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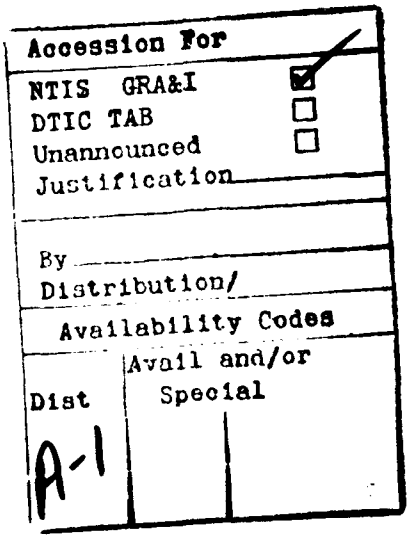

MARINE ECOLOGICAL RISK ASSESSMENT PILOT STUDY FOR ALLEN HARBOR, NARRAGANSETT BAY, RHODE ISLAND[1]

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ABSTRACT

An ecological risk assessment framework was applied to characterize aquatic risks associated with hazardous waste disposal at Naval Construction Battalion Center (NCBC) Davisville, RI. An initial screening phase (I) assessed exposure and related that exposure to toxicological endpoints for bivalves, amphipods, sea urchins, and biomarker assays. Results showed little evidence of major contamination in sediments or tissues except for relatively high levels of polychlorinated biphenols (PBC), butyltin compounds (TBT), and fecal coliforms observed in Allen Harbor. Effects were detected in mussel physiology, sea urchin fertilization and development, biomarker responses, and soft shell clam histology. Possible sources of contamination and toxicity from the landfill leachate, surface runoff, and recreational boating were examined using a temporal and spatial sampling scheme (Phase II). Chemical and toxicological information obtained implicated all three sources as affecting Allen Harbor water quality. Laboratory bioassays of landfill exposure media, employing a variety of marine species using acute and chronic endpoints (Phase III), are being used to provide data for the development of an exposure-response model for risk to the marine environment. The model will define current risk and provide an interpretive framework for long-term monitoring.

INTRODUCTION

OBJECTIVE

- Conduct a marine ecological risk assessment at NCBC Davisville to determine the impact of hazardous waste disposal on Allen Harbor and Narragansett Bay.

BACKGROUND

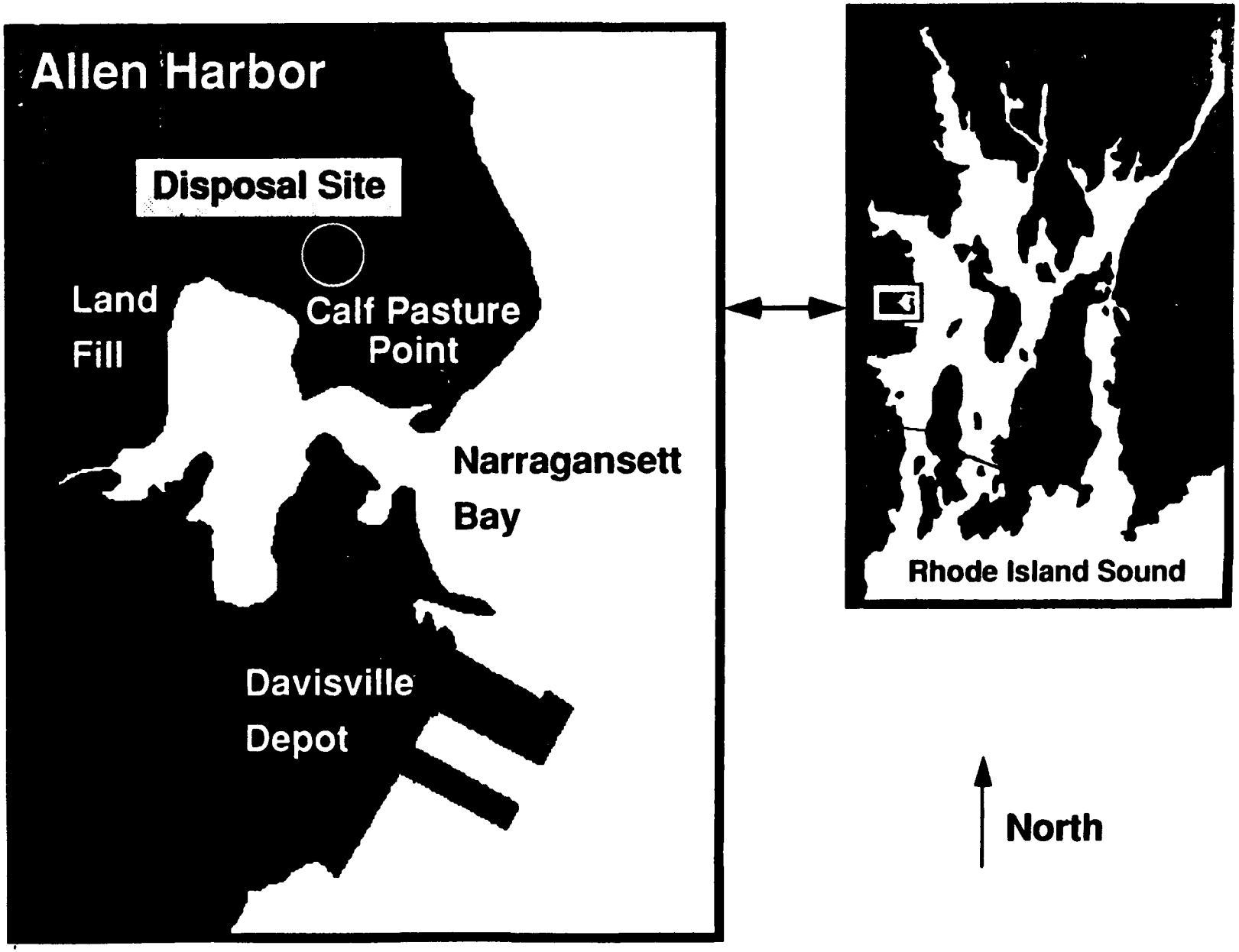
- Allen Harbor, located in Narragansett Bay, RI at NCBC Davisville was closed for shellfishing by Rhode Island Department of Environmental Management.

- Suspected contamination from a 15 acre landfill and disposal area located near Allen Harbor.

- Wastes disposed at the landfill included:

PCB contaminated waste oils		preservatives
solvents	paints	chromic acid
blasting grit	sewage sludge	industrial wastes

Location of Allen Harbor in Narragansett Bay, RI.


Allen Harbor
Disposal Site
Land
Fill
Calf Pasture
Point
Narragansett
Bay
Davisville
Depot
Rhode Island Sound
North

METHODS

PHASE I: INFORMATION GATHERING

- Determine the existence, nature, and extent of adverse effects in Allen Harbor resulting from contaminants originating from NCBC Davisville.

- Activities Included:
    1. Characterize sediment and water column quality
    2. Evaluate natural resouces for:
        abundance, condition indices, histology, and tissue burdens
    3. Evaluate toxicological responses to selected species
    4. Compare results with a series of mid-Narragansett Bay reference stations.

PHASE II: VERIFICATION AND QUANTIFICATION OF TOXICOLOGICAL EFFECTS

- Verify the lack of adverse environmental effects and determine the contribution of environmental effects from the landfill, runoff from the surrounding area, and marina activities.

- Activities included:
    1. Seasonal monitoring of pollution loading from:
        landfill sources
        runoff sources
        boating sources

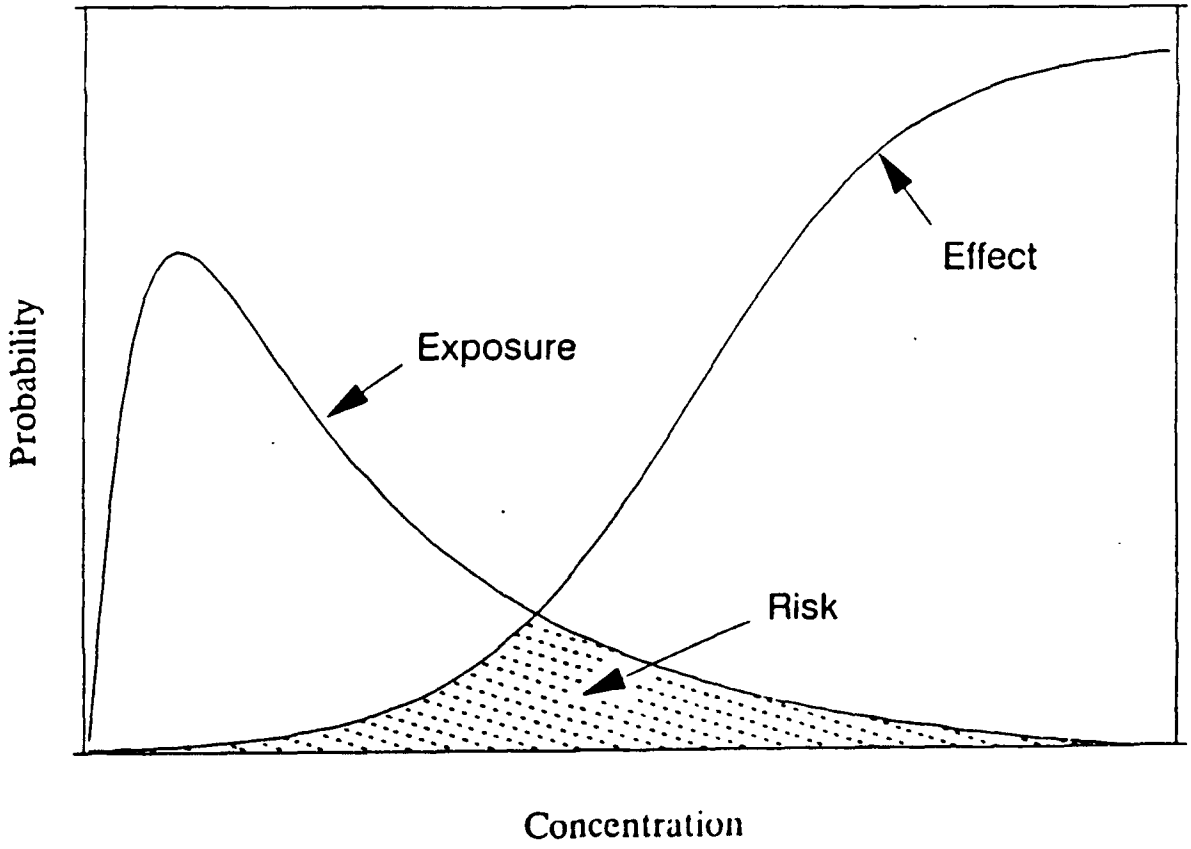
    2. Relating pollution loading to toxicological responses to:
        Water Column Effects on:
            sea urchin fertilization and development
            deployed mussel physiology
            deployed mysid survival, growth and fecundity
        Sediment Effects on:
            amphipod survival
            indigenous clams
            biomarker responses

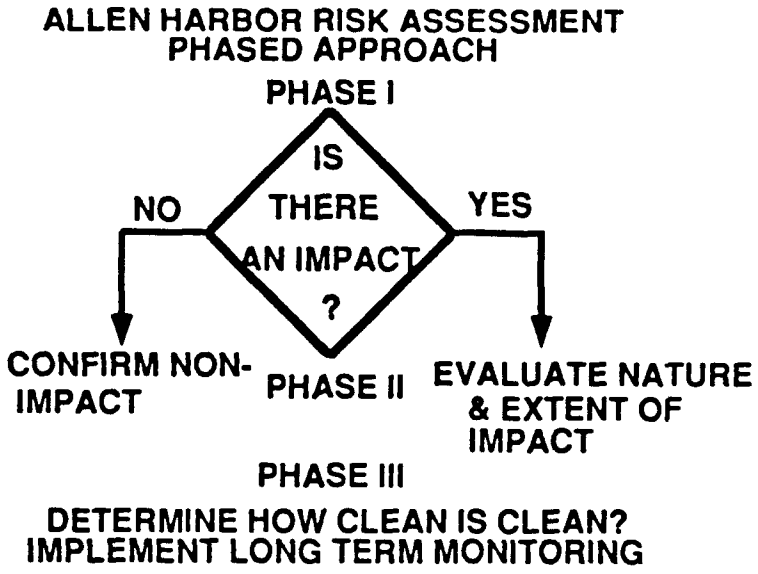
PHASE III: QUANTIFICATION OF ECOLOGICAL RISKS

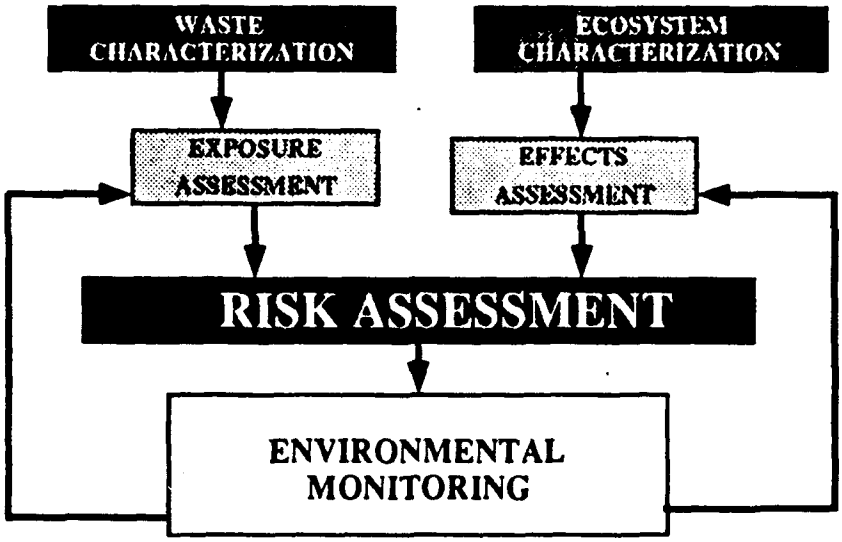
- Evaluate the effects of landfill exposure on marine organisms and establish exposure-response relationship necessary for an ecological risk assessment model.

- Activities included:
  1. Performing laboratory bioassays of:
     landfill seeps
     sediments from the landfill
     extracts of sediments and soils from the landfill
  2. Determining exposure-responses for acute and chronic effects to benthic and water column species.

Exposure-Response Risk Model







Risk Assessment Paradigm used for the Allen Harbor Study.

RESULTS

PHASE I EXPOSURE ASSESSMENT

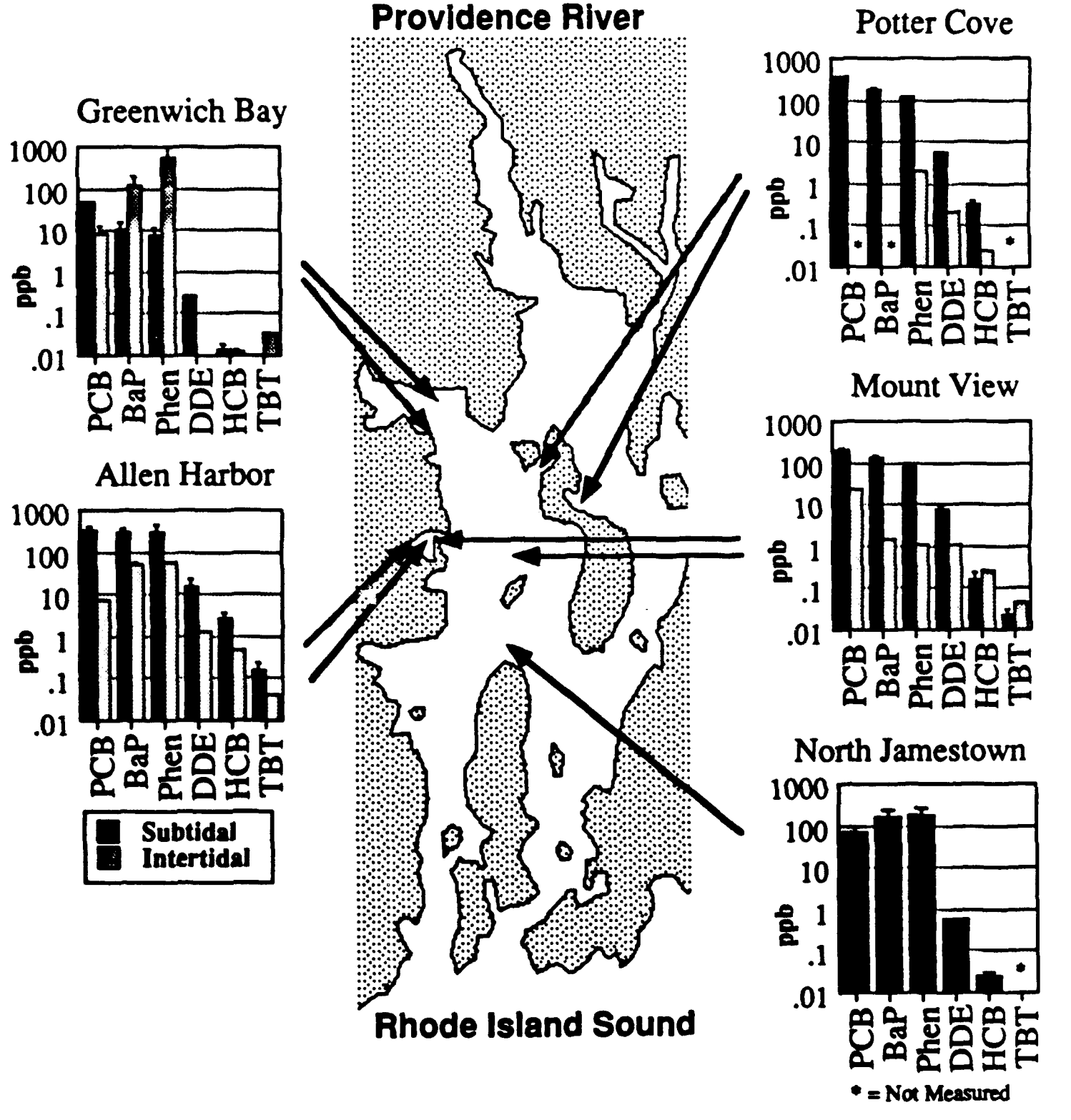
Organics

PCB - Polychlorinated Biphenyls
BaP - Benzo[a]pyrene
Phen - Phenanthrene
DDE - Dichlorodiphenyl-dichloroethene
HBC - Hexachlorobenzene
TBT - Tributyltin

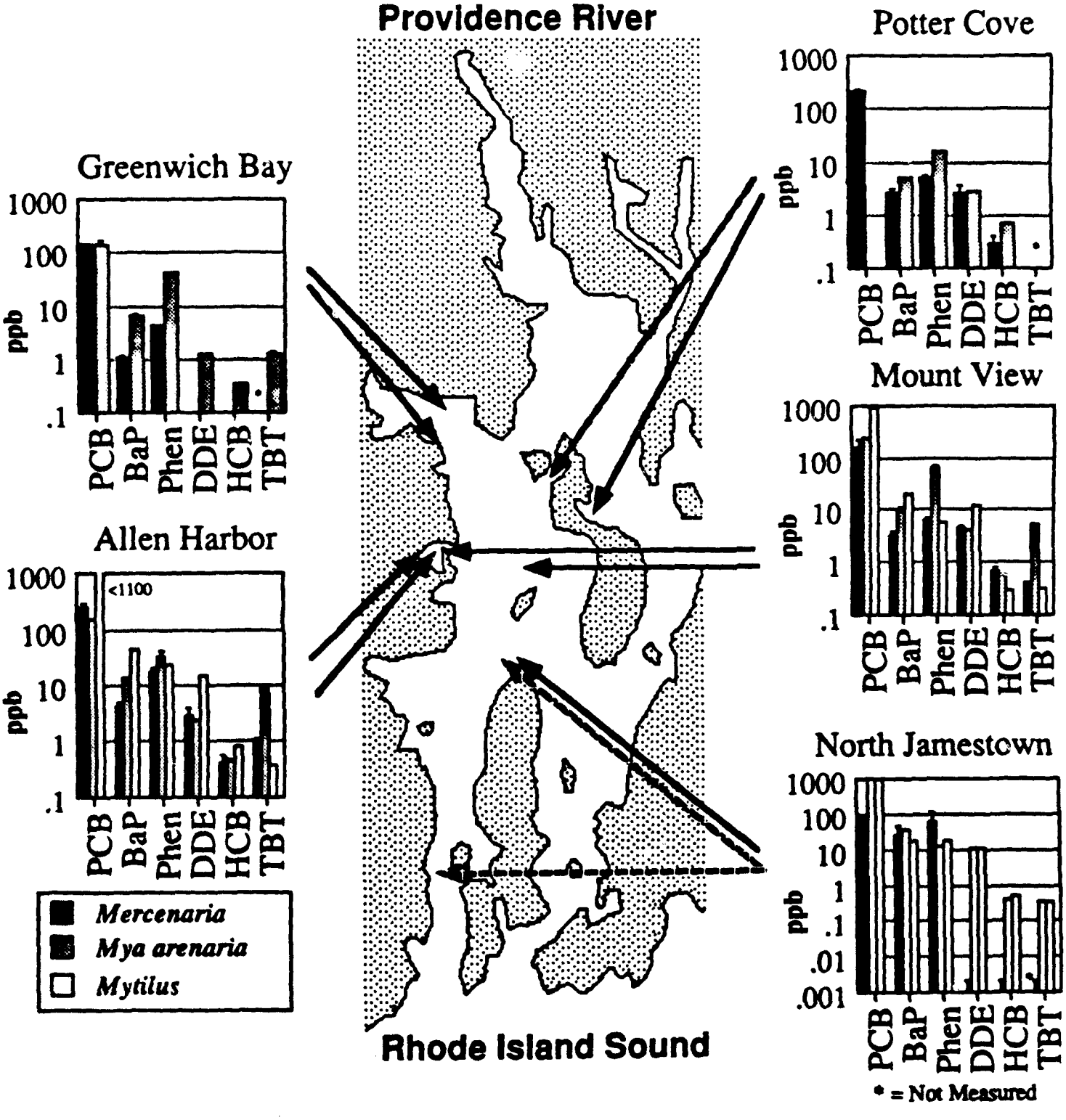
METALS

Cu - Copper
Zn - Zinc
Cr - Chromium
Pb - Lead
Ni - Nickel
As - Arsenic

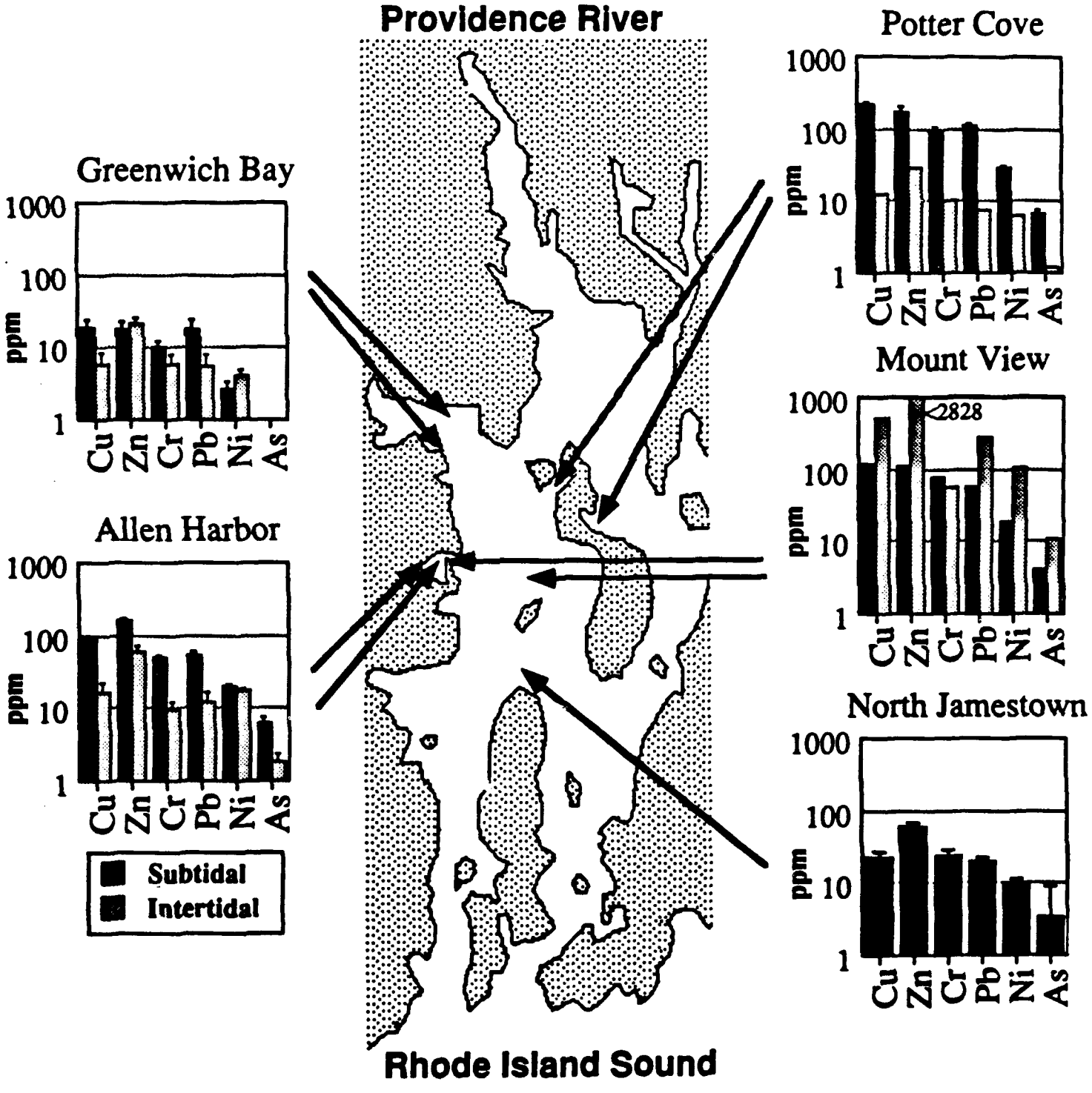
Concentrations of selected organic contaminants in subtidal and intertidal sediments at stations in Narragansett Bay, RI.



Tissue residues of selected organic contaminants in indigenous *Mercenaria mercenaria*, *Mya arenaria*, and deployed *Mytilus edulis*.



Concentrations of selected toxic metals in subtidal and intertidal sediments at stations in Narragansett Bay, RI.



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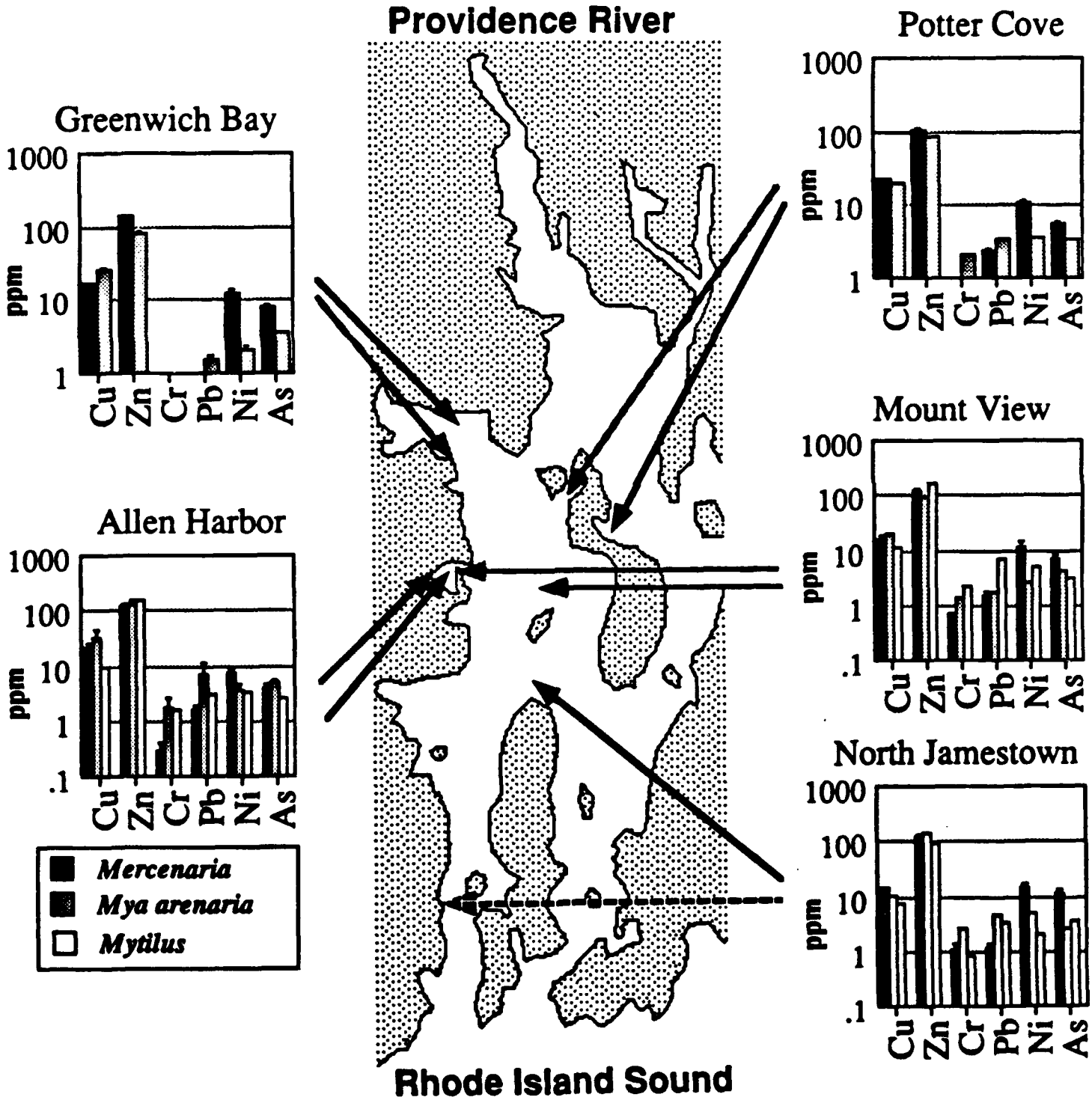


PHASE I EFFECTS ASSESSMENT

AMPHIPOD TOXICITY TEST: *Ampelisca abdita* were collected from a local site and exposed to homogenized whole sediment for 10 days.

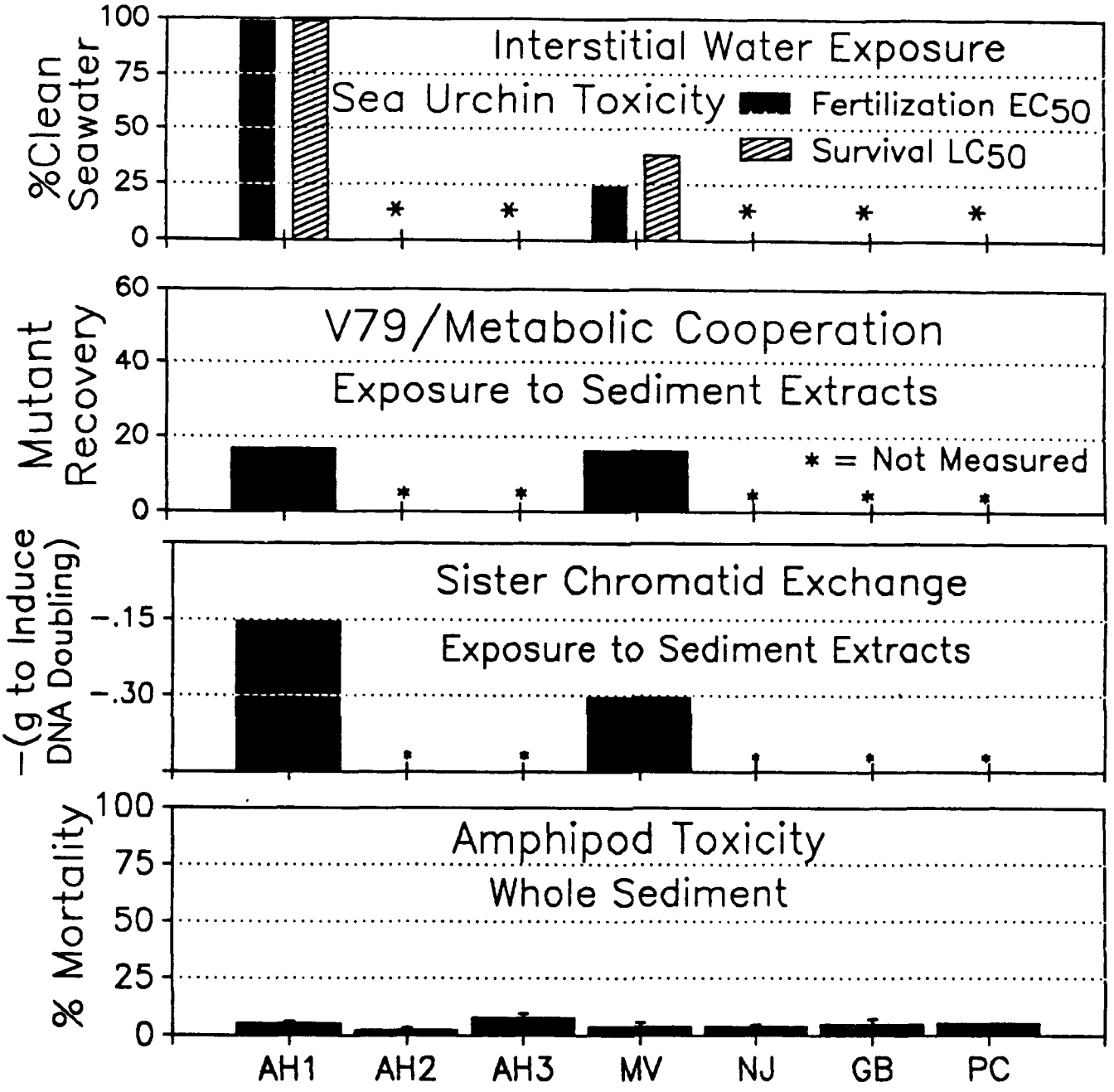
SEA URCHIN FERTILIZATION AND DEVELOPMENT: Gametes of *Arbacia punctulata* were obtained by electrical stimulation. Sperm and egg cells were exposed to interstitial water. Eggs were examined after 20 min for fertilization and after 48 hr for growth, development, and survival.

DEPLOYED MUSSEL SCOPE FOR GROWTH: *Mytilus edulis* (5-7 cm) were collected from a reference site, placed in polyethylene baskets, and deployed for 28 days. Scope for Growth was determined from measure-ments of assimilation efficiency, excretion rate, and respiration rate.

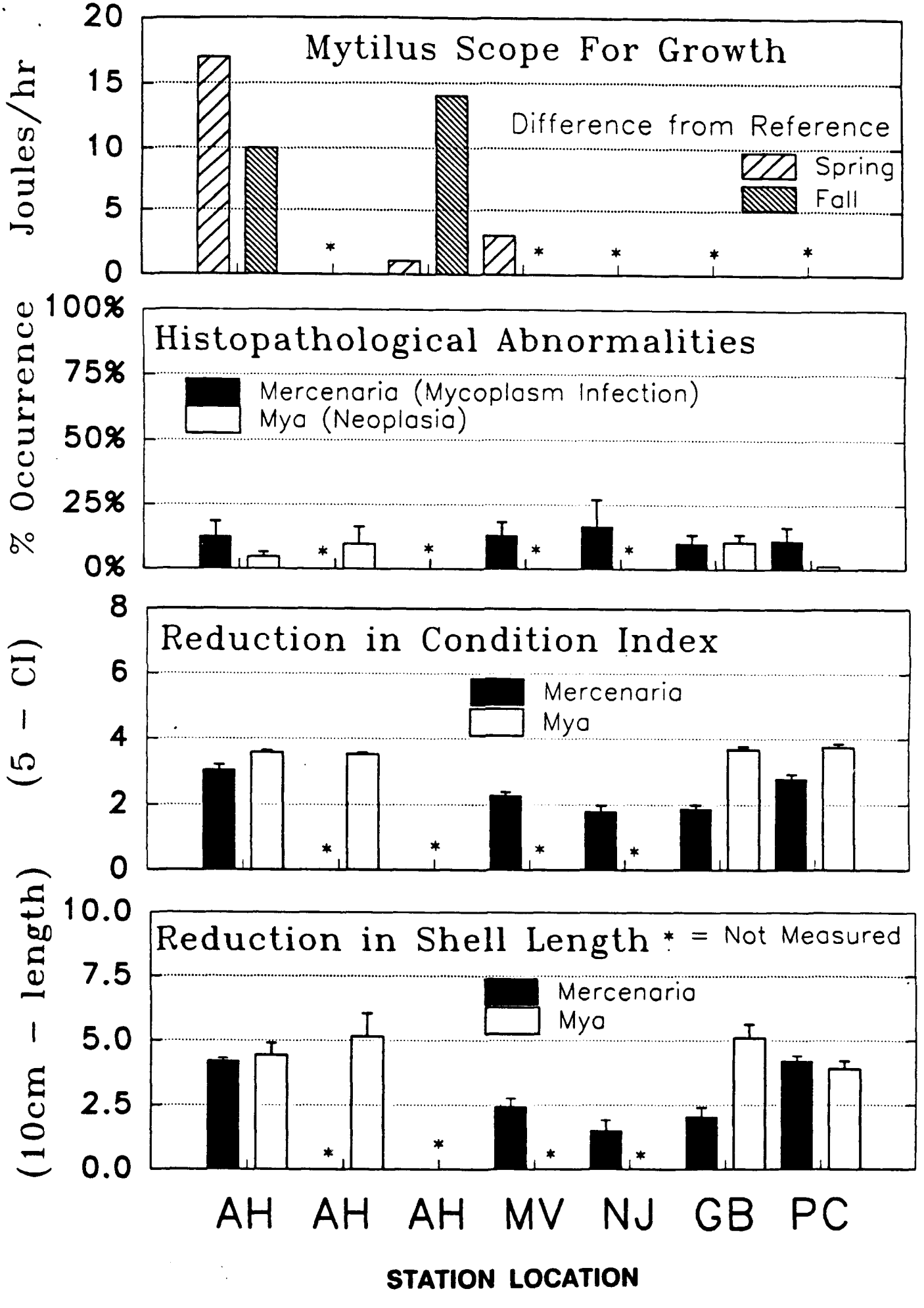
SISTER CHROMATID EXCHANGE (SCE) ASSAY: Chromosomal endpoint used to determine mutagenic potential of sediment contaminants by detecting breaking and symmetrical exchange of DNA in Chinese hamster lung fibroblast cells exposed to sediment extracts for 5 hr and incubated for 19 hr.

V79/METABOLIC COOPERATION ASSAY: Cellular endpoint used to determine tumor-promoting potential of sediment contamiants by detecting inhibition of normal intercellular communication in resistant mutant and sensitive wild type fibroblast cells exposed to sediment extracts.

SEDIMENT TOXICITY



STATION LOCATION


Mytilus Scope For Growth
Joules/hr
20
15
10
5
0
Difference from Reference
Spring
Fall
Histopathological Abnormalities
% Occurrence
100%
75%
50%
25%
0%
Mercenaria (Mycoplasm Infection)
Mya (Neoplasia)
Reduction in Condition Index
(5 - CI)
8
6
4
2
0
Mercenaria
Mya
Reduction in Shell Length
(10cm - length)
10.0
7.5
5.0
2.5
0.0
* = Not Measured
Mercenaria
Mya
AH AH AH MV NJ GB PC
STATION LOCATION

PHASE II RESULTS

Seasonal variation of chemical and toxicological conditions were monitored at stations corresponding to landfill seeps -- North Seep (N), Middle Seep (M), South Seep; and runoff streams -- West Creek (W), North Creek (N), Spink Neck Creek (S).

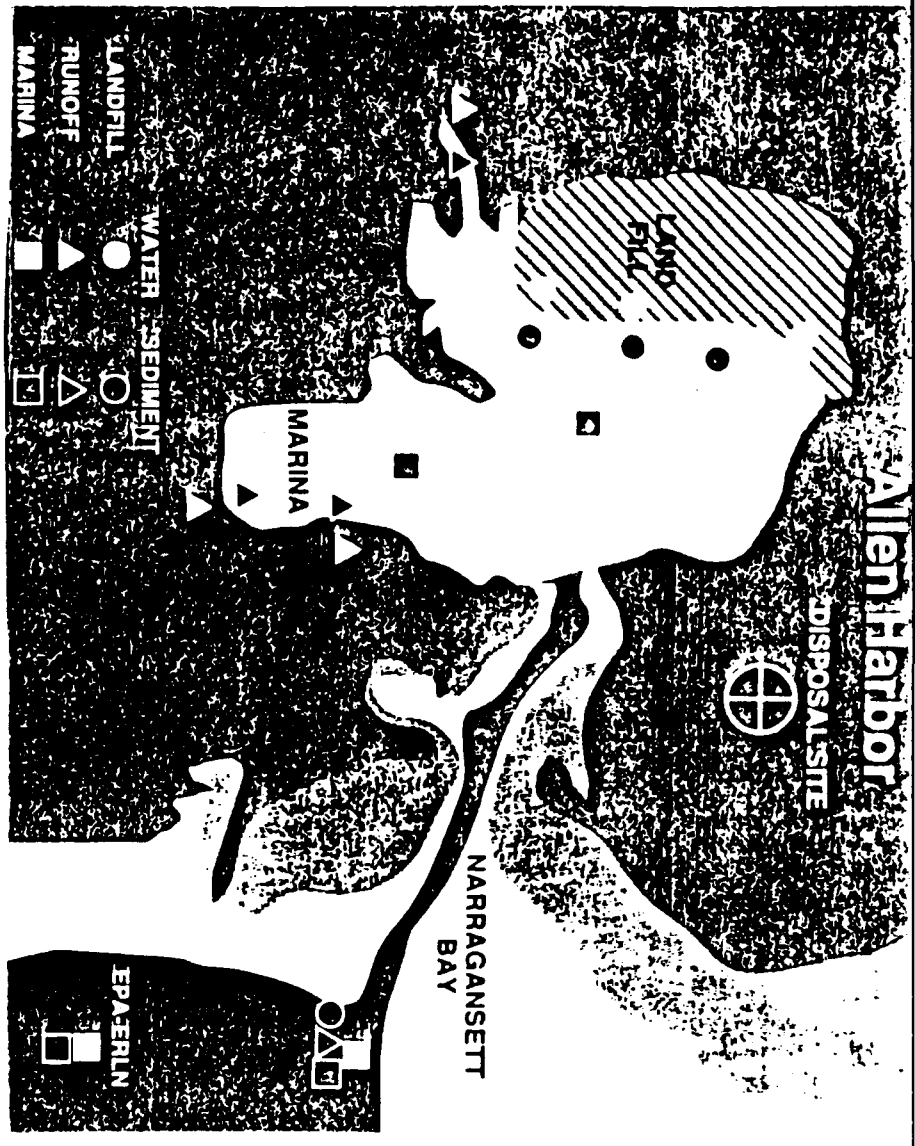
Mussel cages were deployed in Allen Harbor (AH), at the entrance to Allen Harbor (TTN), and at the Mount View (MV) station.

Mussel cages deployed at a reference station located near the mouth of Narragansett Bay (ERLN), were used for comparisons.

Fecal coliform densities within Allen Harbor and in stormwater runoff were also monitored.

Summary of Sampling Events for Phase II

STATION LOCATION	CHEM ANAL.		BAC	TOXICITY TEST		TEST SPECIES							BIO-MARKER TEST
						CLAM		MUSSEL			MYSID		
	WAT	SED		WAT	SED	TIS	CI	TIS	CI	SG	MOR	REP	
LANDFILL	○	◕	○	○	◕	●	●						●
RUNOFF	△	▲	△	△	▲	▲	▲						▲
MARINA		◪	□		◪	◪	◪	□	□	□	□	□	



Sampling Schedule

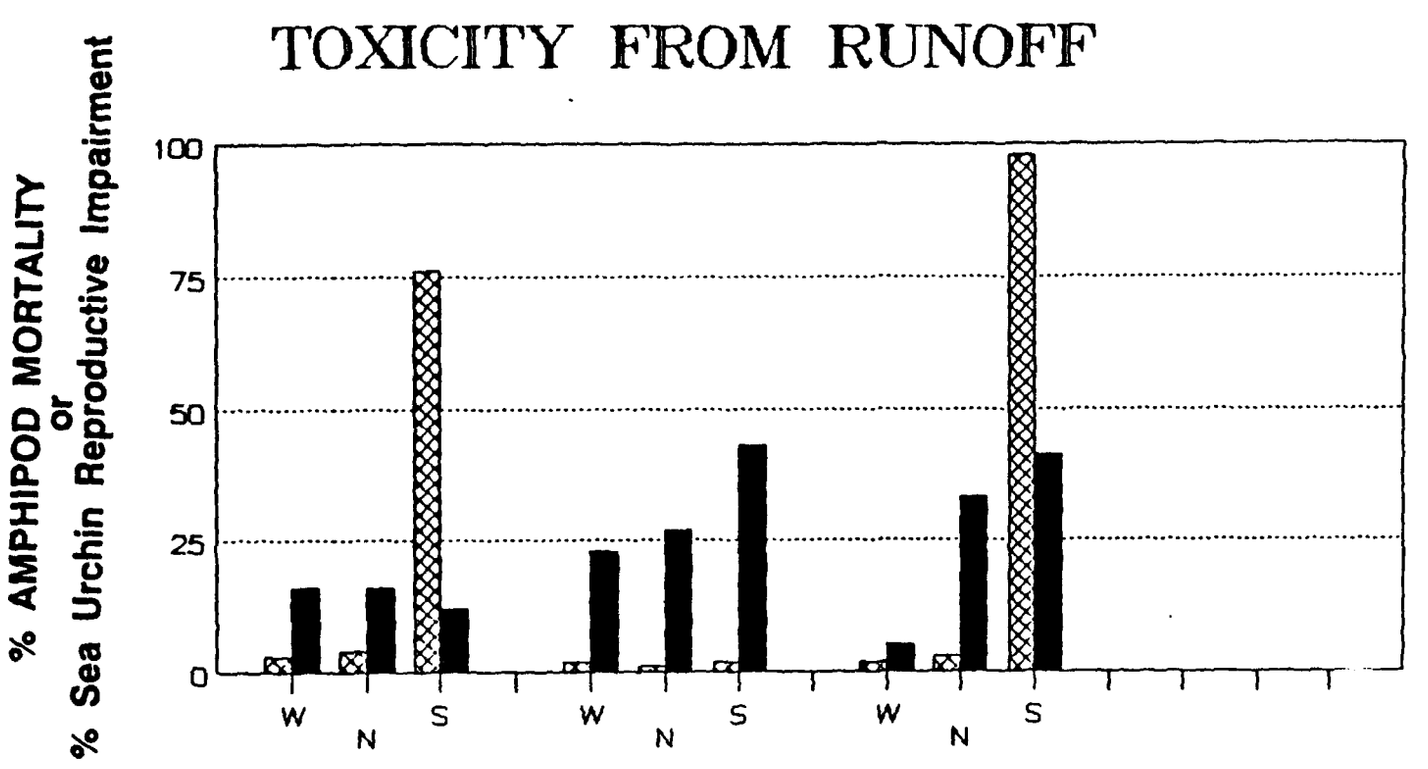
PEAK RUNOFF

PEAK BOATING

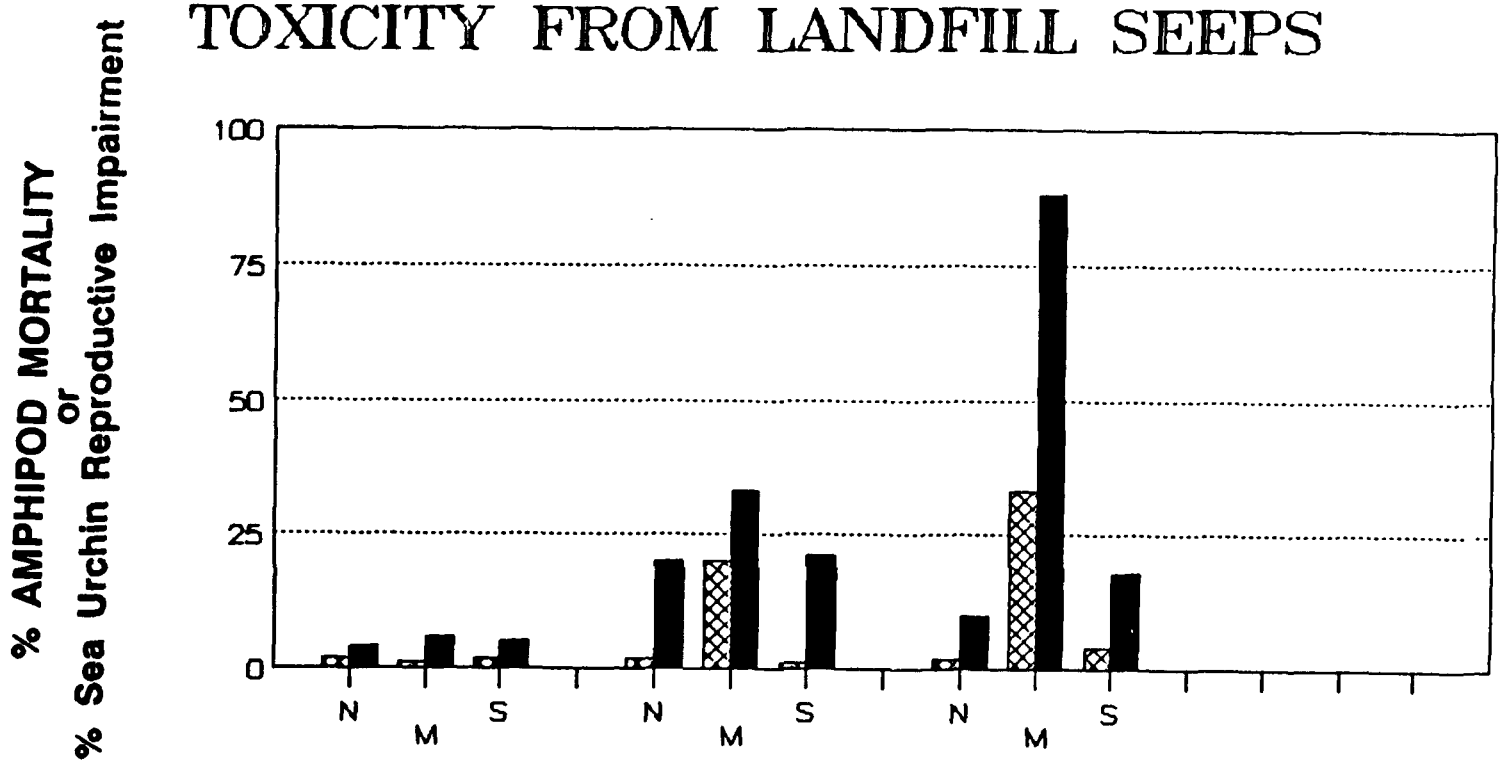
JAN '90	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
			X			X			X		

X = SAMPLING DATE

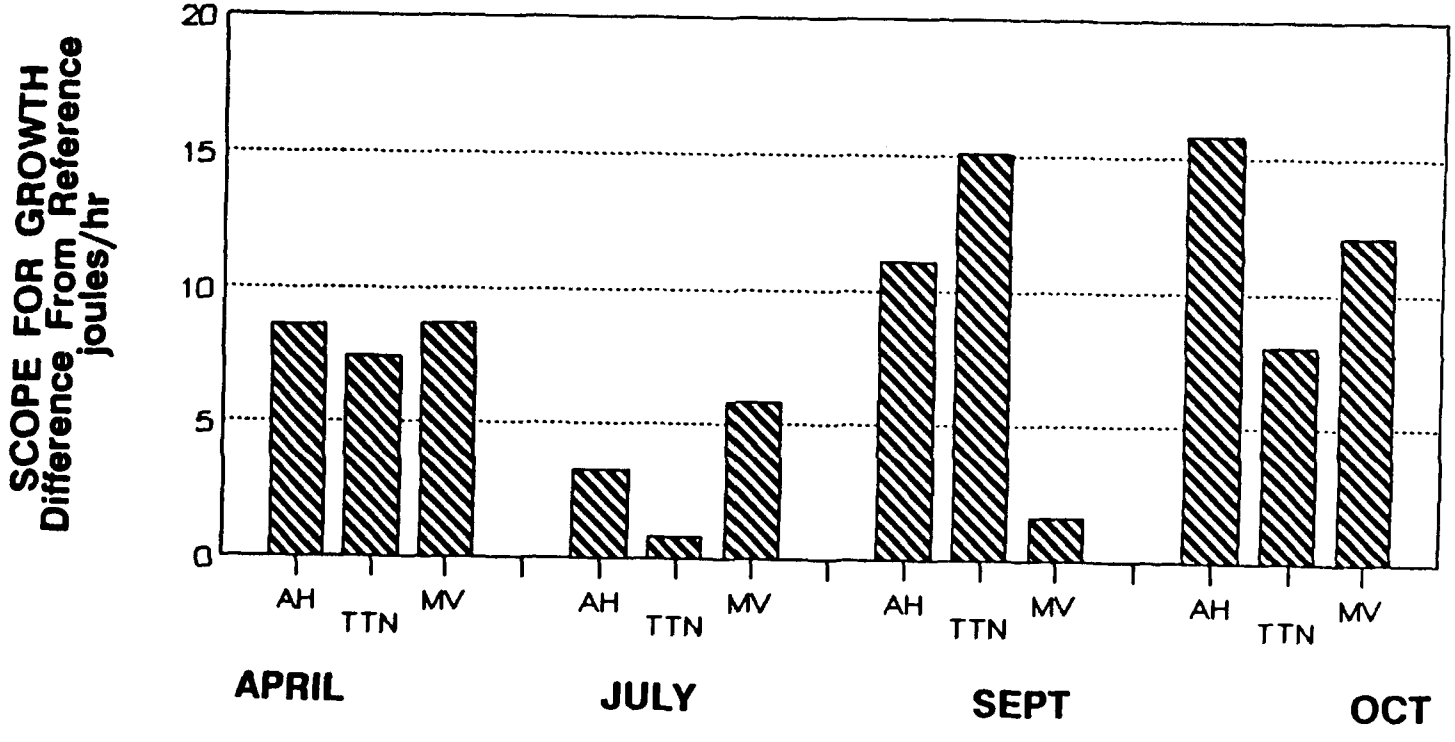
TOXICITY FROM RUNOFF



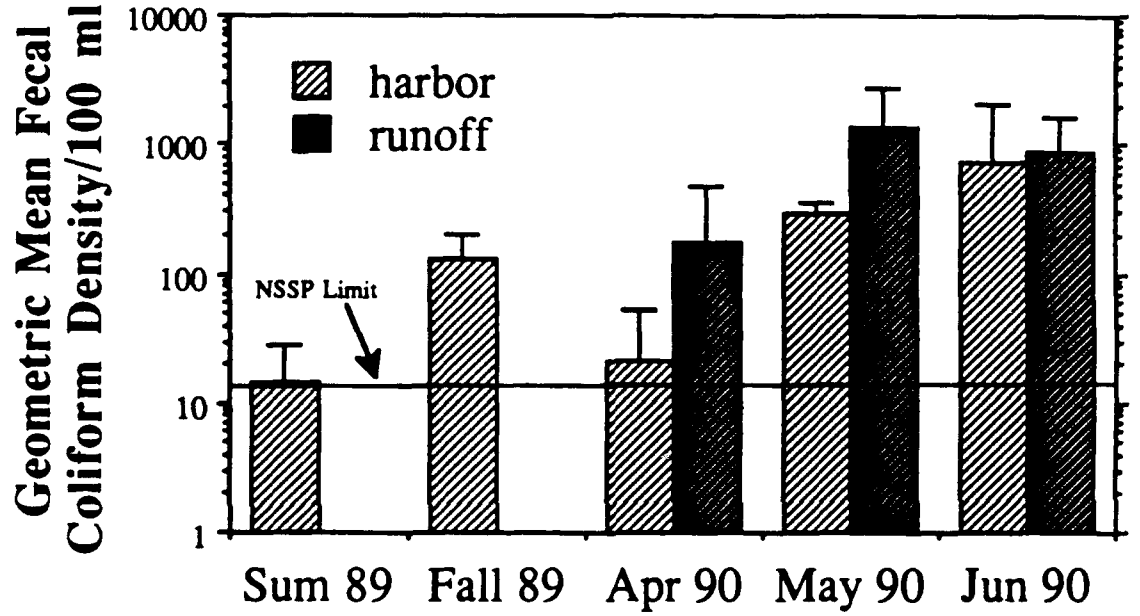
TOXICITY FROM LANDFILL SEEPS



TOXICTY TO DEPLOYED MUSSELS



Fecal Coliform Densities in Allen Harbor



PHASE III (in progress)

Ecological risks from landfill contaminants were quantified by performing dose-response, laboratory bioassays of material collected from landfill seeps, landfill sediments, and extracts of sediments and soils collected from the landfill.

Varying concentrations of landfill media were exposed to benthic and water column species to determine the exposure-response relationships for chronic and acute endpoints.

The resulting data will be used to develop an exposure-response risk model for Allen Harbor.

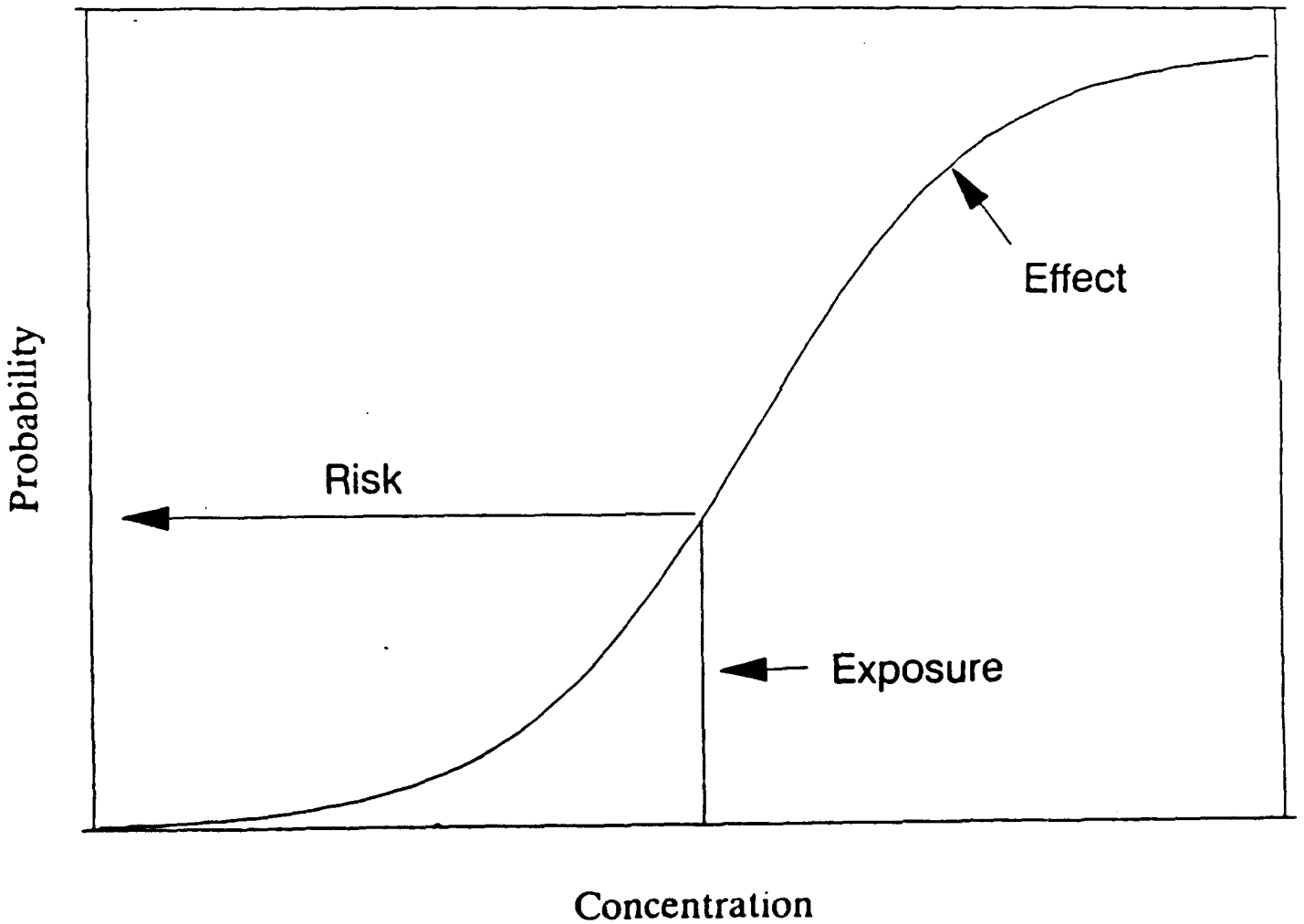
Long Term Monitoring Plan

- Identify variables and parameters for long-term monitoring of ecosystem health
- Long-term monitoring strategy will provide continuous verification of ecosystem health and safety for use in the Risk Management Plan for Allen Harbor.

QUANTIFICATION OF ECOLOGICAL RISK: ALLEN HARBOR PHASE III

EXPOSURE MEDIUM	SPECIES	ENDPOINTS
Seep Water	*Arbacia* (sea urchin)	Fertilization, Larval Growth Development, Survival
	Mysidopsis (mysid shrimp)	Chronic Mortality, Growth, Reproduction
	Champia (red alga)	Reproduction
	Mulinia (coot clam)	Acute Mortality, Development
	Menidia (silverside)	Chronic Mortality, Growth
Sediments	*Ampelisca* (Amphipod)	Acute Mortality
	Cyprinodon (sheepshead)	Chronic Mortality, Growth
	Mulinia (coot clam)	Acute Mortality, Development
Sediment or Landfill Extracts	*Arbacia* (sea urchin)	Fertilization, Larval Growth Development, Survival
	Mulinia (coot clam)	Acute Mortality, Development
	Photobacterium	Acute Mortality

Exposure-Response Risk Model



DISCUSSION

ASSESSMENT OF RISK FOR ALLEN HARBOR

COMPARISON WITH OTHER NARRAGNSETT BAY STATIONS

Qualitative Evaluation

++ High Risk Potential
+ Moderate Risk Potential
-- Low Risk Potential

Allen Harbor versus Narragansett Bay

	Subtidal							Intertidal		
	AH	TTN	MV	NJ	PC	GB	ERLN	AH	CC	MP
Amphipod Toxicity	–	–	–	–	–	–		–	–	–
SCE	+		+							
Metabolic Cooperation	–		–							
Sea Urchin Fertilization	+ +		+							
Development	+ +		+							
Quahog Condition	+	–	–	–	–	–				
Mytilus SFG	+ +	+	–				–			
Phagocytic Index	–						–			
Pathology	–		–	–	–	–		+ +	–	+ +
Coliforms	+ +									
PCBs	+		+	–	+	–		–	–	–
PAHs	–		–	–	–	–		–	+	–
Pesticides	–		–	–	–	–		–	–	–
Sterols	–		–	–	–	–		–		
VOCs	–		–							
Metals	–		–	–	–	–		–	–	–
Butyltin	–		–					+ +	–	–

RISK QUOTIENTS DERIVED FROM SEDIMENT BENCHMARK CONCENTRATIONS

$$\text{Risk Quotient} = \frac{\text{Expected Environmental Concentration}}{\text{Toxic Benchmark Concentration}}$$

Where the Toxic Benchmark Concentration is defined as:

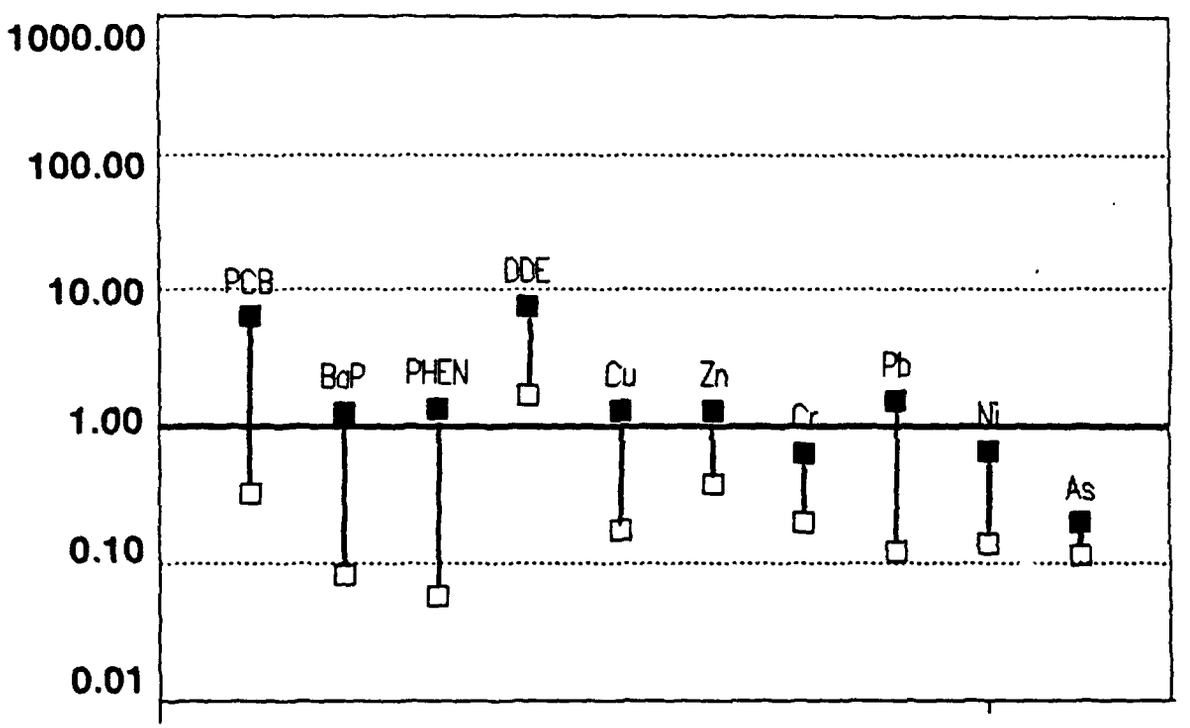
Effects Range Low (ER-L) the concentration below which only 10% of observed toxicological effects have occurred (Long and Morgan 1990).

Apparent Effects Threshold (AET) the concentration above which statistically signification toxicological effects have always occurred (PTI 1988).

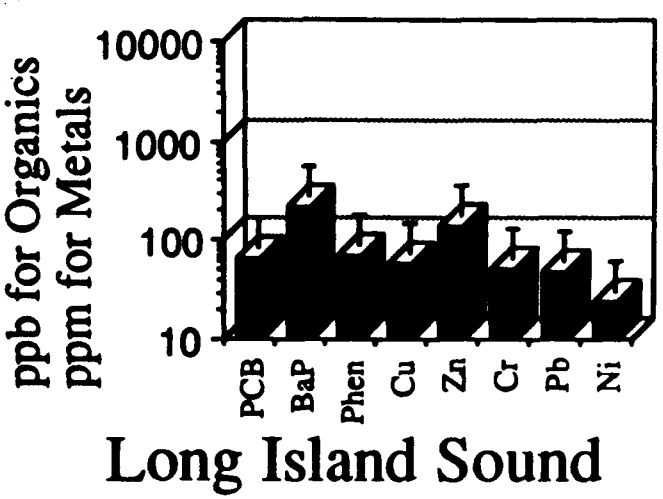
Risk Quotients (RQ) were determined for ER-L (Most Conservative) and AET benchmark concentrations for the mean concentration of contaminants measured in Allen Harbor sediment.

$RQ \geq 1.0$	High Risk
$0.1 \leq RQ < 1.0$	Moderate Risk
$RQ < 0.1$	Low to No Risk

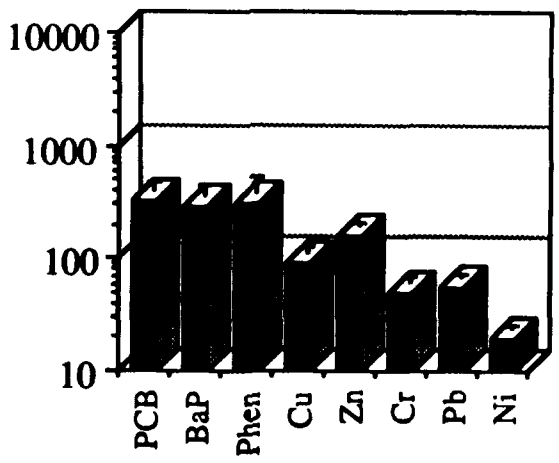
Risk Quotients of Selected Contaminants in Allen Harbor



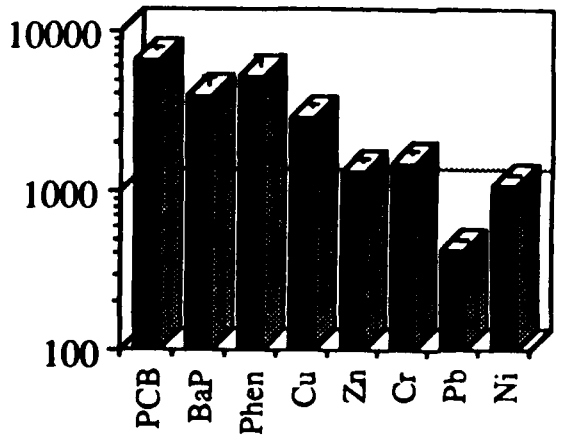
COMPARISON WITH OTHER NORTH EASTERN SITES



Long Island Sound



Allen Harbor



Black Rock Harbor

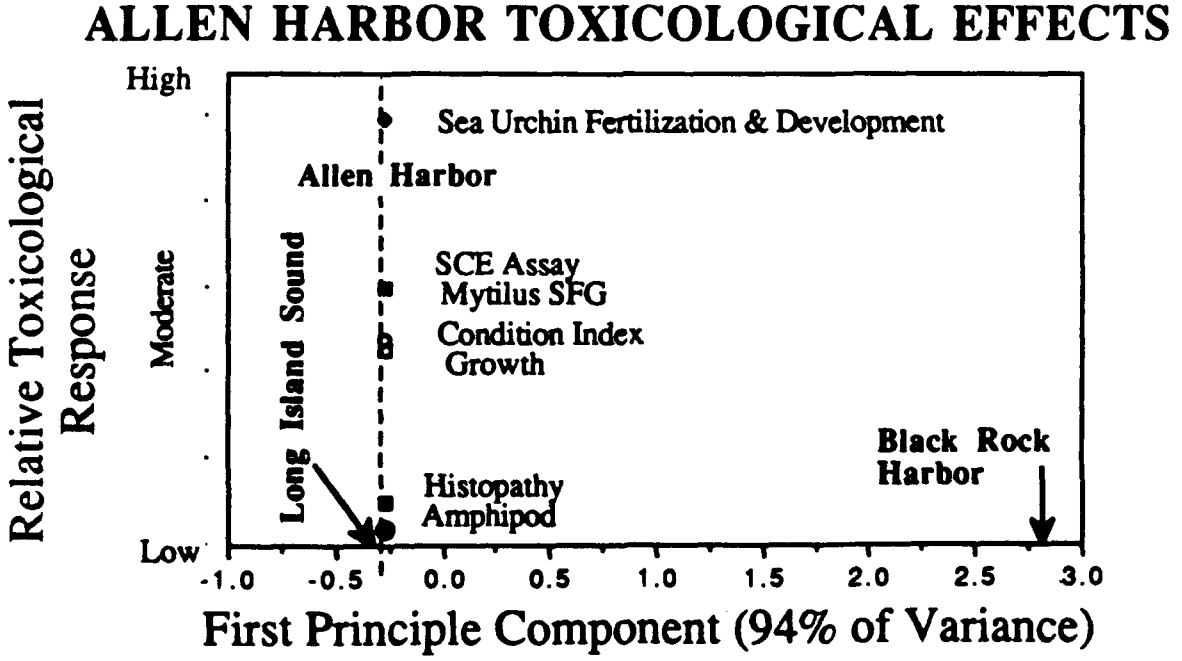
DEVELOPMENT OF EXPOSURE RESPONSE MODEL FOR RISK

An exposure response representation for Allen Harbor was obtained by plotting the relative toxicological response versus the value obtained from principal component analysis of the toxic chemical data.

Principal components were computed from the mean concentrations of PCB, BaP, PHEN, Cu, Zn, Pb, Cr, and Ni obtained for each station in Narragansett Bay (this study) and two other stations: a clean reference site in central Long Island Sound, and a heavily contaminated site in Black Rock Harbor, CT (Munns et al. 1988).

Principal components are linear combinations of the toxic chemical data constructed so that the first principal component will explain the maximum amount of variance in the independent variables (toxic chemical concentrations).

The principal component values for the Long Island Sound and Black Rock Harbor stations are shown for comparison.



SUMMARY AND CONCULSIONS

- The study provides direct measures of environmental health, under true exposure conditions, using endpoints that have ecological significance.
- The approach can be used to identify the source and extent of problems and distinguish between hot spots and nonproblems.
- The risk assessment framework provides a context for developing an understanding of ecotoxicity that can be used to validate methodologies and establish ecological effects databases.
- Case studies are an effective approach for developing biologically-based models to assess risk.
- Ecological risk assessment and monitoring programs provide valuable information to facilitate site closure and determine how dirty a hazardous waste site actually is.

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