MODULE 1 MARINE AND ESTUARINE

1.1

SHELLFISH TISSUE ANALYSES

Shellfish Tissue Analyses

This project addresses multiple needs identified after analysis of historical data collected by SWAT and other studies.

In 1998, interim action levels for shellfish were developed by the State Toxicologist, Bureau of Health that enable data from mussel samples to be evaluated in the context of human health. In the 1980s and early 1990s, blue mussel sample results suggest that human health advisories may be warranted in some areas of the coast due to levels of lead and mercury. Although environmental lead levels have declined nationally in various media since its removal from automotive fuels, it is reasonable to resample these areas to determine if current lead and mercury levels warrant an advisory. When these older samples were taken, organic analyses were not affordable. Many of these areas are near human population centers and/or industry and commerce. To complete the human health assessment, both organic and metal analyses should be conducted.

The Departments of Marine Resources and Environmental Protection have an active program to restore shellfish beds to harvestable conditions by removing sources of human sewage. Once sanitary pollution criteria are met, the DMR can open the area if it is assured that toxic contaminants do not pose a human health threat. In cases where the historical clam population is no longer present, direct sampling of clams makes that assurance impossible. Since a clam restoration project is an expensive commitment, there is a need to have tool available that can predict what tissue levels might likely be once clams have been restored to the area. Blue mussels are found almost everywhere along the coast, even where clams are not. Since mussels can be used to reflect local conditions, it may be possible to develop a relationship between clams, mussels, and perhaps sediment in order to predict levels expected in clams.

In the original Five-Year Plan, establishment of benchmark stations to be monitored over time was identified as a high priority. Those stations have been established and sampled at least once.

During the 2001 sampling season the ME DEP sampled blue mussels from:

Location	Date Sampled
Sandy Point, Stockton Springs	10/07/01
Sears Island, Searsport	09/18/01
Castine-Brooksville (Cape Rosier)	10/06/01
Clough Point, Sheepscot R.	10/16/01
Damariscotta R., Goose Ledge	10/04/01
Englishman's Bay, Great Cove, Roque Bluffs	10/18/01
Medomak R.	10/24/01
Little Kennebec Bay, Johnson-Marston Point, Machiasport	10/18/01
Pepperell Cove, Kittery	10/21/01
Long Island, Casco Bay	11/08/01
Great Diamond Island, Casco Bay	11/08/01

The following text and table gives results for metals in 2001 and compares those results to previous samples taken in the late 1980s. The samples from the late 1980s consisted of a single sample while the 2001 results are based on four replicate samples. Levels of metals are compared to the normal baseline range for Maine. Aluminum and iron are not included in the analysis and are reported as elevated in the table to give an indication of the amount of sediment in the gut of the mussel. When compared to NOAA Status and Trends elevated levels, PAHs were not elevated. The PAHs maybe underestimated due to loss of some of the lighter weight PAHs and other quality assurance issues that are noted on the tables. PCBs and pesticides are not reported because of quality assurance issues during analysis.

Elevated Metals (X) in Mussels Sampled in 2001

	Al	As	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Ag	Hg
Castine-Brooksville			X		X			X	X		
Clough Point, Sheepscot R. estuary	X					X					X
Englishman's Bay, Roque Bluffs	X										
Great Diamond Is., Casco Bay	X	X				X		X		X	
Goose Ledge, Damariscotta R. estuary							X				
Kittery, Pepperell Cove	X	X		X	X	X		X			X
Little Kennebec Bay, Machiasport	X					X				X	
Long Island, Casco Bay							X				
Medomak R. estuary							X*			X	
Sandy Point, Stockton Springs	X										X
Sears Island, Searsport							X				

*without outlier, not elevated

Mercury was elevated in the Sheepscot, at Pepperell Cove in Kittery and at the mouth of the Penobscot River at Sandy Point, Stockton Springs. The one sample that was taken previously at Sandy Point in 1989 had elevated cadmium, chromium and slightly elevated nickel as well as elevated mercury. Levels of cadmium and chromium were in the high end of the normal range in 2001 and nickel was normal and over one third less that it was previously.

The one sample that was taken previously in the Sheepscot at Clough Cove in 1989 had slightly elevated cadmium as well as elevated mercury. In 2001, cadmium was in the high end of the normal range and the mercury was still elevated.

Pepperell Cove near the naval base in Kittery in the one sample taken in 1987 had elevated chromium, lead and mercury. Zinc, cadmium, and copper were in the high normal range. In 2001 mercury, chromium, copper, lead and arsenic were elevated.

Arsenic was not measured in 1987. Cadmium and zinc were in the high normal range in 2001 but slightly lower than in 1989.

Metals in Englishman's Bay were in the normal range in 2001 as they were in 1987.

Metals in the Medomak were in the normal range except for elevated silver that had varied results between the replicates. There was an outlier in one of the nickel replicates and was not considered in the results. Cadmium was elevated in the one sample taken in 1989 but was not elevated in the 2001 sampling.

Goose Ledge in the Damariscotta, Sears Island and Long Island in Casco Bay were in the normal range in 2001 with the exception of elevated nickel. Although the levels of nickel were higher in 2001 than the one sample taken in 1989 in the Damariscotta, the results of replicates were highly variable. Two replicates were in the elevated range and two were in the normal range. At Sears Island the levels of silver and cadmium were greatly lower than the one sample taken in 1989 but the level of nickel was higher. Levels of cadmium, lead and zinc were lower than the one sample taken in 1989 at Long Island while the level of nickel was higher.

In Little Kennebec Bay, the metals were in the normal range in 2001 with the exception of silver that was not measured in 1987. Also the lead levels that were in the high end of the normal range in the one 1987 sample were lower in 2001.

Diamond Cove, Great Diamond Island had elevated arsenic, silver, and lead in 2001. In the one sample taken in 1988 all metals analyzed were in the normal range. Silver and arsenic were not measured in 1988. Lead was in the upper part of the normal range. Lead was almost twice as high in 2001 as it was in 1988.

On Cape Rosier near the abandoned mine cadmium, copper, lead and zinc were elevated in 2001. In the one sample taken in 1989, cadmium, lead and zinc were elevated. Levels of cadmium and lead were lower and levels of copper and zinc were higher in 2001 compared to the 1989 sample.

In summary, levels of mercury were elevated in the Sheepscot, Pepperell Cove in Kittery and at the mouth of the Penobscot River in 2001 and in the late 1980s. The latter two sites have local potential sources of mercury and the Sheepscot is presumed to be elevated because of historic sources. Levels of other metals were lower in 2001 than in the late 1980s at many sites including the Sheepscot and the Penobscot. Pepperell Cove near the naval base in Kittery had elevated or high normal range metals at both sampling periods. At the mouth of an abandoned mine in Cape Rosier a number of metals were elevated in the 1989 and 2001 samplings. One area of concern is Diamond Cove where levels of lead are much higher than in 1989.

Other locations had lower levels of metals or normal levels at both samplings with some exceptions. Nickel was elevated in some of the 2001 samples but the individual replicates had variable results. Silver was elevated at two locations and also had variable results for individual replicates.

The human health assessment has not yet been evaluated.

TABLE 1.2.1 LEVELS OF MERCURY AND % SOLIDS IN 2001 MUSSEL TISSUE SAMPLES

Sample ID	Hg wet(mg/Kg)	Hg dry(mg/Kg)	% solid
Castine-Brooksville 1	0.0079	0.1059	7.50
Castine-Brooksville 2	0.0101	0.1192	8.44
Castine-Brooksville 3	0.0085	0.1120	7.58
Castine-Brooksville 4	0.0084	0.1065	7.92
Clough Point, Sheepscot R. 1	0.0432	0.4246	10.17
Clough Point, Sheepscot R. 2	0.0434	0.6346	6.84
Clough Point, Sheepscot R. 3	0.0382	0.5780	6.61
Clough Point, Sheepscot R. 4	0.0307	0.4367	7.04
Englishman's Bay, Roque Bluffs 1	0.0099	0.0773	12.86
Englishman's Bay, Roque Bluffs 2	0.0100	0.0794	12.60
Englishman's Bay, Roque Bluffs 3	0.0101	0.0746	13.49
Englishman's Bay, Roque Bluffs 4	0.0094	0.0740	12.77
Damariscotta R., Goose Ledge 1	0.0128	0.1516	11.75
Damariscotta R., Goose Ledge 2	0.0109	0.1449	11.60
Damariscotta R., Goose Ledge 3	0.0136	0.1664	12.86
Damariscotta R., Goose Ledge 4	0.0111	0.1432	12.02
Great Diamond Is., Casco Bay 1	0.0160	0.1361	8.42
Great Diamond Is., Casco Bay 2	0.0124	0.1067	7.53
Great Diamond Is., Casco Bay 3	0.0177	0.1378	8.20
Great Diamond Is., Casco Bay 4	0.0140	0.1161	7.72
Pepperell Cove, Kittery 1	0.0313	0.4011	7.81
Pepperell Cove, Kittery 2	0.0344	0.4907	7.02
Pepperell Cove, Kittery 3	0.0291	0.3656	7.95
Pepperell Cove, Kittery 4	0.0316	0.4307	7.34
Little Kennebec Bay, Machiasport 1	0.0101	0.0826	12.21
Little Kennebec Bay, Machiasport 2	0.0109	0.0926	11.73
Little Kennebec Bay, Machiasport 3	0.0114	0.0852	13.39
Little Kennebec Bay, Machiasport 4	0.0117	0.0846	13.79
Long Island, Casco Bay 1	0.0209	0.2605	8.02
Long Island, Casco Bay 2	0.0208	0.2518	8.25
Long Island, Casco Bay 3	0.0176	0.2196	8.03
Long Island, Casco Bay 4	0.0168	0.2015	8.35
Medomak R. 1	0.0087	0.0925	9.41
Medomak R. 2	0.0078	0.0781	9.95
Medomak R. 3	0.0075	0.0789	9.46
Medomak R. 4	0.0071	0.0751	9.50
Sandy Point, Stockton Springs 1	0.0402	0.4067	9.88
Sandy Point, Stockton Springs 2	0.0387	0.4471	8.66
Sandy Point, Stockton Springs 3	0.0391	0.4376	8.93
Sandy Point, Stockton Springs 4	0.0416	0.4214	9.88
Sears Island, Searsport 1	0.0194	0.1739	11.18
Sears Island, Searsport 2	0.0201	0.1570	12.81
Sears Island, Searsport 3	0.0199	0.1677	11.86
Sears Island, Searsport 4	0.0202	0.1639	12.33

TABLE 1.2.2 HEAVY METALS IN 2001 BLUE MUSSEL TISSUE SAMPLES

Values on a dry weight basis
All elements except Ag analyzed by ICP-AES, Ag analyzed by GFAA

	Al mg/kg	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Ag mg/kg
Castine 1	283.37	15.13	7.31	1.63	16.02	445.66	3.29	11.43	223.87	<DL
Castine 2	371.02	11.97	6.60	1.20	10.68	438.67	3.03	8.21	167.52	<DL
Castine 3	381.38	11.89	6.46	1.52	11.16	456.21	0.99	9.72	171.38	<DL
Castine 4	198.26	16.50	6.99	1.50	11.36	388.43	<DL	11.22	202.54	<DL
Clough Point 1	477.38	11.06	1.99	1.72	6.91	636.51	1.56	2.57	77.89	<DL
Clough Point 2	804.98	13.93	2.71	2.82	8.11	990.25	2.49	3.56	93.27	<DL
Clough Point 3	811.01	15.49	2.41	2.82	<DL	1023.73	2.85	3.16	91.74	0.60
Clough Point 4	816.18	15.95	2.79	3.28	7.67	995.49	2.71	4.56	118.10	<DL
Englishman's Bay 1	352.91	9.09	1.25	1.19	6.11	404.74	1.16	2.50	61.07	<DL
Englishman's Bay 2	424.81	10.03	1.39	1.55	6.43	474.79	1.36	2.88	58.90	0.80
Englishman's Bay 3	412.14	8.24	1.28	1.04	6.34	415.60	1.41	2.59	54.72	<DL
Englishman's Bay 4	541.35	8.65	1.41	1.34	7.39	534.54	3.14	3.05	56.52	<DL
Great Diamond Is. 1	350.37	14.32	1.81	1.69	6.41	555.58	2.45	4.33	78.58	<DL
Great Diamond Is. 2	334.92	18.20	2.45	2.14	10.41	707.91	2.59	8.51	120.17	<DL
Great Diamond Is. 3	417.17	17.95	2.29	2.74	10.03	718.17	3.07	8.66	123.04	0.51
Great Diamond Is. 4	786.82	18.83	2.45	2.79	9.72	938.57	2.47	10.12	129.83	0.48
Goose Ledge 1	270.21	13.82	1.37	0.98	8.04	321.88	4.31	2.87	97.59	<DL
Goose Ledge 2	341.32	12.19	1.39	0.69	6.21	407.61	1.09	2.75	79.62	<DL
Goose Ledge 3	194.03	11.29	1.04	0.61	6.72	215.48	9.73	2.06	78.05	<DL
Goose Ledge 4	317.93	12.98	1.42	1.09	8.19	343.06	1.10	2.97	83.00	0.48
Kittery-Pepperell 1	1391.22	17.88	2.54	6.09	13.91	1548.82	2.45	14.18	167.38	0.69
Kittery-Pepperell 2	798.51	19.82	2.45	4.17	12.94	979.20	1.99	9.27	127.65	0.50
Kittery-Pepperell 3	516.89	19.93	3.08	3.15	10.24	740.41	2.10	9.87	224.45	<DL
Kittery-Pepperell 4	613.12	15.27	1.64	2.71	8.10	694.10	1.20	6.71	101.80	0.41
Little Kennebec Bay 1	657.70	7.29	1.20	1.59	9.28	586.29	1.41	2.05	53.37	0.21
Little Kennebec Bay 2	829.57	9.79	1.82	2.10	10.08	821.48	1.51	4.82	76.48	0.54
Little Kennebec Bay 3	1360.69	8.39	1.40	2.09	9.17	1075.60	1.63	2.90	91.04	<DL
Little Kennebec Bay 4	573.62	7.90	1.34	1.52	6.85	570.70	1.36	2.28	65.26	0.17
Long Island 1	497.80	17.09	2.21	1.83	7.35	586.24	5.83	4.89	117.73	<DL
Long Island 2	205.38	15.23	2.18	1.25	7.61	295.68	5.90	3.58	76.13	0.28
Long Island 3	209.65	14.59	1.75	1.14	7.10	275.66	2.27	2.82	88.74	<DL
Long Island 4	158.65	15.26	1.89	1.34	6.04	243.19	2.77	2.46	87.28	0.45
Medomak 1	213.46	11.69	1.65	0.88	7.13	307.37	1.20	2.28	116.95	0.77
Medomak 2	217.27	11.72	1.48	0.83	7.01	295.53	1.08	3.19	97.09	0.51
Medomak 3	280.91	12.05	1.41	1.06	7.07	312.13	18.53	3.03	93.64	<DL
Medomak 4	311.78	12.41	1.46	1.14	6.45	310.81	2.89	2.68	92.86	<DL
Sandy Point 1	366.25	13.00	2.10	2.26	8.85	592.94	1.55	3.52	92.59	<DL
Sandy Point 2	356.89	15.54	2.59	2.43	7.11	695.38	1.74	3.92	91.52	<DL
Sandy Point 3	420.98	13.52	2.69	2.59	8.99	665.26	1.66	3.48	93.67	<DL
Sandy Point 4	515.55	12.82	2.02	2.38	8.24	608.08	1.71	2.88	63.89	<DL
Sears Island 1	100.74	11.86	1.44	<DL	7.23	181.25	2.12	2.31	78.18	<DL
Sears Island 2	168.43	9.68	1.28	0.82	5.95	210.77	6.10	1.72	93.40	0.15
Sears Island 3	138.72	9.03	1.22	0.67	6.73	205.72	5.99	1.51	82.35	0.16
Sears Island 4	134.58	9.29	1.09	0.63	5.69	199.06	12.34	1.37	58.48	0.16

<DL= Less than detection limit

TABLE 1.2.3 HEAVY METALS IN 2001 BLUE MUSSEL TISSUE SAMPLES

Values on a wet weight basis

All elements except Ag analyzed by ICP-AES, Ag analyzed by GFAA

	Al mg/kg	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Ag mg/kg
*reporting limit**	*0.40*	*0.08*	*0.10*	*0.08*	*0.40*	*0.20*	*0.08*	*0.08*	*0.20*	*0.020*
Blank Ck	<0.40	<0.08	<0.10	<0.08	<0.40	<0.20	<0.08	<0.08	<0.20	<0.020
Castine 1	21.25	1.14	0.55	0.12	1.20	33.42	0.25	0.86	16.79	<0.020
Castine 2	31.31	1.01	0.56	0.10	0.90	37.02	0.26	0.69	14.14	<0.020
Castine 3	28.91	0.90	0.49	0.12	0.85	34.58	0.08	0.74	12.99	<0.020
Castine 4	15.70	1.31	0.55	0.12	0.90	30.76	<0.08	0.89	16.04	<0.020
Clough Point 1	48.55	1.12	0.20	0.17	0.70	64.73	0.16	0.26	7.92	<0.020
Clough Point 2	55.06	0.95	0.19	0.19	0.55	67.73	0.17	0.24	6.38	<0.020
Clough Point 3	53.61	1.02	0.16	0.19	<0.40	67.67	0.19	0.21	6.06	0.040
Clough Point 4	57.46	1.12	0.20	0.23	0.54	70.08	0.19	0.32	8.31	<0.020
Englishman's Bay 1	45.38	1.17	0.16	0.15	0.79	52.05	0.15	0.32	7.85	<0.020
Englishman's Bay 2	53.53	1.26	0.17	0.20	0.81	59.82	0.17	0.36	7.42	0.101
Englishman's Bay 3	55.60	1.11	0.17	0.14	0.85	56.06	0.19	0.35	7.38	<0.020
Englishman's Bay 4	69.13	1.10	0.18	0.17	0.94	68.26	0.40	0.39	7.22	<0.020
Great Diamond Is. 1	29.50	1.21	0.15	0.14	0.54	46.78	0.21	0.36	6.62	<0.020
Great Diamond Is. 2	25.22	1.37	0.18	0.16	0.78	53.31	0.19	0.64	9.05	<0.020
Great Diamond Is. 3	34.21	1.47	0.19	0.22	0.82	58.89	0.25	0.71	10.09	0.041
Great Diamond Is. 4	60.74	1.45	0.19	0.22	0.75	72.46	0.19	0.78	10.02	0.037
Goose Ledge 1	31.75	1.62	0.16	0.11	0.94	37.82	0.51	0.34	11.47	<0.020
Goose Ledge 2	39.59	1.41	0.16	0.08	0.72	47.28	0.13	0.32	9.24	<0.020
Goose Ledge 3	24.95	1.45	0.13	0.08	0.86	27.71	1.25	0.26	10.04	<0.020
Goose Ledge 4	38.22	1.56	0.17	0.13	0.98	41.24	0.13	0.36	9.98	0.058
Kittery-Pepperell 1	108.65	1.40	0.20	0.48	1.09	120.96	0.19	1.11	13.07	0.054
Kittery-Pepperell 2	56.06	1.39	0.17	0.29	0.91	68.74	0.14	0.65	8.96	0.035
Kittery-Pepperell 3	41.09	1.58	0.24	0.25	0.81	58.86	0.17	0.78	17.84	<0.020
Kittery-Pepperell 4	45.00	1.12	0.12	0.20	0.59	50.95	0.09	0.49	7.47	0.030
Little Kennebec Bay 1	80.30	0.89	0.15	0.19	1.13	71.59	0.17	0.25	6.52	0.025
Little Kennebec Bay 2	97.31	1.15	0.21	0.25	1.18	96.36	0.18	0.56	8.97	0.063
Little Kennebec Bay 3	182.20	1.12	0.19	0.28	1.23	144.02	0.22	0.39	12.19	<0.020
Little Kennebec Bay 4	79.10	1.09	0.18	0.21	0.94	78.70	0.19	0.31	9.00	0.024
Long Island 1	39.92	1.37	0.18	0.15	0.59	47.02	0.47	0.39	9.44	<0.020
Long Island 2	16.94	1.26	0.18	0.10	0.63	24.39	0.49	0.30	6.28	0.023
Long Island 3	16.84	1.17	0.14	0.09	0.57	22.14	0.18	0.23	7.13	<0.020
Long Island 4	13.25	1.27	0.16	0.11	0.50	20.31	0.23	0.21	7.29	0.037
Medomak 1	20.09	1.10	0.16	0.08	0.67	28.92	0.11	0.21	11.00	0.072
Medomak 2	21.62	1.17	0.15	0.08	0.70	29.41	0.11	0.32	9.66	0.051
Medomak 3	26.57	1.14	0.13	0.10	0.67	29.53	1.75	0.29	8.86	<0.020
Medomak 4	29.62	1.18	0.14	0.11	0.61	29.53	0.27	0.25	8.82	<0.020
Sandy Point 1	36.19	1.28	0.21	0.22	0.87	58.58	0.15	0.35	9.15	<0.020
Sandy Point 2	30.91	1.35	0.22	0.21	0.62	60.22	0.15	0.34	7.93	<0.020
Sandy Point 3	37.59	1.21	0.24	0.23	0.80	59.41	0.15	0.31	8.36	<0.020
Sandy Point 4	50.94	1.27	0.20	0.24	0.81	60.08	0.17	0.28	6.31	<0.020
Sears Island 1	11.26	1.33	0.16	<0.08	0.81	20.26	0.24	0.26	8.74	<0.020
Sears Island 2	21.58	1.24	0.16	0.11	0.76	27.00	0.78	0.22	11.96	0.020
Sears Island 3	16.45	1.07	0.14	0.08	0.80	24.40	0.71	0.18	9.77	0.020
Sears Island 4	16.59	1.15	0.13	0.08	0.70	24.54	1.52	0.17	7.21	0.020

*reporting limit based on a 2.0 g sample weight

TABLE 1.2.4 PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES					
DEP ID		Englishman's Bay, Roque Bluffs 1	Englishman's Bay, Roque Bluffs 2	Englishman's Bay, Roque Bluffs 3	Englishman's Bay, Roque Bluffs 4
Sample ID#		01-MUS-21	01-MUS-22	01-MUS-23	01-MUS-24
Extraction ID		1659	1660	1661	1662
Analytes	DL (ug/Kg				
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	0.53	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthale	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	1.38(a)	<DL(a)	<DL(a)	<DL(a)
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	0.83(a)	<DL(a)	<DL(a)	<DL(a)
fluoranthrene	1.0	<DL	<DL	<DL	<DL
pyrene	1.0	<DL	<DL	<DL	<DL
benz(a)anthracene	1.0	1.06	<DL	<DL	<DL
chrysene	1.0	<DL	<DL	<DL	<DL
benzo(b)fluoranthene	2.0	<DL	<DL	<DL	<DL
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	<DL	<DL
benzo(e)pyrene	2.0	<DL	<DL	<DL	<DL
perylene	2.0	<DL	<DL	<DL	<DL
ideno(1,2,3-cd)pyrene	2.0	<DL	<DL	<DL	<DL
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	<DL	<DL	<DL
% Lipids		0.6	0.7	0.7	0.8
Sample weight (g, dry weight)		39.6	48.8	38.9	42.6
% Solids		13.4	13.9	13.4	13.0
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg	38.9	33.48	35.86	33.7
	65-135%	129.6	111.6	119.53	112.27
* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.					
** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.					
Values below the detection limit are estimated values and should be considered qualitative.					
They are provided for information only.					
(a) There are hits at or above the detection level in the blank for thses samples					
(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries					

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Medomak R. 1	Medomak R. 2	Medomak R. 3	Medomak R. 4
Sample ID#		01-MUS-25	01-MUS-26	01-MUS-27	01-MUS-28
Extraction ID		1620	1663	1622	1623
Analytes	DL (ug/Kg weight)				
naphthalene	1.0	<DL	<DL	0.48	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	<DL(a)	0.92(a)	1.56(a)	<DL(a)
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	<DL(a)	1.06(a)	1.74(a)	0.86(a)
fluoranthrene	1.0	<DL	1.47	2.11	1.01
pyrene	1.0	4.96	1.16	1.87	1.08
benz(a)anthracene	1.0	<DL	0.58	<DL	0.58
chrysene	1.0	<DL	<DL	<DL	0.79
benzo(b)fluoranthene	2.0	<DL	<DL	<DL	<DL
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	<DL	<DL
benzo(e)pyrene	2.0	<DL	<DL	<DL	<DL
perylene	2.0	<DL	<DL	<DL	<DL
ideno(1,2,3-cd)pyrene	2.0	<DL	<DL	<DL	<DL
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	<DL	<DL	<DL
% Lipids		1.17	1.3	1.14	1.72
Sample weight (g, dry weight)		14.1	29.2	16.6	13.9
% Solids		9.8	9.76	10.1	10.3
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg				
	65-135%				

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Great Diamond Is., Casco Bay 1	Great Diamond Is., Casco Bay 2	Great Diamond Is., Casco Bay 3	Great Diamond Is., Casco Bay 4
Sample ID#		01-MUS-41	01-MUS-42	01-MUS-43	01-MUS-44
Extraction ID		1627	1628	1629	1630
Analytes	DL (ug/Kg weight)				
			(b)		
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	4.40(a)	3.80(a)	2.26(a)	3.60(a)
anthracene	1.0	<DL	2.81	<DL	<DL
1-methylphenanthrene	1.0	4.06(a)	3.31	2.62	2.51
fluoranthrene	1.0	20.68	29.00(a)	21.41(a)	16.55(a)
pyrene	1.0	13.56	18.43	14.68	11.53
benz(a)anthracene	1.0	4.66	4.46	3.97	3.99
chrysene	1.0	25.34	28.02	19.72	14.21
benzo(b)fluoranthene	2.0	7.80	10.33	11.21	7.98
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	<DL	<DL
benzo(e)pyrene	2.0	2.54	4.05	4.18	5.85
perylene	2.0	<DL	<DL	<DL	<DL
ideno(1,2,3-cd)pyrene	2.0	<DL	2.64	1.99	1.86
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	<DL	<DL	<DL
% Lipids		2.99	3.02	2.70	2.13
Sample weight (g, dry weight)		11.8	12.1	14.1	18.3
% Solids		8.2	6.9	10.4	8.8
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg	27.53	48.31	33.7	31.85
	65-135%	91.8	161.0	112.3	106.2

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Sandy Pt., Stockton Springs 1	Sandy Pt., Stockton Springs 2	Sandy Pt., Stockton Springs 3	Sandy Pt., Stockton Springs 4
Sample ID#		01-MUS-01	01-MUS-02	01-MUS-03	01-MUS-04
Extraction ID		1631	1632	1633	1634
Analytes	DL (ug/Kg weight)				
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	2.47(a)	1.70(a)	<DL(a)	1.16(a)
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	1.73	2.09	<DL	1.12
fluoranthrene	1.0	5.20(a)	7.86(a)	3.40(a)	3.97(a)
pyrene	1.0	6.31	7.96	3.88	4.78
benz(a)anthracene	1.0	3.54	6.45	1.94	3.04
chrysene	1.0	2.73	5.50	2.59	3.21
benzo(b)fluoranthene	2.0	1.62	2.89	<DL	3.44
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	<DL	<DL
benzo(e)pyrene	2.0	1.07	1.61	<DL	1.12
perylene	2.0	<DL	0.66	<DL	<DL
ideno(1,2,3-cd)pyrene	2.0	0.92	1.00	<DL	0.63
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	<DL	<DL	<DL
% Lipids		0.64	1.59	0.95	0.82
Sample weight (g, dry weight)		27.1	21.1	23.2	22.4
% Solids		10.3	9.9	10.2	9.8
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg	28.7	31.0	23.3	31.8
	65-135%	95.7	103.2	77.5	105.9

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Castine-Brooksville 1	Castine-Brooksville 2	Castine-Brooksville 3	Castine-Brooksville 4
Sample ID#		01-MUS-09	01-MUS-10	01-MUS-11	01-MUS-12
Extraction ID		1635	1636	1637	1638
Analytes	DL (ug/Kg weight)				
		(b)			
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	0.73(a)	0.76(a)	1.34(a)	2.33(a)
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	<DL	<DL	0.84	1.44
fluoranthrene	1.0	0.80(a)	0.92(a)	1.45(a)	2.28(a)
pyrene	1.0	0.60	0.64	1.00	1.36
benz(a)anthracene	1.0	<DL	<DL	1.00	0.89
chrysene	1.0	<DL	<DL	0.77	1.23
benzo(b)fluoranthene	2.0	<DL	<DL	0.77	1.53
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	<DL	<DL
benzo(e)pyrene	2.0	<DL	<DL	<DL	<DL
perylene	2.0	<DL	<DL	<DL	<DL
ideno(1,2,3-cd)pyrene	2.0	<DL	<DL	<DL	<DL
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	<DL	<DL	<DL
% Lipids		0.37	0.43	0.94	1.21
Sample weight (g, dry weight)		30.0	31.2	26.1	23.6
% Solids		8.2	8.3	8.4	8.6
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg	14.7	19.95	21.14	20.62
	65-135%	48.9	66.5	70.47	68.73

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Sears Is., Searsport 1	Sears Is., Searsport 2	Sears Is., Searsport 3	Sears Is., Searsport 4
Sample ID#		01-MUS-05	01-MUS-06	01-MUS-07	01-MUS-08
Extraction ID		1639	1640	1646	1642
Analytes	DL (ug/Kg weight)				
		(b)	(b)		
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	2.07(a)	1.59(a)	<DL(a)	<DL(a)
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	<DL	0.61	<DL	<DL
fluoranthrene	1.0	2.96(a)	2.48(a)	1.50(a)	2.71(a)
pyrene	1.0	1.05	0.83	1.03	2.05
benz(a)anthracene	1.0	0.98	1.16	0.57	0.73
chrysene	1.0	<DL	0.67	0.59	1.41
benzo(b)fluoranthene	2.0	<DL	<DL	0.52	0.61
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	<DL	<DL
benzo(e)pyrene	2.0	<DL	<DL	<DL	<DL
perylene	2.0	<DL	<DL	<DL	<DL
ideno(1,2,3-cd)pyrene	2.0	<DL	<DL	<DL	<DL
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	<DL	<DL	<DL
% Lipids		0.69	0.52	0.73	0.69
Sample weight (g, dry weight)		57.0	50.8	40.60	52.3
% Solids		13.0	12.6	12.76	12.6
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg	14.4	17.12	29.32	23.18
	65-135%	48.07	57.07	97.73	77.27

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Little Kennebec Bay, Machiasport 1	Little Kennebec Bay, Machiasport 2	Little Kennebec Bay, Machiasport 3	Little Kennebec Bay, Machiasport 4
Sample ID#		01-MUS-29	01-MUS-30	01-MUS-31	01-MUS-32
Extraction ID		1651	1645	1641	1647
Analytes	DL (ug/Kg weight)				
			(b)		(b)
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	1.00
2-methylnaphthalene	1.0	<DL	<DL	<DL	0.75
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	0.57
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	<DL	0.81(a)	<DL(a)	2.57(a)
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	0.53	0.50	0.54	1.86
fluoranthrene	1.0	0.74	0.59(a)	0.93(a)	3.28(a)
pyrene	1.0	0.62	<DL	0.61	1.96
benz(a)anthracene	1.0	<DL	<DL	<DL	0.68
chrysene	1.0	0.53	<DL	0.57	1.82
benzo(b)fluoranthene	2.0	<DL	<DL	<DL	1.43
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	<DL	<DL
benzo(e)pyrene	2.0	<DL	<DL	<DL	0.93
perylene	2.0	<DL	<DL	<DL	<DL
ideno(1,2,3-cd)pyrene	2.0	<DL	<DL	<DL	<DL
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	<DL	<DL	<DL
% Lipids		0.54	0.41	0.11	2.74
Sample weight (g, dry weight)		33.80	40.30	46.0	28.00
% Solids		11.57	12.71	12.6	13.61
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg	30.1	19.4	27.22	46.8
	65-135%	100.4	64.53	90.73	155.97

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Damariscotta R., Goose Ledge 1	Damariscotta R., Goose Ledge 2	Damariscotta R., Goose Ledge 3	Damariscotta R., Goose Ledge 4
Sample ID#		01-MUS-17	01-MUS-18	01-MUS-19	01-MUS-20
Extraction ID		1652	1648	1649	1653
Analytes	DL (ug/Kg weight)				
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	0.50	0.74(a)	1.36(a)	<DL
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	<DL	0.72	0.52	<DL
fluoranthrene	1.0	1.57	1.71(a)	4.80(a)	1.10
pyrene	1.0	1.10	1.59	2.92	0.91
benz(a)anthracene	1.0	<DL	<DL	1.93	0.78
chrysene	1.0	0.99	0.63	2.09	0.75
benzo(b)fluoranthene	2.0	0.80	<DL	<DL	<DL
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	<DL	<DL
benzo(e)pyrene	2.0	0.83	<DL	<DL	<DL
perylene	2.0	<DL	<DL	<DL	<DL
ideno(1,2,3-cd)pyrene	2.0	<DL	<DL	<DL	<DL
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	<DL	<DL	<DL
% Lipids		1.23	0.84	0.96	1.07
Sample weight (g, dry weight)		36.30	41.40	42.50	30.80
% Solids		10.89	13.42	11.62	11.00
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg	33.82	34.8	34.2	29.23
	65-135%	112.73	115.87	114	97.43

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Pepperell Cove, Kittery 1	Pepperell Cove, Kittery 2	Pepperell Cove, Kittery 3	Pepperell Cove, Kittery 4
Sample ID#		01-MUS-33	01-MUS-34	01-MUS-35	01-MUS-36
Extraction ID		1654	1664	1657	1650
Analytes	DL (ug/Kg weight)				
			(b)		
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	<DL	2.19	<DL	3.93
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	<DL	1.79	<DL	2.40
fluoranthrene	1.0	4.78	10.40	2.02	12.53
pyrene	1.0	4.98	9.85	2.10	11.67
benz(a)anthracene	1.0	4.67	12.84	5.21	6.80
chrysene	1.0	5.14	6.12	1.25	10.00
benzo(b)fluoranthene	2.0	5.33	5.92	<DL	11.27
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	0.80	<DL	1.20
benzo(e)pyrene	2.0	2.63	4.03	<DL	6.73
perylene	2.0	<DL	<DL	<DL	2.20
ideno(1,2,3-cd)pyrene	2.0	<DL	4.33	0.62	5.13
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	3.58	0.78	3.80
% Lipids		0.72	1.26	0.35	1.68
Sample weight (g, dry weight)		25.50	20.1	25.70	15.00
% Solids		11.06	10.15	10.28	13.72
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg	32.62	46.36	24.18	28.5
	65-135%	108.73	154.5	80.6	95.0

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Long Island, Casco Bay 1	Long Island, Casco Bay 2	Long Island, Casco Bay 3	Long Island, Casco Bay 4
Sample ID#		01-MUS-37	01-MUS-38	01-MUS-39	01-MUS-40
Extraction ID		1665	1655	1656	1658
Analytes	DL (ug/Kg weight)				
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	<DL	<DL	<DL	<DL
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	0.75	<DL	<DL	<DL
fluoranthrene	1.0	1.42	1.78	1.34	1.42
pyrene	1.0	1.30	1.41	0.98	1.03
benz(a)anthracene	1.0	1.00	1.84	1.91	1.81
chrysene	1.0	<DL	<DL	<DL	<DL
benzo(b)fluoranthene	2.0	<DL	<DL	<DL	<DL
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	<DL	<DL
benzo(e)pyrene	2.0	<DL	<DL	<DL	<DL
perylene	2.0	<DL	<DL	<DL	<DL
ideno(1,2,3-cd)pyrene	2.0	<DL	<DL	<DL	<DL
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	<DL	<DL	<DL	<DL
% Lipids		0.58	0.88	0.46	0.46
Sample weight (g, dry weight)		23.9	18.50	24.60	23.2
% Solids		9.31	11.53	10.72	11.33
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg	26.7	26.42	27.88	37.26
	65-135%	89.0	88.07	92.93	124.20

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

TABLE 1.2.4 (CONTINUED) PAHS IN 2001 BLUE MUSSEL TISSUE SAMPLES

DEP ID		Clough Point, Sheepscot R. 1	Clough Point, Sheepscot R. 2	Clough Point, Sheepscot R. 3	Clough Point, Sheepscot R. 4
Sample ID#		01-MUS-13	01-MUS-14	01-MUS-15	01-MUS-16
Extraction ID		1667	1666	1668	1669
Analytes	DL (ug/Kg weight)				
			(b)	(b)	
naphthalene	1.0	<DL	<DL	<DL	<DL
1-methyl naphthalene	1.0	<DL	<DL	<DL	<DL
2-methylnaphthalene	1.0	<DL	<DL	<DL	<DL
biphenyl	1.0	<DL	<DL	<DL	<DL
2,6-dimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
acenaphthylene	1.0	<DL	<DL	<DL	<DL
acenaphthene	1.0	<DL	<DL	<DL	<DL
2,3,5-trimethylnaphthalene	1.0	<DL	<DL	<DL	<DL
fluorene	1.0	<DL	<DL	<DL	<DL
phenanthrene	1.0	0.91	0.80	1.13	1.11
anthracene	1.0	<DL	<DL	<DL	<DL
1-methylphenanthrene	1.0	0.84	1.05	1.13	1.11
fluoranthrene	1.0	4.25	6.05	6.91	5.41
pyrene	1.0	3.67	6.20	6.74	5.02
benz(a)anthracene	1.0	4.16	11.05	5.64	9.76
chrysene	1.0	2.79	3.48	4.23	5.31
benzo(b)fluoranthene	2.0	2.66	2.72	3.68	3.72
benzo(k)fluoranthene	*				
benzo(a) pyrene	2.0	<DL	<DL	1.13	0.58
benzo(e)pyrene	2.0	1.85	1.78	2.37	2.32
perylene	2.0	0.68	0.80	1.27	1.30
ideno(1,2,3-cd)pyrene	2.0	1.14	2.25	1.62	1.59
dibenz(a,h)anthracene	**				
benzo(g,h,i)perylene	2.0	0.65	1.88	0.69	1.26
% Lipids		0.30	0.77	0.62	0.85
Sample weight (g, dry weight)		30.8	27.6	29.1	20.7
% Solids		7.02	8.32	7.46	7.47
Surrogates					
p-Terphenyl	19.5-40.5 ug/Kg				
	65-135%				

* Benzo(k)fluoranthrene coelutes with Benzo(b)fluoranthrene.

** Dibenz(a,h)anthracene coelutes with ideno(1,2,3-cd)pyrene.

Values below the detection limit are estimated values and should be considered qualitative.

They are provided for information only.

(a) There are hits at or above the detection level in the blank for thses samples

(b) The values are considered estimated concentrations due to out of bounds surrogate recoveries

1.2

MARINE SPORTFISH HEALTH ADVISORY

MARINE SPORTFISH HEALTH ADVISORY

Mercury and PCBs in Striped Bass- From previous years in the SWAT program, there are some data on concentrations of mercury and PCBs from striped bass from the Androscoggin River, Kennebec River, Scarorough River, Sheepscot River and Saco River. The results support the current fish consumption advisory issued by the Maine Bureau of Health. There is some variation geographically, but not all regions of the state have been sampled. The highest value for mercury was in large legal-sized(<40in=1016 mm) striped bass collected in 1995 from the lower Kennebec River, while smaller 'schoolies' from the same time and location had lower concentrations (Table 1.2.1). Striped bass collected from York Harbor and the Penobscot River in 2001 exhibited concentrations near the lower end of the range shown for other rivers in previous years. To the contrary, PCB concentrations were higher than found previously in other rivers. Concentrations in fish from both rivers were below the Maine Bureau of Health's Fish Tissue Action Level (FTAL=0.2 ppm) for mercury but greatly exceed the FTAL (11 ppb) for PCB. It is curious that mercury levels are more similar among stations than are PCB. Additional sampling of all rivers will be conducted in 2002 to gather data from the same year.

Mercury and PCBs in Bluefish. We had only two data points for this species for mercury and only one for PCBs. Bluefish seem to have higher concentration PCBs than do striped bass. But to keep the advisory simple, the current Maine Bureau of Health fish consumption advisory has the same recommendation as for striped bass, 2 meals/month. More data are needed. We attempted to catch bluefish of 2 sizes from 2 different areas. Runs of bluefish have been spotty in recent years and 2001 we were able to collect adults from the lower Kennebec River only. The concentration of mercury was within the range of previous years and similar to those of striped bass Table 1.2.1). However, the concentration of PCBs was much higher than measured previously. The concentration exceeded the Maine Bureau of Health's Fish Tissue Action Level (FTAL=0.2 ppm) for mercury and greatly exceeded the the FTAL (11 ppb) for PCB. It is curious that mercury levels are more similar among stations than are PCB. Additional data will be collected in 2002.

Table 1.2.1 Mercury and PCB concentrations in striped bass and bluefish

WATER & LOCATION	STATION CODE	SPECIES CODE	1995 HG ppm	1996 HG ppm	1997 HG ppm	1998 HG ppm	1999 HG ppm	2000 HG ppm	2001 HG ppm
Androscoggin R									
Brunswick	ARB	STB				0.38		0.22	
Kennebec R									
Augusta	KAG	STB			0.33	0.4	0.32		
Phippsburg	KRP	STB	0.17, 0.53						
	KRP	BLF	0.53						0.39
Penobscot R									
Orrington	PBO	STB							0.15
Saco Bay									
Saco		STB						0.18	
Scarborough R									
Scarborough		STB				0.37			
		BLF				0.33			
Sheepscot R									
Wiscasset	SRW	STB						0.22	
York R									
York	YRY	STB							0.12

WATER & LOCATION	STATION CODE	SPECIES CODE	1995 PCB ppb	1996 PCB ppb	1997 PCB ppb	1998 PCB ppb	1999 PCB ppb	2000 PCB ppb	2001 PCB ppb
Androscoggin R									
Brunswick	ARB/ABK	STB				40.7			
Kennebec R									
Augusta	KAG	STB			11.8	15.8	10.7		
Phippsburg	KRP	STB	17.4, 22.4						
	KRP	BLF	48.8						276
Penobscot R									
Orrington	PBO	STB							83.5
Saco Bay									
Saco		STB				16.3		25	
Scarborough R									
Scarborough		STB							
		BLF							
Sheepscot R									
Wiscasset	SRW	STB							
York R									
York	YRY	STB							64.3

Raw data

ID	LENGTH mm	HG mg/kg
Kennebec R, Bath		
KRP-BLF-1	762	0.2215
KRP-BLF-2	762	0.2714
KRP-BLF-3	762	0.2800
KRP-BLF-4	813	0.6376
KRP-BLF-5	838	0.5156
mean	**787**	**0.39**
Penobscot R, Orrington		
PBO-STB-1	625	0.1343
PBO-STB-2	640	0.2019
PBO-STB-3	620	0.1488
PBO-STB-4	585	0.1202
PBO-STB-5	540	0.1223
mean	**602**	**0.15**
York R, York		
YRY-STB-1	622	0.1196
YRY-STB-2	660	0.1472
YRY-STB-3	527	0.0966
YRY-STB-4	578	0.1010
YRY-STB-5	559	0.1376
mean	**589**	**0.12**

Raw data

ID	LENGTH mm	PCB ug/kg
Kennebec R, Bath		
KRP-BLF-1	762	354
KRP-BLF-2	762	155
KRP-BLF-3	762	296
KRP-BLF-4	813	386
KRP-BLF-5	838	188
mean	**787**	**276**
Penobscot R, Orrington		
PBO-STB-1	625	47.9
PBO-STB-2	640	46.2
PBO-STB-3	620	122
PBO-STB-4	585	76.3
PBO-STB-5	540	125
mean	**602**	**83.5**
York R, York		
YRY-STB-1	622	63.0
YRY-STB-2	660	75.8
YRY-STB-3	527	33.6
YRY-STB-4	578	71.9
YRY-STB-5	559	77.4
mean	**589**	**64.3**

1.3

CONTAMINANTS IN SPARROWS IN COASTAL MARSHES

Mercury Exposure Profile for Sharp-tailed Sparrows Breeding in Coastal Maine Salt Marshes

(BRI 2002-11)

BioDiversity Research Institute is a Maine-based nonprofit research group dedicated to progressive environmental research and education that furthers global sustainability and conservation policies. Fundamental studies involve avian conservation and aquatic toxicology. We believe high trophic level piscivorous wildlife are vital indicators of aquatic integrity.

To obtain copies of this report contact:

BioDiversity Research Institute
411 US Route One, Suite 1
Falmouth, ME 04105
(207) 781-3324

staff@briloon.org
www.BRIloon.org

Hg Exposure Profile for Sharp-tailed Sparrows Breeding in Coastal Maine Salt Marshes

(BRI 2002 – 11)

Submitted to:
Maine Department of Environmental Protection
Surface Water Ambient Toxic Monitoring Program
State House Station 17
Augusta, Maine 04333

Submitted By:
W. Gregory Shriver
State University of New York, College of Environmental Science and Forestry,

David Evers
Biological Diversity Research Institute,
and

Thomas P. Hodgman
Maine Department of Inland Fisheries and Wildlife

19 April, 2002

Please cite this report as: Shriver, W. G., D. Evers, and T. Hodgman. 2002. Hg Exposure Profile for Sharp-tailed Sparrows Breeding in Coastal Maine Salt Marshes. Report BRI 2002 – 11

submitted to the Maine Department of Environmental Protection. BioDiversity Research Institute, Falmouth. Maine.

INTRODUCTION

Sharp-tailed sparrows (*Ammodramus* spp.) inhabit wet meadows, marshes, and salt marshes of central and eastern North America. The taxonomy, distribution, and evolutionary history of this group has been debated for over a century. In 1995, based on morphological and genetic evidence, the American Ornithologists Union committee on classification and nomenclature voted to separate this single species with five known sub-species into two species: a northern species, *Ammodramus nelsoni*, with 3 sub-species (*A. n. nelsoni, A. n. alterus*, and *A. n subvirgatus*) and a southern species, *A. caudacutus* with two sub-species (*A. c. caudacutus and A. c. diverus*), limited to coastal wetlands. *A. n. subvirgatus* (hereafter Nelson's Sparrow) and *A. c. caudacutus* (hereafter Saltmarsh Sparrow) are sympatric in coastal Maine, New Hampshire, and the northeast shore of Massachusetts.

The biomagnification of mercury (Hg) in aquatic biota is well known (Watras and Huckabee 1994), however its expression in insectivorous birds is not well studied (see review in Thompson 1996). Terrestrial species have recently been selected to serve as potential bioindicators of contaminants including Tree Swallows (*Tachycineata bicolor*) for Hg exposure (Gerrard and St. Louis 2001) and organochlorines (Secord et al. 1999) and American Robins (*Turdus migratorius*) for lead (Johnson et al. 1999).

We believe sharp-tailed sparrows are an appropriate indicator of methylmercury availability in coastal marshes. Our two target species spend their entire life-cycle in salt marsh habitats of the Atlantic coast. Their small breeding territories afford an excellent opportunity to determine contaminant exposure for target marshes and even specific areas within a marsh. Because of increasing urbanization surrounding these habitats a better understanding of contaminant ecological impacts has been identified and is of national interest (Newman et al. 2002).

The objectives of this study were to 1) determine the extent of Hg exposure in two species of sharp-tailed sparrows in coastal Maine salt marshes, 2) compare blood Hg between Saltmarsh and Nelson's sparrows, and 3) determine if there were differences in Hg exposure among five Maine salt marshes.

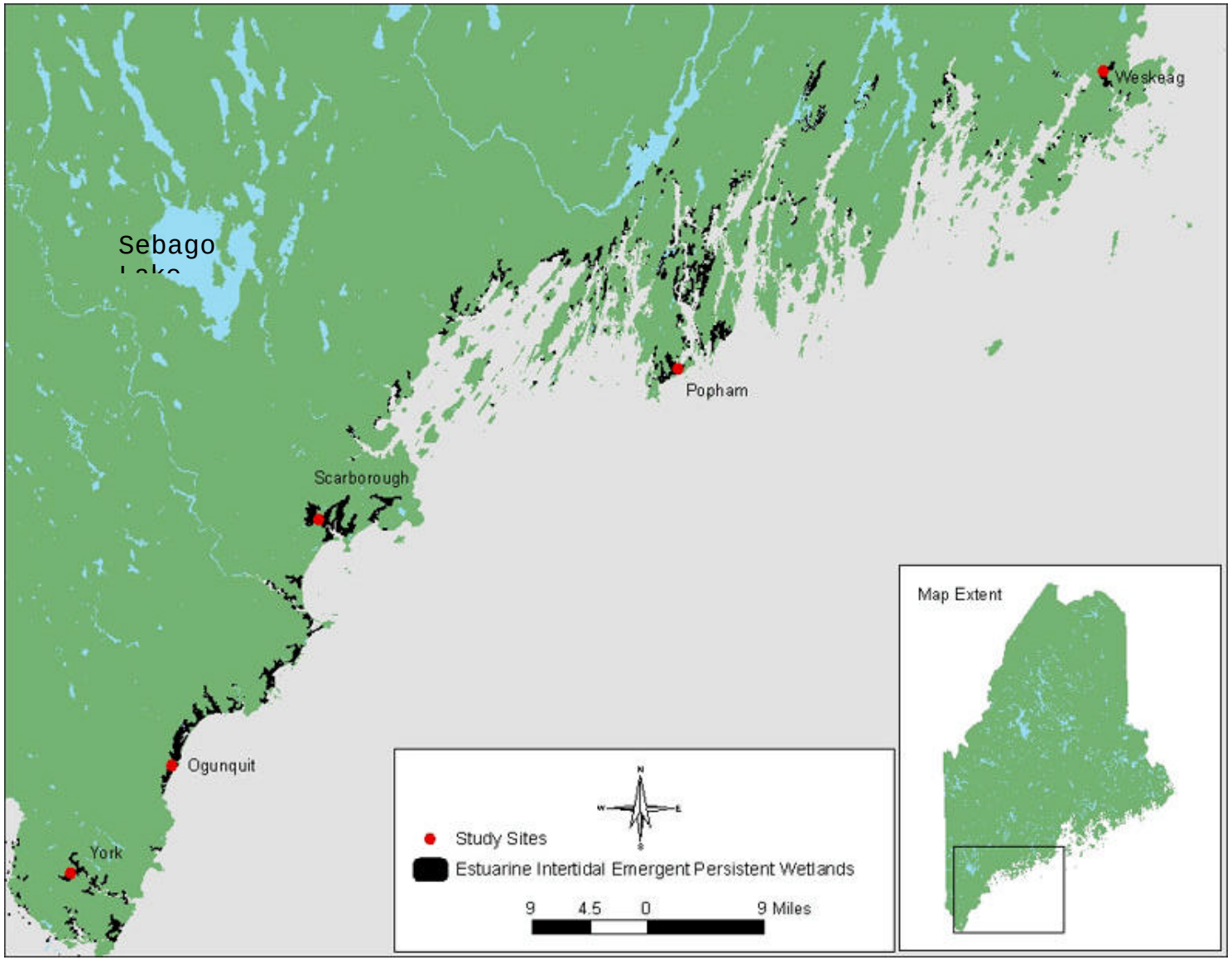
STUDY AREA & METHODS

We sampled sharp-tailed sparrows from 5 marshes along the Maine coast during the breeding seasons (15 June-1 August 2001) of 2000 and 2001 (Figure 1). We used mist nets to capture sparrows and attached a U.S. Fish and Wildlife Service band and three color-bands to each individual. We used a wing cord ruler to measure unbended wing cord and dividers to measure tarsus length. We weighed all sparrows

using a spring scale to the nearest 0.25 gm. We collected 30 µl – 50 µl of blood from the cutaneous ulnar vein for Hg contamination analysis using a micro-pipette. Micro-pipettes were stored in a test-tube and placed in a cooler immediately after collection. All samples were frozen on the day of collection and were maintained at $<25^{o}$ (F) until contamination analyses were conducted. Blood Hg levels are generally not compromised by body burden Hg levels during the breeding season (Evers et al. 1998).

We used independent *t* tests to determine differences in blood Hg levels between species and sex. If differences were significant between species or sex we then conducted further analyses separately. We used ANOVA with Tukey's post-hoc tests to determine if differences existed in blood Hg levels among the 5 sites. If there were differences among sites we then used ANOVA to determine if there were weight (g) or wing cord (mm) differences between high and low Hg level sites. All means are presented $\pm$ 1 SE.

Figure 1. Study sites with estuarine wetlands.



RESULTS

We captured and drew blood from 81 sharp-tailed sparrows (28 Nelson's and 54 Saltmarsh) in 5 marshes on the Maine coast (Table 1). Saltmarsh Sparrows (mean = 0.69 $\pm$ 0.03) had 41% greater blood Hg levels than Nelson's Sparrows (mean = 0.41 +/- 0.03) (t = 6.338, df = 79, P < 0.001, Figure 2). There was no difference in blood Hg levels between males and females for either species (Nelson's t = 1.69, df = 23, P = 0.171; Saltmarsh t = 0.848, df = 48, P = 0.401). We detected a difference in blood Hg levels among sites for both species (Nelson's F = 7.402, df = 4, P = 0.001; Saltmarsh F = 6.154, df = 4, P < 0.001, Figure 3 A and B). Popham beech and Ogunquit were highest in blood Hg for both species (Figure 3A and B). Sparrow weight and wing cord did not differ between high and low Hg level sites for either species (Nelson's weight F = 0.128, df = 1, P = 0.723, Nelson's wing cord F = 4.097, df =1, P = 0.053; Saltmarsh weight F = 1.219, df = 1, P = 0.275, Saltmarsh wing cord F = 1.542, df = 1, P = 0.220). There was a significant difference in weight between sparrow species.

Figure 2. Differences in blood Hg between Nelson’s Sparrow and Saltmarsh Sparrow. Saltmarsh Sparrows had significantly more blood Hg than Nelson’s Sparrow. (mean+-se ppm)

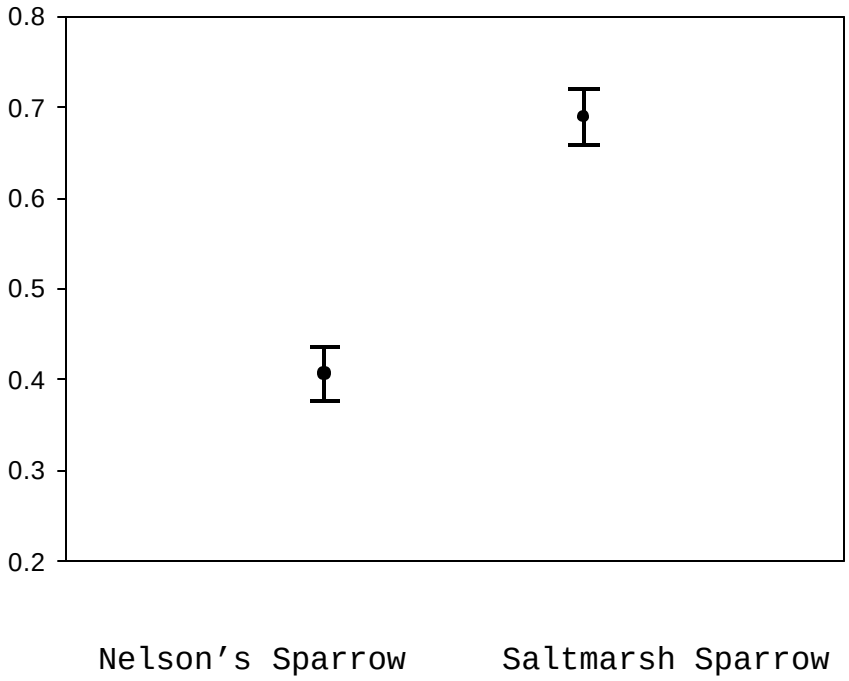
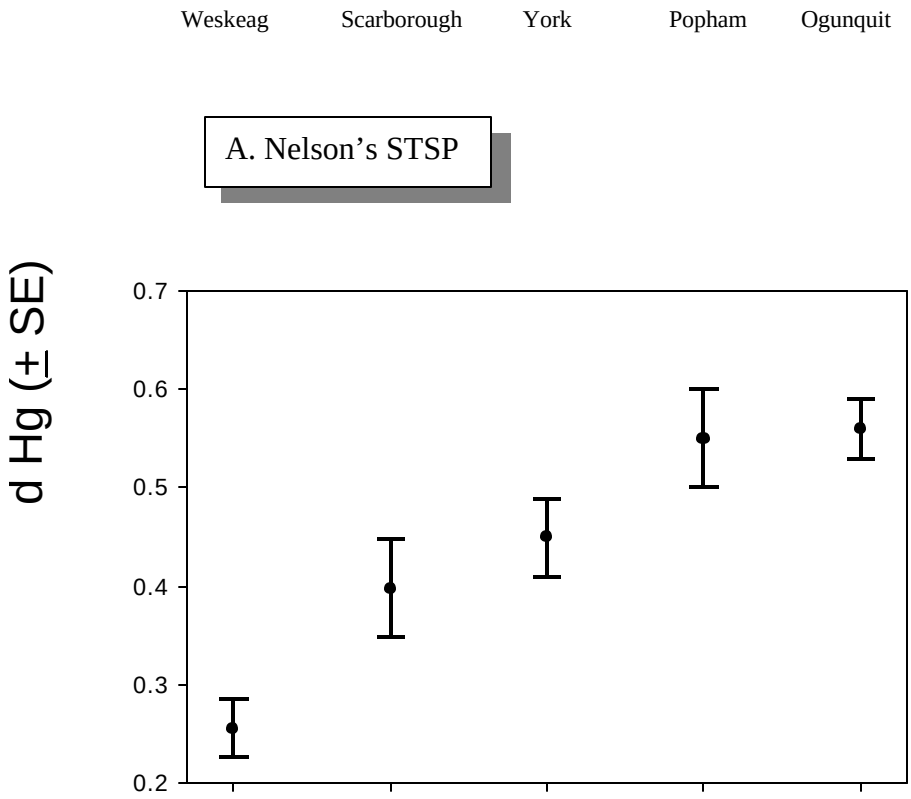
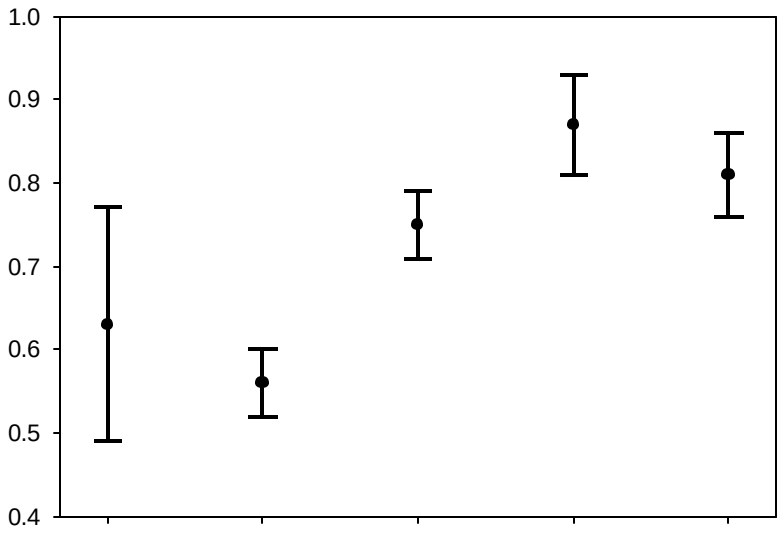


Figure 3. Differences in blood Hg between sites for A) Nelson's Sparrow and B) Saltmarsh Sparrow. Blood Hg levels were highest at Popham and Ogunquit for both species





B SALTMARSH STSP

Table 1. Sampling locations, sample sizes and mean weight and wing cord for Saltmarsh and Nelson's Sharp-tailed Sparrows in coastal Maine (2000-2001).

		Saltmarsh Sharp-tailed Sparrow					Nelson's Sharp-tailed Sparrow				
Site	Lat / Long	Male	Female	Juvs	Mean Weight (g)	Mean Wing Cord (mm)	Males	Females	Juvs.	Mean Weight (g)	Mean Wing Cord (mm)
Weskeag	N 44 04.680 W 69 08.625	4	1	0	21.1 (0.6)	57.9 (2.2)	6	0	3	18.0 (0.8)	57.1 (1.1)
Popham	N 43 44.37 W 69 48.247	6	0	0	22.6 (0.5)	59.8 (0.8)	4	2	0	19.3 (0.7)	55.9 (1.6)
Scarborough	N 43 33.90 W 70 21.67	16	6	0	20.3 (1.6)	57.2 (1.3)	6	2	0	17.7 (1.7)	57.3 (2.1)
Ogunquit	N 43 17.02 W 70 34.92	7	4	0	20.3 (1.6)	57.6 (2.7)	3	0	0	18.3 (1.5)	56.8 (1.0)
York	N 43 09.64 W 70 44.01	6	1	3	19.2 (1.9)	56.9 (2.1)	2	0	0	18.4 (0.9)	57.0 (1.4)
TOTAL		39	12	3	20.7 +/- 1.3	57.9 +/- 1.1	21	4	3	18.3 +/- 0.6	56.8 +/- 0.5

DISCUSSION

We found nearly twice the Hg blood levels in Saltmarsh Sparrows than we did in Nelson's Sparrows at all five sites. This pattern was not predicted as both species spend their entire life-cycle in salt marsh habitat, presumably exposed to the same levels of contamination. Differential prey selection by sparrows could explain differences in the observed blood Hg levels. If Saltmarsh Sparrows, which are larger and have larger beaks, selected carnivorous prey while the smaller Nelson's Sparrows selected herbivorous prey, then we would expect to see higher levels of blood Hg in Saltmarsh Sparrows. Because these sparrows were recently split into two separate species (1995), little is known about dietary differences between them that may explain differences in blood Hg levels we found during this study.

We also found differences among the five salt marshes we sampled; indicating that blood Hg levels in sharp-tailed sparrows may be used as an index to Hg contamination in the salt marshes. This finding was supported by the similar pattern in Hg levels within each species across the five sites. For both species, blood Hg levels were highest in Popham and Ogunquit, intermediate at York, and lowest in Scarborough and Weskeag. This consistency in blood Hg levels in the two species across the five sites indicates that these sparrows may be potential indicators of salt marsh and estuarine Hg contamination.

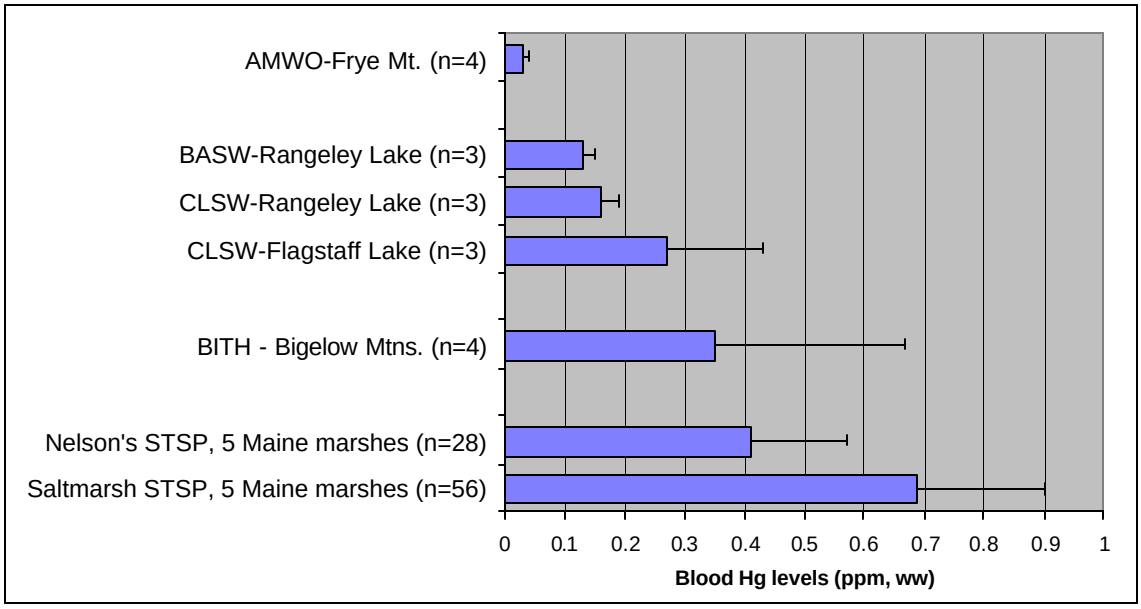
Comparing our sparrow blood Hg levels with other related species is difficult. The handful of terrestrial bird Hg studies are not based on blood, rather their assessments use whole body analysis and/or organs (i.e., lethal sampling). However, our non-lethal sampling strategy for this project is comparable with other such collection efforts with insectivorous birds in Maine. BioDiversity Research Institute staff have sampled terrestrial birds including American Woodcock (*Scolopax minor*) (AMWO), Barn Swallow (*Hirundo rustica*) (BASW), Cliff Swallow (Petrochelidon pyrrhonota) (CLSW), and Bicknell's Thrush (Catharus bicknelli) (BITH) (Figure 4).

The sampling efforts with the swallows are particularly informative as a reference for Hg exposure. Swallows were sampled from two lakes that have thorough biotic Hg risk assessments based on fish and the Common Loon (*Gavia immer*) (Evers et al. 2002). Because swallow sample sizes are minimal statistical comparisons were not attempted. Barn and Cliff Swallows from Rangeley Lake, a low Hg risk system, had mean blood Hg levels considerably less than those found from both sharp-tailed sparrow species in each of the five

marshes. Assuming a relationship exists between fish Hg levels and associated emerging insects, reference blood Hg levels for insectivorous birds are possibly less than 0.20 ppm (ww). Flagstaff Lake is well known for its elevated biotic Hg levels (Evers et al. 2002). Cliff Swallow blood Hg levels tended to be less on Flagstaff Lake than sharp-tailed sparrow blood Hg levels.

Further efforts with swallow species in areas with known biotic Hg assessments as well as at the sharp-tailed sparrow locations will provide further context for assessing hazards related to Hg levels in coastal Maine's salt marshes.

Figure 4. Blood Hg levels in selected insectivorous birds in New England



RECOMMENDATIONS

1. Determine Hg exposure for sharp-tailed sparrows in other Maine coastal marshes with large breeding populations;
2. Determine Hg exposure for Tree Swallows with breeding territories in coastal marshes with sharp-tailed sparrows at some locations for comparative purposes;
3. Determine Hg exposure for swallow species with breeding territories in areas with known biotic Hg levels;
4. Determine prey base of sharp-tailed sparrows and analyze prey items for Hg;
5. Measure levels of other contaminants including polychlorinated biphenyls in sharp-tailed sparrows.

LITERATURE CITED

Evers, D. C., O. P. Lane, C. DeSorbo, and L. Savoy. 2002. Assessing the impacts of methylmercury on piscivorous wildlife using a wildlife criterion value based on the Common Loon. Report BRI 2002-08 submitted to Maine Department of Environmental Protection from BioDiversity Research Institute, Falmouth, Maine.

Evers, D. C., J. D. Kaplan, M. W. Meyer, P. S. Reaman, W. E. Braselton, A. Major, N. Burgess, and A. M. Scheuhammer. 1998a. A geographic trend in mercury measured in common loon feather and blood. Environ. Toxicol. Chem. 17(2):173-183.

Gerrard, P. M. and V. L. St. Louis. 2001. The effects of experimental reservoir creation on the bioaccumulation of methylmercury and reproductive success of Tree Swallows (Tachycineta bicolor). Environ. Sci. Technol. 35:1329-1338.

Johnson, G. D., D. J. Audet, J. W. Kern, L. J. LeCaptain, M. D. Strickland, D. J. Hoffman, and L. L. McDonald. 1999. Lead exposure in passerines inhabiting lead-contaminated floodplains in the Coeur D'Alene River Basin, Idaho, USA. Environ. Toxicol. Chem. 18:1190-1194.

Newman, M. C., M. H. Roberts, Jr., and R. C. Hale. 2002. Coastal and estuarine risk assessment. Lewis Publ., Boca Raton, Forida.

Secord, A. L, J. P. McCarty, K. R. Echols, J. C. Meadows, R. W. Gale, and D. E. Tillitt. 1999. Polychlorinated biphenyls and 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents in Tree Swallows from the Upper Hudson River, New York state, USA. Environ. Toxicol. Chem. 18:2519-2525.

Thompson, D. R. 1996. Mercury in Birds and Terrestrial Animals. In: W. N. Beyer, Gary H. Heinz, Amy W. Redmon-Norwood (Ed.), Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations (pp. 341-355). Clemson, SC: Lewis Publisher.

Watras, C. J. and J. W. Huckabee. 1994. Mercury pollution: Integration and synthesis. Lewis Publ., Boca Raton, Florida.

Raw Data

Note	Flag	Hg, ppm	MDL, ppm	Weight	
Blood, Juvenile, Unk, SSTS, 2001, York		0.68	0.00335	0.0326	Y
Blood, Juvenile, Unk, SSTS, 2001, York		0.784	0.00575	0.0377	Y
Blood, Juvenile, Unk, SSTS, 2001, York		0.734	0.00601	0.0357	Y
Blood, Juvenile, Unk, NSTS, 2001, Weskeag		0.107	0.012	0.0088	W
Blood, Juvenile, Unk, NSTS, 2001, Weskeag		0.131	0.00447	0.0584	W
Blood, Juvenile, Unk, NSTS, 2001, Weskeag		0.201	0.00222	0.0408	W
Blood, Adult, Male, SSTS, 2001, York		0.921	0.00486	0.0458	Y
Blood, Adult, Male, SSTS, 2001, York		0.758	0.00617	0.0362	Y
Blood, Adult, Male, SSTS, 2001, York		0.49	0.00469	0.0464	Y
Blood, Adult, Male, SSTS, 2001, York		0.887	0.00498	0.0438	Y
Blood, Adult, Male, SSTS, 2001, York		0.758	0.00584	0.0367	Y
Blood, Adult, Male, SSTS, 2001, York		0.757	0.00572	0.0371	Y
Blood, Adult, Male, SSTS, 2001, Weskeag; LAB NOTE: slight clot		1.17	0.0813	0.0013	W
Blood, Adult, Male, SSTS, 2001, Weskeag		0.414	0.00263	0.0414	W
Blood, Adult, Male, SSTS, 2001, Weskeag		0.479	0.00434	0.0503	W
Blood, Adult, Male, SSTS, 2001, Weskeag		0.499	0.00336	0.0319	W
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh; LAB NOTE: slight clot		0.665	0.0288	0.0037	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh: NOT ANALYZED, MAY			0.00005		
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.486	0.00326	0.0338	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.581	0.0047	0.0465	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.528	0.00583	0.0371	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.523	0.00511	0.0428	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.545	0.00328	0.0332	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.552	0.00679	0.0159	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.453	0.00361	0.0297	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.424	0.00619	0.0348	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.461	0.00452	0.0479	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.485	0.00609	0.0351	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.488	0.00367	0.0291	S
Blood, Adult, Male, SSTS, 2001, Scarborough Marsh		0.42	0.00521	0.0202	S
Blood, Adult, Male, SSTS, 2001, Popham		0.824	0.00477	0.0452	P
Blood, Adult, Male, SSTS, 2001, Popham		0.816	0.0072	0.0296	P
Blood, Adult, Male, SSTS, 2001, Popham		0.788	0.0045	0.0478	P
Blood, Adult, Male, SSTS, 2001, Popham		1.15	0.00546	0.0393	P
Blood, Adult, Male, SSTS, 2001, Popham		0.773	0.00754	0.0284	P
Blood, Adult, Male, SSTS, 2001, Popham		0.851	0.00525	0.0495	P
Blood, Adult, Male, SSTS, 2001, Ogunquit		0.625	0.00849	0.025	O
Blood, Adult, Male, SSTS, 2001, Ogunquit		0.762	0.007	0.0306	O
Blood, Adult, Male, SSTS, 2001, Ogunquit		0.865	0.00674	0.0158	O
Blood, Adult, Male, SSTS, 2001, Ogunquit		0.782	0.0155	0.0068	O
Blood, Adult, Male, SSTS, 2001, Ogunquit		0.68	0.0053	0.0483	O
Blood, Adult, Male, SSTS, 2001, Ogunquit		0.781	0.00704	0.0446	O
Blood, Adult, Male, SSTS, 2001, Ogunquit		0.813	0.00681	0.0456	O
Blood, Adult, Male, SSTS, 2001,		0.529	0.00542	0.0409	
Blood, Adult, Male, SSTS (Hy), 2001, Popham		0.599	0.00731	0.0302	P
Blood, Adult, Male, SSTS (Hy), 2001, Ogunquit		0.707	0.00595	0.0371	O
Blood, Adult, Male, Otter, 2001, Chain of Ponds - Lower		0.244	0.00434	0.0601	
Blood, Adult, Male, NSTS, 2001, York		0.414	0.00244	0.0525	Y
Blood, Adult, Male, NSTS, 2001, York		0.485	0.00406	0.026	Y
Blood, Adult, Male, NSTS, 2001, Weskeag		0.325	0.00219	0.059	W
Blood, Adult, Male, NSTS, 2001, Weskeag		0.282	0.00321	0.0332	W
Blood, Adult, Male, NSTS, 2001, Weskeag		0.296	0.00221	0.0409	W
Blood, Adult, Male, NSTS, 2001, Weskeag		0.323	0.00237	0.0381	W
Blood, Adult, Male, NSTS, 2001, Weskeag		0.267	0.00298	0.0299	W
Blood, Adult, Male, NSTS, 2001, Weskeag		0.373	0.00352	0.0517	W
Blood, Adult, Male, NSTS, 2001, Scarborough Marsh; LAB NOTE: slight clot		0.484	0.0036	0.0249	S
Blood, Adult, Male, NSTS, 2001, Scarborough Marsh; LAB NOTE: slight clot		0.203	0.00511	0.0134	S
Blood, Adult, Male, NSTS, 2001, Scarborough Marsh		0.431	0.00509	0.0351	S
Blood, Adult, Male, NSTS, 2001, Scarborough Marsh		0.31	0.00328	0.0272	S
Blood, Adult, Male, NSTS, 2001, Scarborough Marsh		0.419	0.00666	0.0268	S
Blood, Adult, Male, NSTS, 2001, Popham		0.599	0.00538	0.0335	P
Blood, Adult, Male, NSTS, 2001, Popham		0.494	0.00516	0.0346	P
Blood, Adult, Male, NSTS, 2001, Popham		0.553	0.00454	0.0397	P
Blood, Adult, Male, NSTS, 2001, Popham		0.546	0.0105	0.0065	P
Blood, Adult, Male, NSTS, 2001, Ogunquit		0.616	0.00795	0.0086	O
Blood, Adult, Male, NSTS, 2001, Ogunquit		0.527	0.0117	0.0058	O
Blood, Adult, Male, NSTS, 2001, Ogunquit		0.539	0.0204	0.0455	O
Blood, Adult, Female, SSTS, 2001, York		0.744	0.00462	0.0468	Y
Blood, Adult, Female, SSTS, 2001, Weskeag		0.569	0.00599	0.0522	W
Blood, Adult, Female, SSTS, 2001, Scarborough Marsh		0.446	0.00378	0.0289	S
Blood, Adult, Female, SSTS, 2001, Scarborough Marsh		0.806	0.0267	0.004	S

1.4

PERSISTENT ORGANIC POLLUTANTS IN SEALS

Final Report to the Surface Water Ambient Toxic Monitoring Program
State of Maine Department of Environmental Protection

An Investigation of Persistent Organic Pollutants (POPs) and Heavy Metals in Tissues of Harbor Seals and Gray Seals in the Gulf of Maine

Susan D. Shaw, Dr.P.H., Marine Environmental Research Institute (MERI)

Background

Levels of environmental contaminants have not been extensively investigated in Gulf of Maine seals despite the fact that they are at the top of the marine food web and are likely to be exposed to polluted habitats and prey in their range. PCBs, dioxins, and mercury (Hg) are prevalent in Maine's marine environment and are of concern because of their documented immune and endocrine-disrupting potential in seals, other marine wildlife, and humans (Shaw and De Guise, 2000; De Guise, Shaw *et al*, 2001). Over the past three decades, endocrine disrupting contaminants have been linked with deleterious impacts on the reproductive and immune systems of seals in the Baltic Sea, the North Sea, and other polluted waters.

This project was initiated in 2001 as part of a multiyear investigation of the impacts of environmental pollutants on the health of Gulf of Maine seal populations. Because the habitat of seals breeding in Maine extends southward past Long Island, NY, in order to ensure that our samples were representative we made an effort to obtain samples from seals throughout the range. A major goal of the first phase of the research is to generate baseline information about contaminant levels in seals and identify some of the factors (age, gender, geographic) influencing their contaminant burdens. The study also includes baseline measures of immune and endocrine function in live animals as possible biomarkers of health status that may be related to contaminant loads.

Sample Collection 2001-2002

From April – February 2001-2002, samples were collected from a total of 64 seals -- 51 harbor seals (*Phoca vitulina concolor*) and 13 gray seals (*Halichoerus grypus*)-- in 5 regions of the Gulf of Maine: mid-coast Maine, southern Maine, Massachussetts Bay, Nantucket/Long Island Sounds, and eastern Long Island (Figure 1). No samples were obtained from downeast Maine. Samples were collected from both freshly dead and live stranded seals (Table 1). Blubber, hair, liver, kidney, and skin samples were collected from dead stranded seals (n=51). Blood and hair samples were collected from live stranded seals (n=13) during rehabilitation. Detailed biometric information was obtained for each study animal. Gender was nearly equally distributed (32 males, 28 females, 4 unknown). Pups and juveniles outnumbered adults.

Tissue Analysis

In dead stranded seals, PCBs, coplanar PCBs, PCDD/Fs, and 22 organochlorine pesticides were quantified in blubber samples. Mercury and inorganics were measured in hair and liver samples. In live stranded seals, metals and inorganics were measured in hair samples. Blood samples were used in assays of immune function (lymphocyte proliferative responses to mitogens). Thyroid hormones, sex hormones, cortisol, and retinol (vitamin A) levels were measured in seal plasma samples. Although in general, sample quality was good, samples were lost in some cases due to sampling limitations and inconsistencies (for example, limited blood samples taken during live animal restraint); in addition, a small fraction of samples deteriorated during shipment and could not be analyzed.

Results and Discussion

The initial focus of the analysis was on exposure assessments, comparing mean levels of organochlorines and metals in stranded seals from different regions, and looking at factors (age, species, sex, condition) influencing contaminant burdens. More preliminary data are presented on *in vitro* lymphocyte proliferative responses to mitogens, thyroid hormones, reproductive hormones, cortisol, and retinol (vitamin A) levels in a small subset of live seals. Analysis of these data are in the early stages, and with larger sample sizes, they will be used in an overall assessment of health risks that may be associated with contaminant burdens in these seals.

Organochlorine Contaminant Levels in Dead Stranded Seals

The dead stranded animals were predominantly harbor seals (92.2%) with 4 gray seals (7.8%). The majority were yearlings (51%) and pups (22%), with 7 adults and 3 fetuses. Four seals were of unknown ages. Gender was equally distributed.

Blubber concentrations of total PCB (sum of 28 congeners) detected in the dead stranded seals (whole group, n=37) was relatively high (mean 25.2 ± 30.4, range 3-150 μg/g, lipid weight) (Table 2). Five animals including two yearlings and two pups had total PCB levels >50 ppm (lipid basis). To assess the potential toxicity of 4 non-*ortho* coplanar PCBs and eight mono-*ortho* semi-coplanar PCBs, their dioxin toxic equivalents (TEQs) were calculated for individual blubber samples. The total TEQ of seals in this study ranged from 14.8 to 391.6 pg/g (ppt). Comparing the total TEQs contributed by non-*ortho* and mono-*ortho* PCBs, the highly toxic non-*ortho* PCBs were predominant in these samples.

Of 22 OC pesticides analyzed in seal blubber (Table 3), six compounds were found at higher (ppm) levels (in descending order)– *p,p'*-DDE, *trans*-nonachlor, oxychlordane, *cis*-nonachlor, endosulfan sulfate, and *p,p'*-DDT. The pesticides heptachlor epoxide, *p,p'*-DDD, *?*-chlordane, *a*-BHC, mirex, and dieldrin were detected in seal blubber at lower (ppb) levels. Aldrin, *ß*-BHC, *d*-BHC, *?*-BHC, a-chlordane, endosulfan, endrin, endrin aldehyde, endrin ketone, heptachlor, hexachlorobenzene, methoxychlor, *o,p*-DDD, *o,p*-DDE, *o,p*-DDT, and were detected in seal blubber at trace levels.

Looking at regional distributions (Table 4), mean concentrations of total PCBs were higher in blubber of seals from southern Maine (mean PCB 34.6 μg/g, lipid weight) and levels of *p,p'*-DDE, *p,p'*-DDT, and *trans*-nonachlor were higher in seals from the mid-Maine coast, but the differences were not significant. Several compounds found at trace levels including a-

chlordane, *d*-BHC, endosulfan, endrin aldehyde, heptachlor, methoxychlor, *o,p*-DDD, *o,p*-DDE, and *o,p*-DDT were significantly higher in mid-coast Maine seals (p=.038). The reasons for the higher pesticide levels in mid-coast Maine seals are not clear, and may be an artifect of the relatively small number of seals in each regional group.

The influence of age, sex, species, and condition on contaminant burdens was examined. Only samples considered to be in good condition were included in the analysis. In general, higher levels of PCBs and OC pesticides were found in pups (mean 35.1 and 19.8 μg/g, lipid basis, for PCBs and *p,p*'-DDE) followed by yearlings, but the differences were not significant with the exception that a-BHC levels were significantly higher in pups (p=.045). No significant differences were found in OC contaminant loads with respect to gender or species.

Little data have been generated on contaminant levels in seals along the US Northeast coast since 1972 when the Marine Mammal Protection Act was passed, thus temporal and spatial trends are not clear. Comparisons with data from the early 1970s must be viewed with caution because sampling locations are not identical and analytical methods have changed substantially. The mean blubber concentrations of PCBs (25.2 μg/g, lipid weight [21.5 μg/g, wet weight]) and *p,p*'-DDE (9.9 μg/g, lipid weight [7.9 μg/g, wet weight]) found in this study were considerably lower than those found in Gulf of Maine harbor seals in 1972 (mean PCB 92.5 and *p,p*'-DDE 35-53 μg/g, wet weight) (Gaskin *et al*, 1973), suggesting a general decrease in PCB and *p,p*'-DDE levels in Gulf of Maine seals over a thirty-year period. However, the PCB levels found in this study are somewhat higher than levels found in Sable Island, Nova Scotia gray seals (15.7 μg/g, wet weight) (Addison *et.al*., 1984) in the mid-1980s.

A more recent study (Lake *et. al.* 1995) analyzed contaminant levels in blubber of 6 stranded dead harbor seals from Cape Cod sampled in 1980 and 9 stranded (live and dead) harbor seals from Long Island, NY, sampled in 1990-92 and found that OC levels had decreased in harbor seals over the period. However, the mean blubber concentrations of PCBs reported in both the 1980 Cape Cod samples (12 μg/g, wet weight) and the 1990-92 Long Island samples (6.7 μg/g, wet weight) were lower than the levels found in this study. Levels of *p,p*'-DDE found in this study were slightly lower than those reported for the 1980 samples (10.9 μg/g, wet weight) but almost two-fold higher than the *p,p*'-DDE levels reported for harbor seals sampled off Long Island in 1990-92 (4.1 μg/g, wet weight). Levels of hexachlorobenzene, trans-nonachlor, and mirex were also higher in seal blubber in this study compared with levels reported in the 1990-92 samples. Although limited by the small sample sizes per region, regional comparisons in this study showed that seals from southern Maine had the highest blubber PCB concentrations and seals from the mid-Maine coast had the highest levels of *p,p*'-DDE, *p,p*'-DDT, and *trans*-nonachlor, suggesting that levels of persistent organochlorines may not be decreasing in seals uniformly across the region. This also underlines the need for more research to clarify temporal and spatial trends in contaminant burdens of Gulf of Maine seals.

Metals and Trace Elements in Stranded Seals

The metals of greatest toxicological concern in seals are mercury (Hg), cadmium (Cd), and lead (Pb) (reviewed by Papa and Becker, 1998). There is little reported information about the levels or toxicological significance of metals other than mercury (arsenic, cadmium, chromium, lead, and silver) and trace elements (selenium, copper, and zinc) in seals from the Gulf of Maine. Until this study, levels of trace elements and toxic metals other than Hg have not been reported in seals along the US Northeast coast.

Mercury

Generally, metals and trace elements in hair of these seals were found at concentrations of minor concern with the exception of Hg. Hg is a known neurotoxin, causing damage to the cerebellum (area of the brain that controls balance) and occipital cortex area (area that controls vision). In seals, low dose Hg exposure causes appetite reduction and weight loss, while high doses result in death from renal failure.

Hair is considered a conservative estimate of the Hg burden in seals, with levels in liver being much higher, and increasing with age. Hepatic concentrations of Hg in the dead stranded seals (n=38) were more than three-fold higher than hair levels (mean 14.5, range 0.2-113.6) (Table 5). Hg levels found in hair of the live seals (mean 2.8, range 0.4-10.2 µg/g dry weight) were similar to the levels found in hair samples of live stranded harbor seal pups from southern Maine (Harris, 1999). Hg levels in hair of the dead stranded seals (predominantly yearlings and pups) were slightly higher (mean 3.7, range 0.7-23 µg/g dry weight), some animals having Hg levels >10 ppm. The Hg levels in hair for both groups (live and dead) are higher than those previously reported in harbor seals from eastern Canada (Sargent and Armstrong, 1973).

Hg levels in hair directly reflect levels in blood during the period of hair growth, thus hair samples taken from pups reflect their blood Hg levels during fetal and neonatal development. Hg passes freely through the placenta and through milk during lactation, and the clearance of ingested Hg is relatively rapid for most mammals. Thus, the Hg level in hair of seal pups reflects the mother's exposure to Hg during late pregnancy and lactation, and the level of Hg in food (fish) if the pup has has begun to feed independently. The threshold level for toxic effects of Hg in young seals is unknown. In humans, maternal hair Hg levels above 10 ppm are associated with neurobehavioral dysfunction in children (Grandjean *et.al*., 1994). In laboratory animals (mice), exposure to low-level Hg contamination has resulted in subtle behavioral changes. Since the seals in this study are predominantly pups and yearlings, maternal transfer of Hg is of concern.

Comparing regional distributions of total Hg, body burdens in hair of the live and dead stranded seals did not vary significantly (Table 6). In the live seals, Hg levels were higher in mid-Maine and Long Island East than in southern Maine, but the differences were not significant. Liver Hg levels in the dead stranded seals were much higher in seals from mid-coast Maine (mean 28.7, range 0.3-113.6 µg/g wet weight) and Long Island Sound (mean 27, range 0.4-104 µg/g dry weight) than in seals from southern Maine and Long Island East, but these differences were not significant. Looking at age differences, liver Hg levels were significantly higher in adults compared with levels in the fetus ($p=.004$). No significant differences were found in Hg burdens with respect to gender or species.

In this study, some of the adult seals showed total hepatic Hg concentrations (mean 93.1 µg/g wet weight, range 51-133.6) that exceed the threshold levels of 60 mg/kg for liver damage in mammals (AMAP, 1998). However, high Hg is known to be common in livers of marine mammals, and in most cases is not associated with any pathology as marine mammals have apparently evolved biochemical mechanisms involving selenium to detoxify and store Hg. Levels as high as 751 ppm (wet weight) have been reported in Wadden Sea harbor seals (Reijnders, 1980) and 1097 ppm (wet weight) in UK gray seals (Simmonds *et.al*, 1993). It is proposed that the tolerance of marine mammals to high Hg exposure involves distribution of Hg from sensitive organs to muscle and other tissue, formation of stable Hg-selenium complexes, conversion of toxic (methylated) Hg to less toxic forms (i.e., divalent), and prevention of oxidative damage (reviewed by O'Shea,

1999). Whereas Hg in fish muscle is mostly in the highly toxic methylated form, in marine mammals the proportion of methylated Hg in liver is low (5-15%), but high in muscle and epidermis. The inactive Hg-Se complexes are stored mainly in the liver and prevent harm to the animal. If selenium levels are inadequate, Hg may be bound to and detoxified by metallothioneins. There is evidence, however that the ability to de-toxify mercury may not be present in newborn and young seals. It is unclear to what extent this places young and developing seals at risk for Hg toxicoses.

Along the US Northeast coast, Lake *et.al.* (1995) reported lower hepatic Hg levels in a subset of Cape Cod harbor seals (n=4) sampled in 1980 (mean 38.5, range 31.6-49.3 μg/g wet weight) compared with levels in Long Island harbor seals (n=3) sampled in 1990-92 (mean 69.9, range 16-138 μg/g wet weight). The hepatic Hg levels found in adults seals in this study exceed levels reported for both the 1980 and 1990-92 groups, suggesting that Hg accumulation may be increasing in Gulf of Maine seals.

Other Metals and Trace Elements

Metals (other than Hg) and trace elements were measured in hair samples from both dead and live stranded seals (dead seals,n=37/live seals, n=12) (Table 7). There were few differences between the two groups. Levels of arsenic were slightly higher in dead stranded seals (p=.047), while the live seals had higher levels of selenium (p=.046), and zinc (p=.033). Levels of the toxic metals Cd, Pb, Ag, As, and Cr were found at relatively low concentrations in both groups.

Some regional differences were found in levels of chromium (Cr), selenium (Se), and zinc (Zn) in hair samples of dead stranded seals (Table 8). Most of these consisted of differences between levels in seals at both locations in Maine versus seals located further south. In mid-coast Maine seals, mean levels of Cr were significantly lower compared with seals from Mass Bay (p=.049) and Long Island East (p=.013). Cr levels in seals from southern Maine were also lower than levels in seals from Long Island East (p=.028). Se levels were higher in seals from southern Maine compared with seals from Mass Bay (p=.028). Zn levels were higher in seals from southern Maine than levels in seals from Long Island Sound (p=.033) and Long Island East (p=.003). No differences were found between levels of metals in seals from regions outside Maine with the exception that Zn levels were slightly higher in seals from Mass Bay versus Long Island East (p=.046).

In the dead stranded seals, levels of nickel (Ni) were significantly higher in pups (p=.014) and yearlings (p=.001) compared with levels in the fetus. Cadmium (Cd) levels were higher in yearlings (p=.05) and adult seals (p=.024) compared with levels in the fetus. No significant differences were found in body burdens of heavy metals or trace elements with respect to gender or species.

Because of the small number of samples obtained from live stranded seals, the utility of the data analysis by region is very limited. Samples were obtained only from southern and mid-coast Maine and Long Island East; other regions (downeast Maine, Massachusetts Bay, Long Island Sound) are not represented. However, some variability by region and age was evident, and the data suggest that live stranded seals along

southern and mid-coast Maine have body burdens of toxic metals comparable to or higher than levels in seals along the eastern shore of Long Island, NY.

Table 9 shows that seals from southern Maine had higher As levels compared with seals from Long Island East ($p=.033$), the latter group having higher levels than those in seals from the mid-Maine coast ($p<.0001$). Seals from southern Maine also had higher Cd levels compared with seals from Long Island East ($p=.038$). Seals from southern Maine had higher Cr levels than seals in other regions, but the differences were not significant. Higher Pb levels were found in hair of seals from Long Island East compared with in seals in southern Maine ($p=.045$). Zn levels were higher in seals from the mid-Maine coast, but the differences were not significant.

In the live seals, no differences were found with respect to species and gender. Significantly higher levels of silver (Ag) were found in pups versus yearlings ($p=.031$). Compared with pups, yearlings had much higher levels of Se in hair, but the differences were not significant.

Markers of Immune Function in Live Stranded Seals

Immune function was examined in a small subset of live animals ($n=6$) comprised entirely of gray seal pups. The assay measures the proliferative response of seal lymphocytes to stimulation by 3 mitogens *in vitro* by quantifying the uptake by blast cells of bromodeoxyuridine (BrDU), a non-radioactive analogue of tritiated thymidine. Results are given as the Stimulation Index (SI), a qualitative measure reflecting the ratio of stimulated to unstimulated cells in culture (Table 10). The preliminary data show that seal lymphocytes responded well to the T cell mitogens Concanavalin A (Con A) and phytohemmaglutinin (PHA) and the B cell mitogen lipopolysaccharide (LPS) at optimal mitogen concentrations.

Looking at the SI for each mitogen, the order of responses was Con A > LPS > PHA in these seals, which agrees with previous studies of mitogen responses in seals. Mitogen responses were not significantly different by region or sex, but this likely reflects the small sample size measured to date. The lymphocyte mitogenic response assay is a promising and important tool available for application in mammalian toxicology studies. It yields unique information about overall health status and nonspecific immune resilience of individuals against pathogenic infections and parasite infestations which in some cases have caused population-level impacts. We plan to apply this assay to a much larger sample size in 2002-2003 comprising all age classes and regions to develop the assay as a marker of health that may be associated with contaminant burdens and associated risks in the populations.

Markers of Endocrine Function in Live Stranded Seals

Thyroid hormones, retinol (vitamin A), estradiol, and cortisol levels were measured in plasma samples from 9 live stranded seals comprising 7 gray seal pups and 2 harbor seal yearlings. Looking at mean concentrations for the whole group (Table 11), triiodothyronine (T3) and retinol (vitamin A) levels appear to be relatively low, while cortisol and free T3 levels are relatively high compared with ranges reported for grey seal pups and harbor seal yearlings in the literature. Comparative data for estradiol levels in young seals was not available. Thyroid hormones and retinol are important for development (somatic and brain) and immune resilience in young animals, and thus the low levels of T3, the metabolically active form of thyroid, and retinol (vitamin A) found in these seals are of concern. High

cortisol levels in plasma could reflect the stress of capture and restraint while sampling the animals.

Looking at mean levels of hormones in seals by region (Table 12), estradiol levels are three-fold higher in seals from Long Island East (mean 23.1 pg/ml) compared with seals in Maine (8.1 pg/ml) ($p=.001$), which could reflect gender differences between regions (2 females, 3 males in NY vs 3 females, 1 male in ME). Vitamin A levels were extremely low in the Long Island seals (mean 4.2 ng/ml), significantly lower compared with levels in Maine seals (mean 90 ng/ml) ($p<.001$). Baseline data on normal ranges of vitamin A in young seals are not available, but the normal range of vitamin A in most young mammals is about 100-300 ng/ml. Alterations of hormones and retinol are established markers of exposure to endocrine-disrupting contaminants (*e.g.*, PCBs, DDE, other pesticides) in seals and other wildlife. We plan to expand the sample size in 2002-2003 in order to examine endocrine function in relation to contaminant loads in these seals.

Summary

While preliminary, these data are the first extensive data reported on organochlorine contaminants and metals in Gulf of Maine seals in 25 years. With the exception of one study involving a small number of harbor seals from Cape Cod and Long Island, the data mainly derive from studies of seals from eastern Canada in the early 1970s. Results of the present study indicate that Gulf of Maine seals may accumulate relatively high body burdens of organochlorines and metals through the marine food chain, in some cases levels that place them at risk for health effects

Because seals are long-lived (30-50 years) and feed at high trophic levels (mainly consuming fish), they have the potential for relatively high contaminant concentrations in their tissues and are excellent indicators of bioaccumulation. While gray seals are more pelagic (as adults), harbor seals are sedentary animals that feed, reproduce, and rest near or on shore. They occur primarily in coastal waters within 20 km of shore, often aggregate in estuaries and protected waters, and are thought to have strong affinity to specific haulout sites.

It is notable that PCB levels detected in seals (predominantly harbor seals) throughout the Gulf of Maine are comparable to or higher than the known threshold level for adverse immune, reproductive, and endocrine effects documented in captive feeding studies on harbor seals (~17-25 ppm) (De Swart *et.al.*, 1994; Reijnders, 1986; Brouwer *et.al*., 1989), and an order of magnitude higher than levels associated with reduced immune responses and endocrine alterations in 4-week old Pacific harbor seal pups (~3 ppm) (Shaw, 1998). Seal pups in this study had much higher levels of PCBs and OC pesticides (mean 35.1 and 19.8 µg/g, lipid basis, for PCBs and *p,p'*-DDE) compared with other age groups, reflecting the importance of maternal transfer of lipophilic OCs to the OC burden of the young seal. These levels are of concern given the declining pupping rates observed among harbor seals in southern and mid-coast Maine (Gilbert and Guldager, 1998).

While limited by the relatively small number of seals sampled from each region, regional comparisons suggest that seals that breed and pup along southern and mid-coast Maine have body burdens of PCBs, OC pesticides, and mercury comparable to or higher than levels in

seals in polluted industrial areas along the Northeast coast. In this study, some of the adult seals showed total hepatic Hg concentrations that exceed the threshold levels of 60 mg/kg for liver damage in mammals (AMAP, 1998). High Hg is known to be common in livers of marine mammals, as they have evolved biochemical mechanisms involving selenium to detoxify (demethylate) and store Hg in less toxic (divalent) forms. However, the ability to detoxify Hg may not be present in newborn and young seals following exposure to the mother's burden *in utero* and in milk, thus young and developing seals may be at risk for Hg toxicoses. Since the seals in this study are predominantly pups and yearlings, maternal transfer of Hg is of concern.

These findings underline the need for additional research on contaminant levels and associated health risks in Gulf of Maine seals. Clearly, additional data are needed to provide a basis for assessing long-term health risks posed by toxic pollutants to these populations.

To date, this study has shown that that seals are appropriate indicators of contaminants that bioaccumulate in the marine environment and with effort, a large number of tissue samples can be obtained for analysis. We are confident that the relationships, protocols, and training developed during the first year will facilitate the collection of analyzeable tissue samples in 2002-2003. The study objectives in 2002-2003 are to enlarge the sample size in order to be representative of all regions in Maine (including downeast Maine) to improve data on age, sex, and condition of the animals, to compare contaminant levels in stranded and wild seals, and to examine relationships between contaminant loads and immune and endocrine markers. The results of this research will provide useful information for sound ecological risk assessment and future monitoring of the the populations.

Acknowledgments

Special thanks to Dana Hartley, Northeast Region Stranding Network Coordinator, Woods Hole, MA, for providing critical information on Gulf of Maine seals, and to Northeast Region Stranding Network personnel including Kirk Trabant; Marine Environmental Research Institute (MERI), Blue Hill ME; Rosemary Seton and Sean Todd, Allied Whale, College of the Atlantic, Bar Harbor, ME; Kim Durham and Rob DiGiovanni, Riverhead Foundation, NY; Katie Touey and Kristin Patchett, Cape Cod Stranding Network, Buzzards Bay, MA; Greg Jakush, Marine Animal Lifeline, Biddeford, ME, and Belinda Rubenstein, New England Aquarium, Boston, MA, for the intensive collection of seal tissues in 2001-2002.

Thanks to my collaborators Diane Brenner and Greg Early, Marine Environmental Research Institute (MERI), Christopher R. Perkins, Ph.D., Environmental Research Institute (ERI), U. of Connecticut; Sylvain De Guise, D.M.V., Ph.D., U. of Connecticut, Dept. of Pathobiology; Peter A. Graham, BVMS, Ph.D., Cert.V.R., M.R.C.V.S., and Thomas H. Herdt, D.V.M., Ph.D., Animal Health Diagnostic Laboratory, Michigan State U. College of Veterinary Medicine; and Stephen V. Lamb, D.V.M., Ph.D., Endocrinology, NYS College of Veterinary Medicine, Cornell University.

References Cited

Addison, R.F., Brodie, P.F., and Zinck, M.E. (1984b). DDT has declined more than PCBs in eastern Canadian seals during the 1970s. *Environ. Sci. Technol.* 18(12):935-937.

AMAP (1998). AMAP Assessment Report: Arctic Pollution Issues. Chapter 7: Heavy metals. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway.

Brouwer, A., Reijnders, P.J.H., and Koeman, J.H. (1989). Polychlorinated biphenyl (PCB)-contaminated fish induces vitamin A and thyroid hormone deficiency in the common seal (*Phoca vitulina*). *Aquat. Toxicol.* 15:99-106.

De Swart. R.L., Ross, P.S., Vedder, L.J., Timmerman, H.H., Heisterkamp, S.H., Van Loveren, H., Vos, J.G., Reijnders, P.J.H., and Osterhaus, A. D.M.E. (1994). Impairment of immune function in harbor seals *(Phoca vitulina*) feeding on fish from polluted waters. *Ambio* 23(2):155-159

De Guise, S., Shaw, S.D., *et. al*. (2001). Atlantic Coast Contaminants Workshop 2000: Consensus Statement of 22 Wildlife and Human Health Experts. *Environ. Health Persp*. December, 2001.

Gaskin, D.E., Frank, R., Holdrinet, M., Ishida, K., Walton, C.J., and Smith, M. (1973). Mercury, DDT and PCB in harbour seals *(Phoca vitulina*) from the Bay of Fundy and Gulf of Maine. *J. Fish. Res. Bd. Can*. 30(1):471-475.

Gilbert, J.R. and Guldager, N. (1998). Status of harbor and gray seal populations in northern New England. *Report to National Marine Fisheries Service*, Northeast Fisheries Science Center. Contract No. 14-16-009-1557.

Grandjean, P., Jorgensen,P.J., Weihe, P. (1994). Human milk as a source of methylmercury exposure in infants. *Environ. Health Persp*. 102:74-77.

Harris, D.E. (1999). Mercury levels in the hair of harbor seal pups. Department of Environmental Protection, State of Maine, Surface Water Ambient Toxics Monitoring Program. Augusta, ME.

Lake, C.A., Lake, J.L., Haebler, R., McKinney, R., Boothman, W.S., and Sadove, S.S. (1995). Contaminant levels in harbor seals from the Northeastern United States. *Arch.Environ. Contam. Toxicol*. 29:128-134.

O'Shea, T.J. (1999). Environmental contaminants and marine mammals. In: Biology of Marine Mammals, Reynolds, III, J.E. and Rommel, S.A. (Eds.), Smithsonian Institution Press, Washington, D.C., 485-564.

Papa, R.S. and Becker, P.R. (1998). Alaska Harbor Seal Contaminants: A Review with Annotated Bibliography. US Dept. of Commerce, NIST Charleston Laboratory, 249 pp.

Reijnders, P.J.H. (1980). Organochlorine and heavy metal residues in harbour seals from the Wadden Sea and their possible effects on reproduction. *Neth. J. Sea Res*. 14(1):30-65.

Reijnders, P.J.H. (1986). Reproductive failure in common seals feeding on fish from polluted coastal waters. *Nature* 324:456-457.

Sargent, D.E. and Armstrong, F.A.J. (1973). Mercury in seals from eastern Canada. J.Fish.Res.Board Can. 30:843-846.

Shaw, S.D. (1998). *Organochlorines and Biomarkers of Immune and Endocrine Effects in Pacific Harbor Seal and Northern Elephant Seal Pups* (Doctoral Thesis). New York: Columbia University School of Public Health, 359 pp

Shaw, S.D. and De Guise, S. (eds). (2000). Endocrine Disruptors in the Marine Environment: Impacts on Marine Wildlife and Human Health. *Proceedings of the Atlantic Coast Contaminants Workshop 2000*, Scientific Report of the Marine Environmental Research Institute: 192 pp.

Shaw, S.D., Brenner, D., Perkins, C.R., Denison, M.S, and Waring, G.T. (2001). Spatial variation in concentrations of dioxin-like compounds and heavy metals in free-ranging US Atlantic coast harbor seals (*Phoca vitulina concolor).* Presentrd at Society of Marine Mammology (SMM), 14th Biennial Conference on the Biology of Marine Mammals, 28 November – 3 December, Vancouver, BC.

Shaw, S.D., Brenner, D., Perkins, C.R., Denison, M.S, and Waring, G.T. (2002). Body burdens of persistent organic pollutants and heavy metals in free-ranging US Atlantic coast harbor seals (*Phoca vitulina concolor*) (in preparation).

Simmonds, M.P., Johnston, P.A., and French, M.C. (1993). Organochlorine and mercury contamination in United Kingdom seals. *Vet. Rec*. 132:291-295.

APPENDIX: Tables

Table 1. Sampling efforts for Gulf of Maine harbor and gray seals 2001-2002

Location	No. Sampled	Dead	Alive
Mid-coast Maine	11	9	2
Southern Maine	9	7	2
Mass Bay	18	18	-
Nantucket/Long I. Sound	8	8	-
E. Long I. Coast	18	9	9
All Regions	64	51	13

Table 2. Mean Concentrations of PCBs (mg/g lipid basis) and TCDD TEQ (pg/g) of Dioxin-Like PCBs in Dead Stranded Seals (whole group, n=37)

Total PCB_{soc} (ppm)	TEQ Non-*ortho* (ppt)	TEQ Mono-*ortho* (ppt)	Total TEQ (ppt)
25. 2 ± 30.4 3-150.1	60.5.± 73.6 11.5-377.2	27.8.± 32.7 3.2-146.5	88.3 ± 81.5 14.8-391.6

Table 3. Mean Concentrations of OC Pesticides (ng/g, lipid weight) in Blubber of Dead Stranded Seals (n=37)

p,p'-DDE	*Trans*-nonachlor	Oxychlordane	*Cis*-nonachlor	Endosulfan sulfate	*p,p'*-DDT
9920.2 ± 11260.1 392.8-50386	1780.5 ± 2291.3 188.3-10074.1	1133.7 ± 1241 2.8-5715.4	1036.7 ± 1698.5 1.2-6721.2	613.1 ± 1139.3 1-5248.9	602.4 ± 1292.2 1-5628.2

Heptachlor epoxide	*p,p'*-DDD	?-chlordane	a-BHC	Mirex	Dieldrin
164.5 ± 311.5 1.8-1518.3	119.2 ± 173.7 2.6-998.2	89.6 ± 526.4 1-3205.2	85.6 ± 73.7 3.7-372	56.1 ± 241.6 1-1358.5	43 ± 185.6 1.2-1064.2

Table 4. Regional Distribution of OCs (mg/g, lipid weight) in Dead Stranded Seals

Region	So Maine (n=5)	Mid Maine (n=5)	Mass Bay (n=16)	Nan/LI Sd (n=4)	LI East (n=7)
Total PCB	34.6. ± 42 3-107.5	24.8 ± 23.4 4.1-64.4	23.8 ± 37.9 4.4-150.1	31.5 ± 16.7 11.7-51.2	18.5 ± 10.7 8-37.3
p,p'-DDE	12.2 ± 10.9 2.2-30.4	13.8 ± 18.7 1.2-46.8	12.2 ± 10.9 2.2-30.4	9.6 ± 9.4 2.2-23.2	8.9 ± 4.6 4.3-17.0
p,p'-DDT	1.2 ± 1.1 .003-3.1	1.4 ± 2.4 0.003-5.6	1.2 ± 1.2 0.003-3.1	0.1 ± 0.2 0.002-0.4	0.003 ± 0.001 0.001-0.003
Cis-nonachlor	0.4 ± 0.6 0.003-1.5	1.3 ± 2.8 0.003-6.3	0.4 ± 0.6 0.003-1.5	1.6 ± 1.5 0.004-3.3	1.1 ± 1.1 0.002-2..5
Endosulfan sulfate	0.2 ± 0.4 0.003-0.8	0.7 ± 1.3 0.003-3.1	0.2 ± 0.4 0.003-0.8	1.2 ± 1.5 0.002-3.0	0.9 ± 0.8 0.003-1.9
Oxychlordane	1.4 ± 1.2 0.2-3.4	1.4 ± 1.9 0.01-4.7	1.4 ± 1.2 0.2-3.4	1.3 ± 0.6 0.5-1.8	1.1 ± 0.6 0.5-2.0
Trans-nonachlor	1.7 ± 1.4 0.3-3.8	2.4 ± 3.4 0.2-8.4	1.7 ± 1.4 0.3-3.8	1.8 ± 1.8 0.3-4.4	1.4 ± 0.7 0.6-2.6

Table 5. Mean Levels of Total Mercury in Hair (mg/g, dry weight) and in Liver

(mg/g, wet weight) of Stranded Seals

Hg	Hair	Liver
Live Seals Mean ± SD Range n	2.8 ± 3.1 0.4-10.2 (12)	-
Dead Seals Mean ± SD Range n	3.7 ± 4 0.7-23 (37)	14.5 ± 32.4 0.2-113.6 (38)

Table 6. Regional Distribution of Total Mercury in Hair (mg/g, dry weight) and in Liver

(mg/g, wet weight) of Stranded Seals

Region	So Maine	Mid Maine	Mass Bay	Nan/LI Sd	LI East

Live Seals (Hair) (µg/g dry weight	0.6 ± 0.03 0.5-0.6 (2)	2 ± 1.6 0.9-3.1 (2)	-	-	2.2 ± 2 0.7-5.6 (5)
Dead Seals (Hair) (µg/g dry weight	4.4. ± 3.8 1.7-12 (6)	2.4 ± 1.3 0.7-4.9 (8)	4.6 ± 5.7 1-23 (13)	4.1 ± 3.5 0.8-10 (5)	2 ± 0.9 1.5-2.9 (5)
Dead Seals (Liver) (µg/g wet weight	1 ± 0.8 0.4-2.6 (7)	28.7 ± 56.6 0.3-113.6 (5)	17.5 ± 35.3 0.2-102.8 (15)	27 ± 51.3 0.4-104 (5)	8 ± 10.2 1-28.7 (7)

Table 7. Mean Levels of Other Metals and Trace Elements in Hair (mg/g, dry weight) of Stranded Seals

Metal	Dead	Live
Silver (Ag)	0.3 ± 0.6 0.08-2.7 (36)	0.1 ± 0.02 0.08-0.1 (9)
Arsenic (As)	1.7 ± 1.6 1.8-2.3 (37)	0.7 ± 0.7 0.1-2.3 (12)
Cadmium (Cd)	0.4 ± 0.3 0.04-1.4 (37)	0.3 ± 0.3 0.05-1 (12)
Chromium (Cr)	3.4 ± 0.4 2.6-4.5 (37)	3.6 ± 1.1 2.9-2.9 (12)
Copper (Cu)	7.4 ± 6.8 2.2 -46.5 (37)	6.1 ± 5.3 3-20.1 (9)
Nickel (Ni)	1.3 ± 1 0.1-6.2 (37)	1 ± 0.7 0.1-2.1 (9)
Lead (Pb)	1.3 ± 1.5 0.3-7.5 (37)	0.7 ± 0.7 0.2-2.1 (12)
Selenium (Se)	3.3 ± 1.3 1.5-6.5 (37)	7.4 ± 6.3 2.7-24.6 (12)
Zinc (Zn)	115.3 ± 48.2 42.9-250.7 (37)	160.5 ± 79.3 66.1-322.1 (9)

Table 8. Regional Distribution of Other Metals and Trace Elements in Hair (mg/g, dry weight) of Dead Stranded Seals

Region/ Metal	So Maine (n=6)	Mid Maine (n=8)	Mass Bay (n=13)	Nan/LI Sd (n=5)	LI East (n=5)
Silver (Ag)	ND	0.09 ± 0.02 0.07-0.1	0.3 ± 0.7 0.08-2.7	0.4 ± 0.8 0.08-1.9	0.7 ± 1.1 0.1-2.4
Arsenic (As)	1.6 ± 1.8 0.5-5.2	1.6 ± 1.4 0.2-3.9	2.1 ± 2.1 0.8-8	2 ± 1.1 0.5-3.3	0.8 ± 0.3 0.6-1.2
Cadmium (Cd)	0.4 ± 0.3 0.1-0.8	0.3 ± 0.2 0.04-0.6	0.3 ± 0.2 0.04-0.7	0.3 ± 0.07 0.2-0.4	0.7 ± 0.5 0.2-1.4
Chromium (Cr)	3.2 ± 0.4 2.7-3.6	3.2 ± 0.4 2.6-3.7	3.4 ± 0.2 3.1-3.7	3.6 ± 0.6 3.1-4.5	3.8 ± 0.3 3.5-4.1
Copper (Cu)	5.7 ± 1.6 3.1-7.6	6 ± 1.8 4-8.5	6.4 ± 2.1 2.2-10.4	6.6 ± 1.6 4.3-8.4	14.6 ± 17.9 4.4-46.5
Nickel (Ni)	1 ± 0.3 0.6-1.5	1.5 ± 1.9 0.2-6.2	1.1 ± 0.7 0.1-2.4	1.6 ± 0.6 0.7-2.1	1.5 ± 0.5 1-2.2
Lead (Pb)	0.7 ± 0.6 0.3-1.9	0.9 ± 0.5 0.4-2.1	1.6 ± 2.2 0.3-7.5	2 ± 1.7 0.6-4.8	1.2 ± 0.8 0.6-2.5
Selenium (Se)	3.8 ± 0.6 3.3-4.8	4.2 ± 1.9 1.5-6.5	2.8 ± 0.9 1.5-4.8	2.8 ± 0.8 1.9-3.9	3 ± 1.1 1.9-4.7
Zinc (Zn)	135.1 ± 19.1 112.8-164.4	98.8 ± 46.6 63.7-209	132.2 ± 64.2 42.9-250.7	99.6 ± 27.7 61.9-122.7	90.1 ± 17.4 64.5-111.3

ND= not detected

Table 9. Regional Distribution of Other Metals and Trace Elements (mg/g dry weight) in Hair of Live Stranded Seals

Region/ Metal	So Maine (n=2)	Mid Maine (n=2)	LI East (n=5)
Silver (Ag)	.09 ± .005 0.08-0.09	ND	ND
Arsenic (As)	2.1 ± 0.4 1.8-2.3	0.2 ± 0.07 0.2-0.3	0.4 ± 0.3 0.1-0.8
Cadmium (Cd)	0.6 ± 0.6 0.2-1	0.09 ± 0.007 0.08-0.1	0.4 ± 0.3 0.05-0.7
Chromium (Cr)	3.9 ± 0.8 3.3-4.4	2.9 ± 0.006 2.9-2.9	3.5 ± 1.2 2.6-5.6
Copper (Cu)	3.6 ± 0.9 3-4.3	4.5 ± 0.3 4.3-4.7	7.8 ± 7 3.1-20.1
Nickel (Ni)	1.1 ± 1 0.4-1.8	0.3 ± 0.04 0.3-0.3	1.2 ± 0.7 0.1-2.1
Lead (Pb)	0.6 ± 0.2 0.5-0.8	0.2 ± 0.01 0.2-0.2	1.2 ± 0.7 0.1-2.1
Selenium (Se)	2.9 ± 0.3 2.7-3.2	6.1 ± 0.9 5.4-6.7	5.2 ± 1.6 3-7.2
Zinc (Zn)	167.3 ± 79 111.5-223.2	238.4 ± 118.3 154.7-322.1	126.5 ± 54.8 66.1-185

ND= not detected

Table 10. Lymphocyte Proliferative Responses to Mitogens (SI) in Seal Blood

Mitogen	Con A	PHA	LPS
Mean ± SD Range n	6.7 ± 1.9 4.2-8.7 (6)	1.9 ± 0.6 1.1-2.6 (6)	3 ± 1.1 1.3-4.6 (6)

Table 11. Mean Levels of Hormones and Retinol (Vitamin A) Levels in Seal Plasma

Hormone	TT4 (µg/dl)	TT3 (ng/dl)	FT4 (ng/dl)	FT3 (pg/ml)	Vitamin A (ng/ml)
Mean ± SD Range n	1.3 ± 0.7 0-28 (9)	36.9 ± 36.8 13-130.2 (9)	2.9 ± 1.4 0.2-4.7 (9)	3.5 ± 1.2 1-4.7 (9)	42.3 ± 48.5 1.5-124 (9)

Hormone	Estradiol (µg/dl))	Cortisol (µg/dl)
Mean ± SD Range n	0.8 ± 0.7 0.3-2.4 (9)	12.9 ± 9.2 6.6-36.6 (9)

Table 12. Mean Levels of Hormones and Retinol in Seal Plasma by Region

Region/ Hormone	Maine * (n=4)	Long I East (n=5)
TT4 (µg/dl)	1.5 ± 1 0-2.2	1.8 ± 0.3 0.8-1.5
TT3 (ng/dl)	57 ± .50.8 13-139.2	20.8 ± 7.1 13-26
FT4 (ng/dl)	2.7± 2 0.2-5	3 ± 1 1.9-4.7
FT3 (pg/ml)	2.7 ± 1.4 1-4.5	4.2 ± 0.5 3.4-4.7
Cortisol (µg/dl)	16.6 ± 13.8 6.6-36.6	9.9 ± 1.4 8.2-11.8
Estradiol (pg/ml)	8.1 ± 2.7 4.4-10.4	23.1 ± 4.7 18.8-30.8
Vitamin A (ng/ml)	90 ± 28.7 56-124	4.2 ± 3.2 1.5-8.7

*Southern and Mid-Maine combined

1.5

MERCURY IN SEALS AND THEIR PREY

MERCURY BIOACCUMULATION AND TOXICITY IN GULF OF MAINE HARBOR SEALS AND THEIR PREY FISH

Dianne Kopec
University of Maine
Biological Sciences dkopec@maine.edu; tel.581-2574

Summary

Considerable progress has been made on the research objectives of our study of mercury bioaccumulation and the trophic transfer of mercury from prey fish to harbor seals in the Gulf of Maine.

Harbor seal haulout site observations of the roughly 700 – 900 seals frequenting Mt. Desert Rock (MDR) documented the site's primary use by adult male harbor seals during the summer 2001 field season Approximately 300 scat samples were collected from known haulout areas for seal prey analysis and selected scat samples were further processed for fecal mercury and hormone metabolite determination.

In the roughly 50 scat samples processed to date, 80% contained identifiable prey hard parts representing 13 separate species of prey fish. Redfish (*Sebastes capensis*), Atlantic herring (*Clupea harengus*), and silver hake (*Merluccius bilinearis*) comprised over 90% of the individual fish consumed. Meal sizes were highly variable and were greatest when redfish were eaten as part of the meal. In addition to otoliths and eye lenses, vertebrae and other prey remains were recovered for future reference.

Initial collections of prey fish from the general populations in the vicinity of Mt. Desert Rock were made from the Department of Marine Resources Fall Trawl Survey in October 2001. Representative samples of six species of fish were collected from each of three depth contours from nearshore to the deep waters adjacent to Mt. Desert Rock. Five species were adequately sampled in one to two depth contours and partial collections of 13 additional fish species and two squid species were completed. An otolith and squid beak reference collection was created from all 26 species sampled for species identification and size estimates from prey hard parts recovered from seal scat.

Preliminary mercury residue analyses refined the acid digestion and analytical methods and documented the expected range in mercury residues for several sample types. Trials of fecal hormone metabolite methods are scheduled for early summer.

METHODS

Seal Counts and Observations

All work was done at Mt. Desert Rock, a three acre granite ledge located approximately 20 miles south of Mt. Desert Island in the central Gulf of Maine. The island is owned by the College of the Atlantic and operated as a marine research station.

Harbor seal counts and observations were used to classify the age structure and sex of haulout groups prior to scat collection. Fifteen haulout areas on the shoreline of the main island were divided into quadrants subject to similar surf conditions depending on surface wind and swell conditions.

The northwest (NW) quadrant, a series of strongly sloping granite ledges, was used primarily when falling tides exposed flat, kelp ledges. Seals had great difficulty hauling there at higher tides or in strong surf. This area also was subject to the highest level of disturbance from human activity around the house and lighthouse tower.

The northeast (NE) quadrant consistently had the highest concentration of seal activity on the island. The gently sloping ledges were accessible at most tides, surf conditions were generally more moderate, and a central ledge provided haulout space even at high spring tides. Random human disturbance was less frequent, although activity on the boathouse ramp flushed seals hauling on the adjacent ledges. At low tide, grey seals occasionally hauled on the seaward tips of small peninsulas jutting to the north.

The southeast (SE) quadrant was primarily a low tide haulout site having deeply furrowed intertidal kelp ledges and pools and a sharply sloping shoreline to the south. Swells from the south creating high surf often limited use to the extreme eastern portion of this quadrant. Unintentional human disturbance was rare.

The southwest (SW) quadrant, used primarily at low tide, was occupied less frequently than other areas. Its kelp covered intertidal ledges were often subject to high surf, even at low tide, and the sharp slope of the upper ledges limited access at high tide. Unintentional human disturbance was not observed at this site.

Natural features that usually created visual barriers between adjacent areas separated the two to five haulout areas within each quadrant. These visual barriers were used to advantage during scat collections by limiting disturbance to those areas where scat was actually being collected.

Observations and counts were made from one of three sites on the island: the 80' lighthouse tower near the center of the island; a wooden platform straddling the ridgeline of the boathouse roof; or a granite ledge that overlooked the SW quadrant.

Following an ebb tide scan of hauled seals from the lighthouse tower, one to four haulout groups were chosen for age and sex determination and subsequent scat collections. This decision was based on the recent disturbance history for scat collection, the time of day and so the angle of the sun from the nearest observation point, and the seals' state of alertness, which significantly effected sex determinations. Counts were made using a 15 – 45 X zoom spotting scope. Detailed counts were not made of seals hauling on the intertidal ledges to the east of the island due to distance from the nearest observation point and the large concentration of grey seals hauling on the ledges, precluding exclusive harbor seal scat collections.

Scat and Fur Collections

On a flood tide, following age and sex determination, selected haulout areas were flushed for scat collections. Haulout areas were systematically searched from the tide line to the upper reaches used by the seals. Scat was not collected from areas where any grey seals were observed hauling. Collection methods varied with the consistency of the sample, using either an inverted Ziploc plastic bag or an acid-washed plastic scoop. Collected samples were placed in an insulated cooler and the haulout area vacated as quickly as possible to minimize disturbance time.

Scat was processed immediately after collection. Fresh scat samples deposited during the most recent tide cycle were selected for additional hormone and mercury

analyses. Subsamples were a composite of the gross sample, combining 4 – 6 randomly collected scoops of fecal material, free of undigested prey parts, in clean, acid-washed storage vials. The vials were frozen on dry ice while awaiting transport to a –20^{o}C storage freezer. Gross scat samples were kept cool in sealed Ziploc plastic bags and frozen at –20^{o}C following transport to shore.

Preliminary mercury analyses of small fecal samples collected sequentially along the length of a firm scat confirmed the potential for significant variability in mercury residue levels. To ensure that fecal subsamples accurately represented mercury concentrations in the entire sample, additional fecal subsamples were collected in the lab prior to sieving. Previously subsampled scat samples weighing greater than 60g were diluted 30% by weight with a known amount of deionized water, thoroughly remixed, and re-sampled. Fecal samples for mercury analyses were freeze-dried to a constant weight to guarantee uniform mixing and dryness.

Prey hard parts were flushed from gross scat samples using nested sieves with mesh sizes ranging from 0.5 mm to 3.0 mm and warm tap water. All otoliths and otolith fragments, squid beaks and eye lenses were collected for prey identification and / or mercury analyses. Additional prey hard parts were collected and archived for future reference. Adhered fecal material was removed from the otoliths and squid beaks in a sonicator with deionized water, and the cleaned otoliths were dried with filtered air and stored in glass vials at ambient temperature. Eye lenses were rinsed with deionized water, stored in glass vials and frozen prior to analysis.

Species identifications of recovered otoliths were made by comparison with known otoliths from the reference collection created for this project and, when relevant, published reference guides. Total length and height measurements were recorded for each otolith using electronic digital calipers accurate to 0.02 mm. Once measured and identified, otoliths from each scat sample were separated by species, size and degree of erosion into groups defined by length (1 mm categories) or by width (0.5 mm categories) if broken tips precluded accurate length measurements. Finally, the weight of all otoliths from each scat sample within an individual size grouping was recorded. Minimum estimates of prey number were made using the maximum number of left or right otoliths recovered for each species, and prey size was estimated using regressions relating otolith length (and degree of digestive erosion) to fish length for each species.

The diameter of recovered fish eye lenses was recorded and used to separate lenses into 0.5 mm groups for weighing. Available methods do not allow species identification of fish eye lenses. Squid eye lenses were recognized by their unique half-moon shape, and measured and stored separately.

During the later half of the 2001 field season harbor seals underwent their annual molt at MDR. Seals hasten shedding by rolling and rubbing on the rough granite ledges at the haulout areas, packing shed fur into small crevasses in the rocks samples were it was easily collected. More complicated fur collection methods using Velcro strips and mats proved to be less effective.

Prey Fish Collections

Potential prey fish from the general vicinity of Mt. Desert Rock were collected during the Department of Marine Resources (DMR) Fall Trawl Survey. Trawls conducted on 18 and 19 October 2001 provided collections from three separate depth

contours. The trawls encompassed three areas: the shallow, nearshore waters of upper Frenchman's Bay, SSW of Sorrento (DMR tow sites 3A and 7); mid-depth trawls due south of the mouth of Frenchman's Bay, midway between Otter Point on Mt. Desert Island and Schoodic Pt. (DMR tow sites 54 and 94); and deepwater trawls three to six miles WSW of Mt. Desert Rock (DMR tow sites 483 and 501).

At each depth contour, up to 20 fish of each species, representing the range of size classes caught in the trawl, were collected, euthanized if necessary, then immediately bagged and chilled on crushed ice for transport to the lab for processing. At the lab, fish were weighed to 1.0 g, total and fork length was recorded to 1 cm and the fish were individually bagged in Ziplocs and frozen at -20^{o}C.

Subsequently, fish were partially thawed and dissected to remove otolith and eye lens pairs for identification, size relationships and mercury analyses. Removed otoliths were air-dried, measured and weighed and the resulting data used to create regressions of otolith length (height and weight) to total fish length. Eye lenses were also measured and pairs weighed prior to storage at -20^{o}C for mercury analysis. The remaining whole fish was homogenized with a food processor and / or a Tissue Tearer, depending on fish size, and frozen for mercury analyses.

Mercury Analyses

Preliminary mercury analyses were begun on seal fecal samples, scat otolith samples and whole trawl fish samples; analyses of otoliths from trawl fish and eye lenses from both scat and trawl fish remain pending. Acid digestion of samples were done using a CEM MARS-X microwave digestion system. Mercury residues were determined using a MERLIN cold vapor atomic fluorescence spectrometer. Standard calibration and reference procedures were followed.

RESULTS

Harbor Seal Counts and Scat Collections

During the 2001 summer field season 700 to 900 harbor seals hauled regularly on the main island at Mt. Desert Rock, with an additional 100 to 200 harbor and grey seals using the intertidal ledges immediately east of the island. On the island, the NE and SE quadrants were used consistently throughout the summer field season. The NW and SW quadrants were used infrequently by small numbers of seals after mid-July. The reason(s) for this shift in hauling patterns is not known, but surf conditions and unintentional human disturbance from activity near the residence and boathouse may have been factors.

Given this hauling pattern, most detailed observations were made on seals hauling on the more sheltered eastern side of the island. The percent of seals sexed varied between 10 and 50%; averaging 20% in a given haulout area. This number was lower than expected, and reflects the mid summer shift away from the NW and SW quadrants. No consistent pattern was found between the percent of seals sexed within a haulout group and the observed sex ratio ($r^2 = 0.09$)

Table 1 summarizes the sex and age class observations made prior to scat collections at MDR. The NW and SW quadrants had the highest percent of hauled

females, ranging from 12 - 45%. Reduced seal activity in these quadrants restricted the number of scat collected to 20 samples.

The NE quadrant had the highest seal counts, averaging 600 seals at low tide. Adult male harbor seals dominated this quadrant, where over 90% of the scat samples were collected. The SE quadrant was also dominated by males, but had the highest percentage (10 – 20 %) of subadult harbor seals. Despite persistent attempts, few scat samples were collected in this area.

During the late summer molt, over 30 fur samples were collected for mercury residue analysis.

Seal Prey Identification

Of the approximately 300 scat samples collected at MDR, 47 samples (15%) have been processed to date. The findings discussed below are preliminary until the remaining scat samples are processed. Over 80% (39) of the scat samples contained identifiable otoliths. Thirteen species of fish have been identified and four otoliths remain unidentified.

Redfish (*Sebastes capensis*) comprised 60% of the individual fish eaten (**Table 2**), followed by Atlantic herring (*Clupea harengus*) and silver hake (*Merluccius bilinearis*). A minimum average of 2.4 fish were eaten per meal, excluding meals containing redfish. When redfish were included in a meal, the average minimum meal size rose to 19 fish per meal.

Preliminary estimates of the prey size of silver hake were made using regressions of otolith length, or height, to total fish length. In the samples processed to date, seals ate silver hake ranging in size from 15 – 25 cm, approximately 1 to 2 year old fish.

Prey Fish Population Samples

Through the gracious cooperation of personnel from DMR's Fall Trawl Survey, potential harbor seal prey fish were collected for measurement and mercury analysis at up to three depth contours found between MDR and the mainland (**Table 3**). Representative samples of six fish species were collected at all three depth contours, and an additional five species were adequately sampled at 1 – 2 depth contours. In addition, partial collections of 13 fish species and two squid species were made.

Otoliths and eye lenses were removed from all trawl fish collected for measurement and subsequent mercury analyses. Silver hake, like other species analyzed, showed a strong correlation between fish total length and otolith length (r^2=0.98, df=48, P=0.000), otolith height (r^2=0.98, df=51, P=0.000) and otolith weight (r^2=0.89, df=53, P=0.000). Similar regressions for each species will be used to estimate prey fish length after compensation for otolith erosion during digestion.

Mercury Analyses

Fresh scat samples collected within one tide cycle of deposition (n = 154) were subsampled and freeze-dried in preparation for mercury residue analysis. Preliminary mercury analyses on a limited number of scat samples (n = 6) established the expected range of total mercury residues in seal fecal samples and confirmed potential residue variability within a single sample. Overall fecal total mercury residues in six separate scat samples collected from the NW and SW quadrants at MDR ranged from 50 ng Hg /g

feces (dry wt.) to 460 ng/g (dry wt.). Fecal mercury residues ranging from 250 ng/g to 450 ng/g were found in single firm scat subsampled at 1 cm intervals along its length. The limited number of samples analyzed to date precludes an evaluation of fecal mercury residues in relation to mercury residues in ingested fish.

Over 480 individual otoliths have been recovered and identified from the 47 scat samples processed to date. Otoliths from the same species and size class, when corrected for digestive erosion, will be analyzed separately for total mercury. Based on preliminary mercury analyses of mixed samples of otoliths collected previously, total mercury residues are expected to range from 2 – 90 ng Hg / g otolith (dry wt.).

Representative collections of 11 species of prey fish from fish populations sampled in the vicinity of MDR have been processed in preparation for total mercury residue analyses. The mercury analytical results will establish background mercury levels in the species and age class of prey fish consumed by harbor seals, and allow comparison with mercury levels in prey fish actually ingested by the seals. In addition, for six of those 11 species, regional comparisons will identify variation in whole fish mercury residue levels associated with distance from the mainland. Preliminary mercury analyses of one fish species, collected from the shallow depth contour, found total mercury residues ranging from 10 to > 50 ng Hg/g whole fish (wet wt.).

DISCUSSION

Significant progress has been made in assembling and processing the necessary biological samples required to evaluate the trophic transfer of mercury to harbor seals in the Gulf of Maine. Initial laboratory analyses have been successful and will remain the primary focus of research activities in the coming year.

Final field collections of scat and prey fish will be made this spring and summer with the goal of filling data gaps present in the current sample sets. Scat from mixed gender haulout areas and from areas frequented by subadults will allow comparisons of prey selection and prey mercury residue levels with that found in areas dominated by adult males. Additional prey fish collections are scheduled during DMRs Spring Trawl Survey in late April of 2002.

Mercury Concentrations in prey fish

SPECIES	DMR TOWSITE	DATE COLLECTED	SAMPLE ID #	TOTAL LENGTH (cm)	TOT Hg (ppb)	least squares means	
Atlantic herring	3/7	10/18/2001	1173	9	4.71		
			1153	11	7.42		
			1174	12	6.82		
			1171	13	8.01		
			1016	17	10.73		
			1013	18	12.34		
			1018	20	17.67	14.37	
	94/54	10/19/2001	1498	17	7.18		
			1516	18	19.43		
			1496	19	14.09		
			1501	20	11.35		
			1499	21	10.35		
			1507	22	11.79		
			1497	24	17.50		
			1495	25	15.37	12.23	
	482/501	10/19/2001	1320	19	24.33		
			1322	20	11.52		
			1305	21	13.66		
			1310	22	13.78		
			1317	23	8.46		
			1304	24	22.43		
			1311	25	19.90		
			1314	28	28.50	14.86	
Atlantic cod	3/7	10/18/2001	1069	12	11.62		
			1085	14	21.62		
			1062	15	13.19	15.48	
	94/54	10/19/2001	1451	15	9.90	9.77	
	482/501	10/19/2001	1398	12	14.21		
			1395	13	11.98		
			1397	14	13.67		
			1396	15	10.68	12.66	
alewife	94/54	10/19/2001	1447	13	32.01		
			1448	15	23.81		
			1444	16	17.03		
			1431	17	22.96		
			1433	18	16.01		
			1426	19	21.08		
			1425	20	24.52		
			1438	26	50.02	25.93	
	482/501	10/19/2001	1369	17	24.97		
			1367	18	19.77		
			1368	19	17.77	20.84	

SPECIES	DMR TOWSITE	DATE COLLECTED	SAMPLE ID #	TOTAL LENGTH (cm)	TOT Hg (ppb)	least squares means	
pollock	482/501	10/19/2001	1301	47	25.39	25.39	
redfish	94/54	10/19/2001	1213	5	14.85	14.96	
	482/501	10/19/2001	1394	2	9.91		
			1389	5	8.63		
			1385	11	10.89	9.77	
red hake	482/501	10/19/2001	1329	21	10.23		
			1333	22	15.01		
			1334	24	14.67		
			1332	25	13.44		
			1336	27	13.16		
			1338	28	15.48		
			1339	29	13.44		
			1323	30	18.47		
			1326	34	23.24		
			1325	43	88.87	22.6	
silver hake	3/7	10/18/2001	1164	10	11.67		
			1065	11	6.26		
			1063	12	7.56		
			1058	20	17.80	15.45	
	94/54	10/19/2001	1400	10	7.75		
			1416	19	12.94		
			1407	20	26.50		
			1422	21	25.74		
			1418	22	17.50		
			1405	23	12.80		
			1408	24	10.56		
			1417	25	8.70		
			1403	27	17.44	14.17	
	482/501	10/19/2001	1184	6	6.71		
			1178	9	8.79		
			1192	11	8.08		
			1197	22	22.62		
			1187	23	23.06		
			1182	24	23.36		
			1188	25	20.70		
			1186	26	26.40		
			1189	27	22.83		
			1177	29	24.97	18.14	

Mercury in Alewives

ID #	TOTAL LENGTH (cm)	WEIGHT (g)	[TOT Hg] ng/g
1154	12	16	12.74
1125	13	20	13.39
1028	14	27	27.39
1026	15	31	17.16
1024	16	36	22.64
1038	17	40	23.35
1035	18	50	26.07
1031	20	74	>50.00
1032	22	94	23.60
1015	23	123	30.62

*provisional results pending completion of full data set

TRAWL FISH COLLECTED - October 2001 *identified harbor seal prey		TOW SITE	n	TOTAL LENGTH (cm)			WEIGHT (g)		
				mean	std. dev.	min - max	mean	std. dev.	min - max
ATLANTIC HERRING *	*Clupea harengus*	3/7[1]	25	14.64	3.41	9-20	24.92	15.2	5-46
		94/54[2]	22	20.27	2.07	17-25	59.23	21.67	33-120
		482/501[3]	21	21.81	2.23	19-28	76.86	24.84	135-1614
ALEWIFE *	*Alosa pseudoharengus*	3/7	31	16.13	3.54	12-24	39.06	28.08	16-123
		94/54	26	17.35	2.15	13-26	43.88	26.1	19-165
		482/501	11	18.64	1.03	17-21	55.82	10.56	46-85
DAB *	*Hippoglossoides platessoides*	3/7							
		94/54							
		482/501	5	22.6	7.54	14-31	114	102.89	20-241
BUTTERFISH *	*Peprilus triacanthus*	3/7	8	11.63	1.19	10-13	24.88	6.03	15-33
		94/54	17	13.06	1.68	9-15	29.18	9.25	10-49
		482/501	3	16.33	2.52	14-19	64.33	32.32	37-100
GREY SOLE *	*Glyptocephalus cynoglossus*	3/7							
		94/54							
		482/501	25	16.4	3.51	9-28	23.6	21.64	3-120
WINDOWPANE	*Scophthalmus aquosus*	3/7	4	15.25	1.5	14-17	48.25	13.72	34-64
		94/54	24	15.33	1.31	13-19	42.71	10.88	25-72
		482/501							
WINTER FLOUNDER	*Pleuronectes americanus*	3/7	32	15.25	5.63	6-27	52.22	57.94	3-256
(blackback)		94/54	23	19.57	5.86	10-33	123.22	123.53	13.461
		482/501	8	29.13	3.4	23-33	278.75	134.03	152-481
REDFISH *	*Sebastes norvegicus*	3/7							
		94/54	3	5	0	5-5	1.5	0.5	1-2
		482/501	10	5.3	2.21	2-11	3.7	5.38	2-19
CUSK	*Brosme brosme*	3/7	1	12			12		
		94/54							
		482/501							
RED HAKE *	*Urophycis chuss*	3/7							
		94/54	5	20.4	7.02	8-25	66.4	35.77	35-91
		482/501	18	27.72	5.06	21-43	144	120.42	15-554
SPOTTED HAKE	*Urophycis regia*	3/7							
		94/54	1	23			105		
		482/501							
WHITE HAKE *	*Urophycis tenuis*	3/7	21	18.76	5.28	12-28	59.05	39.36	13-134
		94/54	24	20.58	3.98	12-25	73.91	32.07	12-112
		482/501	17	28.94	3.86	24-36	173.65	74.61	81-299
SILVER HAKE *	*Merluccius bilinearis*	3/7	9	11.56	3.24	10-20	12.56	14.95	6-52
(WHITING)		94/54	24	21.13	3.08	10-27	62.38	25.71	6-135
		482/501	22	21.73	6.52	6-29	81.41	43.11	2-164

LONGHORN SCULPIN *	*Myoxocephalus octodecemspinosus*	3/7							
		94/54	23	16.87	3.55	12-22	52.74	32.17	15-110
		482/501							
SEAROBIN	*Prionotus carolinus/evolans?*	3/7	2	22.5	3.54	20-25	125.5	48.79	91-160
		94/54							
		482/501							
SEA RAVEN	*Hemitripterous americanus*	3/7	1	12			24		
		94/54	2	18.5	9.19	12-25	112	128.69	21-203
		482/501							
ATLANTIC SILVERSIDE	*Menidia menidia*	3/7							
		94/54	2	11	1.41	10-12	7.5	3.54	5-10
		482/501							
RAINBOW SMELT	*Osmoerus mordax*	3/7	28	16.29	1.82	14-21	26.86	10.18	14-52
		94/54							
		482/501							
ATLANTIC COD *	*Gadus morhua*	3/7	3	13.67	1.53	12-15	21	6.08	14-25
		94/54	2	15	0	15-15	27	5.66	23-31
		482/501	4	13.75	1.71	12-16	19.75	7.04	12-29
HADDOCK *	*Melanogrammus aeglefinus*	3/7	2	15.5	0.71	15-16	30.5	0.71	30-31
		94/54	5	14.8	3.27	9-17	27.4	12.6	5-35
		482/501							
POLLOCK *	*Pollachius virens*	3/7	3	16.33	3.51	13-20	53.3	37.54	20-94
		94/54							
		482/501	1	47			869		
ATLANTIC MACKERAL	*Scomber scombrus*	3/7							
		94/54	9	27	1.58	25-30	150.44	30.05	116-205
		482/501							
ILLEX SQUID	*Illex illecebrosus*	3/7							
		94/54	4	9	2.45	7-12	22	9.7	15-36
		482/501							
LOLIGO SQUID	*Loligo pealei*	3/7	1	9			28		
		94/54	2	7.5	0.71	7-8	24	4.24	21-27
		482/501	1	13			38		
DOGFISH	*Mustelus canis*	3/7							
		94/54	1	618			930		
		482/501							

PREY SPECIES	PREY FREQUENCY	
	MINIMUM # of INDIVIDUALS*	% of TOTAL
REDFISH *Sebastes capensis*	171	60%
ATLANTIC HERRING *Clupea harengus*	56	20%
SILVER HAKE (WHITING) *Merluccius bilinearis*	31	11%
RED HAKE *Urophycis chuss*	7	2%
RED/WHITE HAKE *Urophycis spp.*	7	2%
ATLANTIC COD *Gadus morhua*	2	<1%
GREY SOLE *Glyptocephalus cynoglossus*	2	<1%
LONGHORN SCULPIN *Myxocephalus octodecemspinosus*	2	<1%
ALEWIFE *Alosa pseudoharengus*	1	<1%
DAB *Hippoglossoides platessoides*	1	<1%
BUTTERFISH *Peprilus triacanthus*	1	<1%
UNKNOWN *Tobe identified*	4	1%

QUADRANT	*X* HARBOR SEAL COUNTS (when occupied)	% SEXED	% MALE	% ADULT	# SCAT COLLECTED / SUBSAMPLED
NW	155	20 - 50%	70 - 90%	> 95%	13 / 5
NE	600	18 - 30%	> 95%	> 95%	264 / 151
SE	290	10 - 30%	> 85%	80 - 90%	3 / 2
SW	100	20 - 40%	50 - 70%	> 95%	7 / 1

1.6

ANTIBIOTICS

Antibiotic Compounds

Pharmaceutical chemicals in water has immerged as a world-wide concern. Most studies relate to large municipal waste outfalls and animal feedlots where pharmaceutical inputs are presumably high. Concern is focused on the issue of human health implications by exposure through drinking water. Ecological studies are few yet. Two marine industries in Maine have been the topic of much speculation over the past 10 years, lobster pounds and finfish aquaculture. Both use antibiotics (Oxytetracycline) in medicated feed to control disease, although in the finfish industry, vaccination has dramatically lowered the need for medication. Studies in Washington State have shown antibiotic buildup in sediment under finfish net pens.

Because oxytetracycline does not act solely on the target pathogen but on beneficial bacteria as well that may be ecologically important in nutrient recycling, we proposed an initial survey to determine whether oxytetracycline is present and at what concentrations in and around lobster pounds and finfish aquaculture operations.

The study is being directed by the Maine Department of Marine Resources via a private consultant. The samples have been collected and have been sent for analysis. The data will be reported in a later report.