to Fuller's earth in suspension, and in control tanks for 48 hours. Parallel analysis of the sediment was performed for the metals Pb, Cr, Zn, Ca, As; for PCBs; and for hexane extracts. The sediments were all substantially polluted with low correlations among components. Twenty-four-hour TLm and 48-hour TLm increased proportionately with sediment concentration but displayed species specificity. The relationships observed permit use of mummichog data to index gross toxicity of sediments throughout the harbor. Further comparison of mummichog 24-hour TLm value with benthic species diversity determined in a previous study permitted zoning of the entire harbor into highly toxic, moderately toxic, low toxic, and slightly toxic zones. Gross toxicity of sediments determined by bioassay can therefore be used as an index of the suitability of the sediments for benthic macroinvertebrate communities.

Problems in the variance analysis of nine environmental monitoring variables: determining the number of samples needed to detect a change in mean of 50%

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Marine Technology Soc., Washington, DC (USA), IEEE, New York, NY (USA)

National Symposium on Monitoring Strategies (at) Oceans '86 "Science-Engineering-Adventure", Washington, DC (USA), 23-25 Sep 1986

OCEANS '86 CONFERENCE RECORD: SCIENCE-ENGINEERING-ADVENTURE, VOL. 3, MONITORING STRATEGIES SYMPOSIUM, pp. 974-979, 1986

IEEE PUBLISHING SERV., NEW YORK, NY (USA)

OCEANS '86

An analysis was conducted for nine environmental monitoring variables; the concentration of cadmium and PCBs in marine sediments, the incidence of fin erosion in Dover sole and winter flounder, the incidence of black gill disease in rock crabs, the incidence of skeletal anomalies in Ammodytes, the incidence of genetic abnormalities in Atlantic mackerel embryos, a fecundity index for striped bass, an index of nesting success in osprey and brown pelicans, and a mortality index for fish and shellfish larvae. The variables were classified as physical or biological monitoring variables and the number of samples expected to be required to detect a change in mean of 50% was estimated for each monitoring variable. The direction of change is that expected under the assumption of decreasing environmental quality. Problems in handling and acquiring encountered data were discussed and methods for calculating the appropriate variance estimate and determining the appropriate data transformation were presented.

The distribution of heavy metals in the hard clam, *Mercenaria mercenaria*, in the Lower Chesapeake Bay region

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ESTUARIES, 2(1), 1-8, Mar. 1979

Populations of the hard clam, *M. mercenaria*, were sampled at 30 sites in the lower Chesapeake Bay region in 1972 and 1973. Subsamples were taken for analysis for Cd, Cu, and Zn. Emphasis was placed on samples from the York and James rivers, two commercially utilized clam grounds. The levels of metals determined were comparable to those reported from other regions except Southampton Water in the UK. Differences in levels between the York and James rivers were statistically significant indicating that the James River probably suffers from contamination by these metals. Copper varied significantly with the age of the organism whereas Cd and Zn varied with salinity. In *Mercenaria*, the salinity of the sampling site must be considered before Cd and Zn data can be interpreted.

A-201

Short-term and long-term uptake of zinc by the mussel, *Mytilus edulis*: a study in individual variability

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ARCH. ENVIRON. CONTAM. TOXICOL., VOL. 16, pp. 723-732, 1987

In previous studies, the zinc concentration of the whole soft tissue of the mussel *Mytilus edulis* showed a high degree of unexplained residual variability which could not be accounted for by any known ecological or physiological factors. This high variability was almost entirely due to the unusually high degree of variability in kidney zinc concentrations (range 97-7,864 mcg/g; n + 561). In the present study, unfed mussels were exposed to natural levels of zinc (labelled with zinc-65) in clean seawater in a laboratory aquarium. In spite of the environmental homogeneity in the laboratory environment, the kidney showed a high coefficient of variation (around 70%) for zinc-65 concentrations after 66 days of exposure to the radioisotope. Other tissues showed only low coefficients of variation (10-30%). This suggested that the high variability of kidney zinc was not a result of unknown ecological factors (differences in microhabitat), but was due to biochemical differences between individual mussels. In a second experiment, it was noted that the zinc-65 and stable zinc concentrations of the kidney showed significant positive correlation after only six days exposure to zinc-65, indicating that the factors leading to the high variability of zinc in the kidney were operative within the first few days after uptake. Hence, kidney zinc variability appeared more likely to be the result of short-term processes (zinc uptake, elimination of zinc from short term compartments) than long-term processes (granule excretion). Female mantle had a higher stable zinc concentration but a lower radio-zinc concentration than male mantle. The radio-zinc concentrations of the mantle's edge was greater than that of the mantle without an edge.

Mechanisms for trace metal enrichment at the surface microlayer of an estuarine salt marsh

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MAR. CHEM., VOL. 11, NO. 3, pp. 235-244, 1982

The relative contributions of adsorption to particulate surfaces, complexation with surface-active organic ligands, and uptake by micro-organisms were evaluated with respect to their importance in the surface microlayer enrichment ("partitioning") of Cd, Pb, and Cu. The contributions of each process were inferred from field data in which partitioning of the dissolved and particulate forms of Cd, Pb, and Cu, total and dissolved organic carbon, particles and total bacteria were observed. In the South San Francisco Bay Estuary, particle enrichment appears to control trace metal partitioning. Trace metal association with the particulate phase and the levels of partitioning observed were in the order Pb > Cu > Cd and reflect the calculated equilibrium chemical speciation of these metals in computer-simulated seawater matrices.

Polychlorinated biphenyls in blue crabs from South Carolina

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BULL. ENVIRON. CONTAM. TOXICOL., VOL. 39, pp. 857-862, 1987

Using knowledge of previously documented elevated polychlorinated biphenyls (PCB) levels in the sediments of the upper portion of Campbell Creek, the South Carolina Wildlife and Marine Resources Department (SCWMRD) initiated analysis of crab tissue from that area to ascertain the body burdens of PCBs in blue crabs. Initial screening results indicated potentially significant levels of PCBs; SCWMRD contacted the SC Department of Health and Environmental Control (SCDHEC) for more intensive study and definition of the situation. The subsequent work was conducted between June and October 1985. Overall, the PCB levels measured in blue crabs from the Campbell Creek area, except those collected where the highest sediment concentration of PCBs existed, appeared to fall within the ranges observed in South Carolina and elsewhere.

Polychlorinated biphenyl (PCB) and trichlorobenzene (TCB) plasticizers: Impact on microbial processes in the saltmarsh and soil ecosystems

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DISS. ABST. INT., PT. B - SCI. & ENG., VOL. 42, NO. 4, 1981

Order FAD No. 8122097

Accumulation of polychlorinated biphenyl (PCB) (Aroclor 1242) in decomposing S. alterniflora was monitored in a flow-through percolator for 4-month periods at 20° C. The detritus removed 90% of the dissolved PCB. Biomagnification was 3 to 4 times higher in the active detritus than in the abiotic control. PCB depressed CO_2 evolution but did not affect C:N ratio. A mathematical component model predicting the change of ash free dry weight (AFDW), total carbon (C), and total nitrogen (N) in decomposing S. alterniflora shows that the decay equation $X_t = X_o e^{rt}$ explains AFDW and C changes. R values ranged from 0.004 to 0.02 per day. N fluxes were influenced by four functions: (1) loss of soluble N; (2) loss of recalcitrant nitrogenous plant material; and (3) loss of microbial N. A logistic function (4) which describes microbial colonization of S. alterniflora is responsible for incorporation of N into the detritus.

4-505

Appropriate ecology: A modest stress-strain proposal

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SECOND INTERNATIONAL SYMPOSIUM ON BIOLOGY AND MANAGEMENT OF TROPICAL SHALLOW WATER COMMUNITIES (CORAL REEFS, BAYS AND ESTUARIES), 20 JULY - 2 AUGUST 1980, PAPUA NEW GUINEA, pp. 723-729, 1981

BULL. MAR. SCI., VOL. 31, NO. 3

The author discusses photosynthesis, community respiration, and plant-community cover as a measure of the response of benthic, planktonic, and salt-marsh communities to stresses (including heavy metals, sewage treatment effluents, crude petroleum, induced siltation, and mechanical disturbance). The stress-strain curves are mathematically simplified to yield two measures: (1) the half-effect, a value of stressor needed to reduce community function to half its natural value; and (2) the slope, the rate of change of function per unit stressor. These values characterize sensitivity, and the rates at which each changes through time give measures of resiliency of the community.

Cadmium and marine invertebrates

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10th International Conference of the IAWPR Toronto, Ont. (Canada), 23-27 Jun 1980

WATER POLLUTION RESEARCH, PART 4, pp. 1085-1086, 1981

IAWPRC/PERGAMON, OXFORD (UK)

WATER SCI. TECHNOL., VOL. 13, NO. 4-5

Cadmium in sea water is extremely lethal to stage 1 lobster larvae (Homarus americanus) with a long-term lethal threshold of 0.03 mg Cd/L. It is moderately lethal to shrimp (Crangon septemspinosa, Pandalus montagui), the bivalve (Macoma balthica) with 144-hr LC50's ranging from 2.2 to 3.1 mg Cd/L, and adult lobsters with a long-term lethal threshold of 5 mg Cd/L. Cadmium is relatively non-toxic to the marine worm (Nereis virens) with a long-term lethal threshold greater than 10 mg Cd/L.

1-306

Heavy metal levels in Geukensia demissa from the Mystic River Estuary in relation to anthropogenic addition, salinity, and gut contamination

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8th Biennial International Estuarine Research Conference, Durham, NH (USA), 28 Jul 1985

ESTUARIES, VOL. 8, NO. 2B, p. 47A, 1985

The extent of Cu, Fe, and Zn addition to the Mystic River Estuary (MRE) by marina activities, dredging operations and sewage outfall was examined using the estuarine mussel Geukensia demissa. Levels of these metals in the tissues of mussels significantly increased with distance up the estuary. Laboratory experiments were subsequently performed to determine if processes known to affect metal levels in organisms (salinity and gut contamination) could be responsible for the variations observed in the field. Results are discussed.

Heavy metals as indicators of geographical origin of the American eel (Anguilla rostrata); [Les Metaux Lourds Comme Indicateurs d'Origine Geographique de l'Anguille d'Amerique (Anguilla rostrata)]

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CAN. J. FISH. AQUAT. SCI., VOL. 39, NO. 7, pp. 1004-1011, 1982

American eels (A. rostrata) were sampled from the St. Lawrence River and many of its tributaries. Heavy metal concentrations (Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Zn) in muscles were analyzed in relation to collection site, age, length, and weight of the specimens. Among the essential heavy metals, zinc, copper, and especially manganese, can be used to distinguish the samples by their origin. In the Saguenay River, which is contaminated by mercury wastes, it is possible to distinguish two types of eels according to their mercury content, weight, and length. This suggests the hypothesis that these two types lived in different parts of the drainage system. Metal concentrations in the eels seem to depend on the availability of these metals in bottom sediments. Analysis by flexible grouping and principal coordinates yields groups that are not sufficiently homogeneous and distinct to identify specific patterns of heavy metal content for the different sample sites.

Spatial/temporal patterns of macrobenthos, sediments and pollutants in Raritan Bay-lower N.Y. Bay

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Fairleigh Dickinson Univ., Madison, NJ, USA

6th Biennial International Estuarine Research Conference, Gleneden Beach, OR (USA), 1-5 Nov 1981

ESTUARIES, VOL. 4, NO. 3, p. 302, 1981

Seasonal sediment sampling at 82 stations throughout Raritan Estuary were analyzed for macrobenthos, size-grade, metals and HC. Distinct, allopatric communities of clams Tellina agilia and Mercenaria mercenaria were delineated showing seasonal spatial distribution. Mercenaria density was lower than earlier studies. Results of the macrofaunal study do not indicate any major change in the quality of the environment in the last 6 years. Only 30% of stations showed seasonal (mostly winter/spring) variations in silt/clay; stabilized sand and mud areas were delimited. Most metals displayed large intrastation statistical variability but only Cr, Cu, Fe, Mn, Pb, and Zn showed well defined seasonal variability.

Correlation of body burden of heavy metals with physiological stress indicators in Mytilus edulis and Mya arenaria exposed to heavy metals in the field

Page, D.S.; Gilfillan, E.S.; Hanson, S.A.; Hotham, J.R.; Foster, J.C.; Stegeman, J.J. (ed.)

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2nd International Symposium on Responses of Marine Organisms to Pollutants, Woods Hole, MA (USA), 27-29 Apr 1983

PROCEEDINGS OF THE SECOND INTERNATIONAL SYMPOSIUM ON RESPONSES OF MARINE ORGANISMS TO POLLUTANTS HELD AT WOODS HOLE OCEANOGRAPHIC INSTITUTION, MASSACHUSETTS, USA, 27-29 APRIL 1983, p. 505, 1984

ELSEVIER APPLIED SCIENCE PUBLISHERS, LONDON (UK)

MAR. ENVIRON. RES., VOL. 14, NO. 1-4

In order to evaluate possible metal inputs into the Piscataqua River estuary, samples of two bivalve mollusks, Mya arenaria and Mytilus edulis, were taken from a number of sampling locations in the estuary over two growing seasons. The samples were analyzed for Pb, Cr, Cu, Ag, Zn, and Cd. At the same time the specific activities of two enzymes, Aspartate aminotransferase and glucose 6-phosphate dehydrogenase, were measured. The results demonstrate a significant dose/response relationship between physiologically significant enzyme systems and tissue metal concentrations.

On Spartina alterniflora litter and the trace metal biogeochemistry of a salt marsh

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ESTUAR. COAST. SHELF SCI., VOL. 18, NO. 3, pp. 331-346, 1984

The trace metals copper, nickel, zinc, manganese, and iron, as associated with the aqueous surface microlayer retained on fallen Spartina alterniflora litter, were studied in spatial and seasonal contexts. In two Delaware salt marshes, major spatial and seasonal variability in metal retention by the litter was observed. This seasonal accumulation is biologically mediated as sulphate reduction in anoxic marsh sediments releases H^+ in the spring/summer and fall. The release of H^+ decreases retention of metals, especially iron, by the recumbent litter. For both marshes, during all seasons studied, the litter exhibited the following ranges in total metal content (dry weight basis): copper: 0.5-11 ppm; nickel: 2-11 ppm; zinc: 12-80 ppm; manganese: 40-350 ppm; and iron: 1600-8100 ppm. The existence of two distinct chemical and physical types of microlayer in the salt marsh is reported.

Spartina alterniflora litter in salt marsh geochemistry

Pellenbarg, R.E.; Sigleo, A.C.; Hattori, A. (eds.)

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Symposium on Marine and Estuarine Geochemistry, International Congress of Pacific Basin Societies, Honolulu, HI (USA), 16-21 Dec 1984

MARINE AND ESTUARINE GEOCHEMISTRY, pp. 305-314, 1985

LEWIS PUBLISHERS, CHELSEA, MI (USA)

Abiotic interactions between Spartina alterniflora litter and the waters and sediments of a salt marsh were examined. The litter was shown to be capable of scavenging the aqueous surface microlayer and associated trace metals from marsh tidal waters. Such litter-water interactions can lead to an eight-fold increase in litter zinc content in the short term. Litter sediment interchanges were affected by redox processes in the anoxic sediments of the marsh which seasonally release dissolved, reduced iron. As the reduced iron was oxidized at the sediment surface, and retained in part as a coating on litter, other metals such as copper and zinc were enriched in the litter by coprecipitation.

Spartina alterniflora litter and the aqueous surface microlayer in the salt marsh

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ESTUARINE AND COASTAL MARINE SCIENCE, 6(2), 187-195, Feb. 1978

Aliquots of Spartina alterniflora litter were deployed in Canary Creek Marsh, Delaware, to intercept trace metals carried as dissolved and particulate burdens in the water and as part of the microlayer carried on the marsh waters. Litter contacting the water column only was enriched some 2.5 times in Cu and Zn and 1.5 times in Fe, as compared with nondeployed litter. However, litter contacting the metal rich microlayer was enriched an average of 2.5 times in Cu and 4 times in Zn and Fe. Also, the potential for Spartina to release humic/fulvic substances was examined in the laboratory by comparing the IR spectra of chloroform extracts of freeze dried microlayer material, Spartina solids, and aqueous leachates from the solids. Spartina apparently releases materials with IR spectra similar to those from the microlayer, and isolated fulvic acids. The role of Spartina decomposing to release metal chelators (fulvic acids) which sequester dissolved trace metals then migrate to the microlayer for entrapment by Spartina litter is discussed. The microlayer enriched litter would yield trace-metal-rich detritus. Such a mechanism may account in part for introducing trace metals to the biota of the salt marsh.

Trace metal partitioning in the aqueous surface microlayer of a salt marsh

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ESTUARINE, COASTAL AND SHELF SCIENCE, VOL. 13, NO. 1, pp. 113-117, 1981

The trace metals copper, cadmium, lead, iron, and zinc were studied in the microlayer of a Delaware salt marsh. Freeze-dried microlayer samples were extracted with organic solvents of differing polarity. The majority (approximately 95%, excluding cadmium) of trace metals in the microlayer could not be extracted with any of the organic solvents used, and are presumed associated with the inorganic phases of the microlayer. For organic-solvent-recoverable metals, acetone extracted the largest proportion of those metals. Portions of the work reported here strongly suggest that humic-like materials sequester the organically soluble metals in the salt marsh surface microlayer.

The estuarine surface microlayer and trace metal cycling in a salt marsh

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SCIENCE, 203(4384), 1010-1012, Mar 9, 1979

The tidal budgets of trace Cu, Zn, and Fe carried as dissolved, particulate, and microlayer components fluxing in and out of the Canary Creek salt marsh (Delaware coast) were examined. The aqueous surface microlayer in the salt marsh averaged 10% of the Cu, 19% of the Zn, and 23% of the Fe relative to the total metal flux including the dissolved and seston components. Such trace metals cycle in the salt marsh by net import on the surface microlayer and net export in the dissolved and seston components during maximum monthly tides.

Application of a wetland animal bioassay for determining toxic metal uptake from dredged material

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US Army Engineer Waterways Exp. St., Vicksburg, MS 39180, USA

International Symposium on Ecotoxicological Testing for the Marine Environment, Ghent (Belgium), 12 Sep 1983

ECOTOXICOLOGICAL TESTING FOR THE MARINE ENVIRONMENT. VOLUME 2. EXPERIENCE PAPERS: TESTS WITH SPECIFIC GROUPS OF ORGANISMS, TESTS WITH SPECIFIC CHEMICALS, TESTS USING A SPECIFIC TECHNOLOGY, TESTS STUDYING SPECIFIC EFFECTS, CASE STUDY, pp. 457-464, 1984

STATE UNIV. GHENT, (BELGIUM); INST. FOR MAR. SCI. RES., BREDENE (BELGIUM)

The bioavailability and animal uptake of toxic metals from contaminated dredged material to be placed in a wetland creation disposal environment was investigated using a solid-phase animal bioassay. The objective of this study was to apply, document, and verify existing animal contact bioassay procedures to predict the movement of toxic metals into sediment-dwelling animals colonizing wetlands created with dredged material. The sandworm (Nereis virens) was exposed to a flooded (reduced) contaminated sediment from Bridgeport, Connecticut, USA. The sediment was collected and maintained in the reduced state to simulate conditions in an intertidal wetland environment. The sediment tested proved to be toxic to the sandworm unless it was diluted with uncontaminated material.

Liver cadmium uptake, catalase inhibition and cadmium thionein production in the killifish (Fundulus heteroclitus) induced by experimental cadmium exposure

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MARINE ENVIRONMENTAL RESEARCH, 3(2), 101-111, Apr-Jun 1980

Liver catalase activity, used as an index of Cd poisoning in F. heteroclitus, was inhibited following both in vivo and in vitro exposure to dissolved Cd at a concentration >1 mg/L. Preexposure at 1 mg Cd/L prevented catalase inhibition at higher subsequent doses of Cd. Comparison of the effects of in vivo and in vitro exposure showed in vivo exposure to Cd to result in greater catalase inhibition. Cadmium and Cu binding, determined by gel chromatography, occurred at 3 distinct liver cytosol fraction peaks. Both metals showed enhanced cytosol concentrations with Cd exposure and relative changes in peak levels as related to Cd exposure regimes. Cadmium thionein (mol wt of 7-10,000) was found in the killifish liver and was correlated with adaptive responses in liver catalase activity. High molecular weight Cd binding was a better index of Cd toxicity to liver catalase than total liver Cd concentration.

Epizootic neoplasia of soft shell clams collected from New Bedford Harbor

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HAZARDOUS WASTE, VOL. 1, NO. 1, pp. 73-81, 1984

Soft shell clams (Mya arenaria) were collected from tidal flats in southeastern New England. Their haemolymph was analyzed for the presence of neoplastic cells. The prevalence of neoplasia varied from 10-90% with the highest prevalence found in New Bedford Harbor, a site containing high levels of pollutants, including PCBs, heavy metals and industrial wastes. Further analyses showed that quantifiable levels of Aroclors 1242 and 1254, congeners of PCB, could be detected in neoplastic cell extracts derived only from clams collected from New Bedford Harbor. These studies suggest an association between the high prevalence of disease and the location of soft shell clams at or near an industrially contaminated site.

The kidney of the quahog (Mercenaria mercenaria) as a pollution indicator

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Symposium on Pathobiology of Environmental Pollutants: Animal Models and Wildlife as Monitors, Storrs, CT (USA), 1977

ANIMALS AS MONITORS OF ENVIRONMENTAL POLLUTANTS. SYMPOSIUM ON PATHOBIOLOGY OF ENVIRONMENTAL POLLUTANTS: ANIMAL MODELS AND WILDLIFE AS MONITORS, pp. 119-129, 1979

NATIONAL ACADEMY OF SCIENCES, WASHINGTON, DC (USA)

The kidneys of quahogs collected from 10 variously polluted areas around Rhode Island were analyzed histochemically, chemically, and histopathologically with methods involving light and electron microscopy, and atomic absorption. The quantity, size, and color of the kidney concretions in quahogs collected from the high-pollution areas were different from those collected in areas of low pollution. Analyses of these concretions revealed a predominance of heavy metals. Interelemental ratios of trace metals depended on the various colors of the concretions. The trace metals manganese, calcium, zinc, copper, lead, cadmium, and iron were identified.

Production of epibenthic diatoms in a Southern California impounded estuary

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JOURNAL OF PHYCOLOGY, 14(3), 273-279, Sept. 1978

In situ epibenthic diatom production was determined for 4 sites within Bolsa Bay (Orange County), California, to assess the effect of estuarine impoundment by a tidal gate. Mean annual values of 26 and 41 mg C/m2/hr were found in the finer sediment of the outer bay, whereas mean annual values of 41 and 59 mg C/m2/hr were found in the coarser, more stable sediment of the inner bay. Low production in the vicinity of the mouth of a flood control channel is thought to be caused by heavy metal inhibition in conjunction with sediment instability, a shallow photic zone, and heavy grazing pressure. Seasonal production peaks in spring and fall were closely correlated with the concentration of nitrate and silicate but not with phosphate. Even though Bolsa Bay has been cut off from the sea, drained and subjected to fill, it is as productive as other coastal wetlands throughout the world.

Lead in the Bolsa wetlands of southern California, USA: Effect of flood control channelization

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MARINE POLLUTION BULLETIN, 10(12), 349-351, Dec 1979

The distribution of Pb in sediments of an estuary receiving flood control discharge was examined. Relatively high concentrations of Pb with a mean value of 64 ppm were found within the outer portion of Bolsa Bay, California, which receives flood control runoff. Significantly lower concentrations of Pb with a mean value of 9 ppm were found within the impounded inner portion of the bay which does not receive flood control discharge.

Evaluation of New York Bight lobsters for PCBs, DDT, petroleum hydrocarbons, mercury, and cadmium

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BULL. ENVIRON. CONTAM. TOXICOL., VOL. 29, NO. 6, pp. 711-718, 1982

The New York Bight is routinely exposed to waste from the neighboring urban environments. As a generalized predator of the ocean floor in adult stages and a resident of the water column during larval stages, the lobster (Homarus americanus) has potential to uptake and accumulate those contaminants to which it is exposed. Storage of such compounds in bodily tissue may be of toxicological importance to both lobster and man, a consumer of lobster. Five potentially toxic compounds were chosen for study which might reflect the impact of disposal operations in the Bight. All lobsters were tested for DDT, petroleum hydrocarbons, total polychlorinated biphenyls (PCBs), mercury (Hg), and cadmium (Cd).

The eulamellibranch Mercenaria mercenaria (L.): A review and current data on metals accumulation and the internal transport of cadmium

Robinson, W.E.; Morse, M.P.; Penney, B.A.; Kakareka, J.P.; Meyhoefer, E.U.; Vernberg, F.J.; Thurberg, F.P.; Calabrese, A.; Vernberg, E.B. (eds.)

Edgerton Res. Lab., New England Aquar., Cent. Wharf, Boston, MA 02110, USA

Symposium on Physiology and Pollution of Marine Organisms, Mystic, CT (USA), 1-3 Nov 1983

MARINE POLLUTION AND PHYSIOLOGY: RECENT ADVANCES, pp. 83-106, 1985
UNIVERSITY OF SOUTH CAROLINA PRESS, COLUMBIA, SC (USA)

BELLE W. BARUCH LIBR. MAR. SCI., NO. 13, 1985

The content and concentration of various metals (Ag, Ba, Cd, Cu, Fe, and Zn) were measured in individual tissues (adductor muscles, blood cells, blood plasma, digestive glands, gills, kidneys, mantle, pericardial glands, and remaining viscera) of the quahog, M. mercenaria. Similar analyses were conducted on tissues from clams exposed to elevated levels of either Cd or radiolabeled ^{109}Cd (0.1 mcg/ml) in 0.45 mcm filtered sea water (15° C, 30-32 ppt). Although small in size, the kidneys were clearly the major organs that concentrated Ag, Ba, Cd, Cu, Fe, and Zn, and to some extent Mn and Ni. Following exposure to 100 ppb Cd for 15 days, a 14-fold increase in Cd concentration was detected in the kidneys, with a lesser, but appreciable, accumulation of Cd in the gills, digestive glands, mantle, and remaining viscera.

Metal interactions within the kidney, gill, and digestive gland of the hard clam, Mercenaria mercenaria, following laboratory exposure to cadmium

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ARCH. ENVIRON. CONTAM. TOXICOL., VOL. 15, NO. 1, pp. 23-30, 1986

Mercenaria mercenaria were exposed to 0.1 mcg Cd/ml seawater (^{109}Cd + stable carrier) for either (1) periods of 1 hour to 31 days, or (2) a period of 3 days followed by depuration in clean seawater for 2 to 64 days. Cd accumulated at increasing rates in the kidney, but at decreasing rates in all other organs of the clam during the laboratory exposure period. Measurement of total Cd levels confirmed that ^{109}Cd was accumulated by the clam tissues and not simply exchanged. The overall rate of Cd accumulation was significantly greater for the kidney than for the gill, mantle, digestive gland, pericardial gland, adductor, or remaining viscera, but not significantly different among the other organs. No loss of Cd or other detectable metals occurred even after 64 days depuration. The degree to which Cd accumulated in the kidney, gill, and digestive gland did not correlate with the concentrations of other metals already present in these organs (except with Zn in the digestive gland).

The occurrence of copper, iron and zinc in the hard shell clam, Mercenaria mercenaria, and sediments of Southampton Water

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ESTUARINE AND COASTAL MARINE SCIENCE, 9(4), 423-434, Oct 1979

To provide the background data needed for the accurate assessment of the significance of observed fluctuations, the concentrations of Cu, Fe, and Zn were measured in M. mercenaria collected from several localities in Southampton Water. Considerable seasonal, age, and geographical fluctuations in tissue metal concentrations are revealed. All metal concentrations in clam tissue are lower at the seaward end of the estuary, but although sediment metal levels generally follow a similar trend, tissue and sediment values appear to correlate with each other only for Fe. There appears to be little evidence of any significant effect on metal uptake which could be attributable to the operation of Marchwood Power Station.

4-58

Accumulation of PCBs, mercury and cadmium by Nereis virens, Mercenaria mercenaria and Palaemonetes pugio from contaminated harbor sediments

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AQUAT. TOXICOL, VOL. 3, NO. 3, pp. 249-260, 1983

Accumulation of polychlorinated biphenyls (PCBs), mercury, and cadmium by sandworms (N. virens), hard clams (M. mercenaria), and grass shrimp (P. pugio) exposed to contaminated sediments from four sites in New York Harbor was studied for a 100-day period. Of the three contaminants monitored, only PCBs were found to bioaccumulate above background (control) concentrations. Small increases in PCB body burden were detected in M. mercenaria and P. pugio, whereas higher concentrations were measured in N. virens. Uptake was affected by the organic content of the sediment. Bioaccumulation factors (concentration in tissue/concentration in sediment) for N. virens ranged from 1.59 in a low organic sediment to 0.15 in a high organic sediment. Results from this study support the hypothesis that sediment concentration alone does not reflect bioavailability and that toxicity tests (bioassays) and field monitoring remain the most direct method for estimating bioaccumulation potential of sediment-bound contaminants.

L 519

Chemical extractions of heavy metals in sediments and metal uptake by Palaemonetes pugio and Mercenaria mercenaria

Rule, J.H.

Old Dominion Univ., Norfolk, VA (USA), Applied Marine Research Lab, 1984

NTIS Order No.: AD-A165 202/3/GAR

Sediments from four sites in the Hampton Roads Harbor and Elizabeth River system were subjected to solid phase bioassays using Palaemonetes pugio (grass shrimp) and Mercenaria mercenaria (clams). A reference sediment from an offshore potential disposal site was included. Metal levels in both organisms after exposure to the sediments varied little between sites. All of the test sites would be acceptable for ocean disposal with respect to the metals tested. Metal concentrations in Palaemonetes were generally greater than in Mercenaria. Since there was no significant difference in the concentrations in tissue for either organism, there was no correlation of metal uptake with sediment extraction method. Out of four sites and seven metals studied with two test organisms, only four instances of bioaccumulation occurred. Palaemonetes were enriched with respect to the sediment in chromium, copper, nickel, lead, and zinc; Mercenaria were enriched in lead and zinc.

Heavy metal in surface sediments from three embayments of central-south Chile

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MAR. POLLUT. BULL., VOL. 17, NO. 12, pp. 567-568, 1986

An analysis of sea water, sediment, and the ribbed mussel (Aulacomya ater) samples for potential pollutants such as heavy metals, DDT, DDE, and petroleum hydrocarbons was carried out in April 1979, in the littoral area of Concepcion, Chile. Data on heavy metal content in sediments of the coastal areas in Chile have not previously been published except for Hg. Hoffman (1978) reports concentration levels of 0.045 ppm Hg in surficial sediments of San Vicente Bay.

Water quality criteria for aquaculture in thermal effluents, heavy metals and residual antifouling products

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World Symposium on Aquaculture in Heated Effluents and Recirculation Systems, Stavanger (Norway), 28 May 1980

AQUACULTURE IN HEATED EFFLUENTS AND RECIRCULATION SYSTEMS, pp. 99-112, 1981

HEENEMANN VERLAGSGESELLSCHAFT mbH, BERLIN (FRG)

SCHRIFTEN DER BUNDESFORSCHUNGSANSTALT FUER FISCHEREI, VOL. 16-17

The quality of marine power plant waters for thermal aquaculture was tested. Measurements were made of heavy metal concentrations in eel, sea bass, sea bream and shrimp held in condenser discharge water to determine if abnormal metal accumulation occurred. Fish and shrimp from other locations were analyzed to provide comparative data. Hg, Cd, Cr, Pb, Ni, Zn, Co, Mn, and Fe were measured in "whole body". The resistance to residual antifouling compounds was assayed on shrimp, grey mullet, sea bass, sea bream, and eels.

Fish scales: A possible record of short-term variability in environmental heavy metal exposure

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8th Biennial International Estuarine Research Conference, Durham, NH (USA), 28 Jul 1985

ESTUARIES, VOL. 8, NO. 2B, p. 32A, 1985

The scales of teleost fish are calcified structures whose elemental composition has been shown to reflect that of the aqueous environment. In Fundulus heteroclitus exposed to heavy metals, it was found that metals were incorporated into those circuli which formed during the exposure period.

Effects of metals on nitrogen fixation and denitrification in slurries of anoxic saltmarsh sediment

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MAR. ECOL. (PROG. SER.), VOL. 18, NO. 1-2, pp. 89-95, 1984

The effect of metals on nitrogen fixation and denitrification was examined in short-term experiments with saltmarsh sediments. At concentrations of 1000 ppm (weight metal: weight dry sediment), HgCl, $PbCl_2$, $CdCl_2$, $ZnSO_4$, $CuCl_2$, K_2, Cr_2O_7, K_2CrO_4, and Na_2MoO_4 decreased acetylene reduction throughout the experiments by more than 30%. $FeCl_3$ decreased it a lesser extent, while $NiCl_2$ greatly stimulated nitrogenase activity. The initial rate of nitrous oxide production was inhibited by $HgCl_2$, $PbCl_2$, $NiCl_2$, $K_2Cr_2O_7$, K_2CrO_4, $ZnSO_4$, $CuCl_2$, $FeCl_3$, and $CdCl_2$. Maximum production was stimulated substantially by $PbCl_2$, $K_2Cr_2O_7$, and K_2CrO_4, and somewhat by Na_2MoO_4, $ZnSO_4$, and $CuCl_2$.

PCB residues in bivalves and sediments of Raritan Bay

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BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY, 23(4-5), 690-697, Nov 1979

Sediments and bivalves (clams, Mercenaria mercenaria and Mya arenaria, and oysters, Crassostrea virginica) in the Raritan Bay-Lower New York Bay area were analyzed to determine the amount and types of PCB compounds present. No relationship was found between sediment silt-clay content and sediment PCB content, sediment silt-clay content and tissue PCB content, or tissue PCB content and sediment PCB content. Tissue PCB content was usually higher than sediment content. Sediments appeared to contain mixtures of various homologs of Aroclors; Aroclors 1016 and 1242 appeared in all samples. Mixtures of Aroclors also occurred in tissue, with 1016 and 1242 the most prevalent. The types and amounts of PCBs found may indicate downstream transport; stations with higher values are toward the center of the bay and may represent concentration and deposition from hydrographic conditions. Higher tissue values of PCB in the bivalves occurred in the center and lower portions of the bay.

Some metals in benthic invertebrates in Gdansk Bay

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Dep. Anal. Chem., Med. Acad., al. K. Marksa 107, 80-416 Gdansk, Poland

MAR. POLLUT. BULL., VOL. 17, NO. 11, pp. 503-507, 1986

The concentrations of Fe, Mn, Ni, Pb, Cu, Co, Zn, Cd, Ca, and Mg were determined in Mya arenaria, Macoma balthica, and other invertebrates from the Gdansk Bay. Both regional and species changes of some metals concentrations in mollusks were noted. The mean concentrations of Mn and Fe were significantly higher in Mya than in Macoma. Size-dependent variability of some metal concentrations in mollusks and Mesidothea was observed. Significant correlations between certain pairs of metal concentrations in Mya and Mesidothea were found.

Mussels as bioindicators of PCB pollution: a case study on uptake and release of PCB isomers and congeners in green-lipped mussels (*Perna viridis*) in Hong Kong waters

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ENVIRONMENTAL POLLUTION, VOL. 47, pp. 41-62, 1987

The uptake and release of PCB isomers and congeners were examined in green-lipped mussels (*Perna viridis*) through a transplantation experiment in two locations in Hong Kong waters. Rapid rates of uptake and release of relatively less lipophilic lower-chlorinated PCBs were observed in the mussels, indicating that the primary mechanism of bioaccumulation of lipophilic pollutants in *P. viridis* complies with the concept of equilibrium partitioning. Thus, data for contaminant concentrations are most appropriately based upon lipid weights of samples when using mussels as bioindicators of aquatic PCB pollution. Considering the kinetic parameters of PCBs based on lipid weight-related data, it is concluded that *P. viridis* has the ability to respond rapidly to changes in ambient levels of PCBs. This is significant in determining the usefulness and limitations of mussels as bioindicators for monitoring programmes investigating aquatic pollution by PCBs.

Effects of *in vivo* cadmium exposure on ATPases in gills of the lobster, *Homarus americanus*

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BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY, 23(1-2), 33-35, Sep 1979

In vitro tests of Cd on lobsters (*H. americanus*) exposed in a flowing seawater system to 6 ppb Cd for 30 days showed small increases in ATPase activity. Gill homogenates showed an almost 25% increase in ouabain-insensitive ATPase activity. No difference in sodium-potassium activated ATPase was apparent between control and Cd-exposed animals.

A-324

Effects of environmental parameters on the elimination of cadmium by eastern oysters, Crassostrea virginica

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ARCH. ENVIRON. CONTAM. TOXICOL., VOL. 16, pp. 733-743, 1987

Laboratory studies were conducted to test the effects of salinity, humic acid, and temperature on the rate of elimination of ^{109}Cd from laboratory-dosed juvenile oysters, Crassostrea virginica. After 140 days, oysters maintained at 34 parts per thousand (ppt) salinity retained 67% of the ^{109}Cd dose (CPM), oysters in 20 ppt salinity retained 72%, and those in 6 ppt salinity retained 80%. The presence of humic acid in 14 ppt salinity water enhanced the amount of ^{109}Cd eliminated in 140 days relative to oysters in control tanks without humic acid: oysters exposed to 10 parts per million (ppm) humic acid retained 65%, oysters exposed to 1 ppm humic acid retained 67%, controls retained 72%. Temperature had a significant effect on the rate of Cd elimination. Oysters held at 28°C and 20 ppt for 28 days retained 75%, oysters at 20°C and 20 ppt retained 81%, and those at 12°C and 20 ppt retained 88% of ^{109}Cd dose. The effects of a strong Cd-chelator, ethylenediamine tetraacetic acid-sodium salt (EDTA), were compared with those of the relatively weaker chelator, humic acid, on the rate of Cd elimination by oysters. No difference was observed between the two chelators over a 28 day depuration period. Cadmium concentrations were monitored in the water and Cd, Cu, Zn, Mg, and Fe concentrations were determined in the animals on the final day of the studies. Particle clearance assays were performed to determine if the rate of filtration by the oysters held in each of the test treatments correlated with the rates of Cd depuration. No direct correlations was observed.

9-225

A study of indication of trace metal pollution of marine areas by analysis of salt marsh soils

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MARINE ENVIRONMENTAL RESEARCH, 2(1), 19-31, Jan 1979

Salt marsh soils from the mean water level and from different levels above the mean water level at two Danish coastal lagoons, which differ in water pollution due to differences in the character of the surrounding land use, were analyzed for EDTA-extractable Pb, Cu, Zn, and Ni and for organic matter and cation exchange capacity. From the results a positive correlation was apparent between the trace metal loading of the soils, expressed by the trace metal concentration in relation to the content of soil organic matter, and the mean trace metal concentration of the lagoon water, submerging the salt marsh at high water. This opens up the possibility of using analyses of salt marsh soils as an indication of trace metal pollution of protected coastal waters.

The uptake of hydrophobic toxicants and the biochemical measurement of stress in marine fishes

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DISS. ABST. INT., PT. B - SCI. & ENG, VOL. 44, NO. 2, 1983

The importance of dietary fat in enhancing the absorption of hydrophobic toxicants such as DDT, 4,4'PCB, and benzo(a)pyrene was investigated in the saltmarsh killifish (Fundulus heteroclitus). When compared to a similar control diet containing no lipid, diets containing 20% dietary fat (triolein) enhanced the uptake of a single dose DDT by 87%, that of PCB by 180%, and that of benzo(a)pyrene by over 10 fold. The results of this part of the study revealed (1) benzo(a)pyrene was quantitatively transferred from initial fat droplets to the product phases during hydrolysis of the lipid carrier, (2) product phase containing dissolved benzo(a)pyrene was observed in contact with the absorptive epithelium, (3) after absorption, resynthesized triglyceride and benzo(a)pyrene were found reassociated in intracellular lipid droplets, and (4) benzo(a)pyrene was subsequently removed from the droplets and metabolized within the enterocyte prior to transport from the intestinal tissue.

Viability of embryos of the winter flounder Pseudopleuronectes americanus exposed to combinations of cadmium and salinity at selected temperatures

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MARINE BIOLOGY, 44(2), 117-124, 1977

Developing eggs of P. americanus were exposed to 9 combinations of Cd and salinity at 5° and 10° C. Overall mean times to 50% hatch ranged from 7.7 days at 10° C to 17.9 days at 5° C. Mean percentages of total hatches ranged from 50 to 100% for all treatment combinations. Response-surface analyses indicate percentages of viable hatches were generally lowest at 10% S (salinity) and highest in the 25 to 30% S range. Regression analyses of viable hatch data show that at both temperatures Cd significantly influenced viable hatch in all experiments. Viable hatch was also significantly influenced by the linear and quadratic effect of salinity in both tests at 5° C and in 2 of 3 tests at 10° C. The interaction between Cd and salinity also significantly affected viable hatch at 10° C.

Metallothionein and mercury tolerance in the killifish, *Fundulus heteroclitus*

Weis, P.; Stegeman, J.J. (ed.)

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2nd International Symposium on Responses of Marine Organisms to Pollutants, Woods Hole, MA (USA), 27-29 Apr 1983

PROCEEDINGS OF THE SECOND INTERNATIONAL SYMPOSIUM ON RESPONSES OF MARINE ORGANISMS TO POLLUTANTS HELD AT WOODS HOLE OCEANOGRAPHIC INSTITUTION, MASSACHUSETTS, USA, 27-29 APRIL 1983, pp. 153-166, 1984

ELSEVIER APPLIED SCIENCE PUBLISHERS, LONDON (UK)

MAR. ENVIRON. RES., VOL. 14, NO. 1-4

Synthesis of metallothionein (MT) as a possible mechanism by which *Fundulus heteroclitus* adapts to heavy metal pollution has been investigated in relation to responses to methylmercuric chloride (meHg) and $HgCl_2$ (Hg^{2+}) at different life stages. Clutches of embryos from unpolluted sites exhibit teratogenic responses to a standard dose of meHg or of Hg^{2+} which range from little or no effect (tolerant) to severely affected or almost complete inhibition of development (susceptible). At the time of hatching, untreated embryos from tolerant clutches had twice as much of a protein which co-migrates in SDS-PAGE gels with *Fundulus* MT as do those of susceptible clutches. These data suggest that metallothionein is not a significant factor in Hg tolerance in *Fundulus* adults, and has a questionable role in embryonic and larval tolerance to Hg^{2+}.

Search for a physiological component of methylmercury tolerance in the mummichog, Fundulus heteroclitus

Weis, J.S.; Weis, P.; Renna, M.; Vaidya, S.; Vernberg, F.J.; Thurberg, F.P.; Calabrese, A.; Vernberg, W.B. (eds.)

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Symposium on Physiology and Pollution of Marine Organisms, Mystic, CT (USA), 1-3 Nov 1983

MARINE POLLUTION AND PHYSIOLOGY: RECENT ADVANCES, pp. 309-326, 1985

UNIVERSITY OF SOUTH CAROLINA PRESS, COLUMBIA, SC (USA)

BELLE W. BARUCH LIBR. MAR. SCI., NO. 13, 1985

Heavy metal tolerance can be acquired by both short-term physiological mechanisms and by long-term genetic selection. In view of previous findings that Fundulus heteroclitus embryos from a polluted environment (Piles Creek) are more tolerant to methylmercury than embryos from a cleaner habitat (Southampton), the short-term component of tolerance was investigated in four experiments.

Effect of zinc on fin regeneration in the mummichog, Fundulus heteroclitus, and its interaction with methylmercury

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U.S. National Marine Fisheries Service

Fishery Bulletin, 78(1), 163-166, 1980

F. heteroclitus taken in the vicinity of Montauk, New York, had the lower portion of each caudal fin amputated and were then exposed to varying concentrations of methylmercuric chloride and/or $ZnCl_2$. Based on the results of 3 experiments, Zn accelerated regenerative growth and counteracted the growth retarding effects of methylmercury. The heavy metals also affected initial wound healing and blastema formation.

Congenital abnormalities in estuarine fishes produced by environmental contaminants

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Symposium on Pathobiology of Environmental Pollutants: Animal Models and Wildlife as Monitors, Storrs, CT (USA), 1977

ANIMALS AS MONITORS OF ENVIRONMENTAL POLLUTANTS. SYMPOSIUM ON PATHOBIOLOGY OF ENVIRONMENTAL POLLUTANTS: ANIMAL MODELS AND WILDLIFE AS MONITORS, pp. 94-107, 1979

NATIONAL ACADEMY OF SCIENCES, WASHINGTON, DC (USA)

Selected heavy metals and insecticides have been studied for sublethal effects on embryos of three species of estuarine fish. The insecticide studies indicate that carbaryl and parathion can induce cardiovascular abnormalities and developmental arrest in killifish (Fundulus heteroclitus). DDT, malathion, and carbaryl caused optic abnormalities in the Atlantic silverside (Menidia menidia) at concentrations as low as 0.01 ppm. Of the heavy metals studied, mercury salts caused craniofacial defects; lead interfered with ability to uncurl after hatching; and cadmium has no observable effect in concentrations below 10 ppm. Methylmercury was the most potent teratogen, causing anomalies seen in all other experiments with killifish and doing so at lower concentrations.

Effects of cadmium, zinc, salinity, and temperature on the teratogenicity of methylmercury to the killifish (*Fundulus heteroclitus*)

Weis, J.S.; Weis, P.; Ricci, J.L.; Lasker, R.; Sherman, K. (eds.)

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2nd ICES Symposium on the Early Life History of Fish, Woods Hole, MA (USA), 2 Apr 1979

THE EARLY LIFE HISTORY OF FISH: RECENT STUDIES, pp. 64-70, 1981

CONSEIL INT. EXPLOR. MER., COPENHAGEN (DENMARK)

RAPP. P.-V. REUN. CIEM., VOL. 178

Congenital anomalies produced in embryos of *F. heteroclitus* by methylmercury were investigated in relation to possible interactions with salinity, temperature, cadmium, and zinc. The abnormalities, which at 0.02-0.05 ppm included craniofacial defects, cardiovascular defects, and skeletal abnormalities, were reduced in frequency of incidence and degree of malformation when cadmium or zinc was present. Neither of these metals alone had any significant effect on embryos exposed at concentrations up to 10 ppm. Reduction of salinity from 30 ppt. to 10 ppt. and reduction of temperature from 25° to 16° C increased the teratogenicity of methylmercury. Eggs from different females were found to have different susceptibilities to the teratogenic effects of the methylmercury under identical conditions.

Pollutants and regeneration in estuarine killifish (Fundulus spp.) and fiddler crabs (Uca spp.)

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Symposium on Pathobiology of Environmental Pollutants: Animal Models and Wildlife as Monitors, Storrs, CT (USA), 1977

ANIMALS AS MONITORS OF ENVIRONMENTAL POLLUTANTS. SYMPOSIUM ON PATHOBIOLOGY OF ENVIRONMENTAL POLLUTANTS: ANIMAL MODELS AND WILDLIFE AS MONITORS, p. 394, 1979

NATIONAL ACADEMY OF SCIENCES, WASHINGTON, DC (USA)

Regeneration of caudal fins in the killifish (Fundulus heteroclitus) was retarded by treatment with 10 ppb DDT, malathion, parathion, or carbaryl. Cadmium chloride at 0.01 and 0.1 mg/l retarded wound healing and subsequent regeneration. Regeneration in the fiddler crabs (Uca pugilator) and (U. pugnax) was studied after single or multiple autotomy of limbs and exposure to insecticides or heavy metals. Exposure to DDT at 10 and 25 ppb accelerated the rate of limb regeneration and, in animals with multiple autotomy, shortened the time to ecdysis. These responses may be the result of heightened excitation of the nervous system and the resulting secretion of neuroendocrine factors promoting limb regeneration and molting.

Toxaphene degradation in estuarine sediments

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JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY, 26(1), 280-282, Jan.-Feb. 1978

Sediment was taken from the Baruch Plantation, an estuary near Georgetown, South Carolina, which is uncontaminated by industries or human habitation and which receives little freshwater input other than through rainfall. The samples were collected at low tide from within the reducing layer of the sediment, 20 cm depth. The top 5 cm of the sediment column revealed no detectable toxaphene, although low levels of other chlorinated pesticides and PCB (Aroclor 1254) were found. In the laboratory toxaphene degradation occurred quickly in flasks containing sterilized sediment, unsterilized sediment, and sterilized sand containing $Fe_3(OH)_8$. The normal toxaphene fingerprint was greatly altered within a few days by the formation of compounds having shorter gas chromatography (GC) retention times. That these changes in the sediment system were caused by chemical rather than biological processes was suggested by the breakdown of toxaphene in sterile as well as unsterile samples, and was confirmed by the similar GC pattern of products isolated from the Fe(II)/Fe(III)-sand system. There was no breakdown in the sand control system. The breakdown of toxaphene in salt marsh sediments and in the Fe(II)/Fe(III)-sand system probably occurs by a reductive dechlorination mechanism.

Contaminants in lobsters from an experimental culture facility

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CAN. TECH. REP. FISH. AQUAT. SCI, NO. 1027, 1981

The hepatopancreas of five dead lobsters (Homarus americanus) were analyzed by gas chromatography and/or mass spectrometry. Most samples contained polynuclear aromatic hydrocarbons, benzothiazole, PCB, p,p'-DDE, trans-nonachlor, hexachlorobenzene, and a dichlorobenzene. BHT (2,6-tert-butyl-4-methylphenol) was detected in all samples. The metabolite of BHT, 2,6-di-tert-butyl-4-methylene-2,5-cyclohexadienone, was detected in one sample, containing a very high level of BHT. Other compounds detected in some samples included methyl and ethyl esters of fatty acids, pentyl benzoate, and tentatively identified aliphatic nitriles. Some of the contaminants were determined quantitatively. The origin and significance of the contaminants were discussed.