USDA Northeastern Ecosystem Research Cooperative

Northeast Mercury Research Group

Abstracts from the 27-28 November, 2001 Workshop

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Decision Support System for Managing Common Loons in New Hampshire

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By the early 1970's the Common Loon population in New Hampshire had experienced a dramatic decline in historic numbers and is currently listed as a species of management concern by U. S. Fish & Wildlife. The Loon Preservation Committee (located in Moultonborough, New Hampshire) has collected information for 25 years concerning Common Loon nest sites and nesting pairs found in New Hampshire. The following will be discussed during this presentation: 1) data collection methods, 2) database development, 3) spatial analysis, and 4) initial habitat prioritization results. Decision Support System components developed for the Loon Preservation will be demonstrated using: ArcView, Tracking Analyst and ArcIMS. This work is sponsored by the University of New Hampshire and Loon Preservation Committee.

Mercury Data Collected by the Canadian Wildlife Service and our Research Partners in New Brunswick and Nova Scotia

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Since 1995, the Canadian Wildlife Service has been actively studying mercury in common loons, their fish prey and the lakes where they breed in Nova Scotia (NS) and New Brunswick (NB) with the help of many research collaborators. Collection of field data has concentrated on the lakes of Kejimkujik National Park in southwest NS and the Lepreau area of southwest NB. With the help of BioDiversity Research Institute in the mid-1990s, we collected loon blood and feather samples from these areas for total mercury analysis (n=63 blood & 42 feather). At Kejimkujik NS, Parks Canada caught 677 yellow perch from 24 lakes and from these fish, Environment Canada measured total mercury concentrations in 242 composite samples of whole perch. Total mercury was also analysed in fillets from 81 brook trout and 31 white perch from Kejimkujik. Environment Canada has monitored water chemistry in the Kejimkujik lakes for decades, and a complete dataset is available on watershed characteristics, hydrology and lake morphometry. Since 1999, a large team of researchers led by the Geological Survey of Canada has intensively studied the biogeochemistry of mercury and methylmercury in Kejimkujik lakes and watersheds. At Lepreau NB, the University of New Brunswick collected 865 fish of 23 species from 18 lakes. From these fish, Environment Canada analysed total mercury in 191 composite samples of whole fish. Lake chemistry data is also available for these Lepreau lakes. In other parts of NS and NB, Environment Canada has data for total mercury in 100 composite samples of whole yellow perch (n=284 perch) from 34 lakes, as well as lake chemistry data. Finally, Environment Canada has monitored wet deposition of total mercury in

precipitation since 1996 and total gaseous mercury in air since 1995 at Kejimkujik NS and St. Andrews NB (near Lepreau).

Mercury Distribution Along an Urban Gradient in New England Streams

Ann Chalmers and David P. Krabbenhoft, U.S. Geological Survey

The New England Coastal Basins study unit, as part of the U.S. Geological Survey's National Water Quality Assessment program, has evaluated relations between concentrations of total mercury (Hg_T) and MeHg in stream water and bed sediment, and Hg_T in fish tissue at sites over a range of urban land use. Water and bed sediment were sampled during 1998 – 2000 from 55 five stream sites from Rhode Island to Maine. Fish tissue was sampled at a subset of 27 sites. Sediment, water, and fish tissue samples were collected during summer low flow conditions within a week of each other to show patterns of MeHg accumulation and partitioning relative to site and watershed conditions. Concentrations of Hg_T in water and bed sediment ranged from 1 to 13 nanograms per liter (ng/L) and from 7 to 3,100 nanograms per gram (ng/g) dry weight, respectively. Concentrations of MeHg in water and sediment ranged from 0.04 to 1.8 ng/L and from 1 to 38 ng/g dry weight, respectively, and were positively correlated with concentrations of organic carbon. Methylation efficiency, as estimated by $MeHg/Hg_T$, ranged from 0.003 to 0.282 for sediment and water samples, with a median value of 0.071. Methylation efficiency was highest at sampling sites with low urbanization and high organic carbon concentrations. Hg_T concentrations in fish tissue (mixed sunfish species) ranged from 42 to 349 ng/g wet weight and were positively correlated with concentrations of MeHg in water.

Mercury contamination in piscivorous wildlife in Quebec

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Results from recent studies indicate an increase of mercury in the environment and its accumulation in aquatic food webs. An inventory of loons in the Mauricie and the Laurentides regions (Québec) have been conducted. Four sampling seasons were conducted in La Mauricie National Park and the Laurentides in 1997, 1998, 1999 and 2001. Reproductive success was assessed and loon families were captured at night and banded for a total of 23 lakes. Collection of feathers and blood was done before releasing the birds, to measure mercury contamination and various biological parameters as biomarkers. Small fish of various species were also sampled on most lakes for mercury analysis in loon prey. The mean levels of Hg in loons sampled during the three first years are within normal range of samples from north-east of North America but some individuals have levels considered at risk. Data are still partial and the study

must continue to determine more precisely the risk level and potential effects on the population of Québec loons. Similar studies are conducted in many other areas in North America. The combination of the results of all these linked studies will give a wide picture of the effects of mercury on this piscivorous species and help in decision making on pollution abatement.

Long-term objective:
1- To document the mercury contamination in loons in the Mauricie and the Laurentides regions ;
2- To determine wether loons are exposed to mercury concentrations in fish sufficient to have negative impacts on their reproduction and survival.

Data: Partial data for 23 lakes on : lake position, morphometry, physicochemistry, mercury in small fish, loon reproductive success ; mercury levels in blood and feathers and biomarkers for 82 loons (36 males, 23 females, 23 juveniles).

Products:
- Two conferences, in 1998, Fredericton ; in 2000, Quebec.
- BRI annual reports.
- Other reports and scientific papers to come.

Mercury bioaccumulation, biomagnification, and biodilution in aquatic food webs.
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Recent studies have emphasized the need for understanding the accumulation and fate of Hg at different trophic levels and across a broad spectrum of lake types. To address both issues, metal concentrations total Hg concentrations were measured in the water, two size fractions of zooplankton and in fish from twenty lakes in contaminated to pristine watersheds in the Northeastern USA. Our goals were to examine links between watershed characteristics and aqueous metal levels in lakes, and relationships between aqueous concentrations, metal burdens in different plankton groups and in fish. Aqueous concentrations of Hg were highest in cool water lakes and Hg in plankton biomagnified from small plankton (45 - 202 µm) to macrozooplankton (> 202 µm) and from macrozooplankton to fish. Metal levels in zooplankton were predictive of Hg fish suggesting that food is an important source of bioaccumulation for Hg. Moreover, Across the range of lakes, we found that Hg concentrations (ug metal /g organisms) in the particulate fraction (0.4-47 um) and the small (47-202 um) and large (>202 um) zooplankton fractions decreased with increased abundance in each fraction. These results suggest biodilution of metal contaminants in phytoplankton and zooplankton. We also found a significant decrease in the Hg burdens of consumers (zooplankton and fish) with an increase in biomass of their prey (algae and zooplankton, respectively) suggesting trophic dilution. Our findings demonstrate the importance of investigating upper and lower trophic levels separately to fully understand metal transfer pathways in aquatic food webs.

Surface water mercury concentrations in Canada's Atlantic Provinces

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Environment Canada has collected surface water mercury concentration data under two programs over the last five years. As part of our acid precipitation monitoring program, we have collected over one hundred samples in lakes throughout an area stretching over 1000 km (Fig. 1) which encompasses three Provinces: New Brunswick, Nova Scotia, and Newfoundland. The sites were selected to represent acidification-sensitive areas, as we as representing areas containing high abundances of lakes.

Samples were collected using clean bottle, clean hands procedures, in 500 ml Teflon bottles. Concurrently, samples were collected for major ion analyses, total organic carbon (TOC) and Fe, Al, anf Mn. Total mercury (Hg_t) in water samples was analyzed using a Brooks-Rand Model III, Cold Vapour Atomic fluorescence spectrophotometer. At the time the survey was taken, we did not have access to methyl mercury (MeHg) analytical methods, and thus none are available from these sites.

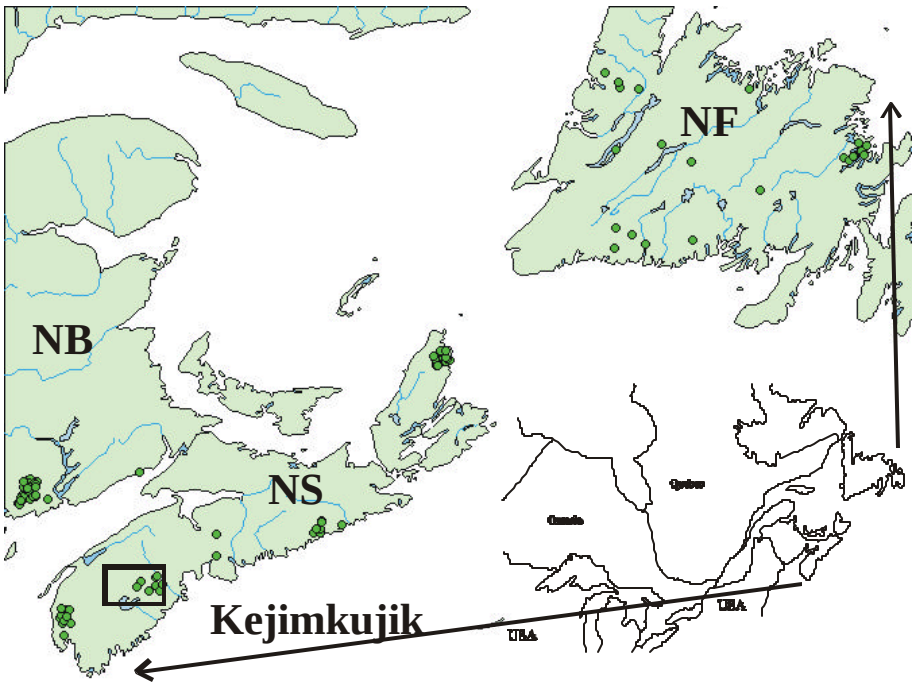

Figure 1 Location of sampling sites in Atlantic Canada. NB is for New Brunswick, NS for Nova Scotia, and NF is Newfoundland

A rudimentary analysis of the survey data (Fig. 2) shows that surface water Hg_t concentrations range from 1 to 16 ng L^{-1}, with a median value of 2.3 ng L^{-1}. Further analysis shows that there is a good, positive correlation between TOC and Hg_t in the sample population (Fig. 3).

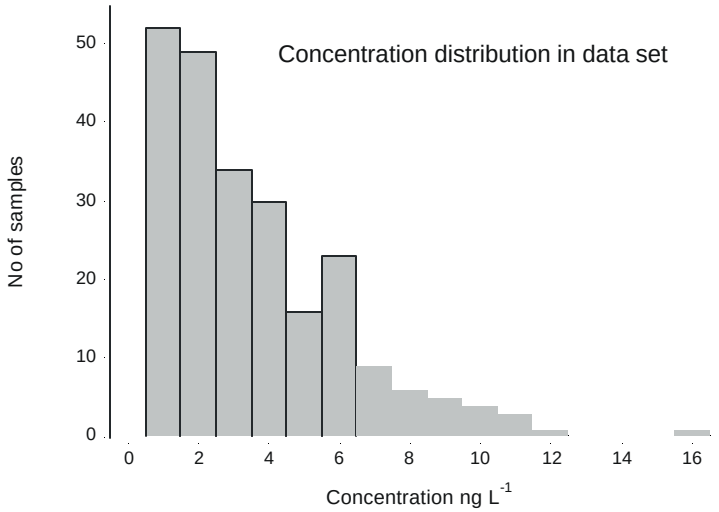

Figure 2 Concentration distribution of samples collected in the monitoring network.

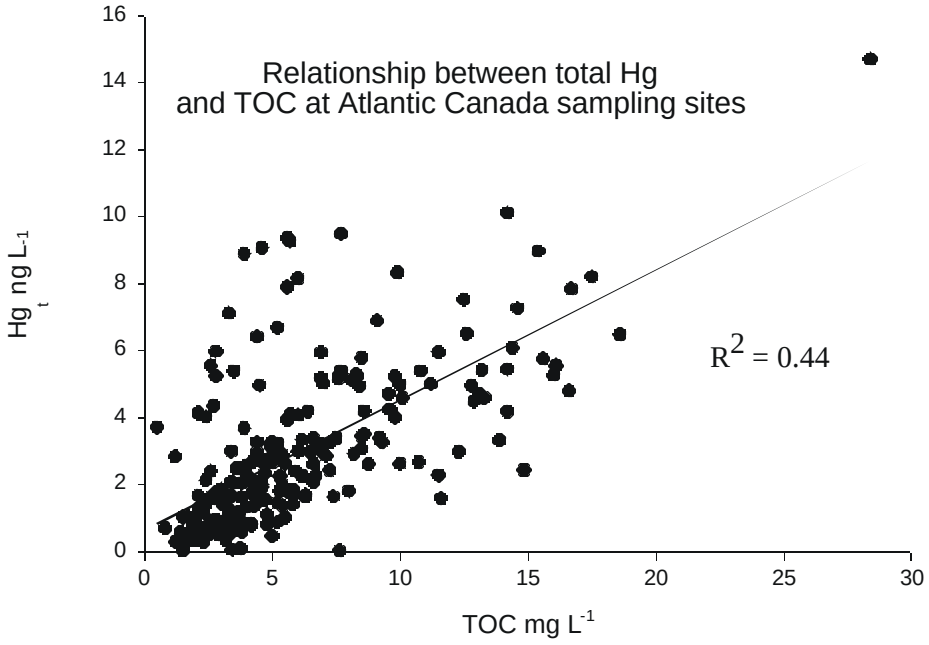

Figure 3 Relationship between TOC and Hgt in the sample population.

Another mercury study where a great deal of data has been collected is located in Kejimkujik National Park in southwestern Nova Scotia (Fig. 1). Approximately 40 stream and lake sites have been sampled in a 400 km^2 area at least twice, some as often as 50 times. We have two

main studies in this area. The first's purpose is to construct aquatic input-output budgets for two lakes, a brown and a clear-water lake. Eight streams at two lakes have been sampled monthly for the past three years in order to produce enough information to construct accurate Hg_t and MeHg budgets.

The second study is designed to determine quantitative relationships between wetland abundances, topography, TOC generation and seasonality in producing Hg_t and MeHg in the region's waters. We've sampled approximately 30 sites and analyzed their catchments using GIS approaches to see if we could construct a model predicting Hg concentrations, knowing what the catchment basins look like. A GIS model has been constructed which we are now testing with data collected elsewhere.

Research activities on the transport, bioavailability and fate of mercury in lake/watersheds of the northeastern U.S.

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The research activities of Charles Driscoll on the transport, bioavailability and fate of mercury (Hg) in lake/watershed ecosystems of the northeastern U.S. include: 1) surveys of the concentrations of total and methyl Hg in water, sediments and fish (yellow perch) in the Adirondack region of New York (Driscoll et al. 1994, 1995) and Vermont and New Hampshire (with Neil Kamman and others), 2) analysis of patterns of Hg deposition in sediments in lakes in the Adirondacks (Lorey and Driscoll 1999), and 3) a detailed lake/watershed mass balance study of total and methyl Hg at Sunday Pond in the Adirondacks.

Surveys of Adirondack lakes show strong relationships between concentrations of total and methyl Hg and concentrations of dissolved organic carbon (DOC). Concentrations of DOC are related to the percentage of the watershed occurring as wetlands. Concentrations of methyl Hg were elevated in lakes in anoxic hypolimnia. Concentrations of Hg increased in yellow perch with increasing age class, reflecting different food sources with fish age. Concentrations of Hg in age 3+ to 5+ yellow perch increased with decreases in lake pH and concentrations of aluminum. The bioconcentration factor of methyl Hg in yellow perch decreases with increasing concentrations of DOC. This analysis suggests that DOC is important in the supply of total and methyl Hg, but DOC limits the bioavailability of Hg probably through complexation reactions (Driscoll et al. 1994, 1995).

Lakes in Vermont and New Hampshire show similar patterns to those in the Adirondacks. However, differences in lake/watershed characteristics (i.e., forest, agricultural, urban) increase the variability in the mercury concentrations in lake water, sediments and fish. Concentrations of Hg in yellow perch are similar to values reported for other lake districts in eastern North America, but lower than values in the Adirondacks.

Sediment cores have been collected for eight lakes in the Adirondacks (Lorey and Driscoll 1999). These sediment cores have been sectioned and analyzed for Hg and dated with ^{210}Pb. These data suggest that Hg deposition to Adirondack lake sediments has increased markedly over the last 100 to 150 years (approximately 3.5x). Our results also suggest that sediment Hg deposition have decreased (~30%) over the last 15 to 20 years. Sediment Hg deposition is a strong function of the watershed to lake surface area. Analysis suggests that watershed retention of atmospheric Hg has decreased over the last 150 years. We have developed a simple model to describe the historical deposition, watershed accumulation and loss and sediment deposition of Hg in the Adirondacks.
A detailed Hg mass balance study in being conducted for a lake/watershed in the Adirondacks, Sunday Pond watershed. This study has been underway for two years and includes investigation of wet deposition, throughfall, litterfall, soil, soil water, groundwater, stream water and lake water. We observed that fluxes of Hg are elevated in forest floor leachate in comparison to wet deposition. This pattern suggests that either dry deposition of Hg is a significant input and/or the forest floor is exhibiting net release of Hg. Elevated fluxes of Hg from the forest floor are retained in the lower mineral soil, coinciding with retention of DOC in the soil profile. The watershed and lake are net sinks for atmospheric deposition of Hg (80%). The watershed and lake are also net sources of methyl Hg. Rates of methyl Hg production are high within riparian wetlands.

References:

Driscoll, C.T., C. Yan, C.L. Schofield, R. Munson and J. Holsapple. 1994. The mercury cycle and fish in the Adirondack lakes. Environ. Sci. Technol. 28:136A-143A.

Driscoll, C.T., V. Blette, C. Yan, C.L. Schofield, R. Munson and J. Holsapple. 1995. The role of dissolved organic carbon in the chemistry and bioavailability of mercury in remote Adirondack lakes. Water Air Soil Pollut. 80:499-508.

Lorey, P. and C.T. Driscoll. 1999. Historical trends in mercury deposition in Adirondack lakes. Environ. Sci. Technol. 33:718-722.

New Hampshire Department of Environmental Services

Robert Estabrook, New Hampshire Department of Environmental Services

The New Hampshire Department of Environmental Services maintains a database (in Foxpro) of mercury concentrations in freshwater fish from New Hampshire surface waters. The database includes both data collected by state officials and data collected by others from New Hampshire waters. The database was developed (1) to provide data to Public Health officials for the purposes of fish consumption advisories and (2) to provide information to decision makers on future mercury reduction strategies. Data from targeted special studies, long-term trend studies and random fish collections are all included in the database.

The database currently contains 1314 records for total mercury, wet weight. A total of 25 different fish species are represented, with the major species being yellow perch (510), largemouth bass (166), smallmouth bass (165), and eastern chain pickerel (123). Most of the analyses (1108) are for individual fish fillets with skin off. Most of the analyses (1015) were conducted by the NH Public Health laboratories. Fish length and weight data are available for nearly all analyses with age data currently available for 220 analyses. Total mercury, dry weight (128) and methyl mercury, wet and dry weight (15) are available for a limited number of analyses.

Fish were collected from a variety of surface waters, including 155 different lakes and 7 different rivers. A total of 987 fish analyses were from lakes and reservoirs and 287 from rivers and impoundments. A wide range of water quality characteristics was encountered in the dataset. For example, the lakes and reservoirs ranged in pH from 4.9 to 8.0, ANC from –0.3 to 32.8 mg/L and apparent color from less than 5 to 150 chloroplatinate units.

Collaborative Mercury Research Network (Canada): Case study examining Hg in eastern Canada's mink and otter population

Doug Evans, Trent University

Fish in many lakes and rivers of Eastern North America contain elevated levels of Hg. For fish-eating mammals such as mink and otter, this presents a potential health risk. Moreover, fish-eating mammals could act as sentinel organisms, or early-warning systems for potential human health problems in populations that consume large quantities of fish. For these reasons, the study of Hg dynamics in mink and otter populations is valuable.

There is some limited evidence to suggest that mink and otter populations in some areas are being impacted by Hg exposure. Recent analysis of Hg concentrations in captured animals in Ontario indicates that there are very few older individuals that contain high concentrations of Hg. Moreover, it appears that population demographics are different in regions of high Hg exposure than in regions of low exposure. While these observations are preliminary and require corroboration, there is experimental evidence to suggest that such impacts are to be expected. Dosing experiments with captive animals indicates that chronic exposure (such as might be obtained from eating fish) to food containing between 1 and 2 mg Hg/kg wet weight can induce Hg toxicosis. Concentrations of Hg in fish in many lakes in eastern Canada are in this range. Thus, it is perhaps not unexpected if Hg is impacting populations of mink and otter.

The Canadian Collaborative Mercury Research Network (COMERN) is supporting research designed to test the hypothesis that changes in population statistics for mink and otter occur as a function of Hg exposure. This will be done by examining the population structure in areas with differing Hg concentrations in prey fish in Nova Scotia, Quebec and Ontario. The overall health of captured (by trappers) animals will be assessed, as will concentrations of total and methyl Hg in target tissues including brain, liver and fur.

In an effort to determine the causes of Hg toxicosis, genotoxicity measurements will be made, including the measurement of DNA strand breakage as a function of Hg exposure. AT later stages of the project, the variation in the ability of individuals to demethylate Hg in their brains will be explored, and possible mitigation of Hg exposure by uptake of selenium will be determined.

Assessment of Hg risk to New England wildlife

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Anthropogenic inputs of mercury (Hg) into the environment have significantly increased in the past century. In conjunction, the current availability of methylmercury (MeHg) in aquatic systems has increased to levels posing risks to human and ecological health. Risk levels vary considerably in response to MeHg availability, which is affected by lake hydrology, biogeochemistry, habitat, topography, and proximity to airborne sources. The Common Loon (*Gavia immer*) was selected as the most suitable bioindicator of aquatic Hg toxicity, based on ecological, logistical, and other criteria, including public valuation of natural resources. Opportunistic and probability-based sampling efforts from 1994-2001 indicate the Northeast's breeding loon population is at unacceptable levels of risk to Hg contamination, particularly in Maine and New Hampshire. Based on risk categories developed from the literature and *in situ* studies by BioDiversity Research Institute and their collaborators, 30% of the breeding loon population in Maine is estimated to be at risk, while 46% of the eggs laid are potentially impacted.

Because results from national sampling indicate loons are at most risk from Hg in New England several individual- and population-level parameters were identified to better understand the extent of mercury toxicity. Between 1994 and 2001, we collected 571 abandoned eggs as well as blood and feather samples from 487 adult and 284 juvenile loons. The Hg concentrations in these samples were used to characterize sublethal impacts of Hg on egg development, behavior, developmental stability, immunosuppression, individual survival, and overall reproductive success. In the Rangeley Lakes Study Area of northern Maine and New Hampshire, a total of 185 loon territories were monitored on 43 lakes between 1998 and 2001. Current monitoring efforts and historical data comprise 515 territory-years measured in this focal area. Behavioral observations were conducted for over 1,500 hours on 16 lakes with 38 loon territories from 1998 to 2000.

Several reproductive measures significantly declined for loon pairs at high risk to prey MeHg availability, thereby corroborating studies in high-risk sites in Nova Scotia and Wisconsin that show Hg impacts reproductive success. Based on 223 loon territories representing 748

territory-years surveyed extra-high risk pairs fledged 37% fewer young than pairs at low risk to Hg. Apparent were similar significant patterns of lower productivity on high and extra-high risk territories compared to low and moderate risk territories for other reproductive measures. The implication of long-term declines in these reproductive measures are serious and would not be detected by traditional survey techniques.

Insight into why loons are facing Hg-based population declines can be seen through a hazard assessment process that is based on a weight of evidence approach. Physiological impacts of Hg are measured through two key biomarkers: corticosterone stress hormone levels and flight feather asymmetry. Circulating corticosterone hormone levels are strongly linked with increasing blood Hg levels and are not related to capture and handling stress. Corticosterone hormone levels increase on an average of 14.6% for every one ppm of increase in blood Hg levels (n=239). This indicates that loons with high blood Hg levels have higher rates of chronic stress and may therefore have compromised immune systems. Asymmetry measurements provide insights into developmental stability and potentially reproductive fitness. Three years of flight feather measurements have shown annual agreement that loon breeding populations with greater exposure to Hg have significantly greater asymmetry than populations at low risk (n=227). Greater asymmetry may indicate disruptions from stressors on their embryonic development and current physiological status as well as a potential decline in reproductive fitness.

Many behavioral impacts that appear to be related to the neurotoxic effects of MeHg can rarely be observed in the field. Adult loons in high risk situations left eggs uncovered 14% of the time; this was high compared to 1% in controls. Several cases of direct field observations indicate that adult loons with high Hg body burdens avoid incubating their eggs and display atypical behaviors such as patrolling or sitting next to the nest. A significant negative relationship was documented between adult blood Hg and foraging behavior, and a significant positive relationship between adult blood Hg and brooding behavior. Recategorizing these data according to energy demands revealed a significant inverse relationship between blood Hg and time spent in high energy behaviors. These findings are consistent with other studies linking Hg and lethargy, reduced motivation to hunt prey, and compromised foraging abilities.

Current levels of Hg in some New England aquatic ecosystems also appear to be impacting individual survival of adult and juvenile loons. Recaptured adult loons exhibit a significant annual increase of Hg (9% in males, 5.6% in females) that may significantly reduce lifetime individual performance. A model of this impact indicates a decline of 13 to 8 young produced over a loon's lifetime. Further, juveniles from high-risk territories have significantly increasing blood Hg levels of 3% per day during the summer, potentially reaching dangerous levels after the final feather molt at 11 weeks of age.

Characterization of the risk imposed by MeHg bioavailability in aquatic systems to high trophic level obligate piscivores, such as the Common Loon, indicates negative population level impacts in Maine and New Hampshire. Although the impacts of Hg on loons are varied, complex, and not yet fully understood, the combination of high exposure to a significant part of the breeding

population and the "bottom-line" impact of reducing overall reproductive success to 37%, has created an aquatic landscape that is not sustainable for the Common Loon in parts of the Northeast.

Because of the loon's life history strategy (i.e., long lived, slow maturing, and low fecundity) continual impacts of this stressor can cause an erosion of the non-breeding or buffer population (which serves as a natural cushion to catastrophic events). Once this buffer population is exhausted, the occupancy of established territories will shrink and it will be more obvious that loon populations are declining. However, the realization of shrinking loon populations at that stage will require drastic and potentially expensive efforts to reverse the decline. Models based on a 25-year, statewide comprehensive monitoring effort in New Hampshire show approximately half of its buffer population has been exhausted. Certain areas in Maine, such as the Allagash area, already apparently exhibit exhaustion of the buffer population and a shrinking number of territorial pairs.

Therefore, assessing and fully understanding the hazards of MeHg availability at the population level for the Common Loon is crucial toward its conservation, but even more notably for constructing a Wildlife Criterion Value (WCV). A WCV for Hg will provide a basis for regulations that are appropriate for all wildlife. By viewing the loon as one of the more sensitive indicators of Hg risk this WCV is relatively encompassing. Current collections of Hg exposure data for other species of piscivorous wildlife plus further investigations into impacts on insectivorous birds also contribute to this model. Consolidating Hg data across the Northeast, continued refinement of model parameters, and generating spatially-explicit analyses (with assistance through genetic differentiation of populations using microsatellite techniques) will provide higher confidence in our risk estimates, which will therefore assist in regionally-based policy efforts as well as national regulations that reflect the ecological injury Hg is currently having on aquatic ecosystems.

Use of Spatial Analyst for assessing Hg risk

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Spatial Analyst's "Interpolate a Raster" function is a GIS tool that can be used to interpolate between points to create a gradient map. This tool may be appropriate to use in developing a mercury risk map for northeastern North America. Spatial Analyst creates a grid layer from point data, where every cell in the grid has a specific value. There are three common model types: Inverse Distance Weighed (IDW), Spline, and Kriging. IDW, which averages the values of data points in a specified vicinity of each cell, is most appropriate to use with data that decreases with influence as distance increases. The points are weighed based on their distance from the center of the cell being estimated; a closer point has more influence. The Spline method is similar to IDW, but uses a mathematical function to smooth the grid surface. This method is most appropriate for data that changes smoothly such as elevation, pollution concentrations, and water table heights. Kriging, the most complex model type, is most appropriate for directional

data. Unlike IDW and Spline, which use the point value, Kriging uses the statistical relationship between points with mathematical function to build a surface (ESRI's ArcView 8.1 Help). Each of these model types has a number of parameters that can be changed to create different results. Consequently, a specific objective needs to be determined before the model is run.

References

ERSRI's ArcView 8.1 Help function.

Assessing Hg and MethylHg Burdens in VT and NH Lake Sediments, Waters, and Biota. A Regional Environmental Monitoring and Assessment Program Initiative

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In recent years, the biogeochemistry of mercury in north-temperate lakes has become increasingly well understood. In Vermont and New Hampshire such research has been undertaken on a limited scale only in the Lake Champlain Basin, and not at all in the remainder of the region. Thus, in 1998, USEPA funded an effort to assess total and methylmercury concentrations in the sediments, waters, and biota of a large spatially-randomized sample of VT and NH lakes. This project is part of the EPA Regional Environmental Monitoring and Assessment Program. This comparative observational study of statistically and geographically randomized lakes will produce data which can describe existing mercury contamination patterns across the population of VT and NH lakes greater than 20 acres in size.

The project carries four distinct components: 1) Measurement of Hg, methylHg, and relevant physico-chemical parameters in epilimnetic and hypolimnetic waters, and profundal sediments,

of 90 lakes; 2) Measurement of Hg in macrozooplankton and two size classes of yellow perch of 45 lakes; 3) Measurement of Hg and relevant biomarkers related to Hg contamination in loons and other piscivores , in 45 lakes; and 4) paleolimnological investigations of recent (<200 yBP) Hg deposition to 13 lakes across the study region.

Project data are allowing investigators to link Hg and methylHg concentrations in the sediments, waters, and biota, with physico-chemical constituents known to mediate Hg methylation and bioaccumulation, using multivariate statistical techniques. Landscape-level GIS analyses are being used in conjunction with modeling of atmospheric Hg deposition, to understand geographic variation in Hg loading, and to subsequently model Hg bioaccumulation. The major goal for the study is to ascertain, for VT and NH, the physico-chemical identity(ies) of those lakes which display elevated Hg concentrations in upper trophic level biota. A pressing need for these study results is the refinement of fish tissue consumption advisories for Hg such that they become class or even lake specific. The dataset is also intended to provide necessary information to support development of VT and NH-specific mercury criteria, and to generate baseline indicators for use in assessing the impact of anticipated reductions in Hg emissions. Several publications are anticipated from this project, with one (Paleolimnology of Hg in VT and NH lakes) already in press with the journal *Atmospheric Environment*.

Mercury Studies conducted by USFWS, New England Field Office
Andrew "Drew" Major, U.S. Fish and Wildlife Service

1) ME Eagle Study (1991-1993): Blood and feathers from nestling bald eagles was collected and analyzed for total mercury and organochlorines as part of a Master's Thesis. A total of 132 blood samples and 124 feather samples, representing 107 different nesting territories were submitted for analysis. Results indicated elevated levels of mercury, especially in interior eagle territories.

Cooperative Studies

1) Reservoir Study (1996-1998): Sediment, fish, and loon samples were collected from reservoirs and natural lakes (n=12) in the Androscoggin and Kennebec River drainages to determine the impact of water level fluctuations on bioavailability of mercury. 1996 fish samples included wholebody composites of yellow perch, white sucker, and a species of opportunity for each waterbody at three different length classes. In 1997, 20 individual yellow perch wholebody samples were taken from the same waterbodies. All samples were analyzed for total mercury and a subset was analyzed for methyl mercury.

2) REMAP (1999-2000): The Service portion of the study includes perch samples from a subset of the REMAP lakes. From 46 of the REMAP lakes, 5 yellow perch > 6" were collected. Both fillets and offal were analyzed for total mercury. In addition, 5 individual and one composite (n=5) samples of yellow perch < 6" were analyzed for total and methyl mercury.

3) Southeast NH Study (2000-2001): EPA modelers have predicted that the southeastern corner of NH receives the highest levels of atmospherically transported mercury due to prevailing wind patterns. To investigate this, yellow perch samples in 2000 were collected on 10 lakes from SE NH using REMAP protocols and size classes. Mercury data from common loons had previously been collected (either blood or eggs) on these same lakes. In 2001, the sampling expanded to 15 additional lakes, and only yellow perch (n=5) >6" were collected. Analysis of the 2001 samples is pending.

The Ontario Sport Fish Contaminant Survey

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The Ontario Ministry of the Environment and the Ontario Ministry of Natural Resources collect and analyze fish across Ontario for mercury and a variety of other contaminants. The survey has been underway since the early 1970's, and the data are used primarily to advise anglers about safe consumption rates of fish on a lake, species and size specific basis.

To date over 150,000 samples have been analyzed for mercury from about 2300 sites in over 1600 waterbodies. A significant fraction of the fish are from the Great Lakes, and a number are from areas contaminated by chlor-alkali plants in the late 1960's and early 1970's. The majority of samples, however, come from inland lakes and rivers across the Precambrian Shield of Ontario. Many rivers and large lakes have been sampled at multiple sites. The vast majority of the analyses were performed on skinless, boneless, fillets, but some data are available for other organs as well as whole fish.

The data are maintained in a fully normalized, Oracle relational database consisting of about 20 tables. Although considerable effort has been expended on validating the integrity of the data, there is evidence that a small, but non-trivial portion (1-5%) of the data have been compromised in various ways, probably by data entry and data transcription errors.

The data are georeferenced to the nearest minute (very roughly 1 km). Although large lakes can easily be cross linked to digital map data using lake coordinates, difficulties arise with small lakes in areas of high lake density (the majority of the data). Nonetheless, by using coordinates *and* waterbody name at least 85% of the sites can be associated with a digital waterbody entity with reasonable confidence in the link.

A number of journal and government reports have been published on the data, but there is renewed interest in analysis of the sportfish contaminant data. Research over the past decade indicates that watersheds and their landscape features (e.g., wetlands) play an important role in formation and supply of methylmercury to lakes. Current work is focused on development of models that reduce data complexity but maintain or even enhance the information of interest, the level of Hg contamination in a waterbody. It is hoped that a consolidated index of contamination will provide relatively clear, robust means of uncovering links between geographic attributes.

High Spatial Resolution Estimates of Hg Wet and Dry Deposition Fluxes to the Northeastern US Landscape

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Currently, there is a need to better predict the spatial extent and severity of Hg contamination in higher trophic level organisms such as fish and fish-eating birds and mammals. While many ecosystem characteristics and processes are known to influence the accumulation of Hg in higher trophic-level organisms, the amount of Hg transferred from the atmosphere to a lake and its watershed are likely significant factors in the potential risk to biota. Long-term spatial-patterns of atmospheric deposition also influence the extent of Hg accumulation in ecosystem reservoirs such as organic soils and lake sediments. Thus, knowledge of current and previous atmospheric deposition rates, and spatial patterns in those rates, may provide important information for assessing the persistence of risk in ecosystems exhibiting excessive upper trophic-level Hg contamination.

We are preparing to generate the first high spatial resolution regional estimates of total (wet + vapor + particle) mercury deposition to the Northeastern US landscape. Estimates will be derived at 30-meter ground resolution, allowing the representation and assessment of the effects at this scale of land cover, forest type, topography, and climate on Hg deposition. The complex topography of the Northeastern US results in significant regional and local variation in wet deposition rates of pollutants (Miller et al. 1993, Miller 2000). It is well understood that substantial variation in dry deposition velocities exists due to variations in receptor surface characteristics that correspond to land cover and vegetation type such as leaf area index, leaf morphology, stomatal response to environmental conditions, and due to variation in local microclimate (Miller et al. 1993). While substantial uncertainties remain in our understanding of Hg vapor exchange with forest and crop canopies (Schroeder and Munthe 1998), there appears to be sufficient information on the key biological and physical processes involved to warrant an initial estimate dry deposition fluxes at this time (e.g. Lindberg et al. 1998, Rea et al. 2001).

Estimates of the effects of spatial variation in Hg air and precipitation concentrations will be orders of magnitude coarser than the estimates of effects due to precipitation rate and dry deposition velocity, due to the sparse observation network for Hg. Existing data on total Hg in precipitation, suspended aerosol particles, and Hg-vapor from two monitoring networks operating in the region (MDN and NESCAUM-REMAP) will be assimilated and appropriately combined for use in developing interpolated regional concentration fields for seasonal average Hg concentrations in precipitation, suspended particles, and vapor-phase Hg in air. The spatial resolution of Hg concentrations estimated in this way will be much coarser (10s of kilometers) than the information used determine precipitation rates or dry deposition velocities, but represents the best resolution given currently available sources of data. The concentration fields will be applied to high-resolution estimates of deposition velocities and precipitation rates calculated by Ecosystems Research Group, Ltd.'s High Resolution Deposition Model (HRDM)

to yield high resolution estimates of Hg transfer to the landscape. The HRDM will be modified to incorporate Lindberg et al.'s (1992,1998) parameterizations of the canopy exchange of Hg particles and vapor. The Lindberg (1992) approach has been successfully applied to estimation of Hg dry-deposition to the forest at Underhill, VT. Use of the HRDM for this effort is facilitated by other current research projects that have contributed substantial resources to the development of the required spatial data layers for atmospheric deposition modeling.

Depending on the availability of pending funding, high spatial-resolution Hg deposition estimates for MA, VT and NH could be available by spring of 2002.

References

Lindberg, S.E., T.P. Meyers, G.E. Taylor, R.R. Turner, and W.H. Schroeder. 1992. Atmosphere-Surface Exchange of Mercury in a Forest: Results of Modeling and Gradient Approaches. Journal of Geophysical Research 97:2519-2528.

Lindberg, S.E., P. J. Hansen, T.P. Meyers, and K.-H. Kim. 1998. Air/Surface Exchange of Mercury over Forests – the need for a Reassessment of Continental Biogenic Emissions. Atmospheric Environment 32:895-908.

Miller, E.K. (2000) Atmospheric Deposition to Complex Landscapes: HRDM – A Strategy for Coupling Deposition Models to a High-Resolution GIS. Proceedings of the National Atmospheric Deposition Program Technical Committee Meeting, October 17-20, 2000, Saratoga Springs, New York.

Miller, E.K., A. J. Friedland, E.A. Arons, V.A. Mohnen, J.J. Battles, J.A. Panek, J. Kadlecek and A.H. Johnson (1993) Atmospheric Deposition to Forests Along an Elevational Gradient at Whiteface Mountain, NY USA. *Atmospheric Environment*, 27A: 2121-2136.

Rea, A., S.E. Lindberg, and G.J. Keeler. 2001. Dry deposition and foliar leaching of mercury and selected trace elements in deciduous forest throughfall. Atmospheric Environment 35:3453-3462.

Schroeder, W.H. and J. Munthe. 1998. Atmospheric Mercury – An Overview. Atmospheric Environment 32:809-822.

Linking Bioaccummulated Mercury and Wildlife Population Effects

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This specific project was identified because it could take advantage of a rich collection of data, addressed a problem of immediate concern to the Agency, and provided a focus for the development of approaches and tools for assessing the risks of multiple stressors to populations of wildlife, leading to the development of risk-based criteria. The three major objectives associated with research include: development of mechanistically-based approaches for extrapolating toxicological data across wildlife species, media, and individual-level response endpoints; development of approaches for predicting population-level responses to stressors, and identifying the responses at the individual level that have the greatest influence on population-level responses; development of approaches for evaluating the relative risks from chemical and non-chemical stressors on spatially structured wildlife populations across large areas or regions. This demonstration project focuses on issues starting with the exposure of birds to mercury in the fish (and other dietary components) they consume, rather than focusing on fate and bioaccumulation within the wholly aquatic portion of the food web. Therefore, it will be critical that these efforts to predict effects of mercury in piscivorous wildlife are integrated with those to predict mercury bioaccumulation. To support research to assess effects of mercury on wildlife populations, AED is developing a geographically-referenced, queriable data base containing information on abiotic, biotic mercury and associated environmental data for the northeast region of the US and Canada. These data have been collected by a multitude of public and private sources, for a variety of purposes. The approaches for assembling, accessing, and analyzing these data are based upon those used by the EPA's Environmental Monitoring and Assessment Program for which data management is also housed at AED (For an example of this data management system, and associated data and meta-data, please see www.epa.gov/emap/html/dataI/estuary/data/cp9497/index.html). A demonstration database for mercury in media and biota of the northeastern US and Canada has been developed using these principles is currently under evaluation by AED and potential data contributors and users.

Hg deposition in lake and peat sediments through time in eastern North America

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Approximately 30 lakes and 3 ombrogenic bogs have been cored in Maine, USA. All cores have been dated with ^{210}Pb and analyzed for total Hg, water, ash concentration, and selected other metals (differing on a case by case basis). Accumulation rates have been deconvoluted into three components: background (pre-1880), a variable input influenced by changing sediment accumulation rates, and anthropogenic. Inspection indicates that the onset of the anthropogenic component occurs (according to ^{210}Pb ages) at approximately the same time across wide regions. Hg deposition from the atmosphere has declined over the last several decades, based on lake sediment and peat cores.

The goals of combining data over a wide region include:

1. isolation of the influence of point-sources of Hg pollution
2. identification of watershed factors that contribute to the strength of the atmospheric anthropogenic signal ("focusing" effects)
3. identification of watershed factors that delay recovery of the anthropogenic signal to pre-industrial conditions (catchment-related lag effects)
4. development of maps of inferred atmospheric deposition of Hg through time

Data requirements for interpretation of lake sediment include dated cores, concentration of H_2O, organic matter, and total Hg (or dry density and Hg concentration). Isotopic analyses of Hg would be wonderful but generally are not available.

Data requirements for peat cores include dated cores, density of peat, and concentration of total Hg. Isotopic analyses of Hg would be wonderful but generally are not available.

Using crayfish as relatively non-mobile indicators of MeHg bioavailability

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The Northern crayfish (*Orconectes virilis*) is one of the most common crayfish in New England and is an important food item for many organisms including large piscivorous fishes and birds and a host of aquatic-foraging mammals. Thus, it represents an important trophic link between benthic and water-column food webs in lakes and streams. In addition, crayfish are relatively long-lived (2-3 years for most species), they exhibit high site fidelity with small home ranges (thus do not disperse as widely as fish), they are intimately associated with the substrate, they function at multiple trophic levels simultaneously, and are known to accumulate Hg. Based on these characteristics, crayfish have been suggested as excellent indicator species for mercury bioavailability studies.

We surveyed Hg content in the northern crayfish from 15 sites in New Hampshire and Vermont in summer 2000. Our database includes approximately 150 animals from multiple habitat types (*i.e.*, rivers, reservoirs, ponds, and brooks). We have another 150 animals collected from Maine sites that have yet to be analyzed. In this study, we were interested in comparing the Hg content of crayfish from different habitat types in a localized region to reduce geologic and atmospheric differences. We also wanted to determine whether weight/length relationships were consistent enough among different habitat types to allow prediction of Hg content.

There was a significant relationship between crayfish size (as measured either by wet weight or total length) and abdominal muscle Hg content. Larger crayfish had higher Hg content than small crayfish. There was also a significant difference in the size of crayfish captured from the different sampling sites (ANOVA results: Length, $F_{12,101} = 5.83$, $P << 0.001$; Weight, $F_{12,101} = 5.68$, $P << 0.001$). Regression analyses suggest that weight explained most of

the variation in Hg content across all sites and that site contributed almost no explanatory information for Hg content when all sites were combined. However, habitat type provided significant information when sites were grouped. Crayfish from big river and brook sites had the highest Hg content while pond crayfish had the lowest. Animals from reservoirs were intermediate.

Because of the size differences among sites, and the size/Hg relationship, we standardized all Hg data to tail length. There were significant differences among the sampling sites in mercury content per cm of tail length (ppm/cm or *u*g/g/cm: ANOVA: $F_{12,101} = 9.84$, $P << 0.001$), but the ranking of sites changed. A re-examination of the length/weight data revealed that crayfish from all sites but one grew at the same rate, eliminating growth patterns as the factor causing Hg differences. We suspect that trophic position within sites might help explain Hg content in crayfish. We expect reservoir and pond populations to function lower on the trophic scale (*i.e.*, primarily herbivorous) as macrophytes are more abundant in these habitats and potentially, predation is higher. We expect brook and river populations to forage trophically higher as predation risk may be lower and macrophytes are less abundant.

Common Loons: a long-term mortality dataset

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From 1988-2001, 600 common loons found dead or moribund have been examined as part of a New England-wide mortality study. Results confirm that much summer loon mortality is due directly or indirectly to human activities on breeding lakes. Major findings included numerous deaths from trauma, fishing gear, and fungal respiratory disease (aspergillosis). Entanglement in monofilament plastics and heavy metal toxicosi from ingested sinkers and jigs accounted for over 50% of observed adult mortality.

As part of this study, tissue mercury (primarily liver) has been measured in the majority of birds. A subsample (~ 100) has also had kidney, brain and other tissues analyzed for mercury. In general, our studies have measured total mercury, but one group of samples (~60) was analyzed for the presence of multiple forms of organic and inorganic mercury. Methyl mercury was found to be by far the dominant form of organic mercury present. There was no significant correlation found between the levels of total mercury and methyl mercury found in liver tissues. Although statistical analyses are not complete, we can say with some assurance that there is also no correlation between the presence of elevated liver mercury and fungal respiratory disease.

Compilation of data for a GIS-Based Regression Model to Predict Risk of Mercury Contamination in Fish Tissue in New England

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Elevated mercury (Hg) burden in freshwater fish tissue has resulted in fish consumption advisories and concerns about the health of aquatic fish communities throughout New England. The US Environmental Protection Agency (USEPA), US Geological Survey (USGS) and the New England Interstate Water Pollution Control Commission (NEIWPCC) are initiating a New England-wide study to develop a regional GIS-based regression model for mercury (Hg) in fish tissue. The proposed model will utilize experience and information currently being gained in the development of a joint USGS/USEPA/NEIWPCC New England regional nutrient SPARROW (Spatially Referenced Regressions on Watershed Attributes) model. The proposed Hg model would be used to identify factors contributing to high levels of Hg in fish throughout New England and to predict the risk of mercury contamination. The underlying assumption for development of the Hg model is that some degree of variability in the fish tissue data for a particular species and tissue type can be explained with a combination of data describing physical watershed features and anthropogenic Hg sources. USEPA and NEIWPCC hope that the model will: (1) Assist in understanding factors that contribute to environmental risks from Hg (e.g., atmospheric deposition patterns, basic water chemistry, stream density, watershed size, specific land uses, presence/absence of wetlands, etc. that may result in elevated mercury levels in fish tissue); (2) Aid in prioritizing USEPA efforts to reduce health risks associated with Hg in New England; (3) Help target collection of fish tissue to water bodies more likely to have contaminated fish; and (4) Provides information for the development of a regional Hg Total Maximum Daily Load (TMDL), including information about sources of Hg, the relative magnitude of loading from sources, and potential actions for attaining water-quality standards.

Work to be conducted in 2002 includes compilation of dependent variable (Hg in fish tissue) and independent variable (watershed features, Hg inputs and sources, and water-quality data for water bodies where fish tissue has been analyzed) data needed for the model. Existing New England Hg fish tissue concentration data includes USEPA's National Survey of Mercury Concentrations in Fish (1990-1995) data base, state data bases and files, US Fish and Wildlife Service data, USGS National Water-Quality Assessment Program (NAWQA) data, and other special studies in the region. In addition, ancillary data associated with the tissue data will be gathered where available. This includes data on sampling locations and dates, fish species, tissue type, fish size and age, and water body type (i.e., lakes and streams).

Data for the independent or predictor model variables will include: (1) Point source releases of Hg (such as location and Hg release amounts) from USEPA and other data sources; (2) Hg atmospheric-deposition patterns for New England from the National Atmospheric Deposition Monitoring Network program; (3) Water-quality features (water pH, color, and alkalinity) of water bodies with Hg tissue data; and (4) Watershed features generated from the New England

nutrient SPARROW model, such as land use, population, presence of municipal and industrial wastewater point sources, wetlands, soils, stream networks, streamflow and watershed boundaries.

All data compiled and generated via this project will be maintained in data management systems that will allow linkage to GIS. The dependent variable data will be stored initially in ACCESS or SAS. The explanatory data will be maintained in ARC/INFO format.

Biotic mercury information in New York

Nina Schoch, Adirondack Cooperative Loon Program

The Adirondack Cooperative Loon Program (ACLP) is a cooperative research and education project studying the natural history of the Common Loon (*Gavia immer*) and the effects of contaminants and human interactions on loon populations in the Adirondack Park of New York State. The ACLP was initiated in the spring of 2001 to further expand the contaminant research project conducted by BioDiversity Research Institute and the Northeast Loon Study Workgroup in the Adirondack Park from 1998-2000. The ACLP is a partnership of the Wildlife Conservation Society, the Natural History Museum of the Adirondacks, the NYS Dept. of Environmental Conservation, BioDiversity Research Institute, and the Audubon Society of New York, Inc.

The Adirondack Cooperative Loon Program monitors the return rate and reproductive success of loons color-banded as part of the contaminant research. Contaminant sampling and banding of loons has continued in coordination with BioDiversity Research Institute. An index of the summer loon population in the Adirondack Park is obtained through an annual loon census. Education programs have been developed, including a citizen science website, school "Loon Scientist" programs, and presentations about loon natural history, contaminants, and human interactions with loons. The work of the ACLP is coordinated with other research projects studying loons and water quality throughout New York State and North America.

Environmental mercury studies in northern Vermont

Jamie Shanley, U.S. Geological Survey

Since the early 1990s the USGS in Montpelier has collaborated with the University of Vermont and University of Michigan on various Hg studies in the Lake Champlain basin. Most studies have focused on total Hg dynamics in an 11-ha forested watershed, though we have data from ~20 different streams. Sampling has focused on high-flow periods – snowmelt, summer thunderstorms, fall hurricanes. Total Hg in this catchment ranges from <2 ng/L at baseflow to 80 ng/L at peak. More limited sampling in larger streams (mixed land use) and agricultural streams has shown similar dynamics, from ~2 up to 50 ng/L. Dissolved Hg tends to range only from 2 to about 5 ng/L. Other collaborations with this group include Hg in dry deposition and Hg in soil water.

In a USGS- funded effort, we sampled for Hg during the 6-week snowmelt period in both 2000 and 2001 at Sleepers River Watershed in northeastern Vermont. In 2000 we collected 60 samples from 10 streams in watersheds of different size and land use. Hg ranged from <1 to ~15 ng/L (total) and <1 to ~4 ng/L (dissolved). We had strong correlations between HgD and DOC, and between HgT and TOC, even when samples were pooled across sites. In 2001 we took 70 samples in 3 of the 10 streams for closer study of the temporal dynamics. For about 20% of the samples we also analyzed for MeHg.

We recently started a new study on Hg and MeHg movement in the Lake Champlain. Basin. We spent the first year collecting samples in the major inlets and the outlet during high-flow and low-flow, as well as some in-lake samples and some stream sediments. We will use these data in conjunction with land use data to chose 3 sites for intensive sampling (30-50 samples per year per site).

To summarize our findings from the various studies: (1) Dry deposition accounts for as much as 80% of Hg deposition; (2) Less than 10% of Hg deposited to upland environments is exported in streamwater; (3) Dissolved Hg, in association with DOC, contributes a rather steady flux but a small part of the annual load; (4) Particulate Hg, in association with POC, contributes most of the annual Hg load, primarily in a limited number of episodes.

Mercury Analysis – Overview and Laboratory Perspectives

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Laboratory folks sometimes feel that people submitting samples for analysis consider “the lab” to be a black box into which samples flow and from which data trickles. This presentation will attempt to make the box translucent, if not transparent. Current methods for determining Hg and MeHg in water, sediments, tissues, and air will be outlined and laboratory “challenges” will be discussed (i.e., speciation, homogenization, analysis of small samples). We have recently

examined the distribution of Hg within individual loon feathers and across the body of a single loon. These results and their implications for monitoring and research studies will be discussed.

New England Ambient Mercury Monitoring Network
Alan VanArsdale, U.S. Environmental Protection Agency

The New England ambient mercury monitoring network is a hybrid/nested network composed of routine weekly and event based mercury monitoring sites. The oldest site, Underhill (VT), has the longest uninterupted precipitation event monitoring history in the world. This site, which began making mercury measurements in 1992, has also collected elemental gas phase and particlulate mercury to support efforts to understand total mercury deposition studies in the Lake Champlain watershed. In 1995 the first New England Mercury Deposition Network (MDN) site was established by the National Park Service within the Acadia Nationa Park (ME). Subsequently, five additional MDN sites have been deployed as part of a state and federal collaborative effort to characterize spacial and temporal patterns of mercury in precipitation. These sites have been established and supported by the National Estuary Program (NEP), the Regional Applied Research Effort (RARE), and New Hampshire and Maine state agency inititiatives. Six MDN sites continue to collect precipitation samples in Maine and New Hampshire. In 1997, Regional Environmental Monitoring and Assessment Program (REMAP) funds were used to support existing sites and to deploy two additional precipitation event and gaseous/particulate monitoring sites (East Providence (RI) and Quabbin Reservoir (MA)). These two sites and the Underhill (VT) site were designed to measure gaseous mercury along with trace elements (including mercury) in event-precipitation and on particles. Measurements at the Massachusetts and Rhode Island sites ceased in 1999. The speciation data collected at these three sites (1997-1999) are undergiong analyses by the University of Michigan to determine the relative strengths of local, regional, and multi-regional mercury sources/source regions. In 2001, nine precipitation event monitoring sites were deployed to determine the influence of local emission sources (municipal waste combustors, medical waste combusters, oil and coal fired power plants, and area sources) along the central New England coast and the Lower Merrimack River Valley. Three sites are funded by Massachusetts, with the remaining six sites supported by additional REMAP funds. A total of 20 event samples were collected at each site within this nested dense coastal network during the summer and fall of 2001. Chemical analysis of these samples will be complested by the University of Michigan by the end of 2001. Data analysis will proceed the chemical analysis.

Measurements of Elemental Mercury Flux From a Tidal Estuary During Spring and Summer Conditions.

Alan VanArsdale, USEPA, Byard Moshur, Lakeshore Consulting, and Steve Jones, UNH-JEL

One of the most important questions concerning mercury pollution and long-term depuration of contaminated ecosystems is: What is the role and magnitude of mercury evasion from anthropogenic or natural sources? Recent measurements of mercury flux from a variety of terrestrial and aquatic environments indicate that re-emission of mercury and natural emissions of mercury may be significant contributors to local, continental and global mercury cycles. Measurements of mercury flux, in a variety of environments have shown that seasonal emissions of mercury rivaled those of total mercury deposition and that mercury emissions from both freshwater aquatic systems and terrestrial landscapes vary considerably, with dependence on meteorological conditions.

This research measured air-water and air-mud exchanges of mercury during several tidal cycles within a New England tidal estuary. Flux measurements were made during spring and summer months The measurements were made using flux chamber methods in a small cove located next to the UNH Jackson Estuary Laboratory (JEL). A floatable dynamic flux chamber, capable of rising and falling with the tidal cycle, was constructed to sample mercury flux off tidal mud and estuary water. Ambient and within chamber measurements of elemental mercury were made by pulling air samples into a dual channel Tekran mercury analyzer. Solar and tidal conditions, ambient air and water temperature all contributed to changes in mercury flux during the experiments. The highest elemental mercury flux measurements were recorded during the day when the tide was highest and solar radiation was greatest. Elemental flux measurements during the two measurement periods were not significantly different.