FINAL REPORT

Identifying Pollutants in Species Regularly Consumed by Native Americans in the Passamaquoddy Bay Region

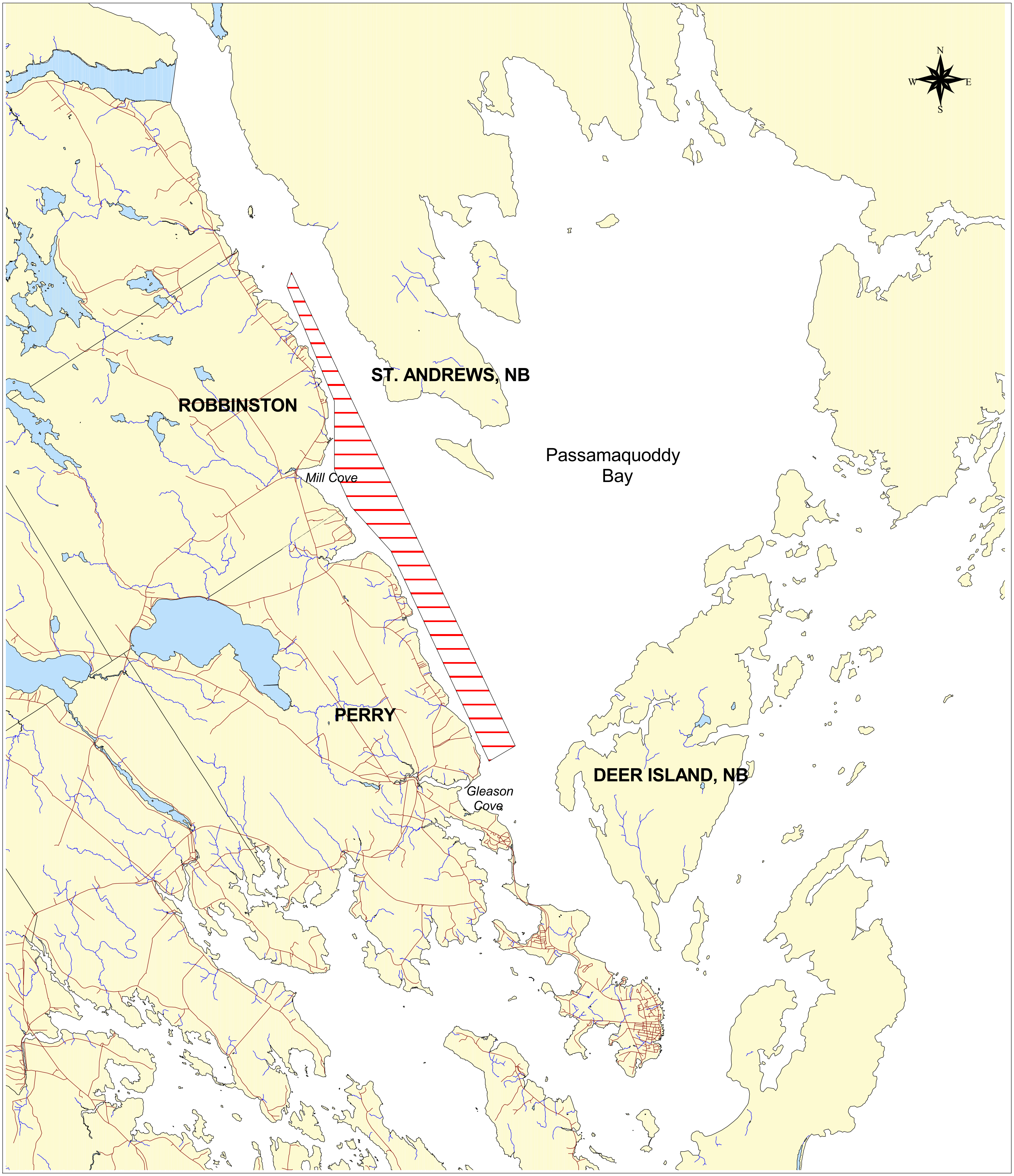
FY 1997 Environmental Justice Project

RESULTS OF THE TOXICS MONITORING PROGRAM

March 9, 2001

Environmental Department of the Passamaquoddy Tribe at Pleasant Point
PO Box 343
Perry, Maine 04667

Community Partner:
Cobscook Bay Resource Center
4 Favor Street
Eastport, Maine 04631

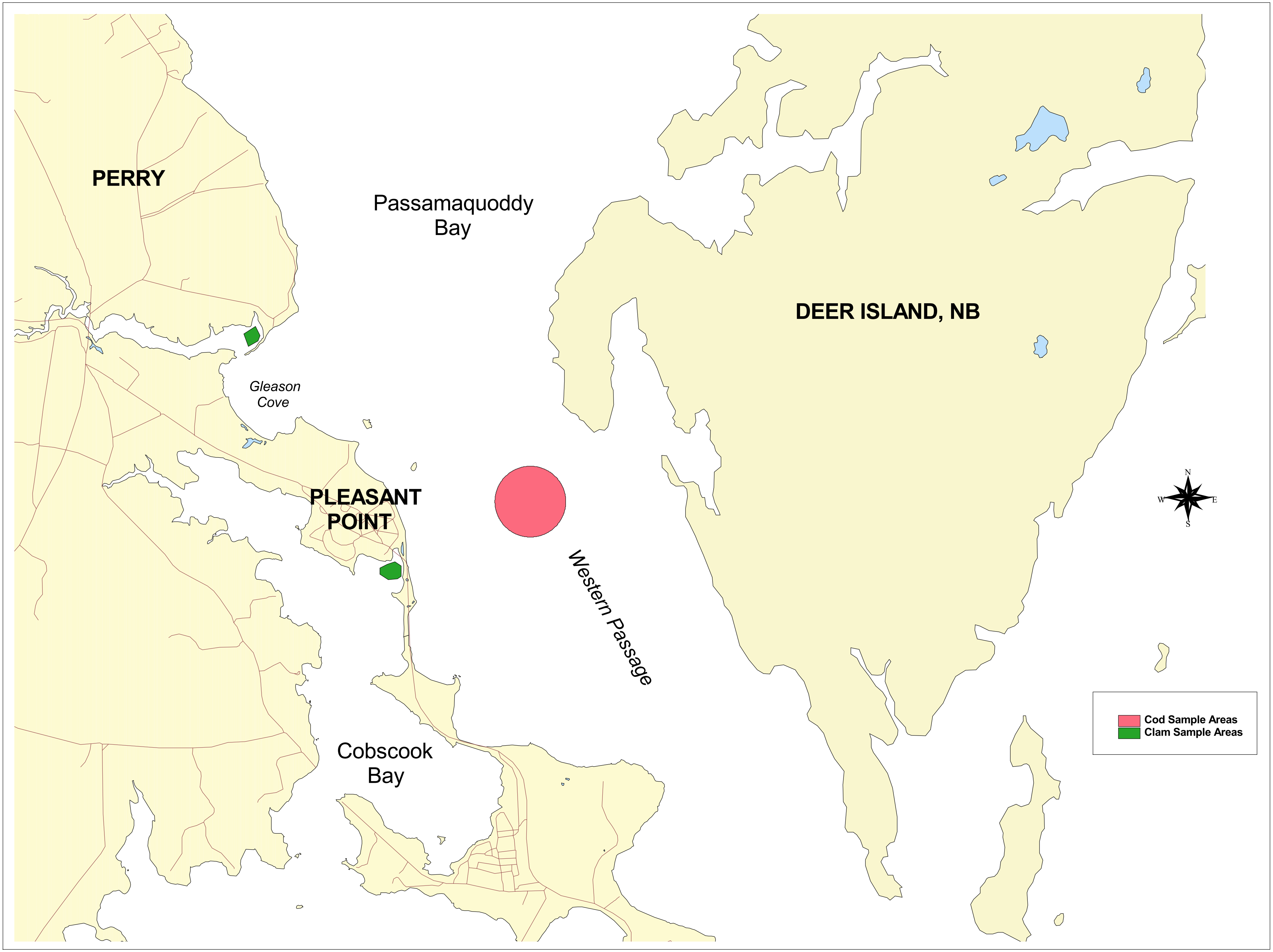


Passamaquoddy Toxics Study: Lobster Sample Areas

Map produced 8/22/00

Created by the Cobscook Bay Resource Center from data provided by the Maine Department of Marine Resources and the Maine Office of GIS.

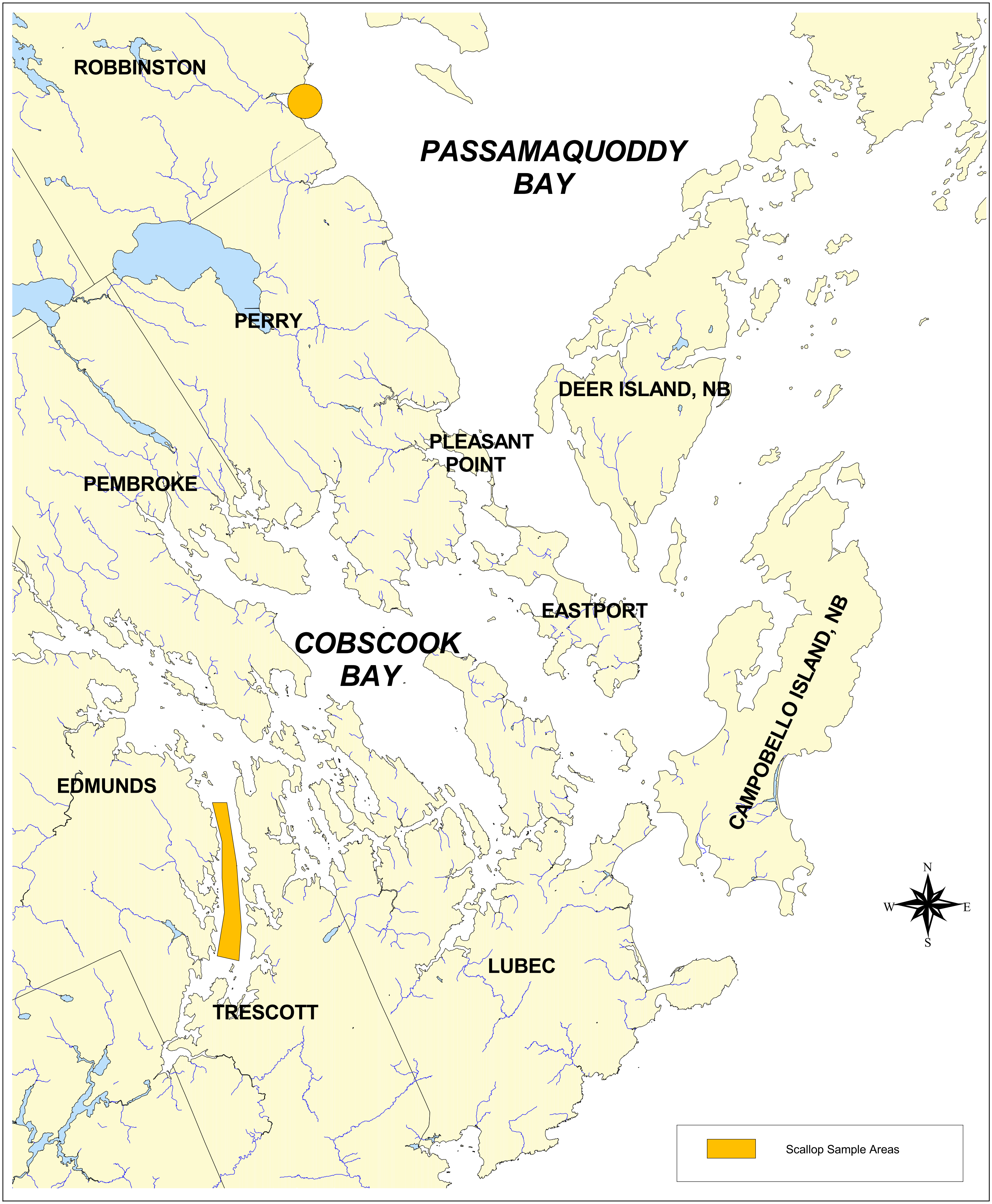
2 0 2 4 Miles



Passamaquoddy Toxics Study: Clam and Cod Sample Areas

Created by the Cobscook Bay Resource Center from data provided by the Maine Department of Marine Resources and the Maine Office of GIS.

Map produced 8/22/00



PASSAMAQUODDY TOXICS STUDY: SCALLOP SAMPLE AREAS

Map produced 8/28/00

Created by the Cobscook Bay Resource Center from data provided by the Maine Department of Marine Resources and the Maine Office of GIS.

ACKNOWLEDGEMENTS

We are grateful to the US Environmental Protection Agency for funding this project under the Environmental Justice program. For assistance in sample collection we would like to thank Fred Moore of the Passamaquoddy Tribe and Dennis Preston. The University of Maine Water Resources Institute and the State of Maine Health and Environmental Testing Laboratory analyzed the samples and provided assistance in initial project design. In particular we would like to thank Therese Anderson from WRI and John Nims and Michael Corbin from HETL for their generous willingness to go beyond the initial project workplan. Thanks to Barry Mower and Chuck Penney at the Maine Department of Environmental Protection for their cooperation in providing us with data and information about Maine's toxics and dioxin testing programs. We would especially like to thank John Sowles of the Maine Department of Marine Resources for his assistance in preparing this report. His comments and suggestions were invaluable.

ABSTRACT

In 1997 the Pleasant Point Passamaquoddy Tribe, in cooperation with its community partner, the Cobscook Bay Clam Restoration Project (which became the Cobscook Bay Resource Center in 1998), undertook this project to identify potential pollutants in marine species often consumed by tribal members. The Toxics Monitoring Program was designed to identify the levels of dioxin and thirteen priority pollutant metals in five marine species. The information gathered was intended to be used as baseline data describing the pollutant levels of certain species in the Passamaquoddy Bay region.

Tissue samples were taken from species collected in Passamaquoddy Bay and in Cobscook Bay. A total of eight composite tissue samples were collected from the following species: lobster, soft-shell clam, cod, and sea scallop. Samples were analyzed for dioxin at the University of Maine at Orono Water Resources Institute lab and were analyzed for heavy metals at the State of Maine Health and Environmental Testing lab. Results obtained from analysis for heavy metals and dioxins were compared with other state, regional, and national studies including the EPA National Study of Chemical Residues in Fish, the State of Maine Surface Water Ambient Toxic Monitoring Program, and the Gulf of Maine Council Gulf Watch Program.

The comparisons to other studies are not meant to be used as a determinant of risk to public health. For health risk assessments to be made, the data must be independently reviewed by a professional risk assessor. It is recommended that the data reported here be independently reviewed by a human health risk assessor and that further, regular testing of these species be performed to determine trends or changes.

INTRODUCTION

In 1997 the Pleasant Point Passamaquoddy Tribe, in cooperation with its community partner, the Cobscook Bay Clam Restoration Project (which became the Cobscook Bay Resource Center in 1998), undertook this project to identify potential pollutants in marine species often consumed by tribal members. The Toxics Monitoring Program was designed to identify the levels of dioxin and thirteen priority pollutant metals in five marine species. The information gathered was intended to be used as baseline data describing the health of certain species in the Passamaquoddy Bay region.

The traditional fishing grounds of the Passamaquoddy Tribe include the St. Croix Estuary, Passamaquoddy Bay, and Cobscook Bay. Today, these areas support the tribe's cultural way of life as well as serving as a source of food. Each area is subject to varied point and nonpoint sources of pollution. In particular, the estuary is influenced by industrial outflow from several municipal wastewater treatment plants and a paper mill. The effects of these sources of pollution on estuarine and marine biota are largely unknown.

Tribal members remain potentially at risk from a number of health threatening pollutants. There is a statewide warning against the consumption of lobster tomalley due to high dioxin content and other contaminants such as cadmium. Lobster and finfish in Passamaquoddy Bay are tested irregularly and infrequently for dioxin content. Other marine organisms such as clams are not tested in this area for dioxin and heavy metals.

Studies performed nationally have documented concentrations of select toxins in fish and shellfish but most work has focused on freshwater, and not marine, species. In the National Study of Chemical Residues in Fish, undertaken by the U.S. Environmental Protection Agency, freshwater fish from thirteen sites in Maine were analyzed for dioxin (U.S. EPA, 1992 a and b). The mean concentrations for six dioxin congeners are summarized in picograms per gram in the table below.

2,3,7,8 TCDD	1,2,3,7,8 PeCDD	1,2,3,4,7,8 HxCDD	1,2,3,6,7,8 HxCDD	1,2,3,7,8,9 HxCDD	1,2,3,4,6,7,8 HpCDD
13.39 pg/g	1.50 pg/g	0.49 pg/g	7.52 pg/g	0.67 pg/g	3.09 pg/g

In the same study, seven freshwater sites in Maine were analyzed for Mercury. The mean concentration for mercury in these sites was 0.30 ug/g. Nationally, 92.2 % of the 374 sites surveyed were found to have detectable levels of mercury in finfish. The mean concentration of mercury in freshwater fish nationally was 0.26 ppm.

In the National Contaminant Biomonitoring Program, freshwater fish were analyzed for their levels of cadmium (U.S. EPA, 1995). In 1984, cadmium was found in a mean concentration level of 0.03 ppm in freshwater fish surveyed.

Studies done outside the United States have documented the levels of mercury in marine fish and shellfish (U.S. EPA, 1995). Concentrations of inorganic mercury were found to be between 0-5.6 ppm. However, most sites were found to have less than .5 ppm inorganic mercury for most species.

The Maine Surface Water Ambient Toxic Monitoring Program is documenting the levels of toxics in freshwater fish and some marine species. In 1995, monitoring was accomplished for levels of toxics in lobsters in eight sites along the Maine coast (Sowles, 1997). The table below summarizes the results of this study in approximate average concentrations in micrograms per gram.

	Lobster Meat (dry weight)	**Lobster Tomalley (dry weight)**
Arsenic	19 ug/g	16.75 ug/g
Cadmium	0.15 ug/g	7.69 ug/g
Chromium	0.41 ug/g	0.23 ug/g
Copper	60.75 ug/g	253.75 ug/g
Lead	0.84 ug/g	1.06 ug/g
Mercury	.83 ug/g	.33 ug/g
Selenium	2.65 ug/g	2.63 ug/g
Zinc	127.5 ug/g	54.25 ug/g

The results of this project are meant to provide the Tribe, the Resource Center, and other interested parties with information about the levels of heavy metals and dioxin in marine species in the Passamaquoddy Bay region. The data will be used to determine future monitoring needs as well as providing the Tribe with information it needs to advise tribal members about the potential health effects of consuming fish and shellfish.

METHODS

Tissue samples were taken from species collected in Passamaquoddy Bay and in Cobscook Bay. A total of eight composite tissue samples were collected from the following species: lobster, soft-shell clam, cod, and sea scallop. The initial proposal for this project called for flounder samples to be taken as well, however, samples of this species were not obtained.

Lobster:
Two composite samples were collected in Passamaquoddy Bay between Gleason Point, Perry and the Robbinston Public Boat Landing by wire lobster trap. Each sample consisted of five individual animals. One sample was collected on 9/18/98 and the animals ranged in size from 1 pound to 2 pounds 8 ounces. The second composite was collected on 10/5/98 and each individual ranged in size from 3 pounds to 3 ¾ pounds. All lobsters were sent to the lab in the shell.

Soft-Shell Clam:
Two composite samples were collected of this species. On 9/18/98, one sample was collected at Gleason Cove, Perry in Passamaquoddy Bay by hand harvest. This composite consisted of 20 animals ranging in size from 70 mm to 87 mm. The second sample was collected on 9/18/98 below the ceremonial grounds at Pleasant Point in Cobscook Bay by hand harvest. This sample consisted of 18 animals ranging in size from 68 mm to 84 mm. All clams were sent to the lab in the shell.

Cod:
One composite sample of cod was collected on 8/28/98 in the deep hole off Pleasant Point in Passamaquoddy Bay. The sample consisted of five animals collected using a hand line. The animals ranged in sized from 1.10 pounds to 3 pounds. All cod composites consisted of whole fish.

Sea Scallop:
A total of three composite samples were collected for scallops. On 11/29/98, a sample was collected by a diver in Mill Cove, Robbinston which is in Passamaquoddy Bay. This sample consisted of 20 muscle only scallop meats and weighed a total of 1.5 pounds. On 11/30/98 two composites were collected by a dragger in Whiting Bay within Cobscook Bay. One sample consisted of 20 muscle only scallop meats weighing 2 pounds and the other consisted of 18 meats and weighed 2.05 pounds.

All samples were wrapped immediately after collection in aluminum foil and placed on ice. After being transported back to the project coordinator's residence they were placed in a freezer and kept frozen until transport to the University of Maine Water Research Institute lab. There shellfish samples were shucked and the soft tissue ground and homogenized. For cod, the whole body sample was used for the composite. The muscle tissue and the tomalley were separated for lobster and analyzed separately. A portion of each sample was analyzed for dioxins and furans at WRI while another portion was sent to the Maine Health and Environmental Testing lab in Augusta to be analyzed for heavy metals. Analysis for the following metals was performed: arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, antimony, selenium, silver, thallium, and zinc.

Dioxins and furans were analyzed using EPA 1613, the method for tetra- through octa-chlorinated dioxins and furans by isotope dilution HRGC/HRMS. Samples were analyzed for metals using EPA 200-7.

RESULTS

Heavy Metals
The following tables display the results of the heavy metals analysis for each composite sample. All results are expressed as parts per million and are in dry weight basis. The following codes apply in the sample identification numbers:

PAS – Passamaquoddy Bay
COB – Cobscook Bay

SCA – Scallop
LOB – Lobster
TOM – Lobster Tomalley
CLA – Clam
COD – Cod

In the results table "ND" stands for Not Detected Down to the Reporting Limit and "J" stands for Approximately.

Sample	As	Be	Cd	Cr	Cu
PAS-SCA-01	4.6	ND 0.05	0.26	0.52	1.4
COB-SCA-02	5.2	ND 0.05	0.29	0.55	0.97
COB-SCA-03	5.3	ND 0.05	0.30	0.46	1.1
PAS-LOB-01	31	ND 0.05	0.18	0.79	100
PAS-LOB-02	72	ND 0.05	J 0.1	1.95	125
PAS-TOM-01	15	ND 0.05	7.2	0.27	225
PAS-TOM-02	37	ND 0.05	44.4	0.25	500
PAS-CLA-01	8.1	0.05	0.4	2.7	13
COB-CLA-02	2.9	ND 0.05	0.21	1.0	3.8
PAS-COD-01	11	ND 0.05	ND 0.1	1.0	3.1

Sample	Pb	Hg	Ni	Sb	Se
PAS-SCA-01	ND 0.4	0.16	ND 0.4	ND 0.5	1.24
COB-SCA-02	ND 0.4	0.21	ND 0.4	ND 0.5	0.89
COB-SCA-03	ND 0.4	0.37	ND 0.4	ND 0.5	1.30
PAS-LOB-01	ND 0.4	0.57	5.2	ND 0.5	5.7
PAS-LOB-02	0.4	1.01	0.71	ND 0.5	5.2
PAS-TOM-01	ND 0.4	0.19	0.43	ND 0.5	3.6
PAS-TOM-02	ND 0.4	0.37	0.40	ND 0.5	4.4
PAS-CLA-01	1.2	0.33	11	ND 0.5	2.4
COB-CLA-02	0.57	0.11	2.9	ND 0.5	0.93
PAS-COD-01	ND 0.4	0.31	ND 0.4	ND 0.5	2.8

Sample	Ag	Tl	Zn
PAS-SCA-01	ND 0.1	ND 0.5	53
COB-SCA-02	ND 0.1	ND 0.5	55
COB-SCA-03	ND 0.1	ND 0.5	51
PAS-LOB-01	3.3	ND 0.5	140
PAS-LOB-02	5.2	ND 0.5	180
PAS-TOM-01	4.8	ND 0.5	65
PAS-TOM-02	10.4	ND 0.5	81
PAS-CLA-01	0.51	ND 0.5	74
COB-CLA-02	0.21	ND 0.5	28
PAS-COD-01	ND 0.1	ND 0.5	45

Dioxins
The following tables display the dioxin analysis results for each composite sample. The codes described above still apply. The results are expressed as parts per trillion (ppt).

Sample ID		PAS-COD-01	PAS-LOB-01	PAS-LOB-02
Compound	**DL(ng/Kg)**			
2378-tcdf	**0.11**	1.41	0.59	0.71
12378-pecdf	**0.25**	<DL	<DL	<DL
23478-pecdf	**0.25**	1.03	0.48	0.63
123478-hxcdf	**0.25**	<DL	<DL	<DL
123678-hxcdf	**0.25**	<DL	<DL	<DL
234678-hxcdf	**0.25**	<DL	<DL	<DL
123789-hxcdf	**0.25**	<DL	<DL	<DL
1234678-hpcdf	**0.5**	0.48	<DL	<DL
1234789-hpcdf	**0.5**	<DL	<DL	<DL
ocdf	**0.5**	3.25	0.47	0.33
2378-tcdd	**0.10**	0.14	<DL	<DL
12378-pecdd	**0.25**	0.19	<DL	<DL
123478-hxcdd	**0.25**	<DL	<DL	<DL
123678-hxcdd	**0.25**	<DL	<DL	<DL
123789-hxcdd	**0.25**	<DL	<DL	<DL
1234678-hpcdd	**0.5**	1.33	0.61	0.55
ocdd	**0.5**	5.67	1.24	2.66
Total TEQ (ND=0)		1.00	0.31	0.39
Total TEQ (ND=DL)		1.20	0.85	0.94
%Lipids		3.50	0.27	0.25
Sample Weight (g)		52.1	49.0	51.3

Sample ID		PAS-CLA-01	COB-CLA-02	PAS-SCA-01
Compound	**DL(ng/Kg)**			
2378-tcdf	**0.11**	0.95	1.33	<DL
12378-pecdf	**0.25**	<DL	<DL	<DL
23478-pecdf	**0.25**	0.51	0.42	<DL
123478-hxcdf	**0.25**	<DL	<DL	<DL
123678-hxcdf	**0.25**	<DL	<DL	<DL
234678-hxcdf	**0.25**	<DL	<DL	<DL
123789-hxcdf	**0.25**	<DL	<DL	<DL
1234678-hpcdf	**0.5**	<DL	<DL	<DL
1234789-hpcdf	**0.5**	<DL	<DL	<DL

ocdf	**0.5**	0.35	0.43	0.63
2378-tcdd	**0.10**	<DL	<DL	<DL
12378-pecdd	**0.25**	<DL	<DL	<DL
123478-hxcdd	**0.25**	<DL	<DL	<DL
123678-hxcdd	**0.25**	<DL	<DL	<DL
123789-hxcdd	**0.25**	<DL	<DL	<DL
1234678-hpcdd	**0.5**	<DL	<DL	<DL
ocdd	**0.5**	1.33	1.85	1.06
Total TEQ (ND=0)		0.35	0.34	0.00
Total TEQ (ND=DL)		0.90	0.90	0.69
%Lipids		0.64	0.70	0.50
Sample Weight (g)		50.8	50.0	50.7

Sample ID		COB-SCA-02	COB-SCA-03
Compound	**DL(ng/Kg)**		
2378-tcdf	**0.11**	<DL	<DL
12378-pecdf	**0.25**	<DL	<DL
23478-pecdf	**0.25**	<DL	<DL
123478-hxcdf	**0.25**	<DL	<DL
123678-hxcdf	**0.25**	<DL	<DL
234678-hxcdf	**0.25**	<DL	<DL
123789-hxcdf	**0.25**	<DL	<DL
1234678-hpcdf	**0.5**	<DL	<DL
1234789-hpcdf	**0.5**	<DL	<DL
ocdf	**0.5**	0.51	0.37
2378-tcdd	**0.10**	<DL	<DL
12378-pecdd	**0.25**	<DL	<DL
123478-hxcdd	**0.25**	<DL	<DL
123678-hxcdd	**0.25**	<DL	<DL
123789-hxcdd	**0.25**	<DL	<DL
1234678-hpcdd	**0.5**	<DL	<DL
ocdd	**0.5**	0.95	0.66
Total TEQ (ND=0)		0.00	0.00
Total TEQ (ND=DL)		0.69	0.69
%Lipids		0.32	0.34
Sample Weight (g)		50.2	49.8

Tomalley Results

Sample ID		PAS-TOM-01	PAS-TOM-02
Compound	**DL(ng/Kg)**		
2378-tcdf	**0.55**	10.6	15.6
12378-pecdf	**1.25**	1.65	1.33
23478-pecdf	**1.25**	4.33	7.85
123478-hxcdf	**1.25**	1.06	0.95
123678-hxcdf	**1.25**	2.33	3.57
234678-hxcdf	**1.25**	1.41	2.26
123789-hxcdf	**1.25**	<DL	<DL
1234678-hpcdf	**2.50**	<DL	<DL
1234789-hpcdf	**2.50**	<DL	<DL
ocdf	**2.50**	1.35	2.21
2378-tcdd	**0.50**	1.08	1.52
12378-pecdd	**1.25**	2.79	3.66
123478-hxcdd	**1.25**	1.16	1.21
123678-hxcdd	**1.25**	6.09	7.95
123789-hxcdd	**1.25**	1.35	1.88
1234678-hpcdd	**2.50**	8.33	9.41
ocdd	**2.50**	12.6	14.3
Total TEQ (ND=0)		8.60	12.6
Total TEQ (ND=DL)		8.75	12.8
%Lipids		14.2	20.8
Sample Weight (g)		10.1	10.0

Dioxin Totals

	PAS-COD-01	PAS-LOB-01	PAS-LOB-02	PAS-CLA-01	COB-CLA-02
TCDF	0.42	0.26	0.36	0.42	0.21
TCDD	0.53	0.15	0.20	0.31	0.18
PeCDF	3.22	2.17	1.85	2.42	2.31
PeCDD	2.61	0.95	1.47	2.06	1.85
HxCDF	2.08	1.66	1.53	1.79	2.01
HxCDD	1.88	1.95	2.37	2.14	2.34
HpCDF	2.49	1.87	2.19	1.65	1.15
HpCDD	3.85	2.51	3.62	3.05	2.66

	PAS-SCA-01	COB-SCA-02	COB-SCA-03	PAS-TOM-01	PAS-TOM-02
TCDF	0.13	0.09	0.17	63.2	58.3
TCDD	0.21	0.14	0.21	18.2	21.6
PeCDF	1.61	1.75	1.51	35.9	43.8
PeCDD	1.47	1.86	2.36	19.6	31.2
HxCDF	1.85	2.06	2.31	23.5	31.4
HxCDD	1.33	2.97	3.36	42.8	51.7
HpCDF	0.76	1.21	0.95	2.31	1.65
HpCDD	1.15	2.01	1.66	14.8	16.2

DISCUSSION

In the following discussion an attempt is made to compare the results of this study with results from other state and regional dioxin and heavy metal testing programs. Unfortunately we have not been able to identify studies which used the exact species that we did in the case of all contaminants. We acknowledge that comparing results from a scallop to a mussel for example is not strictly appropriate. However, we have made some of these comparisons in order to form an initial general context. This study has established a baseline for dioxin and heavy metals in clams, cod, lobster and scallops for the Passamaquoddy region and in future studies better comparisons will be able to be made.

Dioxin

There are 75 different isomers of dioxin, the most toxic of which is the chlorinated 2,3,7,8-TCDD isomer. Only seven of the 75 cogeners are thought to have dioxin-like toxicity. There are 135 individual furan compounds. Of these, only 10 are thought to have dioxin-like toxicity. (Horsley and Witten, Inc., 1998)

"Dioxins/furans are highly persistent in the environment, have a strong affinity for fine grained sediments and accumulate in biological tissue. These contaminants accumulate in fish in proportion to the body lipid content and the age of the animal. PCDDs are particularly resistant to biological breakdown, concentrate in fatty tissues and are not readily excreted. Consequently, repeated exposures can rapidly increase body burdens." (Horsley and Witten, Inc., 1998)

There are no uses for dioxin, it is a waste product created from industrial processes. Dioxin is a probable human carcinogen. (*Dioxin Reassessments*)

In Maine, the only continual testing program for dioxin is carried out by the Dioxin Monitoring Program (DMP). This program is responsible for yearly sampling below at least 12 known or likely sources of dioxin releases to the environment. There has been a health advisory in Maine on the consumption of lobster tomalley because of dioxin contamination since 1994. (Mower, 1996)

Conclusions
When comparing the results from lobster meat and tomalley samples in the Passamaquoddy study with the Maine Dioxin Monitoring Program (DMP), the levels of dioxin appear to be very similar. The following charts (Figure A and B) display levels of dioxin compounds in lobster meat and tomalley samples collected under the Maine program and under the Passamaquoddy study. Each label has a two digit code for the year the sample was collected and a three letter code representing the site where it was collected. The following site codes apply:

BBH	Brave Boat Harbor, Kittery (DMP)
BRK	Brooklyn (DMP)
COR	Corea (DMP)
KRP	Kennebec River Estuary (DMP)
SCB	Saco Bay (DMP)
SCR	St. Croix Estuary (DMP)
PAS	Passamaquoddy Bay (Passamaquoddy study)

Figure A: Levels of the dioxin compound TCDF in lobster meat expressed as parts per trillion.

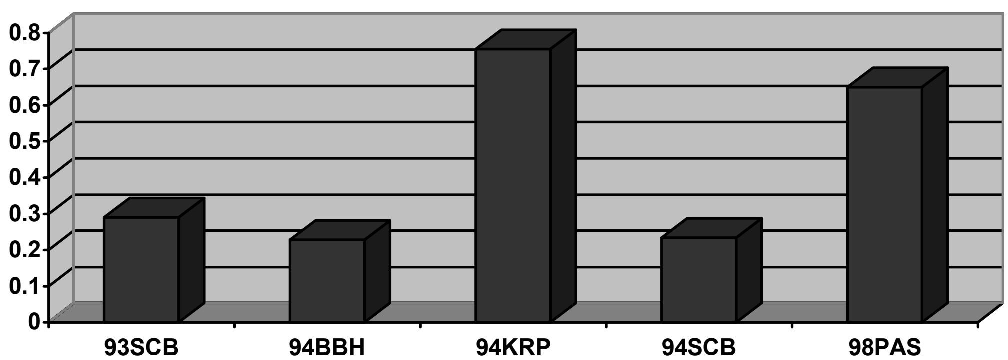
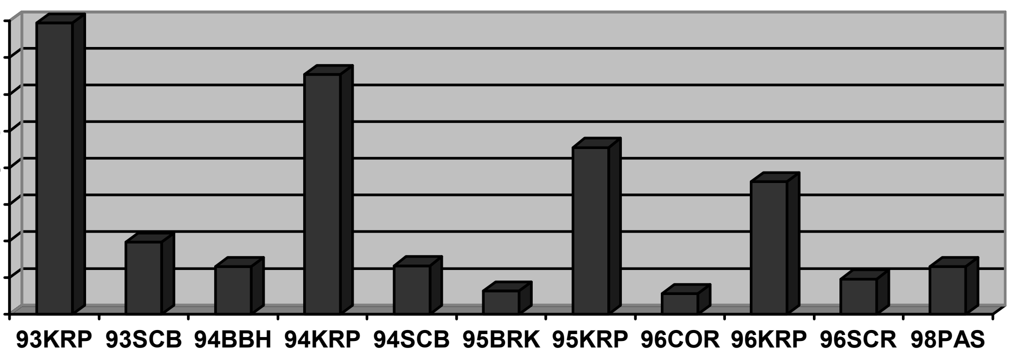


Figure B: Levels of the dioxin compound TCDD in lobster tomalley expressed as parts per trillion.



The scarcity of data on the levels of dioxin in cod, scallops, or clams makes it difficult to say with certainty if the levels observed in the Passamaquoddy study are cause for concern. Further testing on these organisms as well as lobster should be undertaken in the future.

Trace Elements

The results of this study describe levels of heavy metals found in cod, scallops, clams, or lobsters in the Passamaquoddy Bay region. The data have been compared with several state, regional, and national studies of chemical contaminants in fish and shellfish in order to compare the levels of contaminants found in this region to other areas and studies. These studies include the Environmental Protection Agency (EPA) National Study of Chemical Residues in Fish, the Maine Department of Environmental Protection Surface Water Ambient Toxic Monitoring Program (SWAT), the Gulf of Maine Council Gulf Watch Program, and NOAA National Status and Trends Program. The following discussion will detail the results of these comparisons for each species tested.

It is beyond the scope of this project to identify sources of the following pollutants in the Passamaquoddy Bay region. Points of origin of metals in the natural environment are widely varied and may include historical or contemporary industrial outputs, naturally occurring background levels, atmospheric deposition or other sources.

Arsenic

Arsenic is a human carcinogen that is widespread in the environment. Seafood normally contains arsenic in the order of milligrams per kilogram however, most of it is in an organic form that is far less toxic than inorganic arsenic. The highest concentrations of arsenic are found in bottom feeding fish and crustaceans. Lobsters, specifically, are known to store arsenic. (Adams, 1993a; *Gulf of Maine Land Based Pollution Sources*) The Passamaquoddy study reports whole arsenic levels, not broken down into organic/inorganic numbers.

The NOAA National Status and Trends Program Benthic Surveillance Project samples species of bottom dwelling marine finfish and analyzes the levels of certain heavy metals in their tissues. There are nine sites in Maine where sampling occurs for this program. Species of fish collected include longhorn sculpin and winter flounder. Data collected from these sites from 1984-1992 reports a minimum average value of 2.35 ug/g and a maximum average value of 14.92 ug/g for arsenic. (Harmon et al., 1998) The Passamaquoddy study found whole fish concentrations in cod of 11 ug As/g (Table 1) which is about average. To make a proper comparison, however, cod should be compared to other cod. Our data may be the first such analysis on cod.

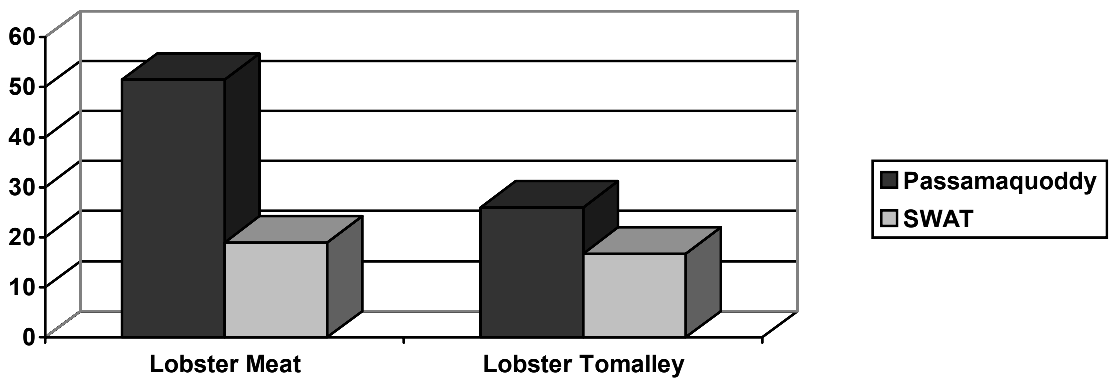
Table 1: Comparisons of trace element levels in marine finfish from the Passamaquoddy study and the National Status and Trends program. All data are expressed in ug/g dry weight.

	Passamaquoddy MEAN	NS&T MIN	NS&T MEAN	NS&T MAX
Silver	ND	0.13	0.69	1.59
Arsenic	11	2.35	8.16	14.92
Cadmium	ND	0.31	1.78	4.51
Chromium	1	0.16	0.5	0.87
Copper	3.1	2.5	20.0	68.98
Mercury	0.31	0.05	0.25	0.42
Nickel	ND	0.09	0.42	1.75
Lead	ND	0.21	1.6	8.22
Selenium	2.8	3.53	5.7	9.93
Zinc	45	78.1	126.9	192

NOAA National Status and Trends Program Mussel Watch project samples mollusks and analyzes the levels of heavy metals in their tissues. Arsenic was measured throughout the United States from 1986-1993. The mean As concentration found during this program in mollusk tissue was 9.3 ug/g. (O'Connor and Beliaeff) In the Passamaquoddy study, As concentrations in clams averaged 5.5 ug/g and in scallops 5.0 ug/g, well below the mean concentration found by the Mussel Watch program.

The 1995 Maine SWAT program report shows an average total As concentration in lobster meat along the coast of 19 ug/g. The average arsenic concentration in lobster meat in the Passamaquoddy study was 51.5 ug/g, exceeding the SWAT average by a large amount. The SWAT program average concentration of As for lobster tomalley was 16.75 ug/g. (Sowles, 1997) Lobster tomalley in the Passamaquoddy study had an average As concentration of 26 ug/g, again exceeding the SWAT program findings. (Figure 1)

Figure 1: Comparison of average concentrations of Arsenic in lobster meat and tomalley in the Passamaquoddy study and the SWAT program. All values are expressed in ug/g.



Beryllium

Beryllium is a naturally occurring chemical component of certain kinds of rocks. It is generally released into the environment through the incineration of fossil fuels and primarily has negative effects on the lungs. (*Public Health Statement*, 1988)

Beryllium was not detected in any of the samples analyzed during the Passamaquoddy study.

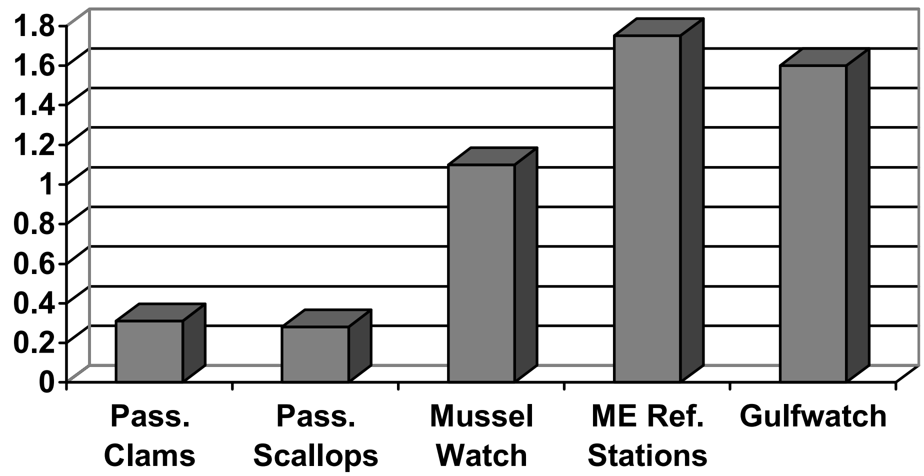
Cadmium

Cadmium is a carcinogen which bioaccumulates in fish and shellfish. In the US, the average person eats food with about 30 micrograms of cadmium in it each day. It accumulates in the body and the concentration increases with age. (Adams, 1993b and *Gulf of Maine Land Based Pollution Sources*)

Cadmium was not detected in the whole body cod sample in this study. (Table 1)

NOAA Mussel Watch data from 1990 records a geometric mean value for cadmium in mollusks sampled from Gulf of Maine locations of 1.1 ug/g and a high value for these same locations of 1.52 ug/g. The high value is determined by adding one standard deviation to the geometric mean. Levels of cadmium in mussels from 23 Maine reference stations had an average value of 1.75 ug/g and a high value of 3.14 ug/g. The high value for the Maine reference stations is the arithmetic mean plus three times the standard deviation. The Gulfwatch program was established by the Gulf of Maine Council on the Marine Environment to use the blue mussel as an indicator of organic and inorganic contamination in the environment. 1995 Gulfwatch data reports a geometric mean value of 1.6 ug/g of cadmium in mussels. (Chase et al, 1996) Cadmium concentrations in clams in the Passamaquoddy study averaged .31 ug/g while levels in scallops averaged .28 ug/g. These results appear to be low. (Figure 2)

Figure 2: Comparison of average concentrations of Cadmium in shellfish. All values are expressed in ug/g dry weight.



In the Maine SWAT program, average concentrations of cadmium in lobster meat were found to be 0.15 ug/g. The average Cd concentration in the Passamaquoddy study was similar at 0.14 ug/g. The SWAT program also showed an average Cd concentration of 7.69 ug/g in lobster tomalley. (Sowles, 1997) Lobster tomalley in the Passamaquoddy study exhibited a mean Cd concentration of 25.8 ug/g, which is higher than the SWAT findings.

Chromium

Chromium is an essential trace element in humans and virtually all foods contain chromium at levels up to 0.5 ppm. Sources of Cr in food include meats, mollusks, and crustaceans, however, finfish are a poor source of dietary Cr. Surveys of contaminants in fish and shellfish (conducted by FDA and NMFS) have found mean levels of Cr ranging from 0.1 ppm to 0.9 ppm wet weight. (Adams, 1993c)

The NOAA National Status and Trends Benthic Surveillance program found a minimum average chromium concentration of 0.16 ug/g and a maximum average concentration of 0.87 ug/g in fish at nine Maine sites. (Harmon et al, 1998) The chromium concentration for cod in the Passamaquoddy study is 1.0 ug/g. (Table 1)

The Mussel Watch program found a geometric mean value of Cr in mussels of 1.39 ug/g and a high value of 2.78 ug/g. The reference mean reported value for Cr at Maine reference stations was 1.53 ug/g while the reported high value was 3.51 ug/g. The Gulfwatch program found an average concentration of 1.9 ug/g Cr in mussels in the Gulf of Maine. (Chase et al, 1996) In comparison, the Passamaquoddy study found an average Cr concentration of 1.85 ug/g in clams. The average level of Cr in scallops in this study was 0.51 ug/g. (Table 2)

Table 2: Comparisons of trace element levels in marine shellfish between the Passamaquoddy study, NOAA Mussel Watch, Gulfwatch, and Maine Reference Stations. All values are averages expressed in ug/g dry weight.

	Passamaquoddy Clams	Passamaquoddy Scallops	Mussel Watch	Gulfwatch	ME Ref. Stations
Silver	0.36	ND	0.22	0.09	0.12
Cadmium	0.31	0.28	1.1	1.6	1.75
Chromium	1.85	0.51	1.39	1.9	1.53
Copper	8.4	1.2	10.3	7.9	6.9
Mercury	0.22	0.25	0.13	0.39	0.12
Nickel	6.95	ND	1.18	1.3	1.8
Lead	0.89	ND	2.97	3.2	2.6
Zinc	51	53	92	97	89

The average concentration of Cr reported under the 1995 SWAT program for lobster meat was 0.41 ug/g. The mean concentration of chromium (1.37 ug/g) in lobster meat found in the Passamaquoddy study was higher. The levels of Cr in lobster tomalley tested under the SWAT program was shown to be 0.23 ug/g on average. (Sowles, 1997) The average value of Cr in tomalley in the Passamaquoddy study were similar at 0.26 ug/g.

Copper

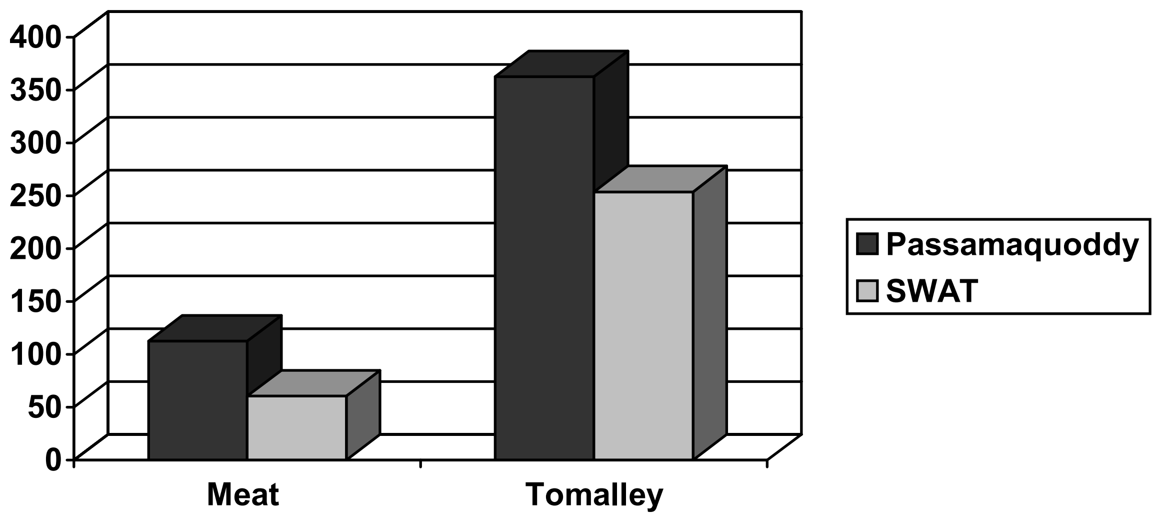
Copper is a naturally occurring essential element commonly found in many foods. Copper accumulates in the liver and may disrupt that organ's metabolism. (*Public Health Statement*, 1990)

The NOAA NS&T Benthic Surveillance program found a minimum average concentration of 2.5 ug/g of copper and a high value of 68.98 ug/g in sculpin and flounder. The average Cu concentration from these nine sites is 20.0 ug/g. (Harmon et al, 1998) In contrast, the concentration of copper in whole body cod in the Passamaquoddy study is 3.1 ug/g. (Table 1)

The Gulfwatch program found a geometric mean concentration of copper in mussels of 7.9 ug/g. The mean value of Cu in mussels found in the NOAA NS&T Mussel Watch program was 10.3 ug/g with a high value of 11.6 ug/g. The average concentration found at Maine reference stations for copper in mussels was 6.9 ug/g and the high value found at these sites was 10.7 ug/g. (Chase et al, 1996) Cu concentrations in the Passamaquoddy study average 8.4 ug/g in clams and 1.2 ug/g in scallops. (Table 2)

The Maine SWAT program found an average level of copper in lobster meat of 60.75 ug/g. The results of the Passamaquoddy study for copper in lobster meat showed a mean concentration of 112.5 ug/g. These results appear to be elevated in comparison with the rest of the state. Lobster tomalley tested under the SWAT program had an average concentration of 253.75 ug/g. (Sowles, 1997) The average Cu level in tomalley in the Passamaquoddy study was higher at 362.5 ug/g. (Figure 3)

Figure 3: Comparison of average concentrations of Copper found in lobster during the Passamaquoddy study and the SWAT program. All values are reported in ug/g dry weight.

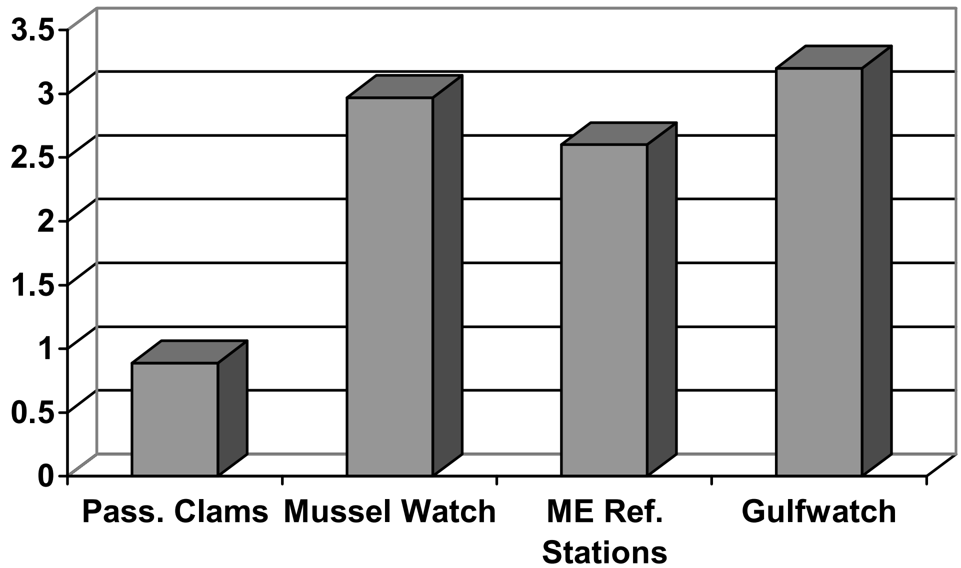


Lead
Lead is an element with no nutritive value. Lead bioaccumulates in fish and shellfish. The average daily dietary intake is 5-10 micrograms per person. Surveys of contaminants in shellfish have found mean lead levels ranging from 0.1 ppm- 0.8 ppm. Lead is particularly toxic to children and is a probable carcinogen. (Adams, 1993d)

No lead was detected in cod, scallops, or lobster during this study.

The average lead concentration reported for the Maine reference stations is 2.6 ug/g with a high value of 6.0 ug/g. The NOAA Mussel Watch program geometric mean value for Pb is 2.97 ug/g and the high value is 6.75 ug/g. Gulfwatch data for lead in mussels reports a mean level of 3.2 ug/g. In comparison, the Passamaquoddy results for Pb in clams average 0.89 ug/g. (Figure 4)

Figure 4: Comparison of average concentrations of Lead in shellfish. All values are reported in ug/g dry weight.



Mercury

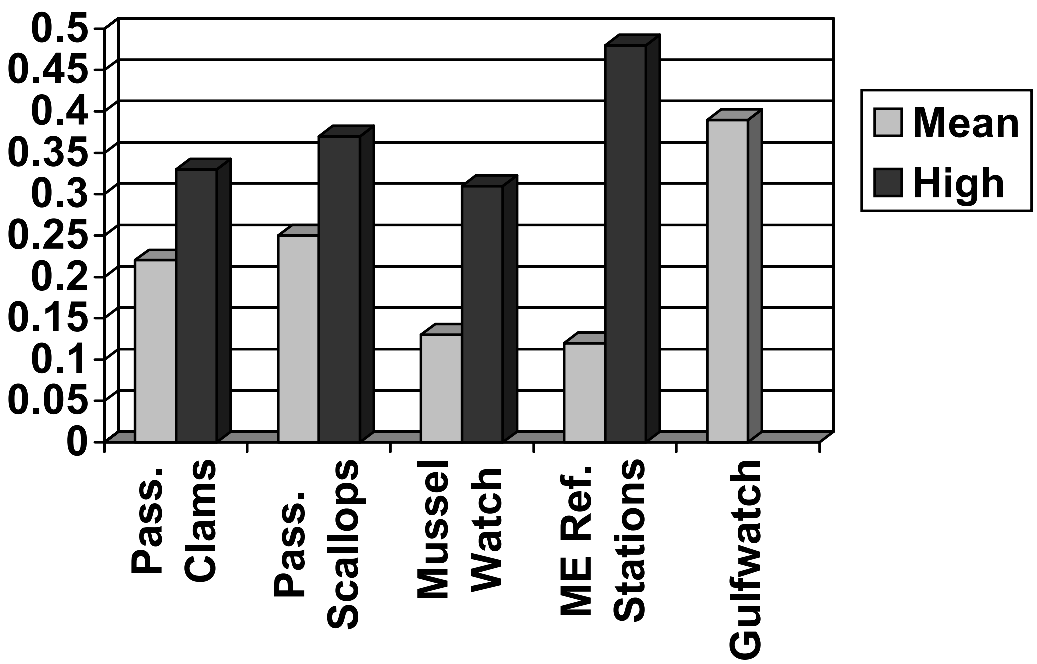
Practically all mercury in fish tissue is in the form of methylmercury which is toxic to humans and animals. Mercury has been found in both fish and shellfish. It accumulates efficiently in the aquatic food web and predators have the highest concentrations. Fish consumption dominates the pathway for human and wildlife exposure to methylmercury. (Horsley and Witten, Inc., 1998; Young)

"Preliminary comparison of concentrations of mercury in mussels from Maine with the rest of the US indicate high concentrations and confirms similar data that Maine waters in general have abnormally high concentrations of mercury for North America. These levels appear to be associated with historical or recent industrial activity." (Horsley and Witten, Inc., 1998)

The NOAA NS&T Benthic Surveillance program minimum average value for mercury in marine finfish in Maine is 0.05 ug/g with a maximum value of 0.42 ug/g. The average concentration for these sites between 1984 and 1992 for Hg is 0.25 ug/g. (Harmon et al, 1998) Similarly, the level of mercury found in cod in the Passamaquoddy study is 0.31 ug/g. (Table 1)

The Mussel Watch geometric mean value for mercury is 0.13 ug/g with a high value of 0.31 ug/g. The Gulfwatch program found an average level of Hg in mussels of 0.39 ug/g. The mean concentration of mercury at the Maine reference stations is 0.12 ug/g and the high value is 0.48 ug/g. (Chase et al, 1996) In comparison, average mercury levels found in the Passamaquoddy study were 0.25 ug/g for scallops and 0.22 ug/g for clams. (Table 2) (Figure 5)

Figure 5: Comparison of average and high concentrations of Mercury in shellfish. All values are reported in ug/g dry weight.



The SWAT program found average concentrations of mercury in lobster meat to be 0.83 ug/g dry weight. The levels of mercury in lobster meat in the Passamaquoddy study averaged 0.79 ug/g. Tomalley tested under the SWAT program exhibited an average mercury level of 0.33 ug/g. (Sowles, 1997) Results of the Passamaquoddy study for tomalley were similar, with a mean concentration of 0.28 ug/g.

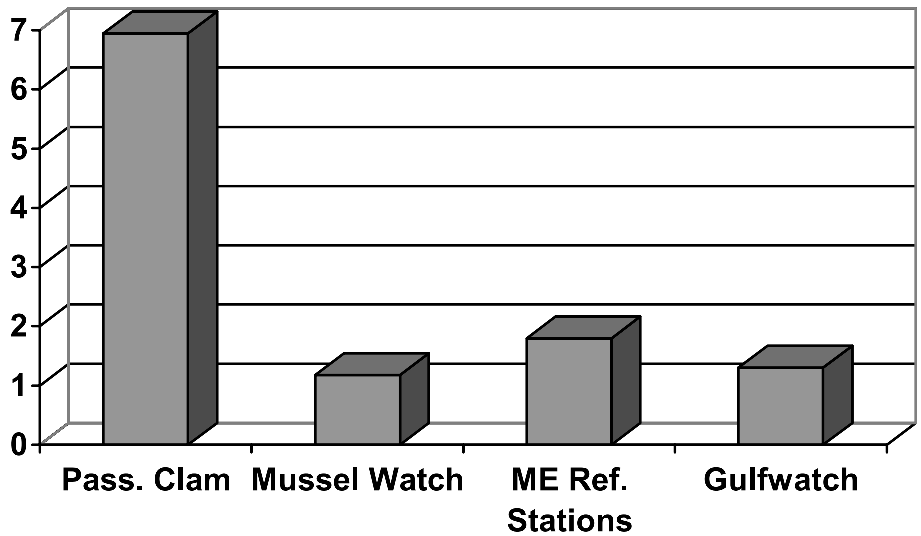
Nickel

Nickel is widely distributed in foods such as cereals, nuts, and cocoa. Surveys of contaminants in shellfish conducted by FDA and NMFS have found mean nickel levels ranging from 0.2 ppm – 2.2 ppm. (Adams, 1993e)

Nickel was not detected in the whole body cod sample or in the scallop samples under the Passamaquoddy study.

Gulfwatch reports a geometric mean value of 1.3 ug/g of nickel in mussels. The mean reference value for 23 Maine sites for Ni in mussels is 1.8 ug/g and the high value is 2.9 ug/g. The NOAA Mussel Watch program found a mean Ni level of 1.18 ug/g and a high value of 1.72 ug/g. The Passamaquoddy study reports a higher average Ni concentration of 6.95 ug/g in clams. (Figure 6)

Figure 6: Average concentrations of Nickel in shellfish. All values are reported in ug/g dry weight.



The Passamaquoddy study found average Ni levels in lobster meat of 2.96 ug/g and in tomalley of 0.42 ug/g. Nickel was not tested for under the SWAT program.

Antimony
Antimony is a metalloid element that is a common urban air pollutant. Long term exposure to Sb may affect the blood and liver. (Young, 1992)

Antimony was not detected in any of the samples taken during the Passamaquoddy study.

Selenium
Selenium is an essential nutrient that is toxic at high concentrations. Humans are exposed to Se in food and intakes range between 0.071 – 0.152 milligrams per person per day on average. Selenium amounts in fish are usually between 0.1 and 0.7 ppm. Seafood may contain the highest levels of Se of any food source. (*Public Health Statement*, 1989)

The NS&T Benthic Surveillance program minimum average level of Se is 3.53 ug/g and the high value is 9.93 ug/g. The average level of Se in finfish between 1984 and 1992 is 5.7 ug/g. (Harmon et al, 1998) The concentration of Se in cod in the Passamaquoddy study is 2.8 ug/g. (Table 1)

The NOAA NS&T Mussel Watch program monitored molluscan tissues around the United States for the presence of selenium between 1986 and 1993. The average concentration of Se in mollusc tissue during this time period is 2.5 ug/g. (O'Connor and Beliaeff) The Passamaquoddy study average concentration of Se in clams is 1.7 ug/g and in scallops is 1.14 ug/g.

The SWAT program reported average Se concentrations of 2.65 ug/g for lobster meat and 2.63 ug/g for tomalley. (Sowles, 1997) The Passamaquoddy study results for Se exceed these amounts with levels averaging 5.45 ug/g for lobster meat and 4.0 ug/g for tomalley.

Silver
Silver is a relatively rare metal that occurs naturally. It has no known physiologic function. (Faust, 1992)

Silver was not detected in cod or scallops under the Passamaquoddy study.

The average concentration of silver in clam samples collected under the Passamaquoddy study (0.36 ug/g) was higher than the average concentration of Ag in mussels samples (0.09 ug/g) collected in Maine and Eastern Canada under the Gulf Watch program. This result is also higher than the average concentrations of Ag found in the Mussel Watch program (0.22 ug/g) and the Maine reference sites (0.12 ug/g). However, the Passamaquoddy average for Ag in clams is lower than the high values reported for these two studies (0.51 ug/g and 0.4 ug/g respectively). (Chase et al, 1996)

The SWAT program average concentration of silver in lobster tomalley (3.32 ug/g) was lower than the average concentration of Ag detected in tomalley during the Passamaquoddy study which was 7.6 ug/g. Silver was not detected in lobster meat during the SWAT study (Sowles, 1997), however an average concentration of 4.25 ug/g was found in lobster meat in the Passamaquoddy study.

Thallium
Thallium metal and its compounds are highly toxic. The primary targets for Tl exposure are the nervous and reproductive systems. (Borges, 1994)

Thallium was not detected in any samples during the Passamaquoddy study.

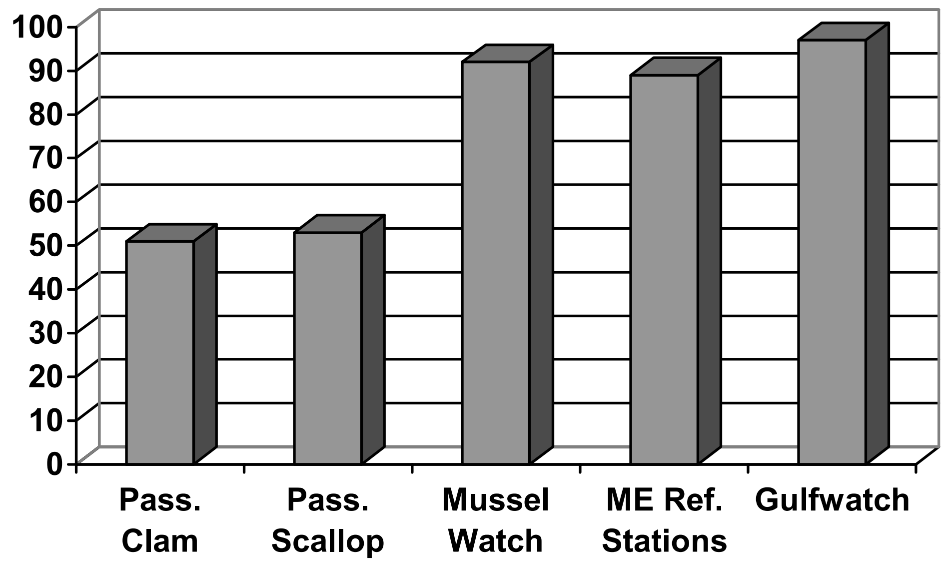
Zinc
Zinc is an essential human element. Zinc is released into the environment through many human activities and can cause gastrointestinal problems. (Opresko, 1992)

Zinc was not detected in scallop samples in the Passamaquoddy study.

The Benthic Surveillance program found a minimum average level of 78.1 ug/g and a maximum average value of 192 ug/g of zinc in sculpin and flounder. (Harmon et al, 1998) The concentration of Zn in cod in the Passamaquoddy study is 45 ug/g well below the minimum concentration found in the NOAA study. (Table 1)

The Passamaquoddy study found an average concentration of Zn in clams of 51 ug/g and in scallops of 53 ug/g. These results are lower than the average concentrations found in the Gulfwatch program (97 ug/g), the Mussel Watch program (92 ug/g) and the Maine reference stations (89 ug/g). (Chase et al, 1996) (Figure 7)

Figure 7: Average concentrations of Zinc in shellfish. All values are reported in ug/g dry weight.



Zinc was found in lobster meat during the SWAT program at an average concentration of 127.5 ug/g. The average level of Zn in lobster meat found during the Passamaquoddy study was 160 ug/g. Tomalley analyzed in the SWAT program had an average level of 54.25 ug/g. In the Passamaquoddy study Zn in tomalley averaged 73 ug/g. (Sowles, 1997) Both lobster meat and tomalley levels in the Passamaquoddy study were higher that the SWAT program.

Conclusions

Results of the trace element analysis indicates levels of thirteen heavy metals present in the marine environment in the Passamaquoddy region. Three elements: beryllium, antimony, and thallium, were not found at all. None of the pollutants were found to be high in Passamaquoddy scallops in comparison to the studies discussed in this report. Only nickel and silver levels appear to be high in clams in comparison to the same studies. However, as noted earlier, comparisons are made against blue mussels and not directly against clams which are known to be in more contact with sediment. Passamaquoddy cod samples were compared to the NOAA Benthic Surveillance program. These comparisons indicate that only the level of chromium is elevated, but again comparisons are to species other than cod.

In comparing levels of trace elements in lobster meat and tomalley from the Passamaquoddy region with the Maine SWAT program, the Passamaquoddy values are higher in many cases. (Table 3) Specific contaminants which are higher include arsenic, cadmium, chromium, copper, selenium, silver, and zinc.

Table 3: Comparisons of average trace element levels in lobster meat and tomalley between the Passamaquoddy study and the Maine SWAT program. All values are expressed in ug/g dry weight.

	Lobster Meat		Tomalley	
	Passamaquoddy	**SWAT**	**Passamaquoddy**	**SWAT**
Arsenic	51.5	19	26	16.75
Cadmium	0.14	0.15	25.8	7.69
Chromium	1.37	0.41	0.26	0.23
Copper	112.5	60.75	362.5	253.75
Mercury	0.79	0.83	0.28	0.33
Selenium	5.45	2.65	4.0	2.63
Silver	4.25	---	7.6	3.32
Zinc	160	127.5	73	54.25

RECOMMENDATIONS

This report describes the levels of 13 heavy metals and dioxin in the tissues of four species of marine organisms. The data have been compared with the results of other studies that have looked at levels of these pollutants in the marine environment. The purpose of this report is to document levels of contaminants found in lobster, cod, clams, and scallops in the Passamaquoddy Bay region during this study. The report is not intended to address human health concerns relating to consumption of marine species. It is recommended that this data be reviewed independently by a human health risk assessor and that further, regular testing of these marine species be performed in order to establish baseline and monitor for changing levels. It would be informative to continually review the literature to find data on the species reviewed in this project. Finally, as funds permit, individual replicates or replicate composites would permit a better assessment of confidence around the means.

REFERENCES

Adams, Michael A.; Bolger, Michael; Carrington, Clark D.; Coker, Curtis E.; Cramer, Gregory M.; DiNori, Michael J.; and Dolan, Scott. 1993a. *Guidance Document for Arsenic in Shellfish* [Online]. US Food and Drug Administration. Available: http://vm.cfsan.fda.gov/~frf/guid-as.html [2000, June 27].

Adams, Michael A.; Bolger, Michael; Carrington, Clark D.; Coker, Curtis E.; Cramer, Gregory M.; DiNori, Michael J.; and Dolan, Scott. 1993b. *Guidance Document for Cadmium in Shellfish* [Online]. US Food and Drug Administration. Available: http://vm.cfsan.fda.gov/~frf/guid-cd.html [2000, June 27].

Adams, Michael A.; Bolger, Michael; Carrington, Clark D.; Coker, Curtis E.; Cramer, Gregory M.; DiNori, Michael J.; and Dolan, Scott. 1993c. *Guidance Document for Chromium in Shellfish* [Online]. US Food and Drug Administration. Available: http://vm.cfsan.fda.gov/~frf/guid-cr.html [2000, June 27].

Adams, Michael A.; Bolger, Michael; Carrington, Clark D.; Coker, Curtis E.; Cramer, Gregory M.; DiNori, Michael J.; and Dolan, Scott. 1993d. *Guidance Document for Lead in Shellfish* [Online]. US Food and Drug Administration. Available: http://vm.cfsan.fda.gov/~frf/guid-pb.html [2000, June 27].

Adams, Michael A.; Bolger, Michael; Carrington, Clark D.; Coker, Curtis E.; Cramer, Gregory M.; DiNori, Michael J.; and Dolan, Scott. 1993e. *Guidance Document for Nickel in Shellfish* [Online]. US Food and Drug Administration. Available: http://vm.cfsan.fda.gov/~frf/guid-ni.html [2000, June 27].

Beryllium. 1988. In *Public Health Statement* [Online]. Agency for Toxic Substances and Disease Registry. Available: http://www.atsdr.cdc.gov/ToxProfiles/phs8807.html [2000, June 27].

Borges, Tim and Daugherty, Mary Lou. 1994. *Toxicity Summary for Thallium* [Online]. Risk Assessment Information System. Available: http://risk.lsd.ornl.gov/tox/profiles/thallium_f_V1.shmtl [2000, June 27].

Chase, Margo; Coomb, Karen; Crawford, Robert; Harding, Gareth; Hennigar, Peter; Jones, Stephen; Pederson, Judith; Robinson, William; Sowles, John; and Taylor, Darrell. 1996. Evaluation of Gulfwatch 1995: Fifth Year of the Gulf of Maine Environmental Monitoring Plan. Gulf of Maine Council on the Marine Environment.

Copper. 1990. In *Public Health Statement* [Online]. Agency for Toxic Substances and Disease Registry. Available: http://www.atsdr.cdc.gov/ToxProfiles/phs9008.html [2000, June 27].

Dioxin documents. In *Dioxin Reassessment* [Online]. US Environmental Protection Agency. Available: http://www.epa.gov/ncea/pdfs/dioxin/dioxreass.htm [2000, June 27].

Faust, Rosmarie A. 1992. *Toxicity Summary for Silver* [Online]. Risk Assessment Information System. Available: http://risk.lsd.ornl.gov/tox/profiles/silver_f_V1.shtml [2000, June 27].

Gottholm, B. William and Turgeon, Donna D. 1992. *Toxic Contaminants in the Gulf of Maine.* National Oceanic and Atmospheric Administration, Rockville, Md.

Gulfwatch. In *Gulf of Maine Environmental Monitoring Program* [Online] Gulf of Maine Council on the Marine Environment. Available: http://www.gulfofmaine.org/library/gulfwatch/ [2000, June 27].

Harmon, Michelle R.; Gottholm, B. William; and Robertson, Andrew. 1998. A Summary of Chemical Contaminant Levels at Benthic Surveillance Project Sites (1984-1992). National Status and Trends Program. NOAA Technical Memorandum NOS ORCA 124.

Horsley and Witten, Inc. 1998. *Impacts of Contaminants on the Resources of the Gulf of Maine*. [Online]. Commission for Environmental Cooperation. Available: http://www.cec.org/statepage/Contam.htm [2000, June 27]

Mierzykowski, Steven E. and Carr, Kenneth C. 1998. *Environmental Contaminants in Fish and Mussels from Meddybemps Lake, the Dennys River, and East Machias River: Eastern Surplus Superfund Site, Meddybemps, Maine*. U.S. Fish and Wildlife Service, New England Field Office, Special Project Report: FY98-MEFO-I-EC.

Mower, Barry. 1996. *Dioxin Monitoring Program*. DEPLW98-14. Maine Department of Environmental Protection.

Mussel Watch data. In *NOAA's National Status and Trends Program* [Online]. Available: http://spo.nos.noaa.gov/projects/nsandt/nsandt.html [2000, June 27].

O'Connor, Thomas P. and Beliaeff, Benoit. Recent Trends in Coastal Environmental Quality: Results from the Mussel Watch Project. National Status and Trends Program. NOAA.

Opresko, Dennis M. 1992. *Toxicity Summary for Zinc and Zinc Compounds* [Online]. Risk Assessment Information System. Available: http://risk.lsd.ornl.gov/tox/profiles/zn.shtml [2000, June 27].

Selenium. 1989. In *Public Health Statement* [Online]. Agency for Toxic Substances and Disease Registry. Available: http://www.atsdr.cdc.gov/ToxProfiles/phs8921.html [2000, June 27].

Sowles, John; Mower, Barry; Davies, Susan; and Tsomides, Leon. 1997. *1995 Surface Water Ambient Toxic Monitoring Program, Technical Report*. DEPLW97-1. Maine Department of Environmental Protection.

Total Arsenic (As). In *Gulf of Maine Land Based Pollution Sources* [Online]. Available: http://sposerver.nos.noaa.gov/projects/gomaine/as.html [2000, June 27].

Total Cadmium (Cd). In *Gulf of Maine Land Based Pollution Sources* [Online]. Available: http://sposerver.nos.noaa.gov/projects/gomaine/cd.html [2000, June 27].

U.S. Environmental Protection Agency. 1992a. *National Study of Chemical Residues in Fish Volume I*. EPA 823-R-92-008a. Office of Science and Technology, Washington DC.

U.S. Environmental Protection Agency. 1992b. *National Study of Chemical Residues in Fish Volume II*. EPA 823-R-92-008b. Office of Science and Technology, Washington DC.

U.S. Environmental Protection Agency. 1995. *Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories Volume I*. EPA 823-R-95-007. Office of Water, Washington DC.

Young, Robert. *Toxicity Summary for Mercury* [Online]. Risk Assessment Information System. Available: http://risk.lsd.ornl.gov/tox/profiles/mercury_f_V1.shmtl [2000, June 27].

Young, Robert A. 1992. *Toxicity Summary for Antimony* [Online]. Risk Assessment Information System. Available: http://risk.lsd.ornl.gov/tox/profiles/antimony.shmtl [2000, June 27].