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NSY PORTSMOUTH
5090.3a

ESTUARINE ECOLOGICAL RISK ASSESSMENT CASE STUDY FOR PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

PROJECT INVESTIGATORS' WORKSHOP

COMPILATION OF PRESENTATION MATERIALS

MARCH 9, 1994

UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NH

Complied by

Marine Environmental Support Office
- East Detachment
Naval Command, Control, and Ocean Surveillance Center
RDTE Division, Code 5221
27 Tarzwell Dr., Narragansett, RI 02882

TENTATIVE AGENDA
PNS PROJECT INVESTIGATORS WORKSHOP
UNIVERSITY OF NEW HAMPSHIRE
March 9, 1994
Morse Hall, Room 301
8:00 - 5:30

Morning Presentations

8:30 - 9:00		Coffee & Donuts
	Speaker	**Topic**
9:00 - 9:10	Robert Johnston	Overview of project and purpose of meeting
9:10 - 9:30	Larry Ward	Sedimentology
9:30 - 9:50	Steve Jones	Microbiology
9:50 - 10:10	Dave Burdick	Salt marsh ecology
10:10 - 10:30	Fred Short	Eelgrass and mussel ecology
10:30 - 10:50		Break
10:50 - 11:10	Richard Langan	Water column and flounder
11:10 - 11:30	Doug Cullen	Water column chemistry
11:30 - 11:50	Robert Bowen	Chemical markers
11:50 - 12:10	Richard Pruell	Bioaccumulation in lobsters and flounders - organic chemistry
12:10 - 12:30	Barbaros Celikkol, Pavlos, Chadwick	Hydrodynamic and contaminant model -
12:30 - 1:30		Lunch - Order in
1:30 - 1:50	Ray Grizzle	Benthic Organisms
1:50 - 2:10	Robert Johnston	Offshore media protection standards and seep results

Afternoon: Group Discussion

	Moderator	**Topic**
2:10 - 3:00	Wayne Munns	Risk synthesis
3:00 - 3:15		Break
3:15 - 4:00	Fred Short/ Robert Johnston	Monitoring report and proposal
4:00 - 5:00	Robert Johnston/ Larry Ward	Future activities/Wrap up

PNS PROJECT INVESTIGATORS WORKSHOP
ATTENDEES

UNH Jackson Estuarine Laboratory	Telephone	FAX
Larry Ward Jackson Estuarine Laboratory	603 862-2175	603 862-1101
Fred Short Jackson Estuarine Laboratory	603 862-2175	603 862-1101
David Burdick Jackson Estuarine Laboratory	603 862-2175	603 862-1101
Richard Langan Jackson Estuarine Laboratory	603 862-2175	603 862-1101
Steve Jones Jackson Estuarine Laboratory	603 862-2175	603 862-1101
UNH Center for Ocean Engineering		
Barbaros Celikkol Mechanical Engineering Kingsbury	603 862-1940	603 862-2486
John Pavlos Mechanical Engineering Kingsbury	603 862-1940	603 862-2486
Robert Swift Mechanical Engineering Kingsbury	603 862-1837	603 862-2486
Naval Research and Development	**Telephone**	**FAX**
Robert K. Johnston NCCOSC NRaD c/o USEPA Environmental Research Laboratory Narragansett 27 Tarzwell Drive Narragansett, RI 02882	401 295-5462	401 295-5462 home FAX 401 782-3030 EPA FAX

Portsmouth Naval Shipyard

Jim Tayon Code 121.5 Environmental Affairs Portsmouth Naval Shipyard Portsmouth, NH 03804-5000	207 438-3832	207 438-1535 FAX backup - 207 438-3526
Mike Pederson Environmental Affairs Portsmouth Naval Shipyard Portsmouth, NH 03804-5000		

Naval Facilities Engineering Command, Northern Division

Lt. Jim Conroy Code 1823JC Installation Restoration Section Northern Division Naval Facilities Engineering Command 10 Industrial Highway Mail Stop 82 Lester, PA 19113-2090	215 595-0567 Ext. 147	215 595-0555
Simeon Hahn Code 1821SH Installation Restoration Section Northern Division Naval Facilities Engineering Command 10 Industrial Highway Mail Stop 82 Lester, PA 19113-2090	215 595-0567 Ext. 190	215 595-0555

Sciences Applications International Corp.	**Telephone**	**FAX**
Wayne Munns SAIC Environmental Research Laboratory Narragansett Narragansett, RI 02882	401 782-3017	

Environmental Protection Agency

Richard Pruell 401 782-3091
USEPA
Environmental Research Laboratory Narragansett
Narragansett, RI 02882

Jack Gentile 401 782-3015
USEPA
Environmental Research Laboratory Narragansett
Narragansett, RI 028822

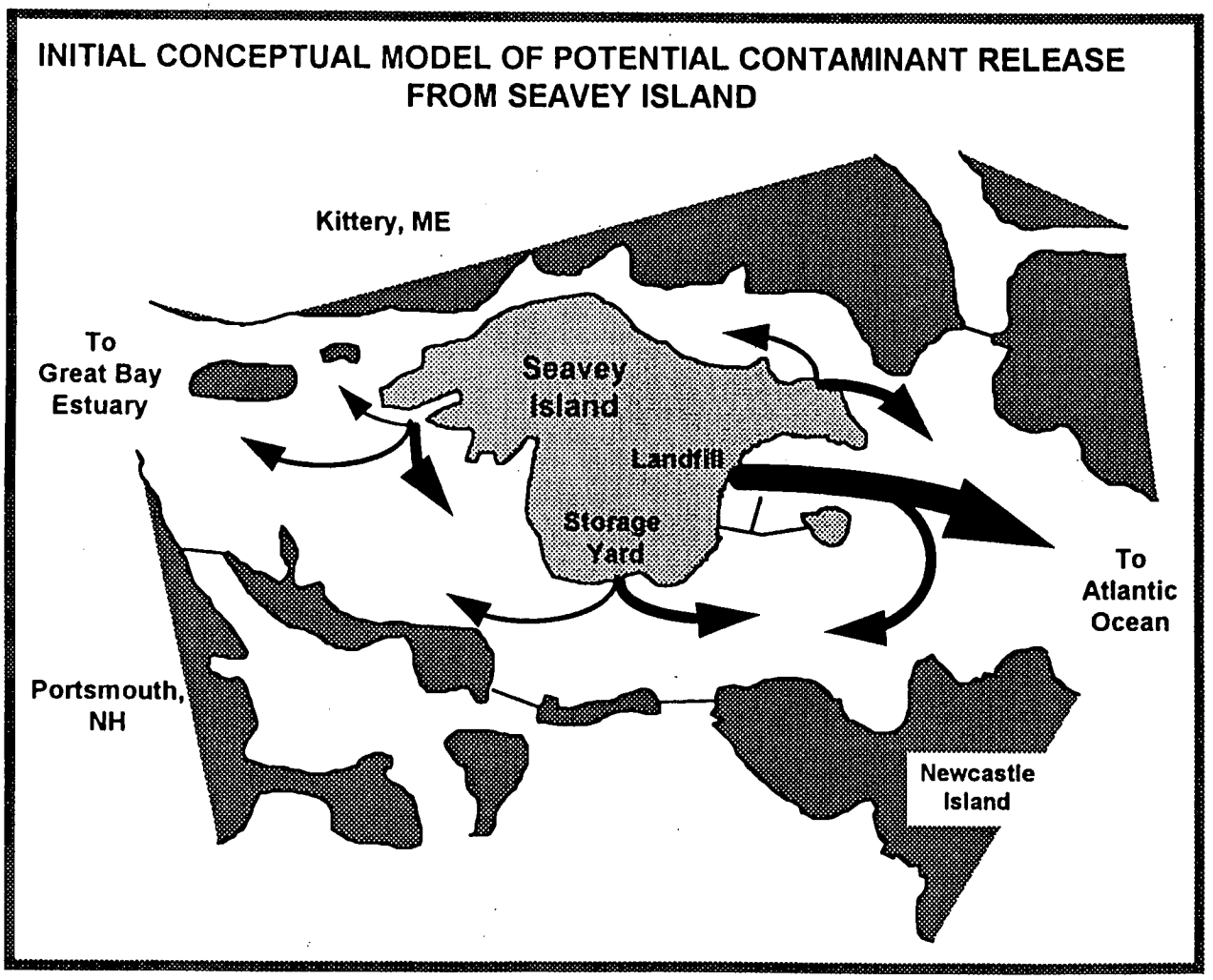
Hal Walker 401 782-3134
USEPA
Environmental Research Laboratory Narragansett
Narragansett, RI 02882

Jerry Pesch 401 782-3007
USEPA
Environmental Research Laboratory Narragansett
Narragansett, RI 02882

University of Rhode Island

Doug Cullen 401 792-6836
Grad School of Oceanography
Center for Atmospheric Chemistry Studies
Narragansett Bay Campus
University of Rhode Island
South Ferry Road
Narragansett, RI 02882

Bob Johnston, NCCOSC



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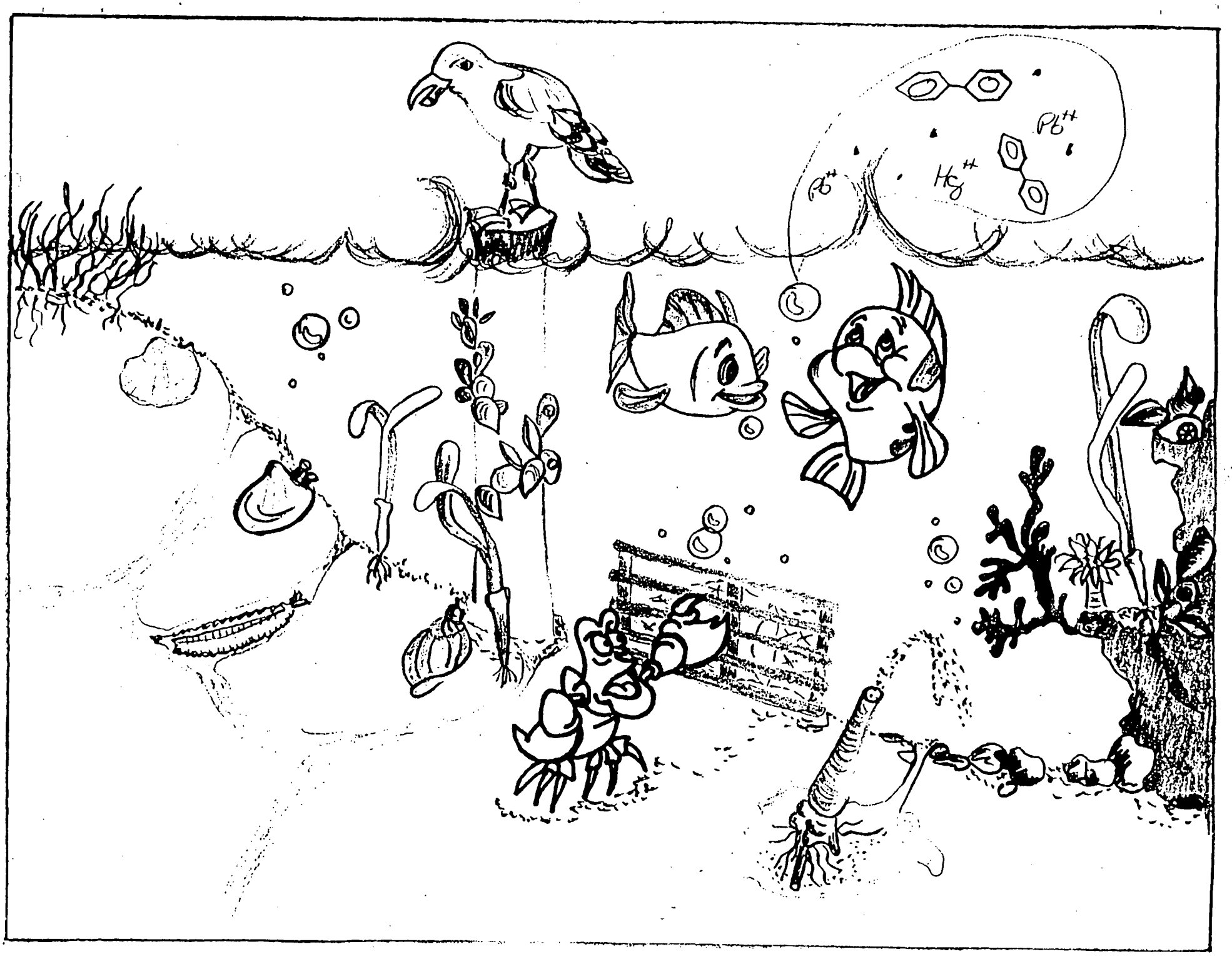
Pb++
Hg++
Pb++

ENDPOINT	FINDING/PHASE II
PELAGIC COMMUNITY	
PRIMARY PRODUCTIVITY	• Within Normal Limits - Continue monitoring.
FLOUNDER	• Tissue Levels Low - Resample to measure abundance and confirm tissue residues.
BENTHIC COMMUNITY	
INFAUNA	• Very High Densities Identified • High Densities Identified - Confirm finding and assess sig.
EPIBENTHIC	
LOBSTERS	• Very Abundant; Sig Recruitment • Bioaccumulation Evident • Below FDA Action Levels - Assess bioaccum. potential. - Delineate important nursery and reproductive habitat.
FUCOID ALGAE	• Within Normal Range • Tissues Higher for Cu
MUSSELS	• Abundance/Density Within Normal Range • Tissue Residue/Exposure - Confirm outliers and assess significance of residues.

ENDPOINT	FINDING/PHASE II
EELGRASS COMM.	• Abundance/Morphology Within Normal Range • Good Habitat Quality • Tissues Higher for Cu, Cr, Pb - Continue monitoring and assess significance of residues.
SALT MARSH COMM.	- Data Gap for Phase II
WATER QUALITY	
DO, Sal, pH, Temp	• Within Normal Range
Nutrients	• Excess Nutrients (NO_3)
Microbes	• Consistent Sewage Input
Hydrodynamics	• Significant Flushing in Lower Estuary - Calibrate/Validate hydrodynamic and transport models. - Determine dynamics of estuarine water movement.
SEA URCHIN	• Toxicity Detected
CONTAM.	• Water Column Data Quality Objective Not Achieved • Heavy Metals in Seep Samples - Resample with appropriate methods and determine loading rates from seeps.
DEP. MUSSELS	• Physiology Within Normal Range • No Appreciable Accumulation

ENDPOINT	FINDING/PHASE II
SEDIMENT QUALITY	
GEOPHYSICAL	• Depositional Areas Identified - Develop sed. distribution map. - Determine sedimentation dynamics.
AMPHIPOD TOX.	• Toxicity Detected - Assess significance.
MICROBES	• Sewage Input Identified - Determine sources.
CONTAMINATION	• Contaminants of Concern Identified (See Table 1) - Assess assimilative and detoxifying capacity of sediments and shoreline substrates. - Determine levels protective of marine organisms.
CHEMICAL MARKERS	• No Unique Shipyard Marker • Significant Sewage Input • Evidence of Runoff, Atmos., and Petroleum Inputs - Assess historical trends of sources inputs. - Determine marker dispersion and deposition rates.

PORTSMOUTH CASE STUDY (PHASE II)
MANAGEMENT STRUCTURE

NCCOSC RDTE DIVISON, SAN DIEGO, CA
Project Officer: R.K. Johnston
Assistant Project Officer: Sandi Harrell

EPA Project Officer: Hal Walker

EPA Environmental Research Laboratory Narragansett (ERLN)
PIs: Hal Walker, R.K. Johnston
QA: Jan Prager
TASKS: Exposure/Response
Marine Chemistry
Risk Synthesis
Long Term Monitoring

EPA ERLN, Exposure Branch
PIs: R. Pruell, W. Boothman
Tasks: Bioaccumulation
Markers
Marine Chemistry

SAIC ERLN Contract
PIs: W. Munns, D. Nacci, R. McKinney, R. Bowen
TASKS: Exposure/Response
Risk Synthesis
Markers
Bioaccumulation
Marine Chemistry

ROW ERLN Contract
PI: D. Sheehan, D. Plueth
Task: Data Management

UNH Jackson Estuarine Laboratory
Cont: N66001-92-D-0092 DO 0011
PI: Fred Short
PM: Larry Ward
QA: David Burdick
TASKS: Marsh/Benthic Ecology
Bioaccumulation
Sedimentology
Long Term Monitoring
Risk Synthesis

UNH Ocean Engineering Program
PI: B. Celikkol
TASKS: Dispersion Dynamics Modeling

Cambell Univ. (CU) Ray Grizzle
Benthic Community Ecology

NCCOSC Code 522
PI: B. Chadwick
TASK: ECOS Survey

CSC
Technical Support
PI: C. Katz

Battelle Marine Sciences Lab (BMSL) Marine Chem
PI: L. Lefkowitz

URI GSO N66001-92-D-0092 DO 0023
Trace Metal Chemistry
PI: R. Arimoto, Doug Cullen

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PHASE II TECHNICAL APPROACH

1. Quantify Ecological Risk From Exposure

    a. Exposure-Response Bioassays
    b. Salt Marsh and Benthic Ecology
    c. Bioaccumulation Potential
        (1) Lobsters
        (2) Flounder
        (3) Food Chain

2. Conduct Detailed Ecological Assessment of Impact or Lack Thereof

    a. Sedimentation and Accumulation
        (1) sediment transport
        (2) suspended sediment dynamics
        (3) geochemical assimilation capacity
    b. Dispersion Dynamics
        (1) track water masses
        (2) measure dispersion coefficients
        (3) quantify current regimes
        (4) modelling
    c. Chemical and Microbial Markers

3. Long Term Monitoring

4. Ecological Risk Synthesis & Analysis

REVISED CONCEPTUAL MODEL

Areas At Risk

Movement of Materials

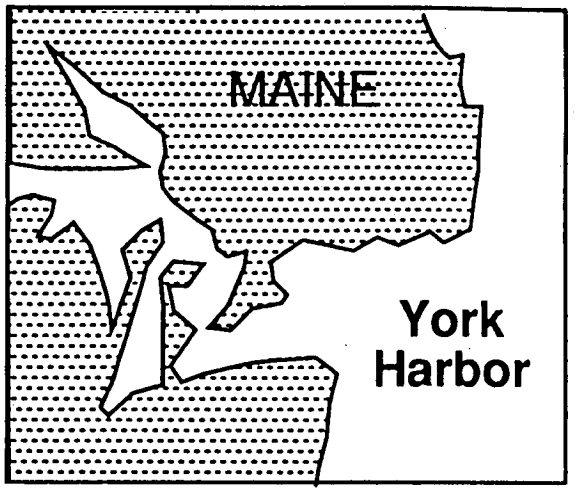
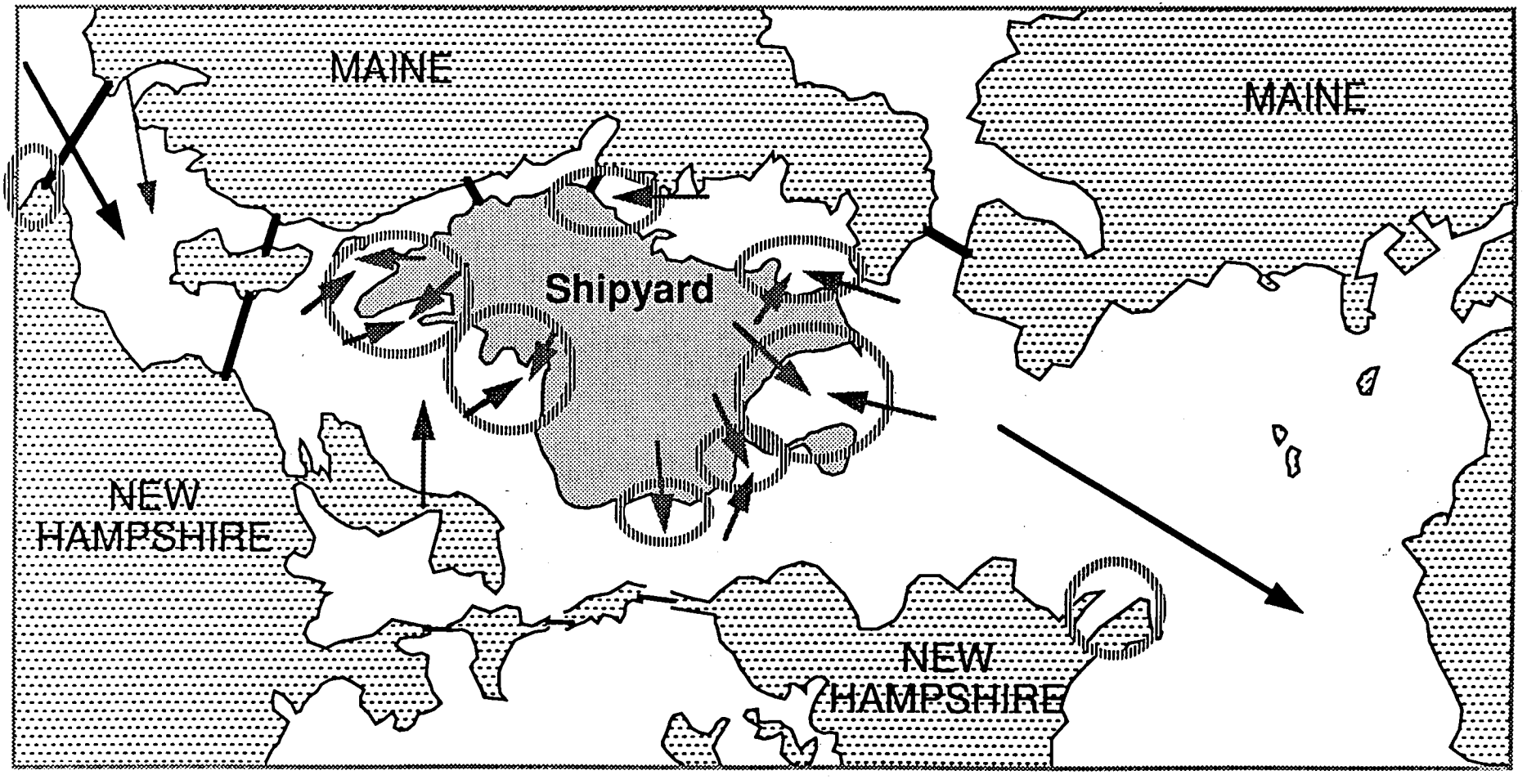


Figure7. Revised conceptual model showing the potential movement of contaminants and areas at risk in the Lower Great Bay Estuary.



ASSESSMENT/MEASUREMENT ENDPOINT	TASK	LAB
PELAGIC COMM.		
Primary Production	Chlorophyll *a*	UNH-JEL
	Pheaophytyn	UNH-JEL
Flounder	Abundance and Field Sampling	UNH-JEL
	Organic/Metal	ERLN
	Hg, CH_3-Hg	BMSL
	Bioaccum.	NCCOSC/ERLN
BENTHIC COMM.		
Infauna	Sed. Texture	UNH-JEL
	Community	CU
Epibenthic Lobster	Habitat, Density	UNH-JEL
	Tagging Study	UNH-JEL
	Organic/Metal	ERLN
	Hg, CH_3-Hg	BMSL
	Bioaccum.	NCCOSC/ERLN
Mussel	Habitat, Density	UNH-JEL
	Monitoring	UNH-JEL
	Residues	BMSL
	Deployed	UNH-JEL/URI
	Lab Bioaccum.	ERLN/SAIC

ENDPOINT	TASK	LAB
BENTHIC COMM.		
Sea Urchin	Pore Water Tox	ERLN/SAIC
	Lab Bioaccum.	ERLN/SAIC
PLANT COMM.		
Eelgrass	Habitat, Density	UNH-JEL
	Metal	BMSL
	Lab Bioaccum.	ERLN/SAIC
Spartina	Habitat, Density	UNH-JEL
	Metal	ERLN/SAIC
SEDIMENT QUALITY		
Geophysical	Distribution	UNH-JEL
	Grain Size	UHH-JEL
	Deposition Rate	UNH-JEL
	Dynamics	NCCOSC/UNH
Geochemical	Deep Cores	ERLN/UNH
	AV Sulphides	ERLN
	Org. Carbon	UNH-JEL/ERLN
	Assimilation	NCCOSC/ERLN
Contamination	Organic, Metal	BMSL
	Markers	ERLN/UNH
	Spiked Sed	ERLN/SAIC
	Transport	UNH-OEP
	MPS	NCCOSC

ENDPOINT	TASK	LAB
WATER QUALITY		
Hydrology	Physical	UNH-JEL
	Nutrients	UNH-JEL
	Dynamics	NCCOSC/UNH
	Currents	NCCOSC/UNH
Contamination	Trace Metal	URI-GSO
	Microbes	UNH-JEL
	Chem. Markers	ERLN/SAIC
	Seeps	UNH/BMSL/URI
	Transport	UNH-OEP
LOADING		
Sources	Markers	ERLN/UNH
	Deep Cores	ERLN/UNH
Rates	Seeps	UNH/BMSL/URI
	Trace Metals	URI-GSO
	Biota/Sediment	NCCOSC
	Modeling	UNH-OEP
Dispersion	Dye Study	NCCOSC/UNH
	Trace Metals	URI-GSO
	Modeling	UNH-OEP

Anticipated Submission dates for OFFSHORE Reports			
Updated: 7 March 94			SUBMITTAL
REPORT TITLE	TYPE	Data Set	DATE
1. Phase I Report	Final		May 94
2. Phase 2 Work Plan	Draft Final		**Mar-94**
3. Sediment Distribution Map	Draft Final		**Jun-93**
	Final		Mar-94
4. Hydrodynamic Model	Draft Final		**Jun-93**
	Final		Mar-94
5. Estuarine Dynamics	Draft Data Report		**Aug-93**
	Draft Final	May-94	Jul-94
	Final		Sep-94
6. Bioaccumulation (Field)	Draft Final	Mar-94	Jul-94
Bioaccumulation (Lab)	Draft Final	Apr-94	Aug-94
7. Monitoring Status Report	Draft Final	**Dec-93**	Mar-94
8. Dispersion Model	Draft Report		Feb-94
9. Sedimentology	Draft Final		Mar-94
10. Estuarine Ecology	Draft Report	**Dec-93**	Mar-94
11. Media Protection Standards	Final Draft		**Sep-93**
	Final	Mar-94	May-94
12. Assimilation Capacity	Draft Final	Mar-94	Jul-94
13. Exposure Response (4 Endpoints)	Final Report	Jun-94	Aug-94
Exposure Response (Sea Urchins)	Final Report	Jun-94	Aug-94
Exposure Response (Aquatic Plants)	Final Report	Jun-94	Aug-94
14. Trace Level Organics (Estuarine)	Final Report	Mar-94	Sep-94
15. Trace Level Organics (Seeps)	Preliminary Rpt	**Nov-93**	**Nov-93**
	Draft Report	**Mar-94**	May-94
	Draft Final	**May-94**	Jun-94
16. Chemcial Markers	Draft Report	**Nov-93**	**Feb-94**
	Draft Final	Mar-94	Apr-94
17. Microbial Markers	Draft Final		Mar-94
16. Risk Synthesis	Draft	Jun-94	Sep-94

Larry Ward, UNH-JEL

OBJECTIVES/ACCOMPLISHMENTS

I. Surficial Sediment Characterization and Distribution Map

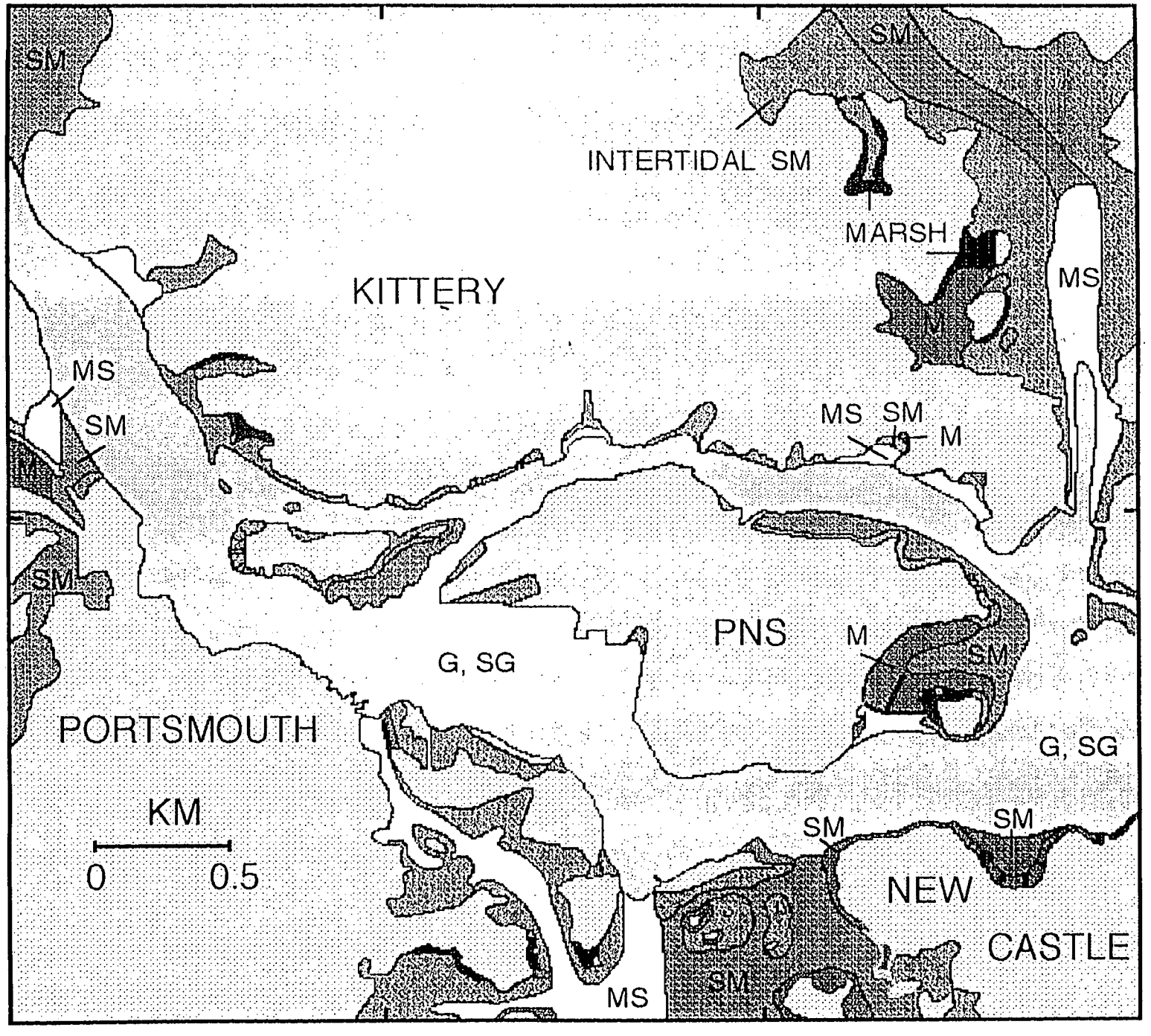
- Grain Size, Moisture, TOM @ 218 Locations
- Surficial Sediment Distribution Map
- Uses - Background Information For
    - Potential Sites of Contaminant Deposition
    - Habitat Characterization
    - Benthic Organism Distribution
    - Numerical Model

II. Subsurface Sediment Characterization - Upper 2 m

- Grain Size, Moisture, TOM, Bulk Density @ 21 Locations
- Age/Depth @ 4 Sites
- Uses - Background Information For
    - Depth of Contaminant Burial
    - Time History of Contaminant Inputs

III. Water Column Sediment Dynamics

- TSS and TOM Distribution in Lower Estuary
- Sedimentation Rate in Water Column in Clark Cove
- Uses - Background Information For
    - TSS Loadings to Estuary
    - Numerical Model
    - Use of Sediment Traps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SM
INTERTIDAL SM
MARSH
KITTERY
MS
MS
SM
M
MS
SM
M
SM
PNS
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G, SG
PORTSMOUTH
G, SG
KM
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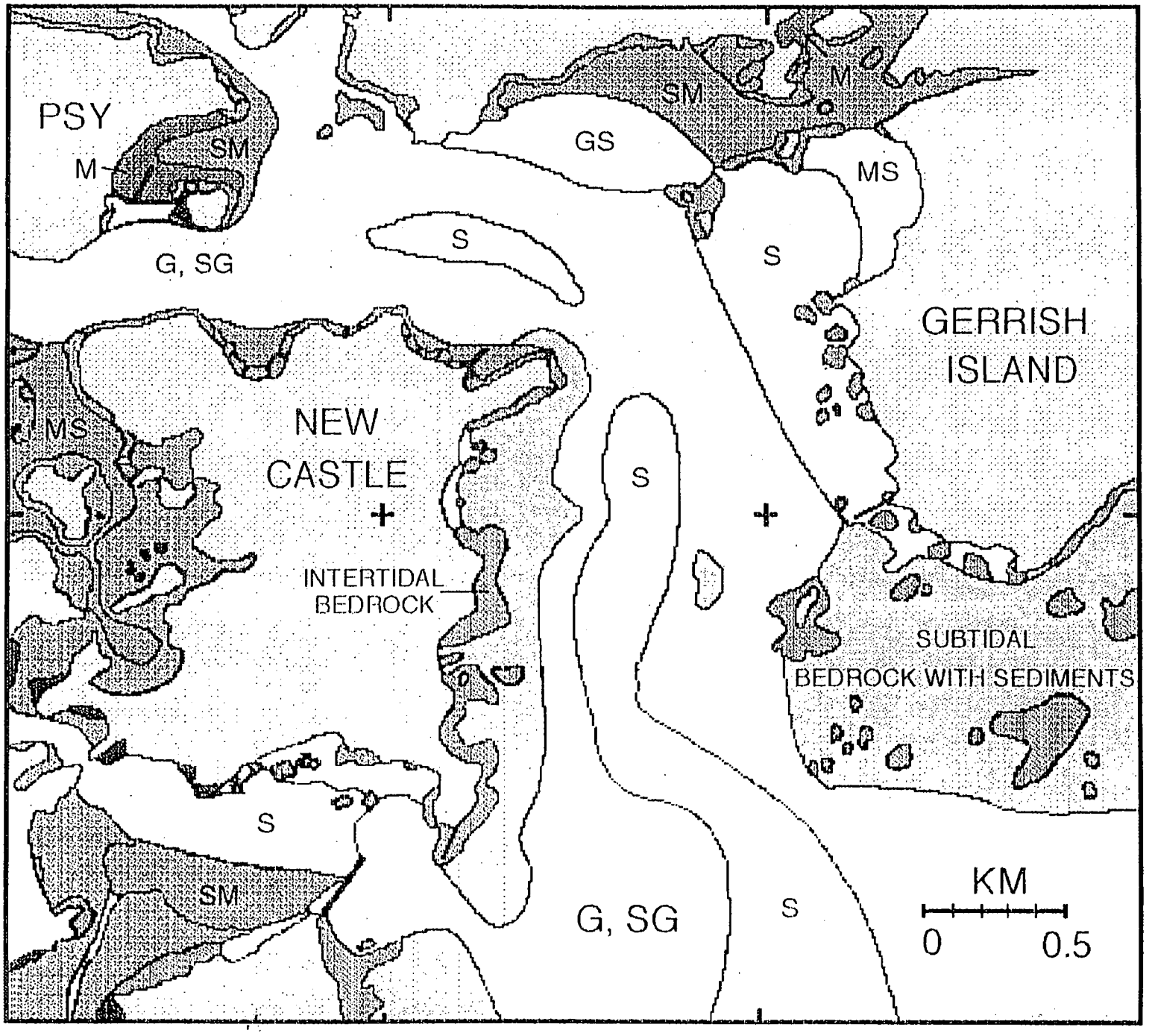
0.5
SM
SM
NEW
CASTLE
MS
SM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ISLAND
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CASTLE
INTERTIDAL
BEDROCK
S
SUBTIDAL
BEDROCK WITH SEDIMENTS
S
SM
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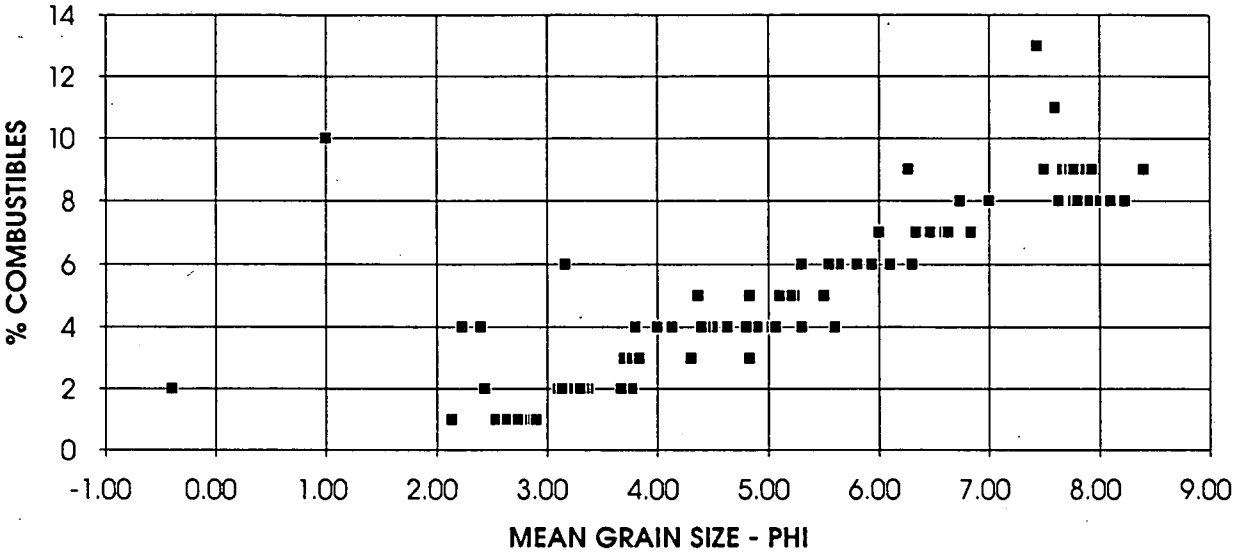
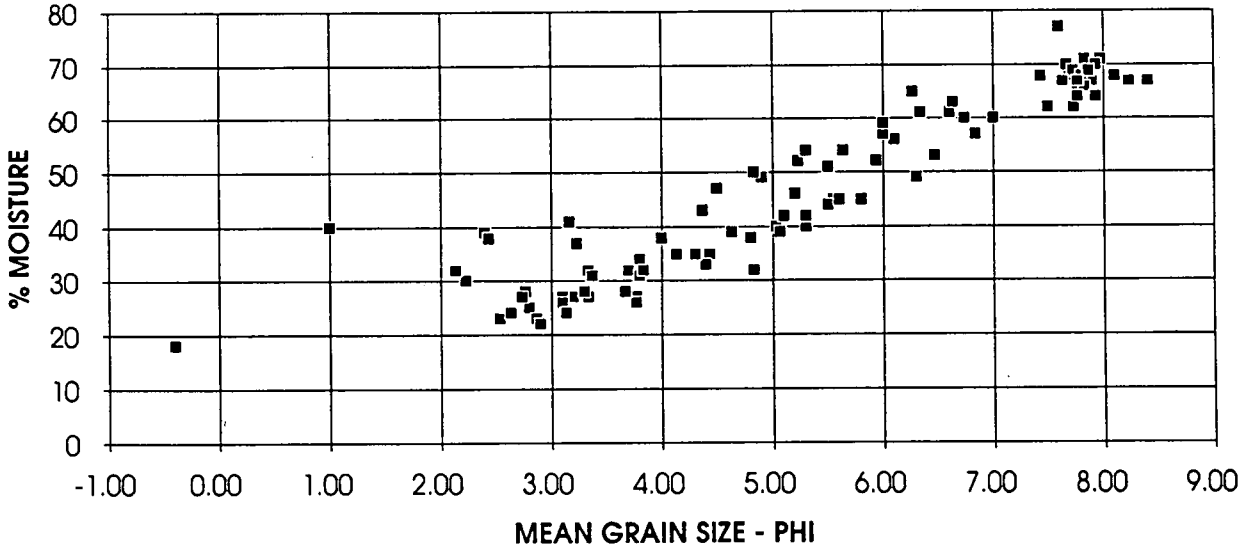
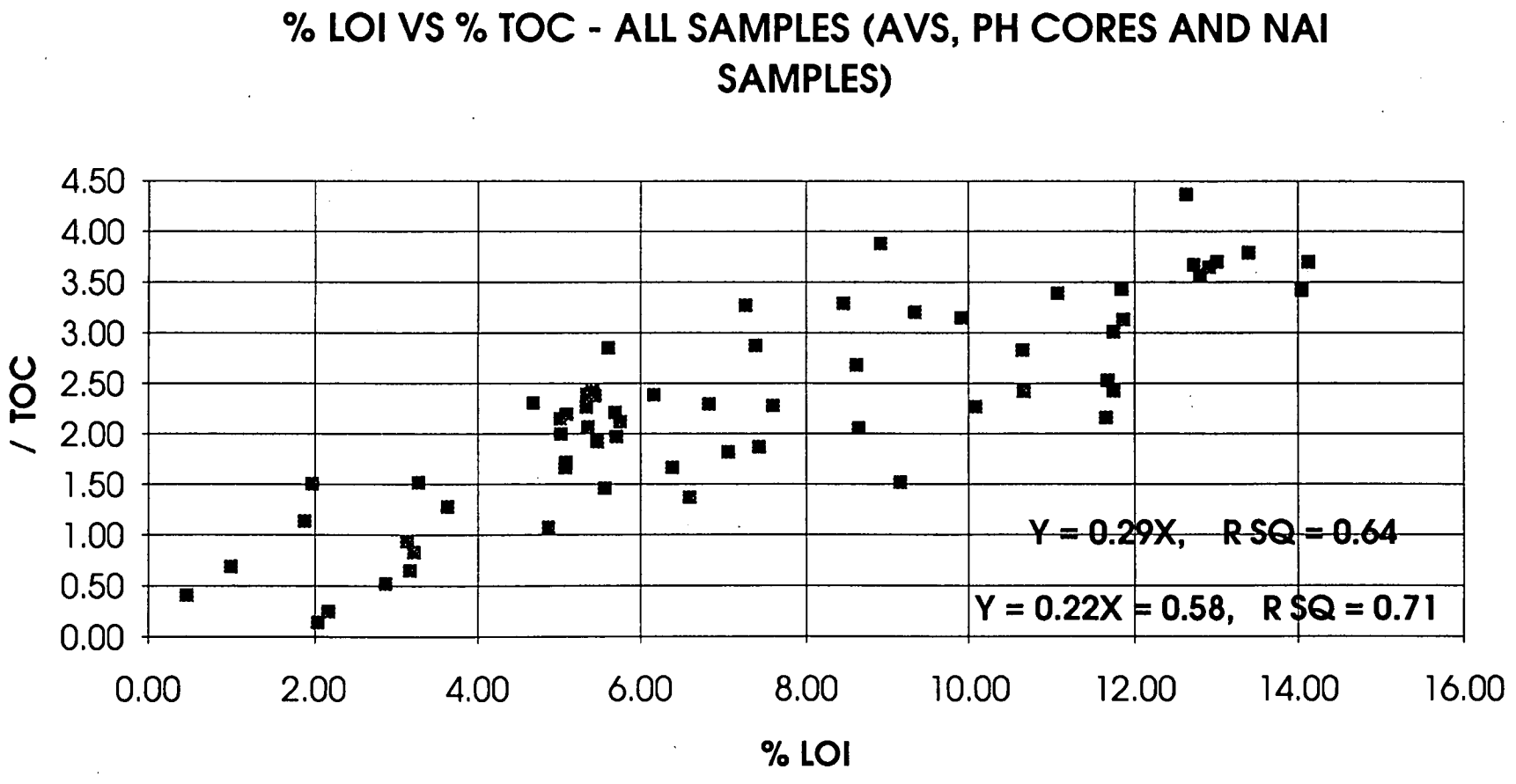
0.5

MEAN GRAIN SIZE VS ORGANIC CONTENT OF PH SAMPLES

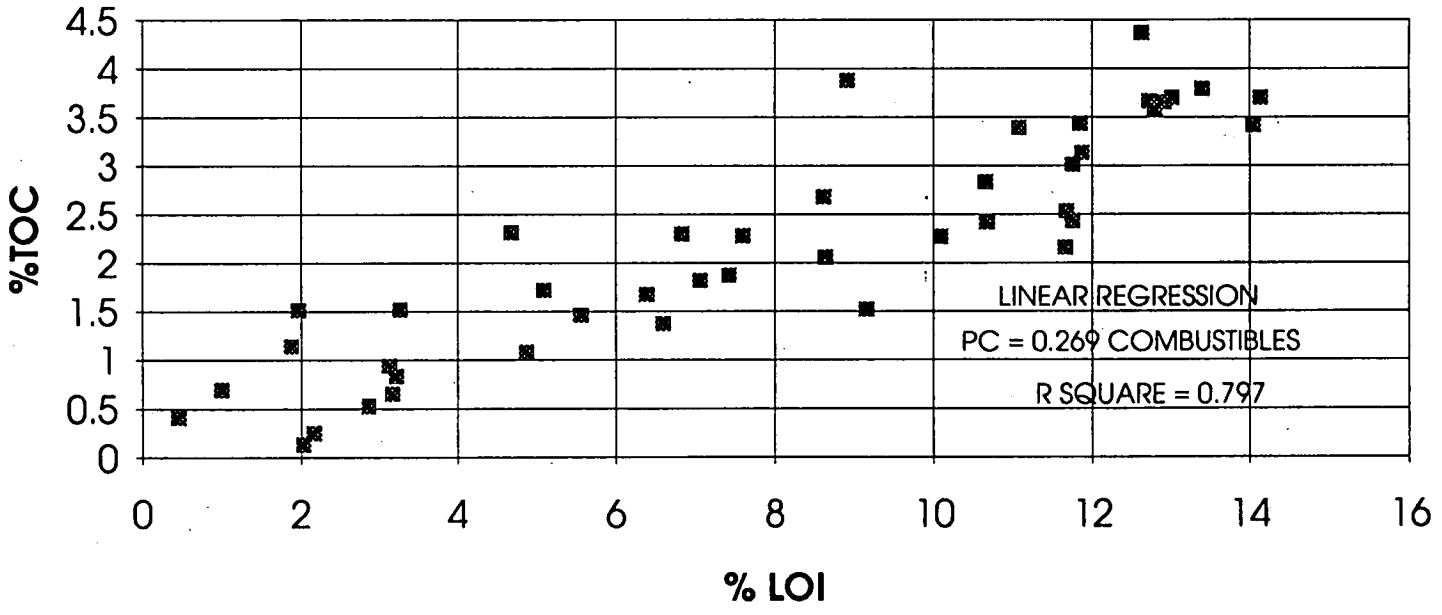


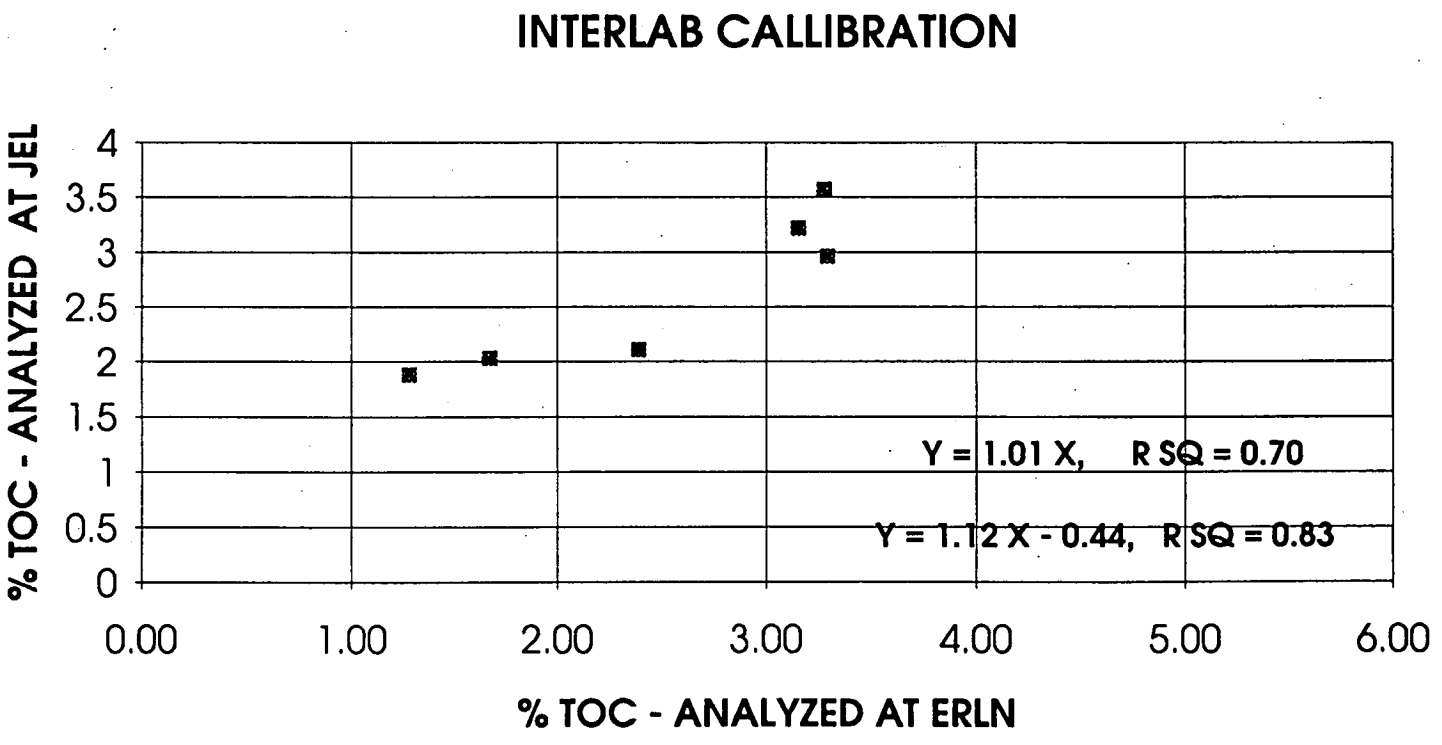
MEAN GRAIN SIZE VS MOISTURE CONTENT OF PH SAMPLES

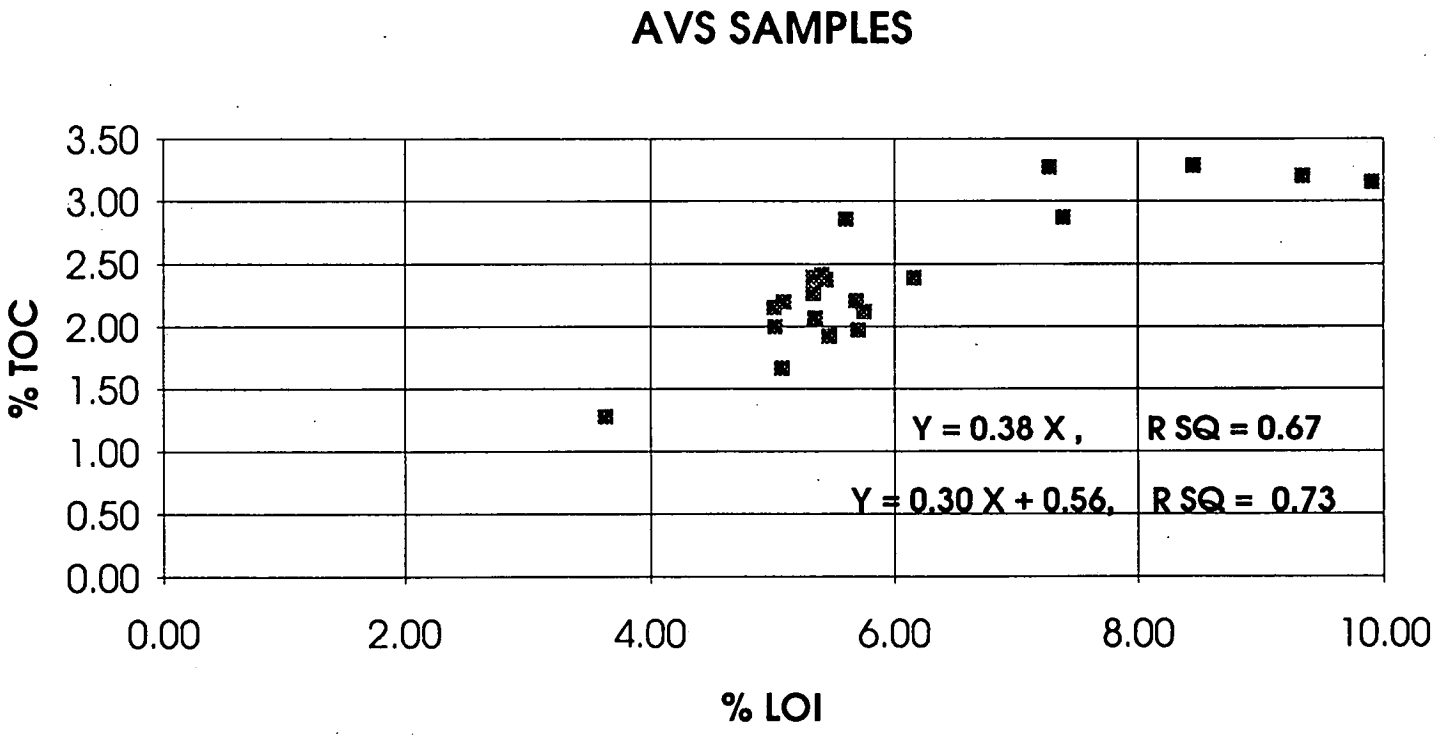


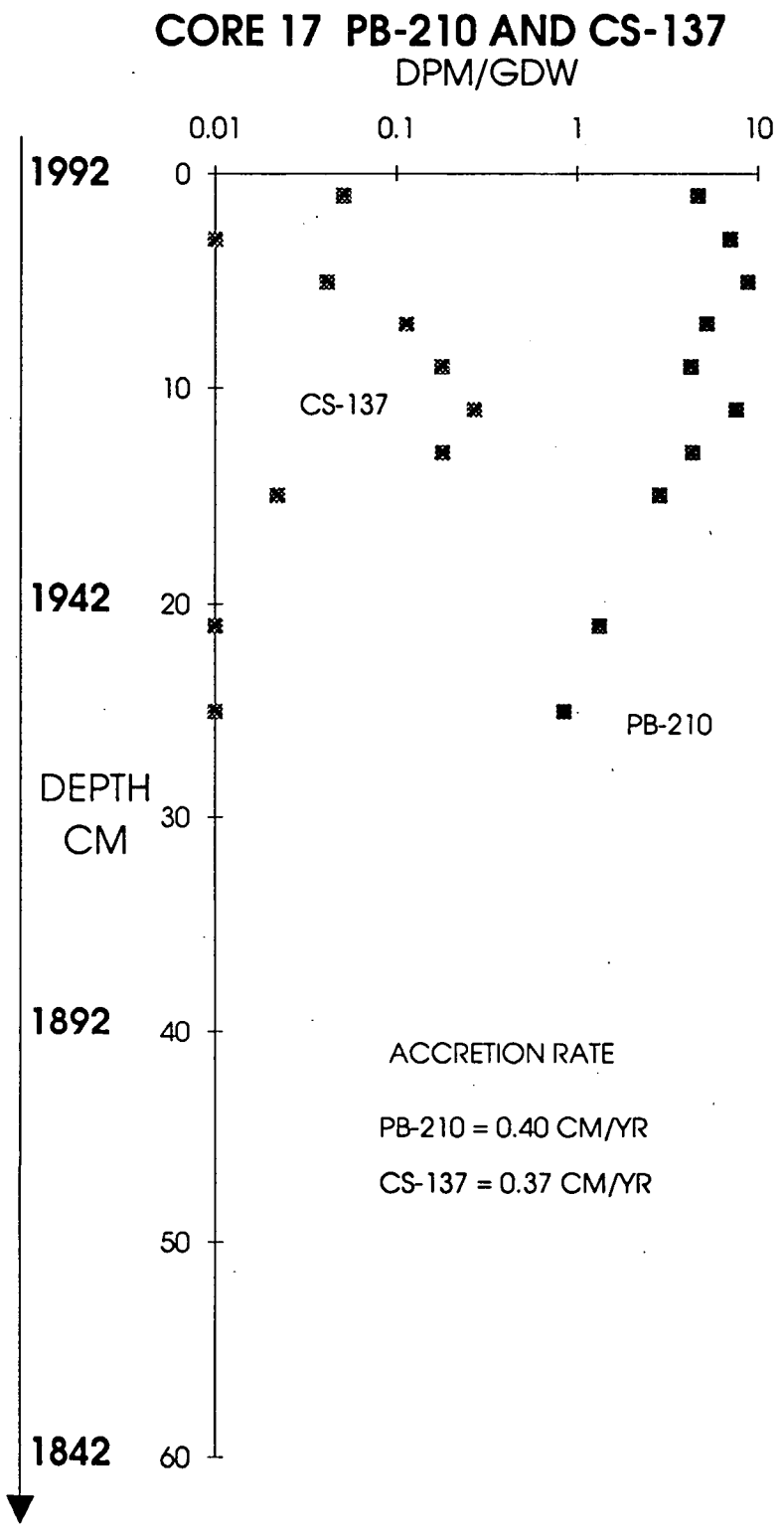

% LOI VS % TOC - ALL SAMPLES (AVS, PH CORES AND NAI SAMPLES)
/ TOC
% LOI
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Y = 0.29X, R SQ = 0.64
Y = 0.22X = 0.58, R SQ = 0.71

TOC VS TOM OF PH SURFACE AND CORE SAMPLES




INTERLAB CALLIBRATION
% TOC - ANALYZED AT JEL
4
3.5
3
2.5
2
1.5
1
0.5
0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
% TOC - ANALYZED AT ERLN
Y = 1.01 X, R SQ = 0.70
Y = 1.12 X - 0.44, R SQ = 0.83


AVS SAMPLES
% TOC
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
2.00
4.00
6.00
8.00
10.00
% LOI
Y = 0.38 X ,
R SQ = 0.67
Y = 0.30 X + 0.56,
R SQ = 0.73


CORE 17 PB-210 AND CS-137
DPM/GDW
0.01
0.1
1
10
1992
0
10
1942
20
30
1892
40
50
1842
60
DEPTH
CM
CS-137
PB-210
ACCRETION RATE
PB-210 = 0.40 CM/YR
CS-137 = 0.37 CM/YR

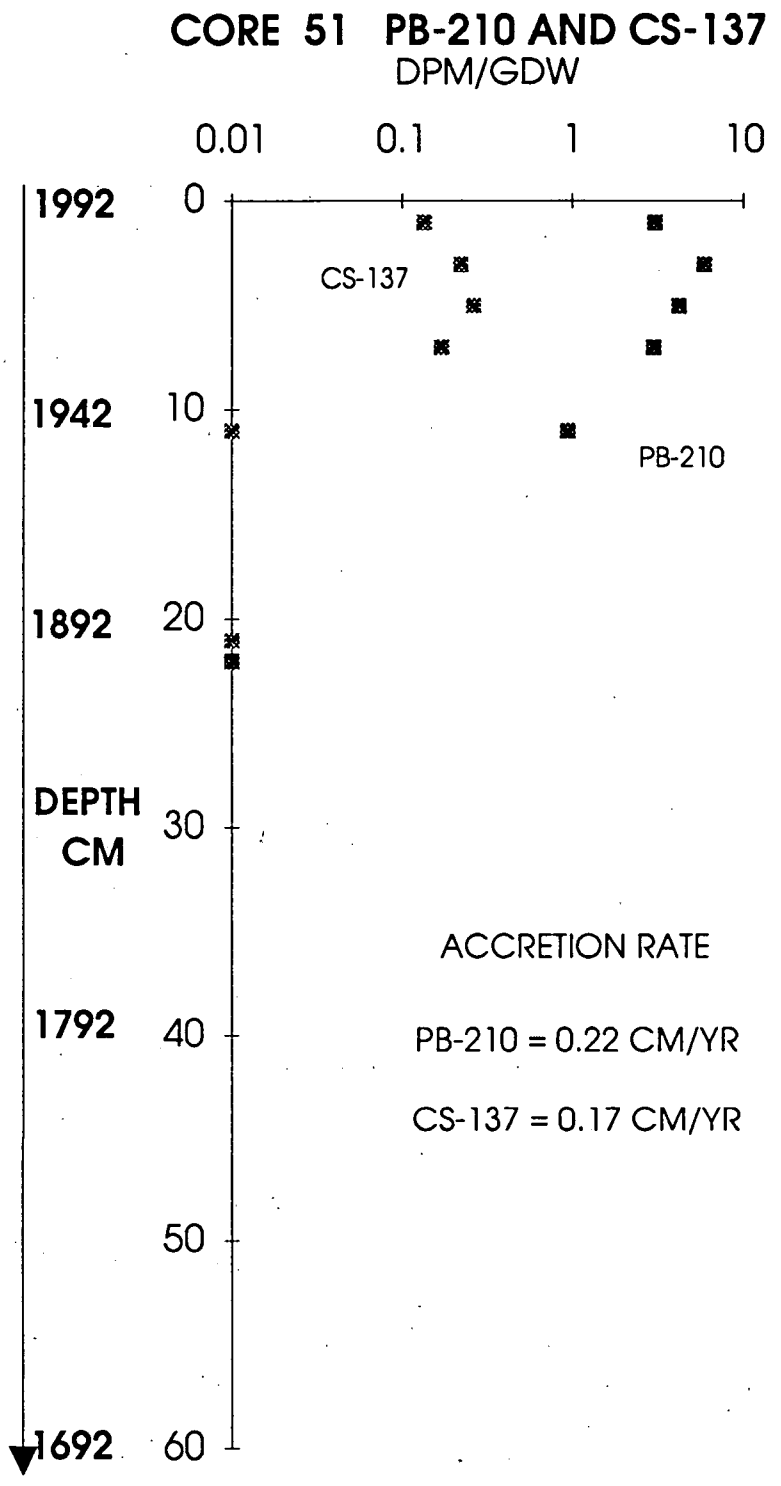
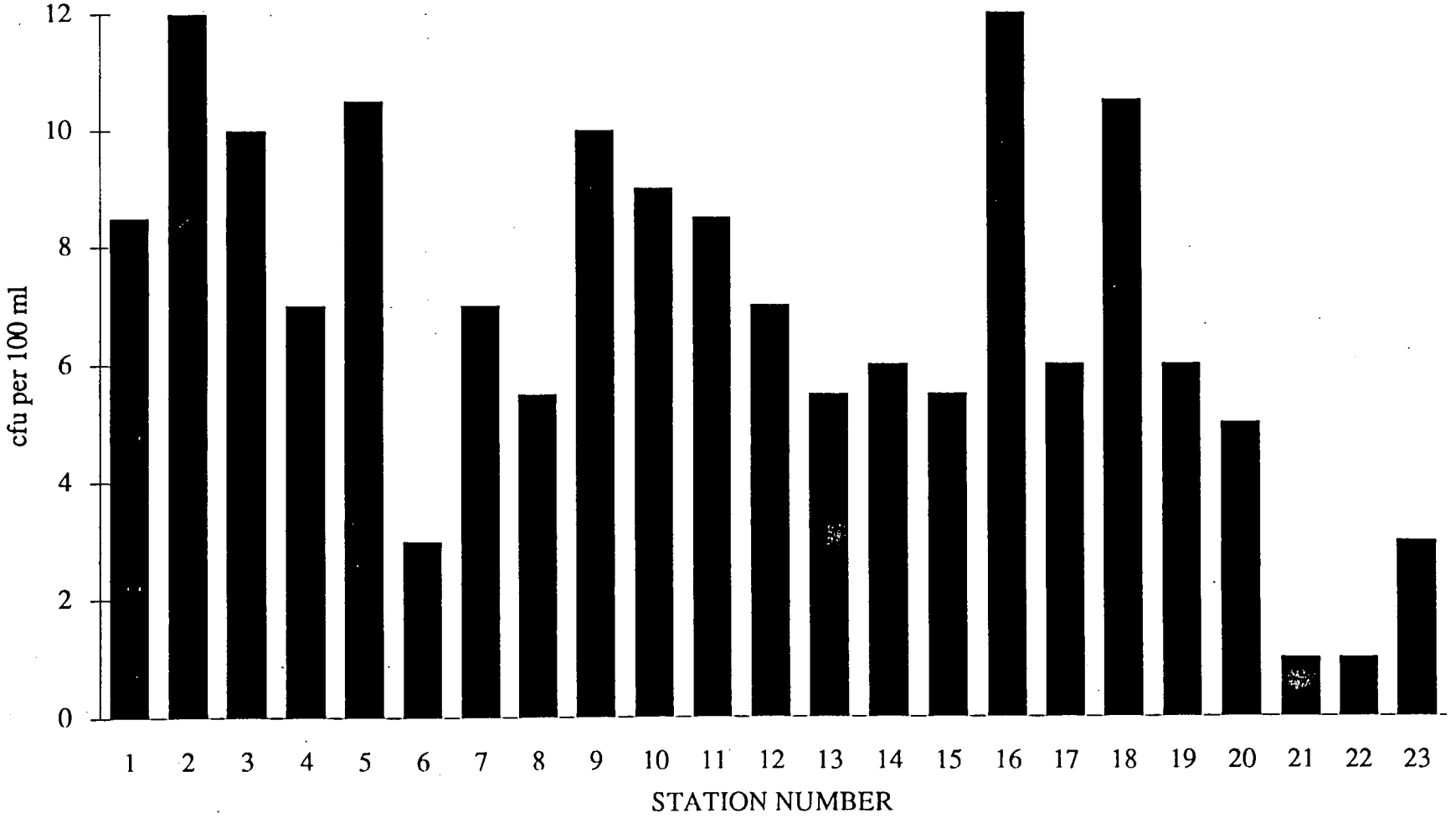
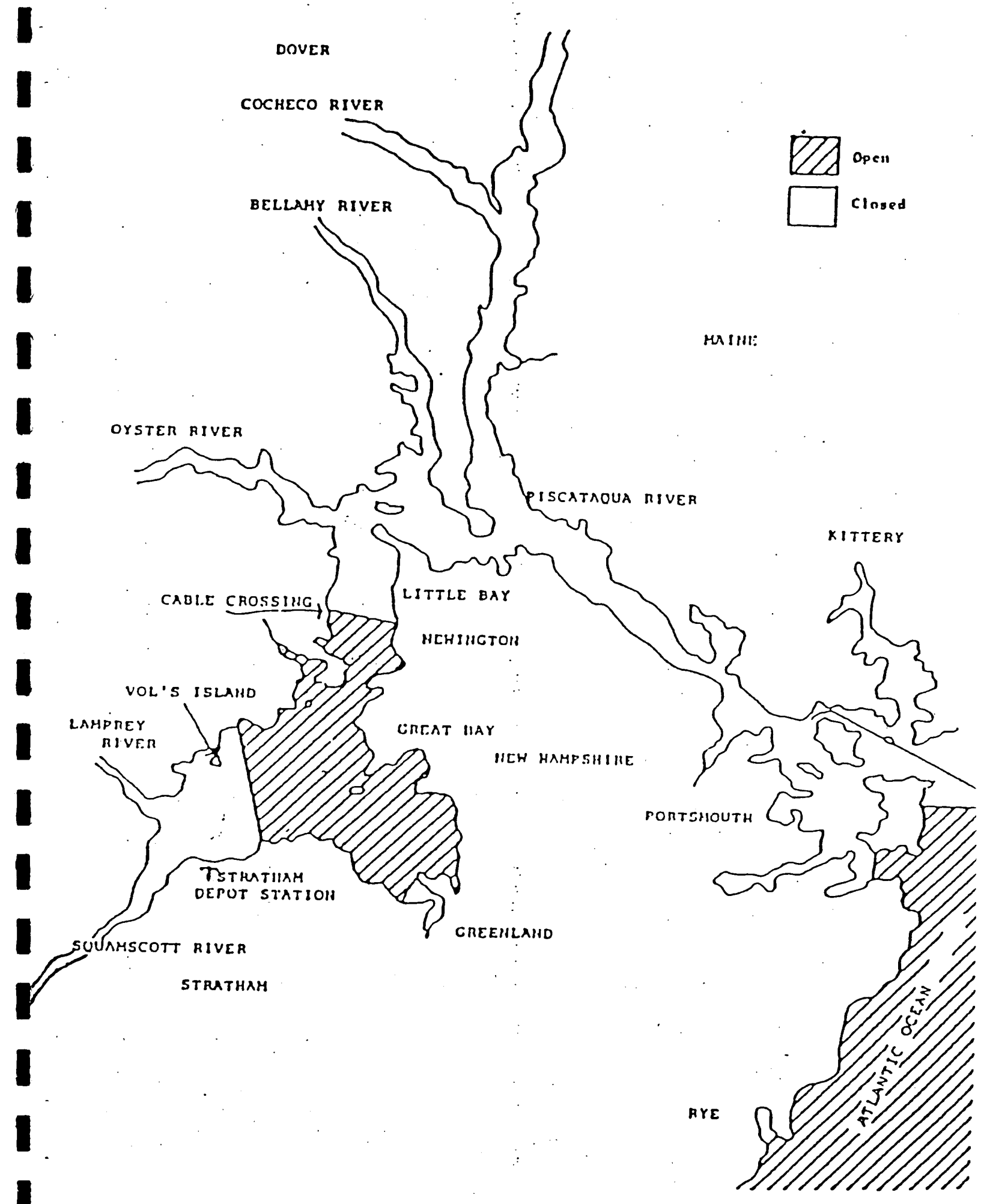

CORE 51 PB-210 AND CS-137
DPM/GDW
0.01
0.1
1
10
1992
1942
1892
1792
1692
DEPTH CM
0
10
20
30
40
50
60
CS-137
PB-210
ACCRETION RATE
PB-210 = 0.22 CM/YR
CS-137 = 0.17 CM/YR

Figure 1. C. perfringens concentrations in water samples from Portsmouth Harbor (#1-21) and York Harbor (#22-23): September, 1991.



Steve Jones, UNH-JEL


DOVER
COCHECO RIVER
BELLAMY RIVER
Open
Closed
MAINE
OYSTER RIVER
PISCATAQUA RIVER
KITTERY
CABLE CROSSING
LITTLE BAY
NEWINGTON
VOL'S ISLAND
LAMPREY RIVER
GREAT BAY
NEW HAMPSHIRE
PORTSMOUTH
STRATHAM DEPOT STATION
GREENLAND
SQUAMSCOTT RIVER
STRATHAM
ATLANTIC OCEAN
RYE

Monthly, seasonal and annual geometric average enterococci concentrations (per 100 ml) in water samples collected from sites near the SHIPYARD in Portsmouth Harbor (PH1-16), in York Harbor(#23) and the upper Great Bay Estuary (Adams Point and Squamscott R.): September, 1991 to December, 1993

Date	Station 1	Station 8	Station 10	Station 15	Station 16	Average PH	Station 23	Adams Point	Squamscott River
Jan	7	3	3	21	7	8	16	38	292
Feb	12	4		0	2	4	15	46	32
Mar	1	1	1	2	2	1	1	1	7
Apr	3	1	3	1	3	2	2	1	6
May	0	1	0		0	0	1	1	30
June	1	1	4	1	0	2	4	0	23
July							9	1	61
Aug	3	1	4	5	5	4		0	73
Sept	10	16	67	143	29	97	2	1	14
Oct	3	4	58	8	5	15	5	8	20
Nov	31	32	61	61		46	23	74	104
Dec	7	3	4	4	2	5	6	30	35
Average	3	2	3	4	2	3	5	3	26
Winter	6	5	3	8	*15*	8	*14*	6	**25**
Spring	1	1	1	**2**	1	1	1	0	**16**
Summer	1	1	**3**	2	2	1	2	1	**26**
Autumn	*12*	*7*	*10*	*11*	2	*12*	9	*27*	***40***
CY 1991	*31*	*17*	*23*	***40***		*6*	3	*14*	***63***
CY 1992	1	2	1	2	2	2	*4*	3	**29**
CY 1993	3	1	6	**8**	6	*6*	*4*	1	**8**

BOLD values are the highest values from amongst different stations.

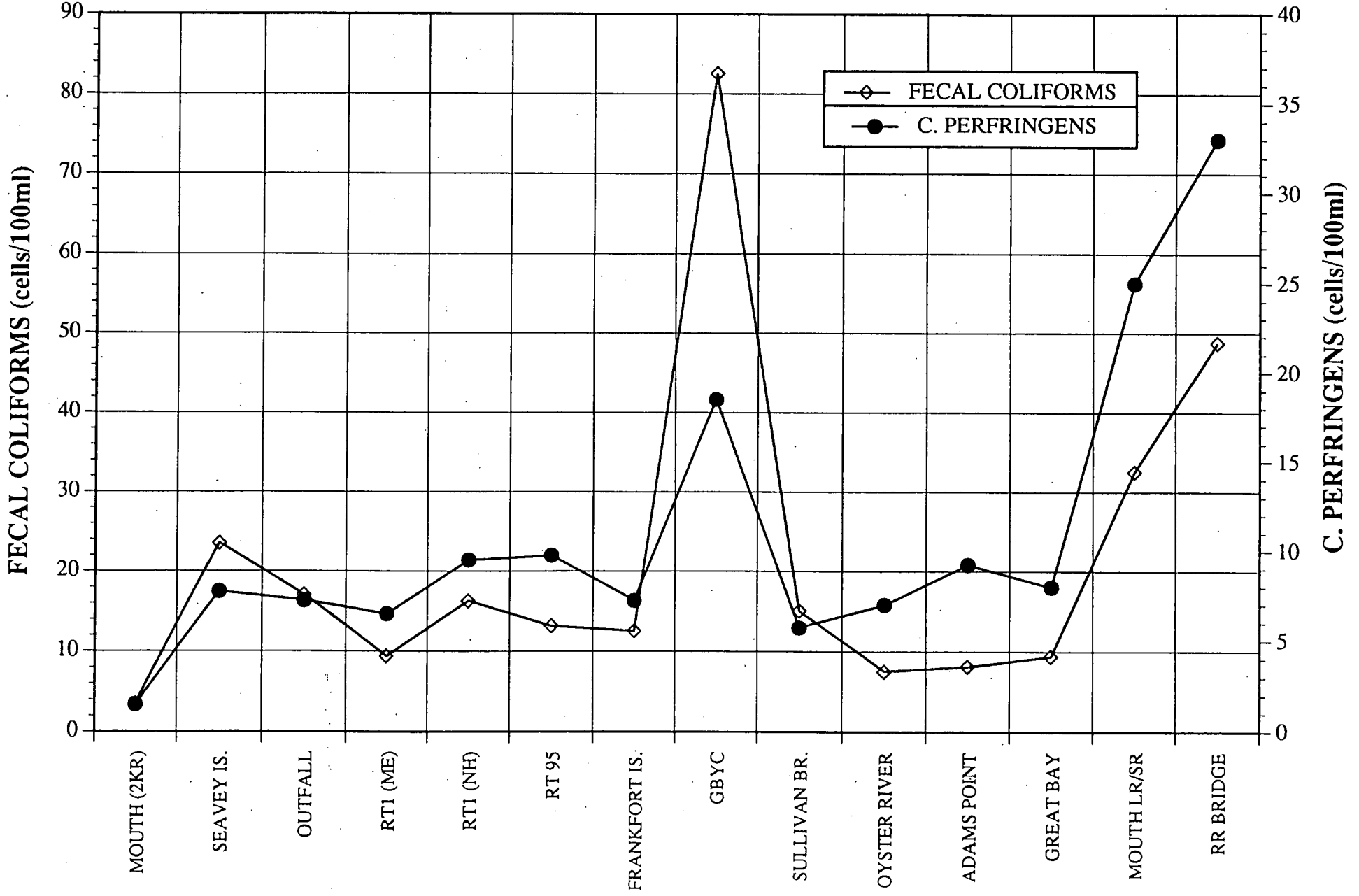
Italicized values are the highest seasonal or annual values for each station.

Monthly, seasonal and annual geometric average C. perfringens concentrations (per 100 ml) in water samples collected from sites near the SHIPYARD in Portsmouth Harbor (PH1-16), in York Harbor(#23) and the upper Great Bay Estuary (Adams Point and Squamscott R.): September, 1991 to December, 1993

Date	Station 1	Station 8	Station 10	Station 15	Station 16	Average PH	Station 23	Adams Point	Squamscott River
Jan	15	12	5	16	16	13	15	82	198
Feb	18	12	6	9	94	28	11	33	41
Mar	23	24	22	24	24	24	6	8	61
Apr	11	2	12	18	14	11	3	30	120
May	5	3	5	8	10	6	2	27	49
June	2	2	5	6	7	4	1	6	19
July	1	5				3	2	7	23
Aug	3	2	3	3	6	3	1	6	46
Sept	3	3	3	6	5	4	2	2	6
Oct							2	5	3
Nov	14	15	15	24		17	11	31	33
Dec	10	6	5	14	11	9	2	61	81
Average	6	5	6	10	12	8	3	13	32
Winter	*20*	*17*	*11*	*17*	***31***	*21*	*9*	20	***74***
Spring	3	2	6	8	**9**	6	1	14	**39**
Summer	3	3	3	5	**6**	4	2	4	**14**
Autumn	11	8	7	***17***	11	11	3	*26*	**27**
CY 1991	*11*	*8*	7	**12**	**12**	11	*4*	*41*	***56***
CY 1992	4	4	5	8	**11**	7	2	15	**33**
CY 1993	10	7	*11*	***16***	*15*	*12*	3	4	**22**

BOLD values are the highest values from amongst different stations.
Italicized values are the highest seasonal or annual values for each station.

PISCATAQUA RIVER/ GREAT BAY ESTUARY
LOW TIDE LONGITUDINAL SURVEY
FECAL COLIFORMS VS. C. PERFRINGENS



PISCATAQUA RIVER/ GREAT BAY ESTUARY
HIGH TIDE LONGITUDINAL SURVEY
FECAL COLIFORMS VS. C. PERFRINGENS

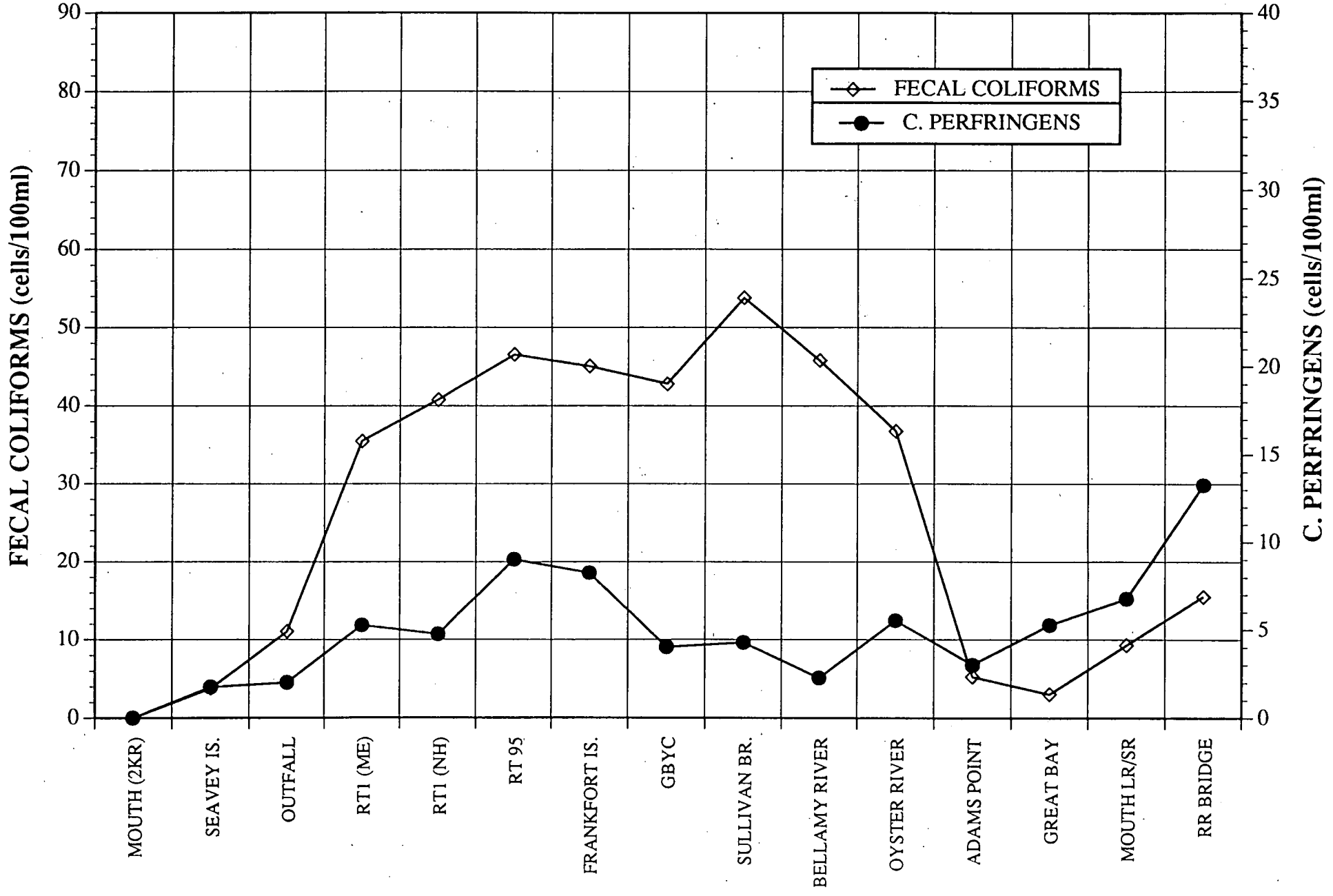


Figure 7. C. perfringens concentrations in surface sediments from Portsmouth (#1-21) and York (#22-23) Harbors: September, 1991.

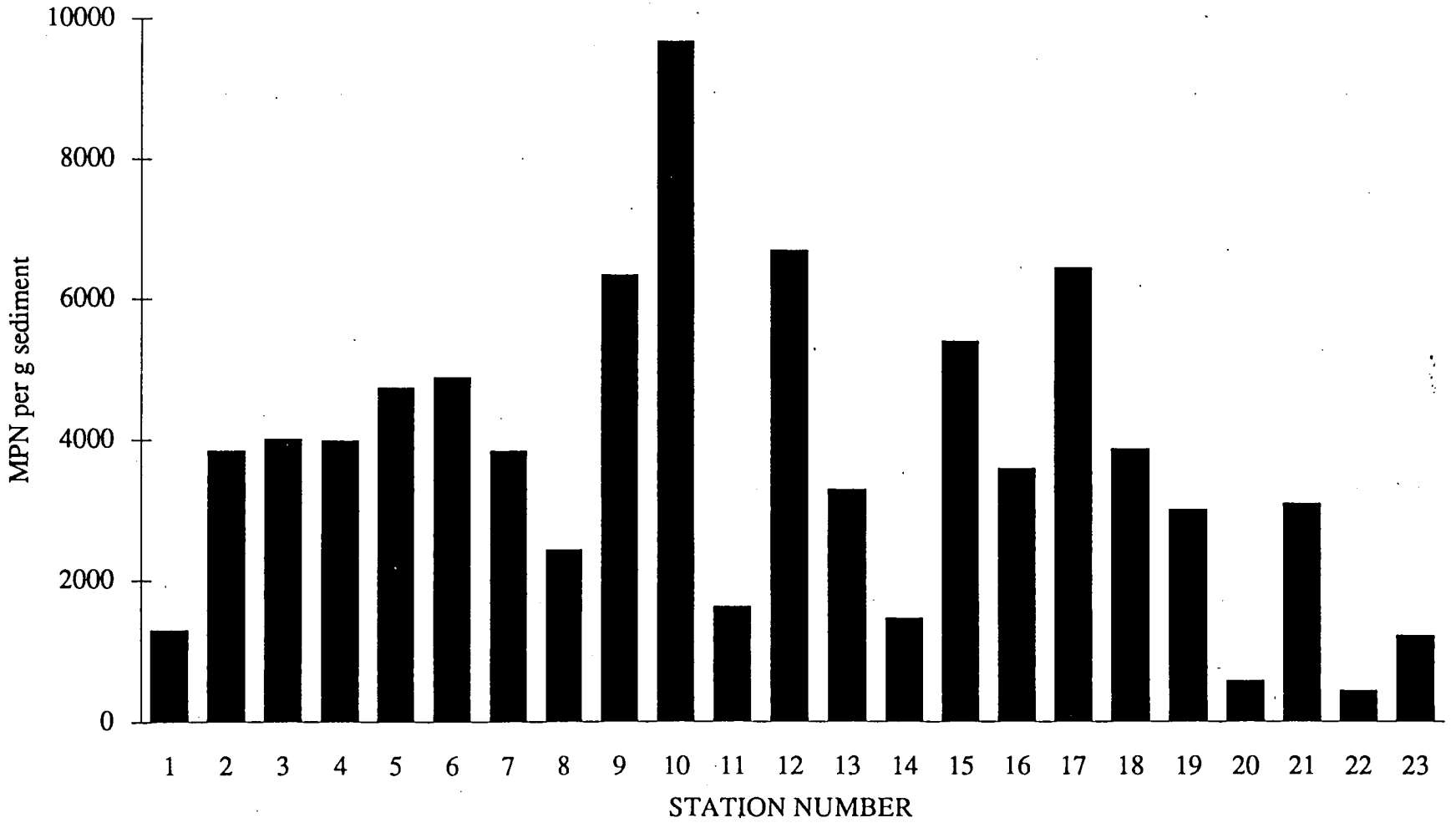
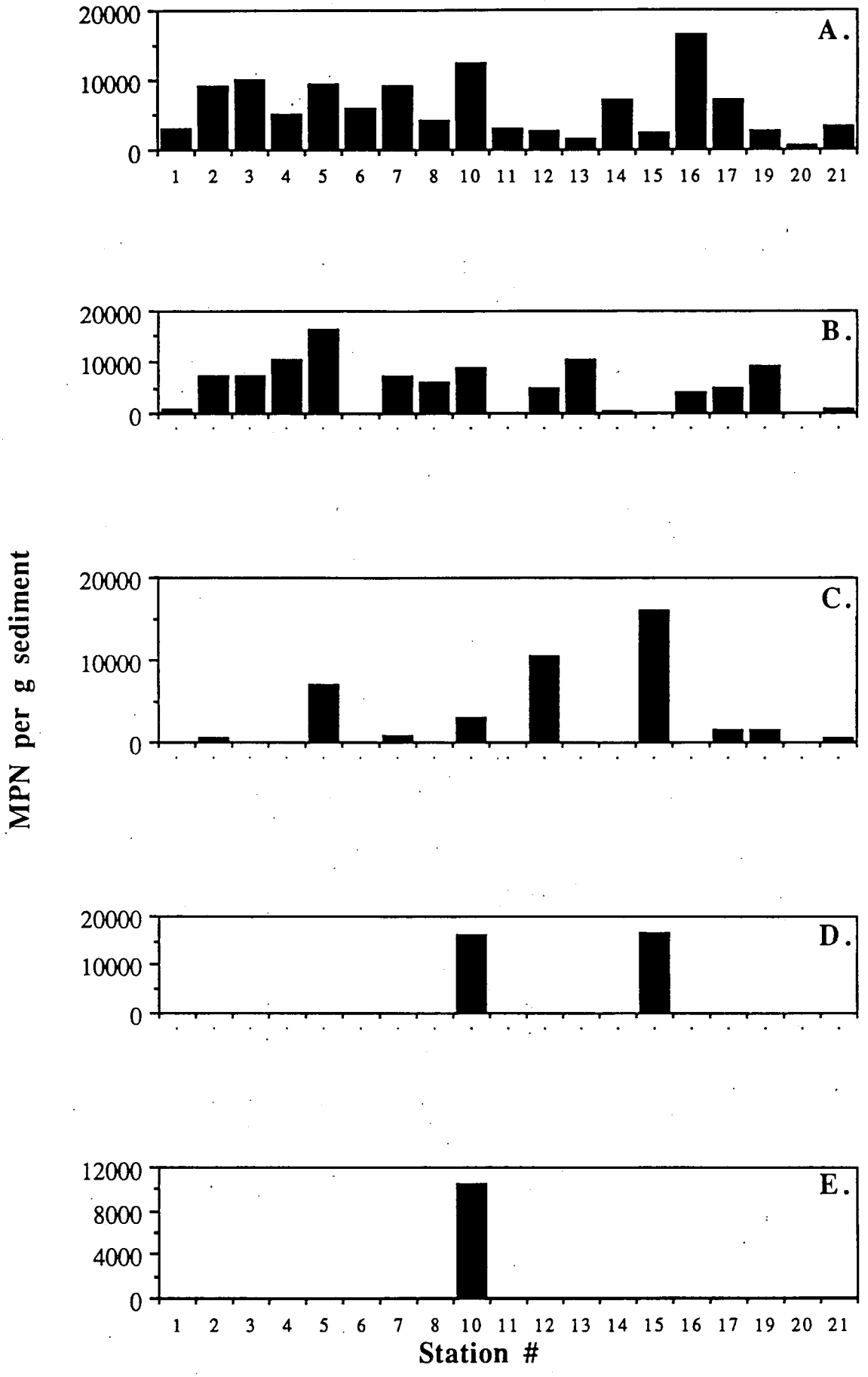


Figure 8. C. perfringens concentrations at different depths (A-E) in sediment cores from Portsmouth Harbor: September, 1991



Relationship between radionuclide and C. perfringens profiles in sediment cores from sites in Portsmouth Harbor.

	Quality of radionuclide profile		Total
	Good	Poor	
	4	7	11
Good Cp profiles	4	2	6
Poor Cp profiles	0	5	5

C. perfringens levels at depth in 2 good sediment cores from Portsmouth Harbor dated by radionuclide profile analysis.

Site #	Location	Sample depth (cm)	Estimated date	C. perfringens Concentration (Cp/g sediment)
51	Chauncey Creek	0-2	1992	3500
		10	1942	250
		30	1842	10
100	Chauncey Creek	0-2	1992	3500
		30	1815	190
		60	1639	<2

C. perfringens levels at depth in 2 acceptable sediment cores from Portsmouth Harbor dated by radionuclide profile analysis.

Site #	Location	Sample depth (cm)	Estimated date	C. perfringens Concentration (Cp/g sediment)
2	Coast Guard Station	0-2	1990	690
		32-34	1925	1500
		68-70	~1840	170
17	Back Channel /Badger I.	7	1975	25000
		20-23	1937	2600
		38-40	1895	2800
		50-52	1865	5800

C. perfringens levels at depth in 2 'poor' profile sediment cores from Portsmouth Harbor dated by radionuclide profile analysis.

Site #	Location	Sample depth (cm)	Estimated date	C. perfringens Concentration (Cp/g sediment)
3	Clark Cove	0-2	NA	18000
		10	NA	68000
		35	NA	48000
15	Rt. 95 bridge New Hampshire	0-5	NA	55000
		30	NA	157000
		60	NA	150000
		90	NA	56000

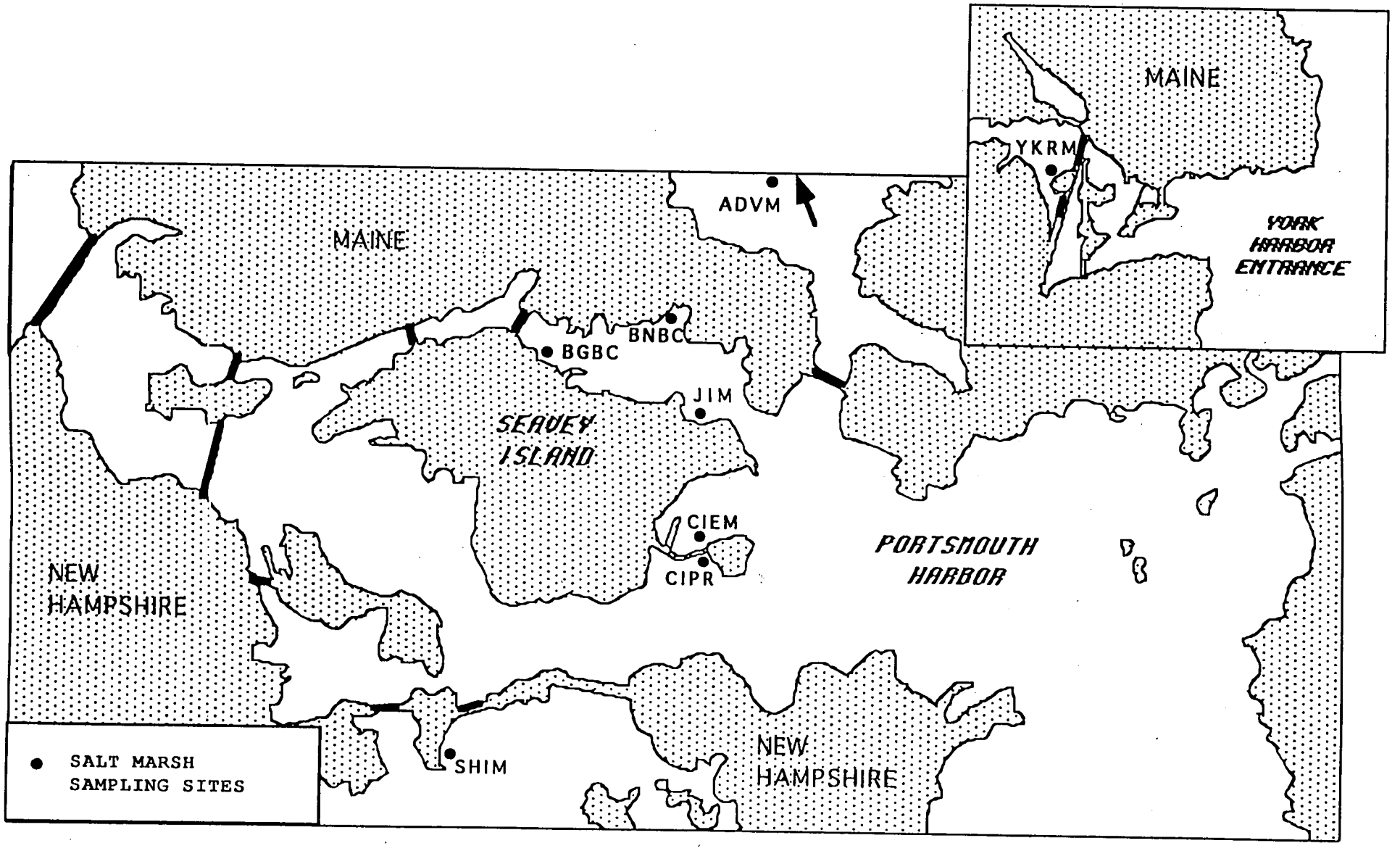
Visual Aids Used in the Presentation of:

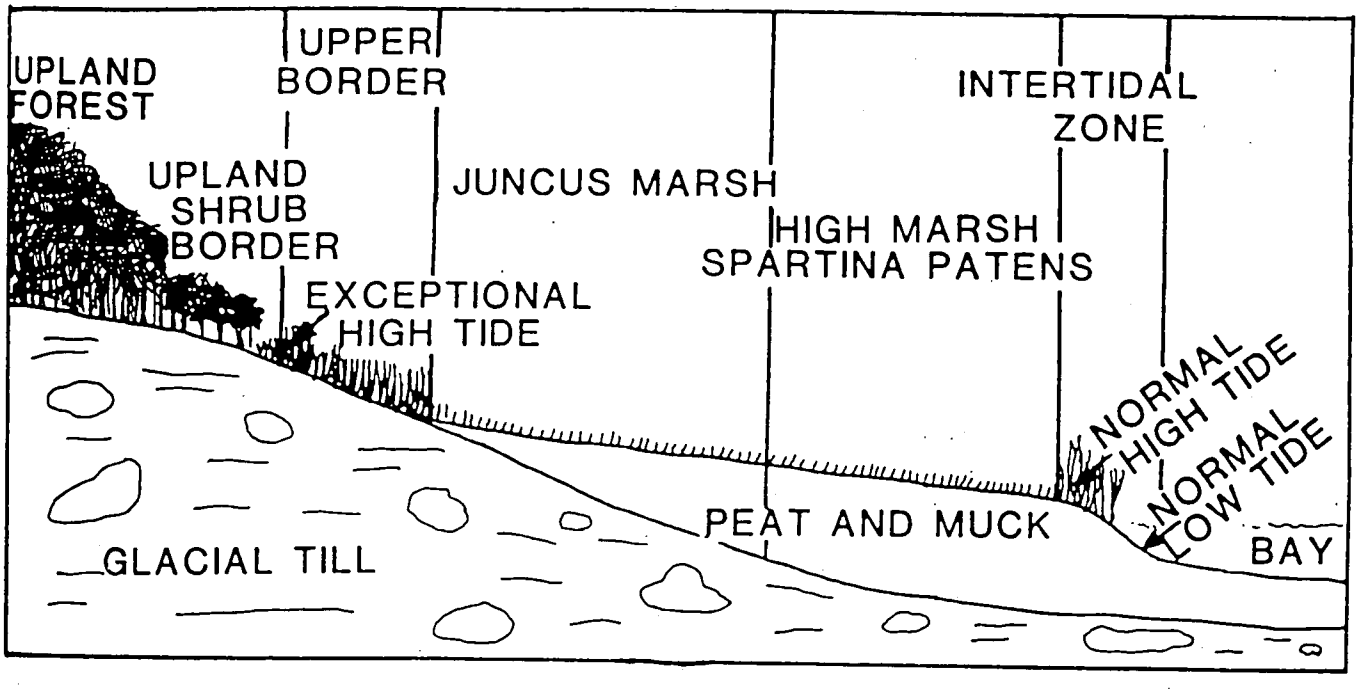
The Effects of Past Disposal Practices on Salt Marshes in and Around the Portsmouth Naval Shipyard

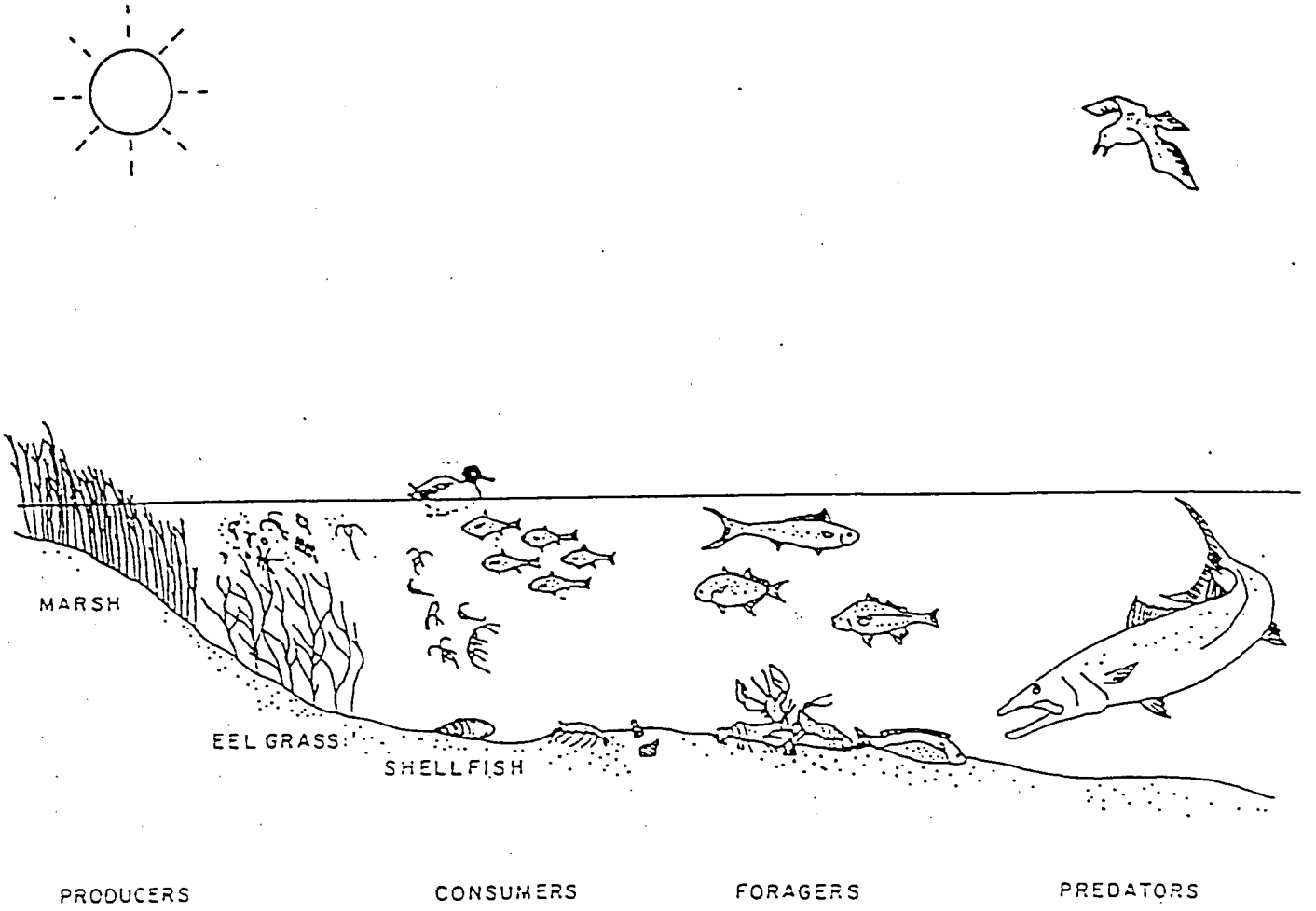
by

David M. Burdick

PNS Project Investigators Workshop
University of New Hampshire
March 9, 1994


MAINE
YKRM
YORK HARBOR ENTRANCE
ADVM
MAINE
BNBC
BGBC
JIM
SEAVEY ISLAND
CIEM
CIPR
PORTSMOUTH HARBOR
NEW HAMPSHIRE
SHIM
NEW HAMPSHIRE
SALT MARSH SAMPLING SITES


UPLAND FOREST
UPPER BORDER
INTERTIDAL ZONE
UPLAND SHRUB BORDER
JUNCUS MARSH
HIGH MARSH SPARTINA PATENS
EXCEPTIONAL HIGH TIDE
NORMAL HIGH TIDE
NORMAL LOW TIDE
PEAT AND MUCK
GLACIAL TILL
BAY


MARSH
EEL GRASS
SHELLFISH
PRODUCERS
CONSUMERS
FORAGERS
PREDATORS

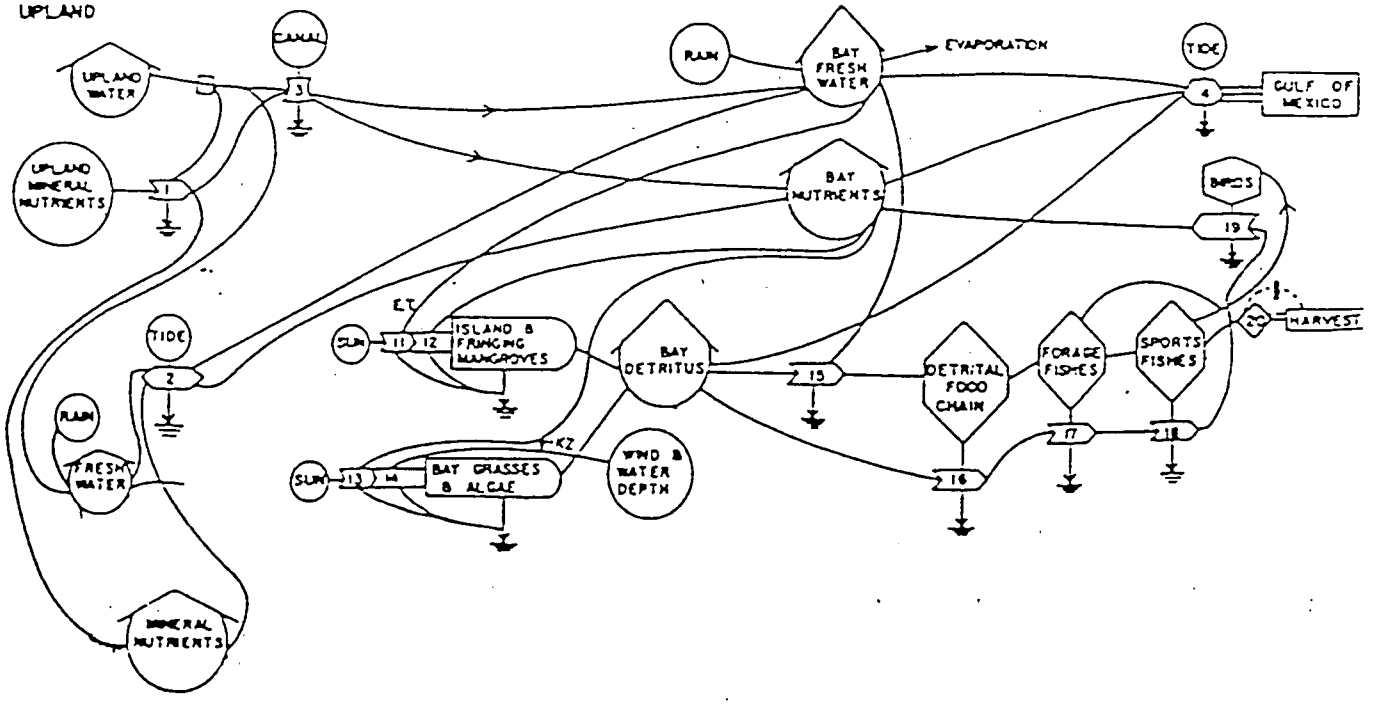

UPLAND
UPLAND WATER
CANAL
3
RAIN
BAY FRESH WATER
EVAPORATION
TIDE
4
GULF OF MEXICO
UPLAND MINERAL NUTRIENTS
1
BAY NUTRIENTS
BMPCS
19
ET
SUN
11
12
ISLAND & FRINGING MANGROVES
BAY DETRITUS
15
DETRITAL FOOD CHAIN
FORAGE FISHES
SPORTS FISHES
20
HARVEST
TIDE
2
RAIN
FRESH WATER
KZ
SUN
13
14
BAY GRASSES & ALGAE
WIND & WATER DEPTH
16
17
18
MINERAL NUTRIENTS

Table 12. Aboveground biomass and other characteristics of the dominant species in salt marsh communties of New York and New England. End of season live standing crop (all material atached to living stems) or peak live biomass are presented. In seasonal studies where only live material was included in estimates, values for the peak standing crop were reported rather than those for September.

Community Macrophyte	Biomass (g/m^2 dry wt)	Height (cm)	Reproductive stems (%)	Study (Location)
Tall *S. alterniflora*	.35-.72	31-81	1-36%	This study
Fucoids	.12-1.35			(Portsmouth, NH
Total	.47-1.91			& York, ME)
Short *S. alterniflora*	.16-.34	21-39	0-5%	
S. patens	.52-.88	29-40	0-15%	
Tall *S. alterniflora*	.83	127		Udell et al. 1969
Short *S. alterniflora*	.51	29		(Hempstead, NY)
S. patens	.50	25		
Tall *S. alterniflora*	.43-1.38	50-142		Nixon and Oviatt 1973 (RI)
Tall *S. alterniflora*	.35-.54			Valiela et al. 1974
Short *S. alterniflora*	.25-.42			(Falmouth, MA)
S. patens	.28-.42			
Fucoids	1.22			Roman et al. 1990
Tall *S. alterniflora*	.67			(Eastham, MA)
Short *S. alterniflora*	.47			
Short *S. alterniflora*	.53	39		Gross et al. 1991 Rye, NH
Tall *S. alterniflora*	.63	50-80	7-18%	Chock 1975
Fucoids	.98			Dover, NH
Total	1.61			
Tall *S. alterniflora*	.12-.72	50-92	4-38%	Nelson et al.
Short *S. alterniflora*	.10-.30	26-35	3-15%	1982, NH
S. patens	.39-.82			Short et al. 1992 MA to Wells, ME
Tall *S. alterniflora*	.43			Linthurst and
Short *S. alterniflora*	.25			Riemold 1978
S. patens	.91			(Bar Harbor, ME)

TABLE 8. SALT MARSH COMMUNITY: SEDIMENT CHARACTERISTICS Values for moisture and organic matter (LOI) are means (SE) of five cores, while all other values are results from a composite of the five sediment samples from each community.

MARSH	Community	% Moisture	% LOI	%GSM	%SSC	Mean	Sort
			PORTSMOUTH NAVAL SHIPYARD				
CIPR	S.a. Tall	61 (9)	23 (6)	59/12/29	-	-0.03	4.56
	S.a. Short	70 (2)	39 (4)	00/29/71	29/48/23	5.95	2.52
	S. patens	61 (4)	26 (5)	18/30/52	-	3.67	4.40
CIEM	S.a. Tall	47 (8)	13 (6)	66/25/09	-	-1.55	3.42
	S.a. Short	58 (4)	17 (3)	19/43/38	-	2.87	4.13
	S. patens	50 (7)	14 (4)	39/48/13	-	0.40	3.18
JIM	S.a. Tall	59 (6)	20 (5)	11/57/32	-	2.60	3.05
BGBC	S.a. Tall	65 (1)	19 (2)	23/19/58	-	3.70	5.26
	S. patens	48 (8)	11 (3)	48/22/30	-	0.97	3.86
			LOWER PISCATAQUA RIVER				
SIM	S.a. Tall	72 (1)	36 (2)	00/00/100	00/45/55	8.78	2.74
	S. patens	76 (2)	45 (4)	00/18/82	18/48/34	6.97	3.36
BNBC	S.a. Tall	64 (8)	27 (7)	03/59/38	62/24/14	3.77	3.30
AVM	S.a. Tall	77 (1)	27 (2)	00/09/91	09/43/48	8.20	3.19
	S. patens	79 (1)	46 (4)	00/01/99	01/45/54	8.68	2.89
			YORK RIVER				
YKRM	S.a. Tall	67 (2)	25 (3)	00/21/79	21/54/25	6.18	3.00
	S.a. Short	69 (1)	26 (3)	00/19/81	19/55/26	6.10	2.53
	S. patens	76 (1)	43 (3)	00/03/97	03/60/37	7.47	2.88
			COMMUNITY MEANS				
	S.a. Tall	64 (2)	24 (2)	20/25/55	23/42/36	4.0	3.6
	S.a. Short	65 (3)	27 (3)	06/30/63	24/52/25	5.0	3.1
	S. patens	66 (2)	31 (3)	18/20/62	07/51/42	4.7	3.4

Table 13. Metal, arsenic, and total PAHs concentration warning levels for sediments and salt marsh sites (either or both tall form *Spartina alterniflora* and *S. patens*) where composite samples of the cores exceeded warning levels.

Contaminant	Warning Levels (ppm) WA	ERM	ERL	Marshes Exceeding: ERL	ERM
Ag	6.1	-	1	BGBC	
As	93	-	33	CIPR	
Cd	6.7	-	5.0	-	
Cr	270	145	80	JIM	CIPR/CIEM/ BGBC/SIM/AVM
Cu	390	-	70	CIPR/CIEM	
Hg	0.59	1.3	0.15	ALL, but YKRM	
Ni	-	50	30	CIEM/BGBC/SIM	CIPR
Pb	530	110	35	ALL	CIPR/BGBC/ JIM/SIM
Zn	960	270	120	CIPR/CIEM/ BGBC/JIM/AVM	
Total PAHs	200-2000	330	4-5	CIPR/BGBC/ BNBC/SIM/AVM	

CORRELATION MATRIX FOR SALT MARSH SEDIMENT METALS AND PAHs

Correlation Matrix for Variables: $X_1 \ldots X_{14}$

	Al	Ag	As	Cd	Cr	Cu	Fe	Hg
Al	1							
Ag	.449	1						
As	.277	.396	1					
Cd	.01	.111	.337	1				
Cr	.193	.718	.561	.219	1			
Cu	.088	.283	.434	.661	.451	1		
Fe	.538	.503	.619	.095	.64	.469	1	
Hg	.316	.495	.653	.132	.723	.232	.535	1
Mn	.275	.017	-.061	-.084	-.158	.127	.337	.088
Ni	.02	.075	.172	.096	.405	.721	.535	.259
Pb	.01	.344	.435	-.266	.293	.144	.331	.389
Sn	.007	.246	-.15	-.132	.184	.395	.231	.061
Zn	-.078	.465	.341	-.174	.39	.242	.54	.277
Total PAHs	-.304	-.043	.061	.082	.034	-.174	-.355	.065

Correlation Matrix for Variables: $X_1 \ldots X_{14}$

	Mn	Ni	Pb	Sn	Zn	Total PA...
Mn	1					
Ni	.346	1				
Pb	.329	.154	1			
Sn	-.016	.52	.109	1		
Zn	.339	.297	.726	.348	1	
Total PAHs	-.365	-.321	-.094	-.11	-.299	1

Table 9. Principal component analysis of the metal concentrations and total PAHs in salt marsh sediments supporting *Spartina* populations. A. Metal Loadings on Oblique Reference Structure following Orthotran/Quartimax rotation.

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

B. Component scores and total PAHs in sediments of each marsh community.

MARSH LOCATION Community	Marsh Scores Comp. #1	Comp. #2	Comp. #3	Total PAHs
Clark Island Piscataqua R.				
Tall S. alterniflora	.90	1.68	-1.23	4.8
S. patens	.23	.99	.50	4.7
Clark Island Embayment				
Tall S. alterniflora	-.59	.15	-.87	1.8
S. patens	-1.54	2.45	.59	1.8
Jamaica Island				
Tall S. alterniflora	-1.21	-.74	2.68	2.5
Back Gate Back Channel				
Tall S. alterniflora	1.60	-.77	-.35	6.0
S. patens	.81	.03	1.32	0.6
Brown Back Channel				
Tall S. alterniflora	-.50	-.13	-1.23	6.3
Shapliegh Island				
Tall S. alterniflora	.00	-.80	-.22	36.5
S. patens	.66	-.15	-.50	13.7
Admiralty Village				
Tall S. alterniflora	.81	-.59	.15	3.5
S. patens	1.30	-.79	-.31	5.2
York River				
Tall S. alterniflora	-1.18	-.49	-.29	2.8
S. patens	-1.30	-.82	-.25	2.9

Table 6. Principal component analysis of the metal concentrations in *Spartina* leaves. A. Metal Loadings on Oblique Reference Structure following Orthotran/Quartimax rotation.

METAL	Oblique Solution Reference Structure Comp. #1	Comp. #2
Ag	.584	.133
Cd	.664	-.557
Cr	.924	.011
Cu	.502	.445
Ni	.896	-.187
Pb	.943	.157
Zn	.106	.909

B. Component scores for each marsh community analyzed for metals.

MARSH LOCATION Community	Marsh Scores Comp. #1	Comp. #2
Clark Island Piscataqua R.		
Tall S. alterniflora	-.64	.76
S. patens	-.60	.29
Clark Island Embayment		
Tall S. alterniflora	-.15	.73
S. patens	-1.24	-.30
Jamaica Island		
Tall S. alterniflora	-.46	-.23
Back Gate Back Channel		
Tall S. alterniflora	1.71	.54
S. patens	.88	1.44
Brown Back Channel		
Tall S. alterniflora	-.70	1.55
Shapliegh Island		
Tall S. alterniflora	-.74	.48
S. patens	2.24	-.24
Admiralty Village		
Tall S. alterniflora	.05	-1.17
S. patens	.19	-1.02
York River		
Tall S. alterniflora	.26	-1.06
S. patens	-.80	-1.78

SALT MARSH COMMUNITY: POPULATIONS AND CHARACTERISTICS IV: Animals living on the vegetation and the surface of salt marshes at low tide. Estimates of individuals are reported as means (SE) for one square meter (n = 5).

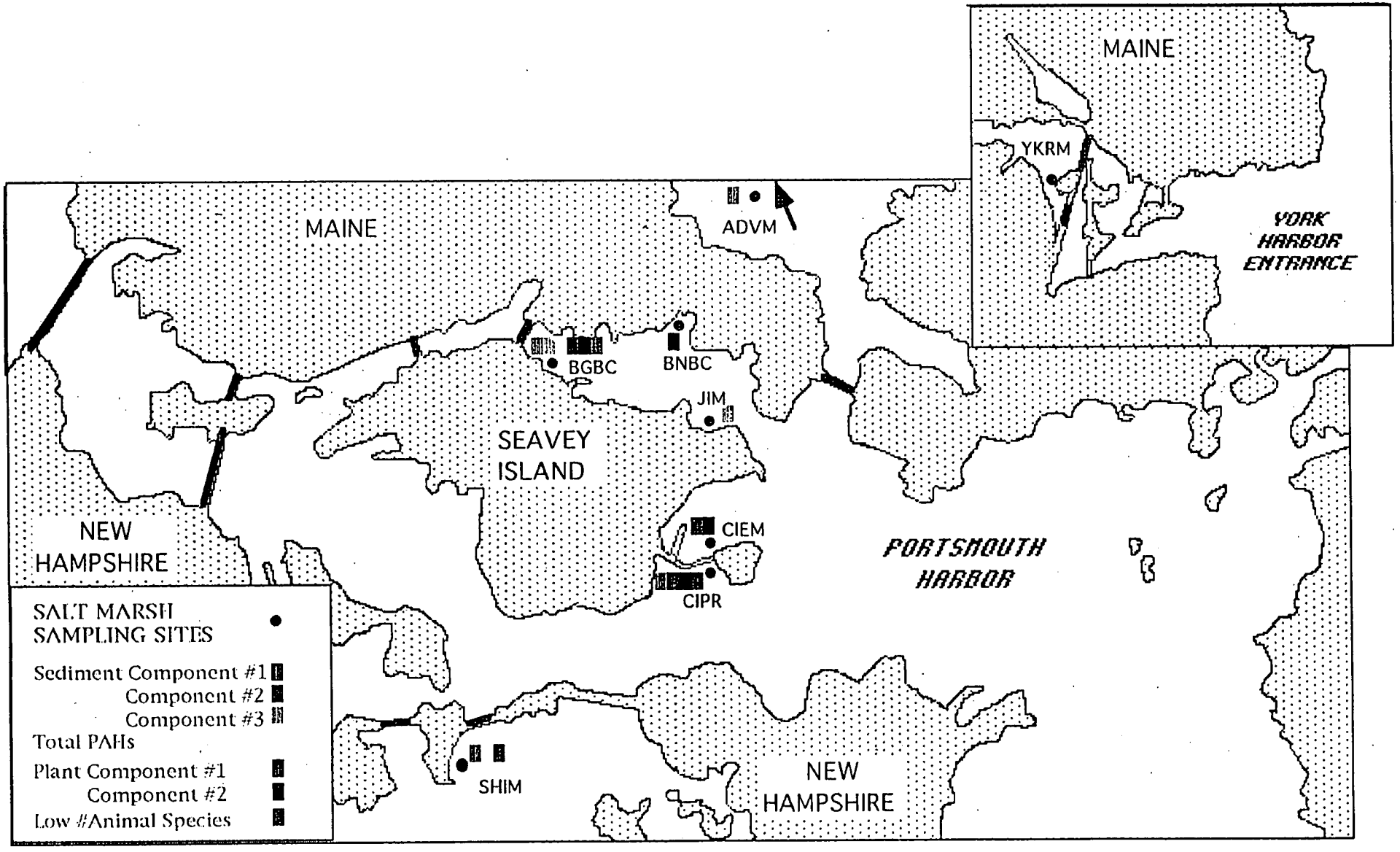
MARSH	Community	EPIBENTHIC MACROFAUNA Molluscs[1]	Crustaceans[2]	Total Marine	Arthropods[3]	#Species[4]
			PORTSMOUTH NAVAL SHIPYARD			
CIPR	S.a. Tall	80 (47)	58 (15)	138 (55)	3 (3)	3.2 (.9)
	S.a. Short	0 (0)	10 (4)	10 (4)	0 (0)	1.4 (.4)
	S. patens	3 (3)	0 (0)	3 (3)	0 (0)	0.2 (.2)
CIEM	S.a. Tall	198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

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

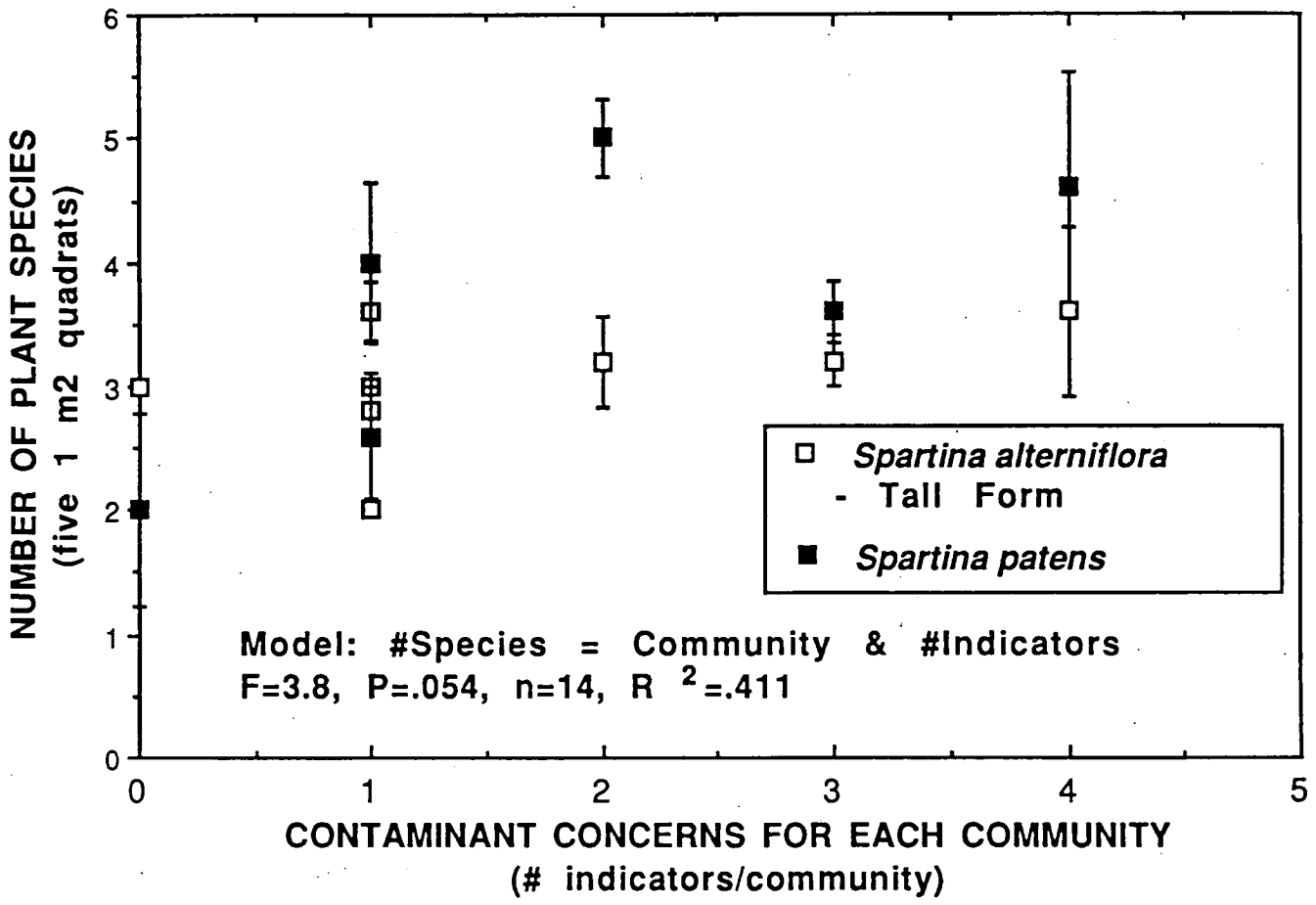
[2]This group was composed of amphipods (54%), barnacles (41%), and green crabs (5%).

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

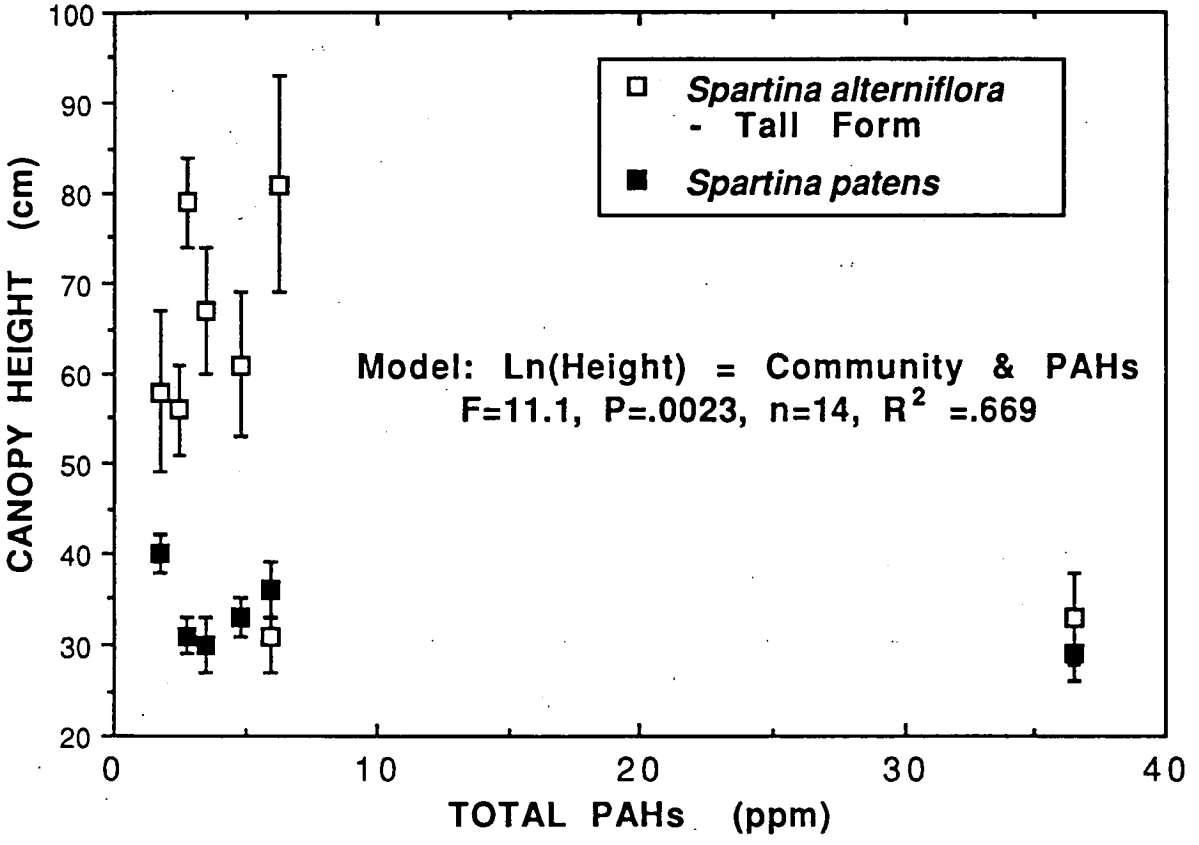
[4]Only molluscs and green crabs were determined to species level; banacles, amphipods, spiders and insects were grouped as one species when found.


MAINE
YKRM
YORK HARBOR ENTRANCE
MAINE
ADVM
BGBC
BNBC
JIM
SEAVEY ISLAND
CIEM
CIPR
PORTSMOUTH HARBOR
NEW HAMPSHIRE
SHIM
NEW HAMPSHIRE
SALT MARSH SAMPLING SITES
Sediment Component #1
Component #2
Component #3
Total PAHs
Plant Component #1
Component #2
Low #Animal Species

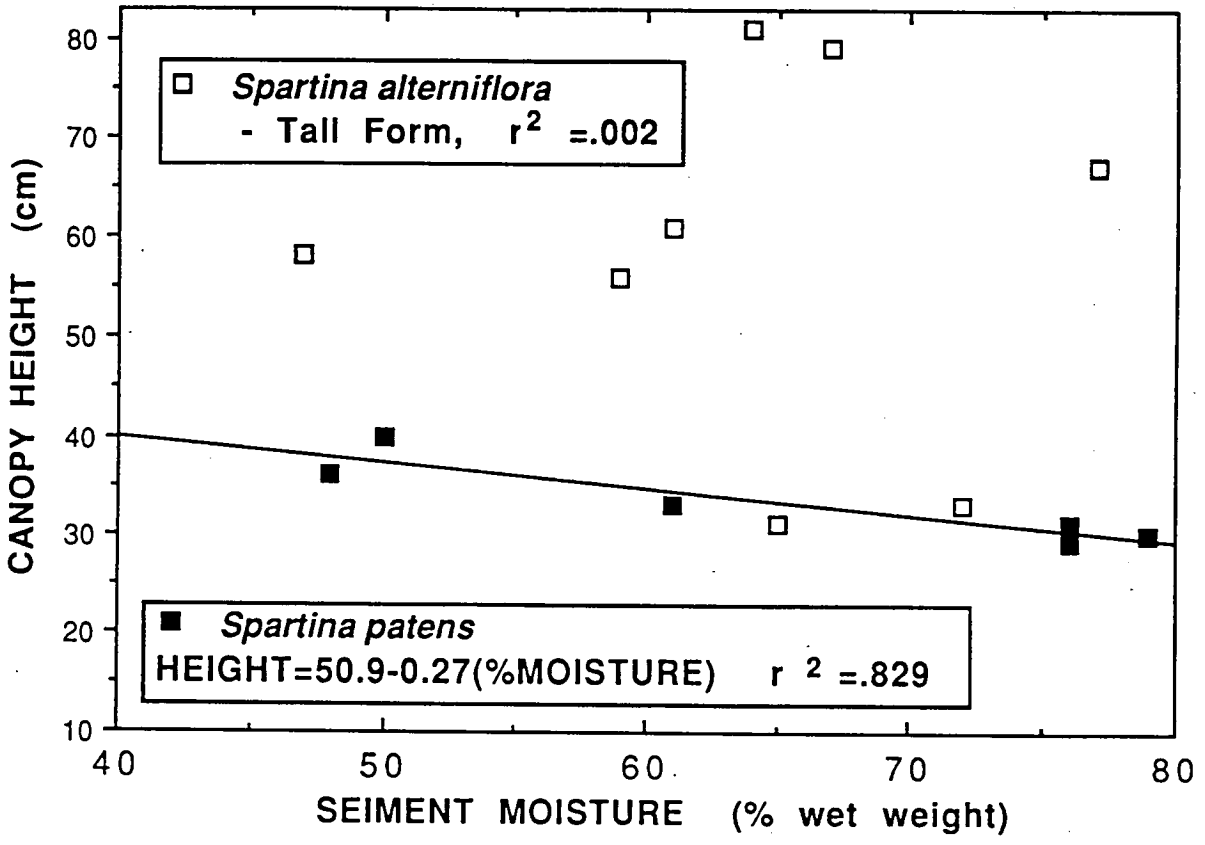
PLANT DIVERSITY AND POTENTIAL STRESS



PLANT VIGOR AND TOTAL PAHs



VIGOR AND SEDIMENT WATERLOGGING



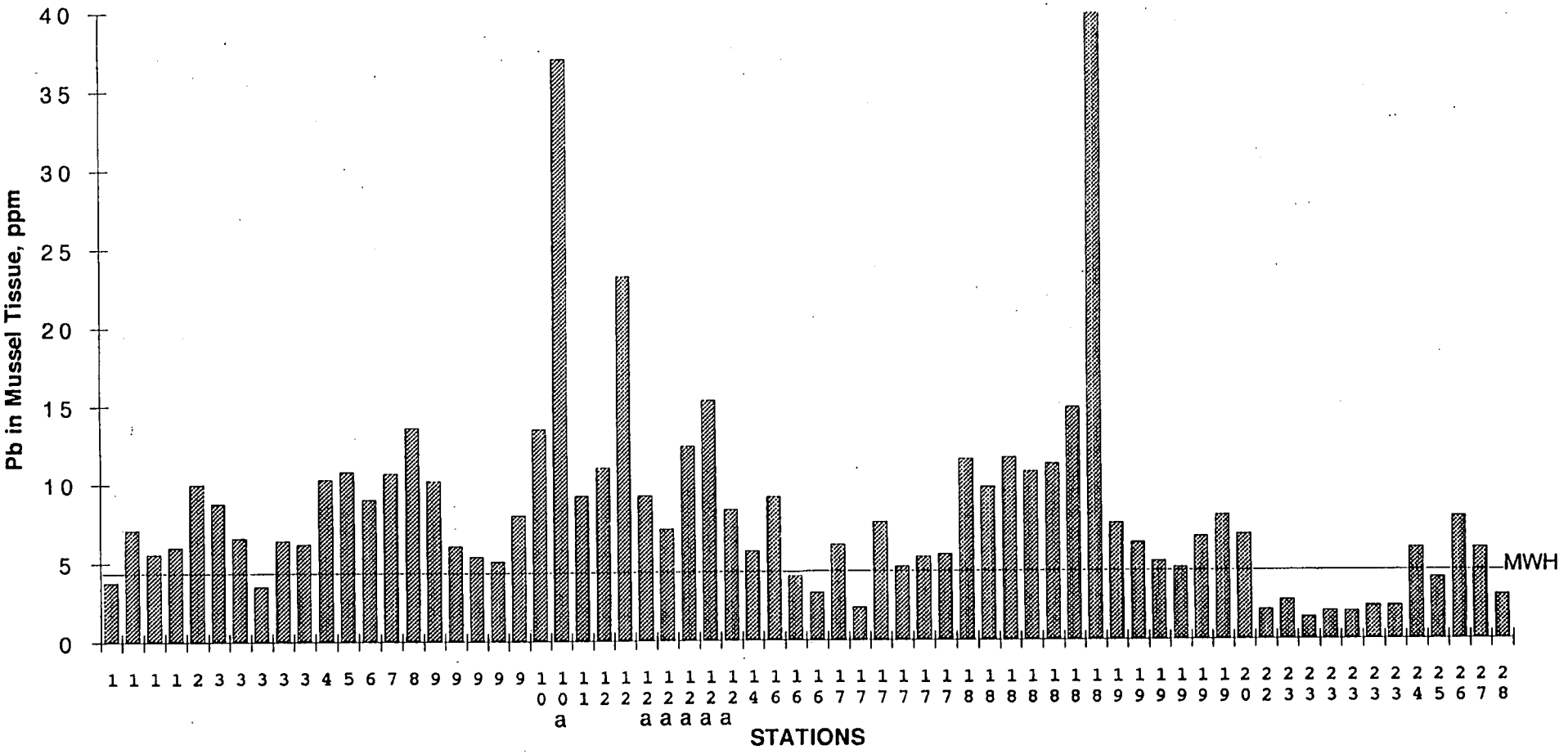
Fred Short, UNH-JEL

Blue Mussel Tissue -- Metal Analysis

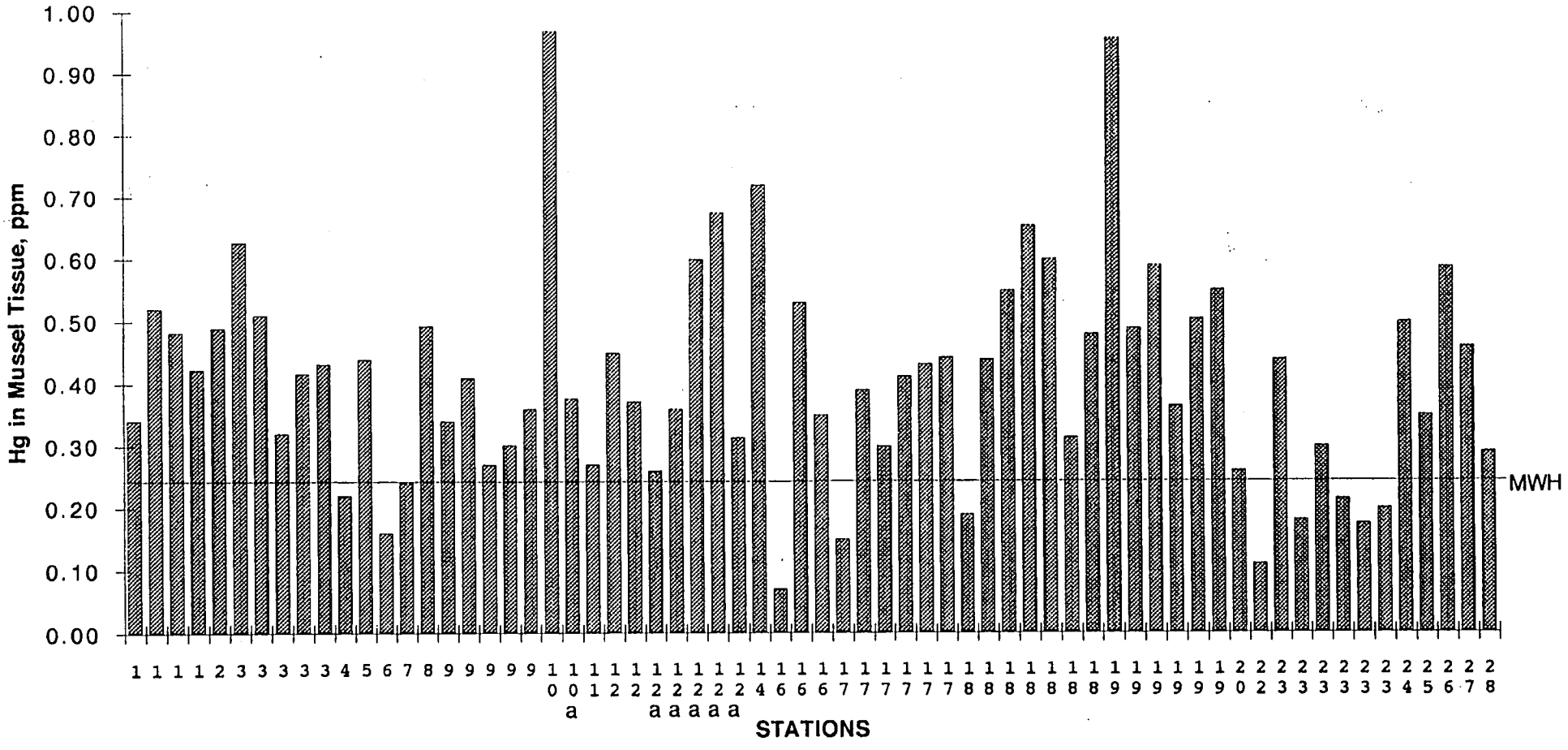
All Phase I and Monitoring Samples (n=70)

Metal	Analysis of Variance	F-Value	P- Value
As	Laboratory Effect	15.268	0.0022
Cd	Laboratory Effect	12.997	0.0006
Cr	Laboratory Effect	16.104	0.0002
Cu	Laboratory Effect	6.348	0.0141
Ni	Laboratory Effect	12.729	0.0007
Fe	Laboratory Effect	15.902	0.0002
Pb	Station Effect	3.391	0.0001
Hg	Station Effect	1.346	0.0372
Mn	Station Effect	2.754	0.0017

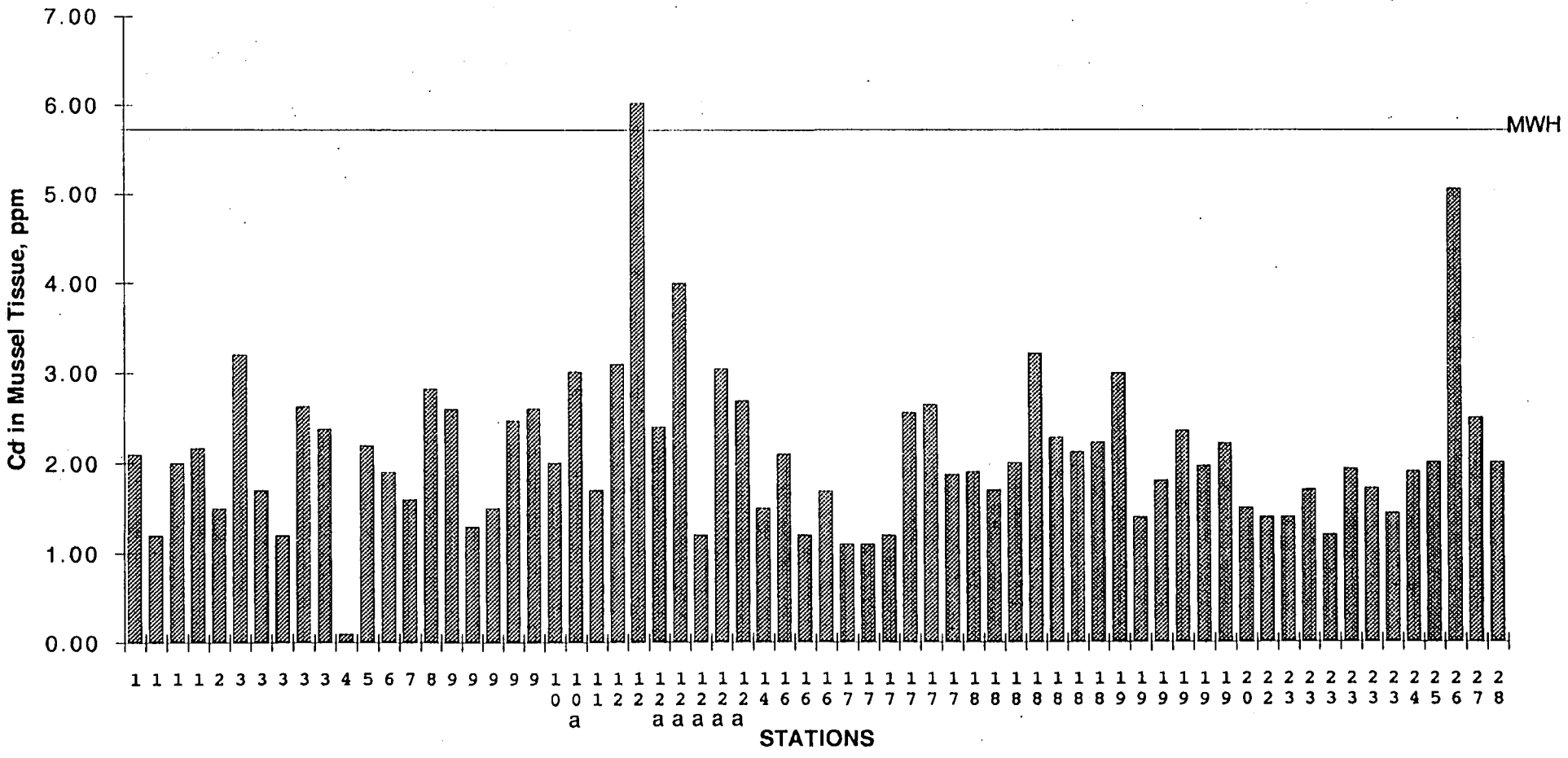
MUSSEL.Spatial cont 1.7 Chart 9



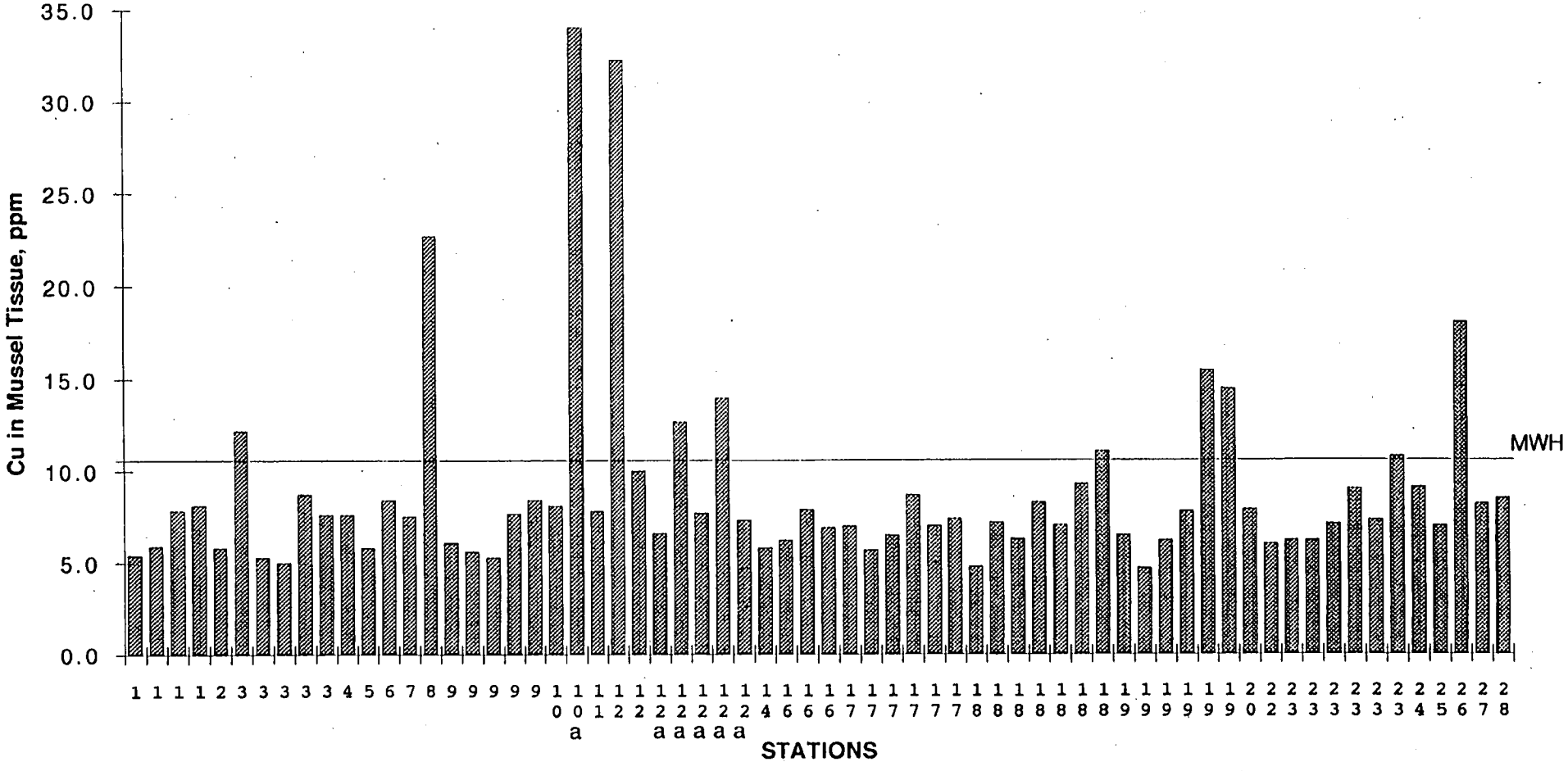
MUSSEL.Spatial cont 1.7 Chart 9

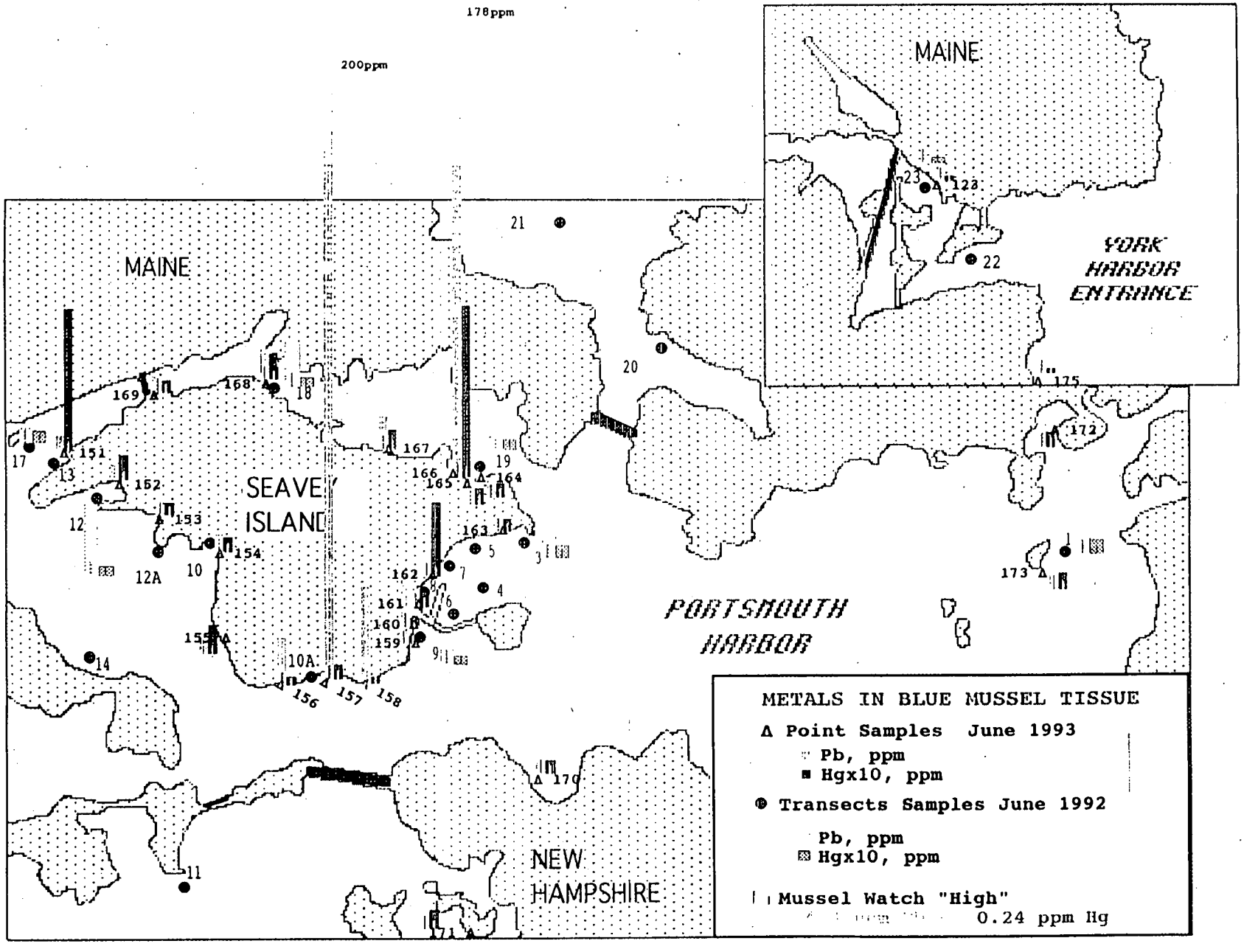


MUSSEL.Spatial cont 1.7 Chart 9



MUSSEL.Spatial cont 1.7 Chart 9

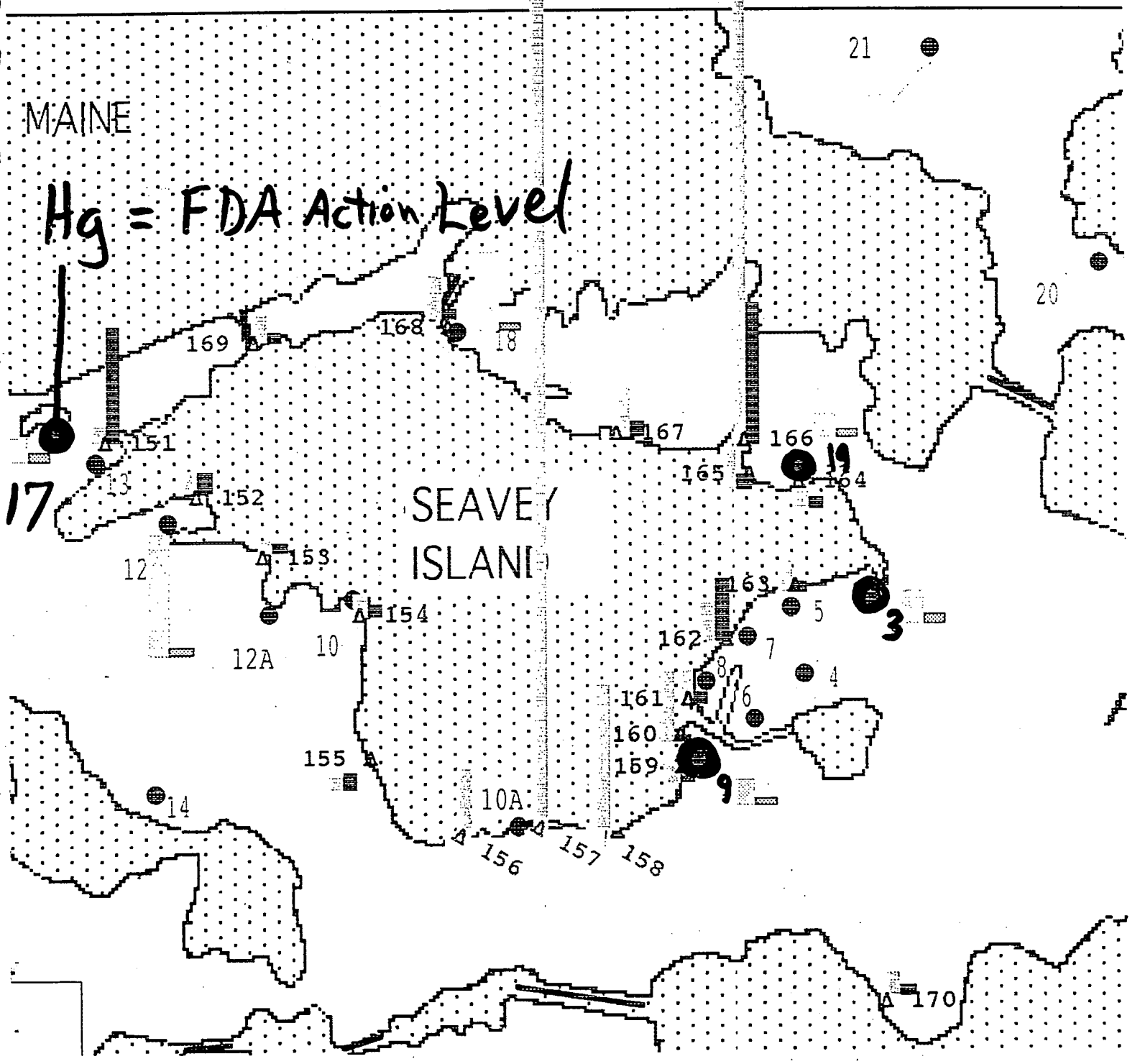




Lead and mercury concentrations in mussel tissue from sampling stations around Seavey Island, Portsmouth Harbor, and York Harbor. Point samples (from 1 m2) were collected at sites 123 and 151-175 as part of a preliminary monitoring program. Transect samples (from 25 m transects) were collected at sites 1,3,9,12,17,18,19, and 23 of the Phase I monitoring. For reference, "high" levels (+1 standard deviation) for lead and mercury from 1990 Mussel Watch data are presented.

Lobster

Tail



Eelgrass Leaf Tissue -- Metal Analysis

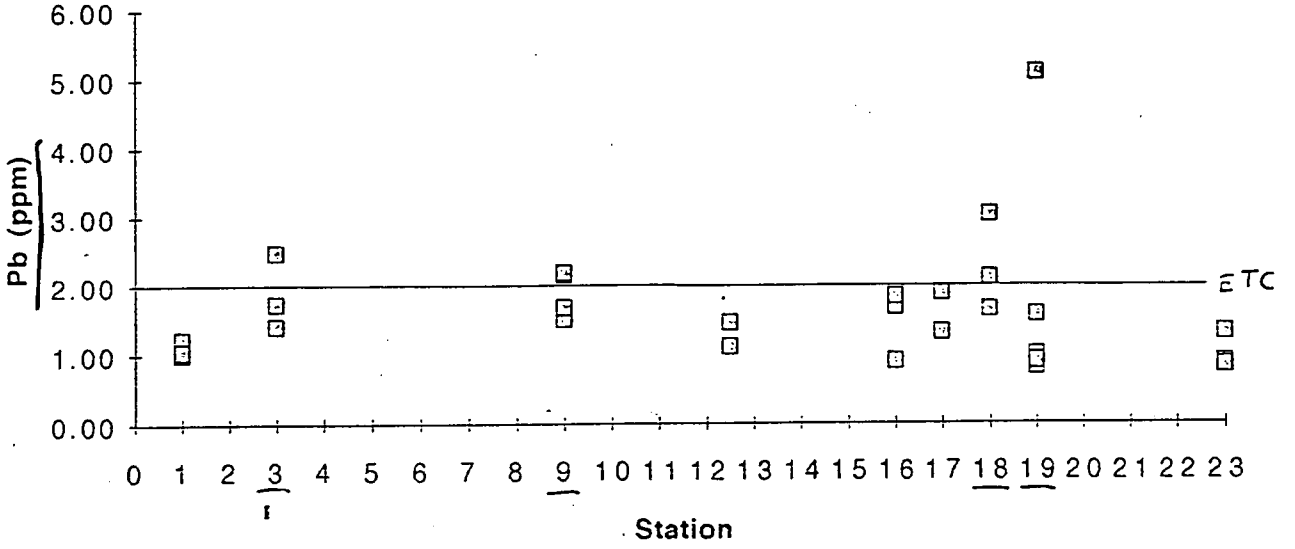
All Phase I and Monitoring Samples (n=61)

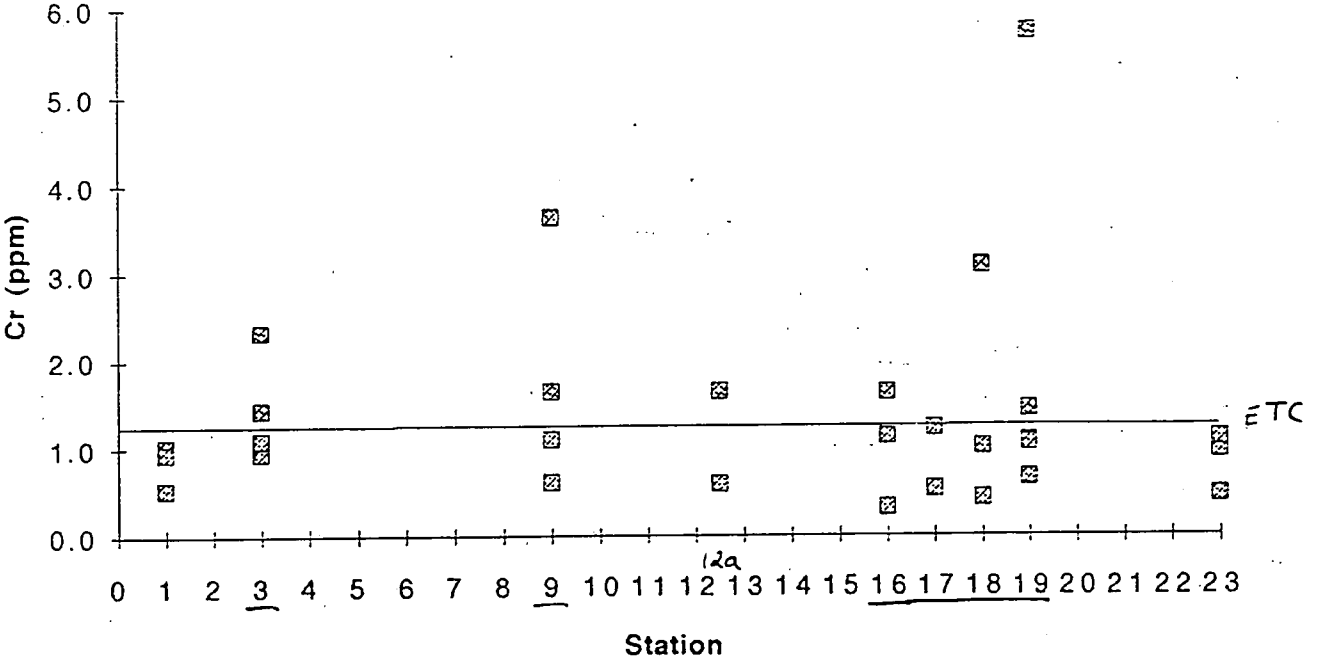
Metal	Analysis of Variance	F-Value	P- Value
As	Sample Drying Effect	7.52	0.0095
Cr	Sample Drying Effect	7.65	0.0089
Fe	Sample Drying Effect	11.84	0.0015
Hg	Sample Drying Effect	26.38	0.0001
Mn	Sample Drying Effect	6.98	0.0121
Ni	Sample Drying Effect	7.57	0.0092
Pb	Sample Drying Effect	12.02	0.0014

With drying effect removed

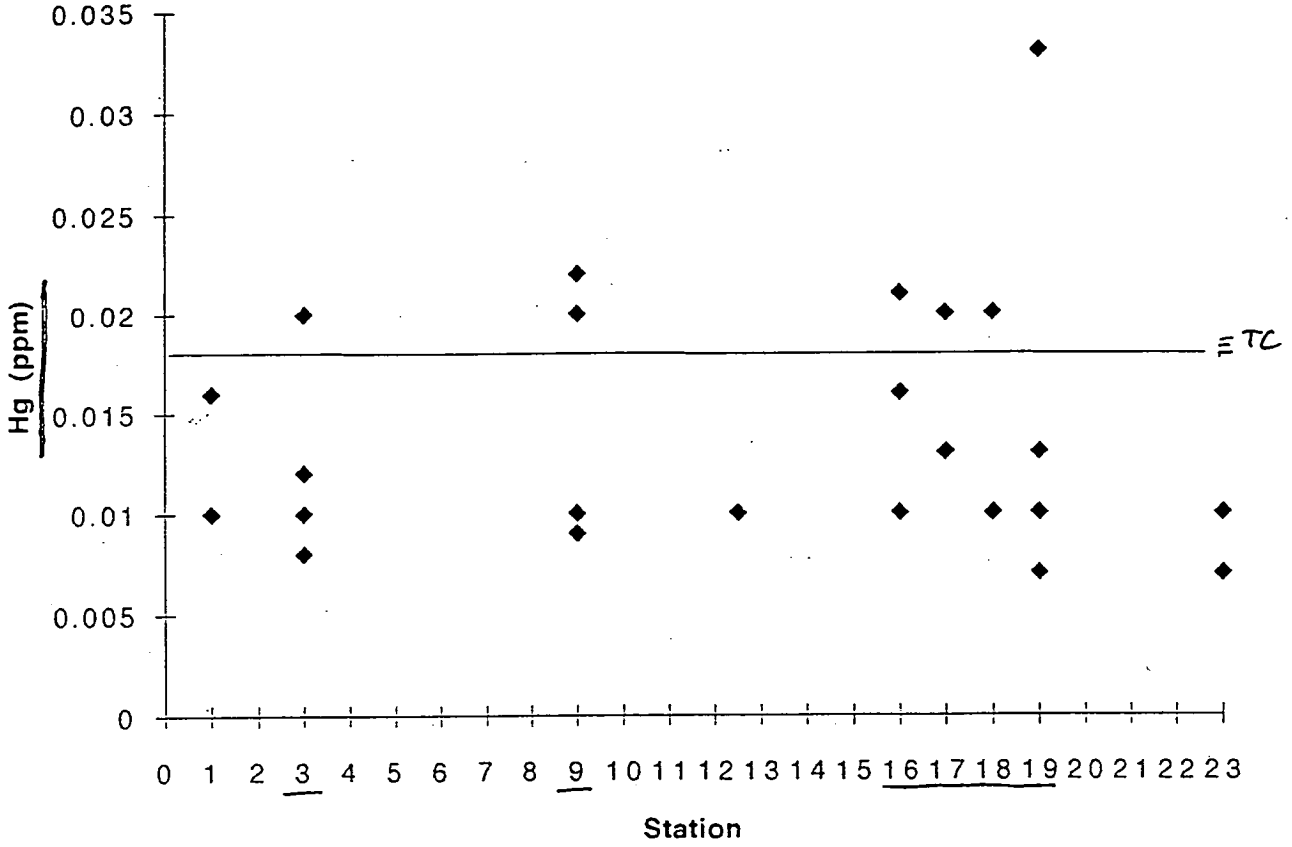
Hg	Station Effect	8.88	0.0001
Zn	Station Effect	3.36	0.0006
Cr	Station Effect	1.96	0.036
Fe	Station Effect	1.87	0.0465
Mn	Station Effect	103	0.0001

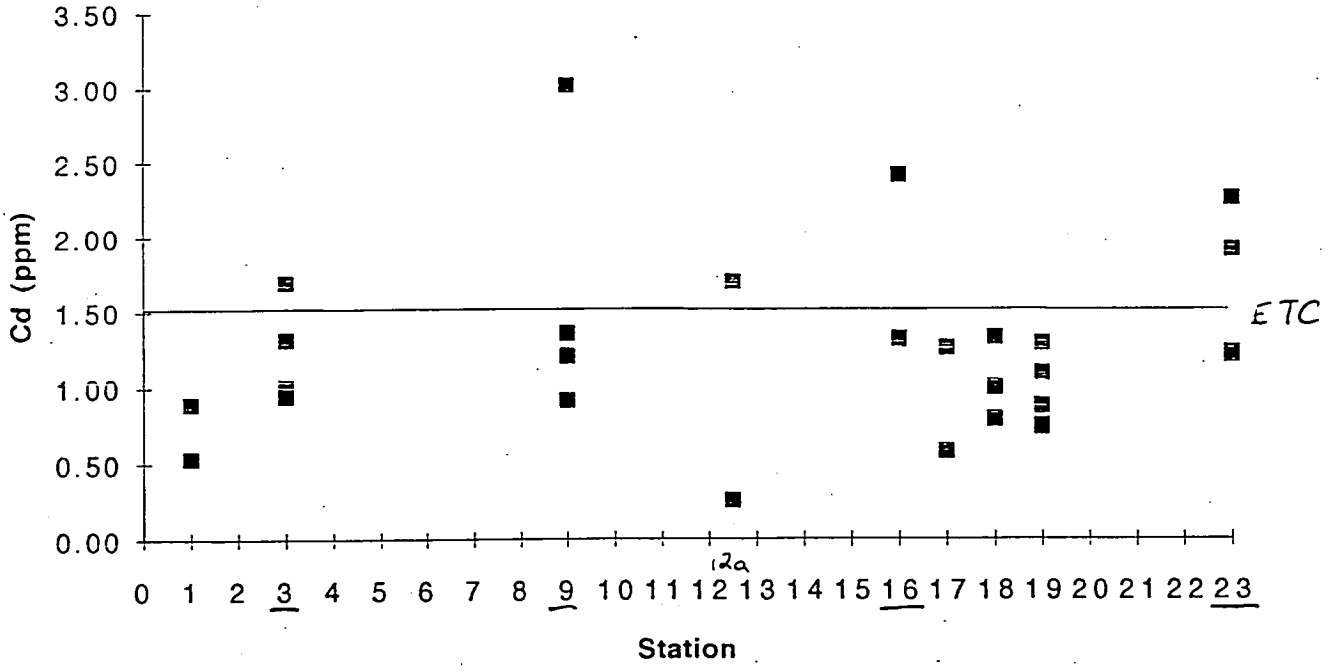
PNS Eelgrass Leaves





PNS Eelgrass Leaves





Eelgrass Root Tissue -- Metal Analysis

All Phase I and Monitoring Samples (n=56)

Metal	Analysis of Variance	F-Value	P- Value
Cr	Laboratory Effect	10.43	0.0029
Zn	Laboratory Effect	12.57	0.0015
Ni	Laboratory Effect	11.68	0.0018

With Laboratory Effect removed

As	Station Effect	4.33	0.0001
Ag	Station Effect	2.46	0.0108
Cd	Station Effect	2.03	0.0135
Cr	Station Effect	4.78	0.0001
Zn	Station Effect	2.13	0.0265
Ni	Station Effect	2.963	0.0029
Mn	Station Effect	11.85	0.0001
Fe	Station Effect	4.23	0.0001
Al	Station Effect	5.17	0.0001

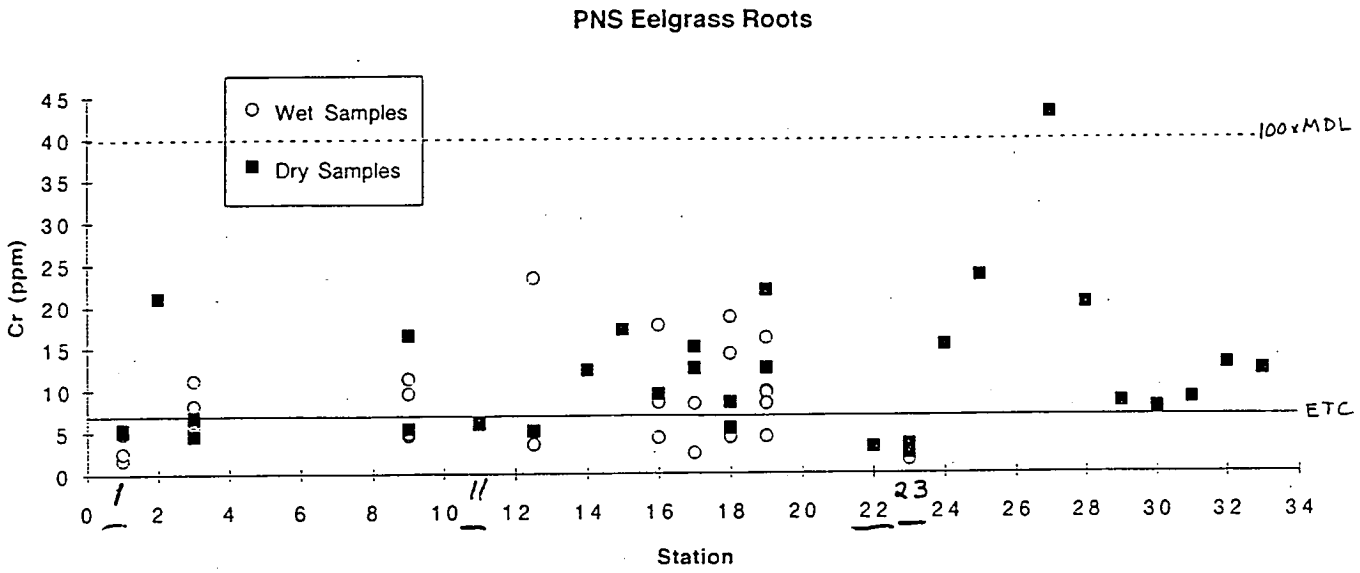


Figure 8. Chromium (Cr) concentrations in eelgrass roots collected from stations around Seavey Island (Sta. 3, 9, 12a, 17, 18, and 19), elsewhere in Portsmouth Harbor (Sta. 1 and 16), and at York River (Sta. 23) and analyzed as wet weight samples (©). In addition, data are plotted for Cr concentrations analyzed on dried eelgrass root tissue from Phase I stations throughout the Great Bay Estuary (*). ETC is an index of comparison for metal concentrations in eelgrass tissue.

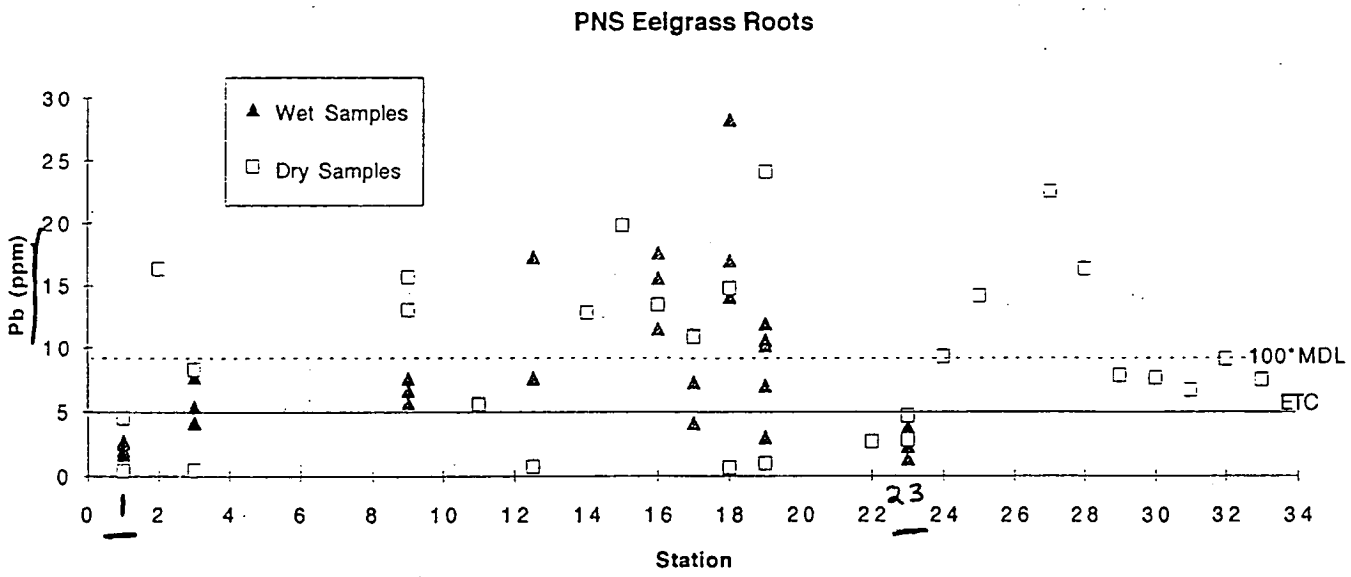


Figure 7. Lead (Pb) concentrations in eelgrass roots collected from stations around Seavey Island (Sta. 3, 9, 12a, 17, 18, and 19), elsewhere in Portsmouth Harbor (Sta. 1 and 16), and at York River (Sta. 23) and analyzed as wet weight samples (A). In addition, data are plotted for Pb

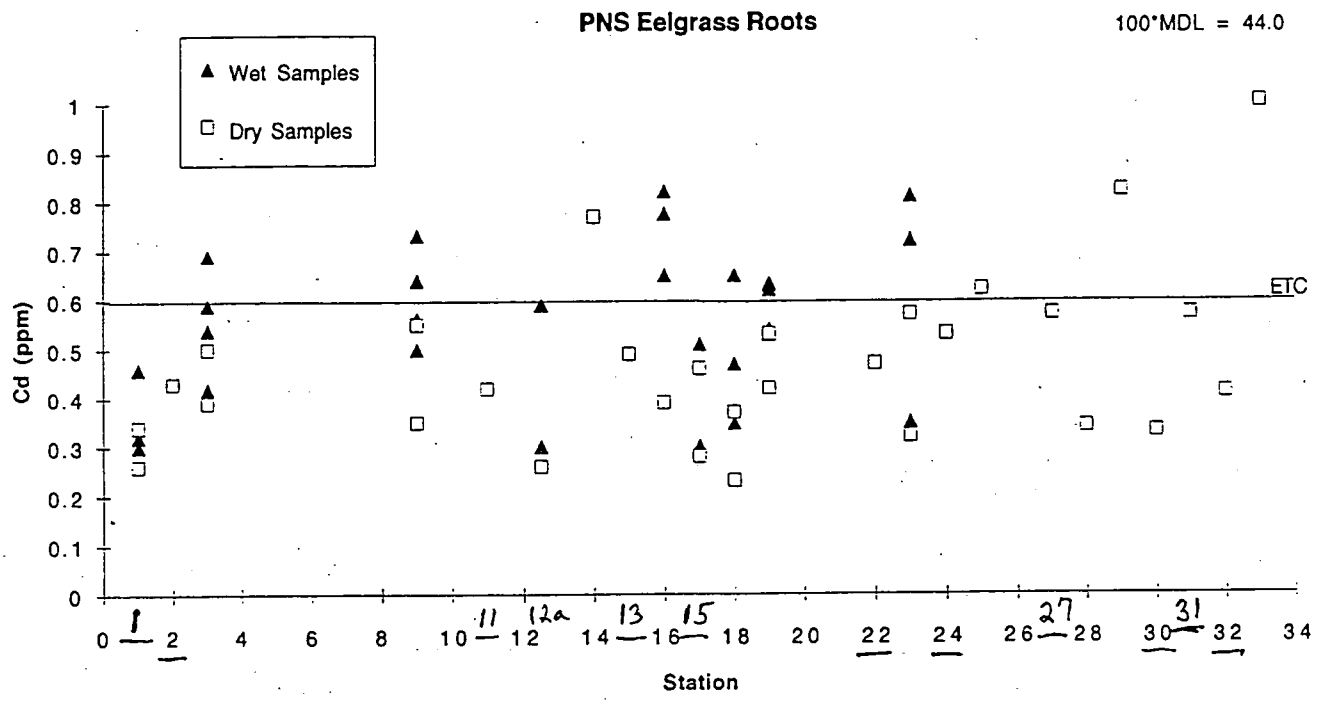


Figure 10. Cadmium (Cd) concentrations in eelgrass roots collected from stations around Seavey Island (Sta. 3, 9, 12a, 17, 18, and 19), elsewhere in Portsmouth Harbor (Sta. 1 and 16), and at York River (Sta. 23) and analyzed as wet weight samples (Δ). In addition, data are plotted for Cd concentrations analyzed on dried eelgrass root tissue from Phase I stations throughout the Great Bay Estuary (). ETC is an index of comparison for metal concentrations in eelgrass tissue.

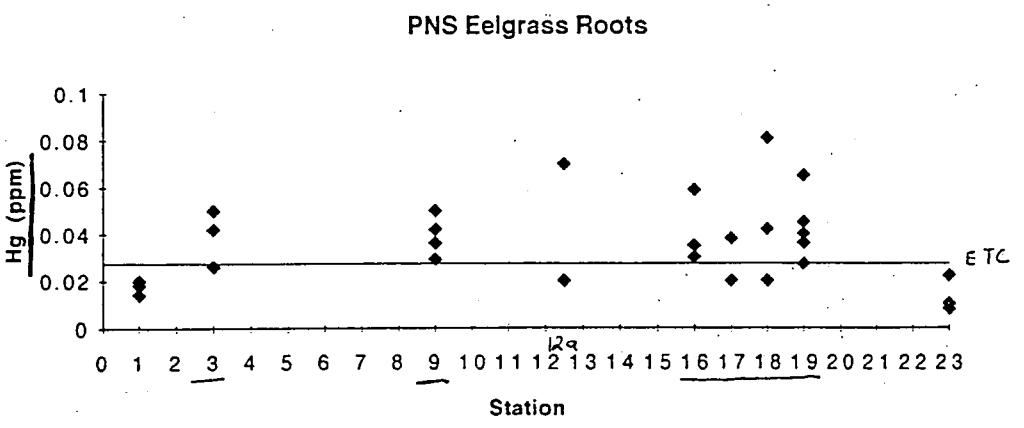
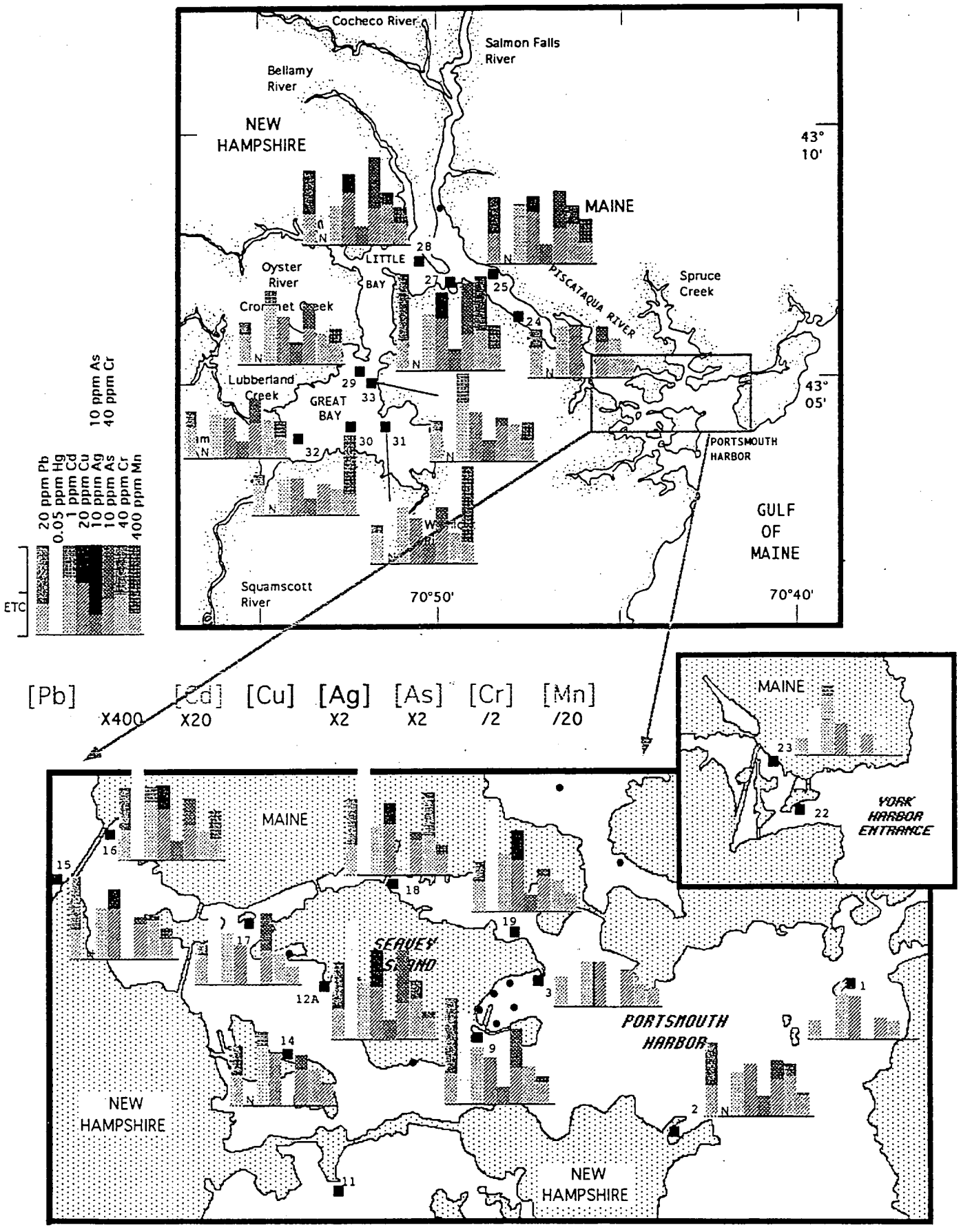
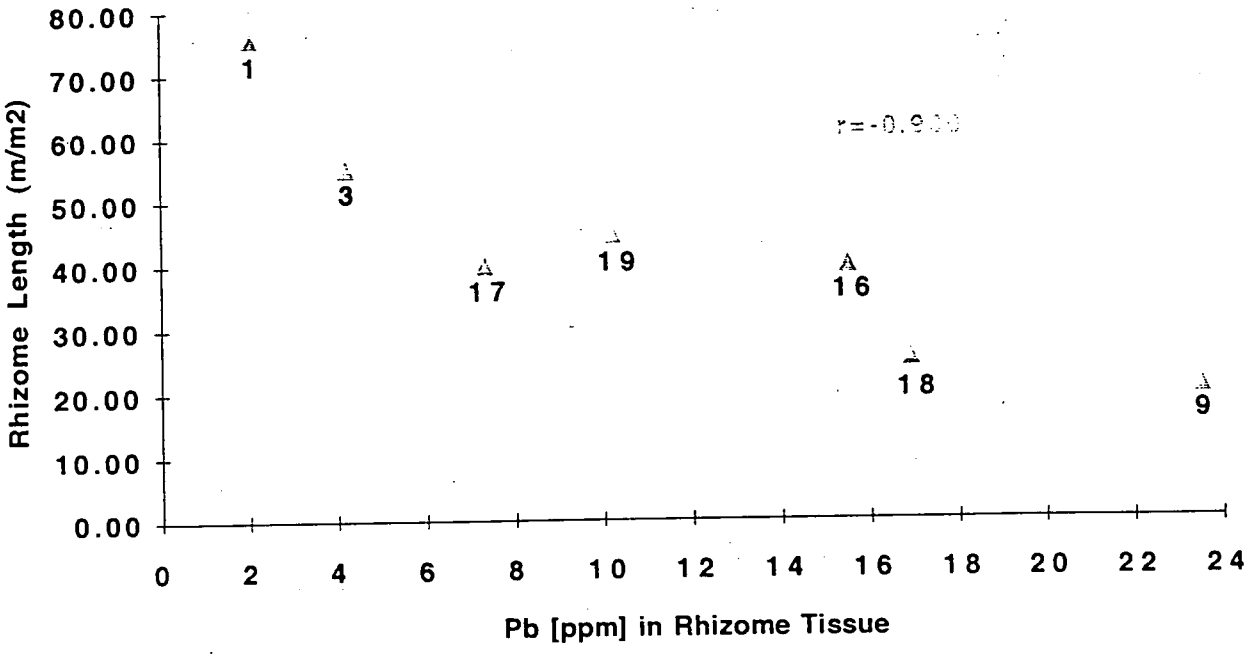
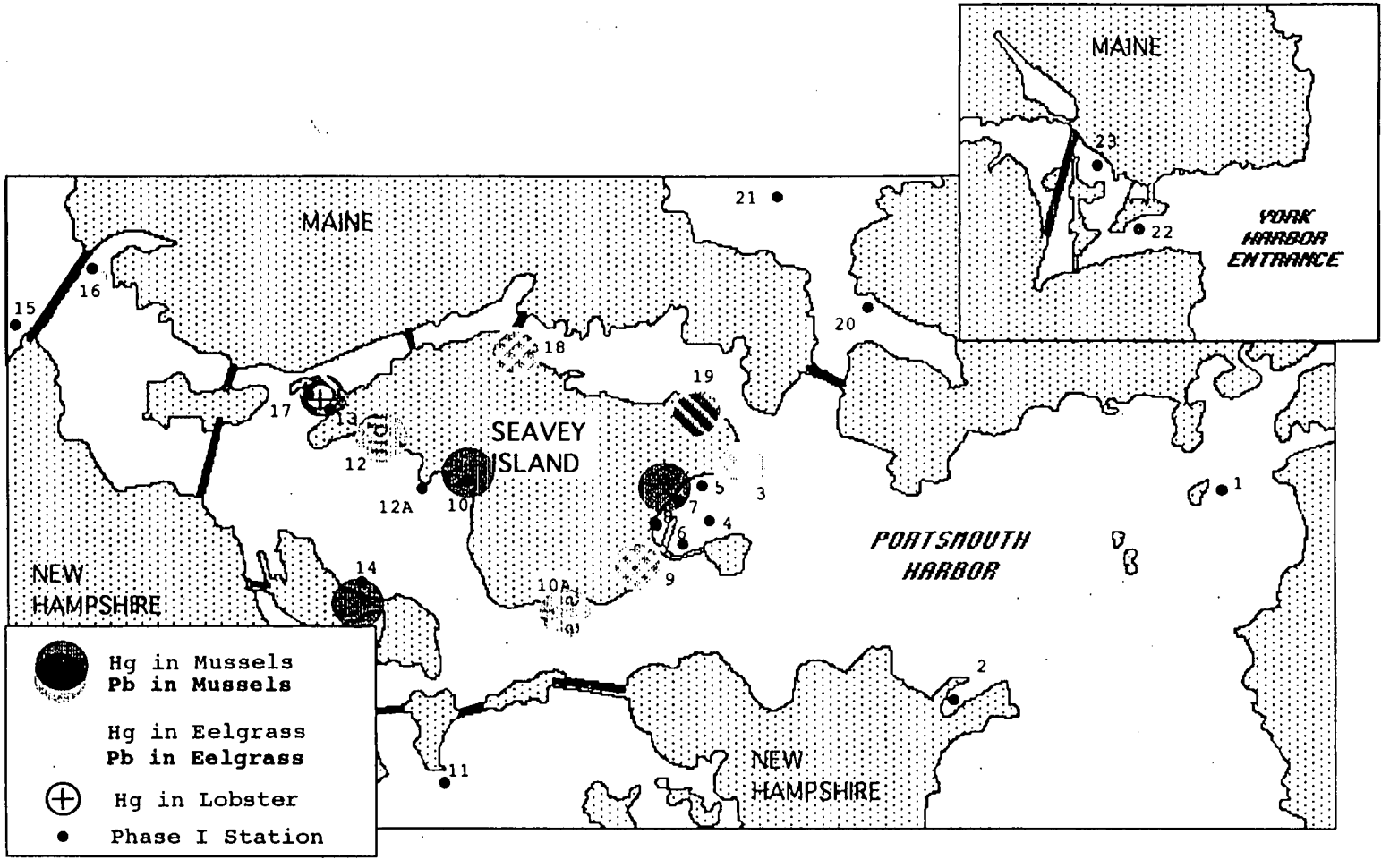


Figure 9(b). Replot of wet root samples only plotted on an expanded scale.


Cocheco River
Salmon Falls River
Bellamy River
NEW HAMPSHIRE
43° 10'
MAINE
Oyster River
LITTLE BAY
Spruce Creek
PISCATAQUA RIVER
Lubberland Creek
GREAT BAY
43° 05'
PORTSMOUTH HARBOR
GULF OF MAINE
Squamscott River
70°50'
70°40'
10 ppm As
40 ppm Cr
20 ppm Pb
0.05 ppm Hg
1 ppm Cd
20 ppm Cu
10 ppm Ag
10 ppm As
40 ppm Cr
400 ppm Mn
ETC
[Pb] X400
[Cd] X20
[Cu]
[Ag] X2
[As] X2
[Cr] /2
[Mn] /20
MAINE
YORK HARBOR ENTRANCE
SEAVEY'S ISLAND
PORTSMOUTH HARBOR
NEW HAMPSHIRE
NEW HAMPSHIRE


80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Rhizome Length (m/m2)
1
3
17
19
16
18
9
0
2
4
6
8
10
12
14
16
18
20
22
24
Pb [ppm] in Rhizome Tissue


MAINE
NEW HAMPSHIRE
SEAVEY ISLAND
PORTSMOUTH HARBOR
NEW HAMPSHIRE
MAINE
YORK HARBOR ENTRANCE
1
2
3
4
5
6
7
9
10
10A
11
12
12A
13
14
15
16
17
18
19
20
21
22
23
Hg in Mussels
Pb in Mussels
Hg in Eelgrass
Pb in Eelgrass
Hg in Lobster
Phase I Station

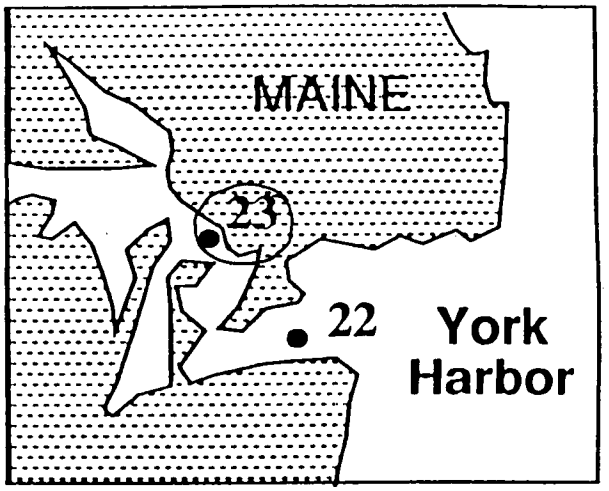
CONCLUSIONS

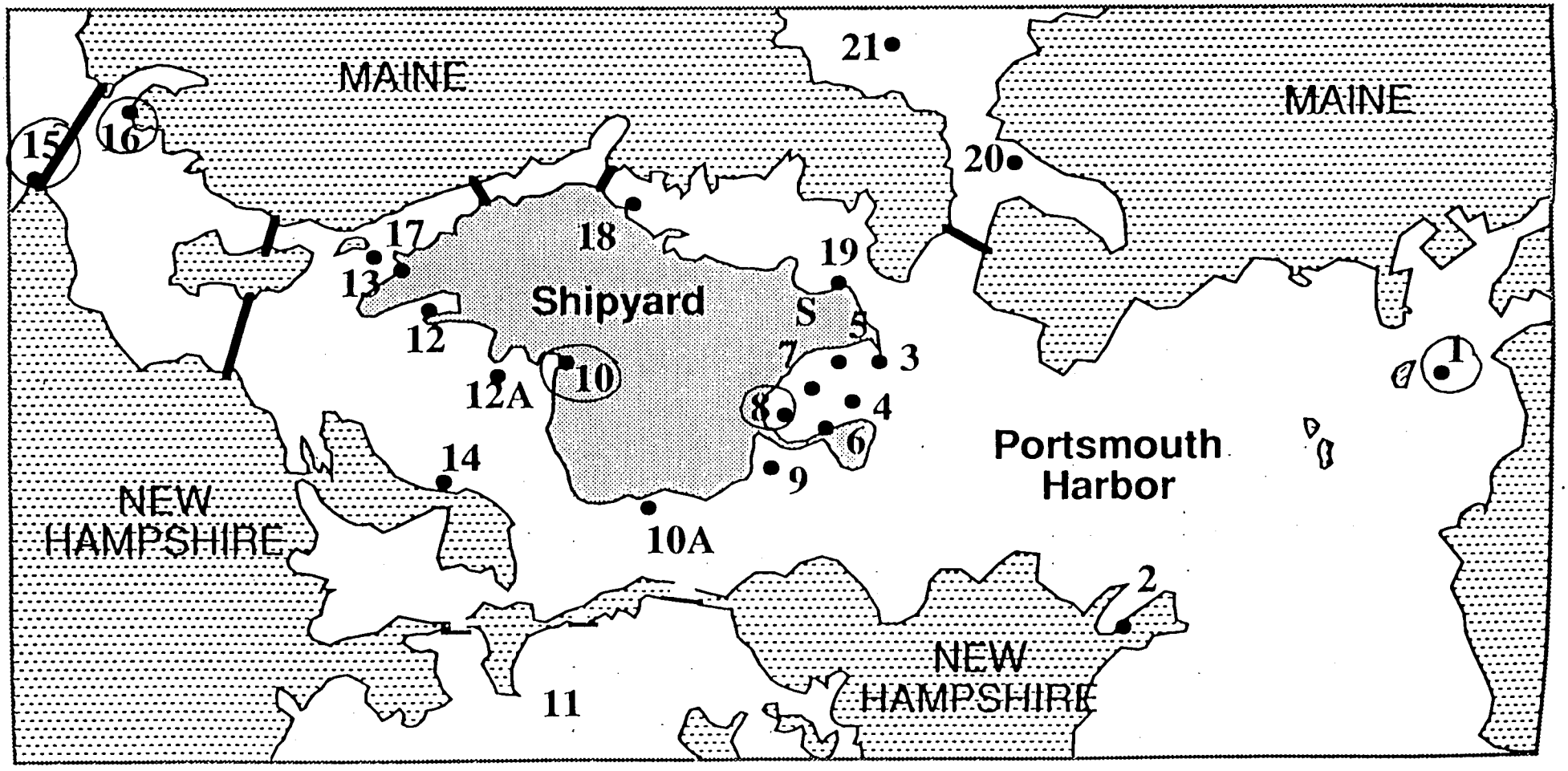
- No eelgrass in Clark Cove.
- Identified spatial and temporal changes in contaminant concentration in biota around PNS.
- These give indirect evidence of some point sources of contaminant discharge from PNS.
- Different indicators suggest common point sources of metal contamination.
- Mussels, eelgrass, and perhaps juvenile lobsters are good sentinel accumulators of metal contamination.

Rich Langan, UNH-JEL

Figure 1. Station Locations in Lower Piscataqua River and York Harbor estuaries.

MONTHLY (QUARTERLY) WATER SAMPLING STATIONS ○





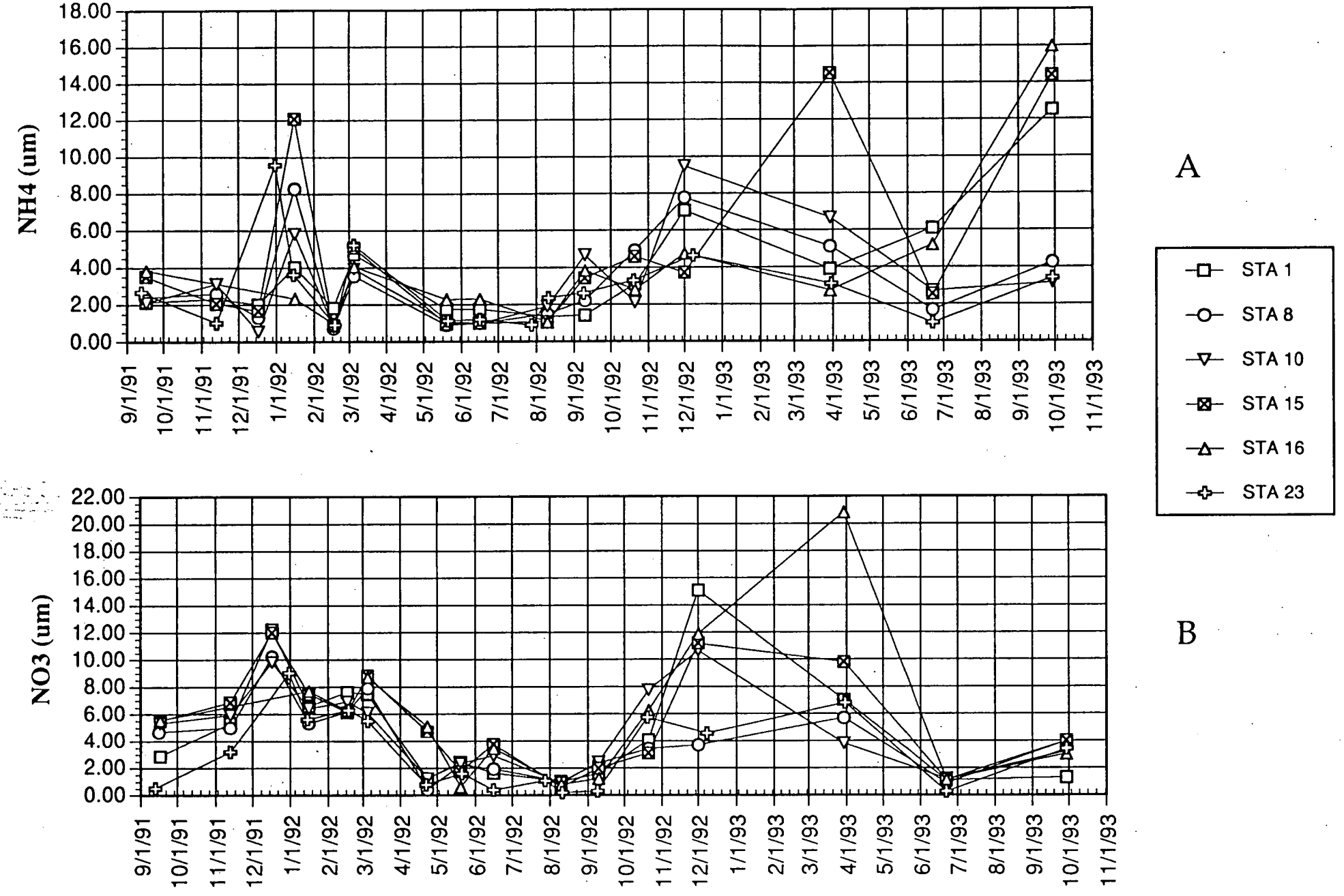


Figure 3. Monthly measurements of ammonium (A) and nitrate (B) at Stations 1, 8, 10, 15, 16 and 23, September 1991 to September 1993.

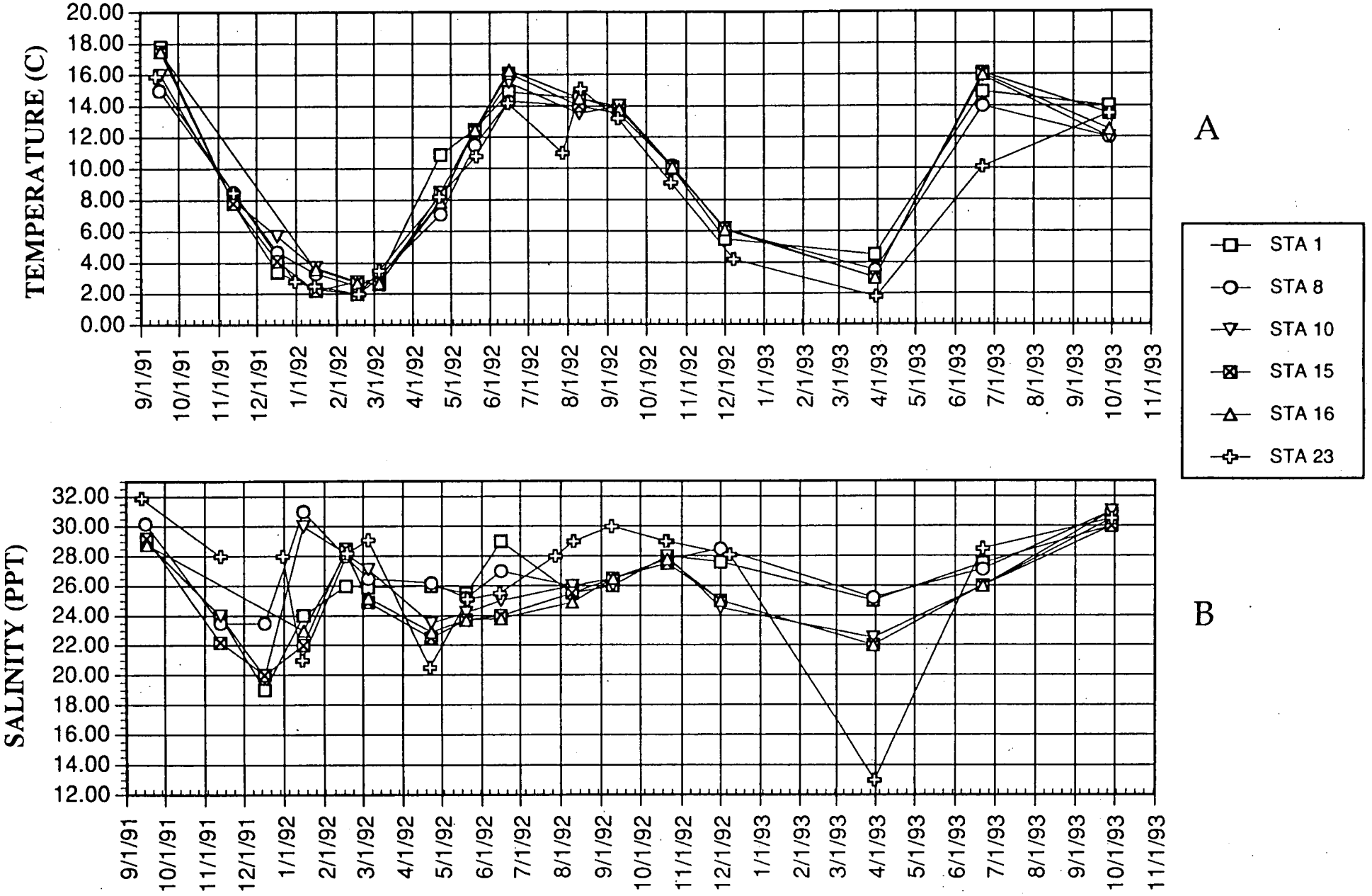


Figure 1. Monthly measurements of temperature (A) and salinity (B) at Stations 1, 8, 10, 15, 16, and 23, September 1991 to September 1993

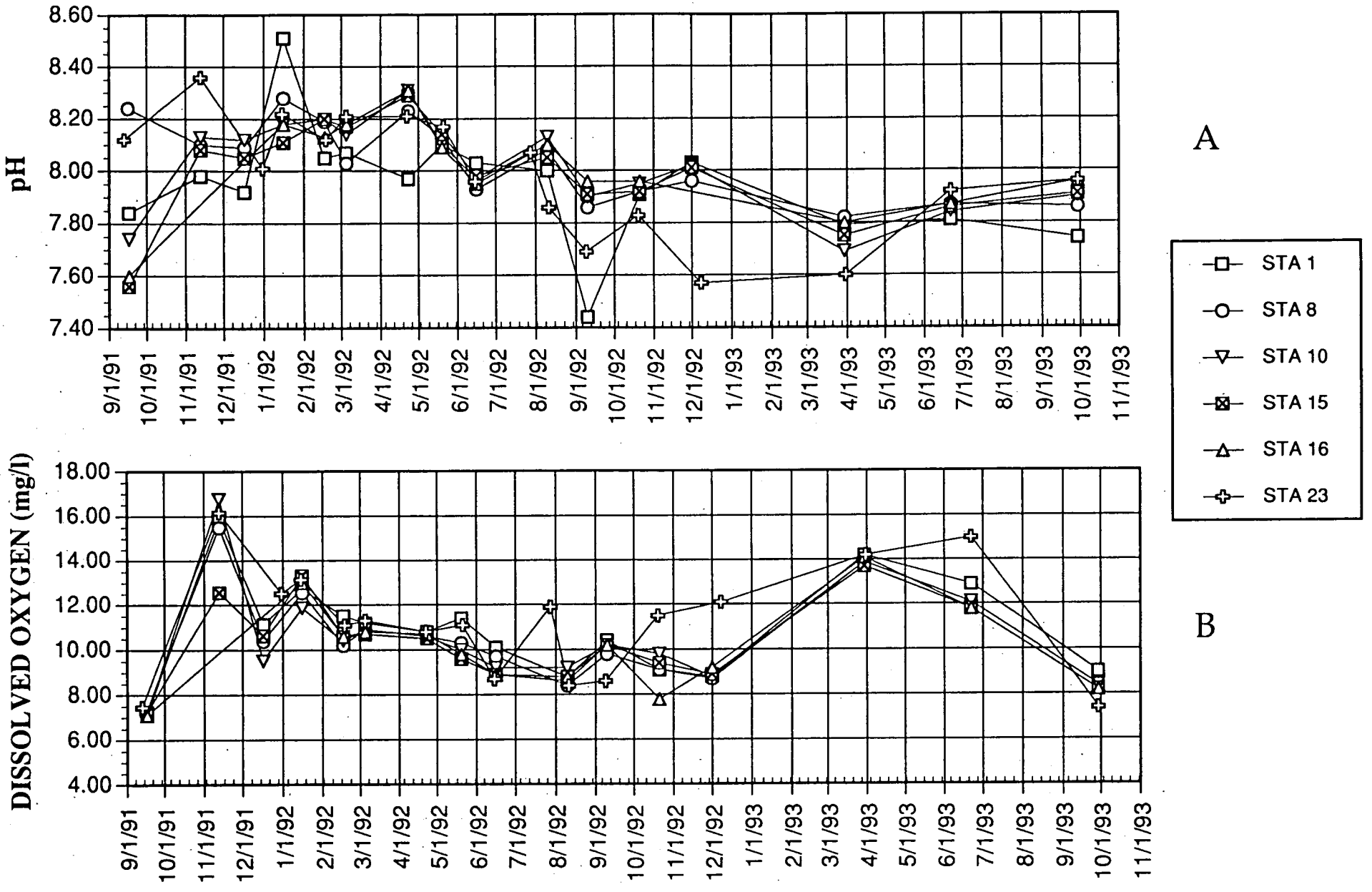


Figure 2. Monthly measurements of pH (A) and dissolved oxygen (B) at Stations 1, 8, 10, 15, 16 and 23, September 1991 to September 1993.

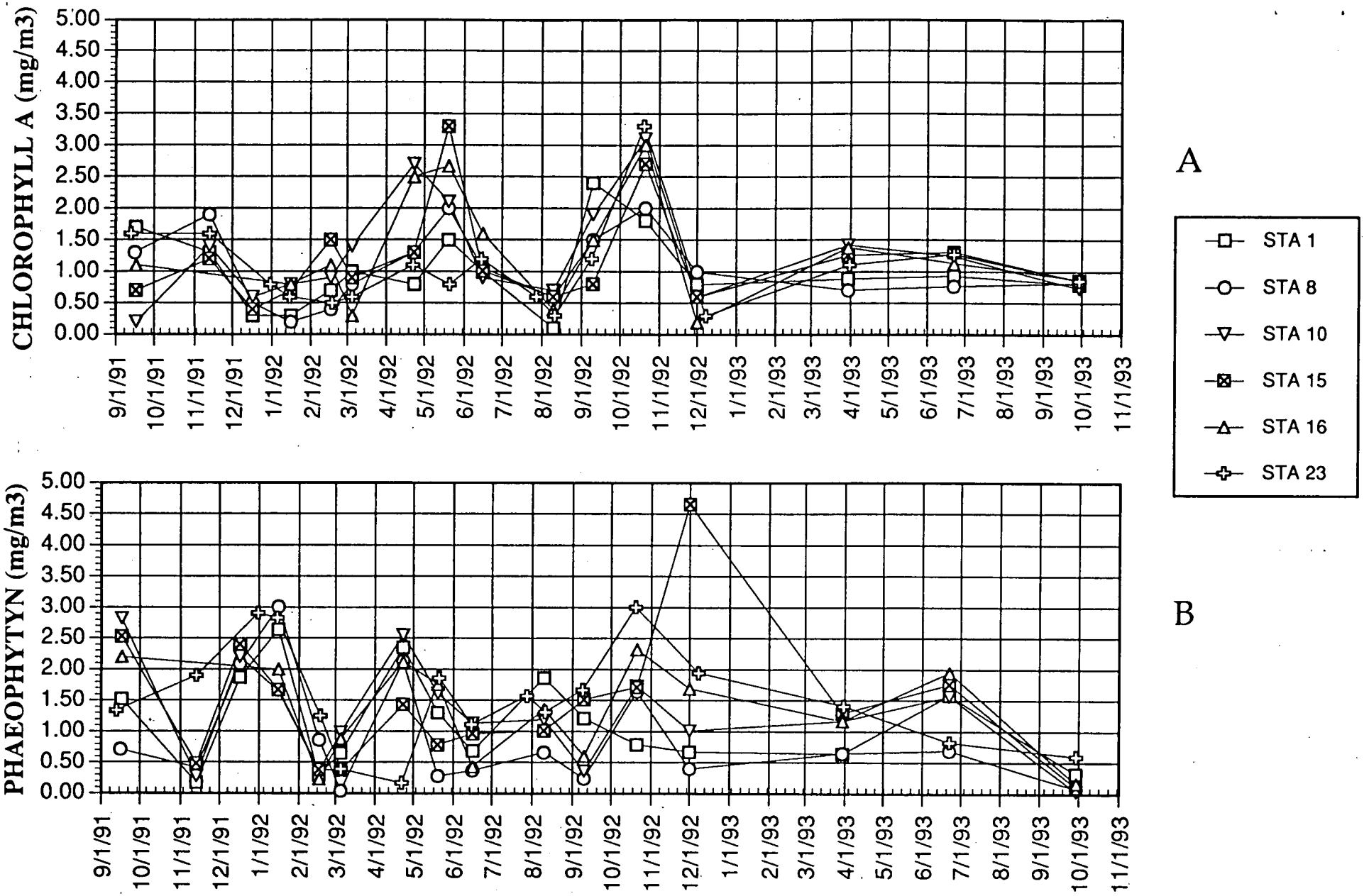


Figure 4. Monthly measurements of chlorophyll a (A) and phaeophytyn (B) at Stations 1, 8, 10, 15, 16 and 23, September 1991 to September 1993.

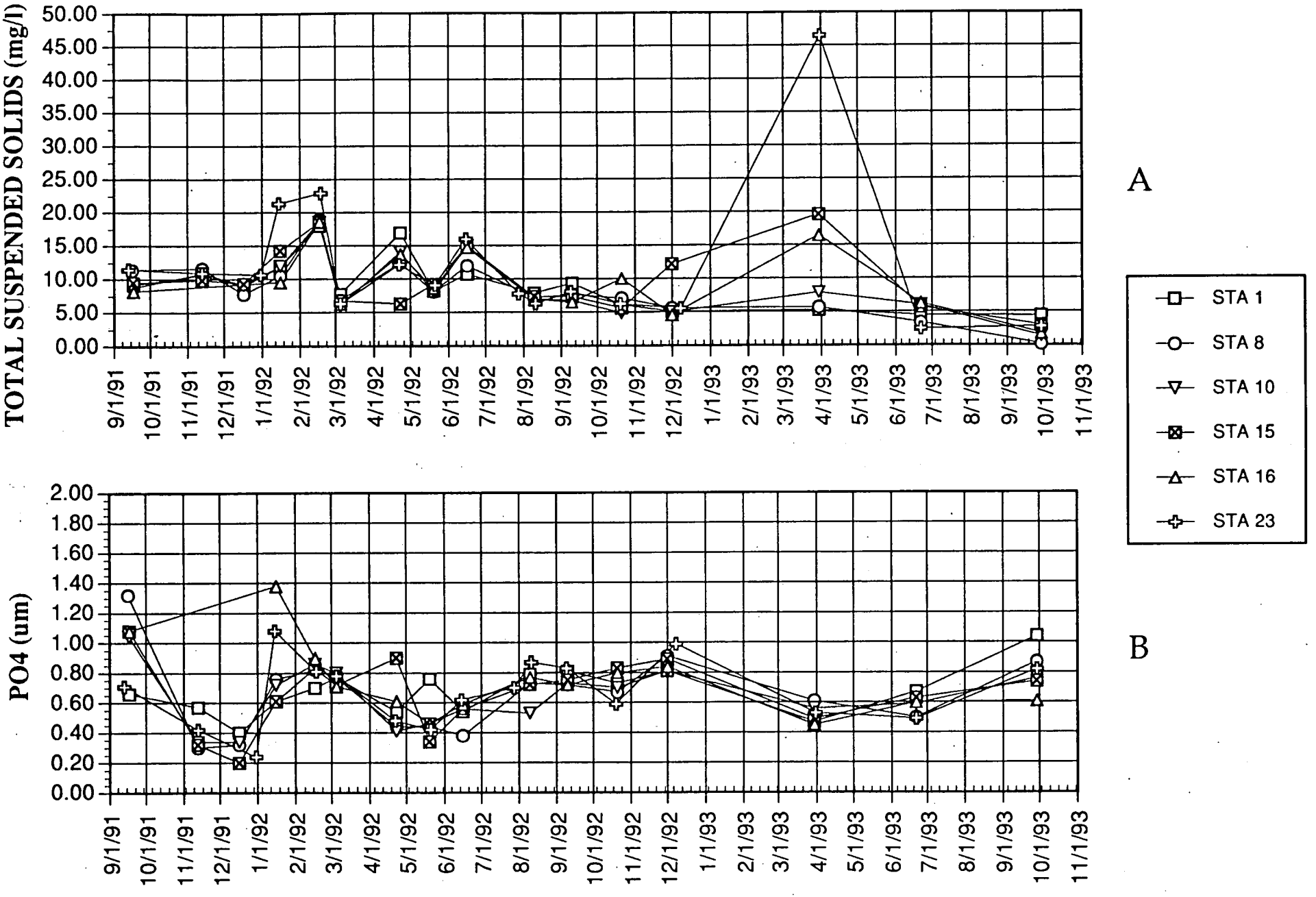


Figure 5. Monthly measurements of total suspended solids (A) and phosphate (B) at Stations 1, 8, 10, 15, 16, and 23, September 1991 to September 1993.

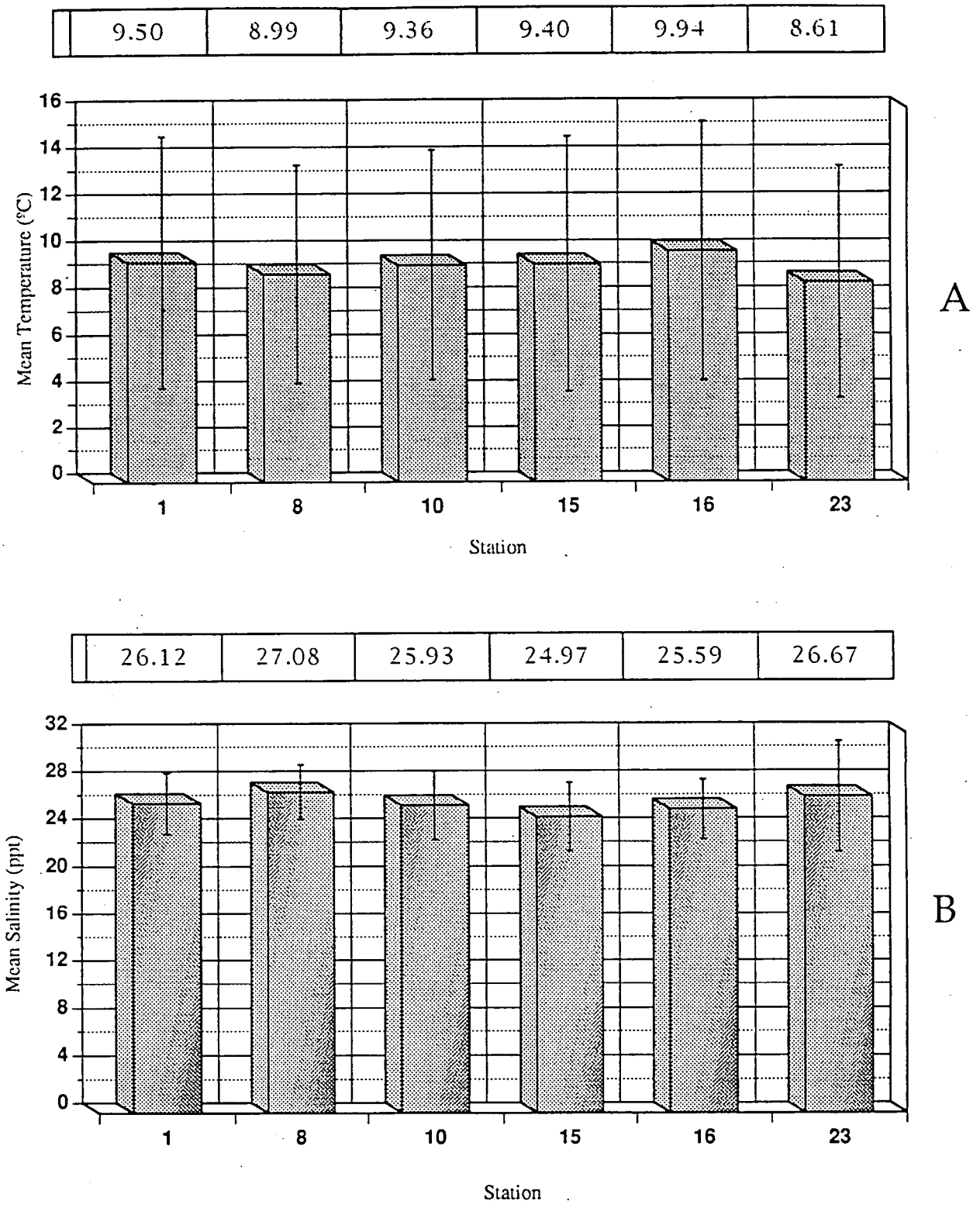
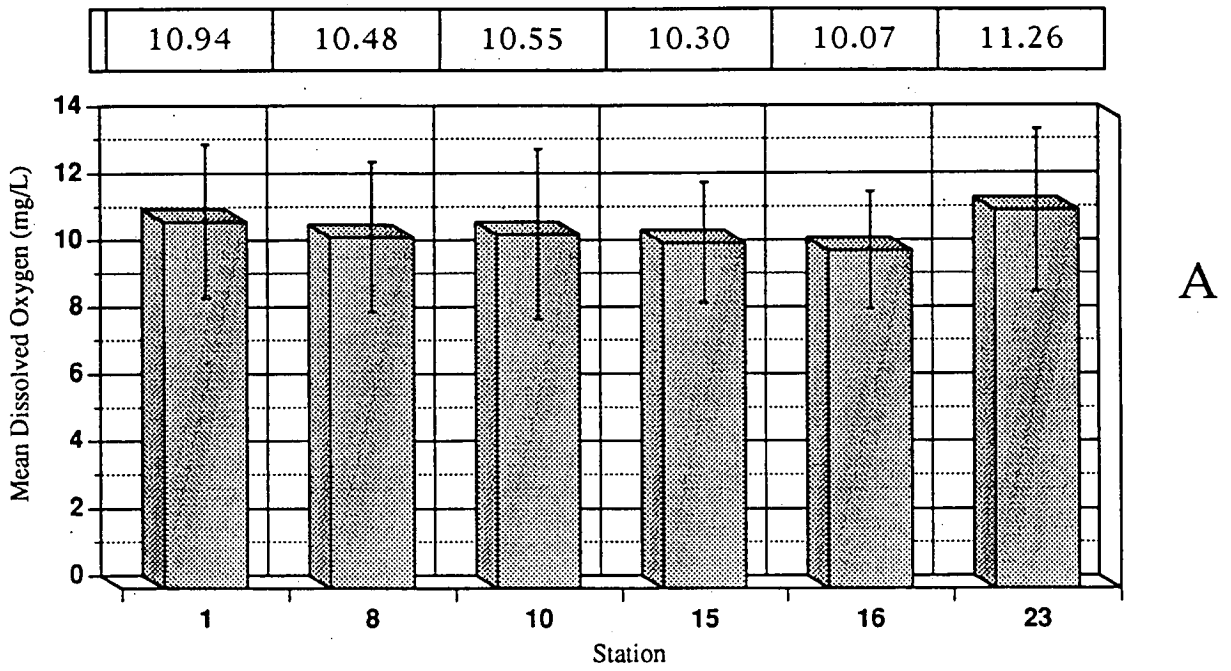


Figure 9. Means and standard deviation (error bars) of temperature (A) and salinity (B) for Stations 1, 8, 10, 15, 16 and 23, September 1991 to September 1993.



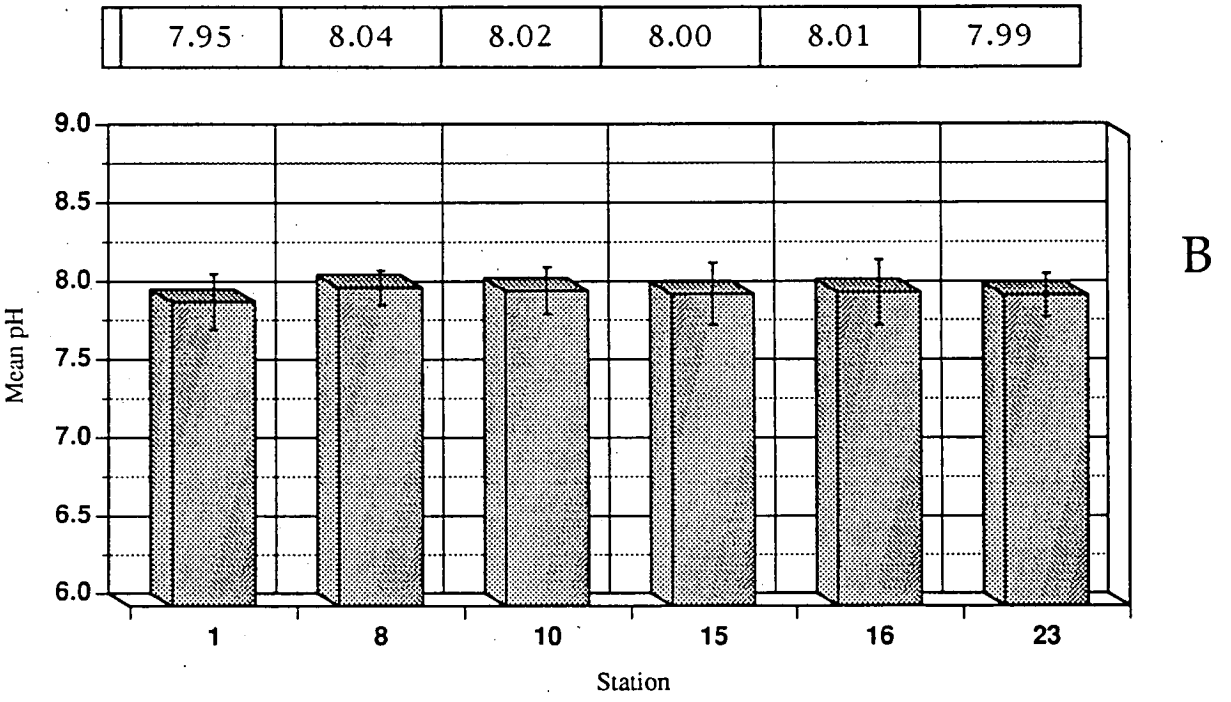


Figure 10. Means and standard deviation (error bars) of dissolved oxygen (A) and pH (B) for Stations 1, 8, 10, 15, 16, and 23, September 1991 to September 1993.

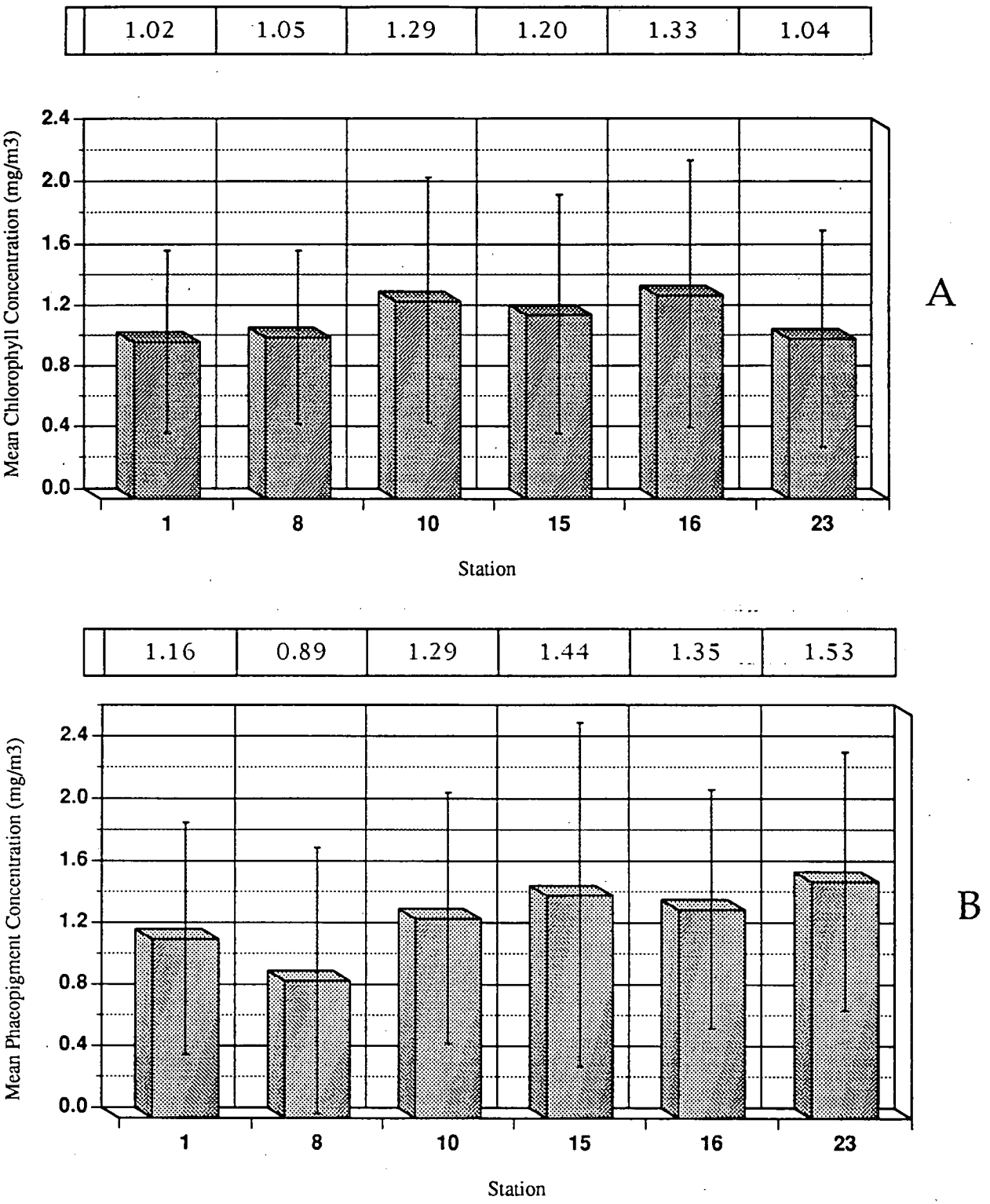
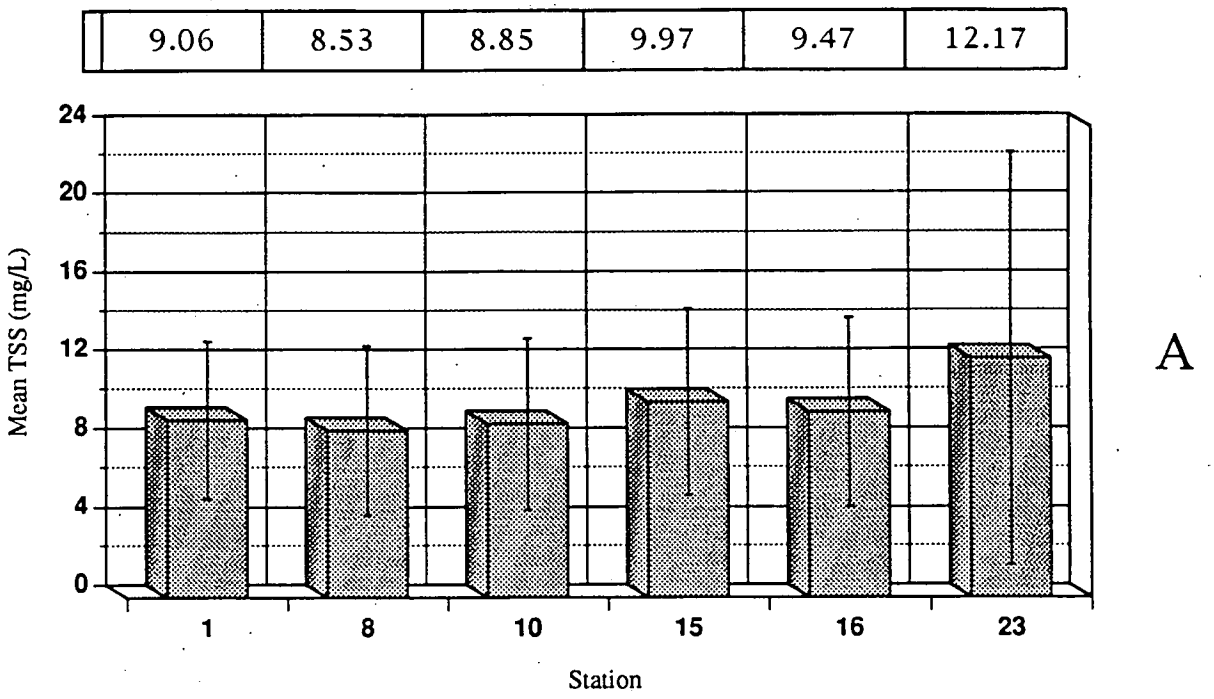


Figure 7. Means and standard deviation (error bars) of chlorophyll a (A) and phaeopigment (B) for Stations 1, 8, 10, 15, 16, and 23, September 1991 to September 1993.



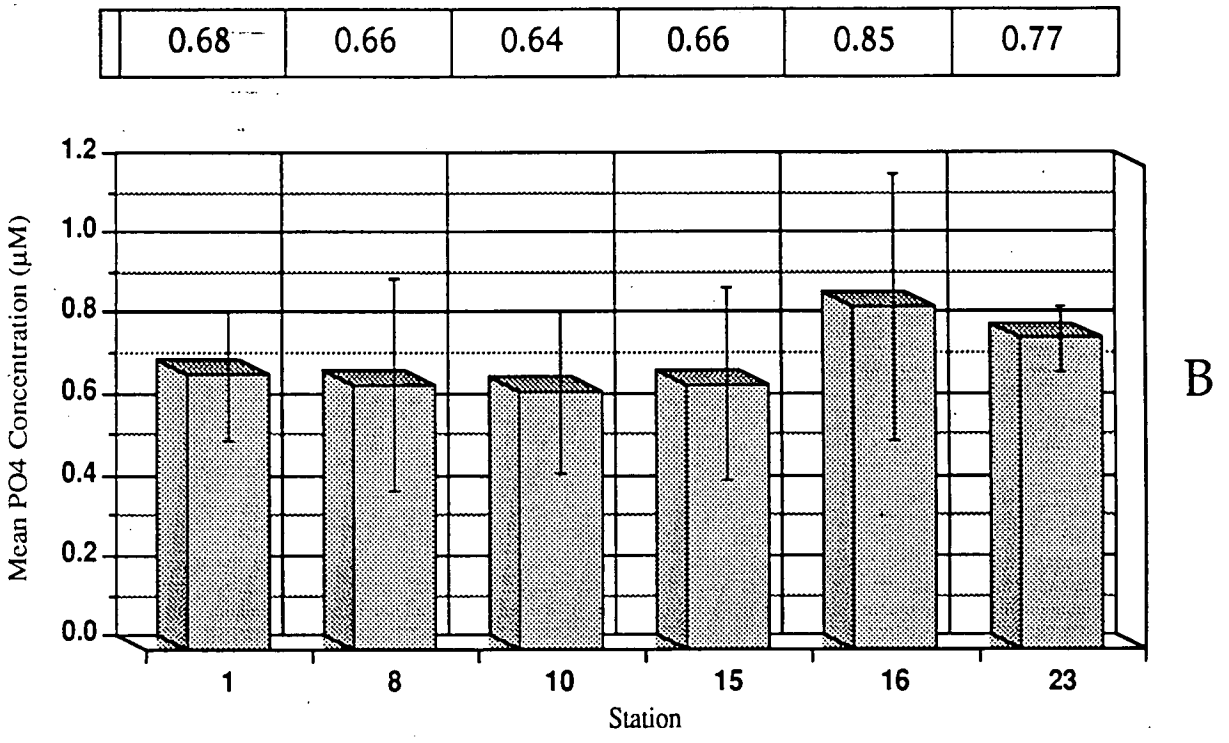
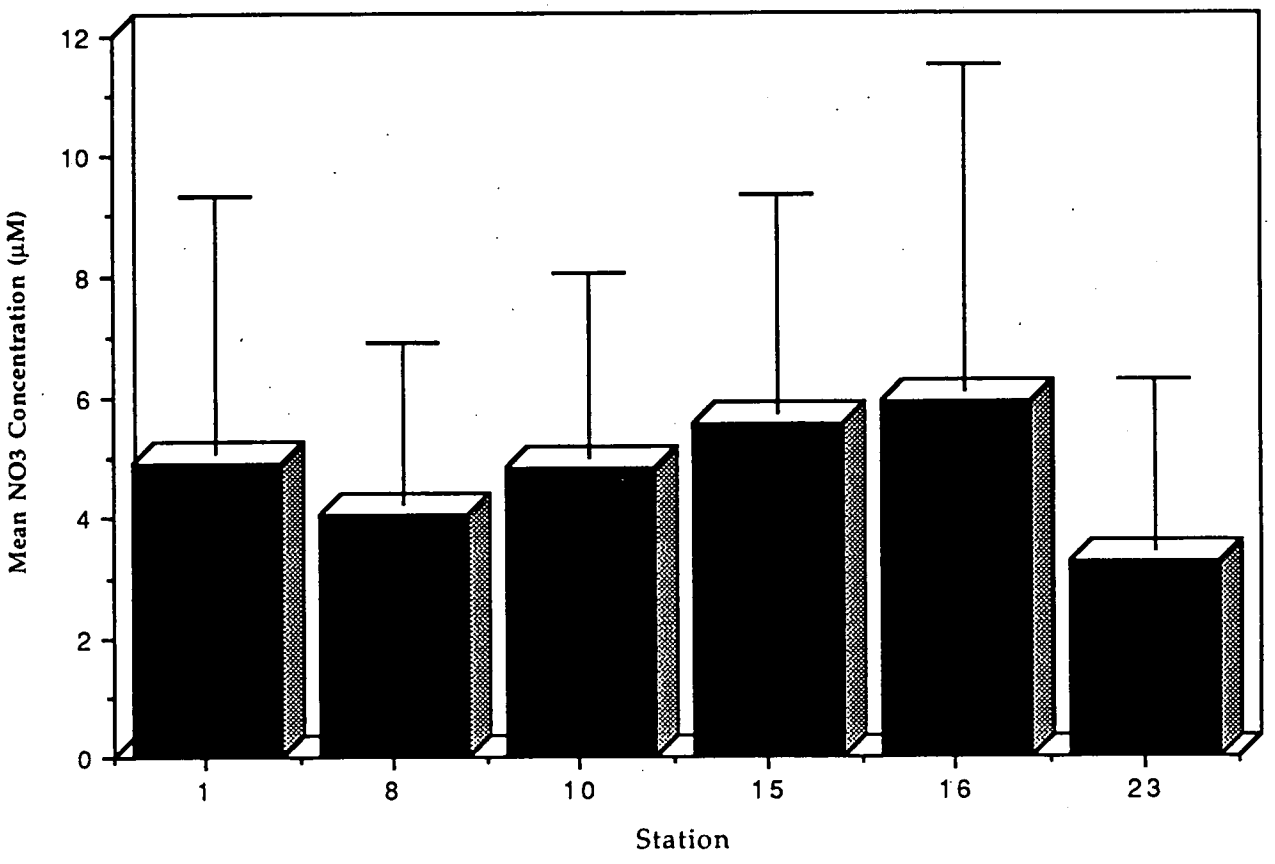
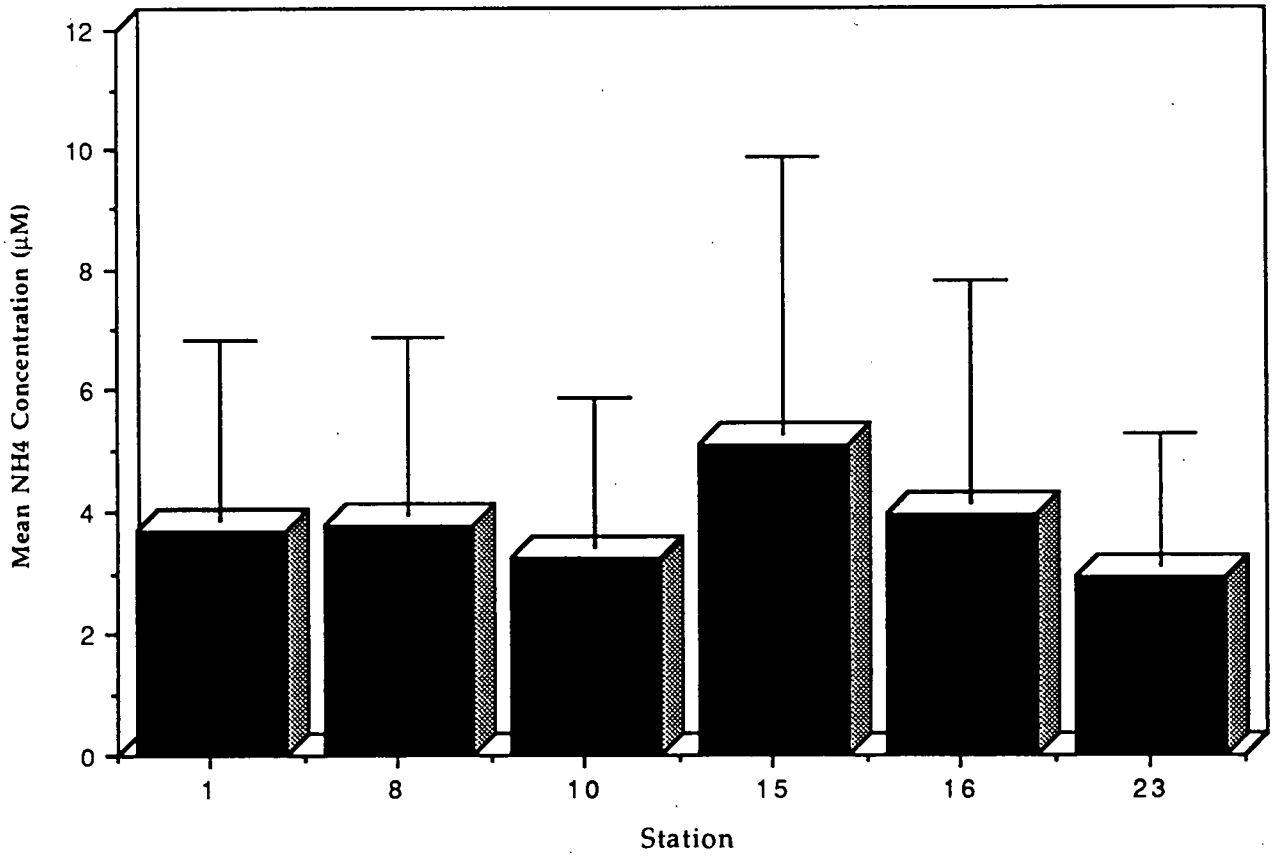


Figure 8. Means and standard deviation (error bars) of total suspended solids (A) and phosphate (B) for Stations 1, 8, 10, 15, 16, and 23, September 1991 to September 1993.

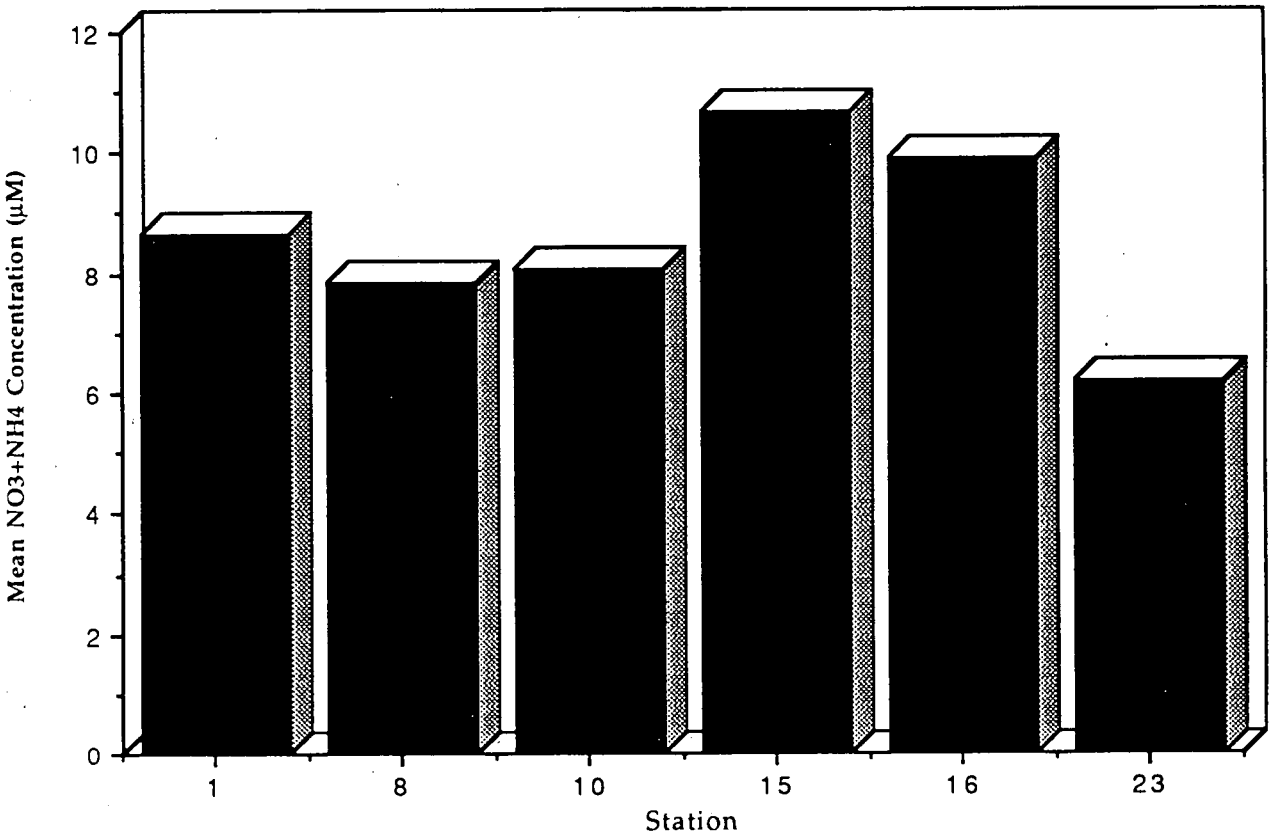
Mean Nitrate Concentration 9/91 thru 9/93



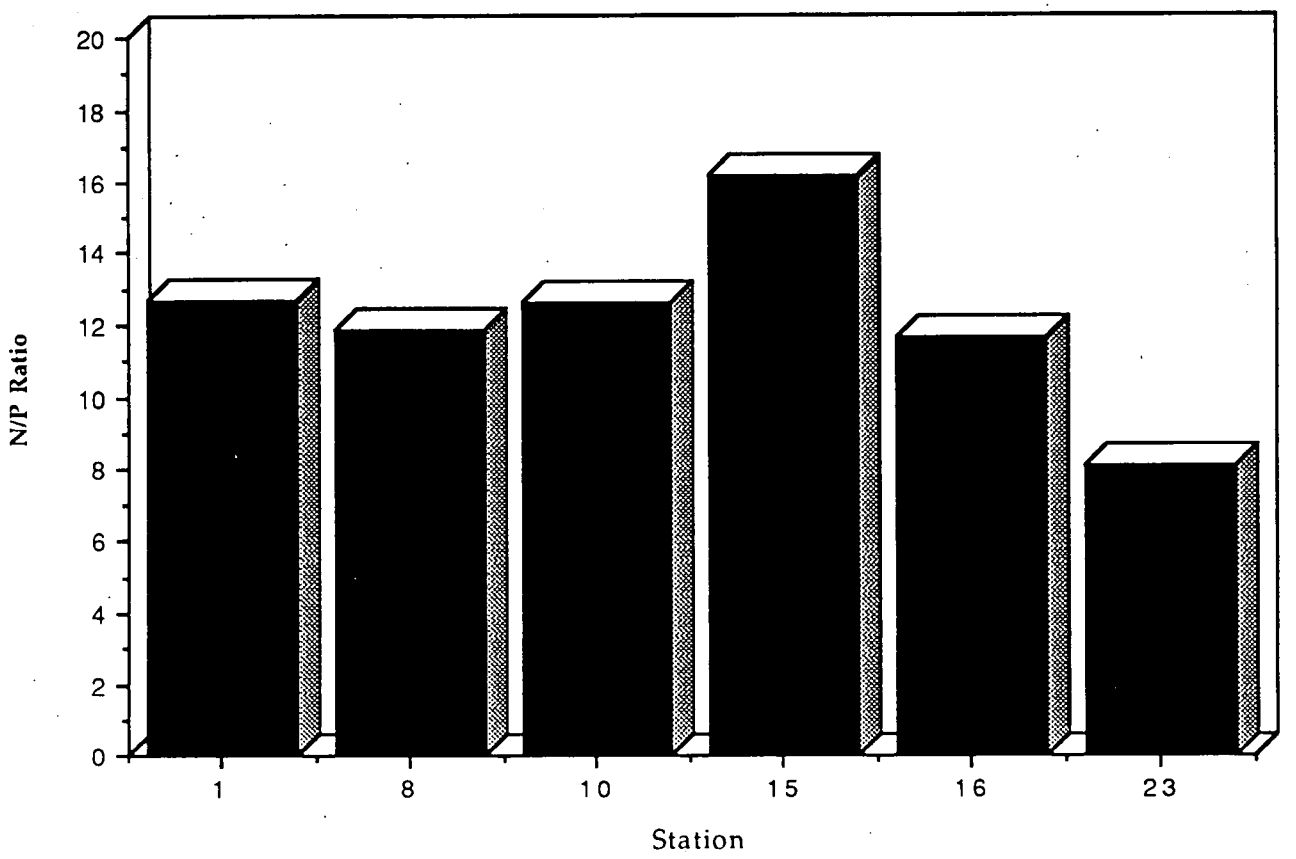
Mean Ammonium Concentration 9/91 thru 9/93

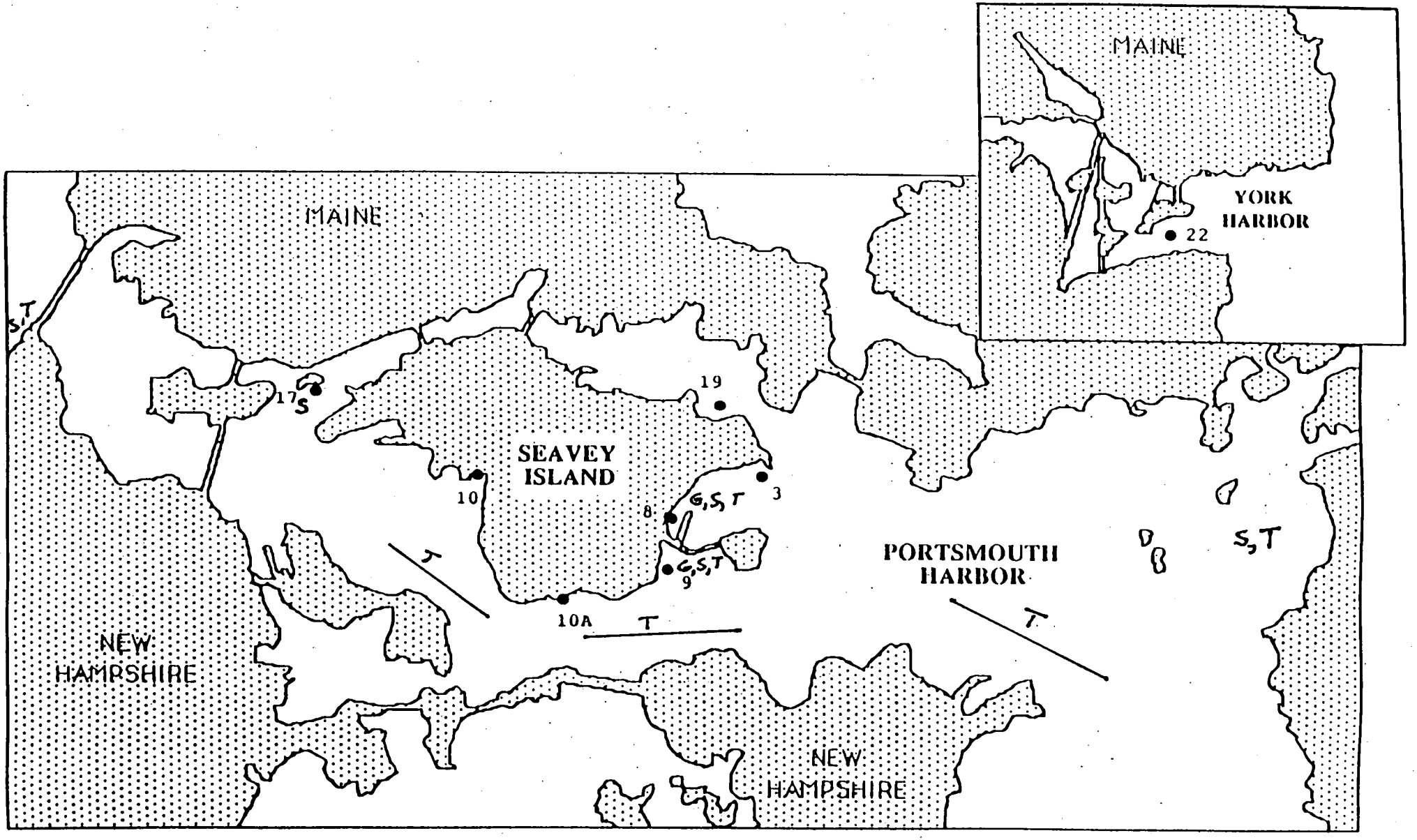


NO3 + NH4 Concentration 9/91-9/93



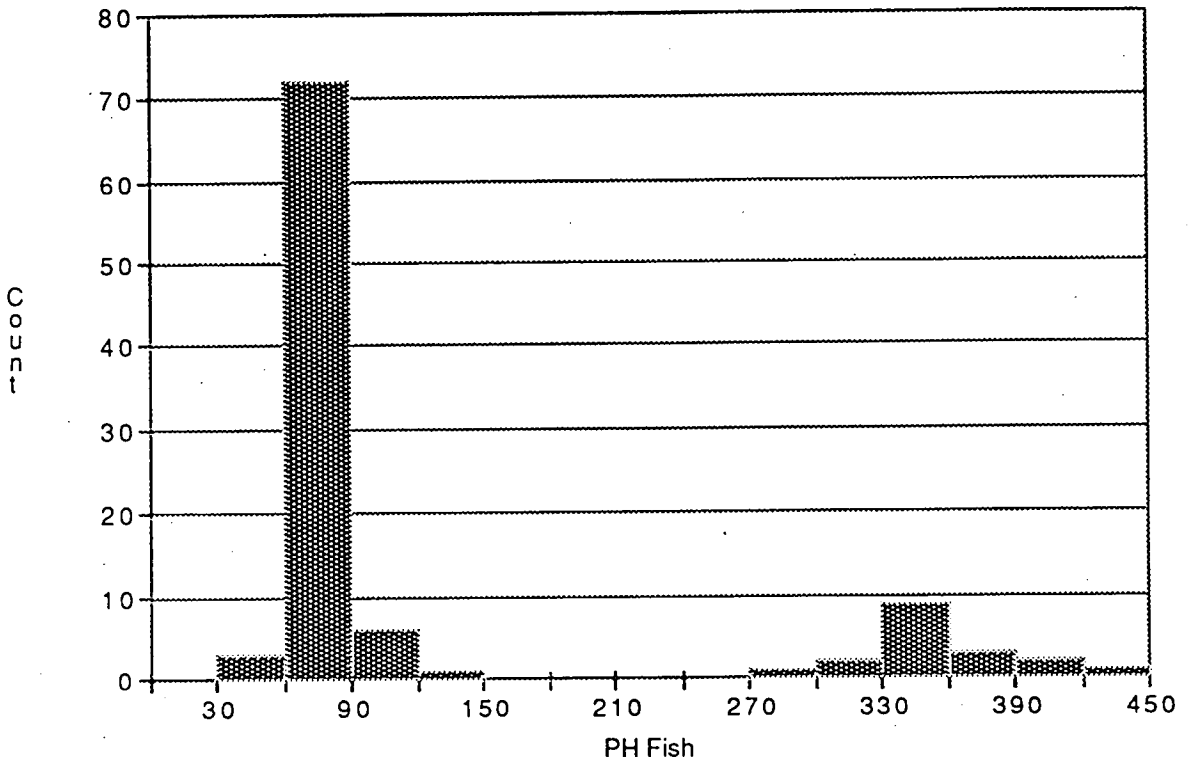
N/P Ratio 9/91 thru 9/93



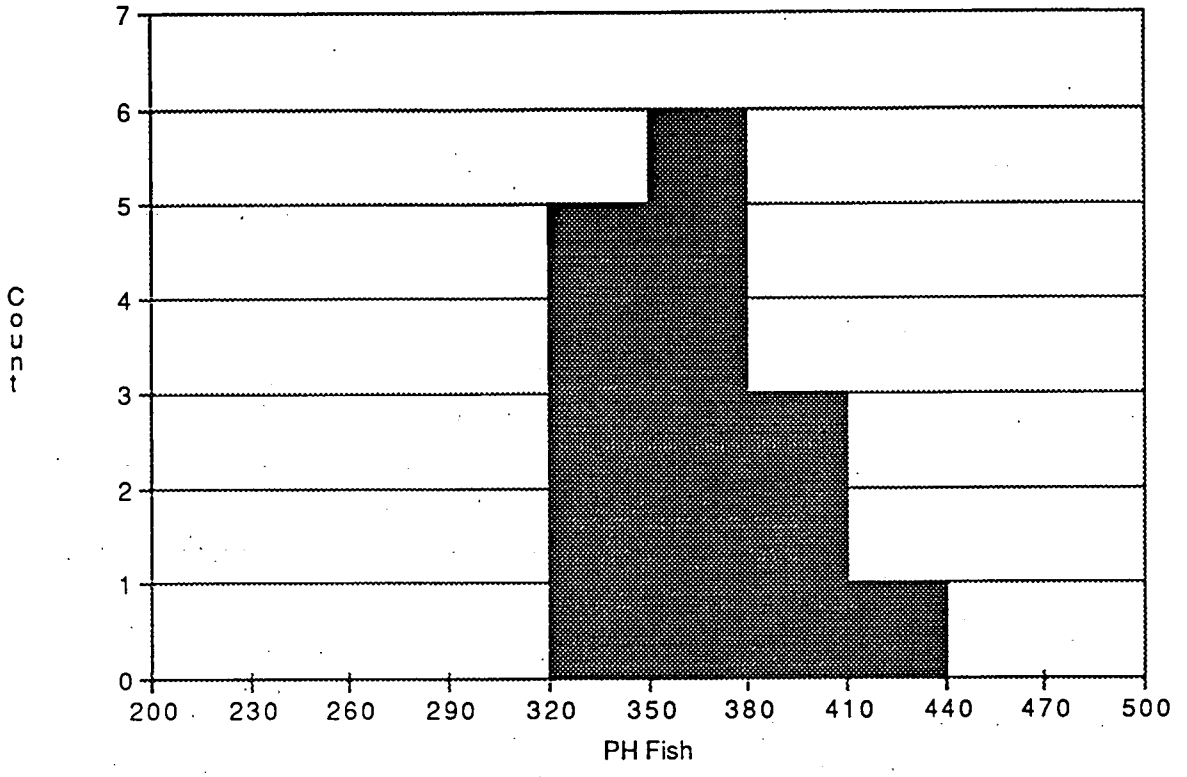


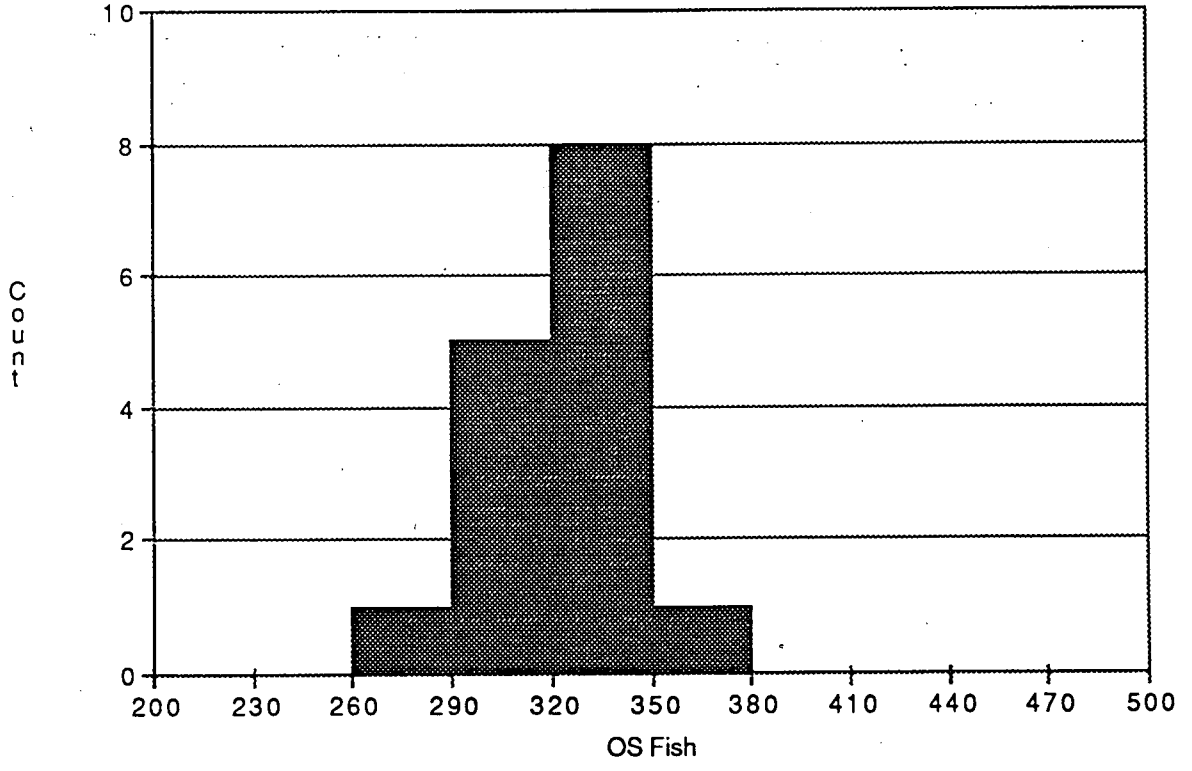
Location of Flounder sampling sites in Portsmouth Harbor, Fall 1992 and Spring 1993.
G=Gillnet, S= Purse seine, T= Otter trawl

Length Frequency Distribution of Flounders Captured by Seine and Trawl
all in Portsmouth Harbor Locations, Spring 1993

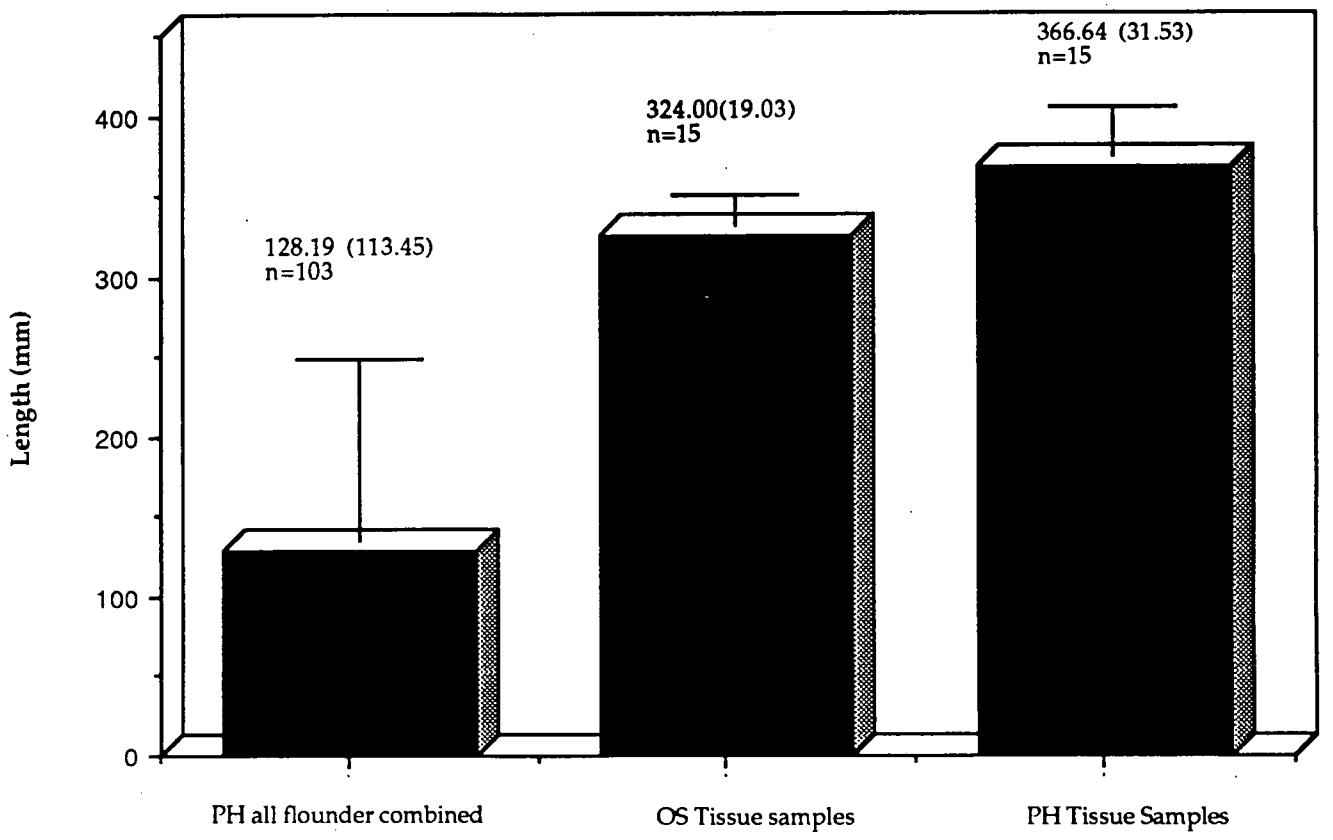


Length Frequency of Winter Flounders used in Tissue Contaminant Analyses

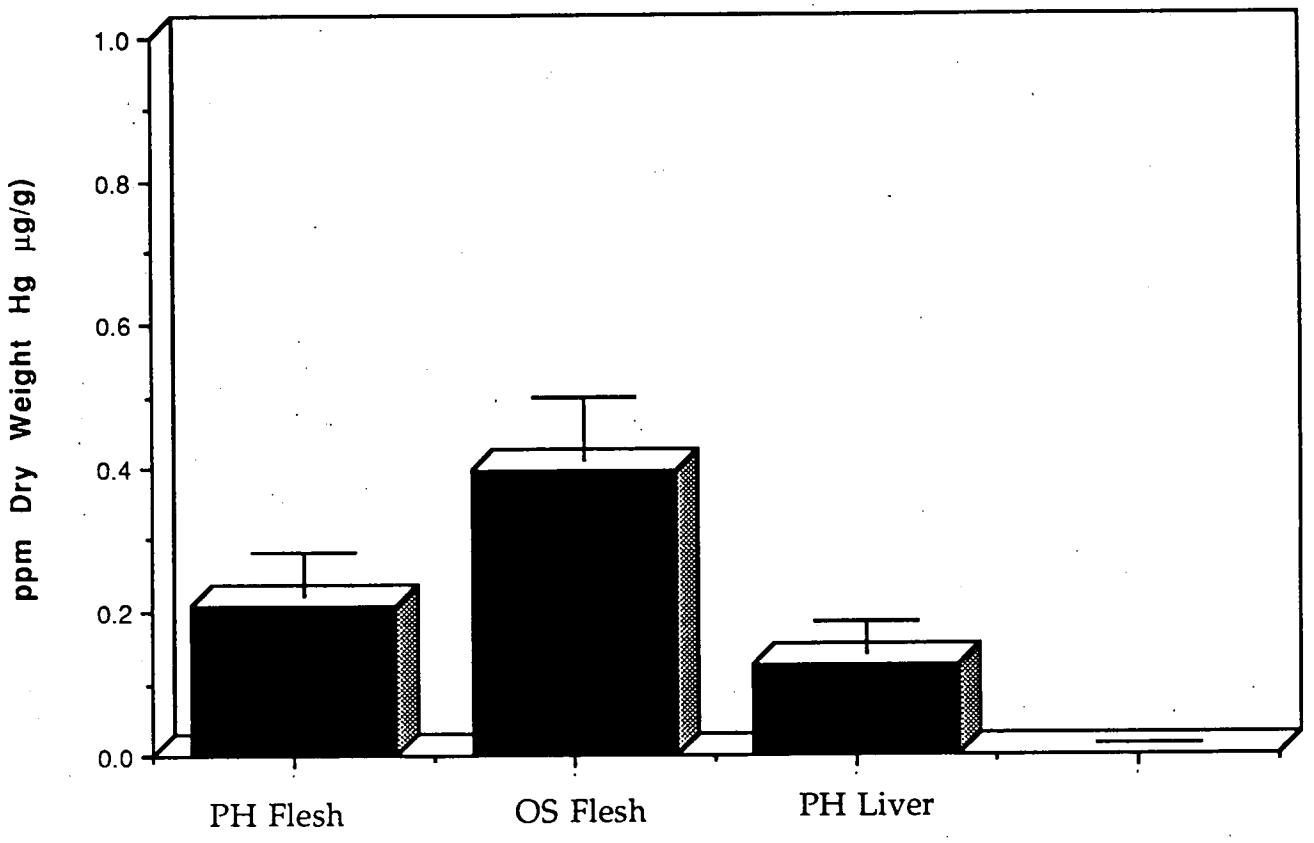


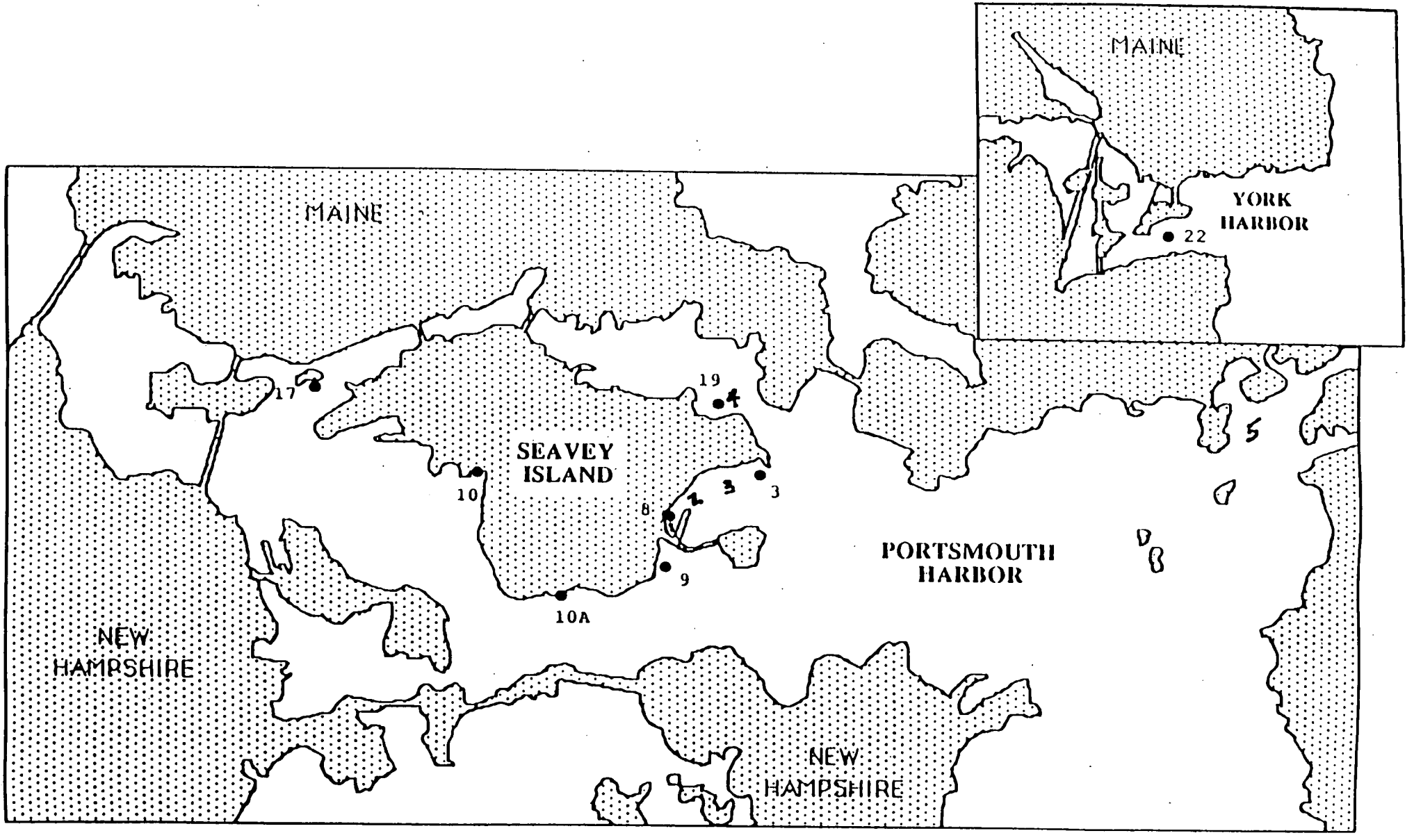


Mean Lengths of Winter Flounder for Tissue Contaminant Studies



Mercury in Composite Winter Flounder Tissues





Location of Mussel deployment sites in Portsmouth Harbor, October thru December 1993.

Concentration of Selected Trace Metals in Waters Surrounding Seavey Island, and a Survey of Dissolved Metal Levels in Seep Sites.

Doug Cullen

Graduate School of Oceanography
Center for Atmospheric Chemistry Studies
University of Rhode Island
Narragansett, RI

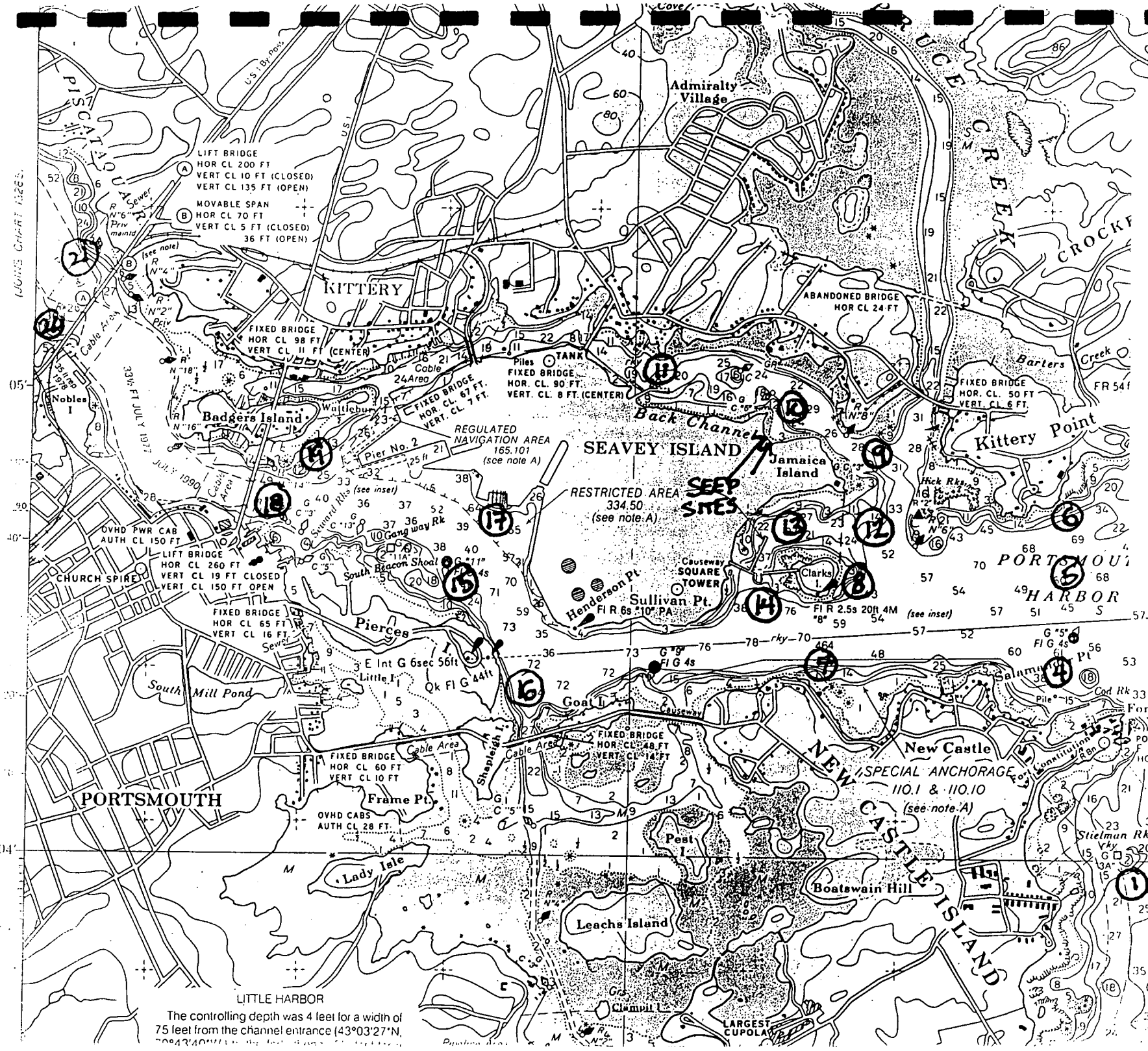
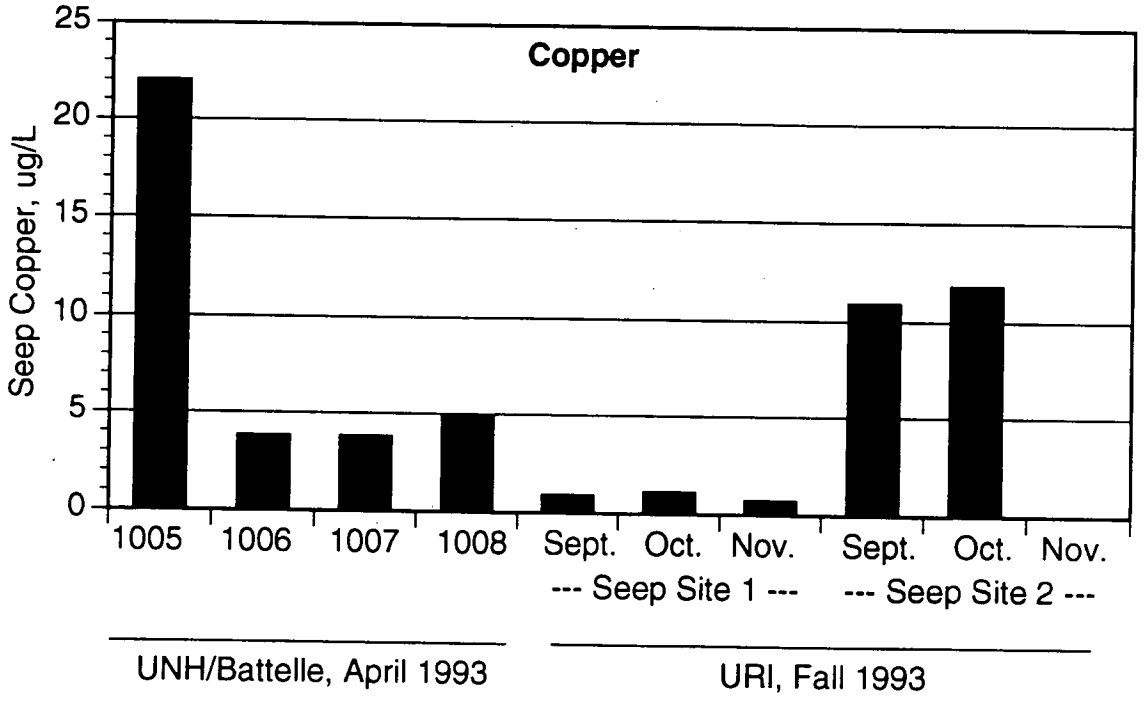
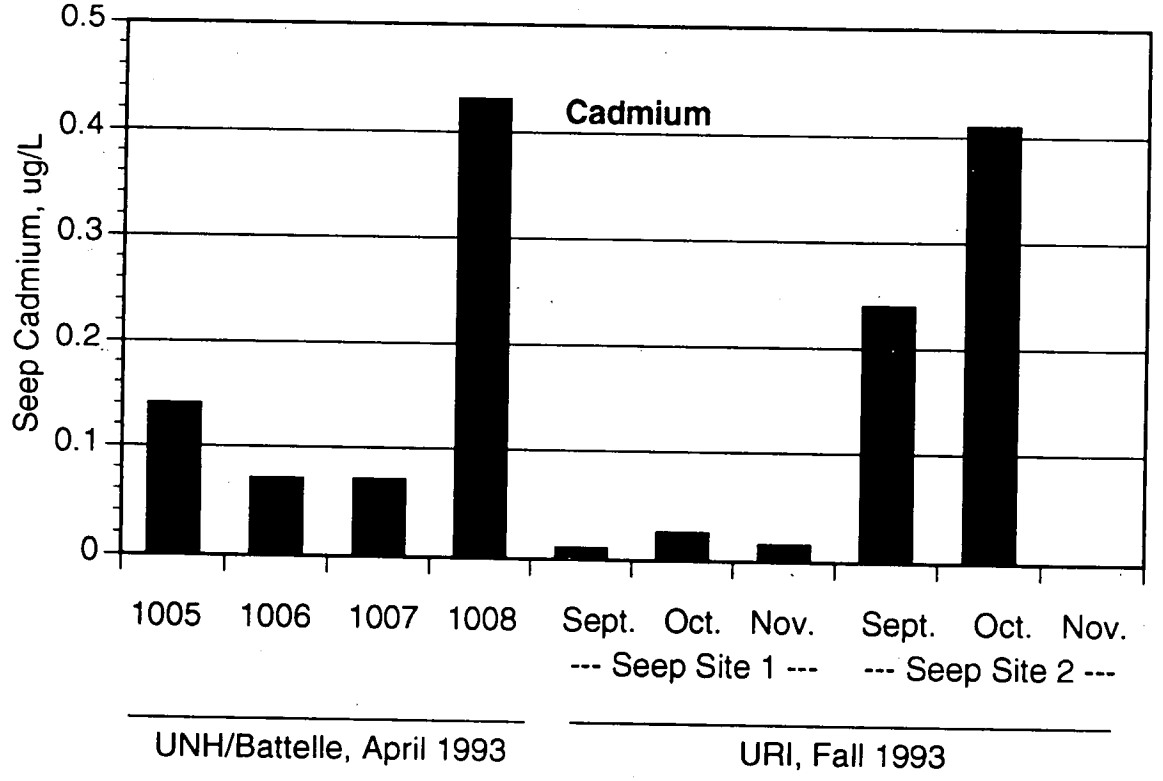


Figure 1. Water column collection sites occupied during the September 14, and 15, 1993, cruise of Portsmouth Harbor and the Piscataqua River. The general area of seep collections on Seavey Island are also indicated.

Back Channel Seep Sites

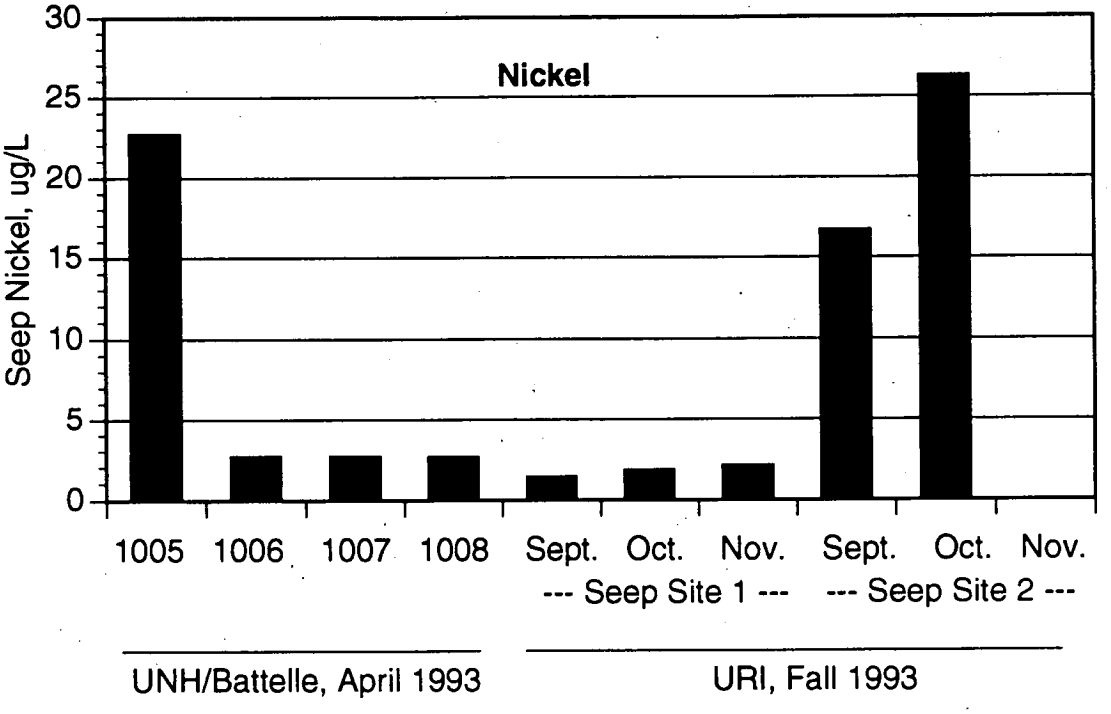
Comparison of UNH/Battelle Seep Site copper and cadmium concentrations collected in April, 1993 (Sites 1005,1006, 1007, 1008), with URI collections of Seep Sites 1 and 2 during the Fall of 1993.

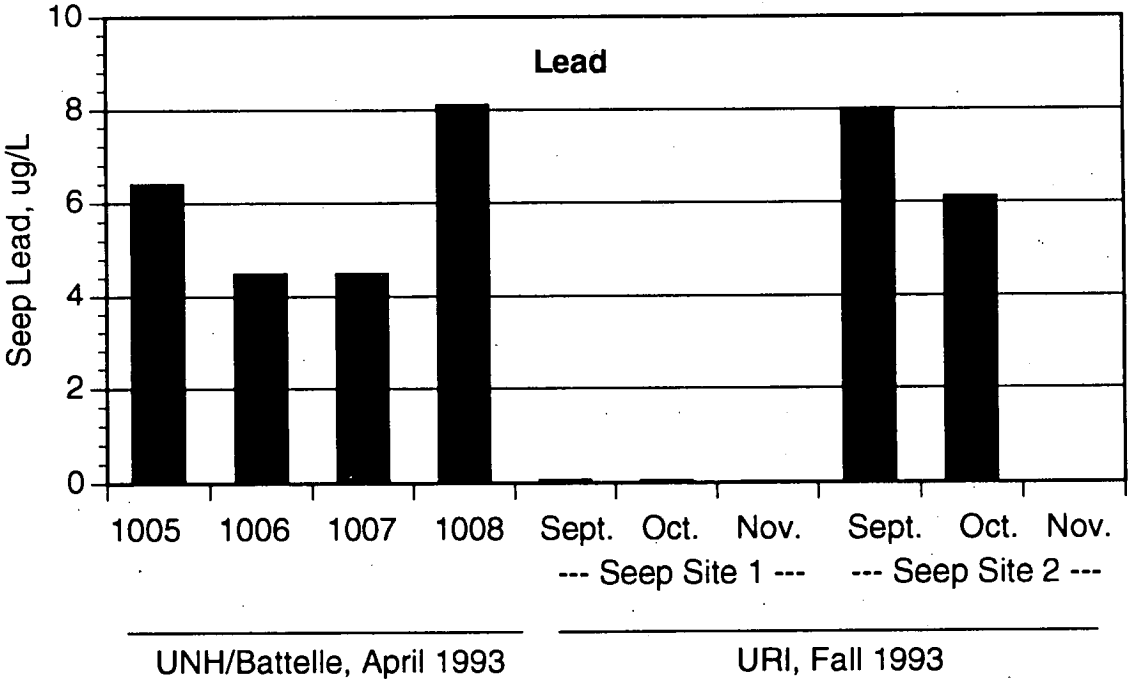




Back Channel Seep Sites

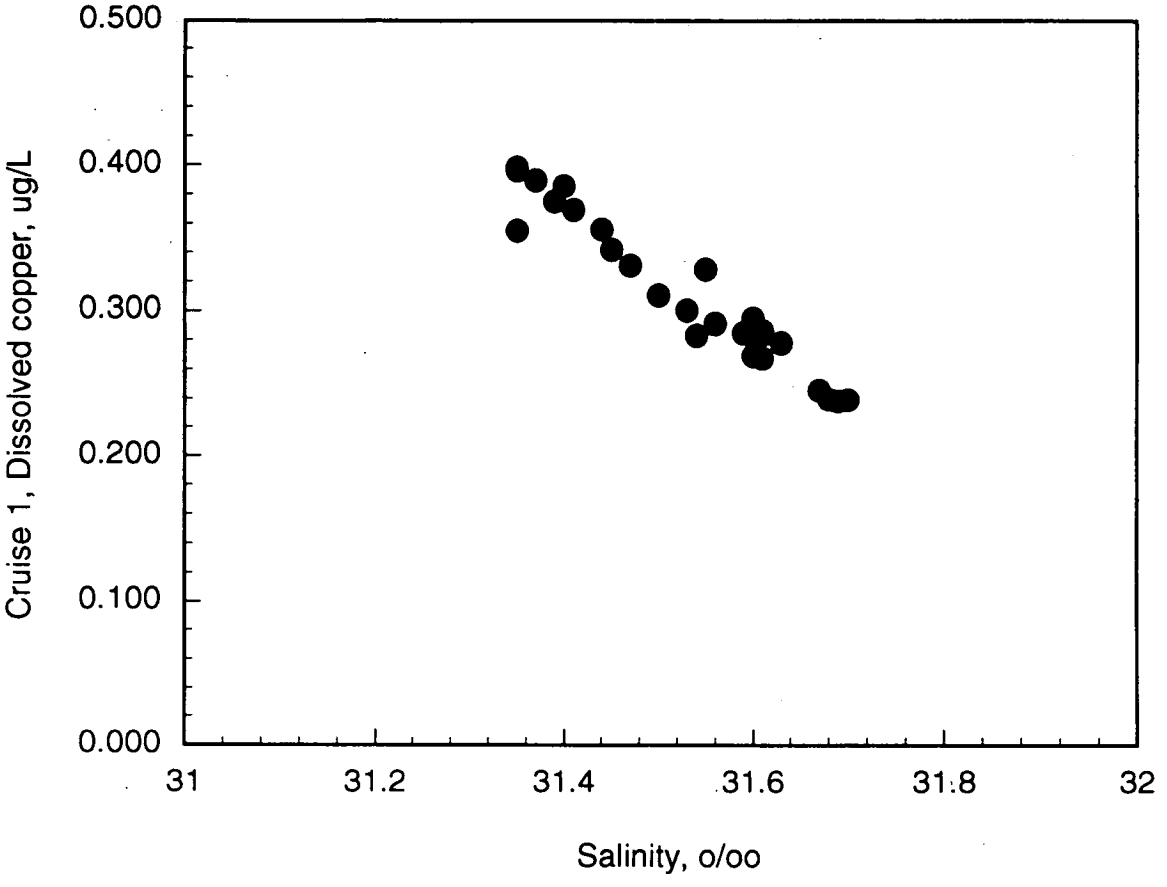
Comparison of UNH/Battelle Seep Site nickel and lead concentrations collected in April, 1993 (Sites 1005,1006, 1007, 1008), with URI collections of Seep Sites 1 and 2 during the Fall of 1993.





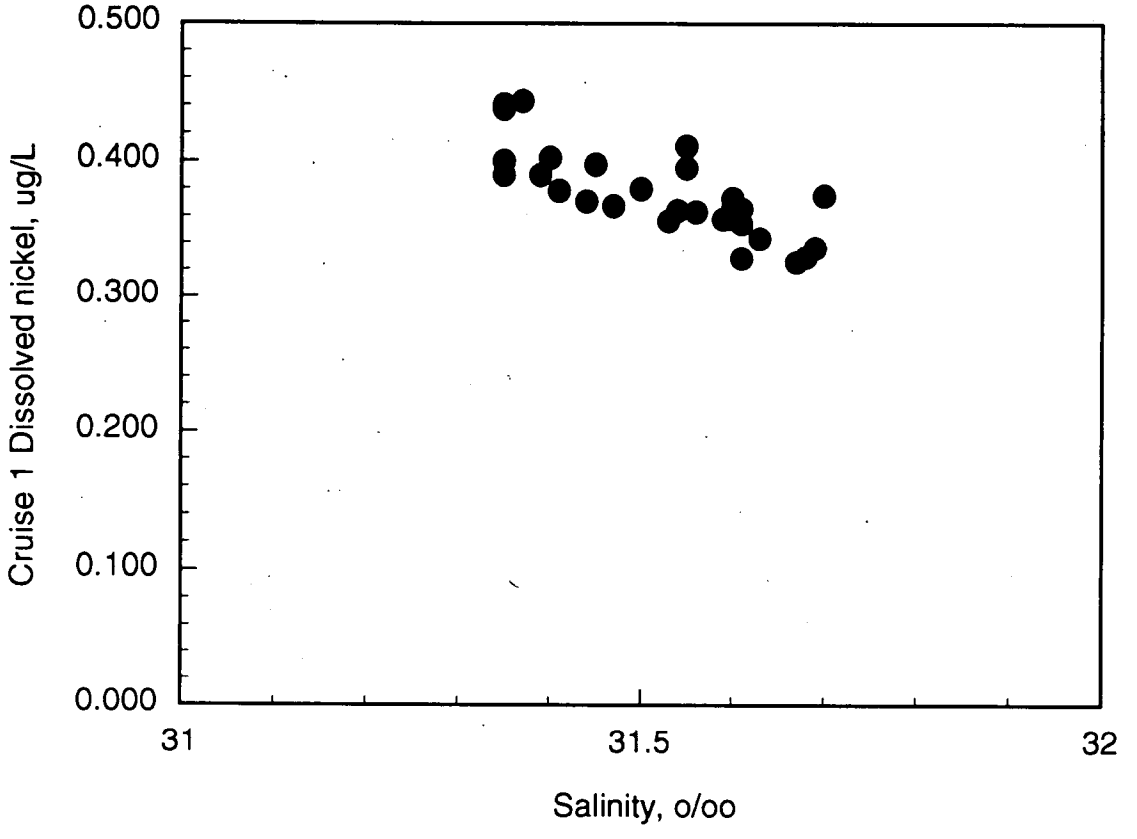
Cruise 1, Dissolved copper versus salinity

Dissolved copper concentrations (ug/L), for water column samples collected during the September 14, and 15, 1993, survey of the Lower Piscataqua River and Portsmouth Harbor.



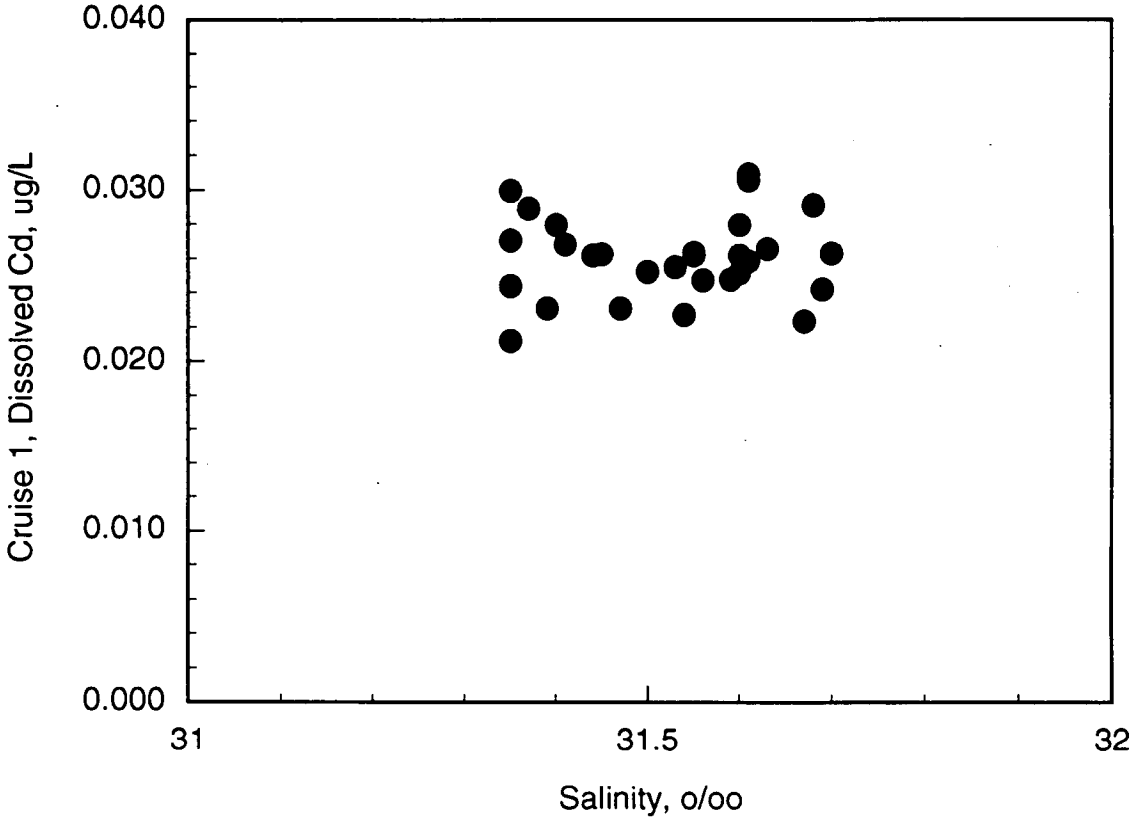
Cruise 1, Dissolved nickel versus salinity

Dissolved nickel concentrations (ug/L), for water column samples collected during the September 14 and 15, 1993, survey of the Lower Piscataqua River and Portsmouth Harbor.



Cruise 1, Dissolved cadmium versus salinity

Dissolved cadmium concentrations (ug/L), for water column samples collected during the September 14 and 15, 1993, survey of the Lower Piscataqua River and Portsmouth Harbor.



Preliminary Conclusions:

Seep Sites

1. Seep Site 2 concentrations were elevated in comparison to Seep Site 1.

2. The levels of metal observed in Back Channel Seeps were comparable for the surveys conducted by UNH and URI.

Water Column

1. Dissolved copper appeared to behave conservatively over the salinity range sampled during the September 1993 cruise.

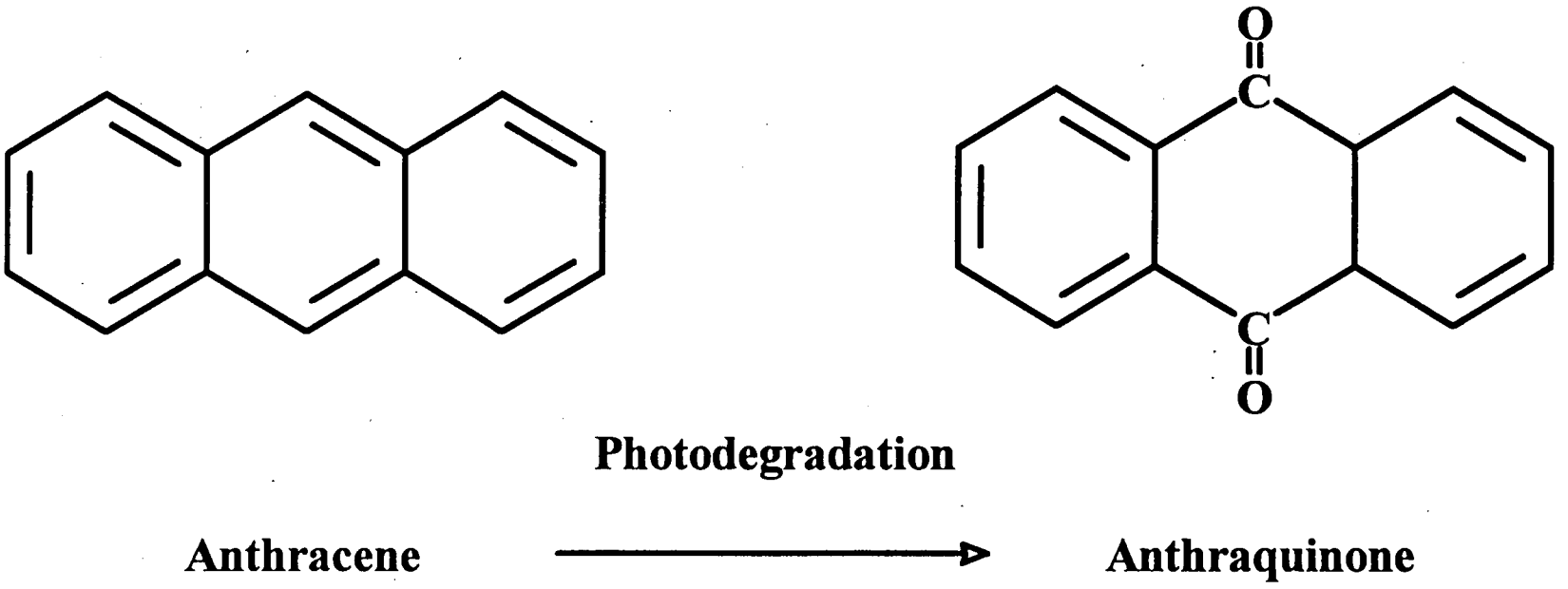
2. Dissolved nickel also appeared to behave conservatively, but further evaluation is needed.

3. Dissolved cadmium, did not demonstrate a clear relationship with salinity, and a closer examination is needed to evaluate the relationship.

CHEMICAL MARKERS OF POLLUTANT SOURCES TO THE LOWER PISCATAQUA RIVER ESTUARY

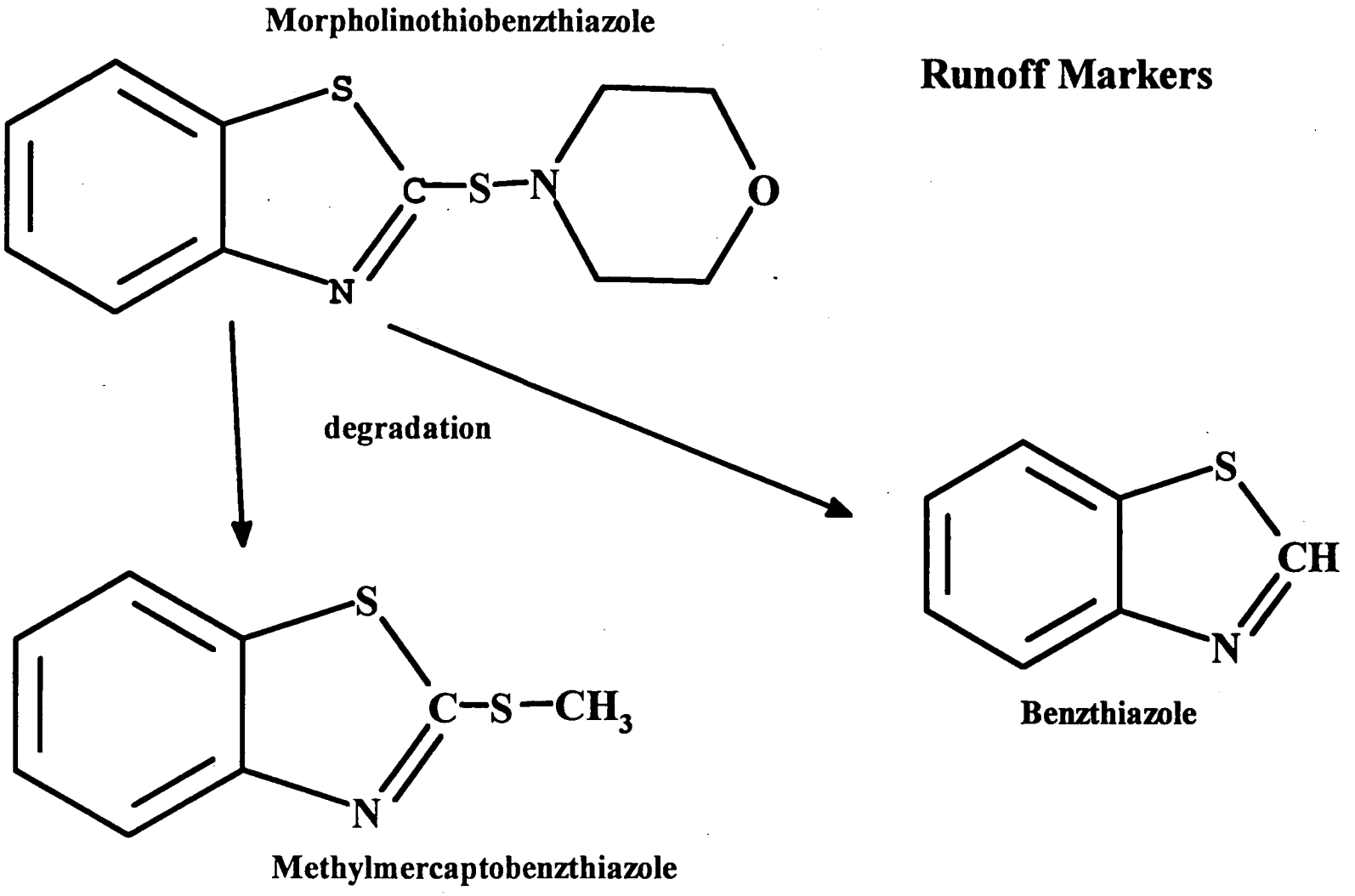
Robert D. Bowen
Science Applications International Corporation
and
Richard J. Pruell
U.S. Environmental Protection Agency
Environmental Research Laboratory, Narragansett, R.I.

Atmospheric Deposition Markers



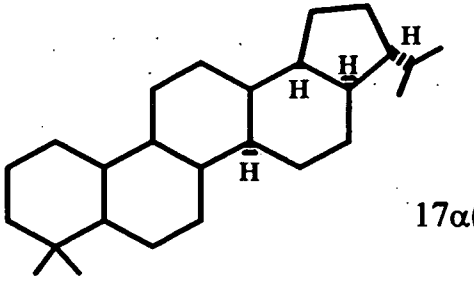
The mole ratio of the photochemical degradation product anthraquinone to the parent anthracene is used as a marker of atmospheric deposition.

Runoff Markers

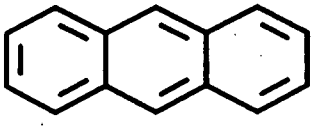


Morpholinothiobenzthiazole and other substituted benzthiazoles are used in the production of automobile tires. In the environment, they have been shown to degrade to the more stable compounds benzthiazole and methylmercaptobenzthiazole. These compounds are used as markers of urban runoff.

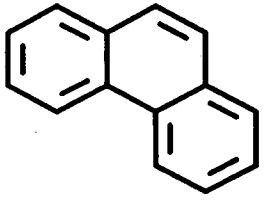
Petroleum Markers



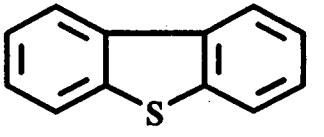
17α(H),21β(H) - Hopane



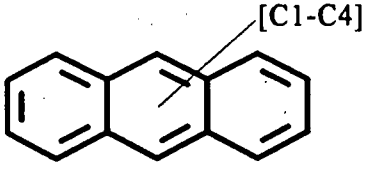
Anthracene

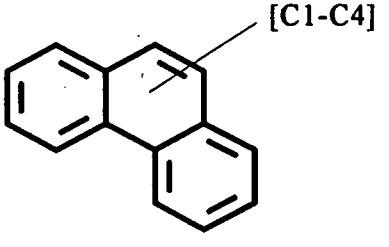


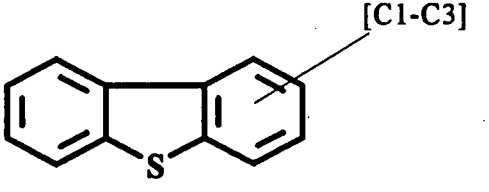
Phenanthrene



Dibenzothiophene





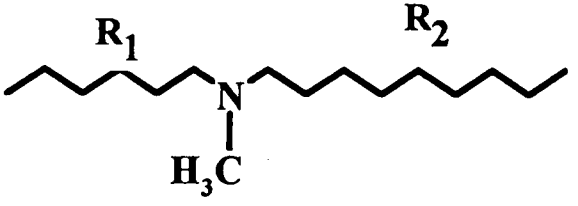


Alkyl Homologs of Phenanthrenes Anthracenes and Dibenzothiophenes

Hopane is used as a a general marker of petroleum inputs to the sediment. The ratios of the alkyl homologs of phenanthrene and anthracene to the parent compounds is high for a petrogenic source of hydrocarbons and low for a pyrogenic source. The ratio of the parent and alkyl homologs of dibenzothiophenes to the parent and alkyl homologs of phenanthrene and anthracene is used as a marker of different oils.

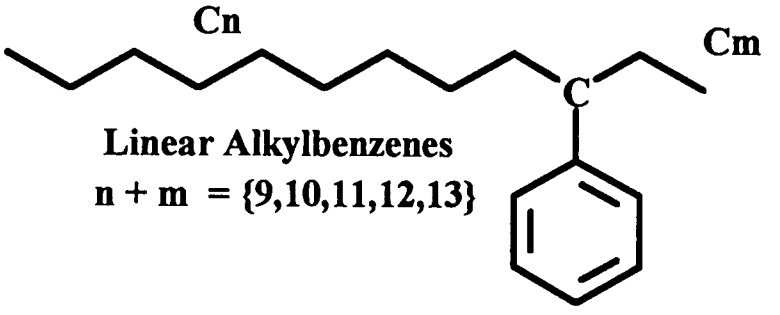
Sewage Markers

Trialkylamines



$R_1 = \{C_{16}H_{33}, C_{18}H_{37}\}$

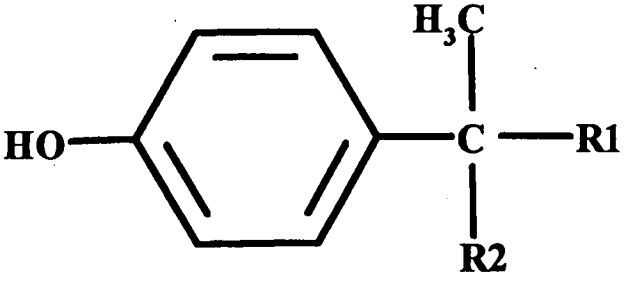
$R_2 = \{C_{16}H_{33}, C_{18}H_{37}\}$



Linear Alkylbenzenes

n + m = {9,10,11,12,13}

Nonylphenols

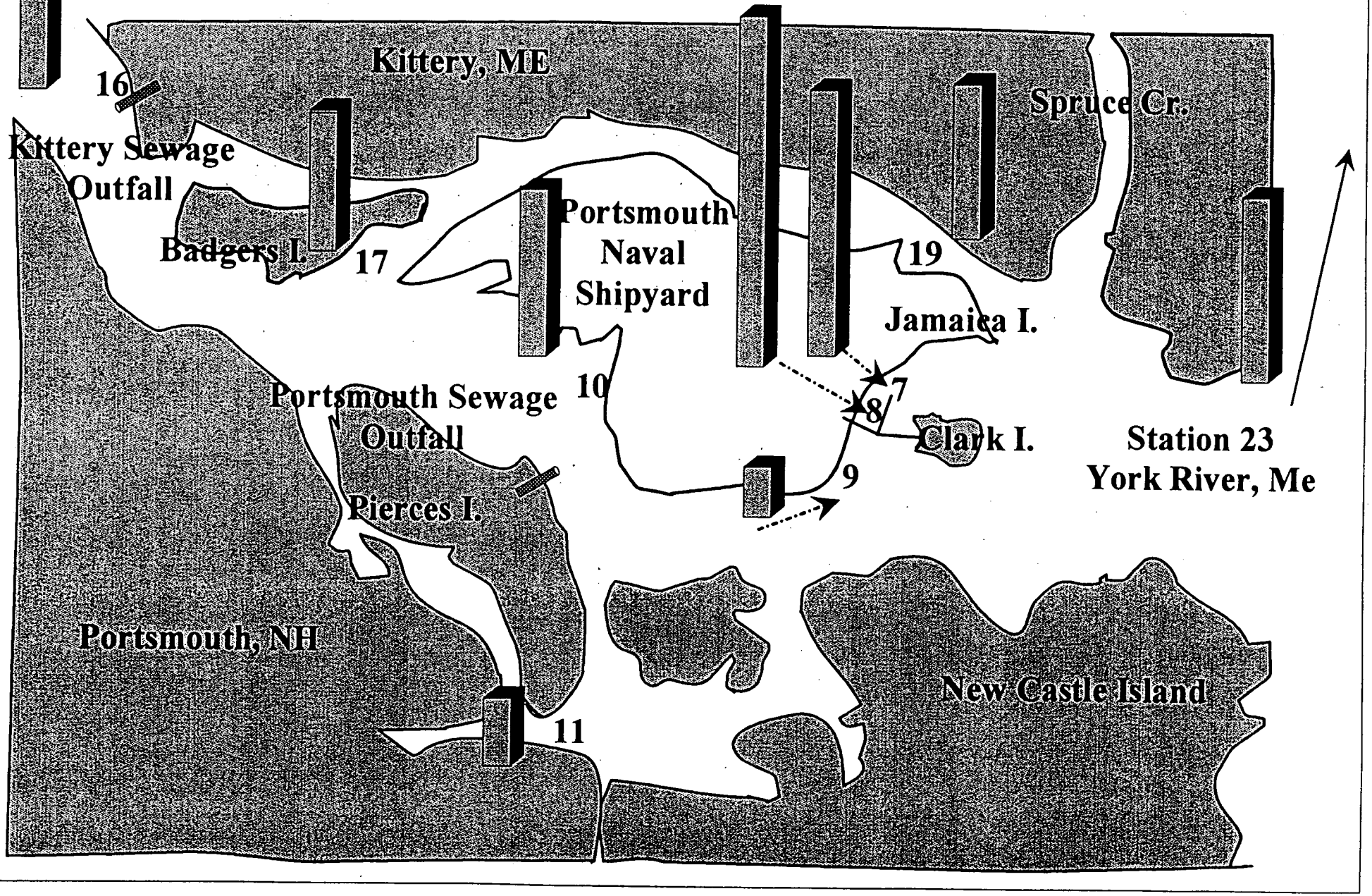


R1 = $\{C_5H_{11}, C_6H_{13}\}$

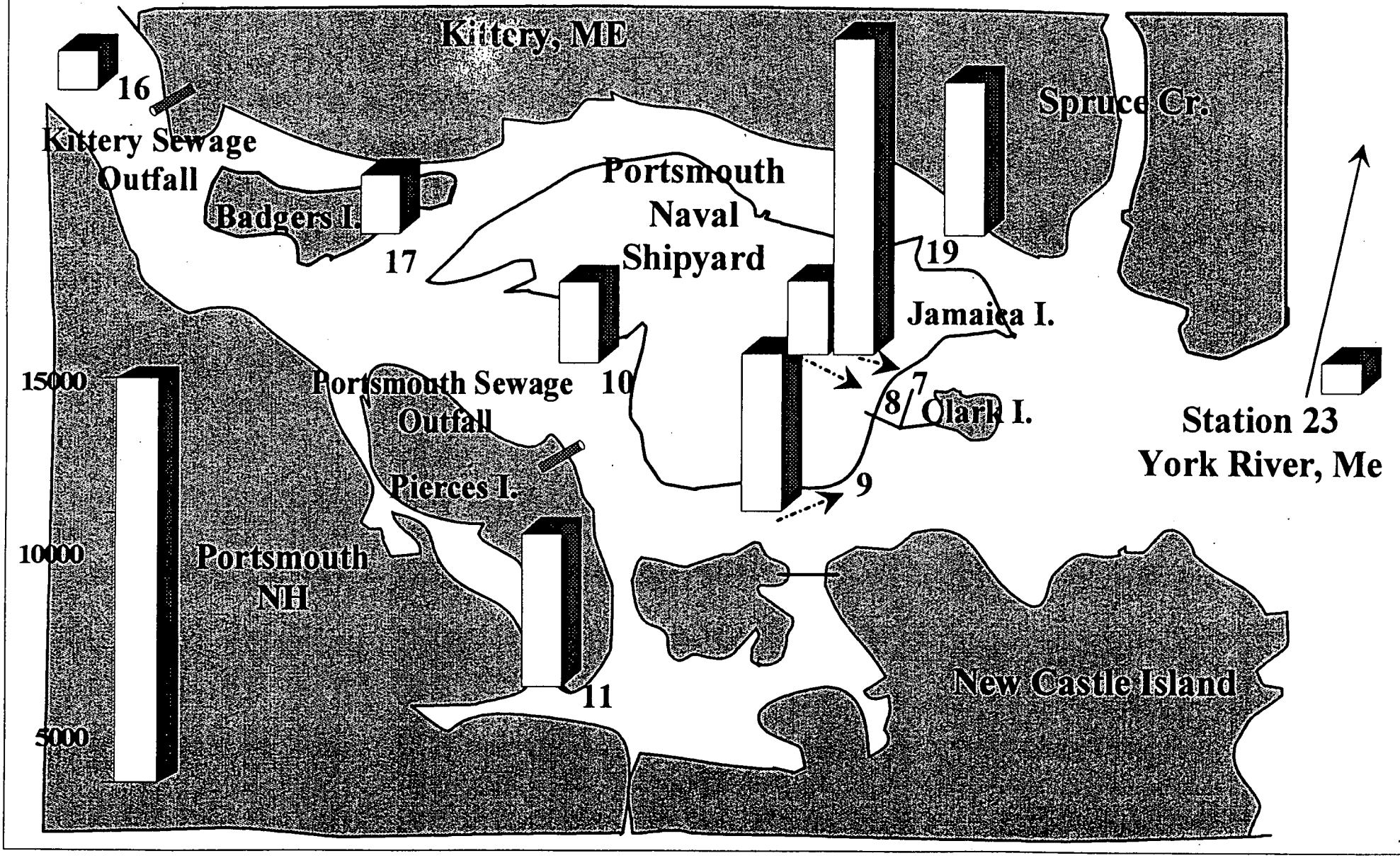
R2 = $\{CH_3, C_2H_5\}$

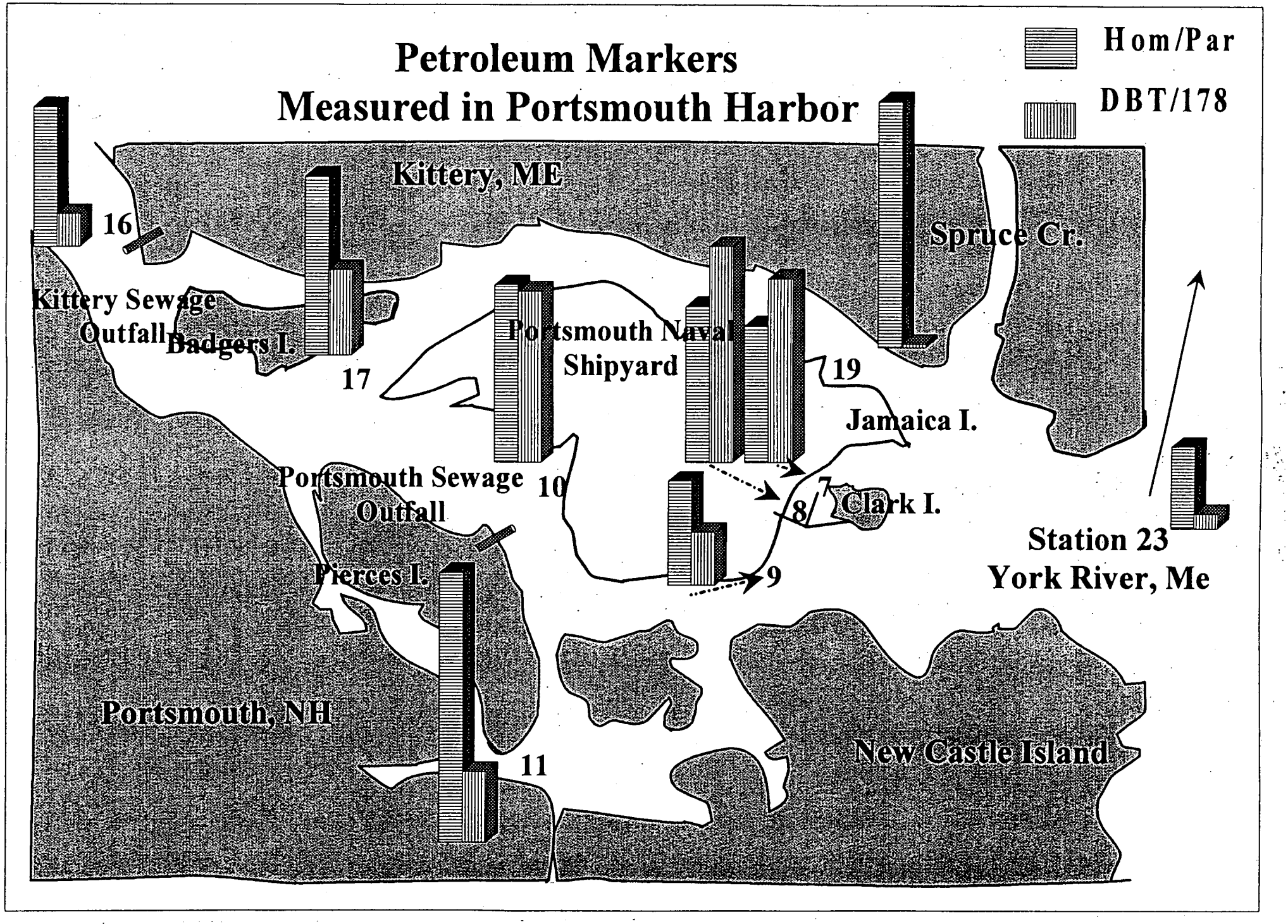
Linear Alkylbenzenes (LABs), trialkylamines such as the dioctadecyltrialkylamine, octyl and nonylphenols all enter the environment as recalcitrant byproducts of the production of surfactants used in detergents and fabric softeners. These compounds are used as markers of sewage material.

Markers of Atmospheric Deposition Measured in Portsmouth Harbor

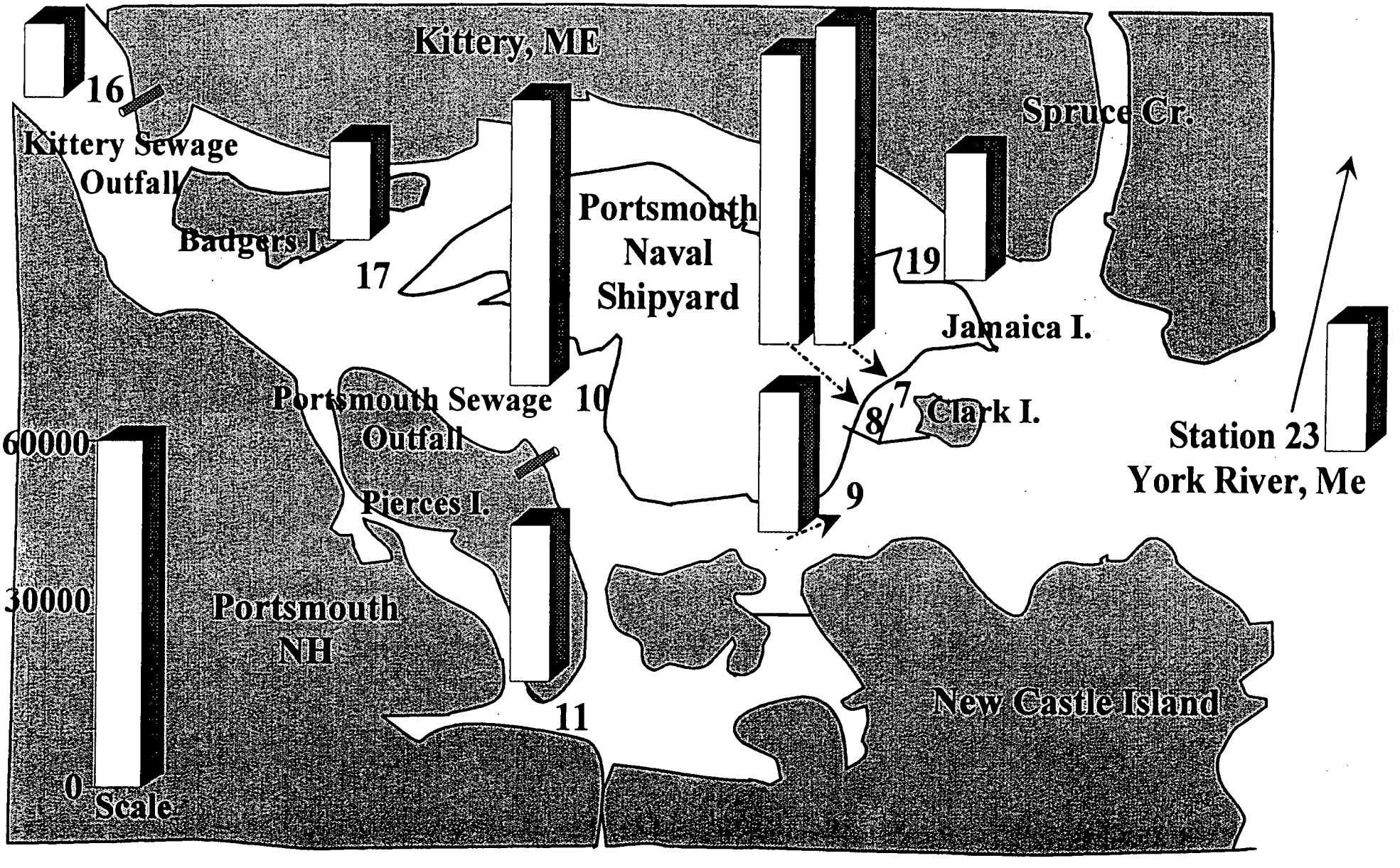


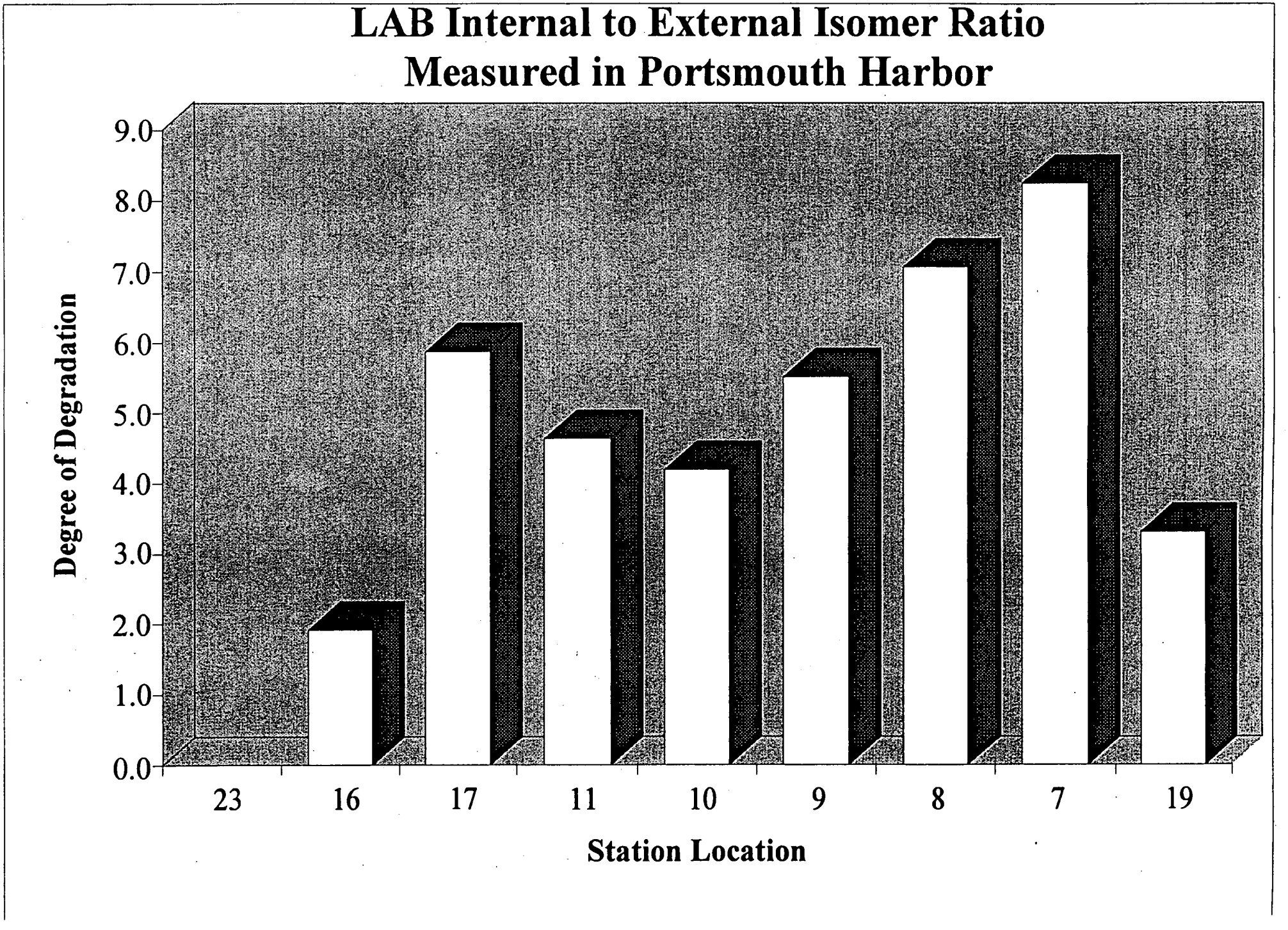
Concentration of Benzthiazole (ng/g carbon) Measured in Portsmouth Harbor




Petroleum Markers
Measured in Portsmouth Harbor
Hom/Par
DBT/178
Kittery, ME
16
Kittery Sewage
Outfall
Badgers I.
17
Portsmouth Naval
Shipyard
19
Spruce Cr.
Jamaica I.
Portsmouth Sewage
Outfall
10
8/7
Clark I.
Station 23
York River, Me
Pierces I.
9
Portsmouth, NH
11
New Castle Island

Concentration of LABs (ng/g carbon) Measured in Portsmouth Harbor




LAB Internal to External Isomer Ratio
Measured in Portsmouth Harbor
Degree of Degradation
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
23
16
17
11
10
9
8
7
19
Station Location

Source Materials Collected and Analyzed for Chemical Markers

Sewage Material

Three samples of sewage sludge from Kittery STP
Three samples of sewage sludge from Portsmouth STP

Atmospheric Material

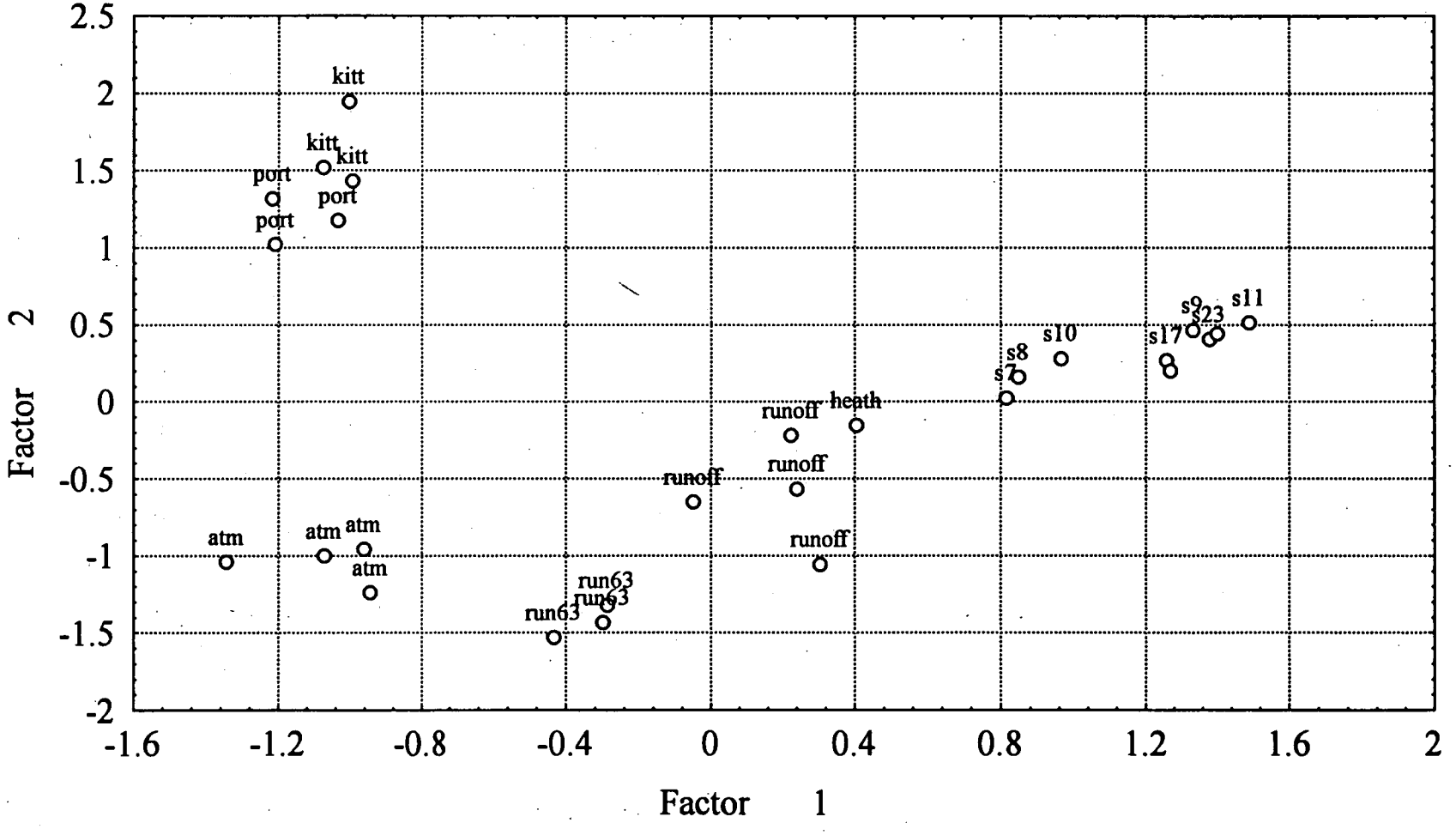
Fiberglass filter collected from HiVol sampling apparatus operated by the state of NH at the Portsmouth Fire Station.
One sample collected for 24 hours every 6 days during August 1993 for a total of 5 samples

Runoff Material

Sediment was collected from each of three cachement basins in Portsmouth NH on or entering Market St.

Samples were analyzed as collected and a portion of the sediment was size fractionated into the <63μm size class and this fraction was analyzed separately

Factor Scores from Log Transformed Data
PNSY Source Materials and Samples



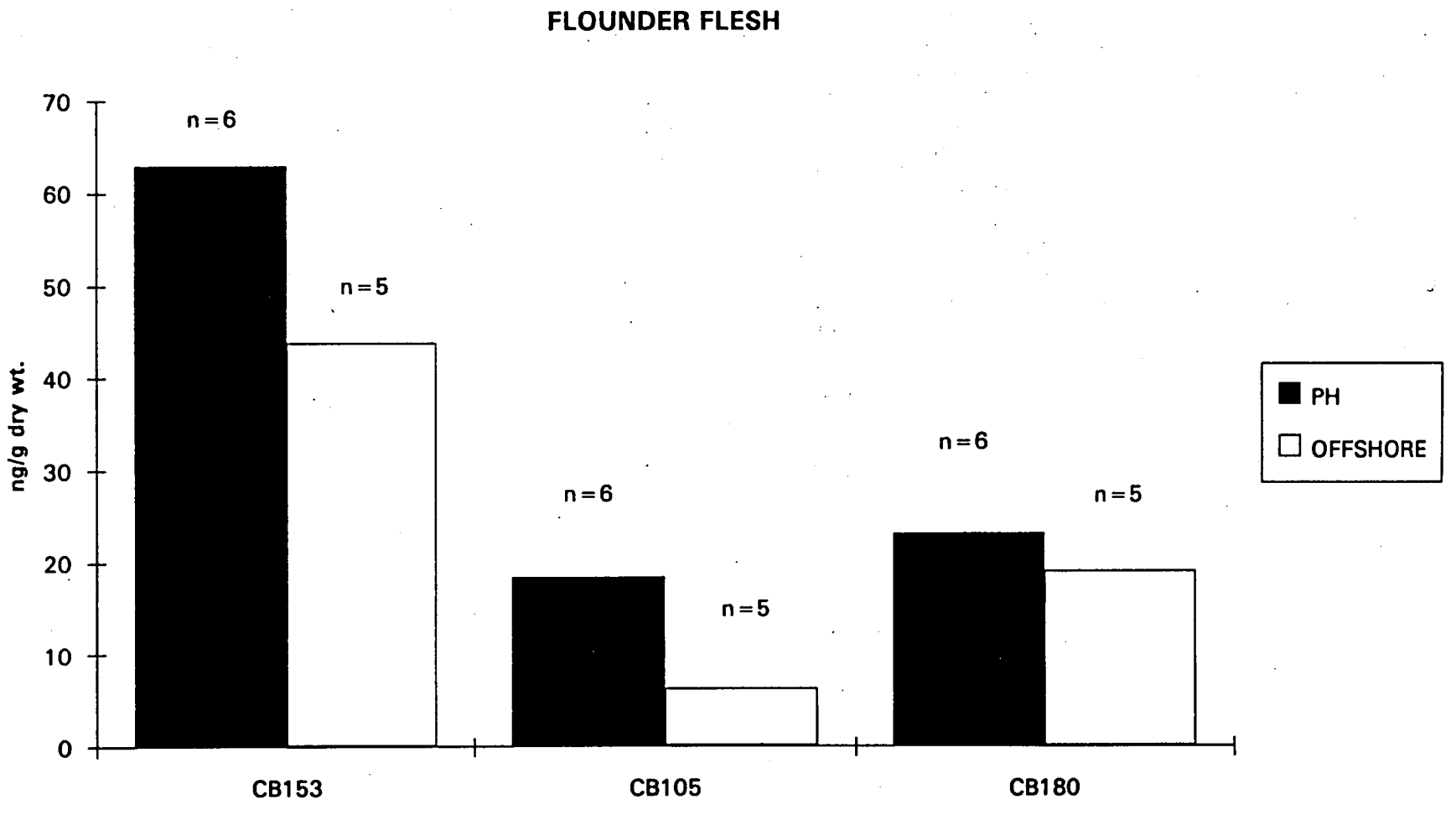
Future Directions

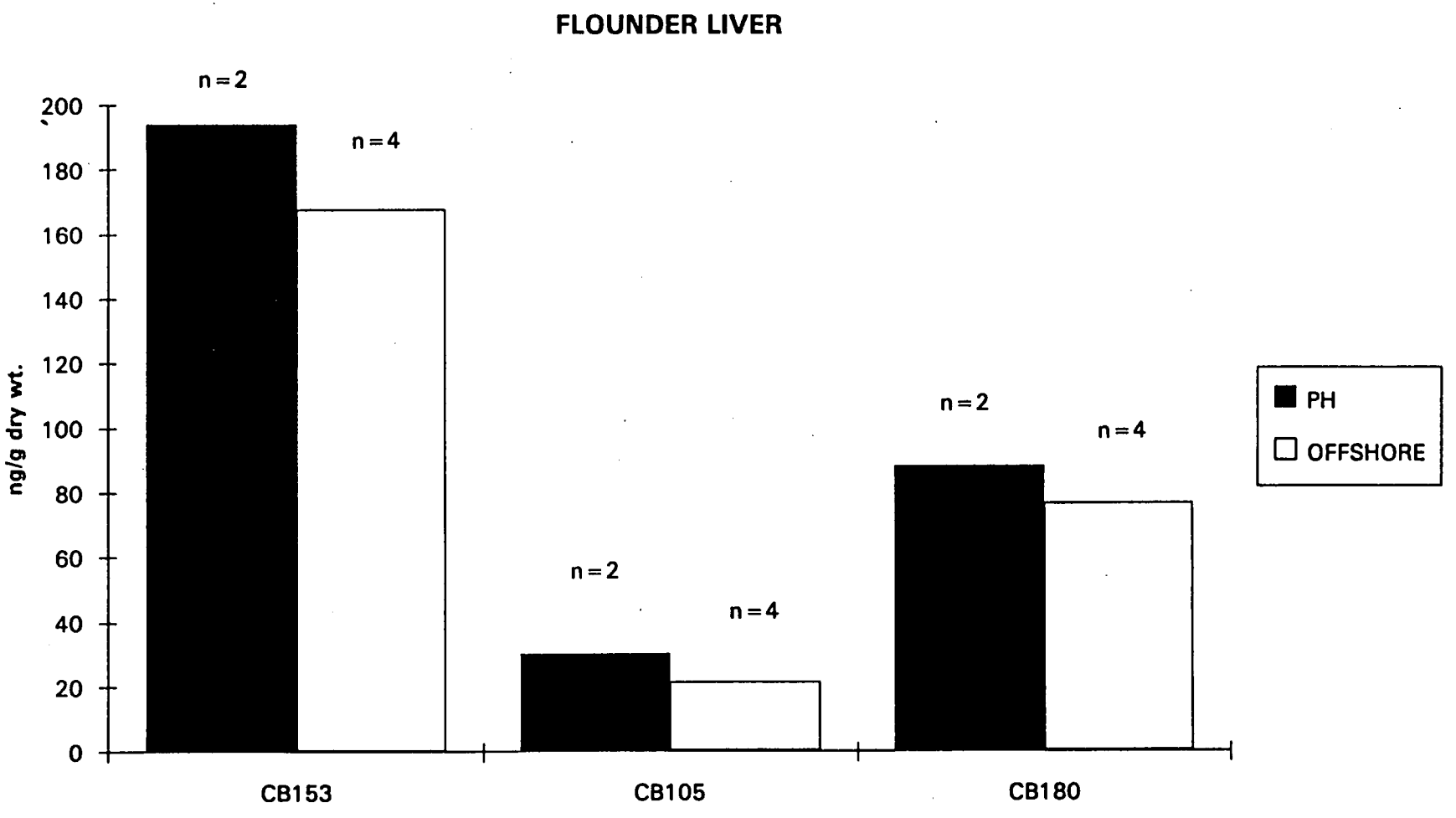
Sediment samples from deep cores collected in the Lower Piscataqua River Estuary will be analyzed for the suite of Chemical Markers used in Phase I of this study.

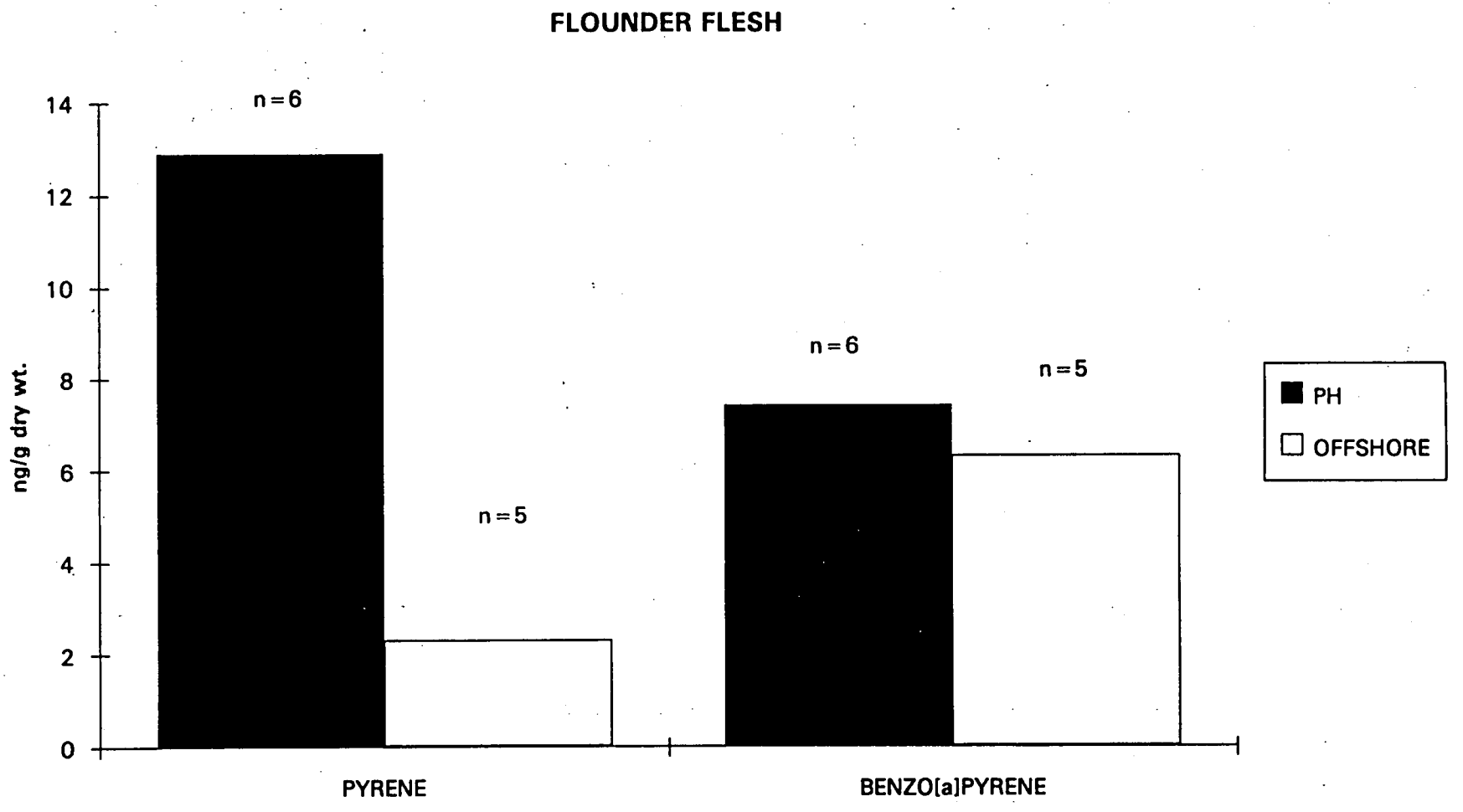
Additional analyses will be done on the surface sediments surrounding the Shipyard using Negative Ion Chemical Ionization GC/MS. This method will add to the suite of compounds detectable in the sediments and may provide a Shipyard specific chemical marker.

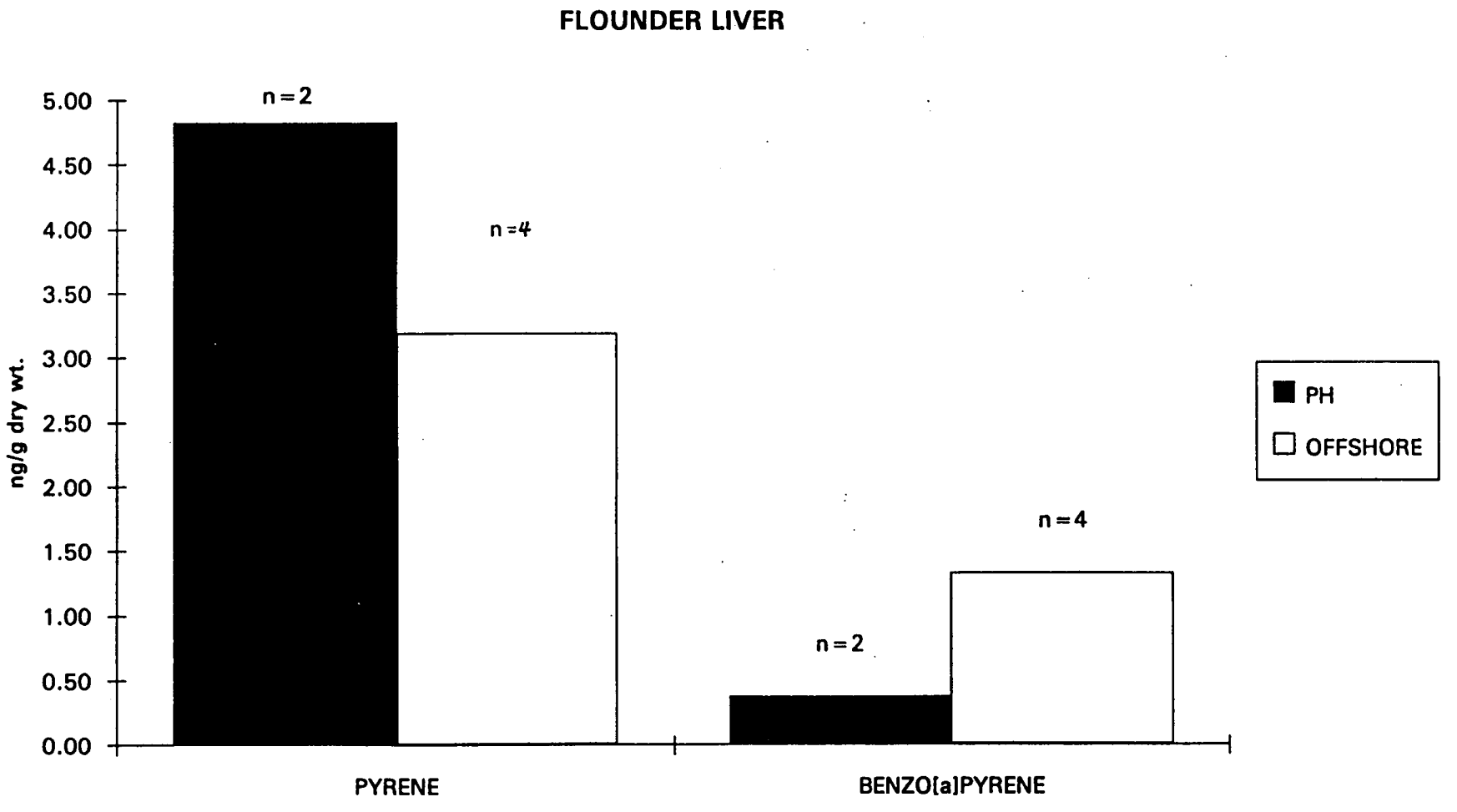
Additional efforts will be made addressing the statistical treatment of the existing data set. The goal will be to assign a quantitative estimate of source loadings to the stations sampled in the estuary.

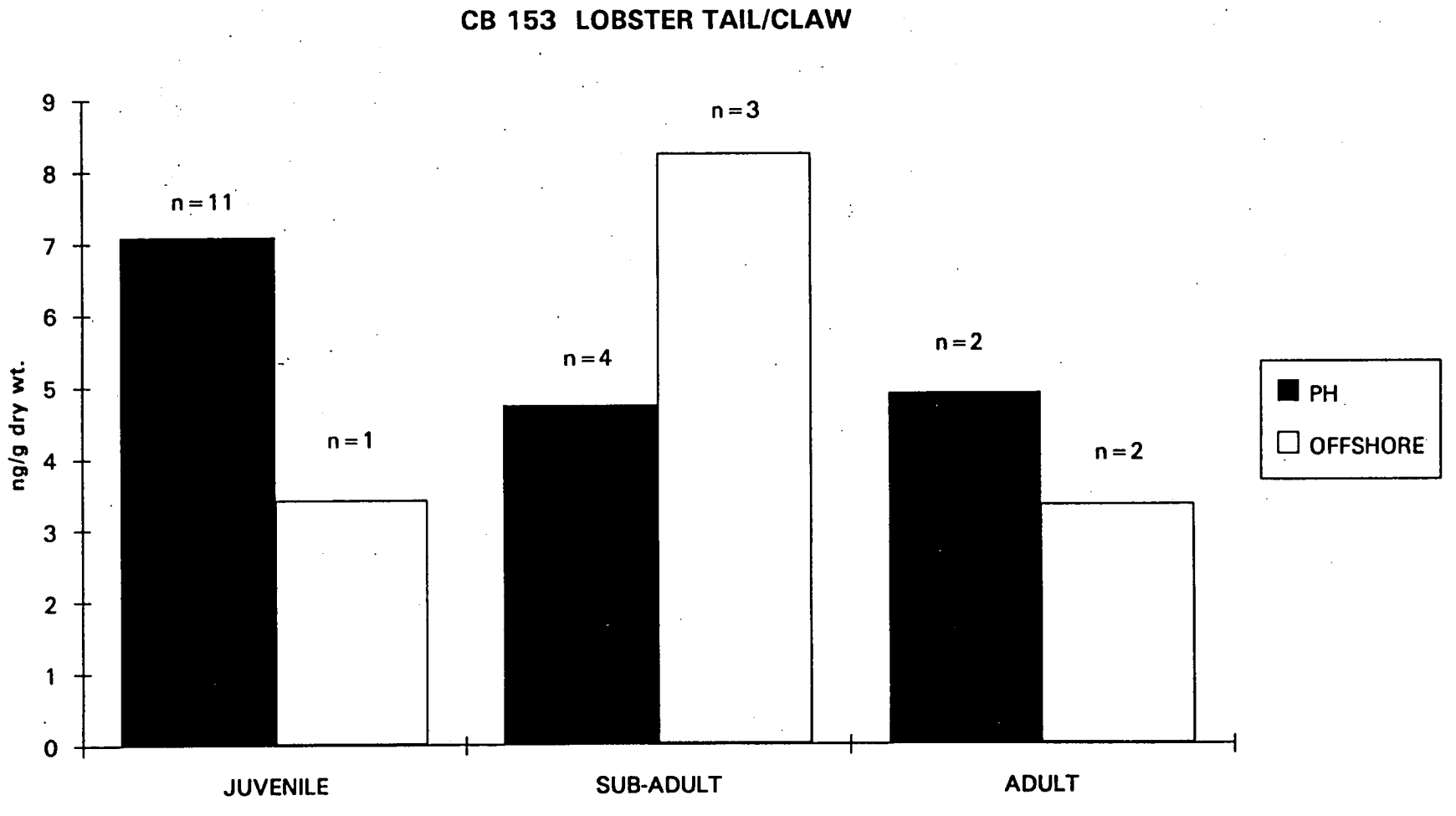
Rich Pruell, ERLN

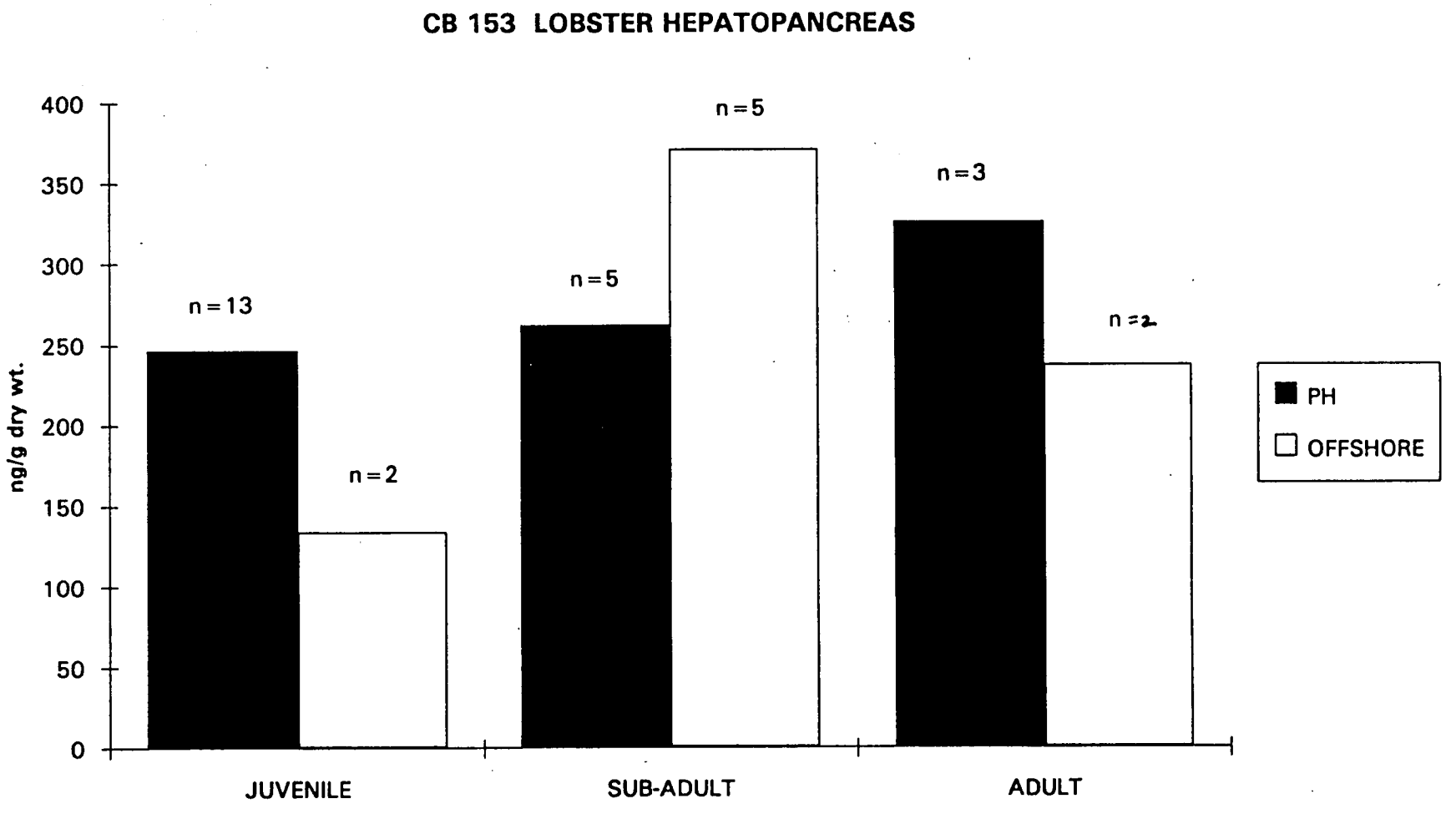


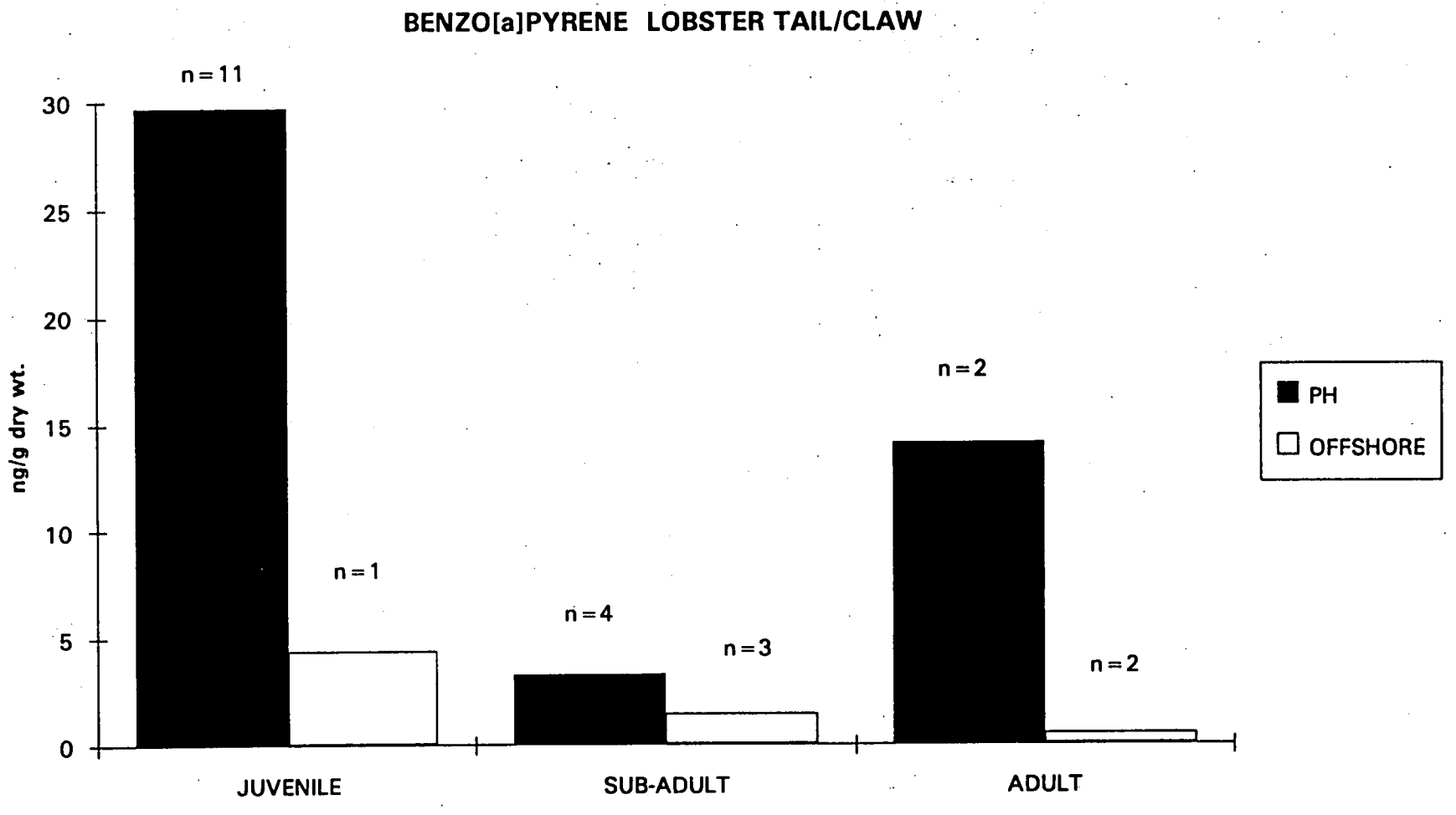

FLOUNDER LIVER
ng/g dry wt.
200
180
160
140
120
100
80
60
40
20
0
n=2
n=4
n=2
n=4
n=2
n=4
CB153
CB105
CB180
PH
OFFSHORE

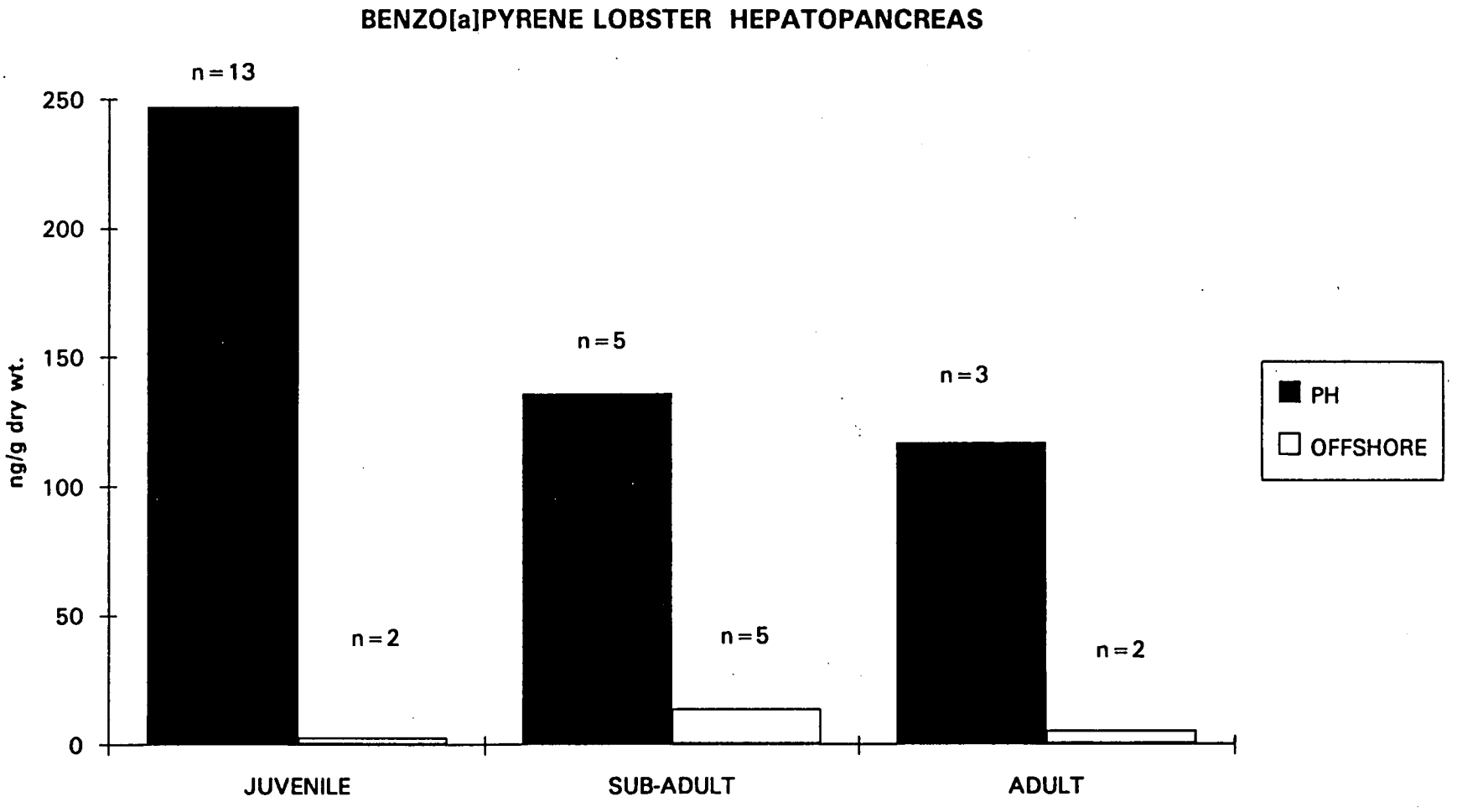

FLOUNDER FLESH
ng/g dry wt.
14
12
10
8
6
4
2
0
n=6
n=5
n=6
n=5
PYRENE
BENZO[a]PYRENE
PH
OFFSHORE


FLOUNDER LIVER
ng/g dry wt.
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
n = 2
n = 4
n = 2
n = 4
PYRENE
BENZO[a]PYRENE
PH
OFFSHORE


CB 153 LOBSTER TAIL/CLAW
ng/g dry wt.
0
1
2
3
4
5
6
7
8
9
n=11
n=1
n=4
n=3
n=2
n=2
JUVENILE
SUB-ADULT
ADULT
PH
OFFSHORE


CB 153 LOBSTER HEPATOPANCREAS
ng/g dry wt.
400
350
300
250
200
150
100
50
0
n = 13
n = 2
n = 5
n = 5
n = 3
n = 2
JUVENILE
SUB-ADULT
ADULT
PH
OFFSHORE


BENZO[a]PYRENE LOBSTER TAIL/CLAW
ng/g dry wt.
30
25
20
15
10
5
0
n=11
n=1
n=4
n=3
n=2
n=2
JUVENILE
SUB-ADULT
ADULT
PH
OFFSHORE


BENZO[a]PYRENE LOBSTER HEPATOPANCREAS
ng/g dry wt.
250
200
150
100
50
0
n=13
n=2
n=5
n=5
n=3
n=2
JUVENILE
SUB-ADULT
ADULT
PH
OFFSHORE

	Stations
Sediment	1-23
Water column (synoptic)	1-23
Water column (monthly)	1, 8, 10, 15, 16, 23
Mussel	1-23, 10A
Lobster and flounder trawls	T1-T9
E lgrass	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 14, 15, 16, 17, 18, 19, 22, 23, 12A
Rockweed	3, 8, 9, 10, 17, 19, 22, 10A
Benthic community	1-23
Mussel and eelgrass (quarterly)	1, 3, 9, 15, 16, 17, 18, 19, 23, 12A
Mussel deployment	2, 8, 10, 15, 19, 22
Current meter deployment	●

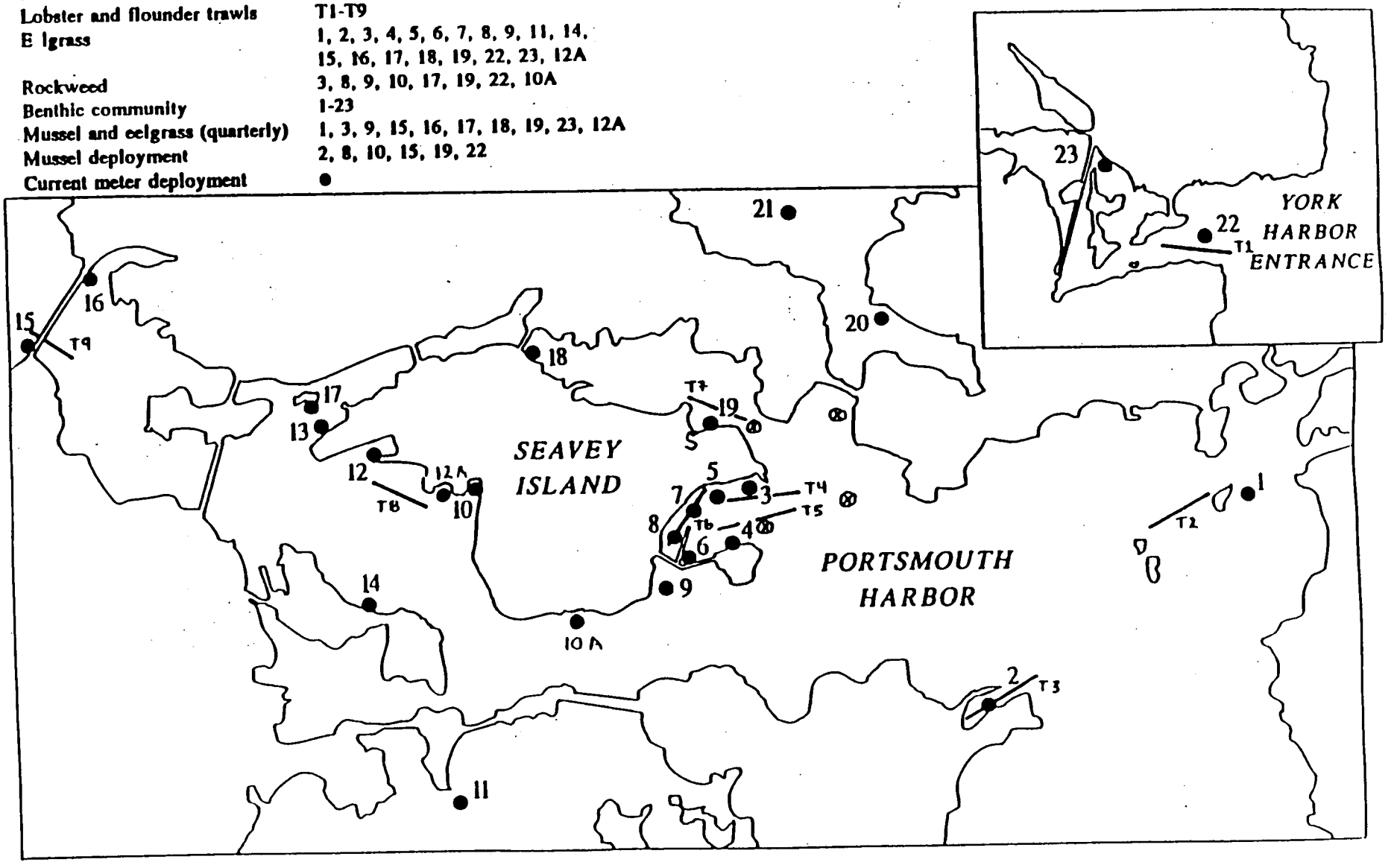
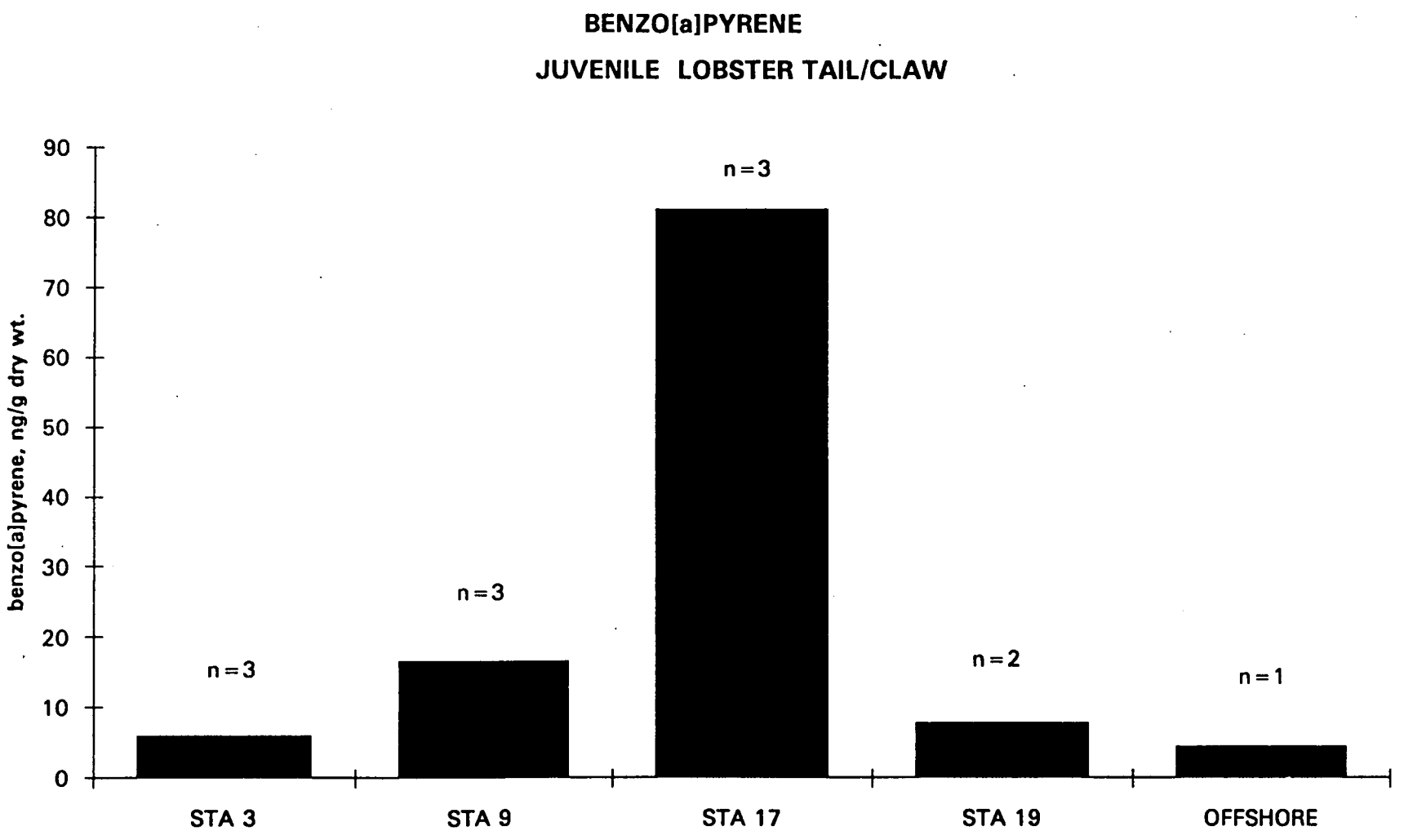
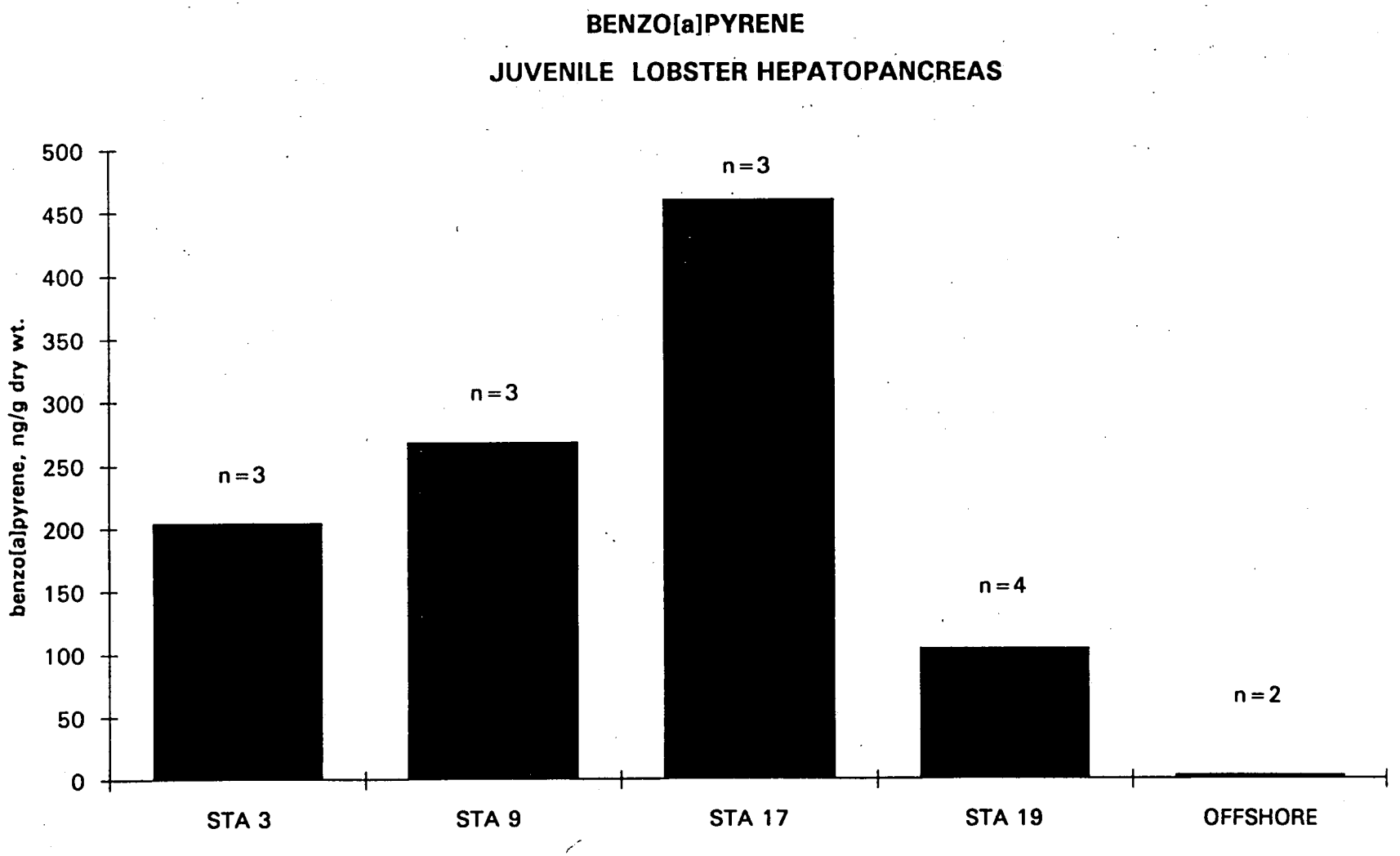
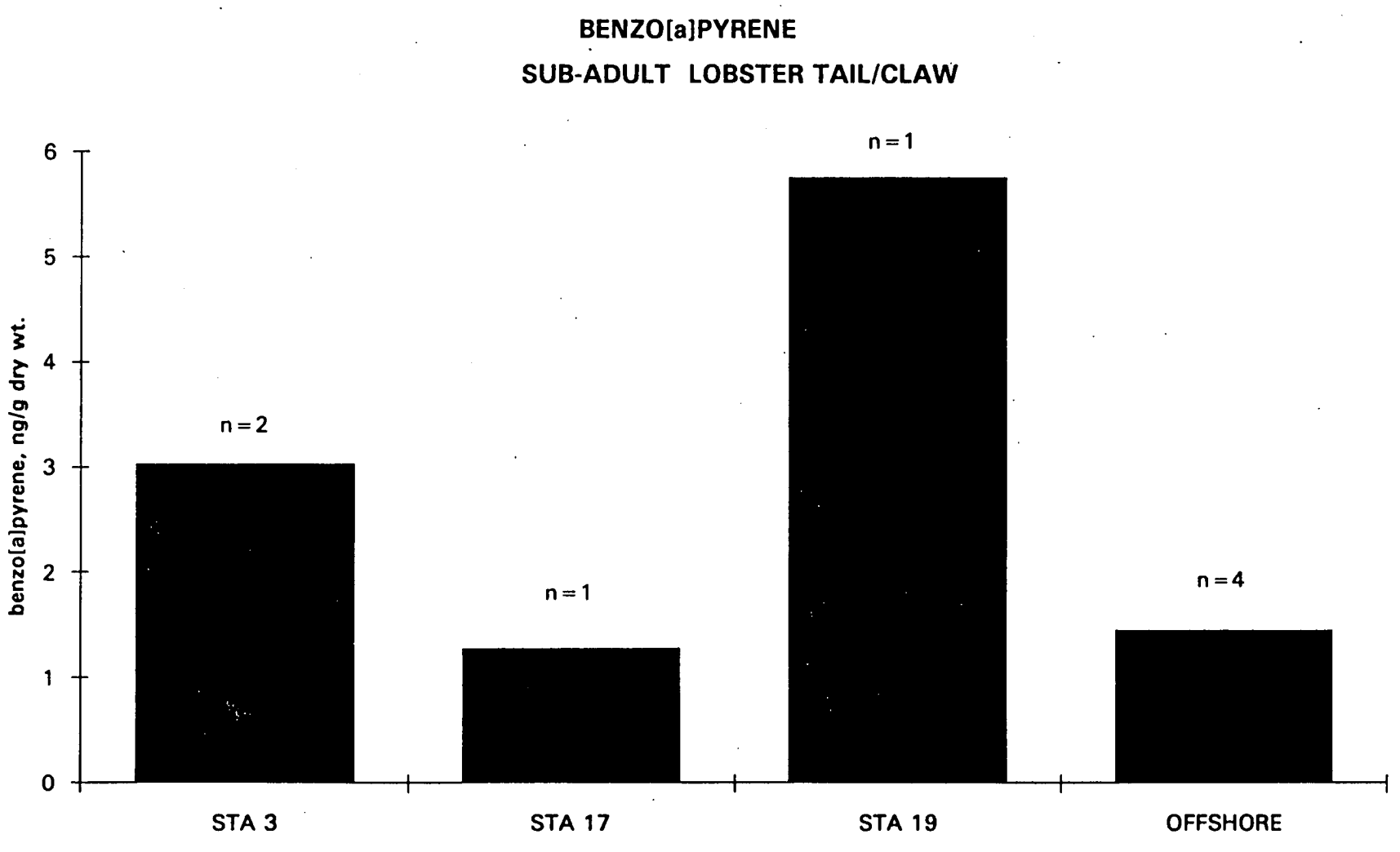
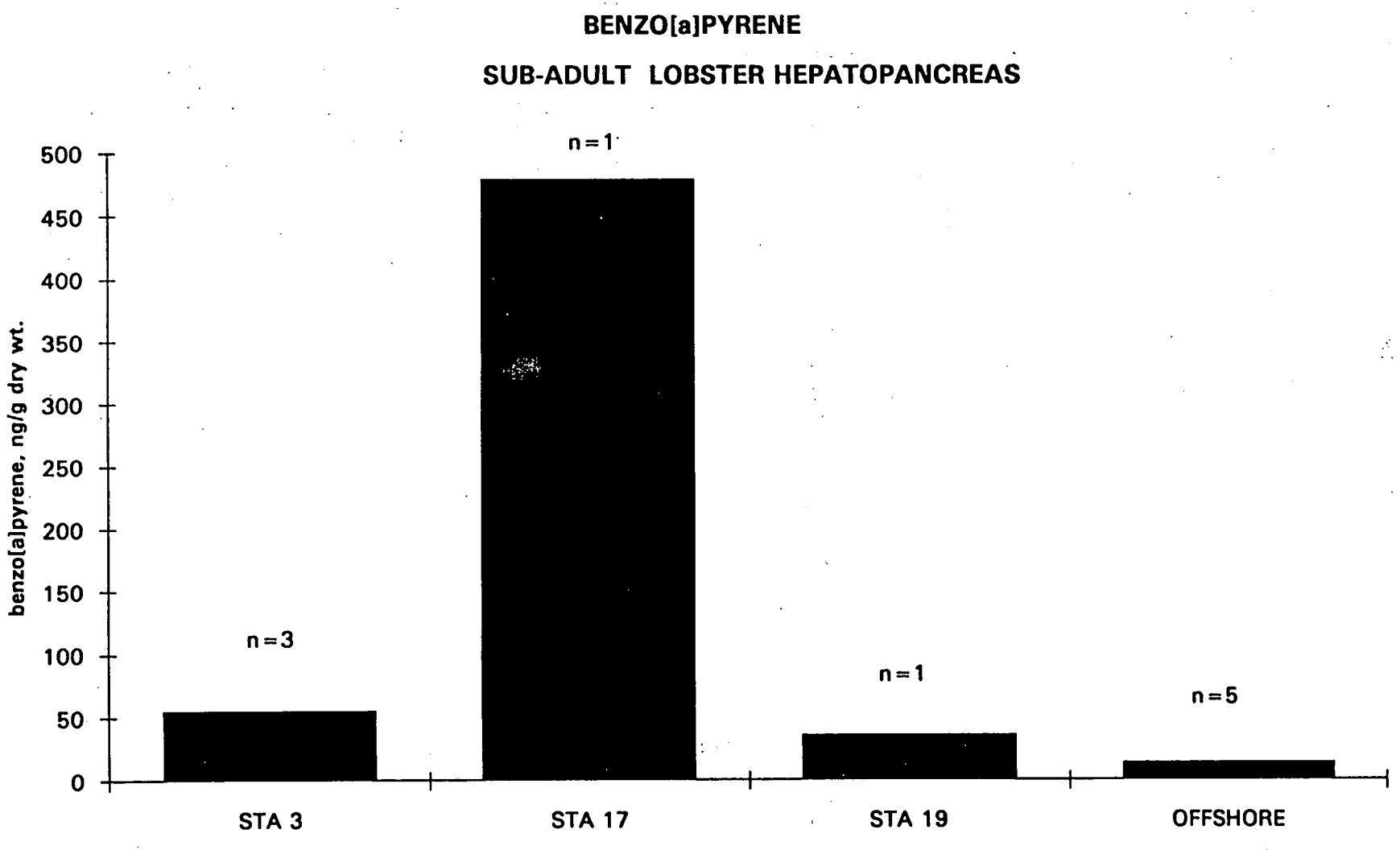


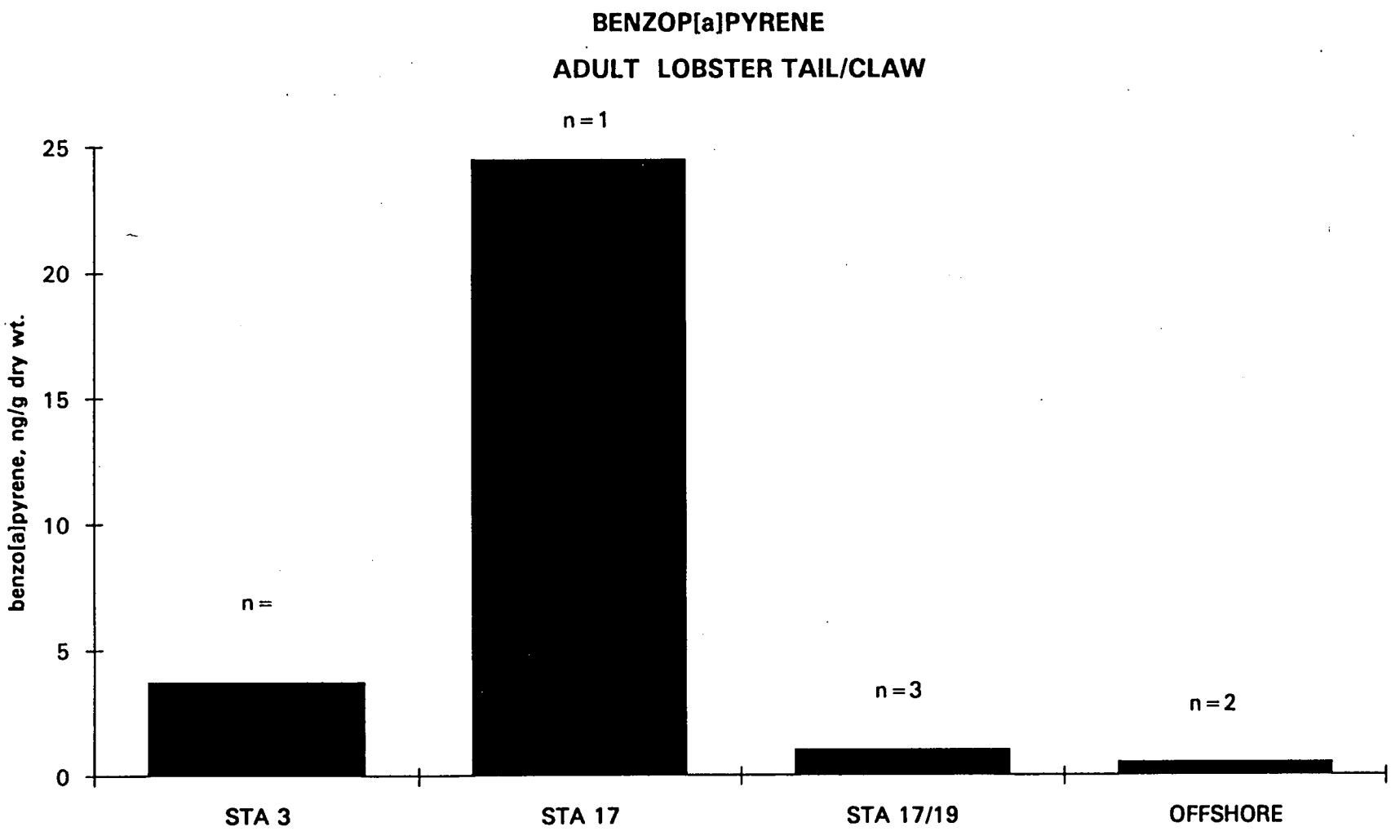
FIGURE 7. Locations of sampling stations in the lower Piscataqua and York Rivers.

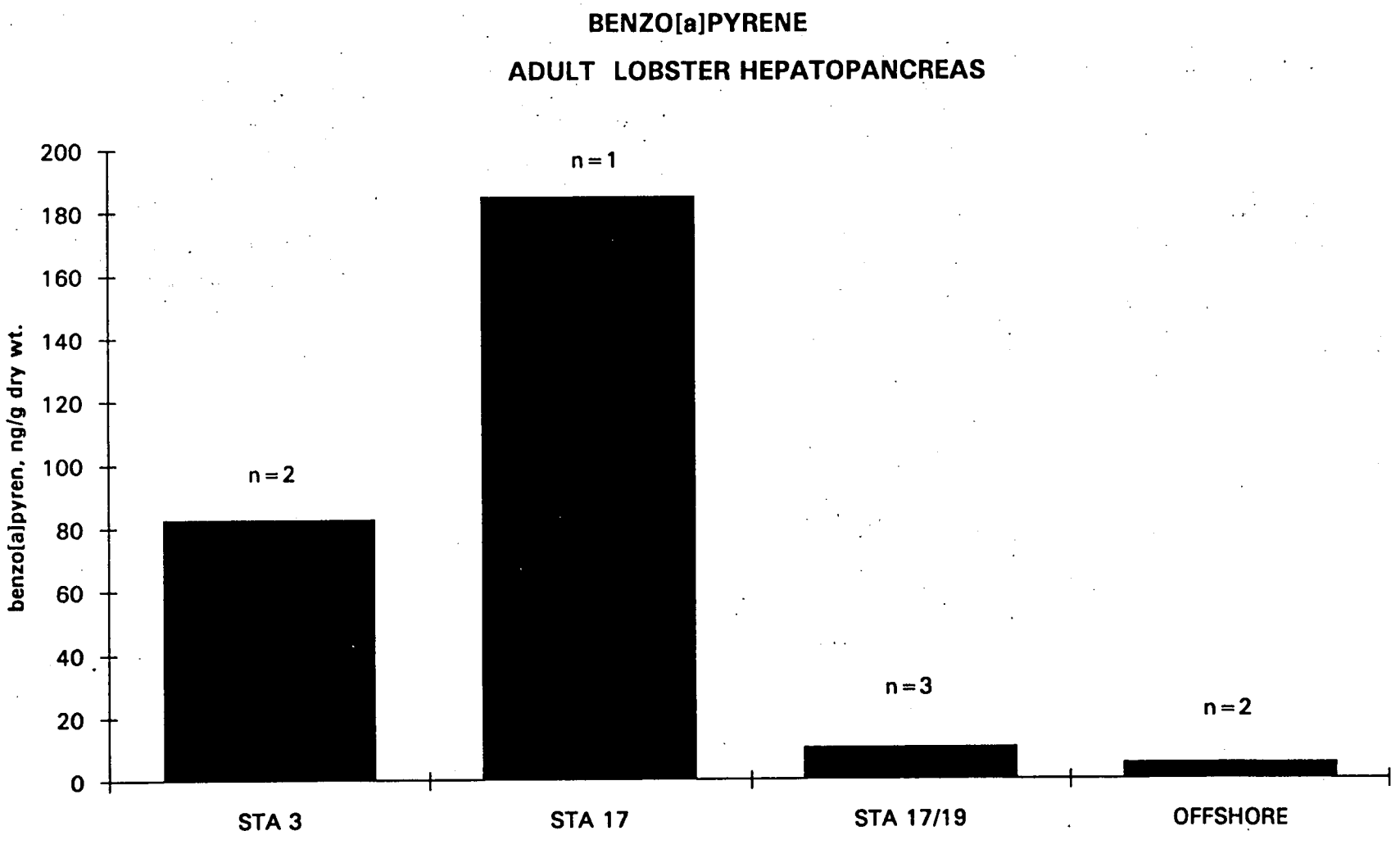

BENZO[a]PYRENE
JUVENILE LOBSTER TAIL/CLAW
benzo[a]pyrene, ng/g dry wt.
90
80
70
60
50
40
30
20
10
0
n=3
n=3
n=3
n=2
n=1
STA 3
STA 9
STA 17
STA 19
OFFSHORE

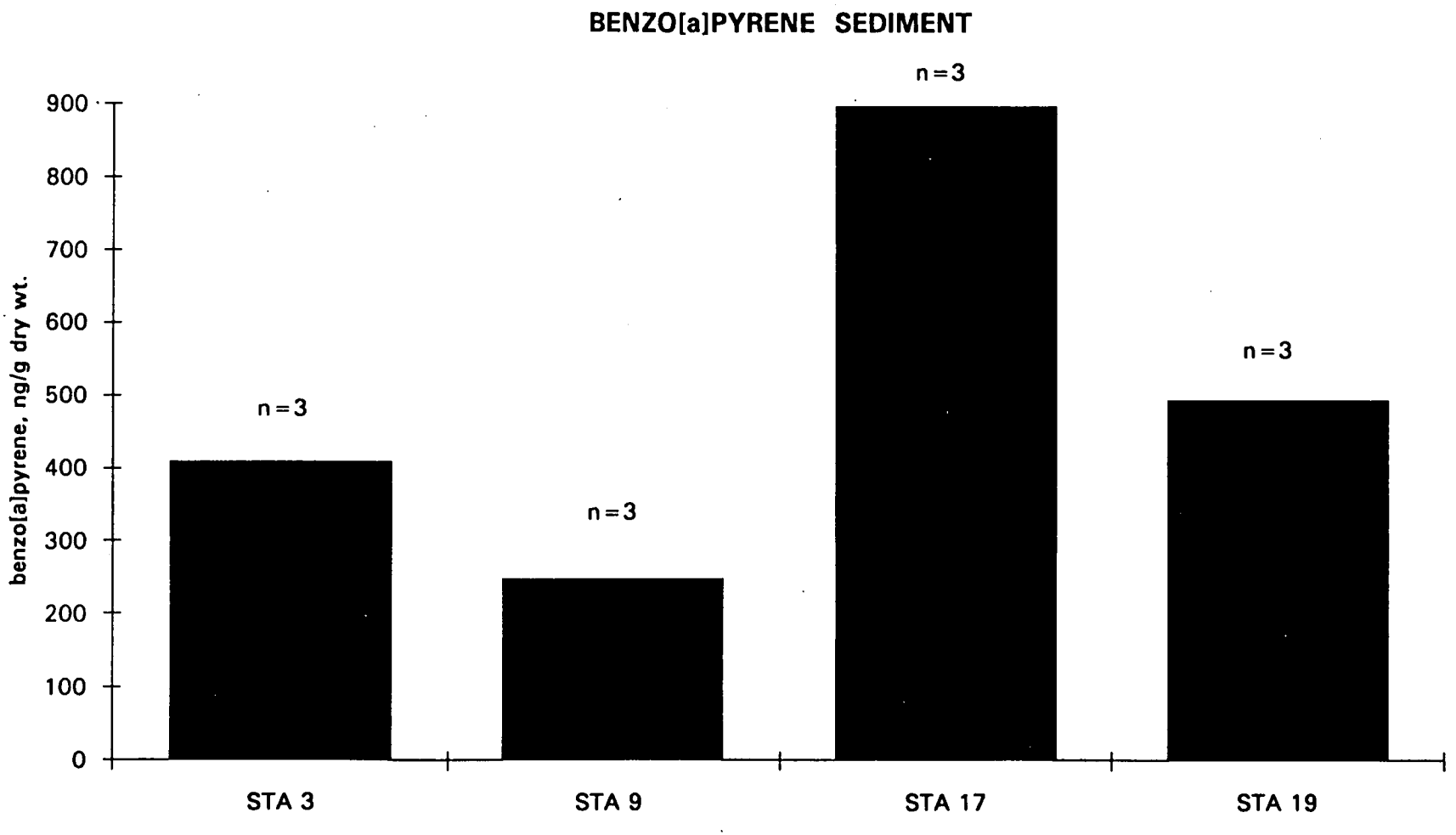

BENZO[a]PYRENE
JUVENILE LOBSTER HEPATOPANCREAS
benzo[a]pyrene, ng/g dry wt.
500
450
400
350
300
250
200
150
100
50
0
n=3
n=3
n=3
n=4
n=2
STA 3
STA 9
STA 17
STA 19
OFFSHORE


BENZO[a]PYRENE
SUB-ADULT LOBSTER TAIL/CLAW
benzo[a]pyrene, ng/g dry wt.
0
1
2
3
4
5
6
n = 2
n = 1
n = 1
n = 4
STA 3
STA 17
STA 19
OFFSHORE


BENZO[a]PYRENE
SUB-ADULT LOBSTER HEPATOPANCREAS
benzo[a]pyrene, ng/g dry wt.
500
450
400
350
300
250
200
150
100
50
0
n=3
n=1
n=1
n=5
STA 3
STA 17
STA 19
OFFSHORE


BENZOP[a]PYRENE
ADULT LOBSTER TAIL/CLAW
benzo[a]pyrene, ng/g dry wt.
25
20
15
10
5
0
n =
n = 1
n = 3
n = 2
STA 3
STA 17
STA 17/19
OFFSHORE

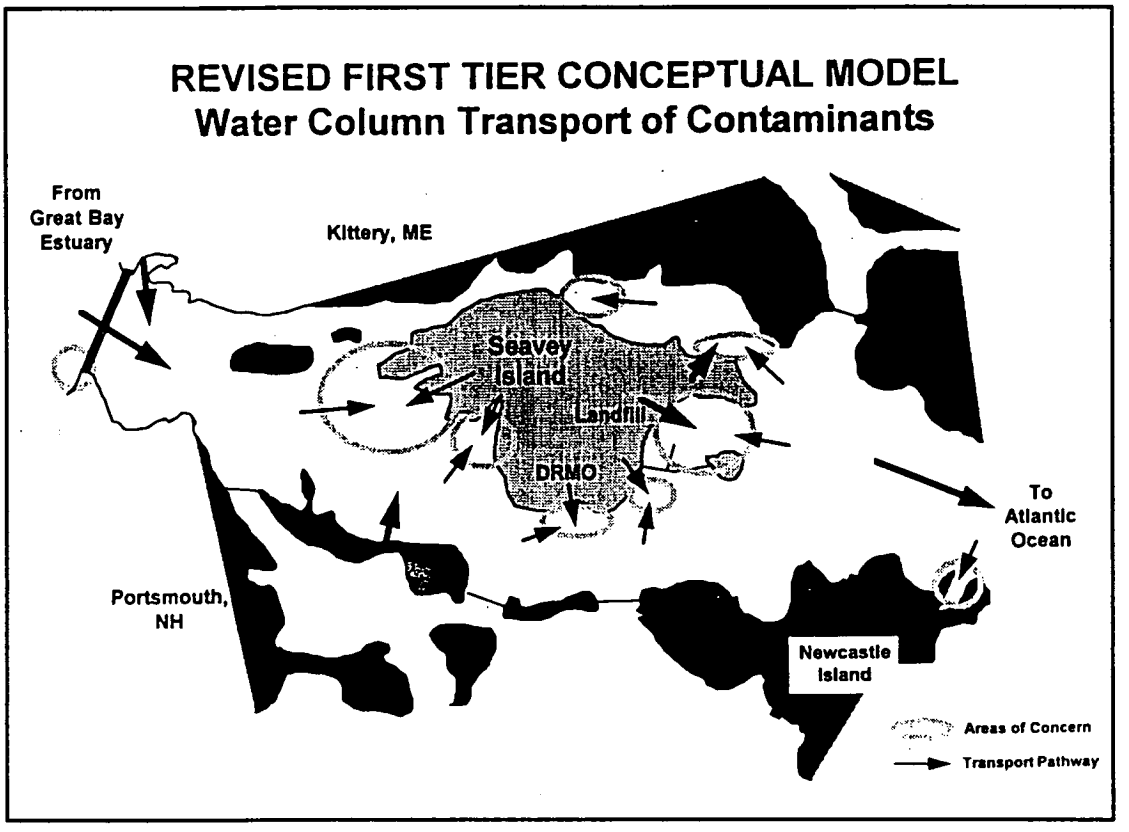

BENZO[a]PYRENE
ADULT LOBSTER HEPATOPANCREAS
benzo[a]pyren, ng/g dry wt.
200
180
160
140
120
100
80
60
40
20
0
n=2
n=1
n=3
n=2
STA 3
STA 17
STA 17/19
OFFSHORE


BENZO[a]PYRENE SEDIMENT
benzo[a]pyrene, ng/g dry wt.
900
800
700
600
500
400
300
200
100
0
n=3
n=3
n=3
n=3
STA 3
STA 9
STA 17
STA 19

Implementation of a One Dimensional Pollutant Fate Model for the Great Bay Estuarine System

Professor Barbaros Celikkol
John Pavlos

University of New Hampshire
Ocean Engineering


REVISED FIRST TIER CONCEPTUAL MODEL
Water Column Transport of Contaminants
From Great Bay Estuary
Kittery, ME
Seavey Island
Landfill
DRMO
To Atlantic Ocean
Portsmouth, NH
Newcastle Island
Areas of Concern
Transport Pathway

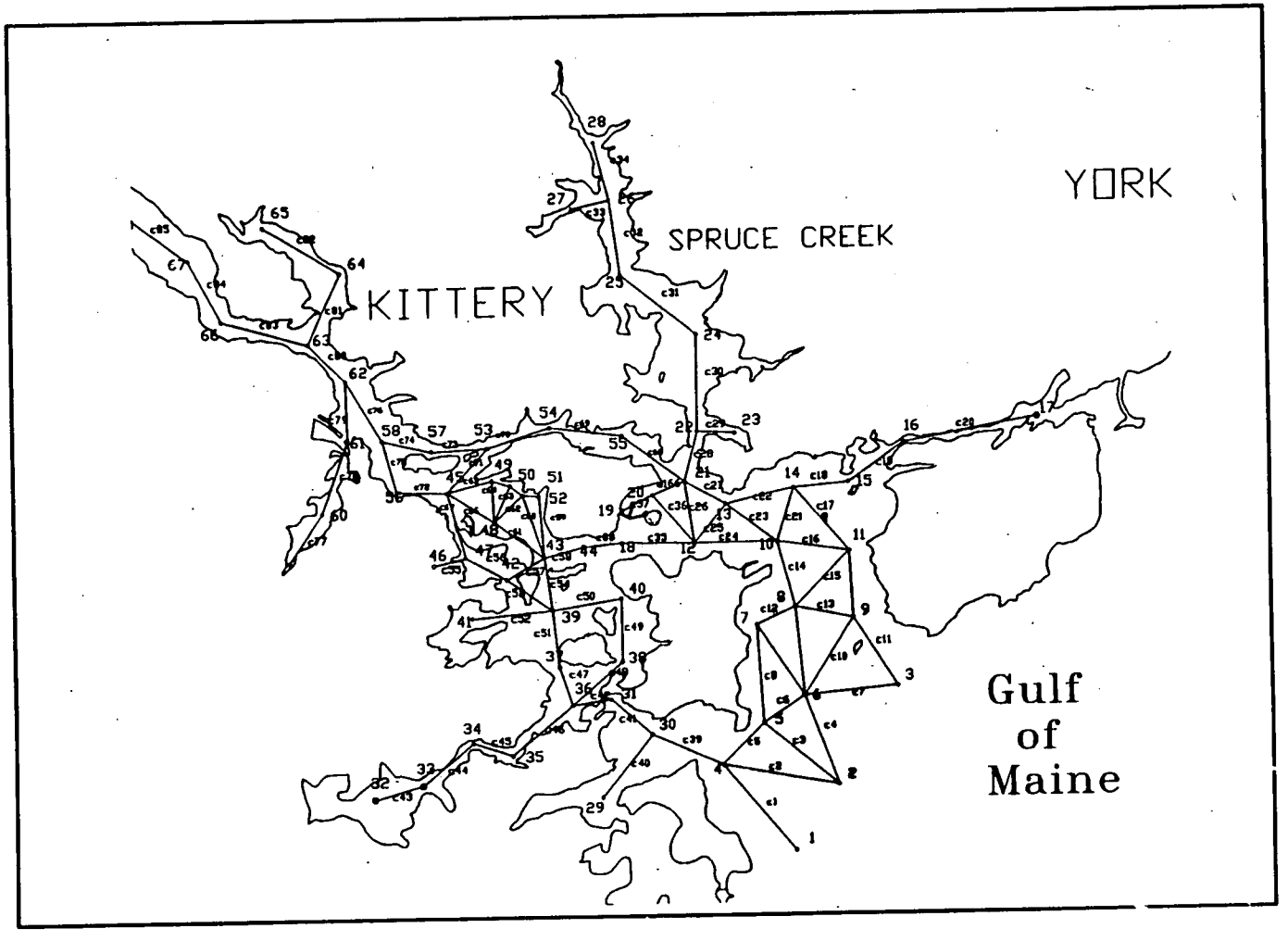
Where is the stuff going?

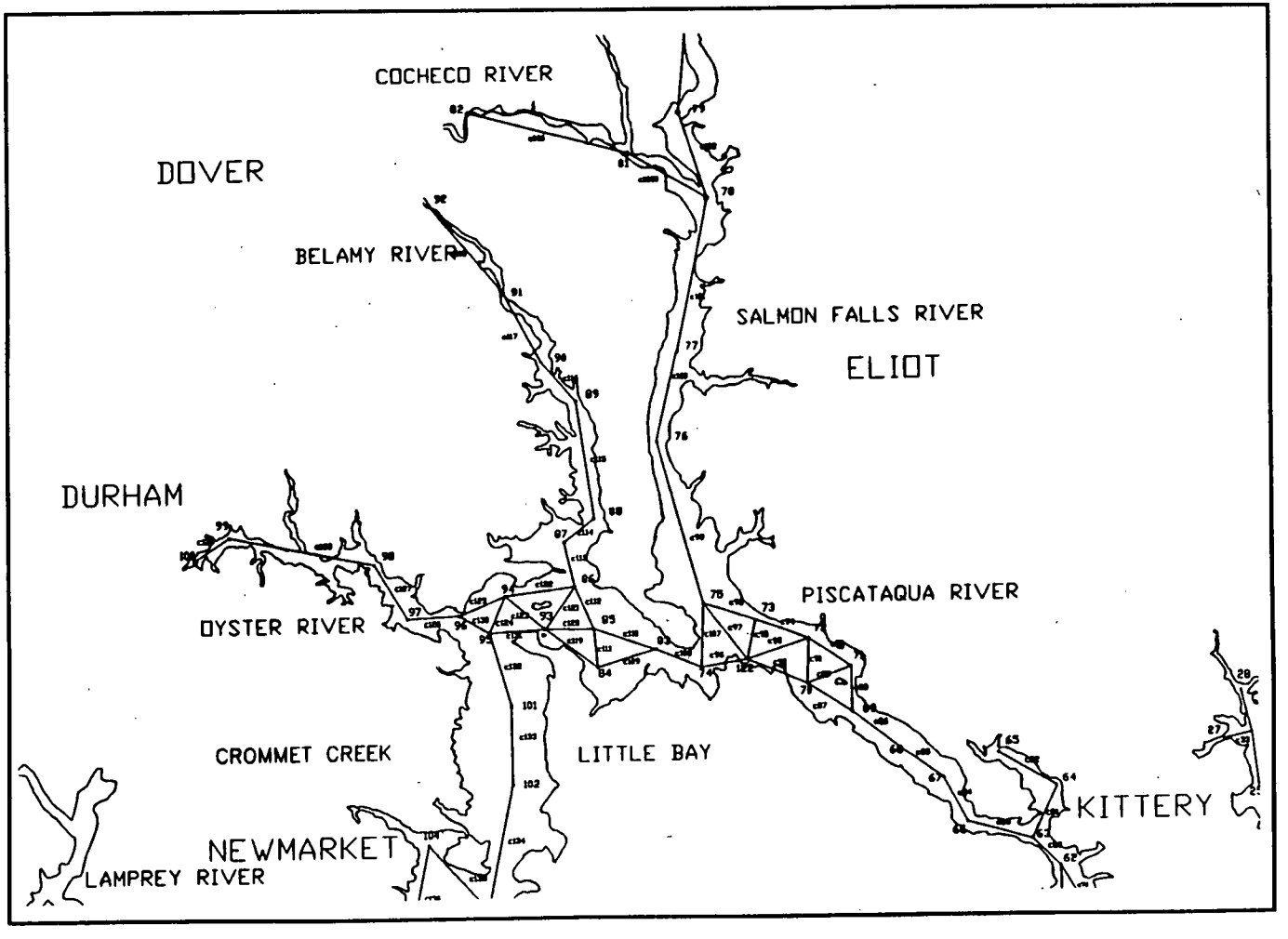
- Near-Field or Far-Field Problem?
- Unique Spatial Distribution?
- Sensitivity of the Estuarine System?
- Flushing Time?

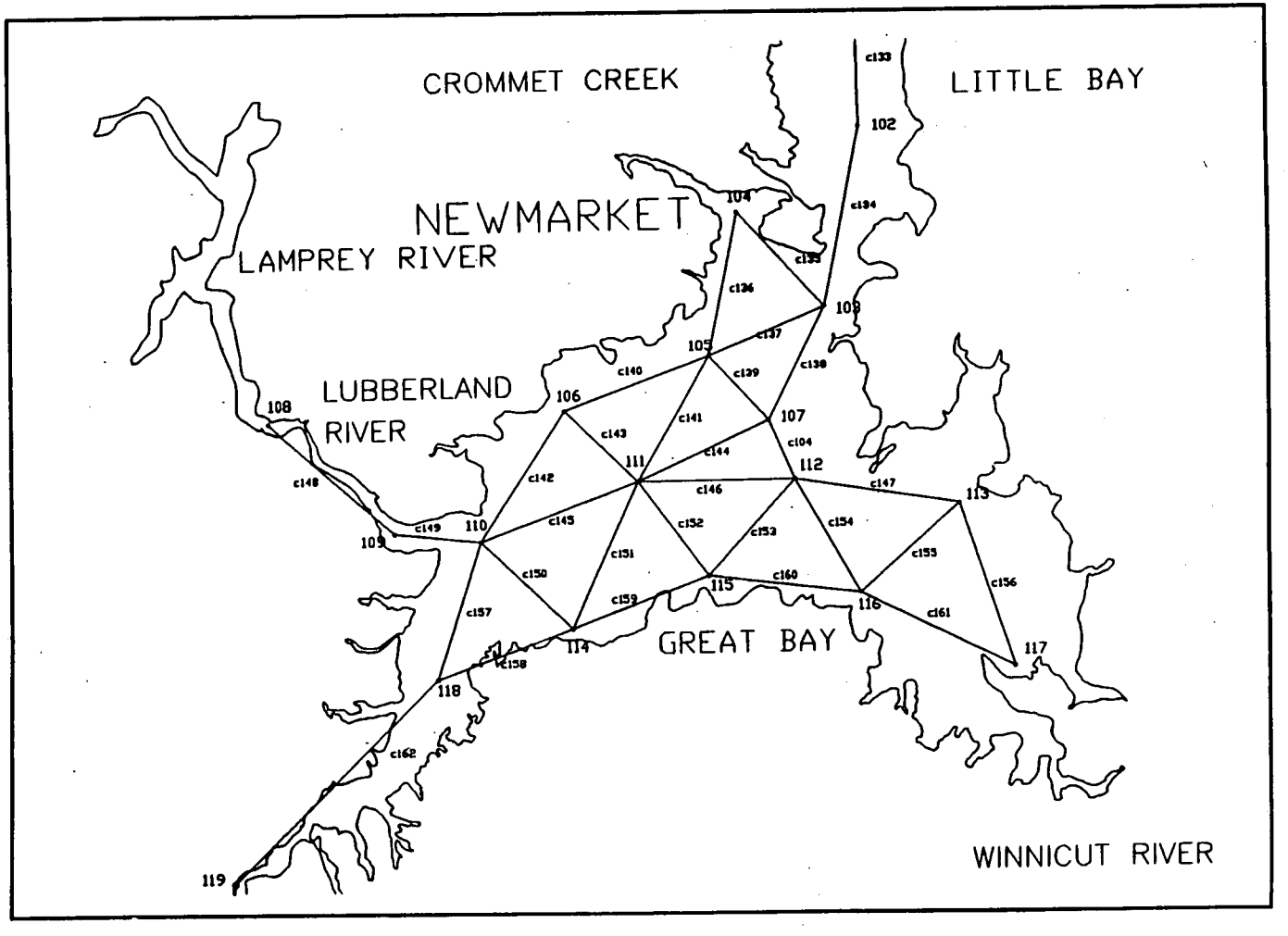
WASP3

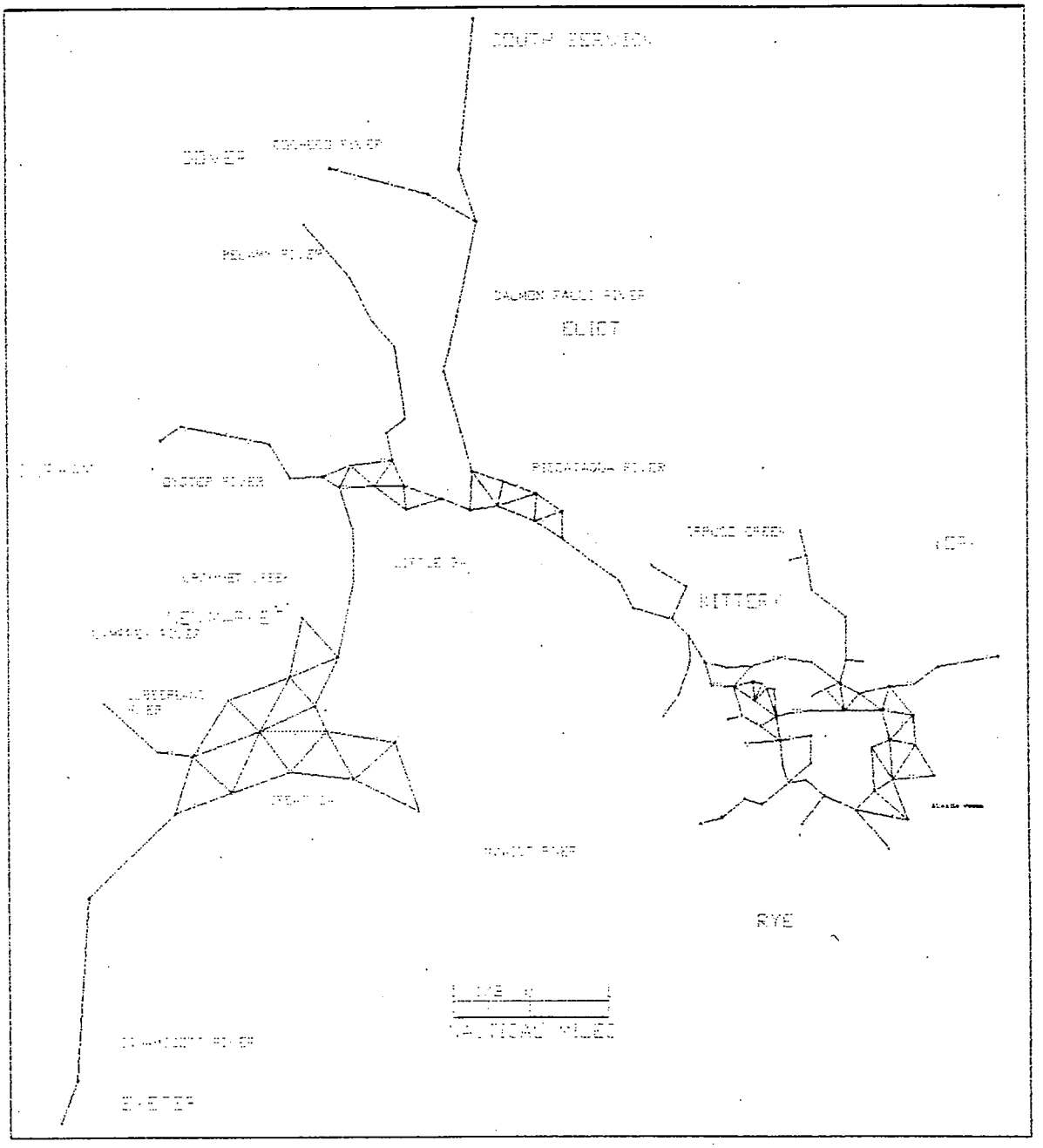
Water Analysis Simulation Program

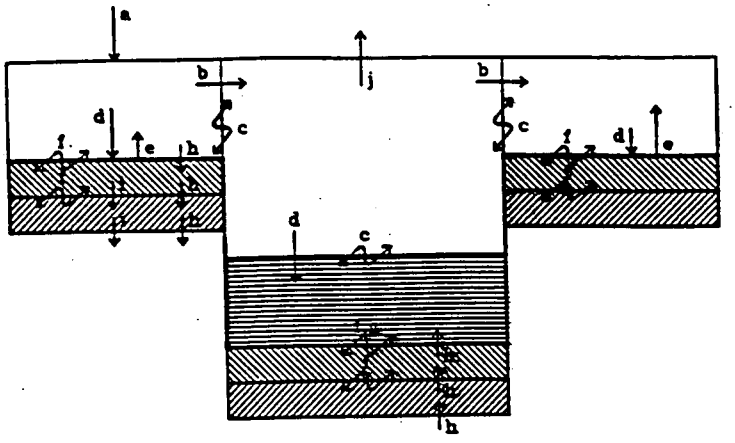
- One Dimensional Model.
- Limited Resolution.
- Limited Simulation Length.


YORK
SPRUCE CREEK
KITTERY
Gulf
of
Maine

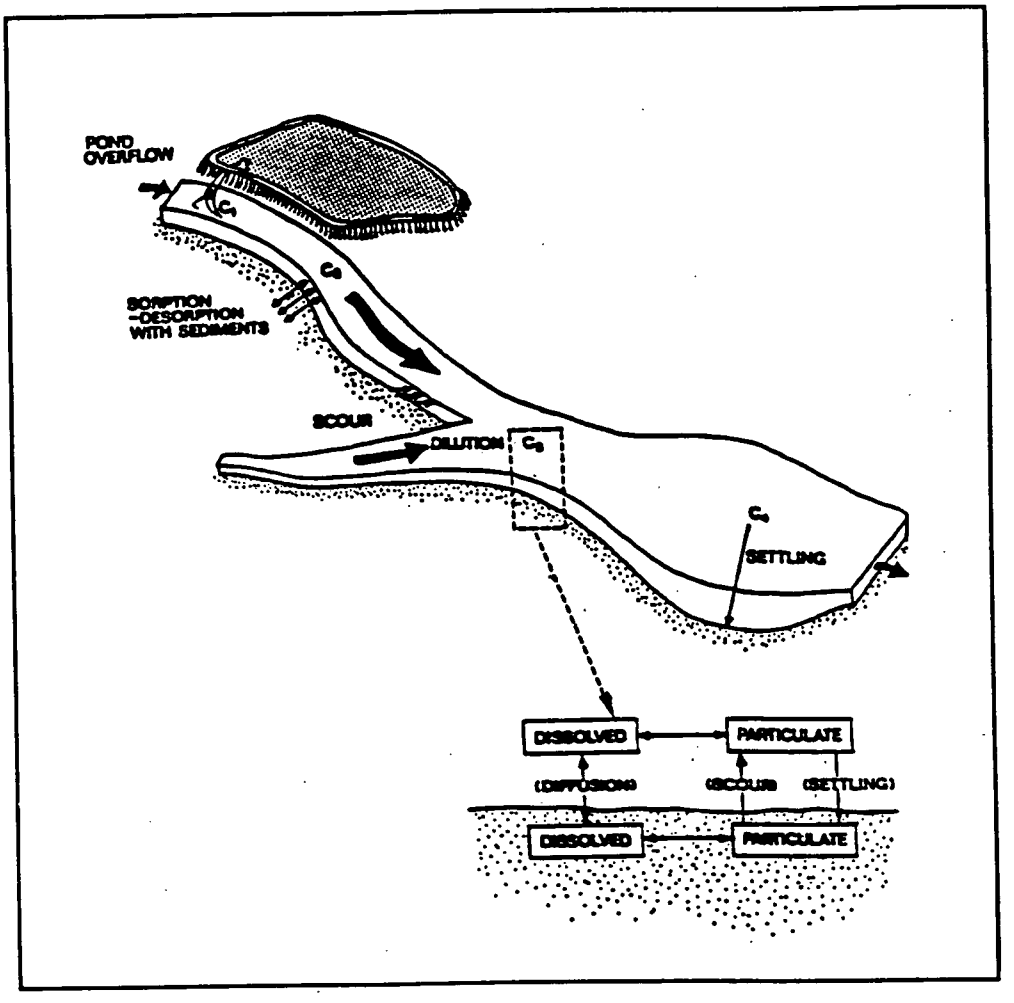

COCHECO RIVER
DOVER
BELAMY RIVER
SALMON FALLS RIVER
ELIOT
DURHAM
PISCATAQUA RIVER
OYSTER RIVER
CROMMET CREEK
LITTLE BAY
KITTERY
NEWMARKET
LAMPREY RIVER

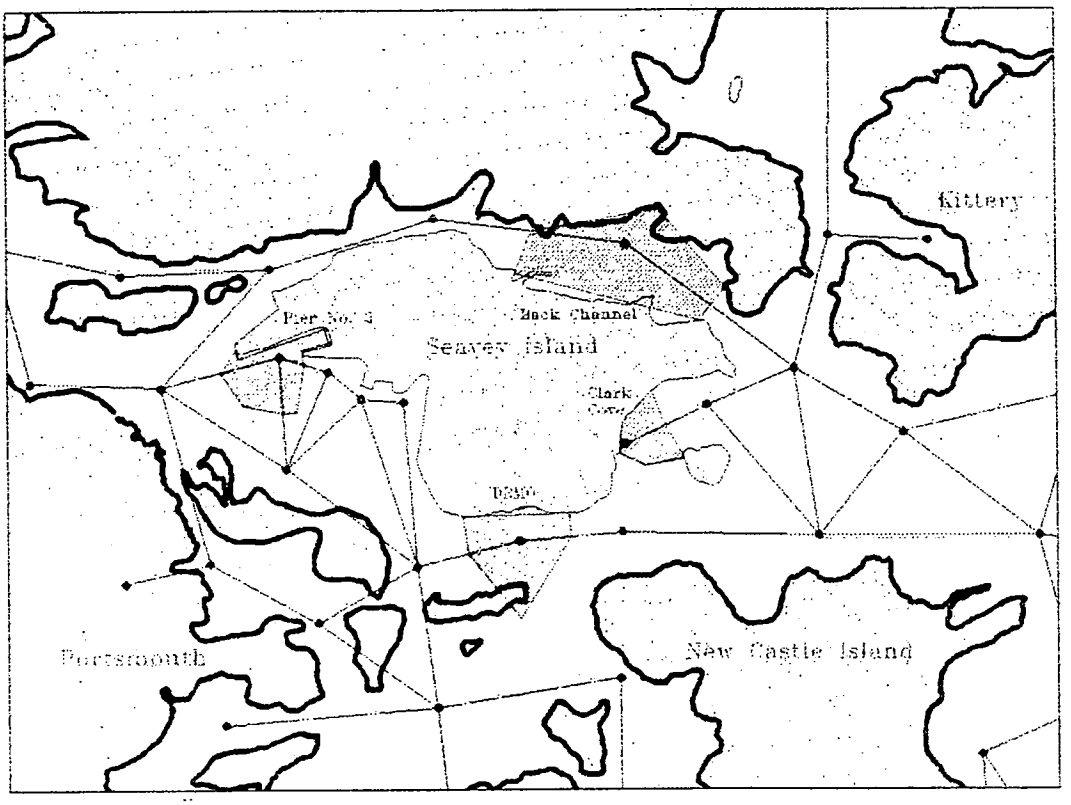

CROMMET CREEK
LITTLE BAY
NEWMARKET
LAMPREY RIVER
LUBBERLAND
RIVER
GREAT BAY
WINNICUT RIVER
102
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
c133
c134
c135
c136
c137
c138
c139
c140
c141
c142
c143
c144
c104
c146
c147
c148
c149
c145
c150
c151
c152
c153
c154
c155
c156
c157
c158
c159
c160
c161
c162


DOVER
ELIOT
KITTERY
RYE



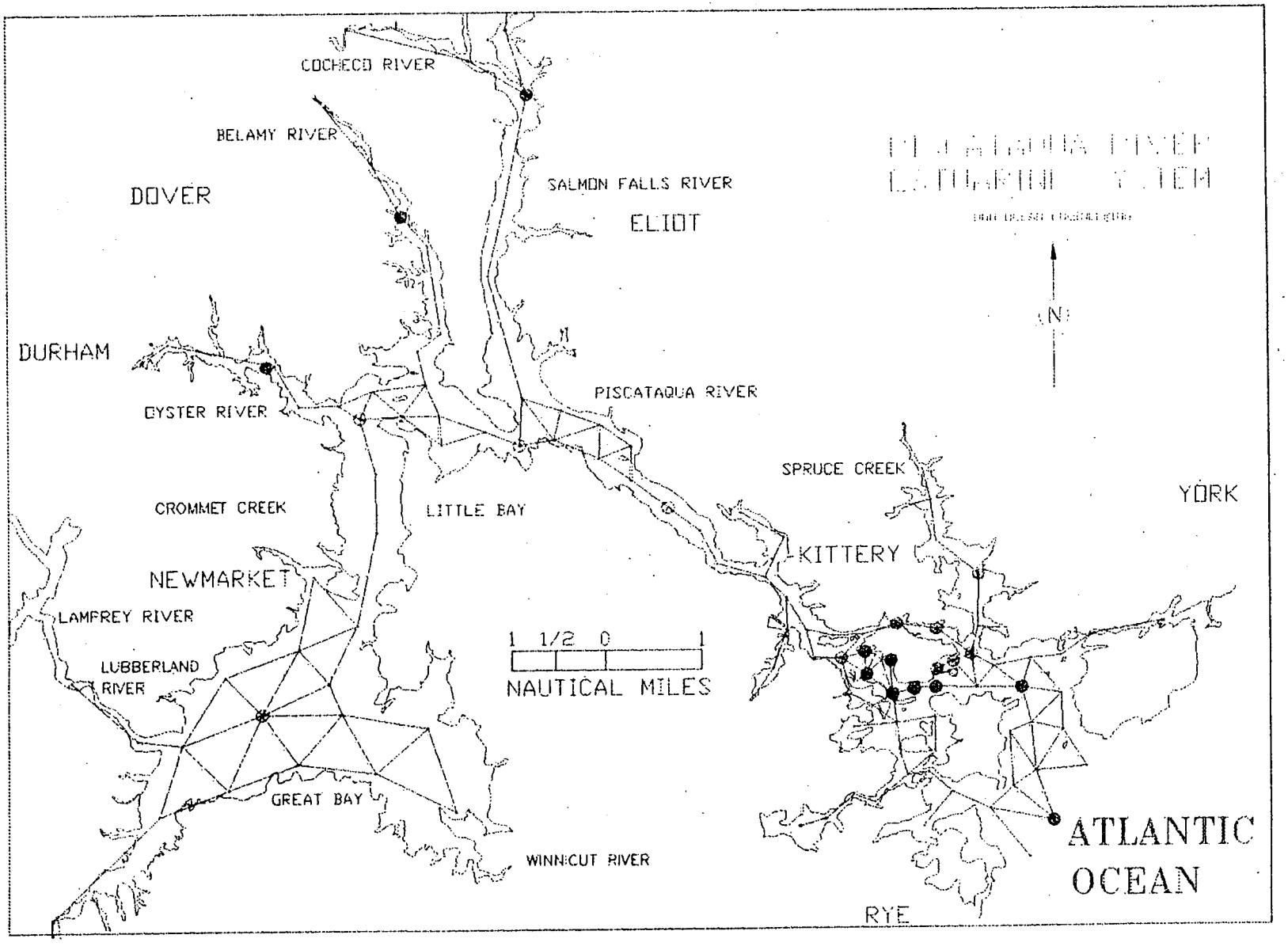
Process	Segment Types
a) Mass Loading	1,2 to Water
b) Advection	1,2 Water-Water
c) Dispersion	1,2 Water-Water
d) Settling	1,2 Water-Water or Water-Bed
e) Erosion	3 Surface Bed-Water
f) Pore Water Diffusion	3,4 Surface Bed-Water or Bed-Bed
g) Sediment Turnover	3 Surface Bed-Water
h) Percolation	4 Bed-Bed or Bed-Water
i) Sedimentation	4 Bed-Bed
j) Volatilization	1 Surface Water

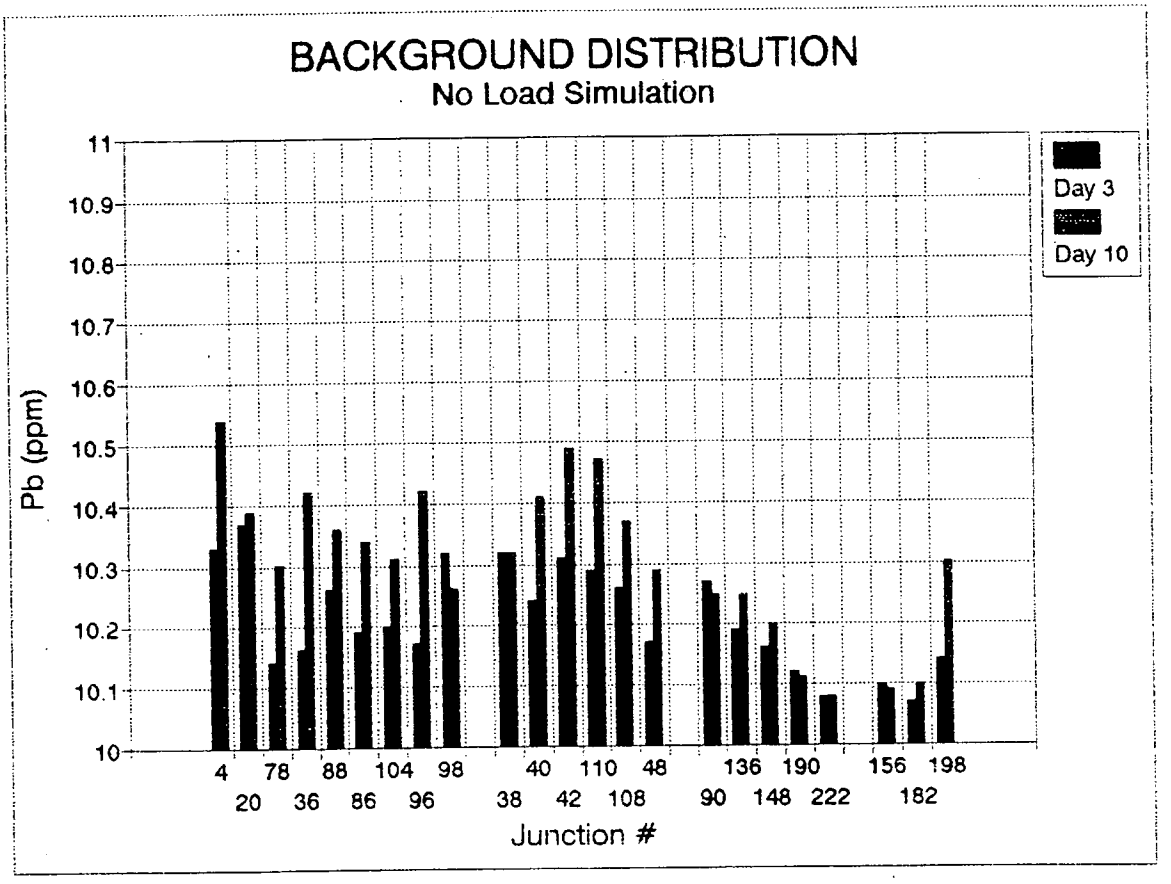

POND
OVERFLOW
SORPTION
-DESORPTION
WITH SEDIMENTS
SCOUR
DILUTION
SETTLING
DISSOLVED
PARTICULATE
(DIFFUSION)
(SCOUR)
(SETTLING)
DISSOLVED
PARTICULATE

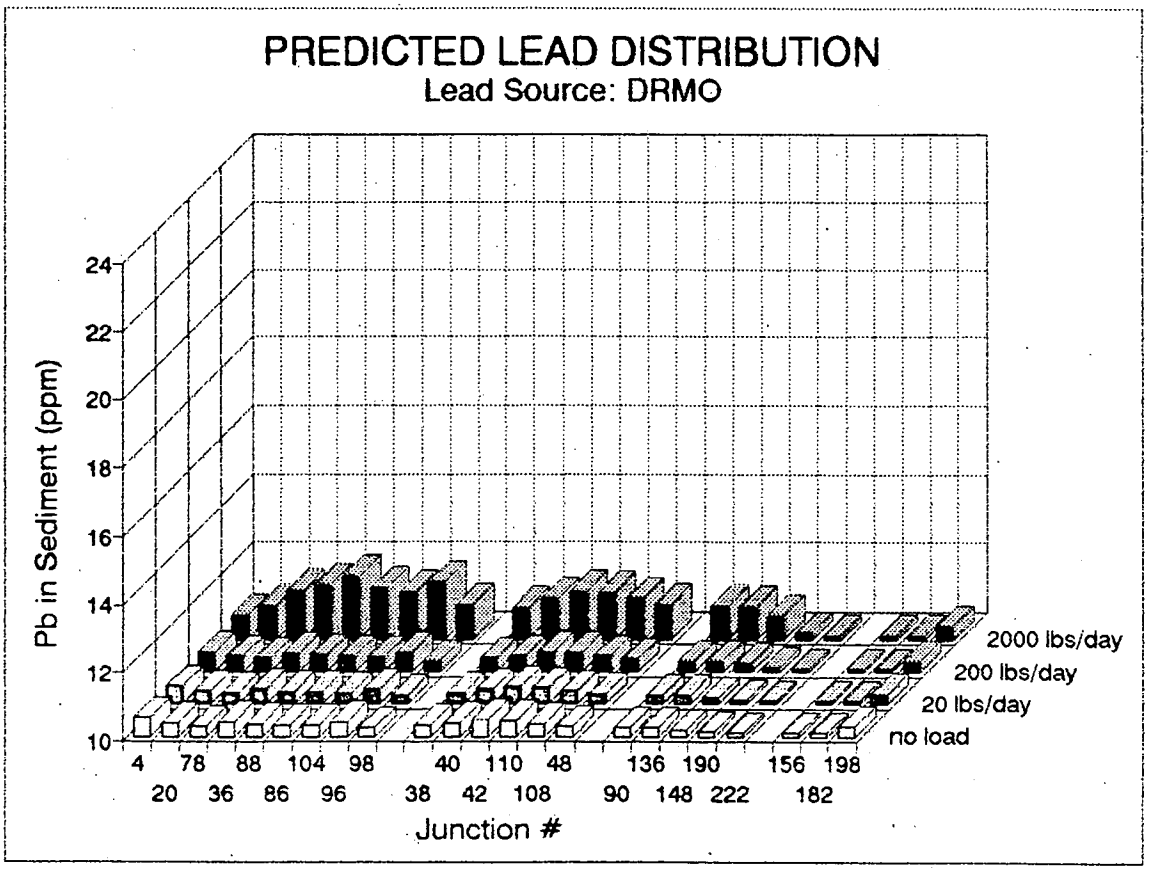

Kittery
Back Channel
Seavey Island
Clark
Portsmouth
New Castle Island

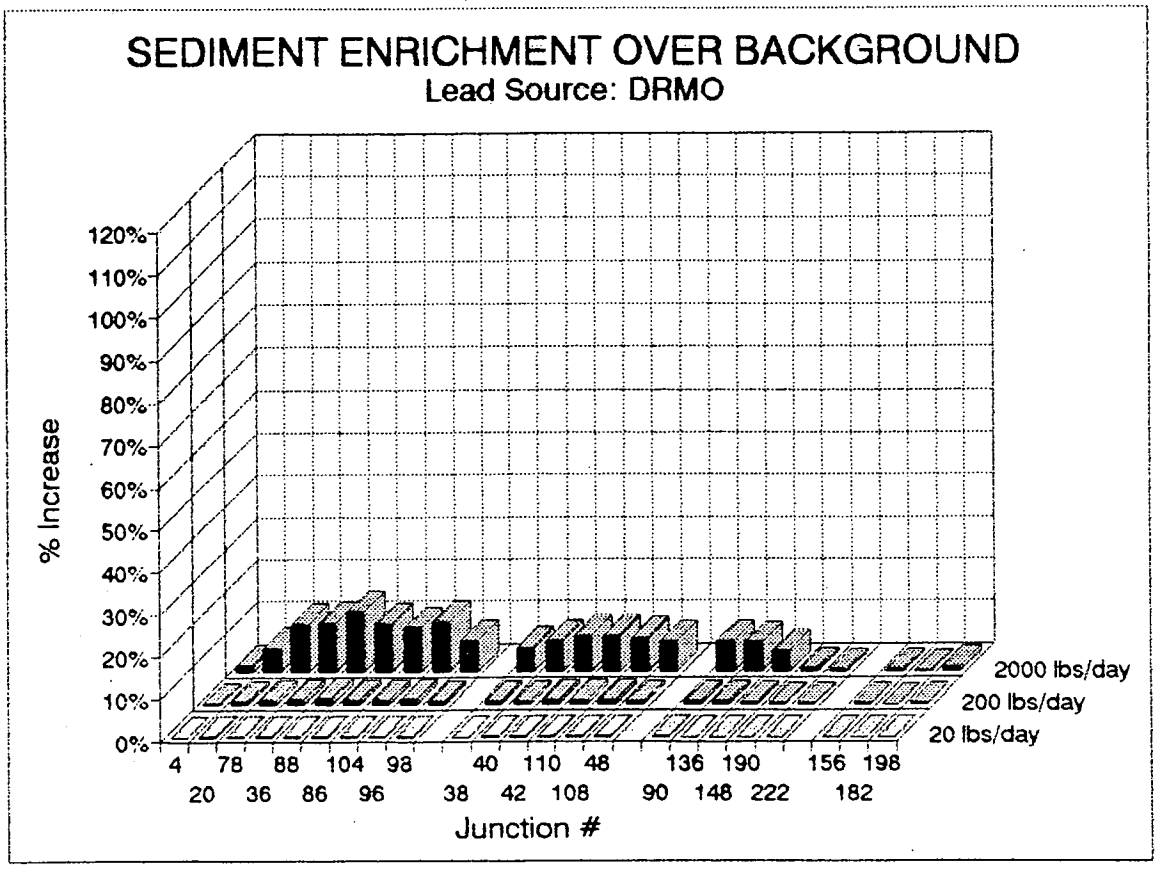
JUNCTION LOCATIONS

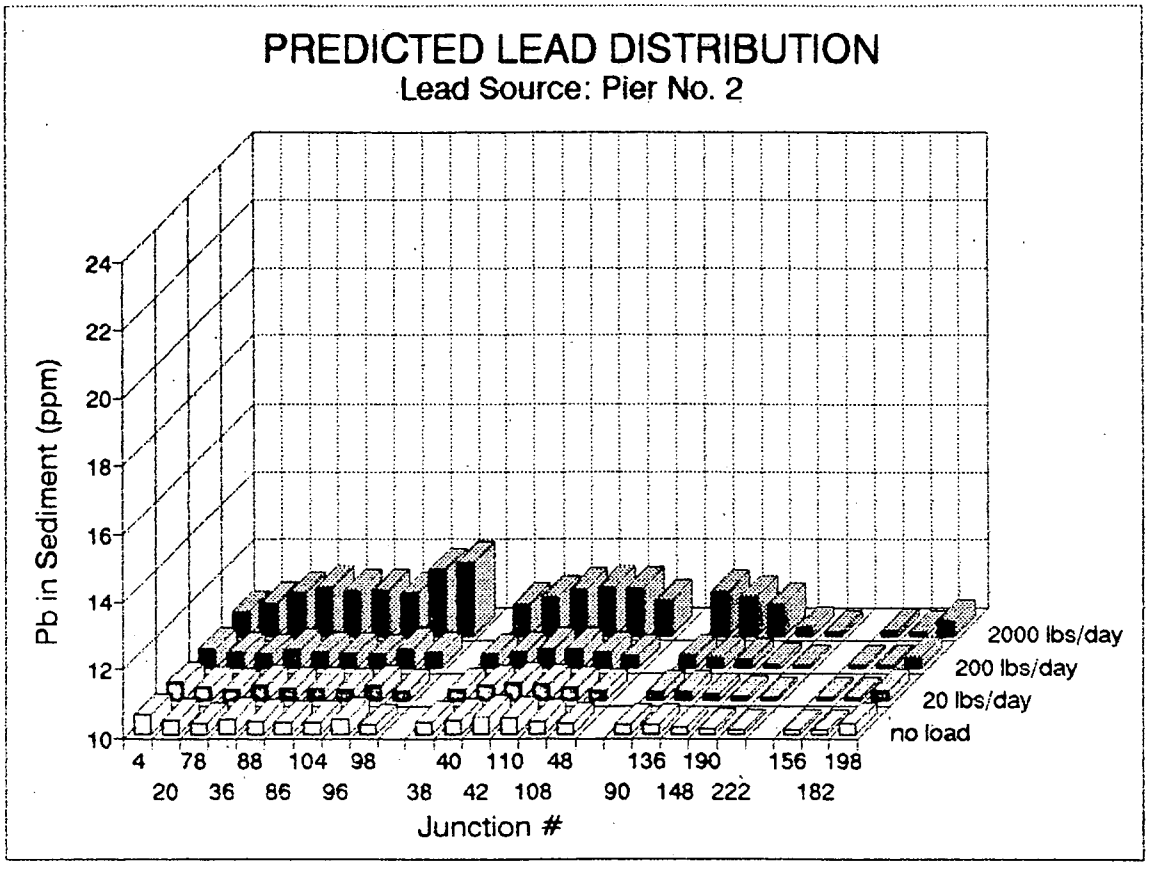
Junction	Station	Location
4	22	Atlantic Ocean.
20	2	Portsmouth Harbor, Coast Guard Station.
78	11	Little Harbor.
36	9	S. Seavey Island, Police Dock.
88	10A	S. Seavey Island, DRMO.
86	(10A)	S. Seavey Island, Goat Island.
104	10	S. Seavey Island, Battery Acid Tank.
96	14	Pierces Island.
98		Pier No. 2
38	7,8	Clark Cove, Inner.
40	4,5	Clark Cove, Outer.
42	(3)	E. Seavey Island.
110	19	Back Channel, East.
108	18	Back Channel, West.
48	21	Spruce Creek.
90	(13)	W. Seavey Island.
136	24	Piscataqua River, Center.
148	27	Dover Point.
190	28	Little Bay.
222	30	Great Bay, Central.
156	26	Salmon Falls River.
182		Bellamy River.
198		Oyster River.

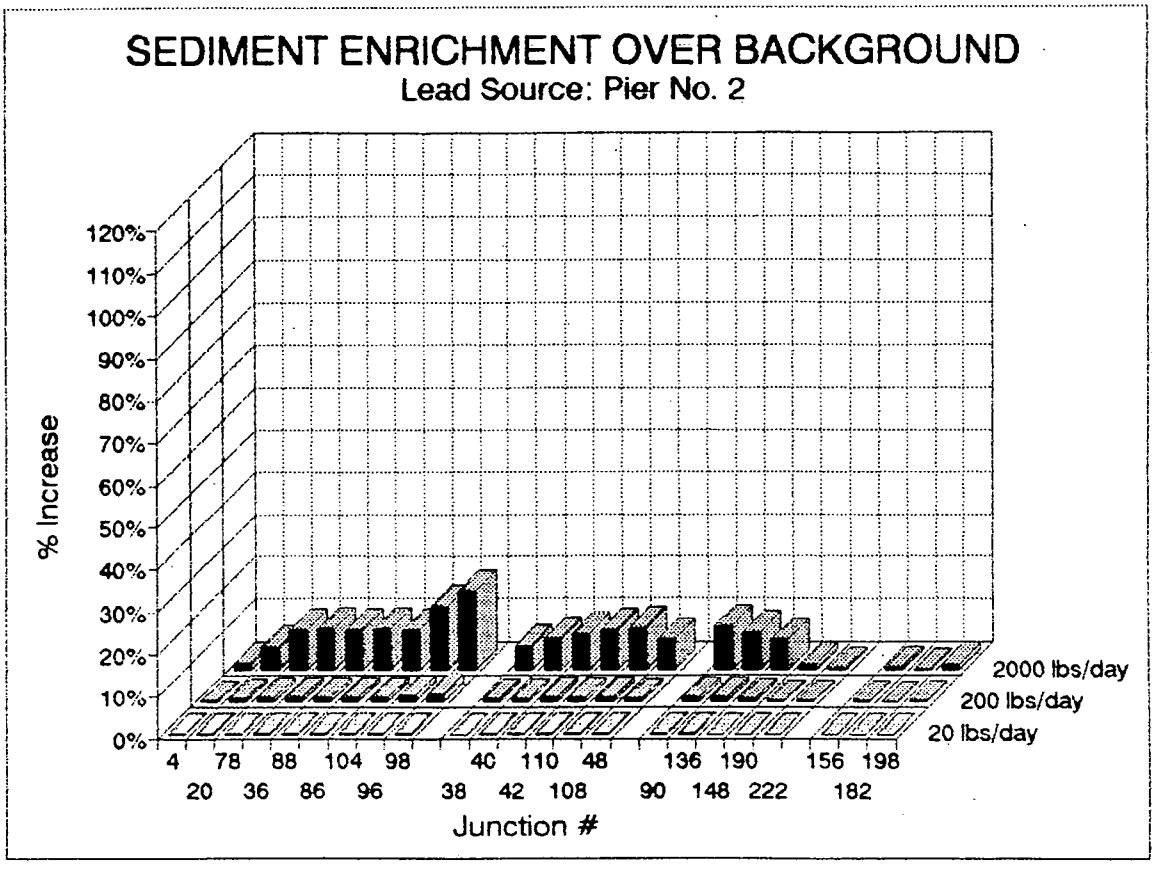

COCHECO RIVER
BELAMY RIVER
DOVER
SALMON FALLS RIVER
ELIOT
DURHAM
OYSTER RIVER
PISCATAQUA RIVER
SPRUCE CREEK
YORK
CROMMET CREEK
LITTLE BAY
KITTERY
NEWMARKET
LAMPREY RIVER
LUBBERLAND RIVER
1 1/2 0 1
NAUTICAL MILES
GREAT BAY
WINNICUT RIVER
ATLANTIC OCEAN
RYE
N

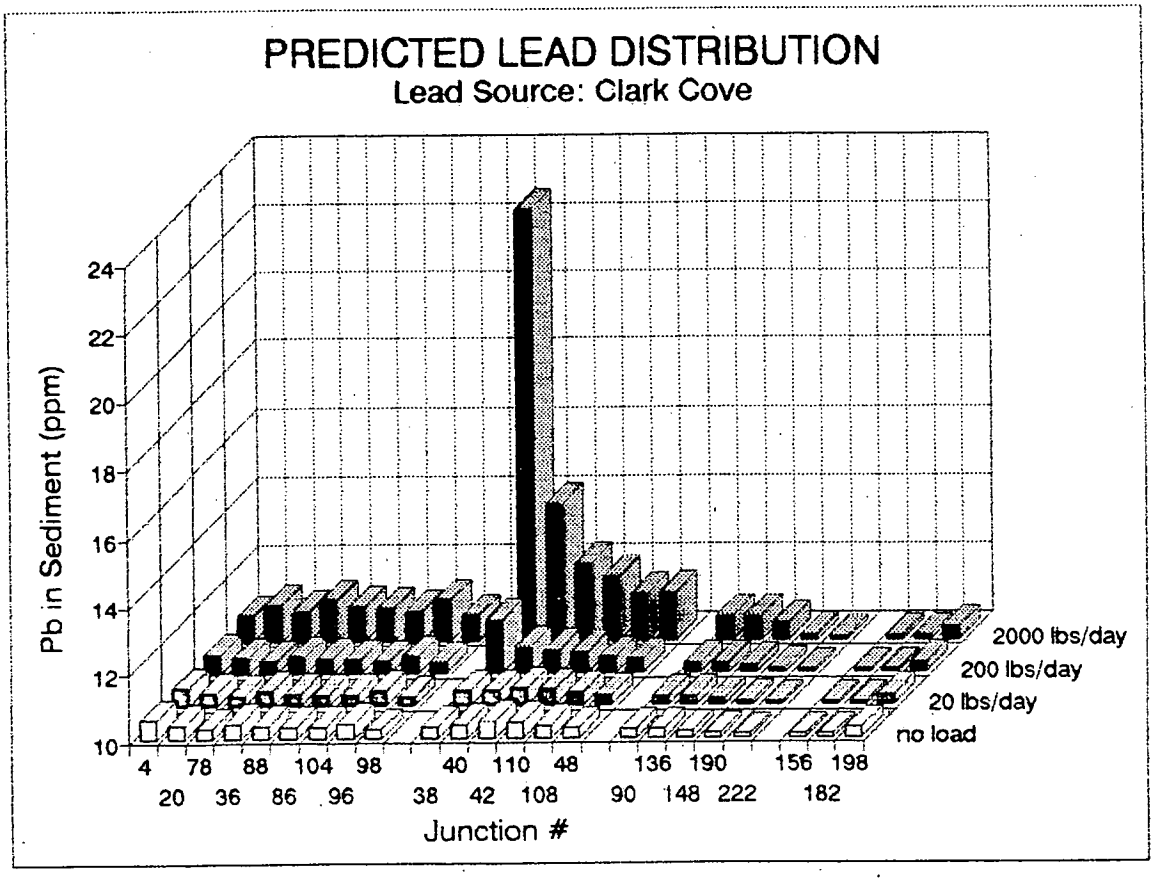

BACKGROUND DISTRIBUTION
No Load Simulation
Pb (ppm)
11
10.9
10.8
10.7
10.6
10.5
10.4
10.3
10.2
10.1
10
Day 3
Day 10
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

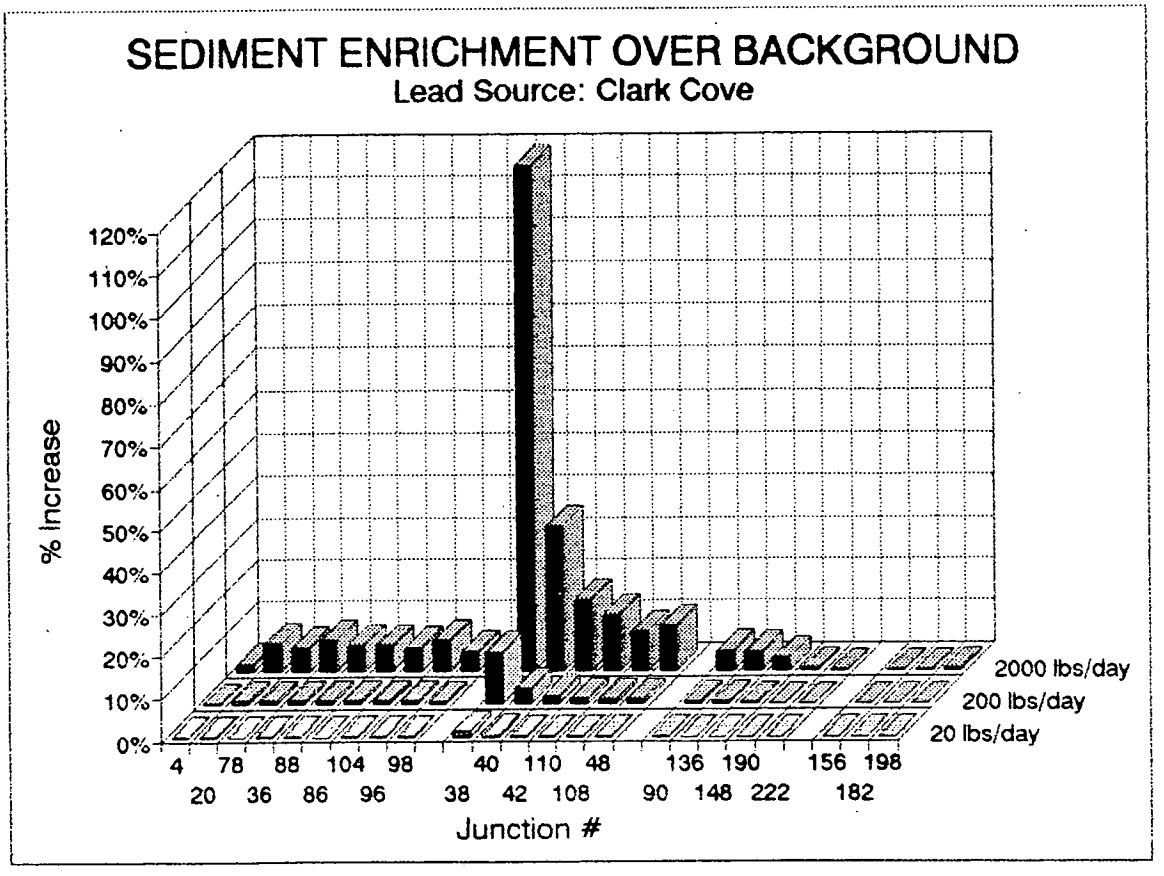

PREDICTED LEAD DISTRIBUTION
Lead Source: DRMO
Pb in Sediment (ppm)
24
22
20
18
16
14
12
10
2000 lbs/day
200 lbs/day
20 lbs/day
no load
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

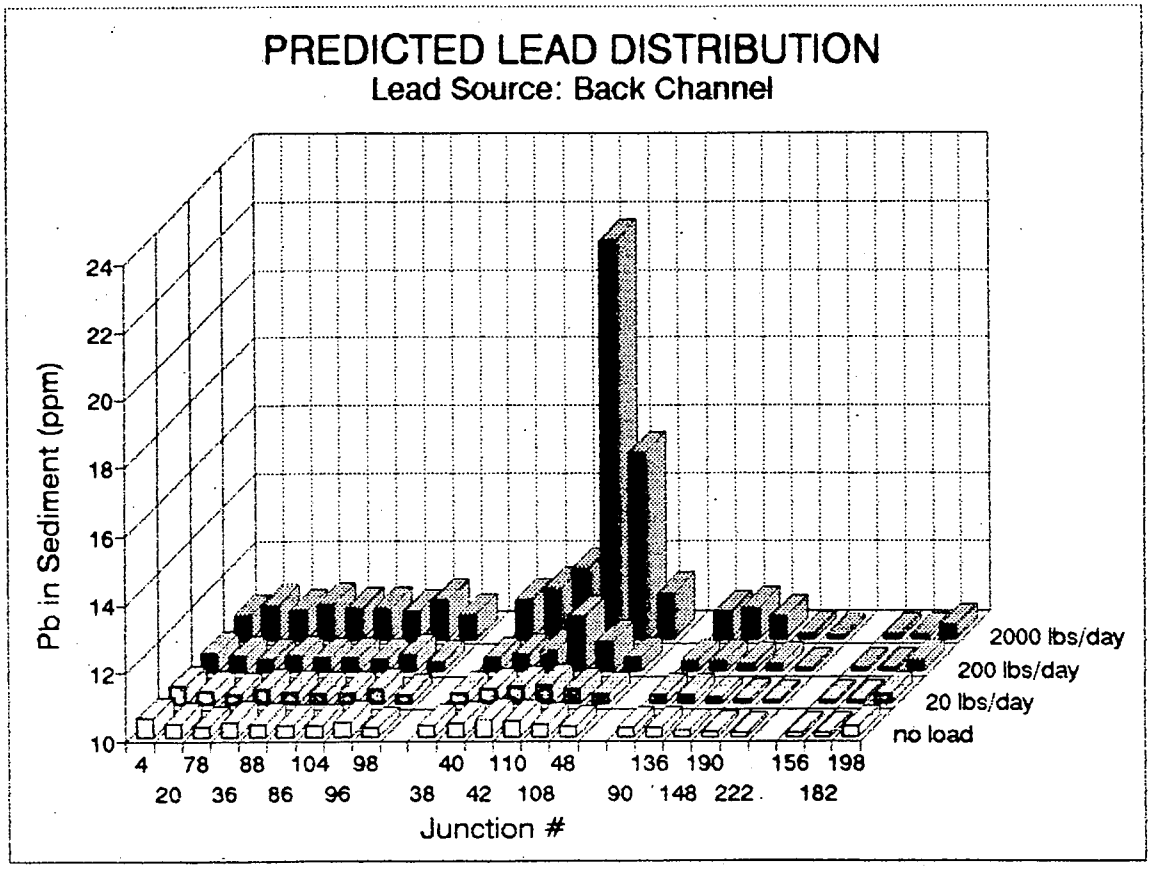

SEDIMENT ENRICHMENT OVER BACKGROUND
Lead Source: DRMO
% Increase
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000 lbs/day
200 lbs/day
20 lbs/day
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

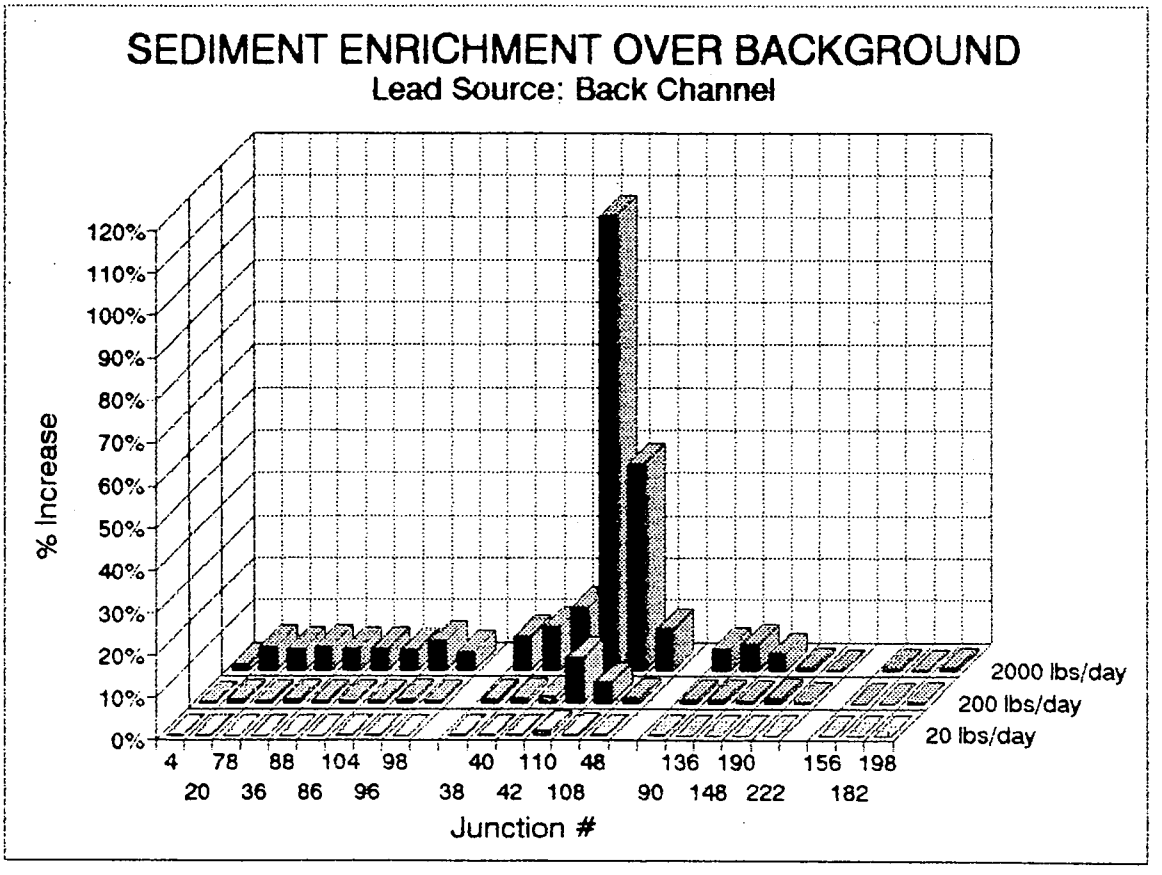

PREDICTED LEAD DISTRIBUTION
Lead Source: Pier No. 2
Pb in Sediment (ppm)
24
22
20
18
16
14
12
10
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #
2000 lbs/day
200 lbs/day
20 lbs/day
no load

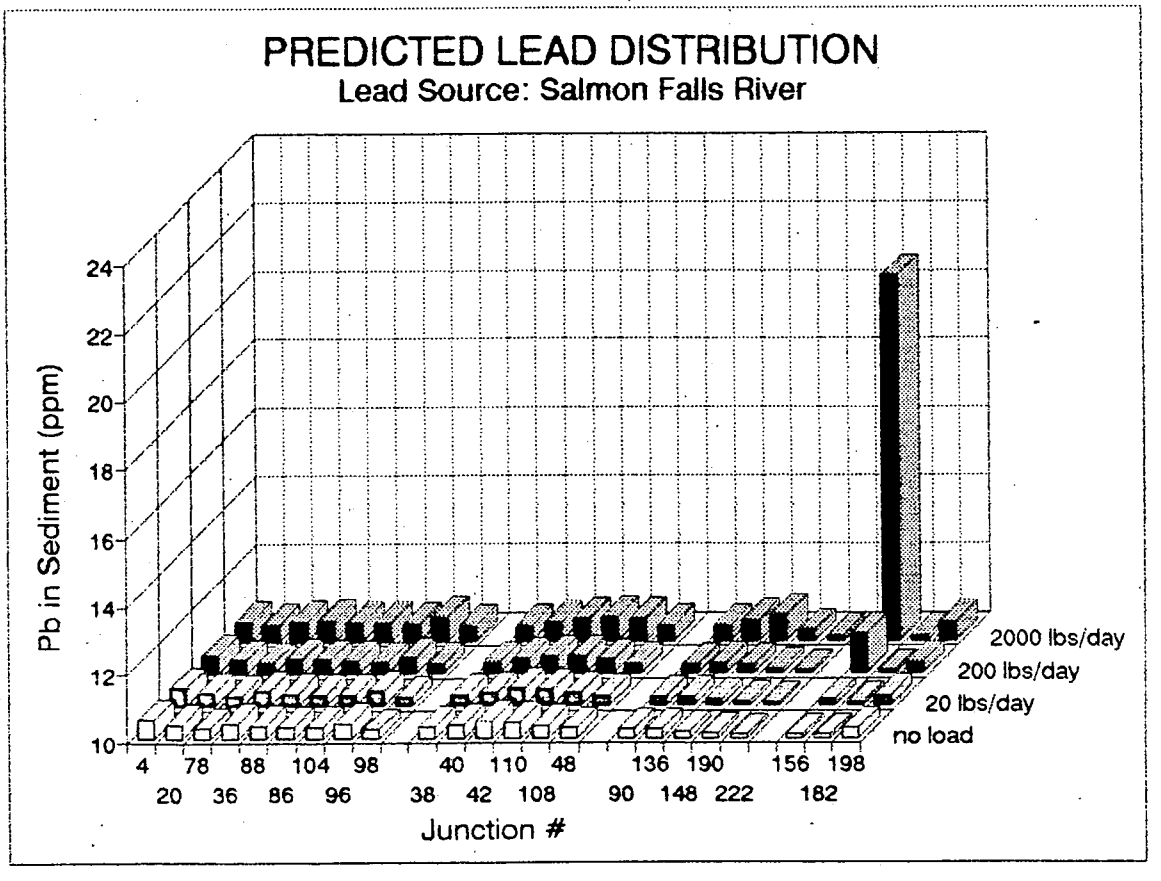

SEDIMENT ENRICHMENT OVER BACKGROUND
Lead Source: Pier No. 2
% Increase
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000 lbs/day
200 lbs/day
20 lbs/day
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

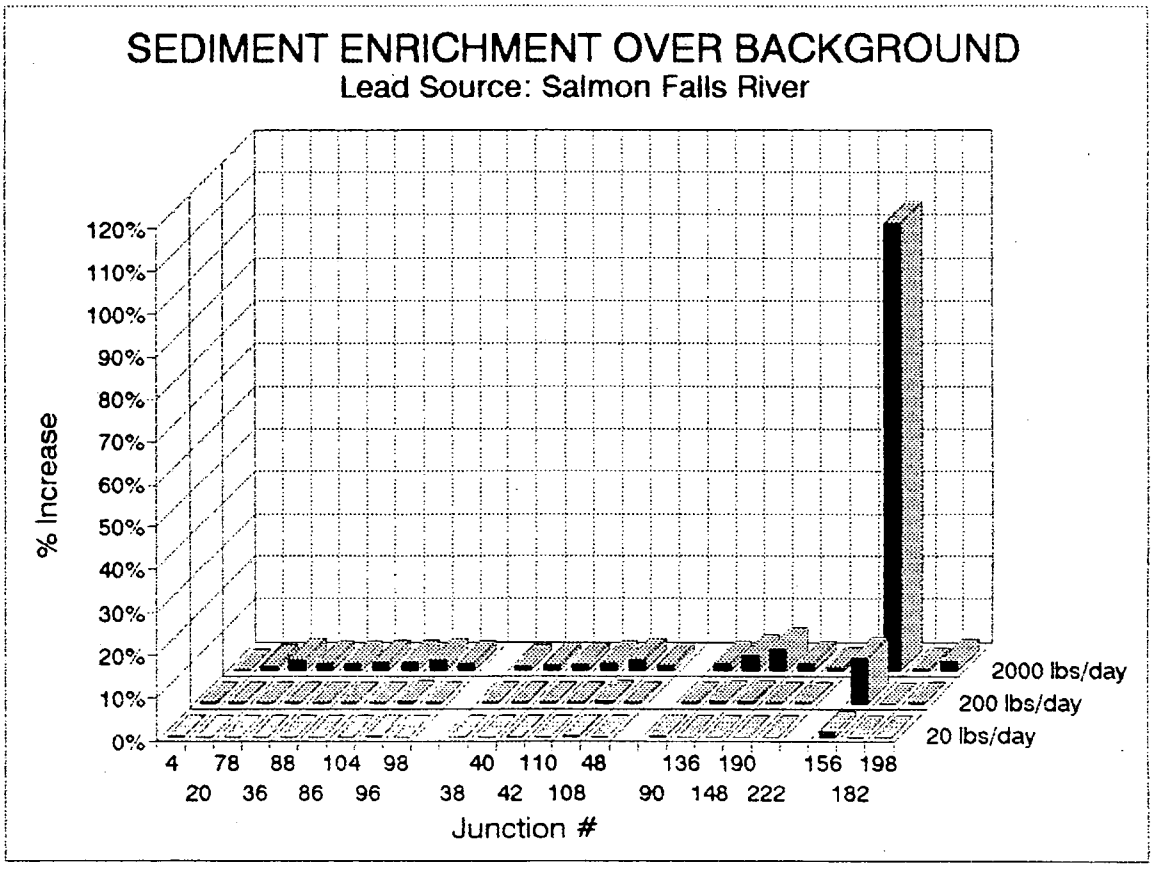

PREDICTED LEAD DISTRIBUTION
Lead Source: Clark Cove
Pb in Sediment (ppm)
24
22
20
18
16
14
12
10
2000 lbs/day
200 lbs/day
20 lbs/day
no load
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

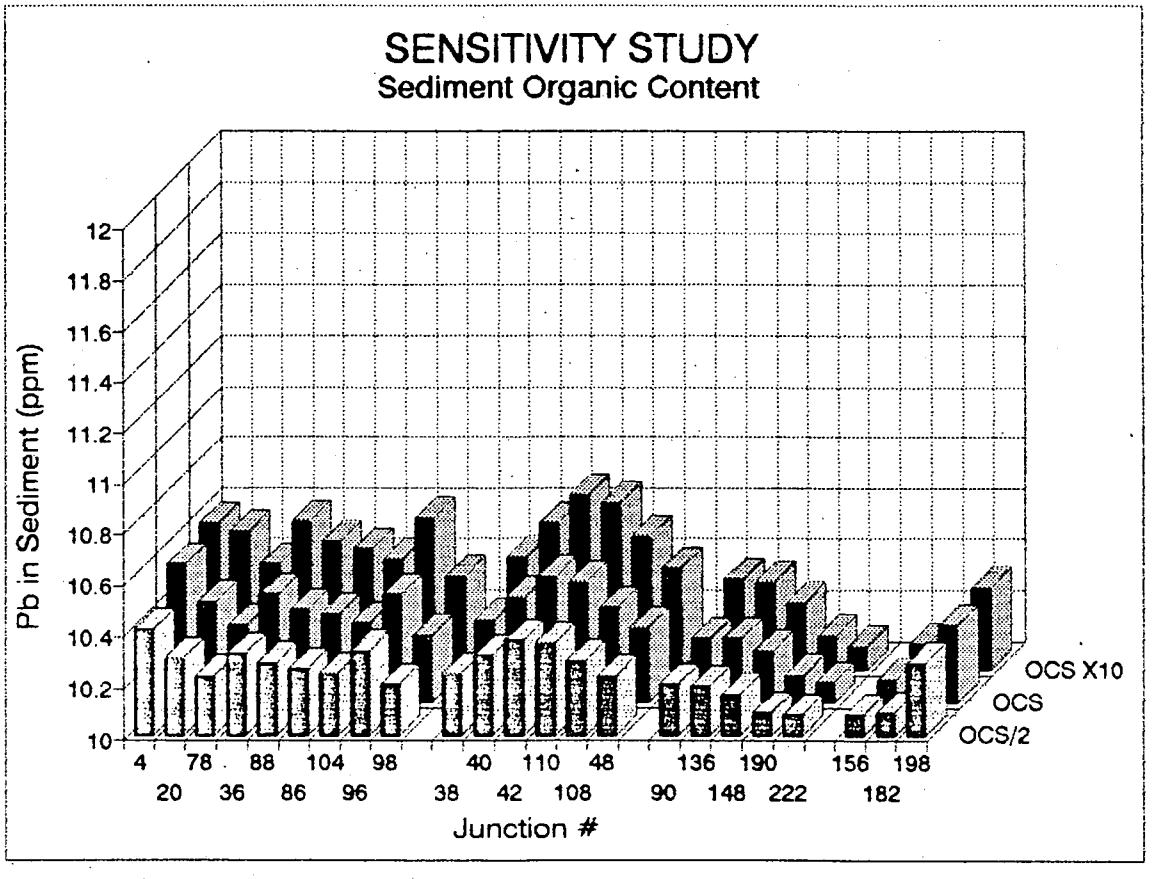

SEDIMENT ENRICHMENT OVER BACKGROUND
Lead Source: Clark Cove
% Increase
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000 lbs/day
200 lbs/day
20 lbs/day
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

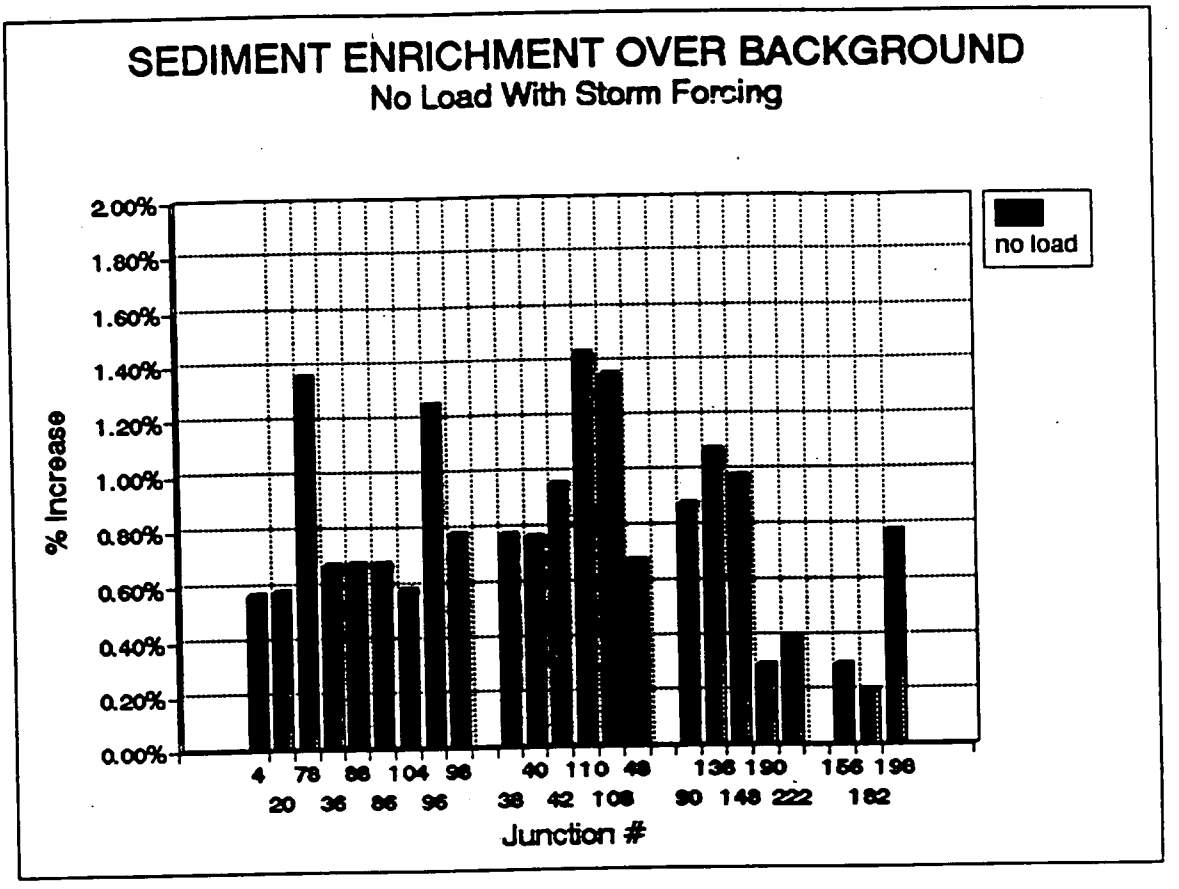

PREDICTED LEAD DISTRIBUTION
Lead Source: Back Channel
Pb in Sediment (ppm)
24
22
20
18
16
14
12
10
2000 lbs/day
200 lbs/day
20 lbs/day
no load
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

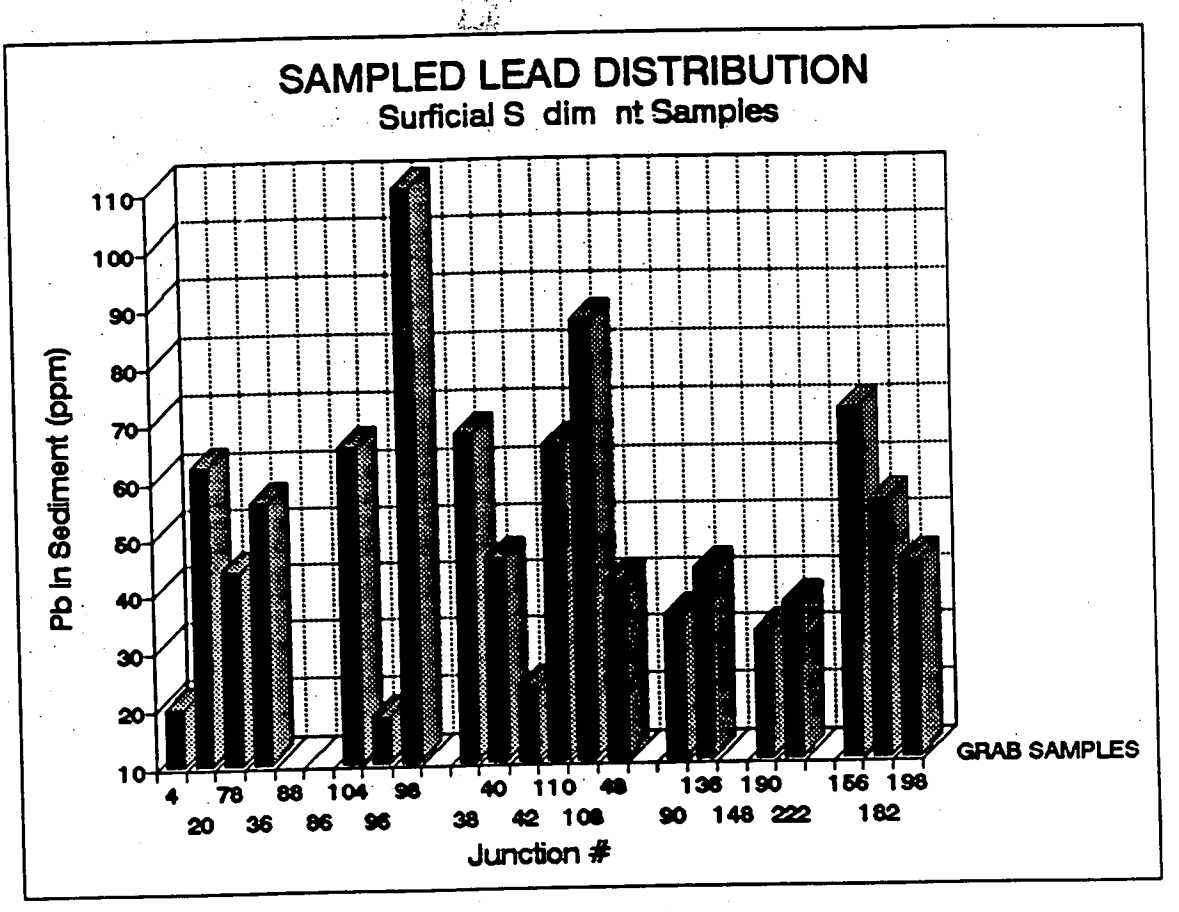

SEDIMENT ENRICHMENT OVER BACKGROUND
Lead Source: Back Channel
% Increase
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #
2000 lbs/day
200 lbs/day
20 lbs/day

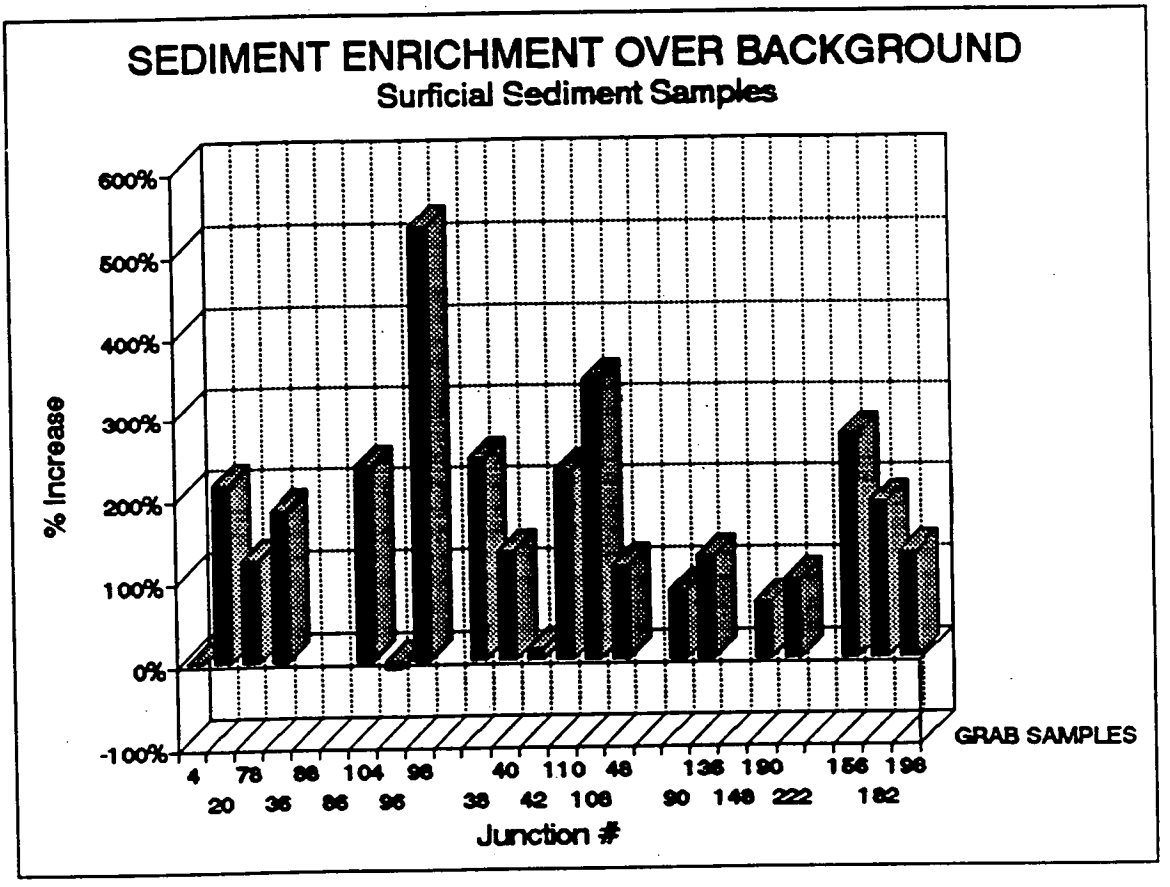

PREDICTED LEAD DISTRIBUTION
Lead Source: Salmon Falls River
Pb in Sediment (ppm)
24
22
20
18
16
14
12
10
2000 lbs/day
200 lbs/day
20 lbs/day
no load
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

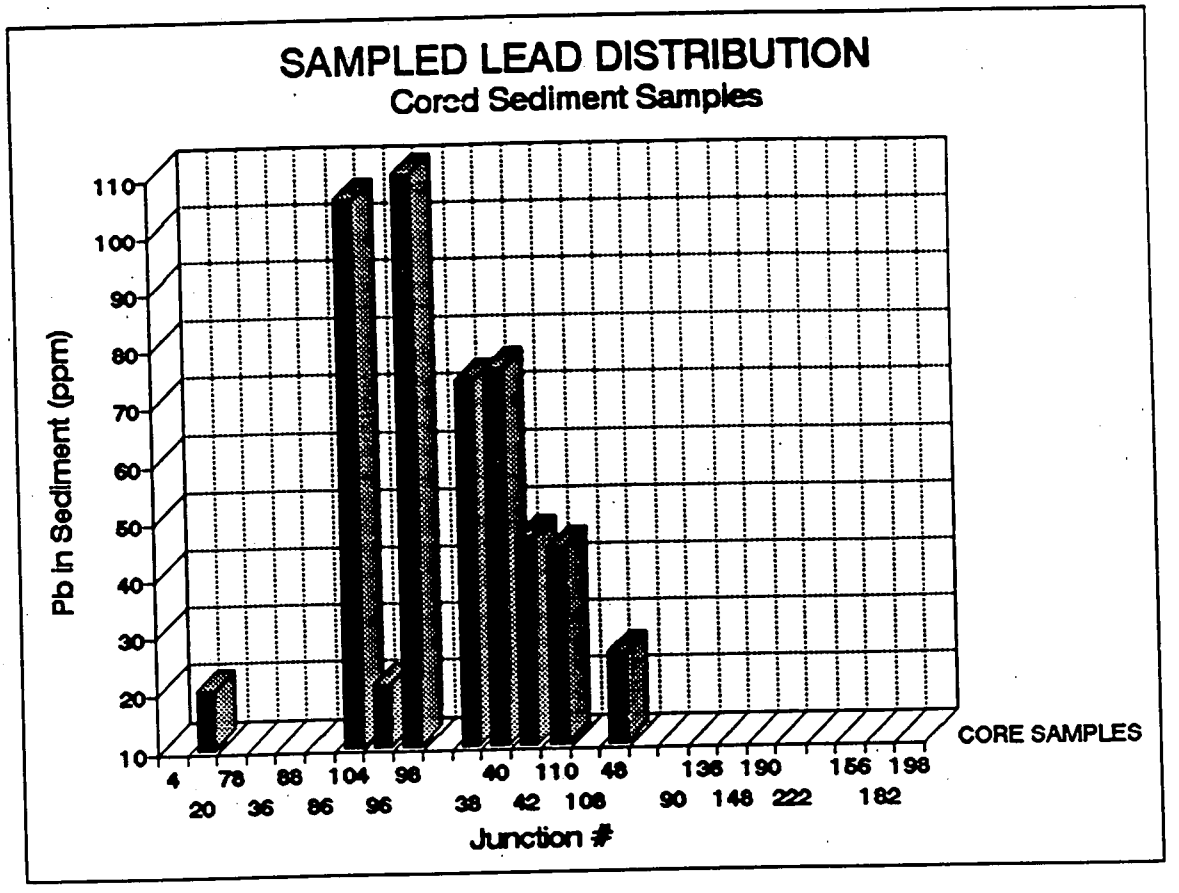

SEDIMENT ENRICHMENT OVER BACKGROUND
Lead Source: Salmon Falls River
% Increase
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000 lbs/day
200 lbs/day
20 lbs/day
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

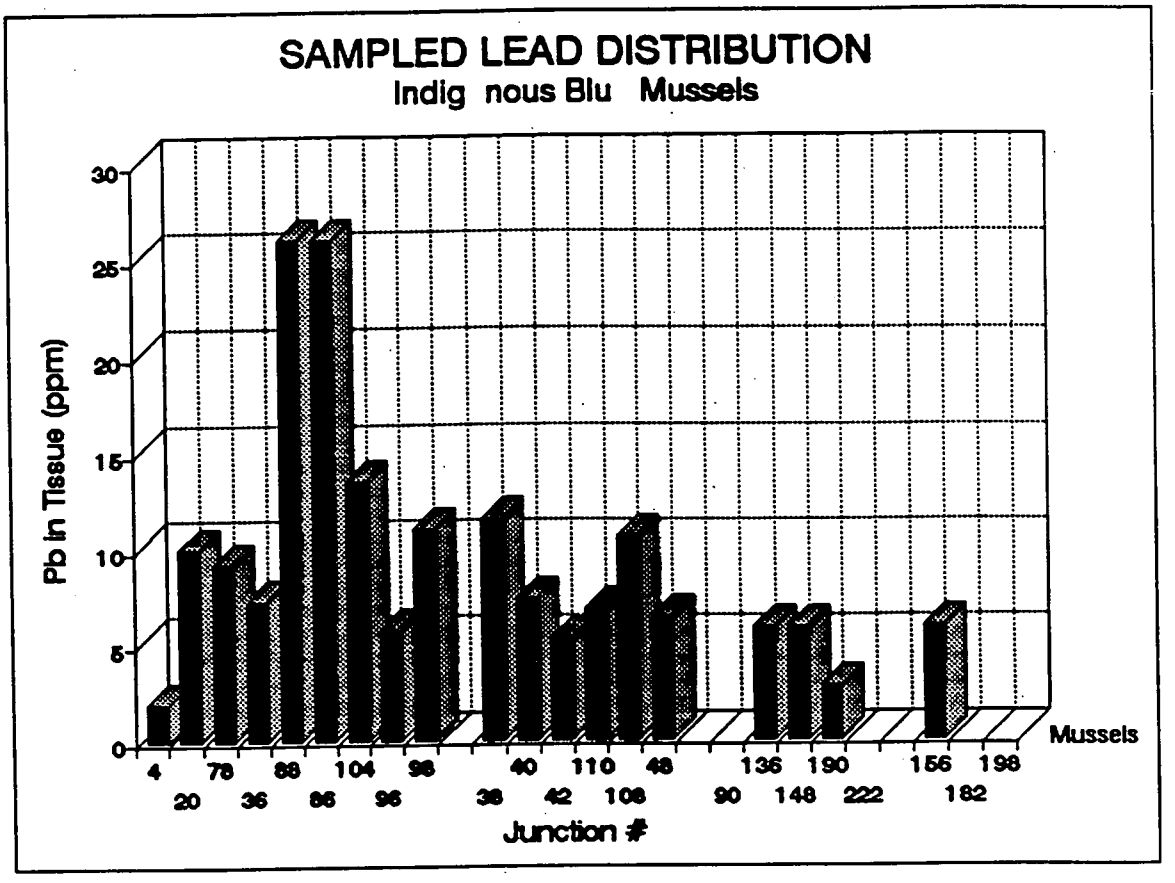

SENSITIVITY STUDY
Sediment Organic Content
Pb in Sediment (ppm)
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
10.2
10
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #
OCS X10
OCS
OCS/2

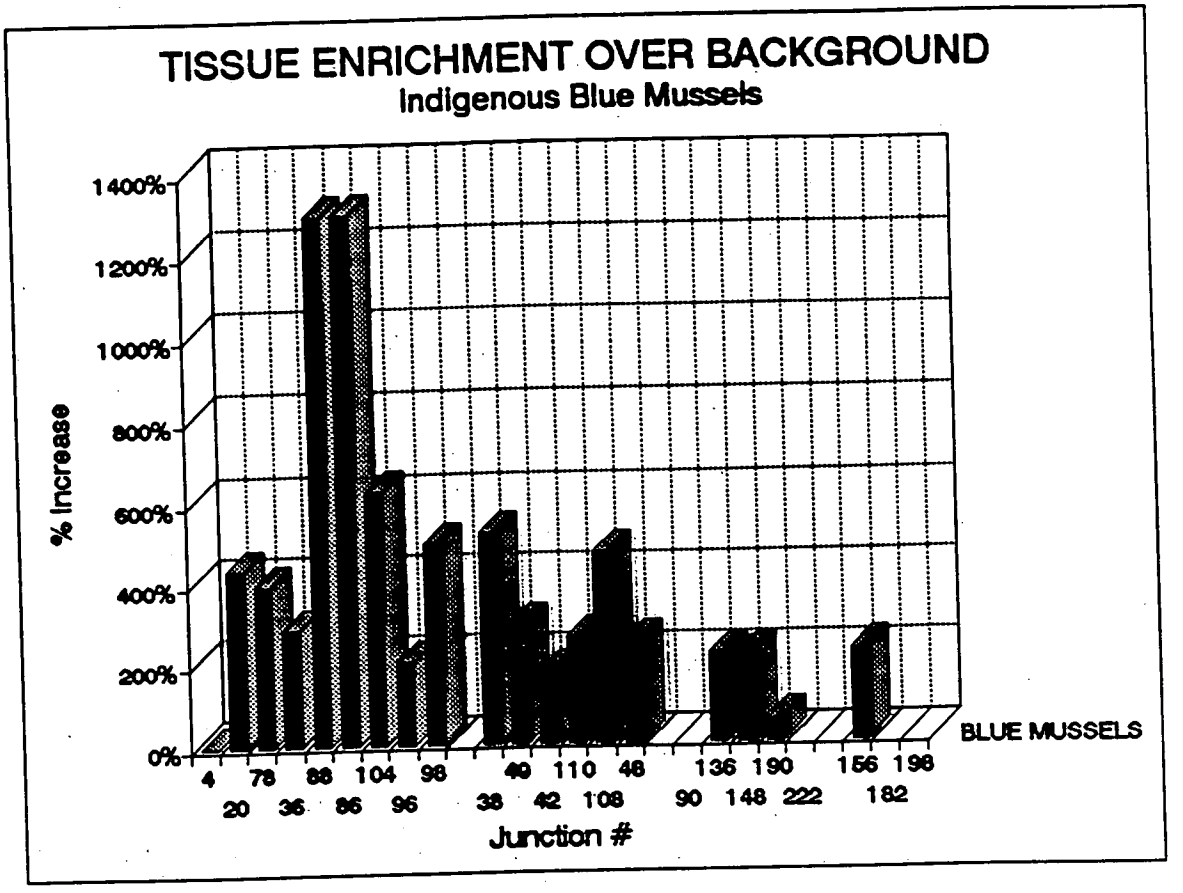

SEDIMENT ENRICHMENT OVER BACKGROUND
No Load With Storm Forcing
% Increase
2.00%
1.80%
1.60%
1.40%
1.20%
1.00%
0.80%
0.60%
0.40%
0.20%
0.00%
no load
4 78 88 104 96 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #

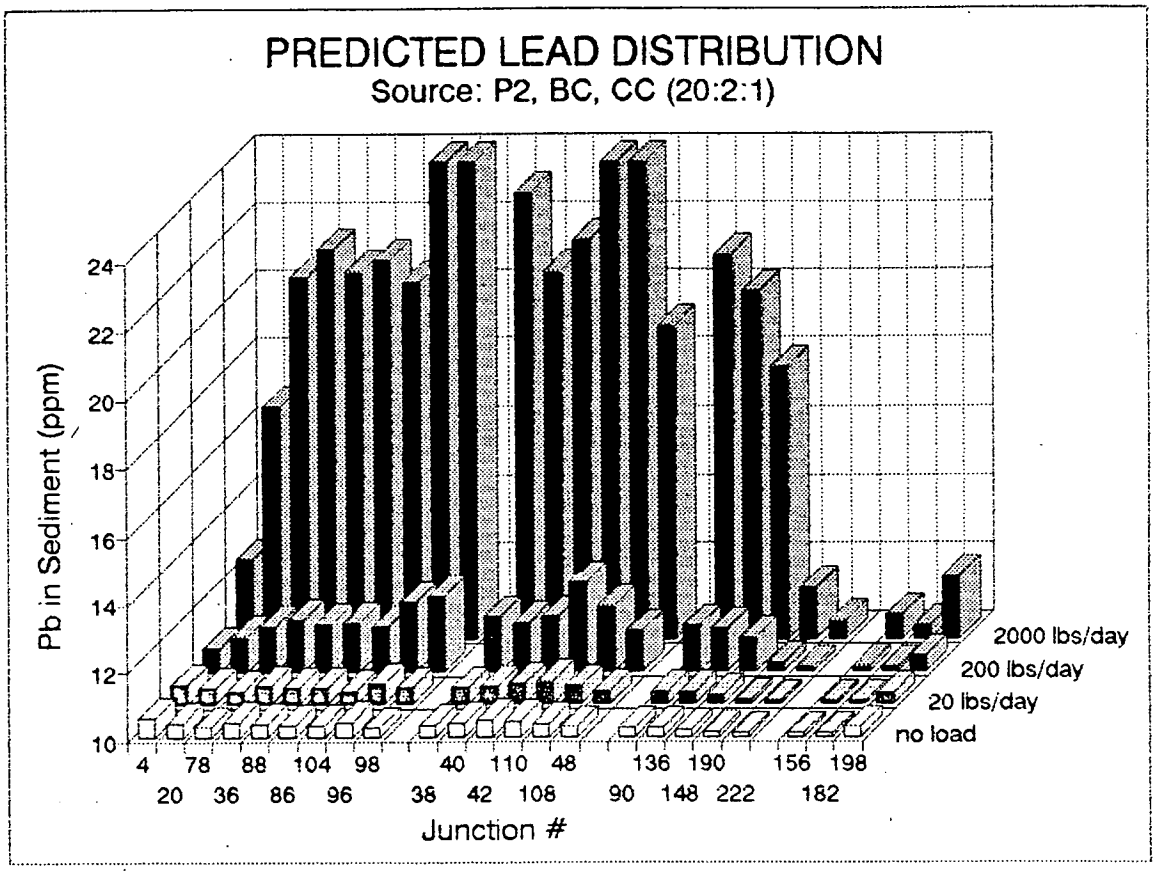

SAMPLED LEAD DISTRIBUTION
Surficial S dim nt Samples
Pb In Sediment (ppm)
110
100
90
80
70
60
50
40
30
20
10
4
20
78
36
88
86
104
96
98
40
38
110
42
48
108
136
90
190
148
222
156
182
198
GRAB SAMPLES
Junction #

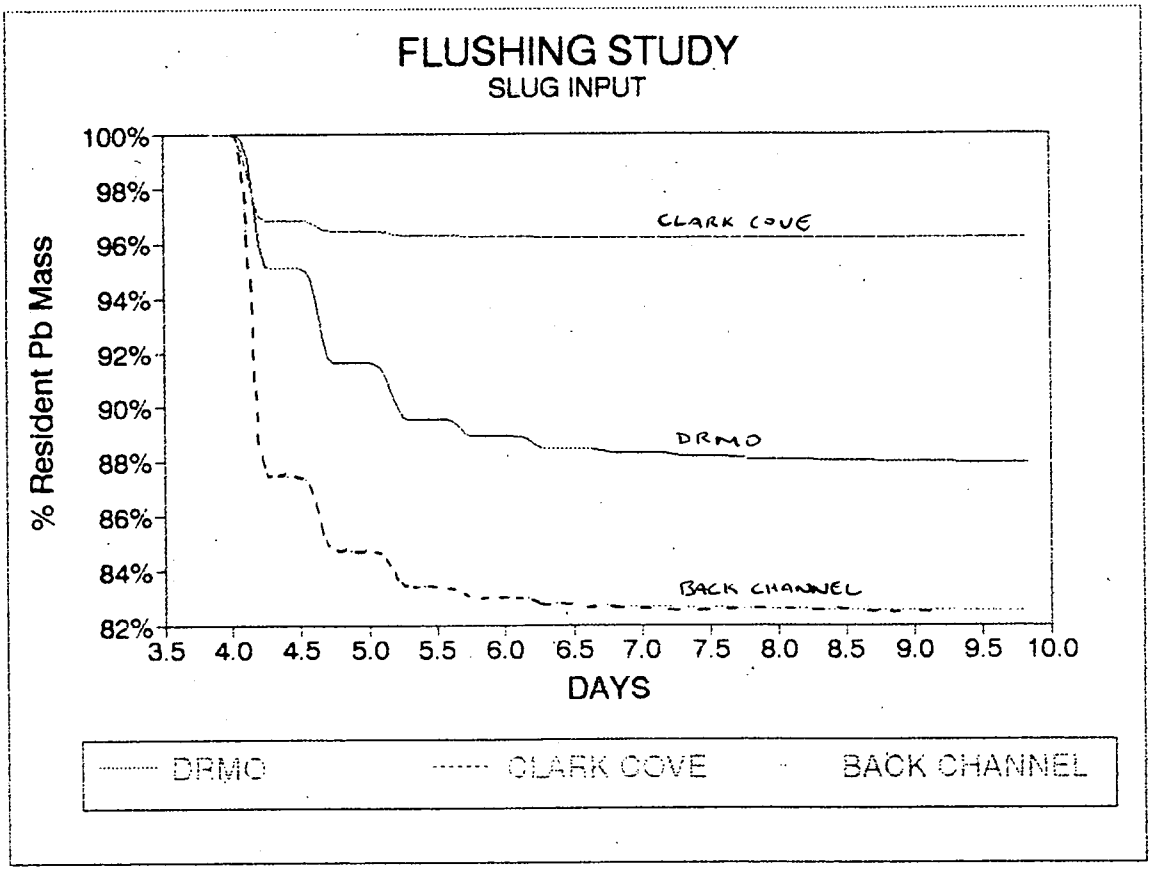

SEDIMENT ENRICHMENT OVER BACKGROUND
Surficial Sediment Samples
% Increase
600%
500%
400%
300%
200%
100%
0%
-100%
4 78 86 104 96 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #
GRAB SAMPLES


SAMPLED LEAD DISTRIBUTION
Cored Sediment Samples
Pb in Sediment (ppm)
110
100
90
80
70
60
50
40
30
20
10
4
78
88
104
98
40
110
48
136
190
156
198
20
36
86
96
38
42
108
90
148
222
182
Junction #
CORE SAMPLES


SAMPLED LEAD DISTRIBUTION
Indig nous Blu Mussels
Pb in Tissue (ppm)
30
25
20
15
10
5
0
4
20
78
36
88
86
104
96
98
38
40
42
110
108
48
90
136
148
190
222
156
182
198
Mussels
Junction #


TISSUE ENRICHMENT OVER BACKGROUND
Indigenous Blue Mussels
% Increase
1400%
1200%
1000%
800%
600%
400%
200%
0%
4
20
78
36
88
86
104
96
98
38
49
42
110
108
48
90
136
148
190
222
156
182
198
Junction #
BLUE MUSSELS


PREDICTED LEAD DISTRIBUTION
Source: P2, BC, CC (20:2:1)
Pb in Sediment (ppm)
24
22
20
18
16
14
12
10
2000 lbs/day
200 lbs/day
20 lbs/day
no load
4 78 88 104 98 40 110 48 136 190 156 198
20 36 86 96 38 42 108 90 148 222 182
Junction #


FLUSHING STUDY
SLUG INPUT
% Resident Pb Mass
100%
98%
96%
94%
92%
90%
88%
86%
84%
82%
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
DAYS
CLARK COVE
DRMO
BACK CHANNEL
DRMO
CLARK COVE
BACK CHANNEL

Summary

- Near-Field Problem.
- Clark Cove & Back Channel Sources.
- 2-3 day Flushing Time @ Shipyard.
- Little Impact from Upper Estuary Sites.

- ☐ Ground Water Model.
- ☐ Near-Field 2D Model.
- ☐ Introduce Biota into Model.
- ☐ Effect of Removing Clark Island Causeway

ESTUARINE ECOLOGICAL RISK ASSESSMENT FOR PORTSMOUTH NAVAL SHIPYARD:

ANALYSIS AND RISK SYNTHESIS

Wayne Munns, SAIC

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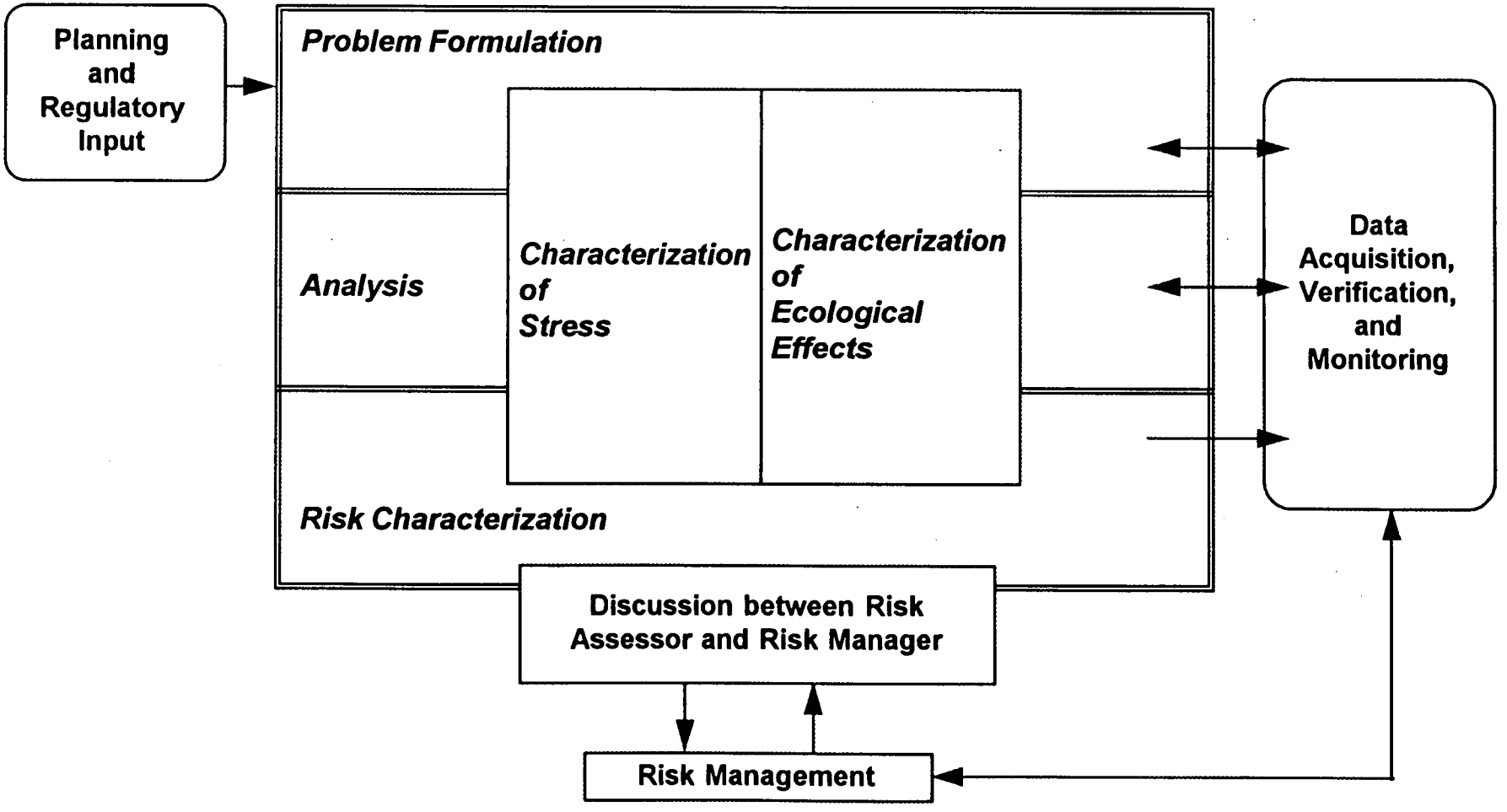
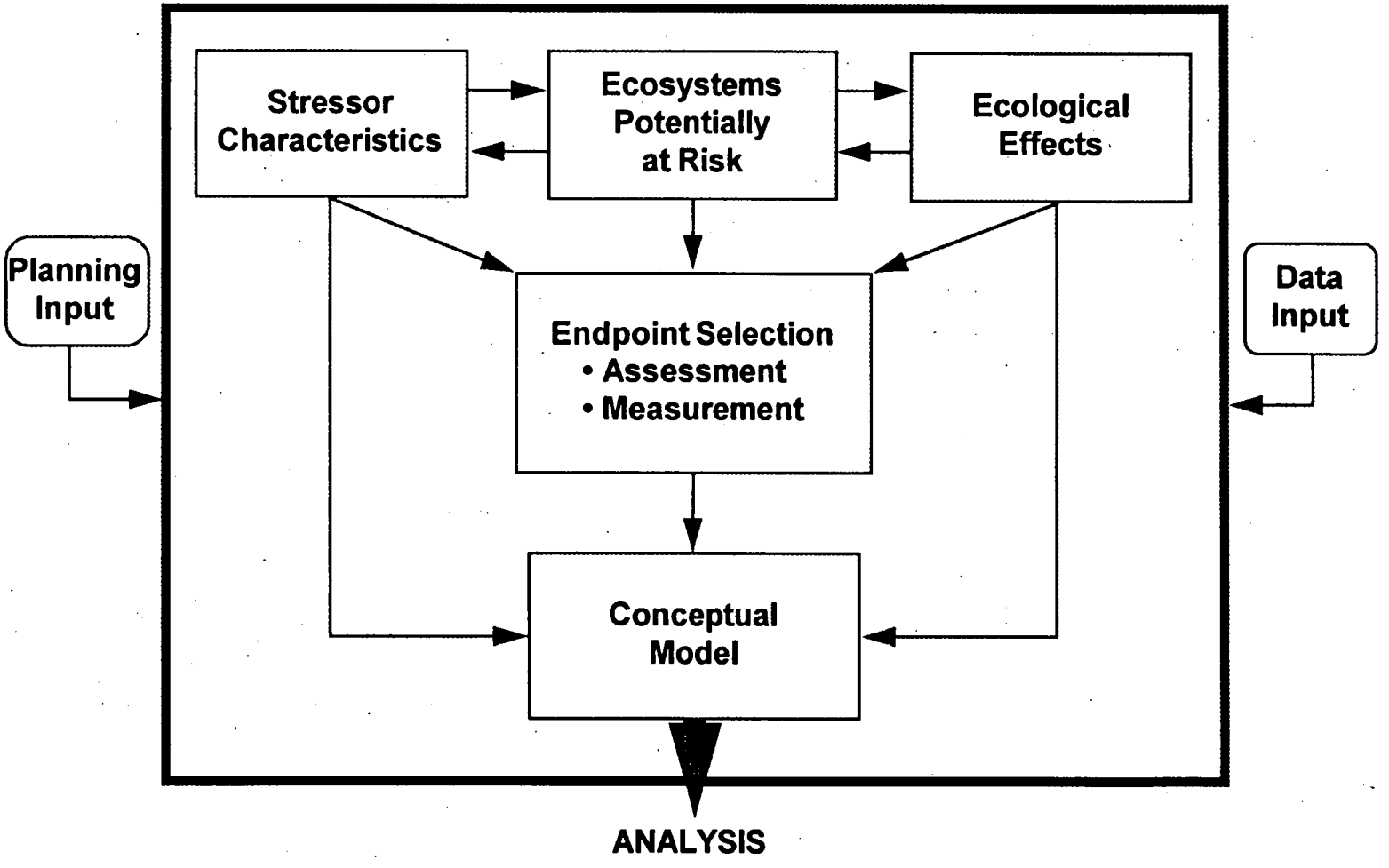
ERA FRAMEWORK



PROBLEM FORMULATION



INITIAL FIRST TIER CONCEPTUAL MODEL

ASSUMPTIONS

- Shipyard Sources (SWMUs)
  - ➢ Landfill, DRMO, CIA, Hg vaults
- Transport Routes to Estuarine System
  - ➢ ground water (primary for both sources)
  - ➢ surface water (primary for DRMO, secondary for Landfill)
  - ➢ wind (secondary for DRMO, tertiary for Landfill)
  - ➢ biological (important for neither)

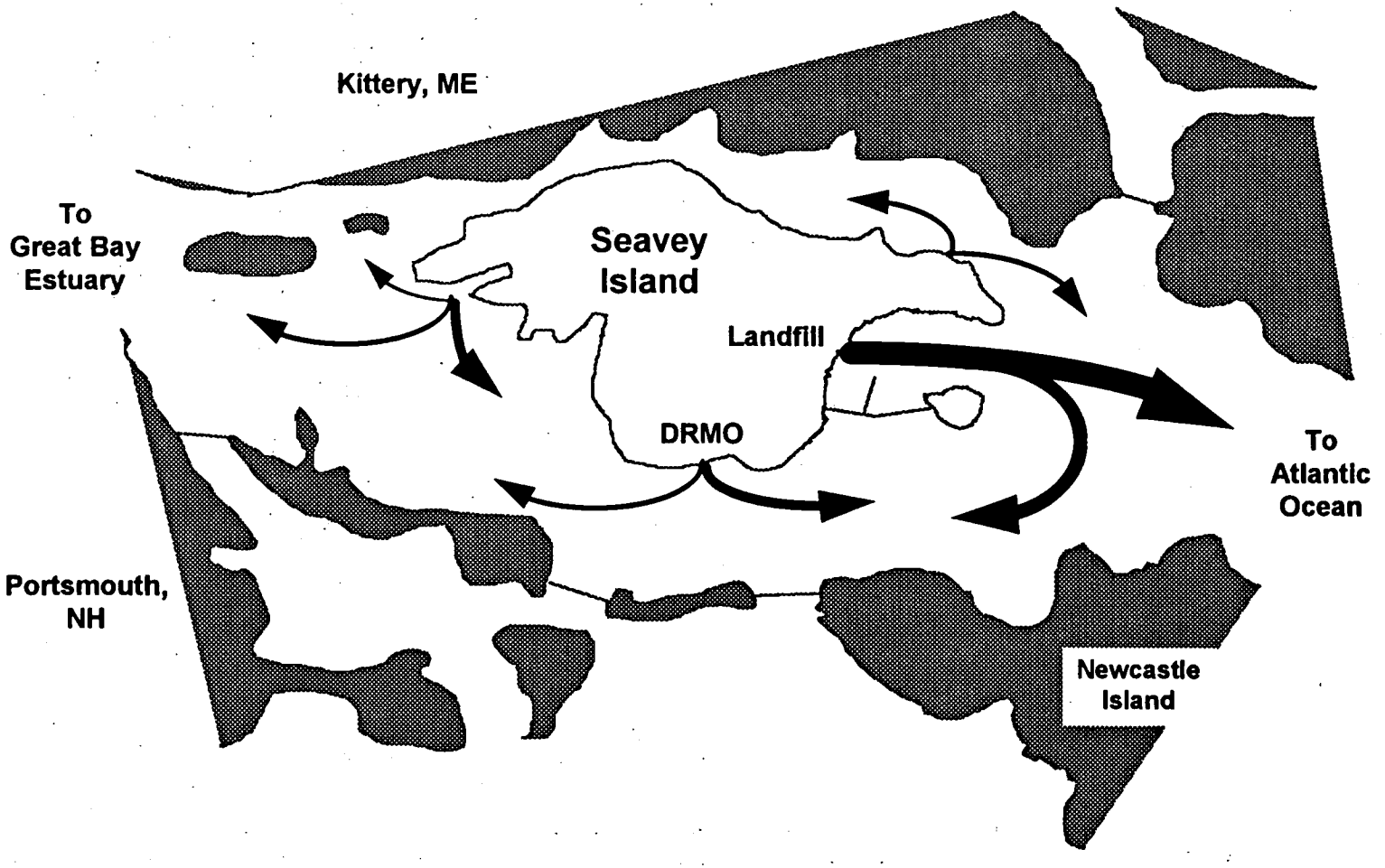
BOUNDARIES OF ASSESSMENT

- Estuarine waters of Piscataqua River and Great Bay Estuary
- Primary focus on lower Piscataqua River and Shipyard

DATA REQUIREMENTS

- Estimates of source strengths
- Estimates of mass fluxes

INITIAL FIRST TIER CONCEPTUAL MODEL
Sources and Transport of Contaminants



INITIAL SECOND TIER CONCEPTUAL MODEL

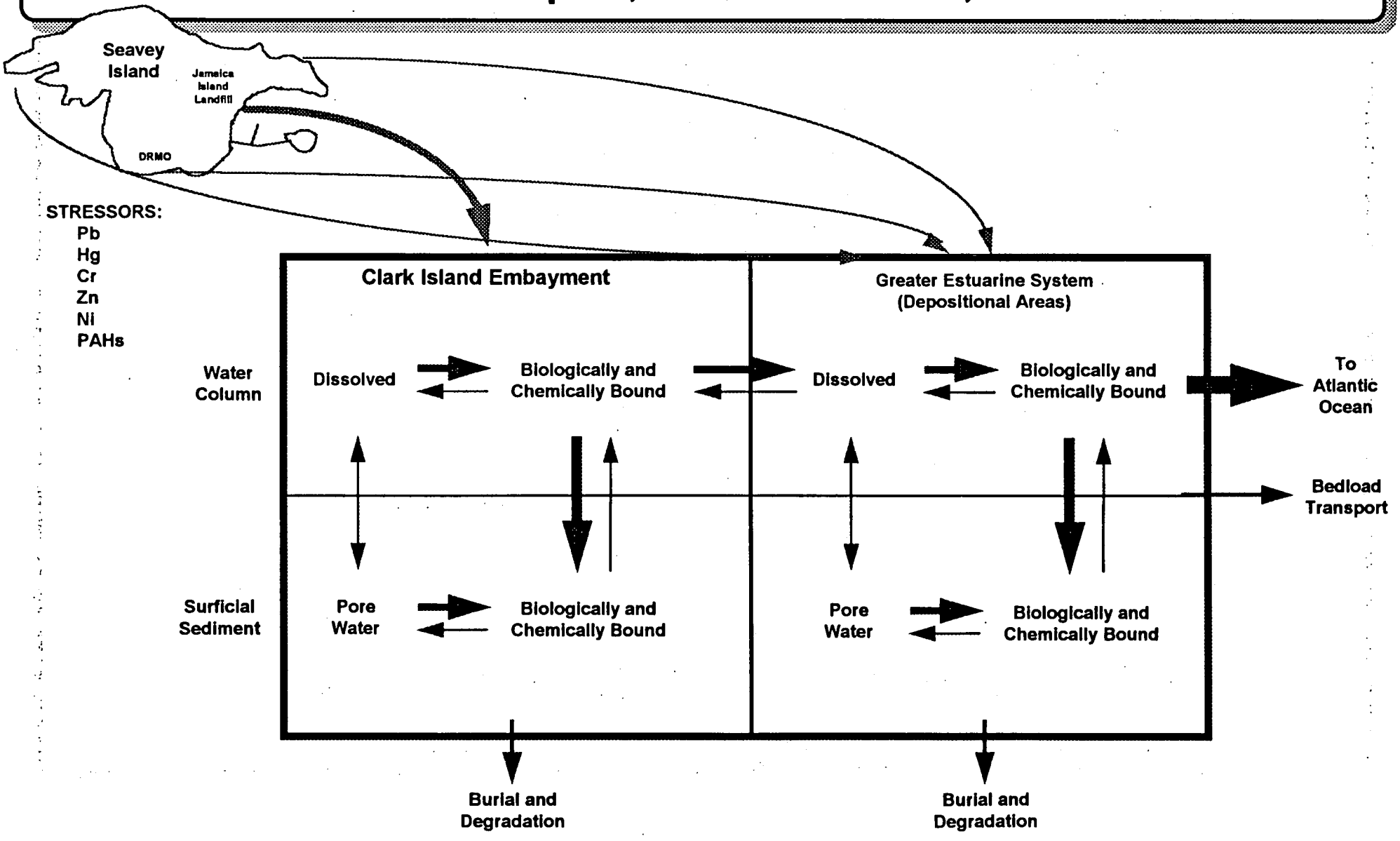
ASSUMPTIONS

- Source Compartments
  - ➢ water
  - ➢ sediments
  - ➢ biota
- Transport Routes
  - ➢ dissolved transport
  - ➢ particle transport
  - ➢ biological transport

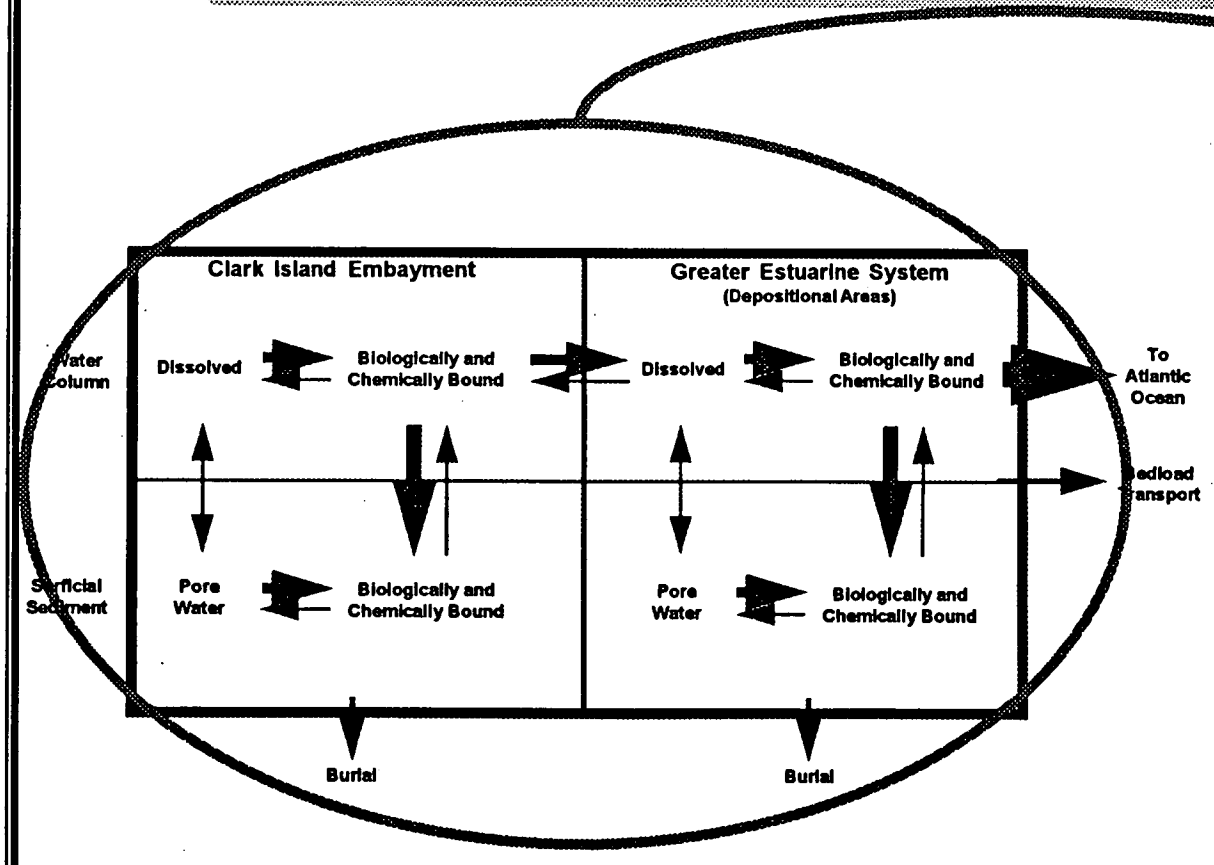
DATA REQUIREMENTS

- Estimates of compartmental concentrations
- Estimates of transport rates (dissolved, particle-bound, biological)
- Estimates of bioavailability and bioaccumulation
- Estimates of burial and degradation rates
- Estimates of effects

INITIAL SECOND TIER CONCEPTUAL MODEL
Stressor Transport, Transformation, and Fate



ESTUARINE ECOSYSTEMS AT RISK



GREATER ESTUARINE SYSTEM

- Pelagic Communities
  - phytoplankton
  - zooplankton
  - fish
- Benthic Communities
  - infauna
  - epifauna and epiflora
- Eelgrass Communities
  - eelgrass
  - lobster
  - infauna
  - epifauna and epiflora
- Salt Marsh Communities

ASSESSMENT ENDPOINTS

STRESSOR CHARACTERIZATION

Stressor Transport, Transformation, and Fate (Physical, Chemical, Biological)

Water Quality

Sediment Quality

EFFECTS CHARACTERIZATION

Health of Eelgrass

Health of Salt Marshes

Health of Macroalgae

Health of Benthic Community

Health of Pelagic Community

Status of Natural Resource Species

MEASUREMENT ENDPOINTS

STRESSOR CHARACTERIZATION

Hydrographic and Geological Attributes of Water Column and Sediments

Stessor Concentrations in Sediment, Water, and Biota

Stressor Source Strengths

Current Velocities and Flow Rates

Stressor Transport Rates and Fates

Sediment Depositional Rates

EFFECTS CHARACTERIZATION

Eelgrass Morphometrics and Population Status

Salt Marsh Morphometrics and Population Status

Benthic Community Status

Lobster Population Status

Flounder Population Status

Mussel Population Status

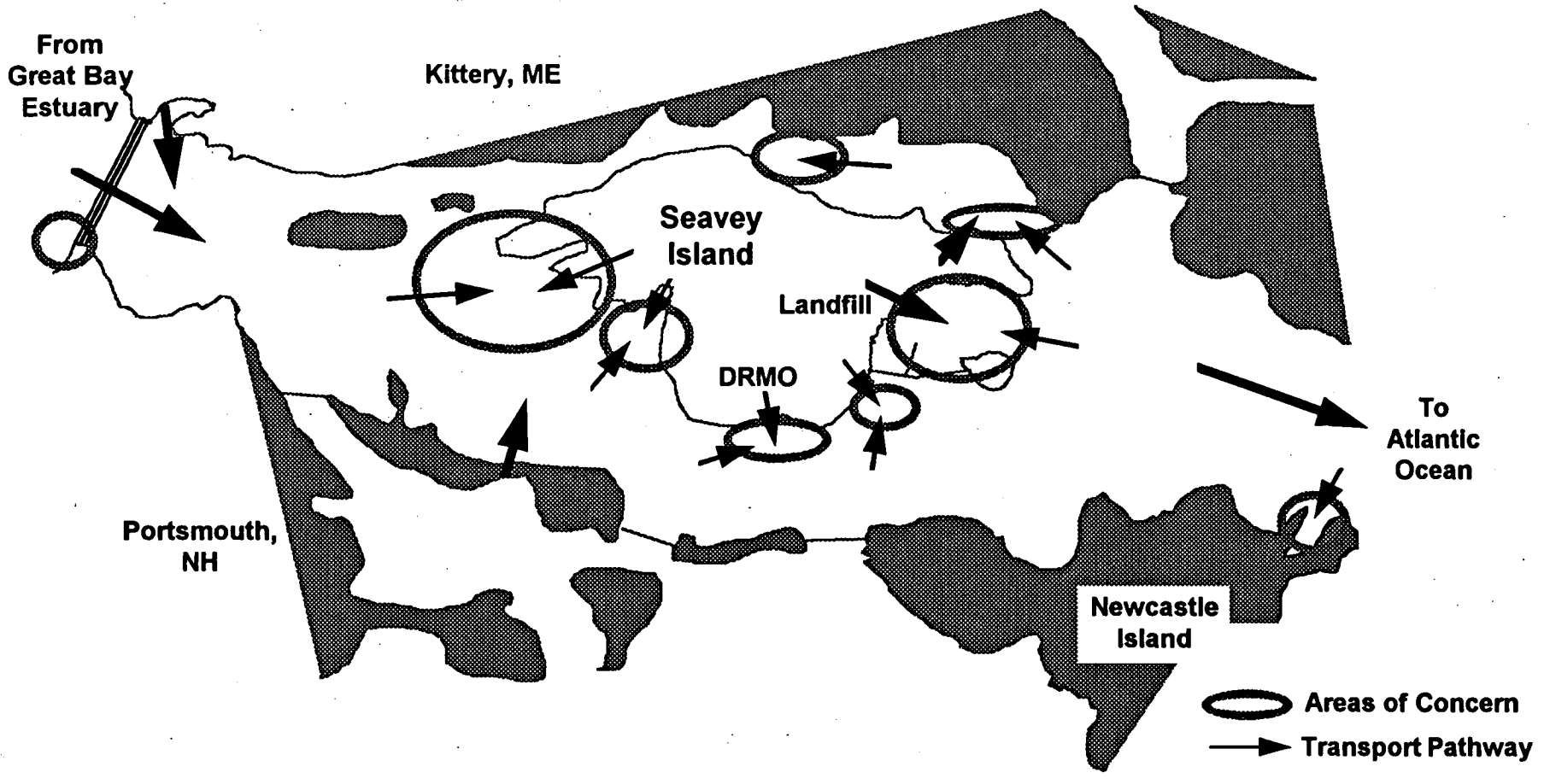
Alga Population Status

Water Toxicity to Urchin Gametes

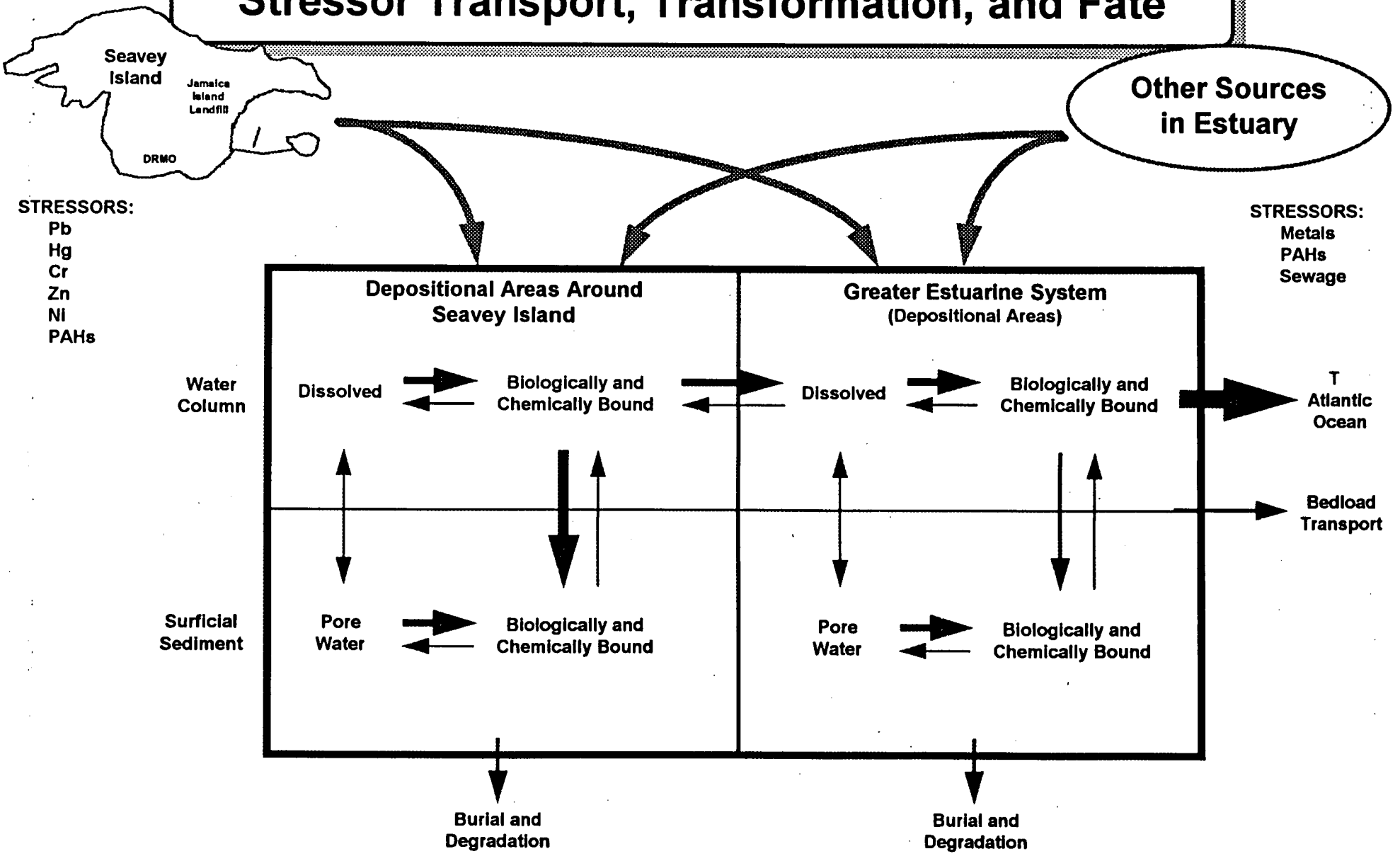
Water Toxicity to Mussel Physiology

Sediment Toxicity to Amphipods

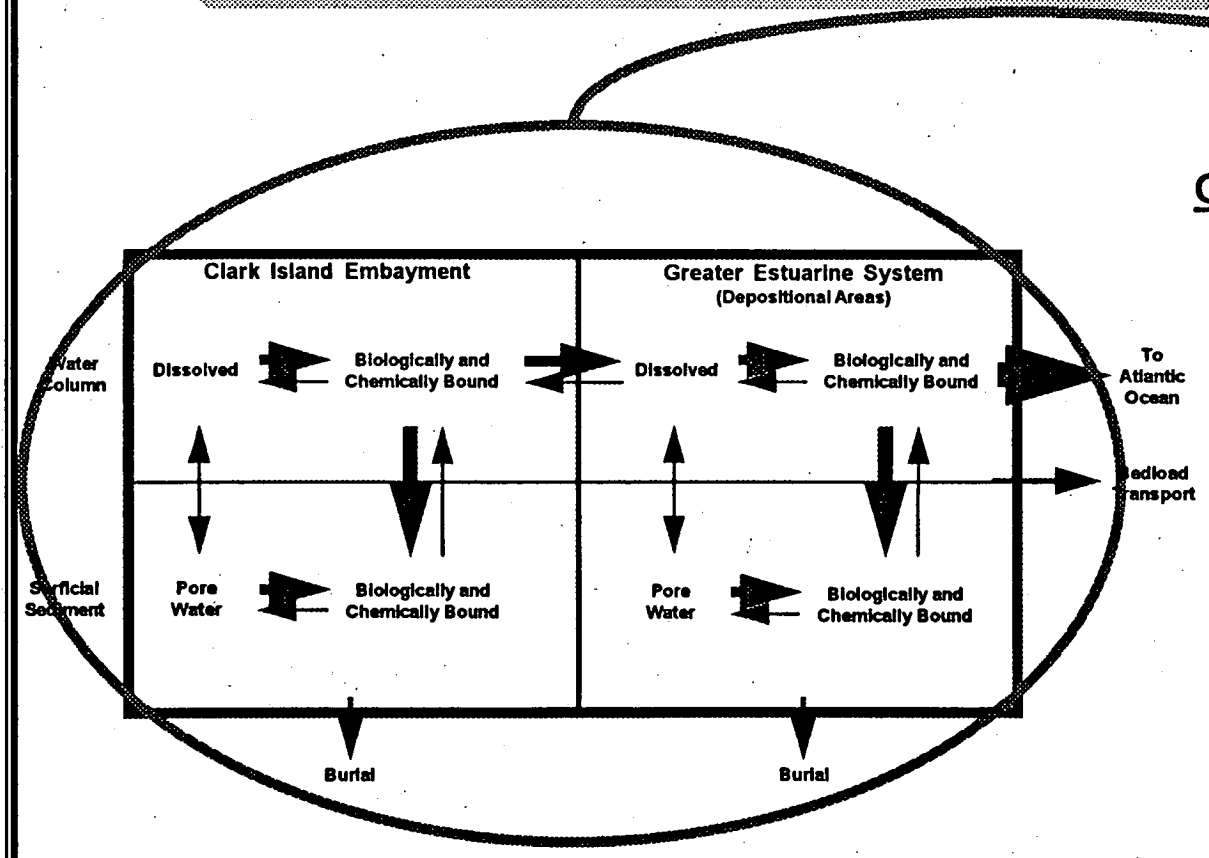
REVISED FIRST TIER CONCEPTUAL MODEL
Sources and Transport of Contaminants



REVISED SECOND TIER CONCEPTUAL MODEL
Stressor Transport, Transformation, and Fate



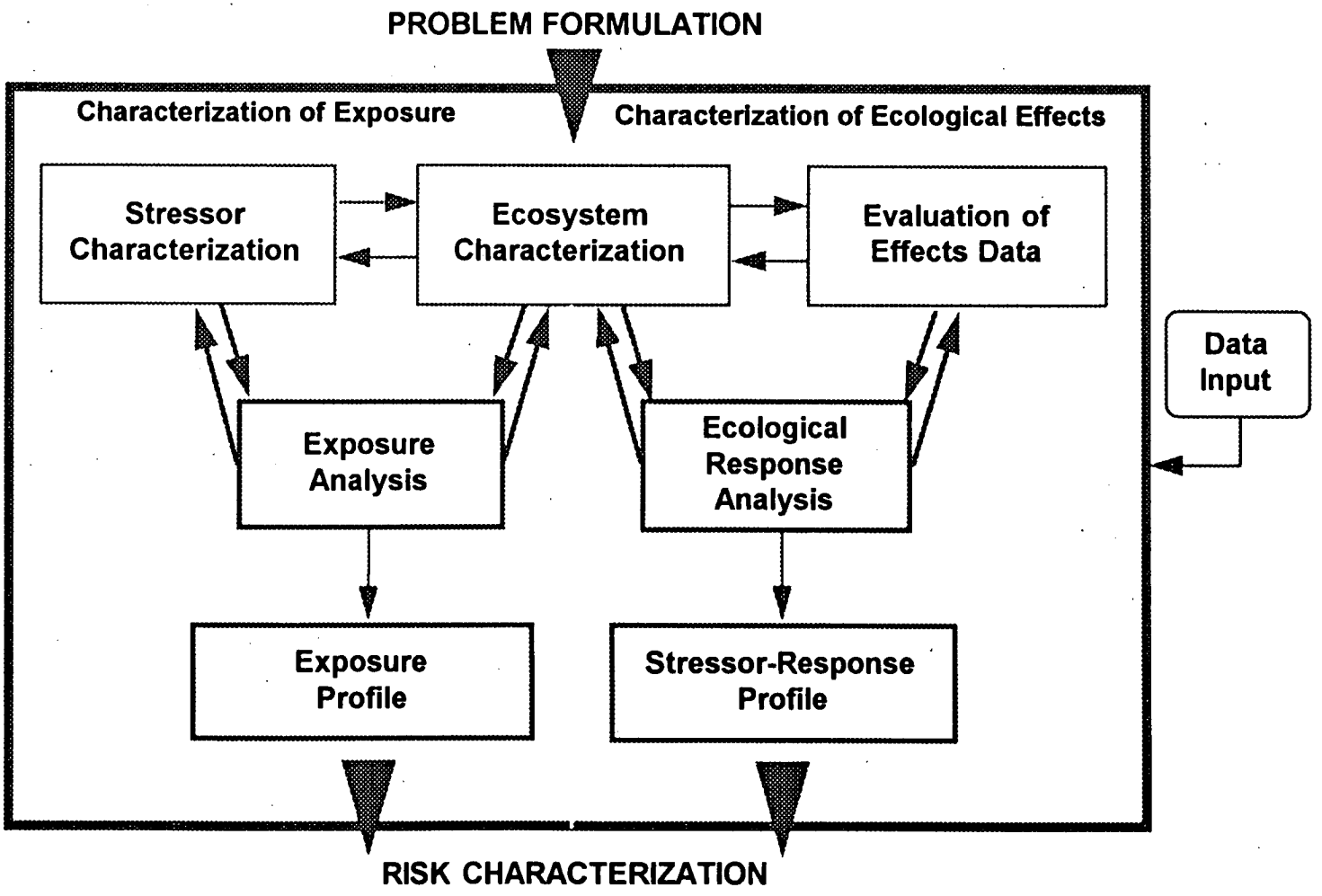
ESTUARINE ECOSYSTEMS AT RISK



GREATER ESTUARINE SYSTEM

- Pelagic Communities
  - perhaps fish (data gap)
  - perhaps impact to larvae
- Benthic Communities
  - infauna (exposure, high densities)
  - epifauna and epiflora (exposure, data gap)
- Eelgrass Communities
  - perhaps (exposure, chemical release)
- Salt Marsh Communities
  - ??? (data gap)

ANALYSIS


PROBLEM FORMULATION
Characterization of Exposure
Characterization of Ecological Effects
Stressor Characterization
Ecosystem Characterization
Evaluation of Effects Data
Data Input
Exposure Analysis
Ecological Response Analysis
Exposure Profile
Stressor-Response Profile
RISK CHARACTERIZATION

ANALYSIS ACTIVITIES

EXPOSURE CHARACTERIZATION

Collection of Hydrographic Data

Implementation and Calibration of DYNHYD

Development of Contaminant Transfer Model (DYNHYD/TOXIWASP)

Development of Sediment Distribution Map

Evaluation of Past Stressor Loadings

Quantification of Current Source Strengths, Evaluation of Past Source Strengths

Quantification of Stressor Concentrations in Water, Sediment, and Biota

Development of a Trophic Transf r Mod l

EFFECTS CHARACTERIZATION

Extant Impact Assessment

Conduct of Stressor-Response Laboratory Investigations

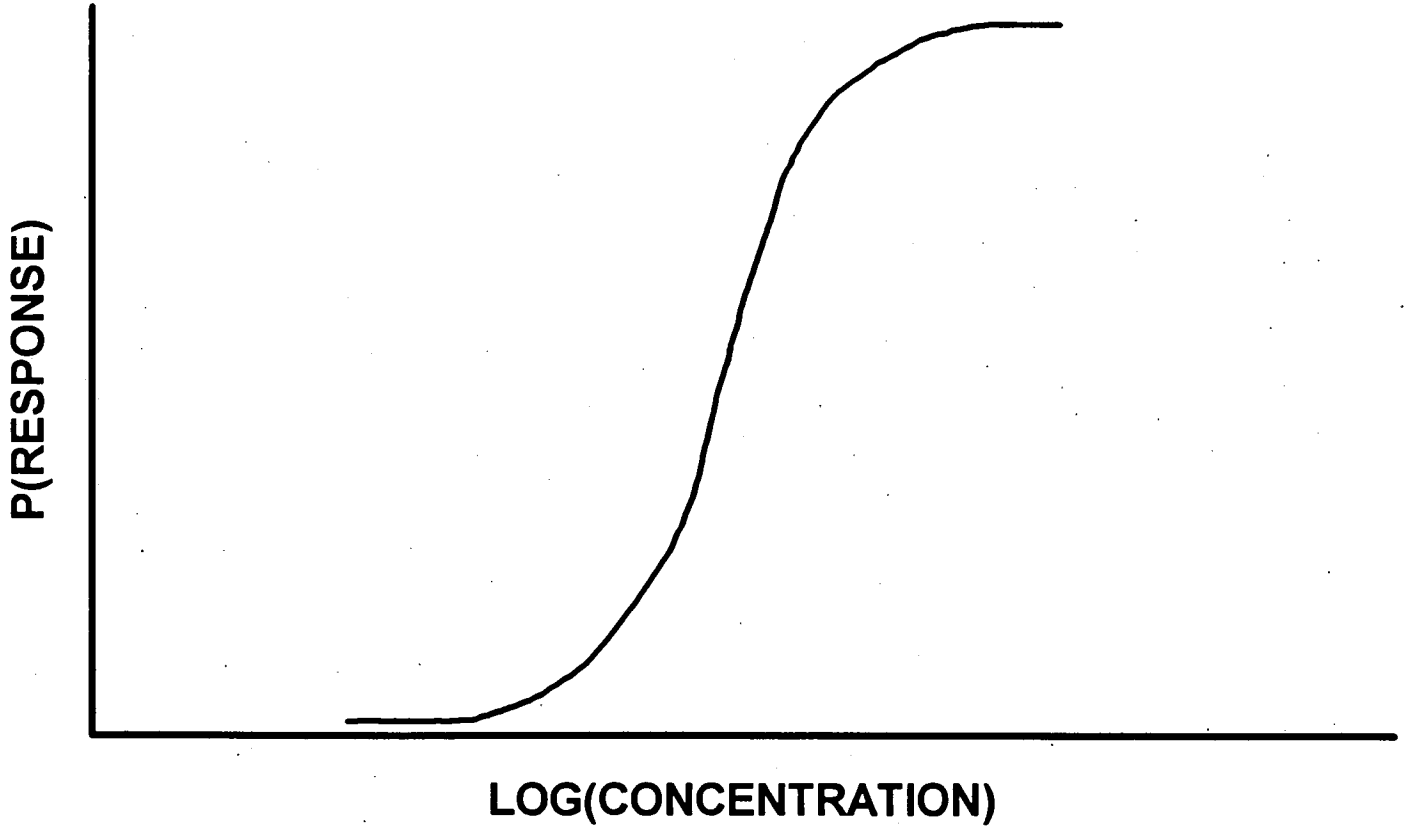
Development of Stressor-Response Models for Benthic and Pelagic Systems

Evaluate Bioaccumulation and Trophic Transfer through Laboratory investigations

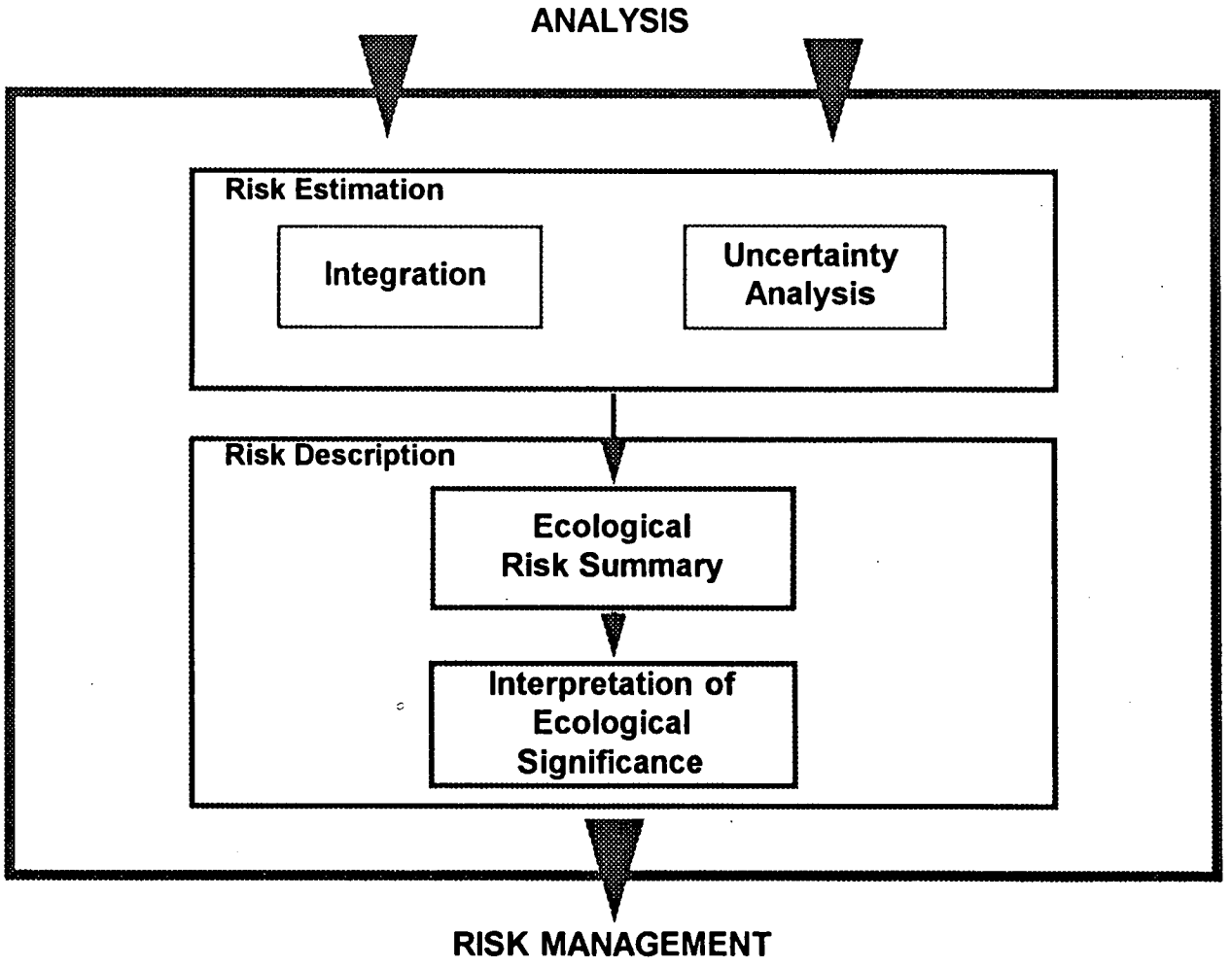
STRESSOR-RESPONSE PROFILES

- Pb as stressor
  - bedded sediment
  - suspended sediment
  - food
- Responses of indicators of systems at risk
  - toxicity and population dynamics of *Arbacia* from suspended sediment and trophic routes
  - toxicity to *Ampelisca* from bedded sediment
  - toxicity to *Ruppia* from bedded sediment (and water)
  - bioaccummulation in *Zostera* and *Ruppia* from bedded sediment
  - bioaccumulation in *Mytilus* from suspended sediment

STRESSOR-RESPONSE MODEL



RISK CHARACTERIZATION



RISK CHARACTERIZATION ACTIVITIES

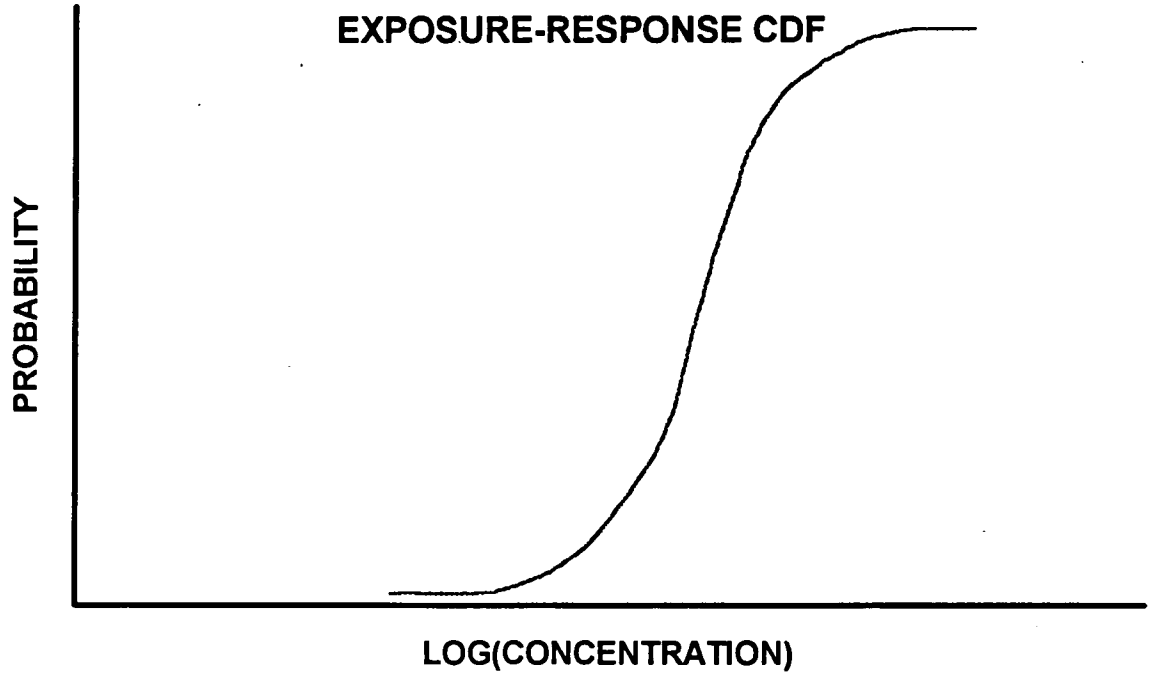
RISKS TO ECOLOGICAL SYSTEMS

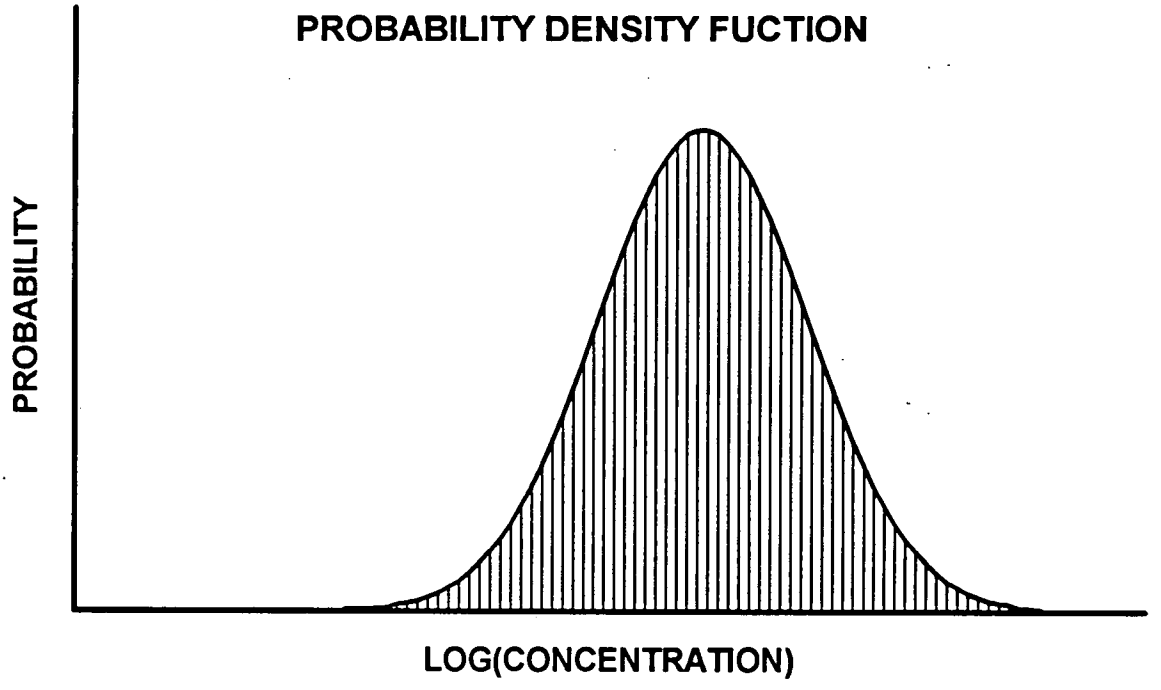
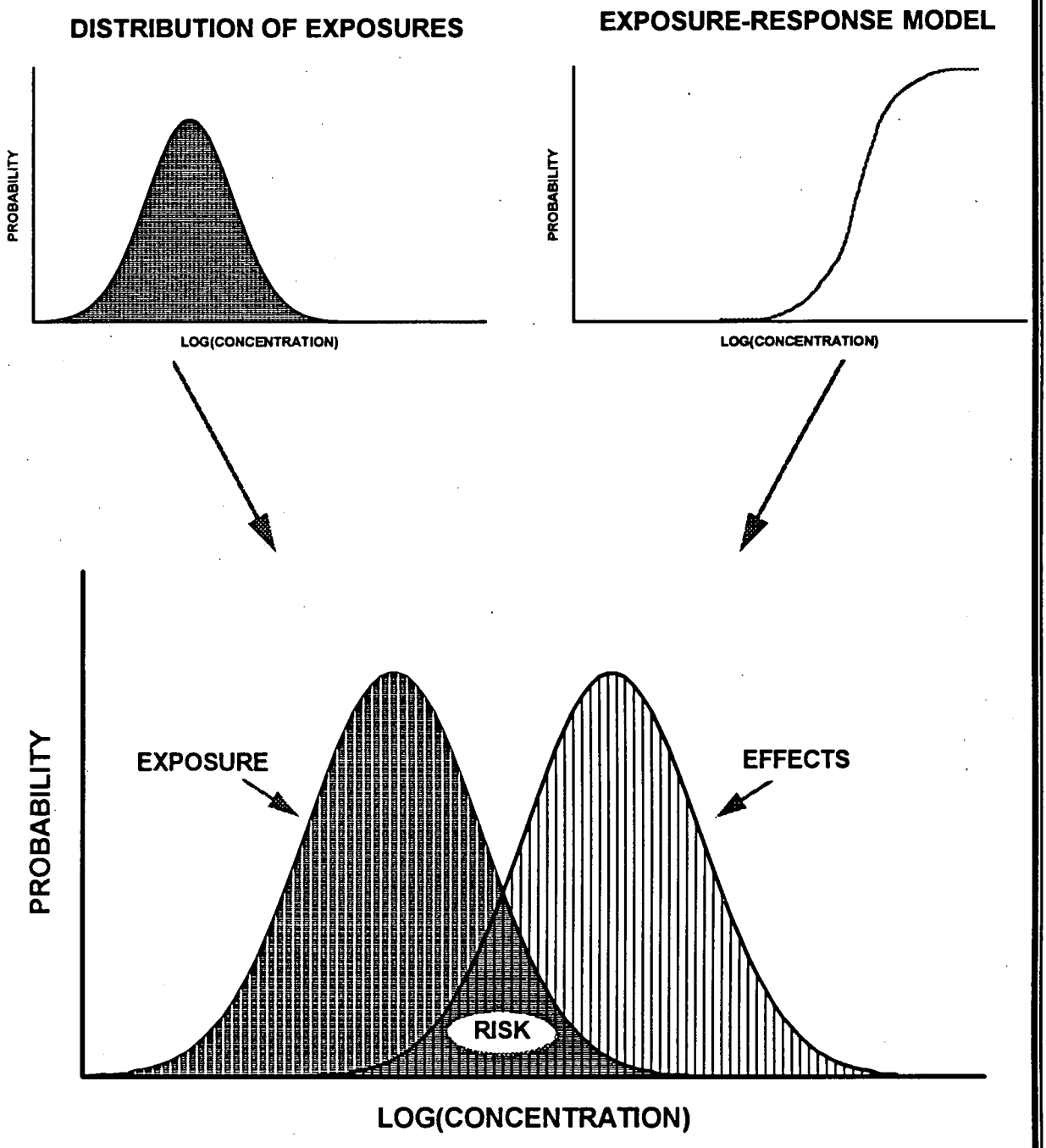
- Incorporate Phase I Findings
- Predict Current and Past Loadings to Depositional Areas
- Develop Scenarios of Future Loadings to Depositional Areas (?)
- Translate Stressor Concentrations to Responses of Benthic and Pelagic Communities
- Incorporate Uncertainity in Risk Calculations for Each Depositional Area (?)
- Incorporate Variability in Risk Characterization for Larger Areas (Lower Piscataqua, Upper Estuary)

RISKS TO ESTUARINE CONSUMERS

- Quantify and Predict Bioaccumulation and Trophic Transfer
- Relate Tissue Burdens to Observed Effects

DISTRIBUTIONS OF RESPONSE THRESHOLDS





RISK AS A JOINT PROBABILITY