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Trace Metals in Quahog Clams from Narragansett Bay 32 pp

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TRACE METALS IN QUAHOG CLAMS FROM NARRAGANSETT BAY

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FINAL REPORT

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FOREWORD

The United States Congress created the National Estuary Program in 1984, citing its concern for the "health and ecological integrity" of the nation's estuaries and estuarine resources. Narragansett Bay was selected for inclusion in the National Estuary Program in 1984 and designated an "estuary of national significance" in 1988. The Narragansett Bay Project (NBP) was established in 1985. Under the joint sponsorship of the U.S. Environmental Protection Agency and the Rhode Island Department of Environmental Management, the NBP's mandate is to direct a five-year program of research and planning focussed on managing Narragansett Bay and its resources for future generations. The NBP will develop a comprehensive management plan by December, 1990, which will recommend actions to improve and protect the Bay and its natural resources.

The NBP has established the following seven priority issues for Narragansett Bay:

* management of fisheries
* nutrients and potential for eutrophication
* impacts of toxic contaminants
* health and abundance of living resources
* health risk to consumers of contaminated seafood
* land-based impacts on water quality
* recreational uses

The NBP is taking an ecosystem approach to address these problems and has funded research that will help to improve our understanding of various aspects of these priority problems. The Project is also working to expand and coordinate existing programs among state agencies, governmental institutions, and academic researchers in order to apply research findings to the practical needs of managing the Bay and improving the environmental quality of its watershed.

This report represents the technical results of an investigation performed for the Narragansett Bay Project. The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement #CX812768 to the Rhode Island Department of Environmental Management. It has been subject to the Agency's and the Narragansett Bay Project's peer and administrative review and has been accepted for publication by the Management Committee of the Narragansett Bay Project. The results and conclusions contained herein are those of the author(s), and do not necessarily represent the views or recommendations of the NBP. Final recommendations for management actions will be based upon the results of this and other investigations.

This report has been reviewed by THIBAULT/BUBLY ASSOCIATES, the Narragansett Bay Project and anonymous reviewers and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency,nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This report is a presentation of data and contains little data interpretation. Quality assurance information is provided but not evaluated in relation to analytical results from other laboratories.

SUMMARY

Trace metals were determined in quahog clams from Narragansett Bay. Four sizes of clams were collected from stations throughout the upper half of Narragansett Bay and Mount Hope Bay. The tissues of the clams were homogenized, digested, and analyzed for cadmium, chromium, copper, lead, mercury, nickel, and zinc. Maximum body burdens for these metals were observed in the Providence River, an area of high pollution input to Narragansett Bay.

I. INTRODUCTION

The quahog (Mercenaria mercenaria) is an important fishery resource in Narragansett Bay and nearby regions. The assessment of this resource should include investigations of contaminant levels in these clams as a function of water quality. The objective of this project was to determine the concentration of cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn) in whole tissues of quahogs from the Narragansett Bay estuary. Data interpretation was not part of this project, so the data is presented here with little interpretation.

This project was conducted as part of Objective IV of the Narragansett Bay Workplan (FY 85): to determine the status of the quahog fishery resource as a function of water quality. The data reported here must be compared to water quality parameters measured by other investigators in order to assess the relationship between water quality and metal body burdens in the quahogs.

a. Design

The two sampling seasons of Fall and Spring were chosen to determine the effect of annual growth cycles on contaminant levels. Since a previous investigator (Cullen, 1984) had shown that the concentrations of metals in quahog tissues may vary with size, three main size classes were chosen for sampling. The sizes were based upon their usage in defining the commercial fishery: littlenecks (4 to 6 cm maximum shell dimension); cherrystones (6 to 8 cm); and quahogs (greater than 8 cm). A fourth size class, the sub-legals (less than 4 cm), was sampled when available.

Samples were collected from several locations in upper Narragansett Bay: Mount Hope Bay, Greenwich Bay, Ohio Ledge, Mount View, and the Providence River (Table 1 and Figure 1). After the clams were collected, they were stored in a freezer. Freezing killed the clams and enabled easy removal of the whole clam after thawing. Following appropriate acid digestions, the samples were analyzed for cadmium, chromium, copper, lead, nickel, and zinc using flame atomic absorption spectrophotometry. The clam digestates were analyzed for mercury using a Jerome gold film analyzer.

II. METHODS

a. Procedures

The procedures and methodology follow the quality assurance/workplan prepared for this project. A simplified flow diagram (Figure 2) illustrates the steps of the procedure.

1) Shucking and homogenization: The frozen clams were spread out on a countertop at room temperature and allowed to thaw for 1-3 hours. The shells were forced open and the whole body of the clam was removed using a plastic spatula. The clams were grouped into batches of four individuals of the same size class and placed in a plastic colander. Excess liquid was allowed to drain from the clams for approximately 15 minutes. The drained clam tissues were then homogenized to a puree in a stainless steel commercial Waring blender. Occasionally, individual clams were homogenized and processed as separate samples.

Table 1. Location of stations where quahog clams were collected for this study.

Station	Location	Latitude	Longitude
Fall 1985 (11/20/85)			
MH-55	Mount Hope Bay	41° 39.20'	71° 14.25'
MH-61	Mount Hope Bay	41° 42.00'	71° 13.77'
MH-62	Mount Hope Bay	41° 39.35'	71° 12.63'
MH-63	Mount Hope Bay	41° 39.38'	71° 15.14'
Fall 1985 (11/21/85)			
GR-1	Greenwich Bay	41° 40.40'	71° 24.59'
OL-1	Ohio Ledge	41° 40.75'	71° 19.75'
MV-1	Mount View	41° 37.45'	71° 23.61'
PR-2	Providence River	41° 45.50'	71° 22.30'
PR-13	Providence River	41° 44.50'	71° 22.50'
PR-30	Providence River	41° 43.90'	71° 21.30'
PR-47	Providence River	41° 43.70'	71° 21.10'
PR-49	Providence River	41° 43.40'	71° 21.90'
Spring 1986 (6/4/86)			
MV-1	Mount View	41° 37.41'	71° 23.64'
GR-2	Greenwich Bay	41° 40.51'	71° 24.10'
PR-1	Providence River	41° 45.50'	71° 22.40'
PR-15	Providence River	41° 44.40'	71° 22.60'
PR-30	Providence River	41° 43.90'	71° 21.30'
PR-47	Providence River	41° 43.70'	71° 21.10'
PR-49	Providence River	41° 43.40'	71° 21.90'
Spring 1986 (6/5/86)			
MV-2	Mount View	41° 37.93'	71° 22.29'
OH-1	Ohio Ledge	41° 40.73'	71° 19.80'
MH-55,56	Mount Hope Bay	41° 39.20'	71° 14.00-.25'
MH-61	Mount Hope Bay	41° 42.00'	71° 13.77'
MH-62	Mount Hope Bay	41° 39.35'	71° 12.63'
MH-64	Mount Hope Bay	41° 38.96'	71° 15.32'

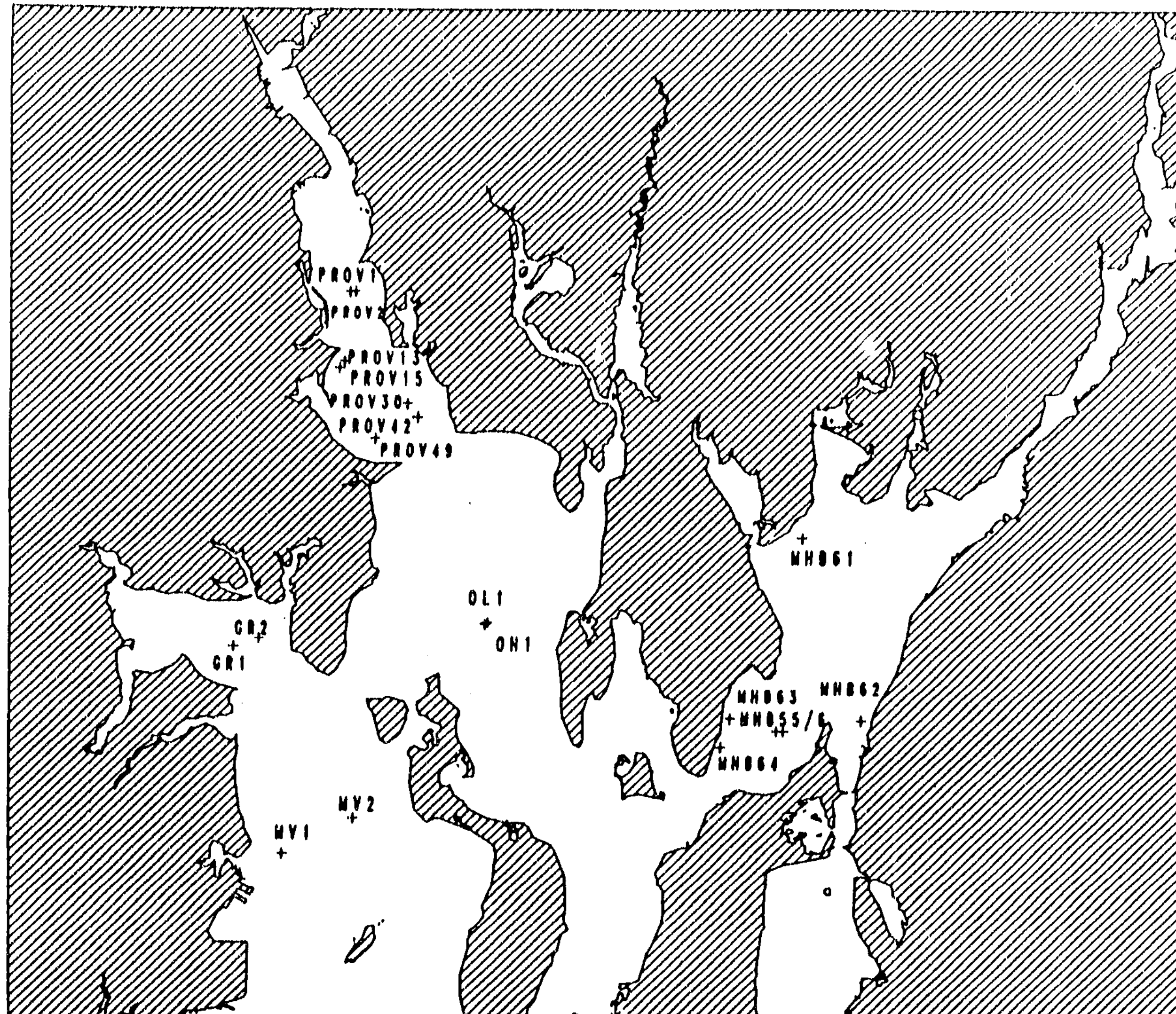

Figure 1. Map of Narragansett Bay showing locations of stations where quahog clams were collected for this study.

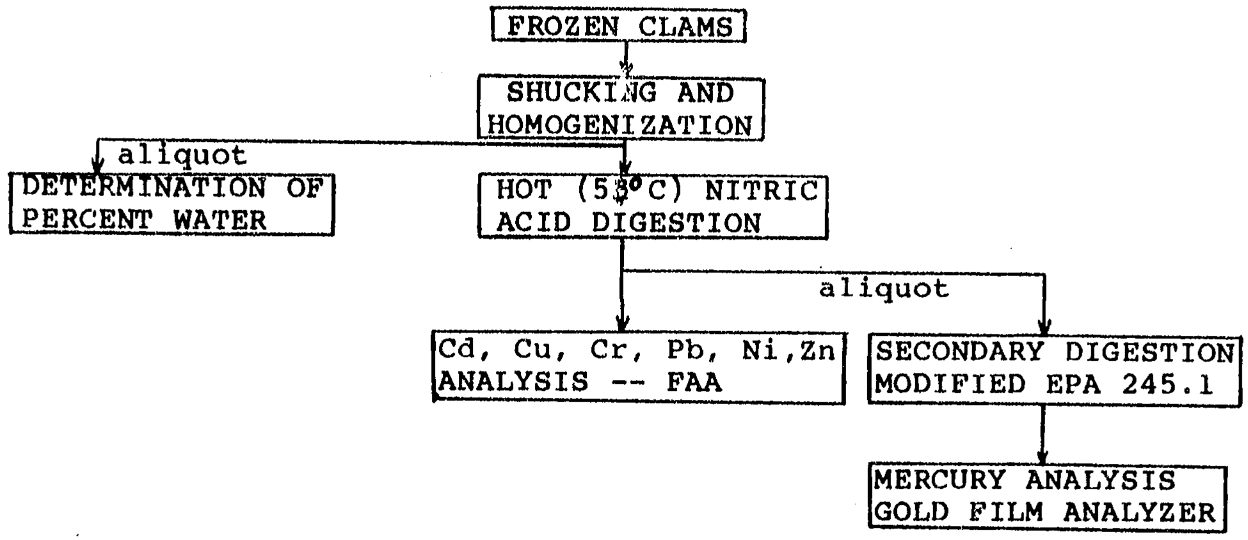

Figure 2. Procedural flow diagram

2) Determination of percent water: An aliquot of the homogenate was taken at the same time the acid digestion was performed, and the dry weight to wet weight ratio was determined by drying at approximately 100^{O} C overnight. The dry weight to wet weight ratios were used to convert homogenate wet weights for the digestions to dry weights.

3) Hot nitric acid digestion: Ten to twenty grams of each homogenate was added to 50 ml screw cap glass test tubes. The same amount of concentrated nitric acid was added and the tubes were allowed to sit overnight. The tubes were then placed in a water bath at 55^{O} C and periodically shaken to maximize contact between the tissues and the acid. The digestions continued until only a waxy residue was left in the tubes (1 to 2 days). The liquid was diluted to 50 ml with deionized water and filtered through acid rinsed glass fiber filters to remove residual materials.

4) Secondary digestion for determination of mercury: The digestion detailed in EPA 245.1 was scaled down for the smaller sample size of the homogenates. It was basically an acid digestion at 95^{O} C which included persulfate and permanganate to completely oxidize organic mercury compounds. The excess oxidants were removed with hydroxylamine prior to analysis.

5) Mercury analysis with a Jerome gold film analyzer: The mercury in the secondary digestion solution was reduced to volatile elemental mercury which was air-purged into the analyzer. Elemental mercury was absorbed onto a gold film. Changes in the resistance of the gold film were directly related to the amount of mercury absorbed on the film.

6) Cd, Cr, Cu, Pb, Ni, and Zn analyses: The digested sample (from II.a.3) was analyzed using direct aspiration flame atomic absorption spectrophotometry.

III. RESULTS

a. Quality Assurance Evaluation

The quality assurance (QA) for this analytical task consisted of three parts. The first QA procedure established a clam reference sample from which frozen aliquots could be analyzed in their entirety with each sample set of clams. This procedure was followed with all sets, but the results were not as consistent as expected. It became apparent that the freezer used to store the pureed aliquots had thawed several times during the course of the experiment (the actual samples were stored in another freezer which did not thaw). Close examination of the stored aliquots revealed color differences (some with substantial black coloring). If the tissues became anoxic in part, it is possible that various metal sulfides were created that would change the effectiveness of the hot nitric acid digestion. These results are not included here because of the storage problems.

The second QA procedure involved preparation of duplicate aliquots of the same blended batch. These duplicates were then digested and analyzed independently. The results for duplicate samples are compared to results for the batch samples in Table 2. The variance between duplicates would be expected to be less than or equal to the variance among batches. The different metals show different responses:

> Copper, nickel, and zinc concentrations were greater than 10 times the detection limit error and duplicates showed less variability than batches.
>
> Cadmium concentrations were approximately 10 times the detection limit error and showed similar standard deviations for duplicates and batches.

Table 2. Data for duplicate samples with means and standard deviations (n-1 weighting) compared to batch averages.

	Sample	"Dry" Wt (grams)	Number Samples Averaged	Cadmium (ug/g) Mean	SD	Copper (ug/g) Mean	SD	Chromium (ug/g) Mean	SD	Lead (ug/g) Mean	SD	Nickel (ug/g) Mean	SD	Zinc (ug/g) Mean	SD	Mercury (ug/g) Mean	SD
Duplicates	PR47-QH - B1	2.80		1.09		13.5		16.8		0.9		23.7		112		0.34	
	PR47-QH - B1R	2.94		1.12		14.2		17.1		2.1		22.5		108		0.34	
Duplicate Average:			2	1.11	0.02	13.8	0.5	17.0	0.2	1.5	0.8	23.1	0.9	110	3	0.34	0.01
Batch Average:	PR47-QH - B		3	1.12	0.03	17.8	5.0	17.6	4.7	1.0	0.2	23.2	4.1	126	26	0.42	0.08
Duplicates	MV1 -CS - B3	3.93		0.62		18.1		0.7		1.1		11.2		129		0.06	
	MV1 -CS - B3R	3.98		0.55		16.9		0.9		0.6		10.6		128		0.07	
Duplicate Average:			2	0.59	0.05	17.5	0.8	0.8	0.1	0.8	0.3	10.9	0.5	129	1	0.06	0.00
Batch Average:	MV1 -CS - B		3	0.64	0.04	16.1	3.0	0.7	0.1	0.8	0.3	10.5	1.6	114	13	0.07	0.04
Duplicates	MV1 -QH - B1	2.71		0.96		14.9		5.9		0.9		22.5		168		0.23	
	MV1 -QH - B1R	2.85		0.67		15.3		6.6		1.0		23.8		152		0.23	
Duplicate Average:			2	0.82	0.20	15.1	0.3	6.2	0.6	1.0	0.1	23.1	1.0	160	12	0.23	0.00
Batch Average:	MV1 -QH - B		3	1.14	0.15	19.8	4.3	6.3	0.7	0.8	0.3	22.4	3.5	160	18	0.25	0.03
Detection limit error estimate for a 3.65 g sample:		3.65			0.07		0.3		0.7		0.7		0.7		1		0.03

Lead concentrations were less than a factor of 2 times the detection limit error so that comparison of duplicate and batch variability was not meaningful.

Chromium concentrations varied from 1 to 24 times the detection limit error and showed no trend in variance between duplicates and batches.

Mercury concentrations were up to 10 times the detection limit error and showed standard deviations for duplicates and batches similar to the detection limit error.

The third QA procedure was an examination of the recovery of spikes made to digested samples (Table 3). Traditionally, an analytical spike recovery is performed by measuring the difference between the concentration of metal found in a spiked sample with the concentration of the original sample. This was not possible in this case because the digested sample volume was too small to allow an aliquot to be removed for spiking and analytical procedures. In this study a separate batch of clams (same size class and station) was digested and used for spike recoveries.

Table 3. Metal spike recoveries for metal addition into digested samples. Additions were 0.01 mg/l (Hg), 0.4 mg/l (Cd,Pb,Zn), 0.5 mg/l (Cr), and 1.4 mg/l (Ni)
Spike for zinc was prepared from the diluted sample (20 fold dilution of original sample prior to analysis).

	Sample	Cadmium (ug/g) Mean	Std Dev.	Copper (ug/g) Mean	Std Dev.	Chromium (ug/g) Mean	Std Dev.	Lead (ug/g) Mean	Std Dev.	Nickel (ug/g) Mean	Std Dev.	Zinc (ug/g) Mean	Std Dev.	Mercury (ug/g) Mean	Std Dev.
Fall '85	GR1 -CS	113%	3%	110%	24%	41%	2%	100%	6%	107%	18%	80%	33%	115%	86%
	PR2 -LN	104%	2%	167%	13%	44%	13%	88%	36%	110%	18%	38%	83%	157%	60%
	OL1 -QH	101%	4%	104%	13%	109%	26%	120%	8%	120%	17%	71%	15%	189%	23%
	PR47-CS	100%	4%	88%	57%	89%	9%	91%	21%	103%	11%	94%	7%	101%	27%
	MV1 -LN	102%	1%	71%	76%	59%	0%	103%	0%	90%	38%	124%	7%	84%	21%
	PR49-QH	108%	2%	80%	19%	129%	7%	119%	14%	36%	115%	68%	14%	223%	45%
	FR13-CS	108%	3%	141%	32%	34%	35%	103%	45%	66%	14%	113%	29%	188%	30%
	MH63-QH	105%	4%	99%	44%	67%	19%	83%	12%	102%	15%	86%	12%	122%	89%
	MH61-CS	109%	1%	105%	11%	82%	28%	91%	14%	103%	6%	70%	38%	143%	101%
Spring'86	MH55,56QH	112%	4%	95%	13%	81%	16%	118%	4%	88%	17%	96%	22%	35%	64%
	MH61-LN	108%	3%	109%	23%	79%	1%	211%	1%	104%	8%	69%	32%	57%	14%
	OH1- CS	107%	1%	123%	18%	79%	6%	98%	14%	112%	14%	94%	3%	65%	29%
	MV2 -QH	110%	2%	99%	26%	73%	13%	92%	11%	87%	49%	63%	18%	49%	41%
	PR1 -CS	100%	1%	38%	377%	89%	12%	118%	29%	82%	24%	127%	38%	6%	63%
	PR30-LN	105%	2%	117%	10%	79%	2%	103%	4%	112%	25%	227%	44%	141%	8%
	GR2 -CS	108%	1%	97%	31%	105%	1%	99%	5%	110%	5%	109%	13%	-1%	5%
	PR49-LN	109%	1%	132%	8%	95%	9%	110%	25%	174%	4%	122%	4%	154%	1%
	PR49-CS	109%	2%	107%	8%	97%	3%	137%	23%	95%	29%	116%	35%	121%	24%
	MV1 -LN	111%	1%	137%	24%	104%	0%	135%	12%	113%	5%	93%	54%	70%	6%
	PR47-LN	107%	2%	118%	19%	113%	4%	98%	20%	119%	10%	107%	16%	110%	18%
	PR47-CS	109%	4%	131%	5%	104%	17%	143%	6%	97%	27%	121%	17%	72%	3%
	PR15-CS	108%	0%	103%	41%	84%	5%	112%	14%	98%	21%	112%	18%	61%	34%
Average:		107%		108%		83%		112%		101%		100%		103%	

The reported spike recovery was based upon comparison of the spiked sample batch with the average of the unspiked sample batches of the same size class clams from the same station. The recoveries reported in Table 3 include an error bar. This was based upon the standard deviation (n-1 weighted) of the metal content of the unspiked batches. The high batch variability observed in this data set resulted in a wide range of calculated spike recoveries. However, when the average of all the recoveries for a given metal was taken, the batch variability was statistically reduced and a reasonable measure of the recovery was possible. With the exception of chromium, all the recoveries were 100 $\pm$ 10 percent. The reduced chromium recoveries may have been related to difficulties in maintaining constant reducing conditions in the flame for both samples and standards. Erratic results for mercury were due to the low level of the spike relative to original sample concentrations. The data were not corrected for spike recoveries.

b) Metal Concentrations in Clams

The concentrations of metals in the clams were reported for the Fall sampling in Table 4 and for the Spring sampling in Table 5. The data were to have been reported on both a wet weight basis (the accepted format of the FDA and other regulatory agencies) and on a dry weight basis. The greater than six month storage time for some of the clams resulted in changes from their original moisture content that could be easily observed. For that reason, the results were reported only on a dry weight basis.

Table 4. Metal concentrations (ug/g dry weight) in clams sampled during November, 1985. Sample names contain three types of information. The first portion of the sample name gives the station where the clams were collected (see Table 1 for listing of stations). The second part of the sample name gives the size of the clams: SL means sub-legals (less than 4 cm); LN means littlenecks (4-6 cm); CS means cherrystones (6-8 cm); and QH means quahog (greater than 8 cm). The letter in the third part of the sample name indicates the type of sample ("B" means a batch of 4 animals and "I" means an individual clam) and the number gives the individual or batch number.

Sample	"Dry" Wt (grams)	Cadmium (ug/g)	Copper (ug/g)	Chromium (ug/g)	Lead (ug/g)	Nickel (ug/g)	Zinc (ug/g)	Mercury (ug/g)
GR1 -LN - B1	3.65	0.85	23.0	1.1	<0.7	12.8	161	0.03
LN - B2	3.60	0.79	14.7	3.0	<0.7	8.0	136	0.03
CS - B1	4.18	0.56	13.1	0.9	<0.6	9.6	115	0.03
CS - B2	3.67	0.58	18.1	0.7	1.0	15.0	168	0.08
CS - B3	3.59	0.80	14.0	<0.7	1.1	10.7	150	0.25
QH - B1	4.15	0.64	22.0	0.9	0.9	15.2	156	0.04
QH - B2	4.02	0.31	11.2	<0.6	<0.6	9.4	129	<0.02
QH - B3	3.55	0.60	19.8	1.6	<0.7	9.3	123	0.11
QH - I1	3.63	0.52	15.7	1.0	<0.7	10.3	123	0.05
QH - I2	3.52	0.49	15.1	1.9	<0.7	8.3	129	0.05
QH - I3	4.03	0.52	24.4	3.8	1.2	11.1	118	0.07
QH - I4	3.77	0.56	15.5	2.1	1.2	30.8	142	0.10
PR2 -LN - B1	2.69	1.16	33.0	3.2	6.3	28.4	281	0.09
LN - B2	2.70	1.08	31.8	4.0	2.3	21.4	181	0.28
LN - B3	3.02	0.94	29.5	2.1	3.4	23.8	268	0.11
CS - B1	3.50	0.82	71.4	4.0	4.7	25.3	181	0.25
CS - B2	3.83	0.62	64.3	3.3	4.1	21.1	203	0.35
CS - B3	3.85	0.93	37.2	5.2	5.2	43.5	300	0.32
CS - I1	3.26	1.15	21.9	9.0	3.4	2.6	281	0.41
CS - I2	1.73	0.95	26.1	8.7	11.2	13.0	432	<0.06
CS - I3	2.99	0.46	26.9	4.0	1.2	13.4	142	0.12
CS - I4	1.99	1.01	62.2	10.1	6.4	18.6	189	0.33
QH - B1	2.93	0.86	84.2	6.6	5.8	21.2	253	0.49
QH - B2	3.03	0.92	58.5	7.5	4.6	23.6	216	0.49
QH - B3	3.13	0.77	55.4	8.3	3.7	15.5	158	0.44
OL1 -LN - B1	3.16	0.69	24.0	<0.8	2.2	24.4	128	2.55
LN - B2	3.08	0.95	15.3	1.0	1.1	11.4	181	<0.03
LN - B3	3.05	0.60	15.1	3.0	3.5	12.3	172	0.05
LN - I1	1.12	0.94	10.9	<2.2	3.6	7.5	251	<0.09
LN - I2	2.08	0.72	11.5	2.7	<1.2	10.9	141	0.22
LN - I3	1.84	0.59	17.3	<1.4	<1.4	8.2	179	<0.05
LN - I4	1.48	0.51	8.5	<1.7	2.8	8.6	206	<0.07
CS - B1	3.08	0.39	17.8	4.8	1.9	15.9	175	0.12
CS - B2	3.05	0.90	17.7	4.4	2.5	15.4	61	0.19
CS - B3	3.00	0.74	15.9	5.4	2.4	16.9	151	0.15
QH - B1	2.80	0.90	17.7	6.9	1.4	22.5	123	0.28
QH - B2	4.01	0.41	20.5	6.3	1.6	22.3	120	0.22
QH - B3	2.62	0.57	17.3	9.5	2.3	28.0	147	0.29

Sample	"Dry" Wt (grams)	Cadmium (ug/g)	Copper (ug/g)	Chromium (ug/g)	Lead (ug/g)	Nickel (ug/g)	Zinc (ug/g)	Mercury (ug/g)
PR30-SL - B1	1.30	1.19	21.1	<1.9	<1.9	17.8	167	<0.08
SL - B2	1.45	1.55	25.7	<1.7	4.4	14.3	197	<0.07
LN - B1	2.08	3.66	37.9	2.0	6.7	22.9	472	0.05
LN - B2	1.76	4.26	73.0	10.9	11.1	26.6	487	0.15
LN - B3	2.72	2.71	39.7	2.3	6.2	23.3	389	0.07
LN - I1	1.12	1.83	30.9	<2.2	8.1	14.2	590	<0.09
LN - I2	0.89	0.48	18.3	<2.8	<2.8	15.3	142	<0.11
LN - I3	0.40	0.74	8.0	<6.3	8.0	11.2	105	<0.25
LN - I4	0.84	1.75	55.5	<3.0	3.6	31.2	292	<0.12
CS - B1	3.96	1.84	69.3	1.4	2.8	39.5	265	0.04
CS - B2	3.50	1.35	21.3	1.5	1.3	15.4	127	0.04
CS - B3	3.67	1.50	20.2	1.4	1.1	18.2	159	0.05
QH - B1	3.36	1.62	31.1	5.1	2.2	20.4	169	0.24
QH - B2	2.86	1.72	34.7	6.5	<0.9	27.4	176	0.40
QH - B3	3.03	1.97	41.5	6.7	2.8	24.4	208	0.35
PR47-LN - B1	2.85	1.25	35.3	1.4	2.2	28.4	186	0.08
LN - B2	3.04	1.13	18.0	<0.8	<0.8	11.0	177	0.04
LN - B3	2.88	1.07	27.6	<0.9	<0.9	15.6	158	0.07
CS - B1	3.39	0.83	14.7	1.3	<0.7	17.9	142	0.07
CS - B2	3.28	0.60	14.3	<0.8	<0.8	18.5	139	0.04
CS - B3	3.30	1.07	26.4	2.0	2.7	21.5	128	0.12
QH - B1	2.80	1.09	13.5	16.8	<0.9	23.7	112	0.34
QH - B2	3.05	1.15	23.3	22.6	1.1	18.9	110	0.43
QH - B3	2.81	1.14	16.6	13.3	1.2	27.0	155	0.49
MV1 -LN - B1	2.99	0.79	36.7	<0.8	<0.8	25.0	139	0.07
LN - B2	2.99	0.90	31.0	<0.8	<0.8	13.2	140	0.08
LN - B3	2.88	0.82	19.9	<0.9	<0.9	11.3	153	0.14
CS - B1	4.24	0.62	12.7	<0.6	<0.6	8.7	105	0.04
CS - B2	3.76	0.68	17.4	0.8	<0.7	11.6	109	0.12
CS - B3	3.93	0.62	18.1	0.7	1.1	11.2	129	0.06
QH - B1	2.71	0.96	14.9	5.9	<0.9	22.5	168	0.23
QH - B2	2.51	1.21	22.9	7.1	<0.5	19.0	174	0.24
QH - B3	2.68	1.24	21.5	6.1	1.0	25.9	139	0.28
QH - I1	2.65	1.35	16.5	9.6	1.5	15.5	82	0.23
QH - I2	2.60	1.23	9.7	8.8	<1.0	6.7	67	0.35
QH - I3	2.72	1.06	14.3	3.3	<0.9	25.3	124	0.19
QH - I4	2.67	1.22	33.6	8.1	1.2	16.1	159	0.45

Sample	"Dry" Wt (grams)	Cadmium (ug/g)	Copper (ug/g)	Chromium (ug/g)	Lead (ug/g)	Nickel (ug/g)	Zinc (ug/g)	Mercury (ug/g)
PR49-LN - B1	2.90	0.95	18.7	5.3	0.9	30.8	180	0.22
LN - B2	2.82	1.24	24.3	4.1	3.4	20.0	195	0.21
CS - B1	2.49	0.99	33.3	11.1	3.4	22.8	174	0.31
CS - B2	2.28	0.72	37.4	9.2	6.6	34.4	278	0.44
CS - B3	2.26	1.39	37.4	8.9	3.3	24.5	256	0.43
QH - B1	2.74	0.67	32.0	7.1	1.8	59.0	214	0.28
QH - B2	2.73	0.90	31.2	8.2	2.0	36.6	229	0.45
QH - B3	2.74	0.70	27.2	7.3	3.6	29.1	198	0.33
PR13-LN - B1	2.81	0.72	30.5	1.8	3.0	24.6	184	0.19
LN - B2	3.06	1.10	25.4	1.7	2.8	13.7	241	0.22
LN - B3	3.01	1.11	32.2	2.1	6.6	17.5	249	0.15
CS - B1	3.12	0.72	29.6	5.2	6.6	22.6	200	0.10
CS - B2	3.09	1.05	29.0	4.2	1.7	21.3	145	0.16
CS - B3	3.00	0.77	22.1	< 0.8	3.0	26.0	195	0.07
QH - B1	3.18	0.97	30.9	1.4	4.6	17.2	221	0.25
QH - B2	3.39	0.92	24.7	1.2	3.8	17.1	226	0.07
QH - B3	3.24	0.77	25.1	3.0	2.1	21.9	190	0.25
MH62-QH - B1	2.89	0.25	10.5	2.6	2.2	12.2	153	0.40
QH - B2	3.10	0.34	13.5	5.1	1.5	15.7	141	0.50
QH - B3	2.98	0.82	18.1	3.3	2.7	13.5	163	0.76
MH63-QH - B1	2.95	0.71	27.3	3.8	2.6	20.3	142	0.42
QH - B2	2.98	0.18	18.7	3.1	1.3	14.8	116	0.62
QH - B3	2.89	0.55	15.6	1.0	2.4	14.8	124	0.32
MH61-LN - B1	2.84	1.04	20.5	1.1	3.5	16.1	175	0.34
CS - B1	2.72	1.00	15.2	1.2	4.2	14.9	232	0.21
CS - B2	2.72	0.83	14.6	5.3	2.7	12.7	166	0.55
CS - B3	2.89	0.96	17.5	4.0	2.9	12.6	228	0.33
QH - B1	2.86	0.65	19.6	3.4	1.7	18.7	163	0.43
QH - B2	3.43	0.47	16.0	3.2	0.8	18.0	174	0.60
QH - B3	3.96	0.46	13.8	5.3	0.7	10.4	91	0.55
MH55-QH - B1	2.61	0.42	21.3	4.8	3.7	26.4	207	0.24
QH - B2	2.92	0.96	18.9	3.7	4.7	14.5	123	0.66
QH - B3	2.87	0.68	14.1	6.1	2.8	13.9	123	0.43
QH - I1	3.06	0.67	16.6	5.3	3.7	21.8	179	0.55
QH - I2	3.06	0.56	9.5	3.2	3.3	9.5	178	0.08
QH - I3	2.57	1.08	17.5	2.03	1.72	16.3	231	0.10
QH - I4	2.59	0.52	17.3	9.25	0.97	8.6	63	0.70

Table 5. Metal concentrations (ug/g dry weight) in clams sampled during June, 1986. Sample names contain three types of information. The first portion of the sample name gives the station where the clams were collected (see Table 1 for listing of stations). The second part of the sample name gives the size of the clams. SL means sub-legals (less than 4 cm); LN means littlenecks (4-6cm); CS means cherrystones (6-8 cm); and QH means quahog (greater than 8 cm). The letter in the third part of the sample name indicates the type of sample ("B" means a batch of 4 animals and "I" means an individual clam) and the number gives the individual or batch number.

Sample	"Dry" Wt (grams)	Cadmium (ug/g)	Copper (ug/g)	Chromium (ug/g)	Lead (ug/g)	Nickel (ug/g)	Zinc (ug/g)	Mercury (ug/g)
MH55,56QH - B1	2.12	0.97	26.3	5.8	4.0	16.9	155	0.72
QH - B2	2.54	0.73	29.8	3.8	3.6	23.9	213	0.49
QH - B3	2.32	0.34	25.6	2.9	4.2	25.1	202	0.46
QH - I1	2.38	0.74	19.6	11.5	3.9	17.0	141	0.41
QH - I2	2.49	1.08	39.9	6.5	3.2	33.3	178	0.47
QH - I3	2.28	0.57	23.9	4.2	<1.1	35.9	171	0.43
QH - I4	2.08	0.82	22.9	2.8	9.1	29.7	346	0.50
MH62-QH - B1	2.37	0.65	19.1	7.2	3.9	29.4	172	0.86
QH - B2	2.48	0.81	19.5	7.1	6.8	16.8	362	0.75
QH - B3	2.34	0.81	19.1	9.4	4.7	13.9	162	0.66
MH64-QH - B1	2.51	0.50	20.3	10.9	2.7	18.8	200	0.79
QH - B2	2.58	0.91	20.2	8.3	4.4	20.3	183	0.66
QH - B3	2.51	0.78	26.0	6.7	4.5	11.0	156	0.72
MH61-LN - B1	2.81	0.75	18.3	1.2	2.7	10.0	188	0.29
LN - B2	2.78	0.50	12.8	1.0	2.9	10.0	133	0.29
LN - B3	2.93	0.82	11.9	1.2	2.8	13.0	197	0.25
CS - B1	2.79	0.48	13.2	1.8	2.7	12.8	122	0.51
CS - B2	2.93	0.67	17.6	2.1	3.1	12.1	164	0.42
CS - B3	2.81	0.84	14.1	1.7	4.8	13.1	203	0.33
QH - B1	2.78	1.06	17.8	4.8	4.8	13.5	219	1.53
QH - B2	2.63	0.82	16.1	5.2	2.9	16.1	148	0.76
QH - B3	2.49	0.68	17.9	6.6	3.8	21.0	156	1.08
OH1- LN - B1	2.64	0.72	20.3	1.2	5.0	11.4	164	0.10
LN - B2	2.71	0.61	23.9	2.3	5.8	15.2	143	0.06
CS - B1	2.23	1.10	26.1	2.2	6.3	21.0	207	0.26
CS - B2	2.23	1.01	20.4	2.5	7.5	13.9	202	0.20
CS - B3	2.27	0.88	26.3	3.4	5.4	15.1	199	0.13
CS - I1	2.25	1.49	28.2	5.2	7.3	16.2	137	0.73
CS - I2	2.05	0.85	29.6	2.0	7.3	16.1	217	0.17
CS - I3	1.92	0.89	27.7	2.2	7.4	29.5	265	0.12
CS - I4	2.42	0.25	32.5	2.0	4.9	23.4	212	0.13
QH - B1	2.50	0.64	23.9	3.4	5.0	26.5	226	0.30
MV2 -QH - B1	1.24	1.49	64.4	8.7	8.8	89.2	366	0.93
QH - B2	1.24	1.01	49.1	7.2	5.8	69.0	449	0.63
QH - B3	1.15	1.48	50.9	4.3	7.6	45.0	407	0.65
QH - I1	1.19	2.27	52.3	4.87	9.54	34.4	414	0.34
QH - I2	1.22	1.31	68.0	11.90	8.36	62.0	397	0.72
QH - I3	1.22	2.09	49.0	7.91	5.23	46.7	434	0.57

Sample	"Dry" Wt (grams)	Cadmium (ug/g)	Copper (ug/g)	Chromium (ug/g)	Lead (ug/g)	Nickel (ug/g)	Zinc (ug/g)	Mercury (ug/g)
PR1 -LN - B1	2.95	0.88	58.9	4.0	3.9	24.2	216	0.37
LN - B2	2.86	0.84	28.5	2.0	3.0	18.0	264	0.14
CS - B1	2.39	1.13	54.5	6.2	4.7	34.8	223	0.56
CS - B2	2.34	1.15	43.8	4.7	8.5	27.2	315	0.31
CS - B3	2.26	1.33	79.4	6.8	5.3	23.7	235	0.49
QH - B1	2.72	1.01	32.6	5.5	5.4	24.1	243	0.27
PR30-LN - B1	2.93	0.92	18.4	0.9	2.7	23.0	165	0.05
LN - B2	3.06	1.16	20.5	1.2	2.2	11.6	157	0.08
LN - B3	2.91	1.05	17.3	<0.9	2.5	16.3	259	0.06
CS - B1	2.36	1.44	18.6	1.4	3.2	17.2	188	0.12
CS - B2	2.58	0.95	25.0	1.1	2.4	12.6	164	0.09
CS - B3	2.51	1.08	20.8	1.2	3.9	18.4	234	0.08
QH - B1	2.93	1.02	20.0	3.1	2.9	17.7	212	0.20
QH - B2	3.04	0.87	16.8	2.0	1.6	13.3	177	0.16
QH - B3	3.02	1.06	20.6	6.8	2.3	16.6	249	0.36
GR2 -LN - B1	2.86	0.72	16.4	<0.9	<0.9	12.8	242	0.07
LN - B2	2.91	0.65	19.3	<0.9	1.9	11.9	212	0.07
LN - B3	2.91	0.53	18.1	<0.9	1.4	11.3	132	0.09
CS - B1	2.92	0.51	15.4	<0.9	<0.9	8.8	121	0.08
CS - B2	3.11	0.45	23.0	0.9	1.4	9.1	120	0.09
CS - B3	3.24	0.45	17.9	1.0	1.2	10.6	143	0.09
QH - B1	3.31	0.35	14.7	<0.8	0.9	11.7	107	0.10
QH - B2	3.50	0.64	13.1	0.9	<0.7	13.7	159	0.10
PR49-LN - B1	2.64	0.59	24.1	1.9	1.5	19.3	158	0.14
LN - B2	2.75	0.67	25.9	2.9	3.8	18.0	164	0.15
CS - B1	2.76	0.60	37.6	4.0	2.7	16.9	119	0.25
CS - B2	2.60	0.65	35.4	4.4	1.2	29.4	189	0.34
CS - B3	2.59	0.85	36.3	4.3	4.1	22.9	197	0.27
CS - I1	2.54	0.94	23.8	2.2	2.4	22.2	176	0.19
CS - I2	2.53	1.44	90.1	6.9	5.7	28.5	200	0.41
CS - I3	2.92	0.89	49.7	7.1	7.8	24.7	395	0.42
CS - I4	2.31	0.56	24.2	1.3	2.2	37.7	552	0.31
QH - B1	2.91	0.46	23.1	6.1	1.5	25.6	302	0.30
QH - B2	2.91	0.84	42.7	5.7	3.7	15.9	153	0.33

Sample	"Dry" Wt (grams)	Cadmium (ug/g)	Copper (ug/g)	Chromium (ug/g)	Lead (ug/g)	Nickel (ug/g)	Zinc (ug/g)	Mercury (ug/g)
MV2 -LN - B1	2.80	0.32	24.8	< 0.9	2.9	20.0	125	0.11
LN - B2	2.77	0.45	19.2	< 0.9	3.9	15.0	216	0.10
LN - B3	2.80	0.70	16.3	< 0.9	5.1	11.2	118	0.09
CS - B1	2.86	0.29	18.4	< 0.9	3.7	13.5	130	0.12
CS - B2	2.89	0.32	18.5	< 0.9	1.9	12.2	139	0.10
CS - B3	2.83	0.43	19.9	< 0.9	3.2	12.3	151	0.10
MV1 -SL - B1	2.71	0.35	15.3	< 0.9	3.1	10.0	156	0.09
LN - B1	2.74	0.34	16.6	< 0.9	2.0	11.0	159	0.08
LN - B2	2.79	0.45	17.2	< 0.9	1.1	10.4	89	0.09
LN - B3	2.69	0.46	23.2	< 0.9	2.6	12.6	214	0.10
CS - B1	2.89	0.22	16.8	< 0.9	< 0.9	12.1	125	0.07
QH - B1	3.17	0.79	21.5	3.7	2.0	12.1	93	0.32
QH - B2	3.15	0.47	16.6	1.4	1.8	18.5	99	0.19
QH - B3	3.24	0.43	14.2	2.8	2.2	20.3	161	0.26
PR47-LN - B1	2.58	0.93	21.5	< 1.0	4.7	18.3	146	0.08
LN - B2	2.64	0.63	21.2	1.0	2.3	15.2	106	0.07
LN - B3	2.76	0.72	26.3	1.6	2.8	19.2	127	0.13
CS - B1	2.42	0.50	26.1	3.3	2.3	17.4	121	0.20
CS - B2	2.50	1.16	25.3	1.3	3.2	30.3	159	0.20
CS - B3	2.50	0.72	24.2	4.3	2.5	23.3	166	0.21
QH - B1	3.06	0.97	24.6	5.2	3.4	14.8	99	0.23
QH - B2	3.06	0.54	22.6	3.5	2.0	21.2	118	0.10
QH - B3	2.91	0.51	21.7	5.1	1.6	27.1	163	0.07
PR15-SL - B1	2.22	0.79	25.5	1.6	8.8	24.2	208	< 0.05
LN - B1	2.58	0.74	34.1	1.4	6.1	13.2	220	0.07
LN - B2	2.77	0.90	30.5	1.5	5.6	18.2	208	0.06
LN - B3	2.57	0.63	24.0	< 1.0	5.3	20.8	356	0.09
CS - B1	2.58	0.51	34.5	3.0	3.8	29.1	199	0.27
CS - B2	2.44	0.48	45.2	2.3	5.8	25.5	241	0.20
CS - B3	2.44	0.54	34.5	2.1	4.5	19.0	199	0.13
QH - B1	2.78	0.71	29.4	2.6	2.3	23.2	429	0.13
QH - B2	2.79	0.64	30.1	4.0	3.2	20.8	212	0.21
QH - B3	2.72	0.41	32.8	2.9	4.0	28.8	204	0.20

Table 6. Means and standard deviations (n-1 weighting) of metal concentrations (ug/g dry weight) in clams sampled during November, 1985. Results reported as less than detection in Table 4 were set equal to the detection limit for these calculations. When only one batch for a particular sample was prepared, the results were included with no standard deviation. The third part of the sample name indicates a batch average (B), an individual average (I), or a single batch result (B1).

Table 6. Averages of metal concentrations in clams collected November, 1985.

Sample	Number of Batches	Cadmium (ug/g) Mean	Std Dev.	Copper (ug/g) Mean	Std Dev.	Chromium (ug/g) Mean	Std Dev.	Lead (ug/g) Mean	Std Dev.	Nickel (ug/g) Mean	Std Dev.	Zinc (ug/g) Mean	Std Dev.	Mercury (ug/g) Mean	Std Dev.
GR1 -LN - B	2	0.82	0.04	18.9	5.9	2.1	1.4	0.7	0.0	10.4	3.4	148	18	0.03	0.00
GR1 -CS - B	3	0.65	0.13	15.1	2.7	0.8	0.1	0.9	0.3	11.8	2.8	144	27	0.12	0.12
GR1 -QH - B	3	0.52	0.18	17.7	5.7	1.1	0.5	0.7	0.1	11.3	3.4	136	18	0.06	0.04
GR1 -QH - I	4	0.52	0.03	17.7	4.5	2.2	1.2	0.9	0.3	15.1	10.5	128	10	0.07	0.02
PR2 -LN - B	3	1.06	0.11	31.4	1.8	3.1	1.0	4.0	2.1	24.6	3.5	243	54	0.16	0.10
PR2 -CS - B	3	0.79	0.16	57.6	18.0	4.1	1.0	4.7	0.6	29.9	11.9	228	64	0.31	0.05
PR2 -CS - I	4	0.89	0.30	34.3	18.7	8.0	2.7	5.5	4.3	11.9	6.7	261	128	0.23	0.17
PR2 -QH - B	3	0.85	0.07	66.1	15.8	7.4	0.8	4.7	1.1	20.1	4.2	209	48	0.47	0.03
OL1 -LN - B	3	0.75	0.18	18.2	5.1	1.6	1.2	2.3	1.2	16.0	7.3	160	28	0.88	1.45
OL1 -LN - I	4	0.69	0.19	12.1	3.7	2.0	0.6	2.3	1.2	8.8	1.4	194	46	0.11	0.07
OL1 -CS - B	3	0.68	0.26	17.1	1.1	4.8	0.5	2.3	0.3	16.1	0.8	129	60	0.15	0.03
OL1 -QH - B	3	0.62	0.25	18.5	1.7	7.5	1.7	1.7	0.5	24.3	3.2	130	15	0.26	0.04
PR30-SL - B	2	1.37	0.25	23.4	3.3	1.8	0.1	3.2	1.8	16.1	2.5	182	21	0.07	0.01
PR30-LN - B	3	3.54	0.78	50.2	19.8	5.1	5.0	8.0	2.7	24.3	2.0	449	53	0.09	0.05
PR30-LN - I	4	1.20	0.69	28.2	20.5	3.6	1.8	5.6	2.8	18.0	9.0	282	220	0.14	0.07
PR30-CS - B	3	1.57	0.25	36.9	28.1	1.4	0.1	1.7	0.9	24.4	13.2	184	72	0.04	0.01
PR30-QH - B	3	1.77	0.18	35.8	5.3	6.1	0.9	1.9	1.0	24.1	3.5	184	21	0.33	0.08
PR47-LN - B	3	1.15	0.09	27.0	8.6	1.0	0.3	1.3	0.8	18.3	9.0	174	14	0.06	0.03
PR47-CS - B	3	0.84	0.24	18.4	6.9	1.4	0.6	1.4	1.1	19.3	1.9	136	7	0.08	0.04
PR47-QH - B	3	1.12	0.03	17.8	5.0	17.6	4.7	1.0	0.2	23.2	4.1	126	26	0.42	0.08
MV1 -LN - B	3	0.84	0.06	29.2	8.5	0.8	0.0	0.8	0.0	16.5	7.4	144	8	0.10	0.04
MV1 -CS - B	3	0.64	0.04	16.1	3.0	0.7	0.1	0.8	0.3	10.5	1.6	114	13	0.07	0.04
MV1 -QH - B	3	1.14	0.15	19.8	4.3	6.3	0.7	0.8	0.3	22.4	3.5	160	18	0.25	0.03
MV1 -QH - I	4	1.21	0.12	18.5	10.5	7.4	2.8	1.1	0.3	15.9	7.6	108	42	0.31	0.12
PR49-LN - B	2	1.09	0.20	21.5	4.0	4.7	0.8	2.1	1.8	25.4	7.7	188	10	0.21	0.00
PR49-CS - B	3	1.03	0.34	36.1	2.4	9.7	1.2	4.5	1.9	27.2	6.3	236	54	0.39	0.07
PR49-QH - B	3	0.76	0.13	30.1	2.6	7.5	0.6	2.4	1.0	41.6	15.6	214	15	0.35	0.09
PR13-LN - B	3	0.97	0.22	29.3	3.5	1.9	0.2	4.1	2.2	18.6	5.5	224	36	0.19	0.04
PR13-CS - B	3	0.85	0.18	26.9	4.2	3.4	2.3	3.7	2.5	23.3	2.4	180	30	0.11	0.05
PR13-QH - B	3	0.89	0.10	26.9	3.5	1.9	1.0	3.5	1.3	18.7	2.8	212	19	0.19	0.11
MH62-QH - B	3	0.47	0.31	14.0	3.8	3.7	1.3	2.1	0.6	13.8	1.8	152	11	0.55	0.19
MH63-QH - B	3	0.48	0.27	20.5	6.1	2.6	1.4	2.1	0.7	16.6	3.1	127	14	0.45	0.15
MH61-LN - B1	1	1.04		20.5		1.1		3.5		16.1		175		0.34	
MH61-CS - B	3	0.93	0.09	15.8	1.5	3.5	2.1	3.3	0.8	13.4	1.3	209	37	0.36	0.17
MH61-QH - B	3	0.52	0.10	16.5	2.9	4.0	1.1	1.1	0.6	15.7	4.6	143	45	0.53	0.09
MH55-QH - B	3	0.69	0.27	18.1	3.6	4.9	1.2	3.7	0.9	18.3	7.0	151	48	0.44	0.21
MH55-QH - I	4	0.71	0.26	15.2	3.8	5.0	3.2	2.4	1.3	14.1	6.2	163	71	0.36	0.32

Table 7. Means and standard deviations (n-1 weighting) of metal concentrations (ug/g dry weight) in clams sampled during June, 1986. Results reported as less than detection in Table 5 were set equal to the detection limit for these calculations. When only one batch for a particular sample was prepared, the results were included with no standard deviation. The third part of the sample name indicates a batch average (B), an individual average (I), or a single batch result (B1).

Table 7. Averages of metal concentrations in clams collected June, 1986.

Sample	Number of Batches	Cadmium (ug/g) Mean	Std Dev.	Copper (ug/g) Mean	Std Dev.	Chromium (ug/g) Mean	Std Dev.	Lead (ug/g) Mean	Std Dev.	Nickel (ug/g) Mean	Std Dev.	Zinc (ug/g) Mean	Std Dev.	Mercury (ug/g) Mean	Std Dev.
MH55,56QH - B	3	0.68	0.31	27.2	2.3	4.1	1.5	4.0	0.3	22.0	4.4	190	31	0.56	0.14
MH55,56QH - I	4	0.80	0.21	26.6	9.1	6.3	3.8	4.3	3.4	29.0	8.4	209	93	0.45	0.04
MH62-QH - B	3	0.76	0.09	19.2	0.2	7.9	1.3	5.1	1.5	20.1	8.2	232	113	0.76	0.10
MH64-QH - B	3	0.73	0.21	22.2	3.3	8.7	2.1	3.9	1.0	16.7	5.0	180	22	0.72	0.06
MH61-LN - B	3	0.69	0.17	14.3	3.5	1.1	0.1	2.8	0.1	11.0	1.8	172	35	0.28	0.03
MH61-CS - B	3	0.66	0.18	14.9	2.3	1.9	0.2	3.5	1.1	12.7	0.5	163	41	0.42	0.09
MH61-QH - B	3	0.85	0.19	17.3	1.0	5.5	1.0	3.8	0.9	16.9	3.8	174	39	1.12	0.39
OH1- LN - B	2	0.66	0.08	22.1	2.5	1.7	0.7	5.4	0.6	13.[illegible]	2.7	154	15	0.08	0.03
OH1- CS - B	3	1.00	0.11	24.3	3.4	2.7	0.6	6.4	1.0	16.7	3.8	203	4	0.20	0.06
OH1- CS - I	4	0.87	0.51	29.5	2.1	2.8	1.6	6.7	1.2	21.3	6.4	208	53	0.29	0.30
OH1- QH - B1	1	0.64		23.9		3.4		5.0		26.5		226		0.30	
MV2 -QH - B	3	1.33	0.28	54.8	8.3	6.8	2.2	7.4	1.5	67.7	22.1	407	42	0.73	0.17
MV2 -QH - I	3	1.89	0.51	56.4	10.1	8.2	3.5	7.7	2.2	47.7	13.9	415	19	0.54	0.19
PR1 -LN - B	2	0.86	0.03	43.7	21.5	3.0	1.4	3.5	0.7	21.1	4.4	240	34	0.26	0.16
PR1 -CS - B	3	1.20	0.11	59.2	18.3	5.9	1.1	6.2	2.1	28.6	5.7	258	50	0.45	0.13
PR1 -QH - B1	1	1.01		32.6		5.5		5.4		24.1		243		0.27	
PR30-LN - B	3	1.04	0.12	18.7	1.6	1.0	0.2	2.5	0.3	17.0	5.7	194	57	0.06	0.02
PR30-CS - B	3	1.16	0.26	21.5	3.2	1.2	0.2	3.2	0.8	16.1	3.1	195	35	0.09	0.02
PR30-QH - B	3	0.99	0.10	19.1	2.1	4.0	2.5	2.3	0.7	15.9	2.3	212	36	0.24	0.10
GR2 -LN - B	3	0.63	0.09	17.9	1.5	0.9	0.0	1.4	0.5	12.0	0.8	195	57	0.07	0.01
GR2 -CS - B	3	0.47	0.04	18.8	3.9	0.9	0.1	1.1	0.3	9.5	0.9	128	13	0.09	0.01
GR2 -QH - B	2	0.50	0.21	13.9	1.1	0.8	0.1	0.8	0.2	12.7	1.4	133	37	0.10	0.00
PR49-LN - B	2	0.63	0.06	25.0	1.2	2.4	0.7	2.6	1.7	18.6	0.9	161	5	0.14	0.00
PR49-CS - B	3	0.70	0.13	36.4	1.1	4.2	0.2	2.7	1.5	23.1	6.2	168	43	0.29	0.04
PR49-CS - I	4	0.96	0.36	47.0	31.2	4.4	3.1	4.5	2.7	28.3	6.8	331	177	0.33	0.11
PR49-QH - B	2	0.65	0.27	32.9	13.9	5.9	0.3	2.6	1.5	20.7	6.9	227	105	0.31	0.02
MV2 -LN - B	3	0.49	0.19	20.1	4.3	0.9	0.0	4.0	1.1	15.4	4.4	153	55	0.10	0.01
MV2 -CS - B	3	0.35	0.07	18.9	0.8	0.9	0.0	2.9	1.0	12.7	0.7	140	11	0.10	0.02
MV1 -SL - B1	1	0.35		15.3		0.9		3.1		10.0		156		0.09	
MV1 -LN - B	3	0.42	0.07	19.0	3.7	0.9	0.0	1.9	0.8	11.3	1.1	154	63	0.09	0.01
MV1 -CS - B1	1	0.22		16.8		0.9		0.9		12.1		125		0.07	
MV1 -QH - B	3	0.56	0.20	17.4	3.7	2.7	1.2	2.0	0.2	17.0	4.3	118	37	0.26	0.07
PR47-LN - B	3	0.76	0.15	23.0	2.9	1.2	0.4	3.3	1.3	17.6	2.1	127	20	0.09	0.03
PR47-CS - B	3	0.79	0.33	25.2	0.9	3.0	1.6	2.7	0.5	23.7	6.5	149	24	0.20	0.01
PR47-QH - B	3	0.67	0.26	23.0	1.5	4.6	1.0	2.3	0.9	21.0	6.1	127	33	0.13	0.09
PR15-SL - B1	1	0.79		25.5		1.6		8.8		24.2		208		0.05	
PR15-LN - B	3	0.76	0.14	29.5	5.1	1.3	0.3	5.7	0.4	17.4	3.9	261	82	0.07	0.01
PR15-CS - B	3	0.51	0.03	38.1	6.2	2.4	0.5	4.7	1.0	24.6	5.1	213	24	0.20	0.07
PR15-QH - B	3	0.59	0.15	30.8	1.8	3.2	0.8	3.2	0.9	24.3	4.1	282	128	0.18	0.04

c) Digestion Blanks

Digestion blanks were prepared with each sample set. The average blanks were calculated for the digested sample and for an average sample (dry weight of 3 g):

	Digest Blank	Average Sample Blank
Cadmium	0.007 mg/l	0.12 ug/g dry weight
Copper	0.04 mg/l	0.6 ug/g dry weight
Chromium	0.08 mg/l	1.2 ug/g dry weight
Lead	<0.05 mg/l	<0.08 ug/g dry weight
Mercury	0.003 mg/l	0.05 ug/g dry weight
Nickel	<0.057 mg/l	<0.08 ug/g dry weight
Zinc	0.49 mg/l	8.2 ug/g dry weight

Samples with less than a 3 g dry weight would have a higher blank on a dry weight basis because all samples were diluted to the same total volume (50 ml).

d) Estimate of Detection Limit Error for Metal Concentration Data

One source of error in the metal concentration data can be estimated by taking the detection limit of the flame atomic absorption measurements to estimate the standard deviation of a given measurement. The amount of sample taken for each digestion is given in Tables 4 and 5. Since all samples were made up to 50 ml, that calculation would be:

(Detection limit) mg/l x 50 ml/(dry wt) g = (Error) ug/g dry wt

The detection limits for the flame atomic absorption measurements and for mercury by the gold film technique were:

Cadmium	0.005	mg/l
Copper	0.025	mg/l
Chromium	0.05	mg/l
Lead	0.05	mg/l
Mercury	0.002	mg/l
Nickel	0.05	mg/l
Zinc	0.10	mg/l

The detection limit for mercury was based upon the procedures used for these samples where 2 ml of sample was taken for the mercury measurements. The detection limit for zinc was based upon the samples being diluted 20 fold before direct aspiration. Detection limits for the other samples were for direct aspiration of the undiluted sample.

An example calculation follows for sample GR1-LN-B1 from Table 4. That sample weighed 3.65 g dry weight. For cadmium, the calculation would be:

0.005 mg/l x 50 ml/(3.65 g dry wt) = 0.068 ug/g dry weight

The metal concentrations for this sample together with the error estimate would be:

Cadmium	0.85	± 0.068	ug/g
Copper	23.0	± 0.34	ug/g
Chromium	1.1	± 0.68	ug/g
Lead	0.0	± 0.68	ug/g
Mercury	0.03	± 0.027	ug/g
Nickel	12.8	± 0.68	ug/g
Zinc	161.	± 1.37	ug/g

The results for lead were less than detection. The error of 0.68 ug/g was rounded to 0.7 ug/g and reported in Table 4 as <0.7 ug/g.

IV. References

Cullen, Douglas J., 1984. A Biogeographical Survey: Copper and Nickel in Mercenaria mercenaria, Relative to Concentrations in the Water Column in a New England Estuary. M.S. Thesis, University of Rhode Island, Kingston, Rhode Island.

U.S. Environmental Protection Agency, 1983. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

Appendix A. Performance evaluation reports for EPA Water Pollution Studies WP016 and WP017 reported by the analytical laboratory during 1986.

for ~~RBH~~ RBB

PERFORMANCE EVALUATION REPORT — DATE: 05/23/86

WATER POLLUTION STUDY NUMBER WP016

LABORATORY: RI002

PARAMETERS	SAMPLE NUMBER	REPORT VALUE	TRUE VALUE*	ACCEPTANCE LIMITS	WARNING LIMITS	PERFORMANCE EVALUATION
TRACE METALS IN MICROGRAMS PER LITER:						
CADMIUM	1	298.	307	269.- 348.	279.- 338.	ACCEPTABLE
	2	115.	119.3	105.- 134.	108.- 131.	ACCEPTABLE
CHROMIUM	1	300.	274	213.- 331.	227.- 316.	ACCEPTABLE
	2	748.	685	534.- 826.	571.- 790.	ACCEPTABLE
COPPER	1	365	380	332.- 422.	344.- 411.	ACCEPTABLE
	2	755	740	657.- 830.	679.- 809.	ACCEPTABLE
IRON	1	1210	1311	1120.-1480.	1170.-1440.	ACCEPTABLE
	2	600	633	538.- 722.	561.- 699.	ACCEPTABLE
MERCURY	1	52.0	50.0	34.4- 65.9	38.3- 61.9	ACCEPTABLE
	2	13.5	15.0	10.1- 20.7	11.4- 19.4	ACCEPTABLE
MANGANESE	1	518	510	443.- 564.	463.- 550.	ACCEPTABLE
	2	158	150	129.- 169.	134.- 164.	ACCEPTABLE
NICKEL	1	495	532	460.- 605.	479.- 587.	ACCEPTABLE
	2	805	911	791.-1030.	821.-1000.	CHECK FOR ERRO
LEAD	1	115	118.3	99.0- 146.	96.1- 139.	ACCEPTABLE
	2	840	851	706.- 984.	740.- 949.	ACCEPTABLE
ZINC	1	390	383	333.- 429.	345.- 417.	ACCEPTABLE
	2	872	893	782.- 994.	809.- 967.	ACCEPTABLE
SILVER	3	2.75	2.60	1.50- 3.42	1.76- 3.35	ACCEPTABLE
	4	18.3	18.2	13.9- 23.2	15.1- 22.0	ACCEPTABLE
MINERALS IN MILLIGRAMS PER LITER: (EXCEPT AS NOTED)						
PH-UNITS	3	6.62	6.70	6.54- 6.83	6.58- 6.80	ACCEPTABLE
	4	4.42	4.50	4.38- 4.59	4.41- 4.56	ACCEPTABLE

* BASED UPON THEORETICAL CALCULATIONS, OR A REFERENCE VALUE WHEN NECESSARY.

PERFORMANCE EVALUATION REPORT DATE: 11/13/

WATER POLLUTION STUDY NUMBER WP017

LABORATORY: RI002

ANALYTES	SAMPLE NUMBER	REPORT VALUE	TRUE VALUE*	ACCEPTANCE LIMITS	WARNING LIMITS	PERFORMANCE EVALUATION
TRACE METALS IN MICROGRAMS PER LITER:						
CADMIUM	1	95.0	100	82.7- 115.	86.7- 111.	ACCEPTABLE
	2	47.0	50.0	40.4- 57.1	42.5- 55.0	ACCEPTABLE
CHROMIUM	1	100	90.0	59.5- 107.	74.2- 103.	ACCEPTABLE
	2	72.0	60.0	44.6- 72.6	49.1- 69.1	CHECK FOR ER
COPPER	1	210	224	194.- 249.	201.- 242.	ACCEPTABLE
	2	23.0	22.4	15.9- 28.8	17.5- 27.2	ACCEPTABLE
LEAD	1	287	315	260.- 365.	273.- 352.	ACCEPTABLE
	2	77.0	94.0	65.9- 103.	70.5- 99.2	ACCEPTABLE
ZINC	1	282	304	255.- 348.	267.- 337.	ACCEPTABLE
	2	18.5	19.0	13.4- 25.7	14.9- 24.2	ACCEPTABLE
NUTRIENTS IN MILLIGRAMS PER LITER:						
AMMONIA-NITROGEN	1	0.426	0.200	.0261- .461	.0784- .409	CHECK FOR ER
	2	2.20	2.00	1.54- 2.44	1.65- 2.33	ACCEPTABLE
DEMANDS IN MILLIGRAMS PER LITER:						
5-DAY BOD	1	145	204	121.- 287.	142.- 267.	ACCEPTABLE
	2	62.2	51.8	28.5- 75.0	34.2- 69.2	ACCEPTABLE
MISCELLANEOUS PARAMETERS:						
TOTAL CYANIDE	1	0.135	0.141	.0854- .178	.0971- .166	ACCEPTABLE
(IN MG/L)	2	0.195	0.219	.133- .284	.152- .265	ACCEPTABLE

* BASED UPON THEORETICAL CALCULATIONS, OR A REFERENCE VALUE WHEN NECESSARY.