

# A Proposed Fish Mercury Monitoring Program for Vermont's Freshwaters

January 15, 2006

A Report to the Vermont General Assembly  
per 10 V.S.A. Chapter 164, §7114

Prepared by the Vermont Fish Contaminant Committee

for

Vermont Department of Environmental Conservation  
Vermont Department of Fish and Wildlife  
Vermont Department of Health

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# 1. Executive Summary

This report answers the charge established by 10 V.S.A. 164, §7114, to prepare a plan addressing fish mercury contamination. The resulting proposed freshwater fish tissue monitoring program is specifically designed to document the occurrence of, and trends in, mercury contamination in freshwater fishes of Vermont, for lakes and rivers, and relate observed changes to management actions. This plan has been developed by the Fish Contaminant Monitoring Committee, which consists of members from the Vermont Departments of Environmental Conservation (DEC) and Fish and Wildlife (DFW), and Health (VDH).

The proposed freshwater fish tissue monitoring program is comprised of three biennially-recurring “rounds” of tissue sampling. In sampling round one, target fishes in specified size ranges are tested from Lakes Champlain and Memphremagog, Vermont’s largest freshwater resources. In round two (two years later), a similar suite of fish species within target size ranges are tested from a suite of 15 inland lakes, and 15 inland third-order or larger rivers. These so-called indicator waters are those which, along with Champlain and Memphremagog, will be used to assess trends in fish mercury, accounting for factors that impact mercury bioaccumulation. In round three (two years following round two), fish mercury testing in a 15-lake and 15-stream randomized selection of waterbodies will be carried out, to provide a statistical assessment of Statewide fish mercury contamination levels. The assessment cycle then begins anew with Champlain and Memphremagog at the next biennium.

In this report, information is also provided regarding where mercury emissions, deposition, and product recycling figures are tracked and maintained. These figures form the basis for overall tracking of the management of mercury. Discussion is provided on how fish mercury changes can be related to management actions, and an example figure is provided showing changes in fish mercury in Lake Champlain to date.

In order to transition from the existing fish monitoring approach to the more rigorous program described above, resources are needed in terms of field support and analytical chemistry. Under the current fish monitoring program, DEC, DFW, and VDH jointly manage the program, and some of the analytical chemistry costs of the proposed program are already accommodated by DEC under its current budget. The total cost for the program, per biennial sampling round, is estimated at approximately \$63,000. A considerable portion of these costs are analytical, and at present a portion of these are already accommodated by the DEC.

A series of recommendations are provided for implementation of this plan. These include: charging the Fish Contaminant Monitoring Committee with management of the program; adoption of the proposed program design; and dedication of resources for field efforts and analytical chemistry. Two specific recommendations are provided that, if implemented, may significantly reduce sample processing time, analytical chemistry costs, and the numbers of fish sacrificed for contaminant testing.

## 2. Statutory charge for this report

10 V.S.A. Chapter 164, § 7114. MERCURY PLANNING

(a) The agency shall develop a plan and identify the necessary resources to accomplish the plan that would provide the necessary data to answer the following questions concerning mercury contamination of fish:

(1) Are fish contaminant levels changing with time and in response to management actions?

(2) Is there a baseline water-column concentration of mercury above which risks to humans and wildlife from mercury become unacceptable?

(b) The plan shall be developed in collaboration among the departments of environmental conservation, fish and wildlife, and health and be submitted to the legislature not later than January 15, 2006.

### 3. Introduction

Mercury is a ubiquitous heavy metal that impacts fish and wildlife resources in Vermont, and significantly affects Vermont's resident and visitor angler use of Vermont's fishery. Mercury is an atmospherically-deposited heavy metal that is emitted from combustion sources, and the largest single source of mercury to Vermont's environment is from the combustion of coal within and outside of New England. Small quantities of mercury also are discharged directly to Vermont waters from wastewater discharges. Vermont has subscribed to the New England Governors and Eastern Canadian Premiers goal of virtual elimination of mercury from the northeast.

The issue of mercury contamination of fishes is not new. Since 1988, Vermont has developed a testing program for fish mercury, and used these results to issue consumption advisories where necessary. However, recent findings regarding the ubiquity of mercury in fishes throughout northeast North America, along with findings of mercury in such diverse wildlife as neotropical migrant songbirds, loons, mink, eagles, and even salamanders has highlighted the need for an expanded testing program to support the public's need for good information about their freshwater fishes. Accordingly, in 2005, the Vermont General Assembly, via 10 V.S.A. Chapter 164, §7114, has directed that a plan be developed to monitor mercury in fish, and to relate observed changes to the management of mercury. This report provides that plan.

Monitoring of fish tissue contaminants in Vermont waters is currently conducted under the Fish Contaminant Monitoring Program. Program activities are directed by the Fish Contaminant Monitoring Committee (FCMC). This group is comprised of members from DEC, DFW, and VDH. The program and committee were instituted in 1988 in a narrow ad-hoc effort to respond to growing concerns over PCB contamination in Lake Champlain. Program focus has gradually expanded since then to cover many contaminants across all state waters.

The program has never been supported by dedicated funding. Program activities are generally conducted as time permits and in conjunction with on-going routine non-program related activities. For any given year, targeted waters are selected by the FCMC during annual meetings. Fish are collected from target waters during routine survey work by the DFW. Fish sample preparation and management are conducted by the DEC member of the FCMC and DEC staff. Samples are chemically analyzed by the DEC LaRosa Laboratory in Waterbury. Priority of lab analysis of fish samples is often low, resulting in inconsistent turn-around times between sample submission and result reports. Data handling and interpretation is primarily the task of the DEC and VDH members of the committee. The information produced by program activities provides much of the basis from which VDH evaluates the need for state fish consumption advisories. The DEC utilizes the information as one element of Federally-mandated ambient water quality and biological monitoring programs. The Fish Contaminant Monitoring Committee also keeps track of other studies of fish contaminants in Vermont waters, and will assimilate non-State data into the fish contaminant database following a quality

vetting process. In this way, information from USEPA and other studies are considered in the derivation of fish consumption advisories.

As of this writing, Vermont's fish contaminant database comprises 979 fish samples that have been analyzed for mercury. These samples have largely been acquired from Lake Champlain and other lakes and ponds. Of the 290 lakes and ponds of 20 acres or larger (excluding Lake Champlain), only 54 lakes have fish mercury data, and of these, the most recently available data for gamefish species dates to 1996. Mercury data from fish from Vermont's streams and rivers are scant and more collections need to be made in these waters to ascertain tissue mercury levels there. The State's most recent efforts (2003 to 2004) have been focused on Lake Champlain. In fact, mercury has been analyzed from fish collected every five years since 1988 at several fixed locations on the lake. Information for Lake Champlain fishes then, is the most complete of any natural water in the state.

Recent studies of fish mercury contamination in northeastern North America<sup>1,2</sup>, Vermont<sup>3</sup>, and nationally<sup>4</sup>, discuss the use of indicator fish species, and indicator waterbodies and waterbody types, in the optimal design of fish monitoring programs. The information from those studies has been considered in the development of this report, in which a fish mercury monitoring program is designed to support human health and ecological risk characterization, while specifically answering the intent of §7114(a)(1).

## **4. Freshwater fish monitoring program**

Detailed below is a freshwater fish tissue monitoring program designed to provide a reliable and recurring stream of fish mercury data that can be used to assess whether tissue mercury levels are decreasing in light of State and Federal initiatives to control mercury releases to the environment. These data will also be provided to VDH for consideration in the fish consumption advisory process.

### ***A. Program design***

The program presented herein leverages three separate sets of sites that are re-visited on a recurring basis. Two sets of sites are comprised of so-called "indicator" sites. It is from these lake and river locations that data would be developed to address the question of whether fish-mercury levels are changing in response to management actions. The same target species, within specific size ranges<sup>5</sup>, are to be collected from the indicator waters over time. The third set of sites is comprised of randomly-selected waterbodies that experience significant fishing use. The use of randomly-selected sites for one-third of the program effort simultaneously provides a statistically-unbiased assessment of statewide fish-mercury levels, and continually-updating information from new waterbodies for advisory development.

Table 1 provides a listing of discrete indicator site and species lists for Lake Champlain and Lake Memphremagog indicator segments, inland lakes and streams indicator locations, and randomly-selected locations. Each set of locations is to be tested every six-years, with two years between each waterbody set. This provides a complete statewide assessment every six years, and yields fresh information biennially. This

biennially-recurring schedule dovetails with federally-required biennial reporting on water quality conditions as part of the Clean Water Act.

Several target species, within target size ranges, have been selected to represent warm and coldwater sites. This species selection accounts for the current understanding of how mercury bioaccumulates to different fish species<sup>2</sup>. The species include lake trout (*Salvelinus namaycush*), brook trout (*S. fontinalis*), smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreum*), yellow perch (*Perca flavescens*), and white perch (*Morone americana*). For the Lake Champlain / Memphremagog and inland indicator sites, the analysis of a small number of smaller, whole fish (e.g. preyfish) allows for assessment of mercury availability to piscivorous wildlife.

The specific lake segments and streams that are shown in Table 1 have been selected accounting for geographic distribution throughout Vermont, and for three important factors that influence mercury bioaccumulation from waters of differing types<sup>3,6</sup>. These factors are acidity, nutrient enrichment, and water level fluctuation. Lake acidity enhances fish mercury bioaccumulation by enhancing the transport of mercury from watersheds to receiving waters, and accelerating the transformation of atmospherically-deposited mercury to toxic methylmercury. Water level fluctuations are known to enhance the rate at which mercury is transformed to the toxic methylmercury form. By contrast, nutrient enrichment in lakes reduces the efficiency by which methylmercury is bioaccumulated, due to dilution of the mercury in a more biologically-rich environment.

It is important to note that not every species listed in Table 1 will be available from each identified waterbody. As such, the sample numbers provided constitute the maximum number of samples likely to be acquired from each category of waterbodies for each biennium.

Table 1. Overall design of the proposed Vermont Fish Mercury Monitoring Program.

Waterbody set	Sampling biennium	Fishery type, target species, number	Locations (preliminary listing)	Total number of samples
Lake Champlain / Memphremagog Indicator Sites	1	<i>Coldwater:</i> Lake Trout (10, 24" or larger)	Otter Creek/Port Henry Main Lake (Grand Isle, Essex N.Y.)	30
		<i>Warmwater:</i> Walleye (5, 18"-20") Smallmouth bass (10, 12"-16") White perch (10, ≥ 6") Yellow perch (10, 6"-10") Yellow perch (10, <6", whole fish)*	Burlington Bay South Lake St. Albans Bay Missisquoi Bay Inland Sea Main Lake Malletts Bay Memphremagog**	Up to 315
Inland Indicator Sites	2	<i>Lakes:</i> Walleye (5, 18"-20") Smallmouth bass (5, 12"-16") Yellow perch (5, 6"-10") Lake trout (5, ≥18") Yellow perch (5, <6", whole fish)*	Bomoseen Willoughby Somerset/Harriman*** Carmi Dunmore Maidstone Shelburne Fairfield Harveys Peacham Rescue Shadow (Concord) Townshend Sunset (Marlboro) Green River	Up to 375

Waterbody set	Sampling biennium	Fishery type, target species, number	Locations (preliminary listing)	Total number of samples
		<i>Streams:</i> Smallmouth bass (5, 12"-16") Yellow perch (5, 6"-10") Brook trout (native stock, 5, ≥6")	Missisquoi River Lamoille River Winooski River Otter Creek Hoosic River Deerfield River West River Black R. (to Conn. River) Ottaqueechee River White River Passumpsic River Nulhegan River Black R. (to Memphremagog) Connecticut River (lower) Connecticut river (upper)	Up to 150
Statewide random	3	<i>Lakes:</i> Smallmouth bass (5, 12"-16") Yellow perch (5, 6"-10") Lake trout (5, ≥18") Yellow perch (5, <6", whole fish)*	15-site random probability survey of selection of lakes > 50 acres in size	Up to 300
		<i>Streams:</i> Smallmouth bass (5, 15"-18") Yellow perch (5, 6"-10") Brook trout (native stock, 5, ≥6")	15-site random probability survey of 3+ order streams	Up to 150

\*Whole fish samples are collected for an assessment of ecological health.

\*\* Sample sizes will be doubled for Memphremagog in the first round of sampling as no fish mercury data exist from this lakes U.S. waters. There exist 15 tissue samples from the central portion of Lake Memphremagog in Canadian waters.

\*\*\* These two reservoirs are part of the Deerfield Chain Hydroelectric Project waters. In order to capture data from both of these important reservoirs, they will be sampled alternately between biennial cycles.

## ***B. Field program logistics***

Carrying out the proposed program requires that on a biennial basis, field staff be available to acquire and process fish samples, under the supervision of DFW field biologists. The current level of staffing within DFW field offices is insufficient to accommodate the enhanced field sampling initiative, particularly during round one, when efforts are dedicated to Lake Champlain and Memphremagog, and therefore would entirely be the responsibility of fisheries biologists in the Rutland, Essex Junction, and St. Johnsbury field offices. Two options are thus available. The first would be to secure dedicated funding to hire a crew of two fisheries technicians, who would be under the supervision of biologists, and whose primary function would be to secure fish tissue samples and prepare them for analysis. The second option would be to contract the field sampling and tissue preparation activities to a qualified contractor.

## ***C. Processing and analysis***

The analysis of fish tissue contaminant levels involves two steps; preparation, and chemical analysis. Preparation (wherein fish are “homogenized”) is most efficiently carried out by the field crew hired/contracted to collect the samples, as this activity can be fit into the overall field effort during poor weather or equipment repair days. Fish tissue preparation is time-consuming, messy, and highly wasteful of fish. Scientists are presently evaluating whether biopsy samples of tissue taken from live fish (so-called biopsy plugs) may be used instead of taking and homogenizing the tissues of individual fishes. This approach has been proven by several studies to yield equivalent data to the traditional methods<sup>7</sup>, and should be strongly considered and further evaluated as a cost and fish-saving measure.

Chemical analysis should continue to be carried out by DEC by the LaRosa Environmental Laboratory, using the EPA-approved cold-vapor atomic absorption method. A second cost-saving measure may be achievable here in regards to analytical chemistry. New instrumentation is available that eliminates the need for preparation of fish tissues by directly processing un-homogenized biopsy plugs. Given that the major cost associated with analytical mercury chemistry is time-consuming tissue preparation, the acquisition of such an instrument, a \$30,000 investment, should be strongly considered.

## ***D. Assessing fish and wildlife mercury risk using water column mercury concentrations***

The environmental risks of mercury contamination are not limited to humans. It is well documented that animals at many levels of the food chain are adversely affected by mercury in the environment. Recent research in New England and elsewhere has focused on fish-eating waterfowl as indicators of ecosystem sensitivity to mercury contamination<sup>3,7</sup>. Under § 304 of the Clean Water Act, USEPA allows for the use of water-column contaminant levels that are shown to be protective of ecological health. Applied to mercury, this approach essentially attempts to establish a maximum water

column concentration beyond which mercury bioaccumulation will adversely affect higher-level organisms. The resulting criterion value is known as a wildlife criterion value (WCV). Studies from Vermont<sup>4</sup> and elsewhere<sup>8</sup> have shown that establishing a WCV that is protective of ecosystem health is a difficult task.

That is not to say that a WCV that is scientifically-linked to ecosystem health is not attainable. The relationships between fish mercury and piscivorous waterfowl mercury are well described,<sup>9</sup> with predictable increases in bird risk as preyfish mercury levels increase. Leveraging this type of relationship, the Great Lakes Initiative has established a very conservative water column criterion (1.3 parts-per-trillion of total mercury) for direct dischargers that is intended to protect aquatic wildlife. The State of Maine has also invested in the development of such a WCV<sup>10</sup>, and although the criterion has not yet been promulgated, it is similarly conservative (1.4 ppt). If developed, these criterion limits may, along with fish concentrations, serve as target values for the purposes of identifying and addressing mercury-impaired waters.

The development of a water-column criterion value for Vermont could adopt one of two approaches: 1) adaptation of an existing value (e.g., Maine's); or, 2) development of a Vermont-specific WCV based on the relationships between water mercury and fish-mercury, and fish mercury and fish-eating bird mercury levels. As water quality criteria carry significant regulatory impact on all potential waste dischargers, the development of a WCV should not be entered into lightly, and should be tailored to Vermont's water quality conditions.

It is recommended that this activity initially be approached by undertaking a sampling of water column mercury levels collected at the same time and place as the whole-bodied fish samples that are acquired during the sampling rounds described in Table 1 (above)<sup>10</sup>. The existence of a relationship between these water mercury concentrations and the associated whole-fish samplings will indicate if a reliable WCV can be developed. This should be carried out for the course of one full statewide assessment cycle, after which time the relationships between water mercury and preyfish mercury will be well understood. An alternate and more costly approach would be to undertake a separate study to specifically develop a WCV for Vermont waters.

### **E. Cost for the freshwater fish monitoring program**

Table two identifies the total cost to carry out the proposed fish monitoring program. The cost estimates provided are in 2005 dollars, and represent the maximum likely costs before processing and chemistry method changes are imposed, and assuming that all possible fish species will be sampled from all identified waters. DEC analytical chemistry costs are broken down by sampling biennium, while DFW costs are recurring biennial costs.

Table 2. Costs associated with the proposed fish mercury monitoring program.

Task area↓ / Lead agency→	DEC	DFW	VDH
Annual program planning	No direct cost needed		
Fish collection			No costs
-crew salary (4 mo)		\$26,200	
-equipment and supplies		\$1,000	
-vehicle lease (3 mo)		\$1,800	
Analytical chemistry*			
-Yr 1 Champlain/Memphremagog	\$24,120		
-Yr 2 Indicator waters- inland	\$37,800		
-Yr 3 Random survey waters	\$32,400		
-Water mercury, all sampling years	\$2,250/year		
Data management /archiving	No direct cost needed		
Total per biennium	\$33,690 (average)	\$29,000	

\*Analytical chemistry costs should be considered the maximum possible expenditures, depending on species sampled.

## **5. Management action tracking**

On a statewide and regional basis, several items are tracked in regards to management actions that address mercury. At the regional and state level, these include emissions inventories and reductions, air mercury deposition, and product use and recycling. DEC and partner agencies formally track these.

### **A. Emissions reductions**

Since 1996, air Mercury emissions and emission reductions have been tracked regionally by the Northeast States for Cooperative Air Use Management (NESCAUM), as part of their agreement with the New England Governors and Eastern Canadian Premiers. The most recently available inventory was issued by NESCAUM in 2004. A Vermont-specific mercury emissions inventory is maintained and updated approximately biennially by the DEC Air Pollution Control Division, and that inventory is provided to NESCAUM. While emission inventories are very useful to track the effects of regulation

on mercury emissions, it should be understood that changes to the inventories from one issuance to the next can result from changes in Mercury use, changes in sources, changes in emissions, or simply changes in how inventories are tabulated.

### ***B. Air deposition***

Vermont hosts the well-known and longest-running atmospheric mercury monitoring station in the world, at Underhill, VT. The maintenance and operation of the site is a joint initiative of the University of VT., the Vermont Monitoring Cooperative (VMC), USEPA, and DEC. The monitoring data are maintained by VMC, and are available to DEC upon request.

### ***C. Mercury in products***

In addition to the mercury sales and product labeling tracking performed by DEC (per 10 V.S.A. Chapter 164), Vermont's solid waste management districts are required to report to DEC the pounds of mercury they take in for recycling and hazardous waste removal. These values, along with fluorescent lamp recycling rates, are tracked by DEC and reported annually in conjunction with the Vermont Advisory committee on Mercury Pollution's annual report to the legislature.

## **6. Relating fish mercury changes to actions**

Given the present composition of the Vermont fish contaminant database, changes in fish mercury levels with time can only be established for Lake Champlain with limited resolution. The available data indicate that walleye mercury levels have declined from before 1990 to between 1999, and have remained steady thereafter. The same data also indicate that walleye levels are considerably lower in the nutrient-rich Missisquoi Bay and South Lake segments, relative to the less nutrient-enriched Otter Creek and Malletts Bay segments (Figure 1). However, because of a lack of data from each segment for each time period, we cannot determine whether walleye mercury declines are system-wide, or segment-specific. The proposed fish monitoring program design will provide the data necessary to completely analyze trends such as that suggested by Figure 1, and in concert with management actions. These data can then easily be examined against trends in mercury emissions, deposition, and product usage and release.

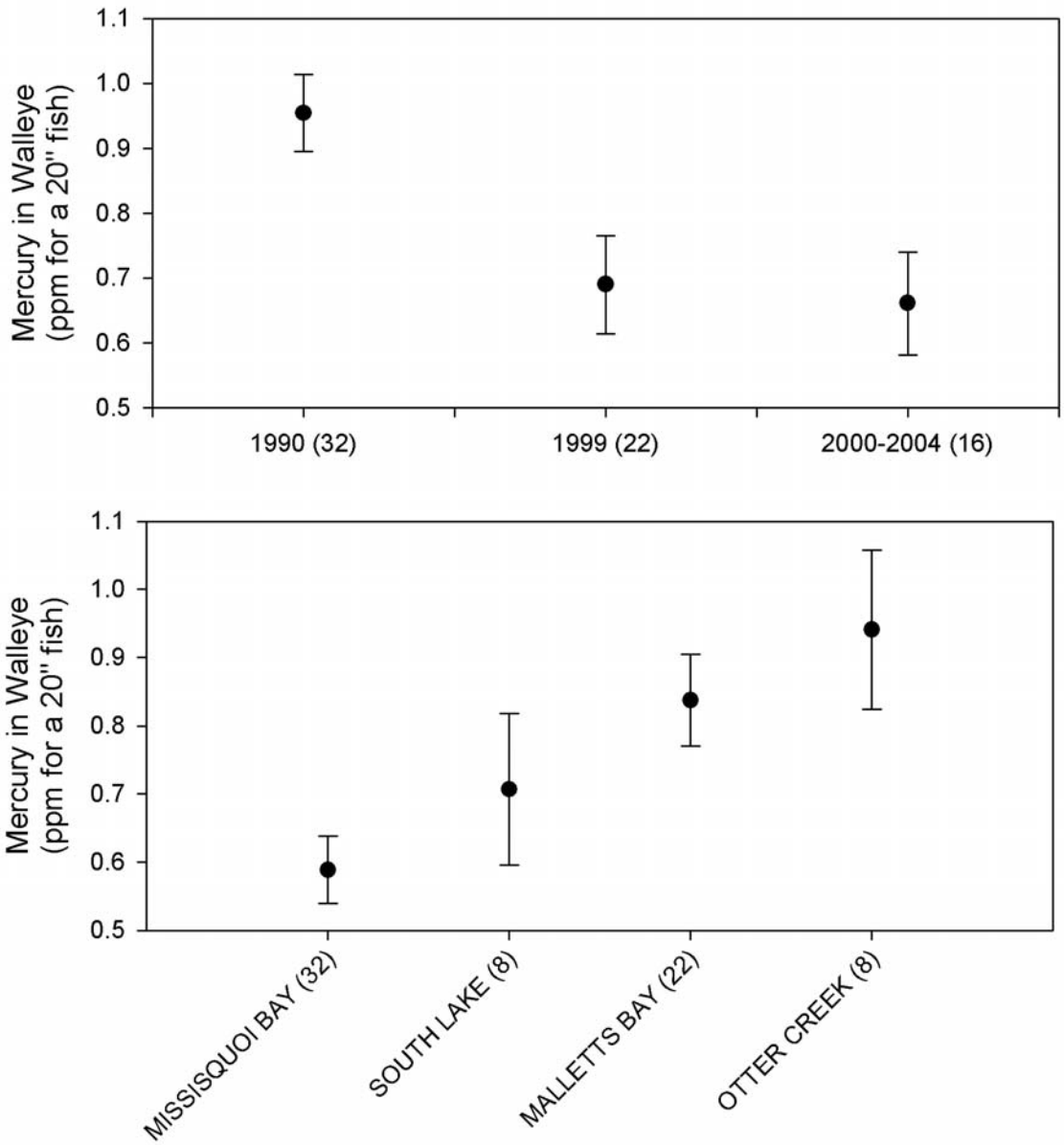


Figure 1. Comparison of mercury concentrations in Lake Champlain walleye from 1987 to present, and in four Lake segments, normalized to fish length (sample size is provided in parentheses, bars are standard errors). Missisquoi Bay and South Lake are nutrient-rich lake segments, which may explain why fish mercury levels are lower in those segments.

## 7. Recommendations

The following recommendations stem from this planning report:

- 1) Retain the FCMC structure to implement and oversee the fish contaminant testing program. The Committee structure ensures coordination amongst DFW, VDH, and DEC.
- 2) Beginning in summer 2007, initiate the proposed fish tissue mercury monitoring program, starting with inland indicator lakes and rivers (sampling biennium 2).
- 3) Ensure that institutional support and funding exists to provide field support to DFW for fish sampling.
- 4) Ensure that institutional support and adequate funding exists within DEC to accommodate analytical chemistry costs for mercury analyses, and to ensure that the resulting data continue to properly be managed.
- 5) Investigate the cost savings and efficiencies achievable by adopting non-lethal biopsy-plugs and updating analytical mercury instrumentation at the LaRosa Laboratory. The savings in sampler time, analysts time, and fish resources may be considerable.

## 8. References and annotations

- <sup>1</sup> Kamman et al., 2005. Mercury in freshwater fish of northeast North America. A geographic perspective based on fish tissue monitoring databases. *Ecotoxicology* 14(1-2).
- <sup>2</sup> Mercury Connections. The extent and effects of mercury pollution in northeastern North America. 2005. Biodiversity Research Institute, Gorham, ME. [www.briloon.org](http://www.briloon.org).
- <sup>3</sup> Kamman et al. 2004. Assessment of mercury in sediment waters and biota in New Hampshire and Vermont lakes sampled using a geographically randomized design. *Environmental Toxicology and Chemistry* 23-5.
- <sup>4</sup> Mason et al. 2005. Monitoring the response to changing mercury. *Environmental Science and Technology* 39(1).
- <sup>5</sup> Fish mercury concentrations are highly related to fish size. Larger (and therefore older) fish bioaccumulate more mercury. Constraining fishes to target size ranges ensures that comparisons of mercury levels across years made within the same lakes or rivers will be valid.
- <sup>6</sup> Driscoll et al., 2006 in press. Mercury Contamination in Remote Forest and Aquatic Ecosystems in the Northeastern U.S.: Sources, Transformations and Management Options. *Bioscience*.
- <sup>7</sup> Petersen et al., 2004. A Biopsy Procedure for Determining Filet and Predicting Whole-Fish Mercury Concentration. *Archives of Environmental Contamination and Toxicology*. 48: 98-107.
- <sup>8</sup> Chen et al., 2005. Patterns of mercury bioaccumulation and transfer in aquatic food webs across multi-lake studies in the northeast U.S. *Ecotoxicology* 14(1-2).
- <sup>9</sup> Evers, D. 2004. Assessing the impacts of methylmercury on piscivorous wildlife using a wildlife criterion value based on the Common Loon, 1998-2003. Biodiversity Research Institute, Gorham, ME. [www.briloon.org](http://www.briloon.org).
- <sup>10</sup> Reference 7 (above) describes that relationships between water-column and fish-tissue mercury levels are only reliable where the samples are collected simultaneously.