ORAL ARGUMENT NOT YET SCHEDULED

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

STATE OF NEW JERSEY, et al.,	
Petitioners,	
v.	No. 05-1097, and consolidated cases
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY,	**Complex**
Respondent.	

On Petitions for Review of Final Actions
of the United States Environmental Protection Agency

FINAL OPENING BRIEF OF GOVERNMENT PETITIONERS

The States of New Jersey, California, Connecticut, Delaware, Illinois, Maine, Maryland Massachusetts, Michigan Department of Environmental Quality, Minnesota, New Hampshire, New Mexico, New York, Pennsylvania Department of Environmental Protection, Rhode Island, Vermont, and Wisconsin, and the City of Baltimore

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CERTIFICATE AS TO PARTIES, RULINGS, AND RELATED CASES

Pursuant to Circuit Rule 28(a)(1), the undersigned counsel of record certify as follows:

A. PARTIES AND AMICI

1. Parties to the Challenges to the EPA Delisting Rule: 70 Fed. Reg. 15994 (March 29, 2005)

Petitioners

The following parties appear in these consolidated cases as petitioners:

In case no. 05-1097, filed March 29, 2005, the State of New Jersey, State of California, State of Connecticut, State of Maine, Commonwealth of Massachusetts, State of New Hampshire, State of New Mexico, State of New York, State of Vermont.

In case no. 05-1104, filed April 1, 2005, the Commonwealth of Pennsylvania, Department of Environmental Protection.

In case no. 05-1116, filed April 11, 2005, the State of Delaware.

In case no. 05-1118, filed April 8, 2005, the State of Wisconsin.

In case no. 05-1158, filed May 18, 2005, Chesapeake Bay Foundation, Inc., Conservation Law Foundation, Waterkeeper Alliance.

In case no. 05-1159, filed May 18, 2005, Environmental Defense, National Wildlife Federation and Sierra Club.

In case no. 05-1160, filed May 18, 2005, Natural Resources Council of Maine, Ohio Environmental Council and U.S. Public Interest Research Group.

In case no. 05-1163, filed May 18, 2005, Natural Resources Defense Council.

In case no. 05-1174, filed May 27, 2005, State of Illinois.

In case no. 05-1176, filed May 27, 2005, the State of Minnesota.

Respondent

The United States Environmental Protection Agency is respondent in these consolidated cases.

Intervenors

The following parties have intervened in these consolidated cases for Respondent: Utility Air Regulatory Group, Cinergy Corp., PPL Corp., PSEG Fossil LLC, NRG Energy, Inc., Florida Power & Light Company, State of Alabama, State of Indiana, State of Nebraska, State of North Dakota, State of South Dakota.

The following parties have intervened in these consolidated cases for Petitioners: Physicians for Social Responsibility, American Nurses Association, The American Public Health Association, American Academy of Pediatrics, Adirondack Mountain Club, Aroostook Band of Micmac Indians, Houlton Band of Maliseet Indians, Penobscot Indian Nation, The Passamaquoddy Tribe at Pleasant Point (Sipayik), The Passamaquoddy Tribe at Indian Township, The City of Baltimore.

Amici

The following parties appear as amici in these consolidated cases:

In support of respondent EPA: Washington Legal Foundation

2. Parties to the Challenges to the EPA Clean Air Mercury Rule: 70 Fed. Reg. 28606 (May 18, 2005)

Petitioners

The following parties appear in these consolidated cases as petitioners:

In case no. 05-1162, filed May 18, 2005, the State of New Jersey, State of California, State of Connecticut, State of Maine, Commonwealth of Massachusetts, State of New Hampshire, State of New Mexico, State of New York, Commonwealth of Pennsylvania, State of Vermont, State of Wisconsin.

In case 05-1164, filed May 19, 2005, Ohio Environmental Council, Natural Resources Council of Maine, U.S. Public Interest Research Group.

In case 05-1167, filed May 19, 2005, Natural Resources Defense Council.

In case 05-1175, filed May 27, 2005, State of Minnesota.

In case 05-1183, filed May 31, 2005, State of Delaware.

In case 05-1189, filed May 27, 2005, State of Illinois.

In case 05-1263, filed July 12, 2005, Mayor and City Council of Baltimore.

In case 05-1267, filed July 14, 2005, Chesapeake Bay Foundation, Inc., Environmental Defense, National Wildlife Federation, Sierra Club, Waterkeeper Alliance.

In case 05-1270, filed July 15, 2005, American Coal for Balanced Mercury Regulation, Alabama Coal Association, Coal Operators & Associates, Inc., Maryland Coal Association, Ohio Coal Association, Pennsylvania Coal Association, Virginia Coal Association, West Virginia Coal Association.

In case 05-1271, filed July 15, 2005, ARIPPA.

In case 05-1275, filed July 18, 2005, Utility Air Regulatory Group.

In case 05-1277, filed July 18, 2005, United Mine Workers of America, AFL-CIO.

Respondent

The United States Environmental Protection Agency is respondent in these consolidated cases.

Intervenors

The following parties have intervened in these consolidated cases for Respondent: Utility Air Regulatory Group, Edison Electric Institute, State of Alabama, State of Nebraska, State of South Dakota, State of North Dakota.

The following party has intervened in these consolidated cases for Petitioners: Michigan Department of Environmental Quality.

Amici

No parties appear as amici in these consolidated cases:

3. Parties to the Challenges to EPA's Final Action on Reconsideration: 71 Fed. Reg. 33388 (June 9, 2006)

Petitioners

The following parties appear in these consolidated cases as petitioners:

In case no. 06-1211, filed June 19, 2006, the State of New Jersey, State of California, State of Connecticut, State of Delaware, State of Illinois, State of Maine, State of Minnesota, State of New Hampshire, State of New Mexico, State of New York, State of Rhode Island, State of Vermont, State of Wisconsin, the Commonwealths of Massachusetts and Pennsylvania, and the Michigan Department of Environmental Quality.

In case no. 06-1220, filed June 23, 2006, National Congress of American Indians, Little River Band of Ottawa Indians, Bay Mills Indian Community, Grand Traverse Band of Ottawa

and Chippewa Indians, Jamestown S'Klallam Tribe, Lac Courte Oreilles Band of Lake Superior Chippewa Indians, Little Traverse Bay Bands of Odawa Indians, Lower Elwha Klallam Tribe, Lummi Nation, Minnesota Chippewa Tribe, Nisqually Tribe, Swinomish Indian Tribe Community.

In case no. 06-1231, filed June 26, 2006, American Nurses Association, The American Public Health Association, American Academy of Pediatrics, Chesapeake Bay Foundation, Inc., Conservation Law Foundation, Environmental Defense, National Wildlife Federation, Natural Resources Council of Maine, Natural Resources Defense Council, Ohio Environmental Council, Physicians for Social Responsibility, Sierra Club, U.S. Public Interest Research Group, Water Keeper Alliance.

In case no. 06-1287, filed July 26, 2006, Mayor & City Council of Baltimore.

In case no. 06-1291, filed August 8, 2006, American Coal for Balanced Mercury Regulation, Alabama Coal Association, Coal Operators and Associates of Kentucky, Maryland Coal Association, Ohio Coal Association, Pennsylvania Coal Association, Virginia Coal Association, West Virginia Coal Association.

In case no. 06-1293, filed August 8, 2006, ARIPPA.

In case no. 06-1294, filed August 8, 2006, Alaska Industrial Development and Export Authority.

Respondent

The United States Environmental Protection Agency is respondent in these consolidated cases.

Intervenors

No parties appear as intervenors in these consolidated cases.

Amici

No parties appear as amici in these consolidated cases.

B. RULINGS UNDER REVIEW

Petitioners State of New Jersey et al, in these consolidated cases seek review of final actions by EPA:

1. A rule entitled "Revision of December 2000 Regulatory Finding on the Emissions of Hazardous Air Pollutants from Electric Utility Steam Generating Units and the Removal of Coal- and Oil-Fired Electric Utility Steam Generating Units from the Section 112(c) List," 70 Fed. Reg. 15,994 (March 29, 2005).

2. A rule entitled "Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units," 70 Fed. Reg. 28,606 (May 18, 2005).

3. A rule entitled "Revision of December 2000 Clean Air Act Section 112(n) Finding Regarding Electric Utility Steam Generating Units; and Standards of Performance for New and Existing Electric Utility Steam Generating Units: Reconsideration, Final Rule" published at 71 Fed. Reg. 33,388 (June 9, 2006).

C. RELATED CASES

The matter on review has not been previously heard in this or any other court. There are no related cases pending before the Court.

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GLOSSARY

Pursuant to Circuit Rule 28(a)(3), the following is a glossary of all acronyms and abbreviations used in this brief:

112(c) List	List of Sources Subject to Regulation Pursuant to 42 U.S.C. § 7412
Act/CAA	Clean Air Act, 42 U.S.C. §§ 7401 et seq.
CAIR	Clean Air Interstate Rule, 70 Fed. Reg. 72,268 (Nov. 22, 2005)
CAMR	Clean Air Mercury Rule, 70 Fed. Reg. 28,606 (May 18, 2005)
Delisting Action/Rule	70 Fed. Reg. 15,994 (March 29, 2005)
EGUs	Electric utility steam generating units
EPA	United States Environmental Protection Agency
Government Petitioners	State and municipal petitioners
HAPs	Hazardous air pollutants, 42 U.S.C. §§ 7412(a)(6); 7412(b)
ICR	Information collection request
MACT	Maximum achievable control technology, 42 U.S.C. § 7412(d)
NOAA	National Oceanic and Atmospheric Administration
NO_x	Nitrogen oxides
NSPS	New source performance standards
RTC	EPA Utility Report to Congress, 65 Fed. Reg. 79,825 (Dec. 20, 2000)
SO_2	Sulfur dioxide
Title IV program	42 U.S.C. §§ 7651-7651

JURISDICTIONAL STATEMENT

This Court has exclusive jurisdiction to review any "nationally applicable regulations promulgated, or any final action taken" by EPA under the Act. 42 U.S.C. § 7607(b). In these consolidated cases, Government Petitioners challenge EPA's nationally applicable regulations at 70 Fed. Reg. 15,994 (Mar. 29, 2005), and 70 Fed. Reg. 28,606 (May 18, 2005), and its final action on reconsideration of these regulations at 71 Fed. Reg. 33,389 (June 9, 2006). As set forth in the Certificate as to Parties, supra, Government Petitioners filed petitions for review of these regulatory actions within the sixty-day period provided in 42 U.S.C. § 7607(b).

STANDING

Government Petitioners suffer injuries due to EPA's mercury rules sufficient to confer standing. First, the rules impose a regulatory and economic burden on the states to either participate in a cap-and-trade program promulgated under section 111 of the Act, or obtain reductions in mercury emissions through other mechanisms. States have incurred economic costs in either promulgating state plans or joining the cap-and-trade program, and will continue to incur costs through the lifetime of the regulations. See Aff. of William O'Sullivan ("O'Sullivan Aff.") ¶ 4; 71 Fed. Reg. 75,117 (Dec. 14, 2006). Second, the rules will make it more difficult for states to comply with water quality standards required under the Clean Water Act. See O'Sullivan Aff. ¶ 7; 33 U.S.C. § 1313(d); West Virginia v. EPA, 362 F.3d 861, 868 (D.C. Cir. 2004) (Injury sufficient to confer standing found where an EPA rule made the state task of devising an adequate state implementation plan more difficult). Finally, the rules injure the interests of Government Petitioners by allowing continued high levels of mercury emissions from power plants. These emissions play a significant contributory role in ongoing impacts to the

natural resources of, and economic burden on, Government Petitioners. See Idaho v. ICC, 35 F.3d 585, 591 (D.C. Cir. 1994) (State standing established based on pollution damage to its natural resources); O'Sullivan Aff., ¶¶ 8-9; Decl. of Ray Vaughan ("Vaughan Decl") ¶¶ 3, 6-13; Comments of Hubbard Brook Research Foundation ("Hubbard Brook Comments") at 7-17, OAR-2002-0056-2038 [JA 733-743]. These injuries can be redressed by a ruling from this Court vacating EPA's mercury rules and requiring the agency to establish source-specific emissions standards for all power plants as required under section 112 of the Act. See O'Sullivan Aff., ¶¶ 8-9; Vaughan Decl. ¶¶ 14-17; Hubbard Brook Comments at 13 [JA 739]; 42 U.S.C. § 7412(d).

STATEMENT OF ISSUES

1. In December 2000, EPA added EGUs to the list of sources subject to regulation under section 112 of the CAA, 42 U.S.C. § 7412, but has now removed EGUs from that list without satisfying the removal criteria in section 112(c)(9). Did EPA exceed its statutory authority, fail to observe procedure required by law, or otherwise act arbitrarily or capriciously?

2. In the Delisting Action, EPA rescinded its December 2000 conclusion that EGUs should be regulated pursuant to CAA section 112. Was EPA's decision to rescind the December 2000 conclusion in excess of statutory authority, arbitrary, capricious, or an abuse of discretion?

3. Through CAMR, EPA uses CAA section 111 to establish a cap-and-trade system for the regulation of a hazardous air pollutant, mercury. Did EPA exceed its statutory authority under CAA section 111(d) which prohibits the use of section 111 to regulate hazardous air pollutants and/or act arbitrarily and capriciously in light of the requirements for a "standard of performance" under section 111?

STATUTES AND REGULATIONS

The relevant provisions of the Act are 42 U.S.C. §§ 7411 (Standards of performance for new stationary sources), and 7412 (Hazardous air pollutants). The rules were promulgated at 40 C.F.R. Parts 60, 63, 72, and 75. The rules, together with relevant portions of statutory and regulatory provisions and legislative history, are contained in the Addendum.

STATEMENT OF THE CASE

State and municipal petitioners ("Government Petitioners") seek review of two rules promulgated by the Environmental Protection Agency ("EPA") relating to the emission of hazardous air pollutants ("HAPs") from electric utility steam generating units ("EGUs" or "power plants"). In 2000, EPA concluded that such emissions, including mercury, warranted regulation pursuant to section 112 of the Clean Air Act ("Act") and added power plants to a list of sources subject to such regulation (the "112(c) List"). 65 Fed. Reg. 79,825, 79,830-31 (Dec. 20, 2000). Having taken that action, EPA was required to establish plant-specific limits on power plant emissions reflecting the maximum degree of reduction in HAP emissions achievable for similar sources. See 42 U.S.C. § 7412(d)(3). EPA was further prohibited from removing power plants from the 112(c) List unless certain criteria were met. See 42 U.S.C. § 7412(c)(9).

EPA failed to meet its statutory duties and instead published two rules that seek to exempt power plants - emitters of more than 150,000 tons of HAPs annually, including over 30% of the nation's mercury emissions, U.S. EPA, Study of [HAP] Emissions from [EGUs] - Final Report to Congress, EPA-452/R-97-005 (Feb. 1998) ("RTC"), at ES-5 [JA 69] - from the stringent regulatory framework of section 112. In the first rule, the "De-Listing Action," EPA removed EGUs from the 112(c) List without attempting to satisfy the statutory removal criteria.

70 Fed. Reg. at 16,002-16.008. EPA then promulgated in the second rule, the "Clean Air Mercury Rule" ("CAMR"), regulations under section 111 that govern power plant mercury emissions through a cap-and-trade scheme, not the statutorily-required plant-specific approach. 70 Fed. Reg. at 28,624-30. Petitioners ask this Court to correct EPA's legal errors, vacate the rules, and direct the agency to promulgate emission standards for the hazardous air pollutants emitted by power plants under section 112 as required by the Act. By orders dated December 8, 2005, and August 21, 2006, this Court consolidated these petitions and designated New Jersey v. EPA (No. 05-1097) as the lead case.

STATEMENT OF FACTS

A. Hazardous Air Pollutant Regulation Under the Clean Air Act

The 1970 Amendments added section 112 to the Act, which specified that the EPA Administrator must list each "hazardous air pollutant for which he intends to establish an emission standard." Pub.L. 91-604, § 4(a), 84 Stat. 1685. After a pollutant was listed, the Act required EPA to propose emission standards set at a level that "provides an ample margin of safety to protect the public health" from the pollutant. Id.

Between 1970 and 1990 when the Act was again amended, EPA established standards under section 112 for only seven hazardous air pollutants. Nat'l Mining Ass'n v. EPA, 59 F.3d 1351, 1353 and n.1 (D.C. Cir. 1995) (citing S. Rep. No. 228, 101st Cong., at 131 (1989)). Of these seven, mercury, along with asbestos and beryllium, were the first pollutants listed as hazardous. See 36 Fed. Reg. 5,991 (Mar. 31, 1971). For even these listed pollutants, EPA established emission standards for only a small subset of their sources. Nat'l Mining Ass'n, 59

F.3d at 1353 and n.1 (citing S. Rep. No. 228, 101st Cong., at 128 (1989) and H.R. Rep. No. 490(I), 101st Cong., at 322 (1990)).

To address the slow pace of EPA's regulatory action, the 1990 Amendments to the Act completely restructured the regulation of HAPs under section 112. Id. These amendments continued the Act's distinct treatment of HAPs[1], and required EPA to set the "most stringent standards achievable" for sources of HAPs which are standards "based on the maximum reduction in emissions which can be achieved by application of [the] best available control technology" ("MACT Standards").[2] Cement Kiln Recycling Coalition v. EPA, 255 F.3d 855, 857 (D.C. Cir. 2001). The new amendments established a list of 188 HAPs, 42 U.S.C. § 7412(b)(1), set a mandatory schedule for issuing emissions standards for the major sources of these pollutants, 42 U.S.C. §§ 7412(c) and (e), and established a "non-discretionary duty" on EPA to promulgate technology-based emission standards for all categories of major emitting sources of listed HAPs. See S. Rep. 101-228, at 3385, 3518, 3541, reprinted in 1991 U.S.C.C.A.N.; 42 U.S.C. § 7412(b),(c), and (e). The only exception to the mandatory standards applies to source categories either: a) listed for regulation because of a single HAP which was later removed from the list of HAPs under section 112; or b) for which EPA makes a formal determination that the emissions of no source in the category exceeds risk thresholds set by Congress. See 42 U.S.C. § 7412(c)(9)(B).

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[1] See H.R. Rep. No. 101-490, at 3339 (May 21, 1990) ("The Clean Air Act distinguishes between two categories of pollutants: hazardous air pollutants and criteria or conventional air pollutants.")

[2] For existing major sources of HAPs, MACT standards must be no less stringent than the "average emission limitation achieved by the best performing 12 percent of the existing sources." 42 U.S.C. § 7412(d)(3)(A).

The 1990 Amendments imposed an additional requirement on EPA before regulating EGUs under section 112. Section 112(n) required EPA to perform by 1993 a study of the health hazards posed by toxic substances emitted from EGUs and determine whether it is "appropriate and necessary" to regulate such emissions as HAPs under section 112. 42 U.S.C. § 7412(n). Once such a determination was made and EGUs were placed on the source category list, Congress required that EPA "shall" regulate EGUs under section 112 through the promulgation of MACT standards. Id.

B. EGU Study and Appropriate and Necessary Determination

EPA undertook the study of hazards to public health reasonably expected to be caused by power plant emissions and in February 1998, five years after the statutory deadline, the agency released its utility report to Congress and the public. 65 Fed. Reg. 79,825 (Dec. 20, 2000). EPA concluded that "mercury from coal-utilities is the HAP of greatest potential concern," RTC, at ES-76, [JA 91], and estimated that approximately sixty percent of the total mercury deposited in the United States comes from "U.S. anthropogenic air emission sources; the percentage is estimated to be even higher in certain regions (e.g., northeast U.S.)." 65 Fed. Reg. at 79,827.

On December 20, 2000, after years of peer-reviewed scientific and technical study including a National Academy of Sciences report, numerous public hearings, and extensive public comment, EPA published its regulatory finding on the emissions of HAPs from EGUs. 65 Fed. Reg. 79,825. In this action, EPA added EGUs to the section 112 List of source categories after concluding that the "regulation of HAP emissions from [EGUs] under section 112 of the [Act] is appropriate and necessary." Id. at 79,826 ("[T]his notice adds coal- and oil-fired [EGUs] to the list of source categories under section 112(c) of the CAA."). EPA determined that:

"[m]ercury is highly toxic, persistent, and bioaccumulates in food chains"; "[m]ost of the U.S. population consumes fish and is exposed to methylmercury as a result"; and "[m]ost of the mercury currently entering U.S. water bodies and contaminating fish is the result of air emissions." Id. at 79,829-30. The agency further found that EGUs:

> are the largest source of mercury emissions in the U.S., estimated to emit about 30 percent of current anthropogenic emissions. There is a plausible link between emissions of mercury from anthropogenic sources (including coal-fired electric steam generating units) and methylmercury in fish. Therefore, mercury emissions from [EGUs] are considered a threat to public health and the environment.[3]

Id. at 79,827. In 2002, EPA formally revised the section 112(c) List to reflect the addition of EGUs pursuant to the December 20, 2000 notice. 67 Fed. Reg. 6,521 (Feb. 12, 2002).

C. 2004 Proposed Rulemaking

On January 30, 2004, EPA proposed two regulatory alternatives to control mercury emissions from EGUs. 69 Fed. Reg. 4,652 (Jan. 30, 2004). The first alternative maintained EPA's December 2000 listing of EGUs and "appropriate and necessary" determination and sought to regulate EGU emissions under section 112 either through MACT standards, or a cap-and-trade plan under section 112. Id. at 4,659-83. Under the second regulatory alternative, EPA proposed to remove EGUs from the section 112(c) List by revising its December 2000 "appropriate and necessary" determination, id. at 4,683-89, and instead use section 111 of the Act

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[3] Mercury converts to methylmercury, a toxic compound, after mercury is "precipitated from the air and deposited into water bodies or land." 70 Fed. Reg. at 16,011. For the sake of simplicity, this brief will refer to mercury concentrations in waterbodies and fish tissue, while recognizing that the actual compound at issue is frequently methylmercury.

to set standards and a cap-and-trade program for mercury emissions from coal-fired EGUs and nickel emissions from oil-fired EGUs, id. at 4,689-4,706.

D. The Final Rules

In the final Delisting Rule, EPA followed the second regulatory alternative of the proposed rule and removed EGUs from the 112(c) List. See 70 Fed. Reg. 15,994. This delisting did not follow the removal requirements of section 112(c)(9), but was instead based solely on the agency's rescission of the December 2000 "appropriate and necessary" determination. Id. at 16,002. As support, EPA "newly interpreted" section 112(n)(1)(A) to require EGU regulation under section 112 only if no other authorities under the Act, "if implemented," would eliminate the public health threat posed by EGU emissions. Id. at 15,997-99. EPA concluded that mercury reductions from two rules yet to be finalized - the Clean Air Interstate Rule ("CAIR") and CAMR - addressed mercury from EGUs sufficiently so that their regulation under section 112 was neither appropriate nor necessary. Id. at 15,997-16,002.[4]

CAIR was published on May 12, 2005, 70 Fed. Reg. 25,162 (May 12, 2005), and CAMR followed six days later. CAMR regulates mercury emissions from EGUs under section 111 of the Act, entitled "Standards of performance for new stationary sources." 42 U.S.C. § 7411. The rule establishes performance standards for new sources under section 111(b) and a cap-and-trade system for mercury from existing power plants under section 111(d). 70 Fed. Reg. at 28,624-30. This system caps nationwide mercury emissions from coal-fired EGUs at thirty-eight tons

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[4] CAIR establishes budgets for emissions of nitrogen oxides ("NO_x") and sulfur dioxide ("SO_2") for the twenty-eight states in the eastern United States. 70 Fed. Reg. at 28,618. CAIR does not regulate EGUs directly and contains no mercury reduction requirements. See id.; 70 Fed. Reg. at 25,209.

beginning in 2010 and fifteen tons beginning in 2018, reductions of 21% and 69% respectively from the approximately forty-eight tons currently emitted from EGUs. 69 Fed. Reg. at 4,691; 71 Fed. Reg. at 33,395. Regulated power plants can either reduce their mercury emissions under the plan or buy credits for such reductions from other plants. 70 Fed. Reg. at 28,632. Credits can also be "banked" to meet future compliance requirements, potentially substantially delaying full implementation of the plan.[5] Id. at 28,629. EPA predicts that as of 2020 — two years after mercury emissions are supposed to be capped at fifteen tons per year — actual mercury emissions will still be at least twenty-four tons per year. Id. at 28,619.

Several parties petitioned for reconsideration of the rules, and on October 28, 2005, EPA granted reconsideration on several issues. 70 Fed. Reg. 62,200. On June 9, 2006, EPA issued its decision on reconsideration to continue with the final Delisting Rule. The agency made only two changes to CAMR relating to state mercury allocations under the cap-and-trade plan and the standards of performance for certain new sources. 71 Fed. Reg. 33,389.

SUMMARY OF ARGUMENT

Both the plain language and purpose of the Act dictate a ruling in petitioners' favor as EPA's mercury rules violate the Act in at least three ways, each warranting that the rules be vacated.

EPA's first error is to disregard the plain language of section 112. The Delisting Rule, which removed EGUs from the list of regulated sources under section 112, is based solely on

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[5] See Congressional Research Service, Mercury Emissions from Electric Power Plants: An Analysis of EPA's Cap-and-Trade Regulations, The Library of Congress (Apr. 15, 2005), OAR-2002-0056-6479.3 [JA 2589] (reporting that EPA officials do not expect full compliance with the 2018 cap until 2025 or beyond).

EPA's rescission of its December 2000 regulatory determination under section 112(n). Section 112(n), however, grants EPA no authority to make such a rescission, and the agency has thus exceeded its statutory authority with the rule. Moreover, a rescission of the December 2000 determination provides no basis to remove EGUs from the section 112(c) List. Section 112(c)(9) alone establishes the requirements necessary to remove "any" source from the list of regulated sources and applies unambiguously to all such sources. EPA admits that it has not met those requirements in the Delisting Rule but contends that section 112(n) somehow exempts power plants from the requirements of section 112(c)(9) and allows the agency to arbitrarily reverse course regarding their regulation. The plain language of the Act, however, belies EPA's claims as section 112(n) evinces a clear congressional desire that EPA "shall regulate [EGUs] under this section" following an appropriate and necessary determination.

EPA's second legal error is its "new interpretation" of a discrete portion of section 112(n) to support a "revised" determination that regulation of EGUs under section 112 is no longer appropriate and necessary. EPA's legal interpretation of section 112(n) contravenes the Act and cannot be squared with Congress's clear desire that all major sources of HAPs be regulated in an expeditious manner through the implementation of plant-specific technology-based standards to address the unique public health threat that HAPs pose. Neither CAIR nor CAMR provide any basis on which EPA may "revise" its determination.

EPA's third error is to disregard the scope of, and requirements for, regulation under section 111 of the Act. CAMR establishes mercury emissions standards through a cap-and-trade system under section 111. Subsection (d) of section 111, however, explicitly limits the scope of that section to those air pollutants that are not "emitted from a source category which is regulated

under section 7412 of this title." Mercury is a listed HAP under section 112, emitted from a number of source categories currently regulated by section 112, and therefore not subject to regulation by section 111. Even if EPA can regulate mercury under section 111, CAMR fails to meet the requirement that standards of performance under that section reflect the "best system of emission reduction . . . adequately demonstrated." 42 U.S.C. § 7411(a). CAMR fails to meet this standard as the rule: a) will allow many power plants to increase their mercury emissions for years; b) sets emission reduction standards that are already significantly exceeded by numerous existing power plants; c) is expected to take at least two decades to reach full implementation; and d) fails to address public health impacts of mercury "hot-spots" near power plants.

STANDARD OF REVIEW

The Court should reverse an agency action if it is arbitrary, in excess of statutory authority, or without observance of procedure required by law. 42 U.S.C. § 7607(d)(9). An agency rule is arbitrary and capricious if the agency relied on factors that Congress did not intend it to consider, failed to consider an important aspect of the problem, offered an explanation for its decision that runs counter to the record, or is so implausible that it could not be the product of agency expertise. Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Ins. Co., 463 U.S. 29, 43 (1983).

In evaluating EPA's interpretation of the statute, the Court must first "determine whether, based on the Act's language, legislative history, structure and purpose, 'Congress has directly spoken to the precise question at issue.' If so, EPA must obey." New York v. EPA, 413 F.3d 3, 18 (D.C. Cir. 2005) (quoting Chevron v. NRDC, 467 U.S. 837, 842 (1984)). If that evaluation is inconclusive, EPA's interpretation must nevertheless be rejected under Chevron if "it appears

from the statute or its legislative history that the accommodation is not one that Congress would have sanctioned." Chevron, 467 U.S. at 845.

ARGUMENT

POINT I

EPA EXCEEDED ITS STATUTORY AUTHORITY AND VIOLATED THE CLEAN AIR ACT BY REMOVING EGUS FROM THE SECTION 112 LIST WITHOUT COMPLYING WITH THE MANDATED PROCEDURE

EPA acted without statutory authority and contravened the clear expression of Congress's intent when the agency removed EGUs from the list of source categories without following the procedure laid out in section 112(c)(9). An agency is bound by the limits of the authority delegated to it, and where the language is clear, as here, the agency simply has no discretion to deviate from the statute's mandate. See Arlington Cent. School Dist. Bd. of Educ. v. Murphy, 126 S. Ct. 2455, 2459 (2006).

A. EPA exceeded its statutory authority in revising the 112(n) determination

EPA's delisting action is based solely on the agency's revision of its six-year-old determination pursuant to section 112(n) of the Act that EGUs should be regulated under section 112. 70 Fed. Reg. at 16,002. The plain language of section 112(n), however, clearly indicates that Congress gave EPA only limited authority to make a single regulatory determination. See 42 U.S.C. § 7412(n). EPA's action was thus unlawful and must be vacated.

Section 112(n) requires EPA to "perform a study of the hazards to public health reasonably anticipated to occur as a result of emissions by EGUs," report the results of that study to Congress by 1993, and requires that the agency "shall regulate [EGUs] under this section, if the Administrator finds such regulation is appropriate and necessary after considering the results

of the study." 42 U.S.C. § 7412(n)(1)(A). Nothing in this language authorizes EPA to revisit the appropriate and necessary determination once made. If the initial listing was in error, the regulatory avenue Congress provided EPA to delist EGUs is section 112(c)(9). See 42 U.S.C. § 7412(c)(9) ("Deletions from the list"). Indeed, if Congress had wanted to authorize EPA to periodically revisit its determination - as EPA asserts - Congress would have done so, as it did in other subsections of the Act. See, e.g., 42 U.S.C. § 7412(b) (EPA shall "periodically review the list established by [112(b)]. . . and, where appropriate, revise such list by rule"); 42 U.S.C. § 7409(d)(1) (EPA to perform periodic review of national air quality standards). No such provision is present in section 112(n), however, and "it is generally presumed that Congress acts intentionally and purposely when it includes particular language in one section of a statute but omits it in another." City of Chicago v. Envtl. Def. Fund, 511 U.S. 318, 338 (1994).

EPA attempts to avoid the plain language of the Act by asserting an "implied" authority based solely on the lack of a deadline in section 112(n)(1)(A) by which EPA must make its appropriate and necessary determination. See 70 Fed. Reg. at 16,001-16,002. From this, EPA claims "sufficient discretion under section 112(n)(1)(A) - in terms of both the substance and the timing of the appropriate and necessary finding - that nothing precludes us from revising our. . . finding." Id. (emphasis added). The tenets of statutory construction, however, do not require Congress to employ superfluous language to proscribe the bounds of agency authority. See Louisiana Pub. Serv. Comm'n v. FCC, 476 U.S. 355, 374 (1986) ("an agency literally has no power to act . . . unless and until Congress confers power upon it"); New York v. EPA, 443 F.3d at 880, 887 (D.C. Cir. 2006) ("Only in a Humpty Dumpty world would Congress be required to use superfluous words while an agency could ignore an expansive word that Congress did use.").

Moreover, the context of the 1990 amendments to the Act, see infra at I.B., indicate that Congress - far from providing implied authority and discretion to EPA - moved to limit the agency's discretion to promote rapid regulation of HAPs. See S. Coast Air Quality Mgmt. District, No. 04-1200, slip op. at 20 (D.C. Cir. 2006) ("EPA's interpretation of the Act in a manner to maximize its own discretion is unreasonable because the clear intent of Congress in enacting the 1990 Amendments was to the contrary."). Indeed, because of Congress' concern for the prompt and effective regulation of HAP emissions, section 112 does not allow judicial review of the listing until emissions standards are promulgated. See 42 U.S.C. § 7412(e)(4); 65 Fed. Reg. at 79,831; S. Rep. No. 101-228, at 3559 ("The Administrator's determination of priorities is given insulation from court challenge because of the complexity of the balancing involved and the extended nature of the litigation that might ensue if all of the schedule were open to challenge in court."). The provision for judicial review at such time does not render the listing any less final. As "[a]n agency construction of a statute cannot survive judicial review if a contested regulation reflects an action that exceeds the agency's authority," EPA's Delisting Rule, based on a faulty claim of implied authority, must fail. Aid Ass'n for Lutherans v. U.S. Postal Serv., 321 F.3d 1166, 1174 (D.C. Cir. 2003).

B. EPA's Delisting Rule Contravenes the Plain Language of Section 112(c)(9)

Even if EPA has authority to revise its appropriate and necessary determination, EPA still may not remove EGUs from the section 112(c) List without following the mandated procedure. Once a source is listed – as EGUs were with the December 20, 2000 Notice of Regulatory Finding, 65 Fed. Reg. 79,825 – EPA is authorized to remove that source from the list under only two circumstances, neither of which is the case here. See 42 U.S.C. § 7412(c)(9).

First, under 112(c)(9)(A), EPA shall delete a source if "the sole reason" that the source was included on the list is the emission of a unique chemical substance and EPA determines that "there is adequate data on the health and environmental effects of the substance to determine that emissions, ambient concentrations, bioaccumulation or deposition of the substance may not reasonably be anticipated to cause any adverse effects to the human health or adverse environmental effects." 42 U.S.C. §§ 7412(c)(9)(A); 7412(b)(3)(9)(C). Here, EPA acknowledges, and the scientific literature and the Act itself are clear, that mercury causes significant adverse impacts to both human health and the environment. See, e.g., 42 U.S.C. § 7412(b); 70 Fed. Reg. at 16,011-12; 69 Fed. Reg. at 4,657; RTC, at 3-22 to 3-25 [JA 150-153].

Second, under section 112(c)(9)(B), EPA "may delete any source category from the list under this subsection . . . whenever the Administrator makes the [applicable] determination." 42 U.S.C. § 7412(c)(9)(B). For non-cancerous pollutants such as mercury, section 112(c)(9) requires "a determination that emissions from no source in the category or subcategory concerned . . . exceed a level which is adequate to protect public health with an ample margin of safety and no adverse environmental effect will result from emissions from any source." 42 U.S.C. § 7412(c)(9)(B)(ii).

Here, EPA failed to make the determination that is a mandatory prerequisite to removing EGUs from the list of regulated sources under section 112. Indeed, EPA has plainly acknowledged that the agency used section 112(n) itself as the basis for delisting EGUs. See 70 Fed. Reg. at 15,994 ("The EPA is revising the regulatory finding that it issued in December 2000 pursuant to section 112(n)(1)(A) of the [Act], and based on that revision, removing coal- and oil-fired [EGUs] from the CAA section 112(c) source category list.") (emphasis added)).

EPA offers no justification for its action sufficient to depart from the literal interpretation of the Act. The agency's argument rests on its claim that section 112(n)(1)(A) "occupies the field in section 112 with regard to Utility Units," and therefore EGUs are not subject to the section 112(c)(9) delisting requirements. 70 Fed. Reg. at 16,032-33. However, "[f]or EPA to avoid a literal interpretation . . . it must show either that, as a matter of historical fact, Congress did not mean what it appears to have said, or that, as a matter of logic and statutory structure, it almost surely could not have meant it." Friends of the Earth v. EPA, 446 F.3d 140, 146 (D.C. Cir. 2006) (quoting Engine Mfrs. Ass'n v. EPA, 88 F.3d 1075, 1089 (D.C. Cir. 2006)). The language of section 112(n)(1)(a) itself provides that EPA "shall" regulate EGUs under section 112 if the "appropriate and necessary" determination is made. 42 U.S.C. § 7412(n)(1)(A). Section 112(n), in other words, plays a threshold role, not a preemptive one. The presence of an express exemption for EGUs from section 112(c)(6), where no such exemption exists in section 112(c)(9) further supports the conclusion that Congress did not mean to preempt the regulatory scheme of section 112 through section 112(n)(1)(A). Compare 42 U.S.C. § 7412(c)(6) with 42 U.S.C. § 7412(c)(9); see Russello v. United States, 464 U.S. 16, 23 (1983) ("where Congress includes language in one section of a statute, but omits it in another . . . it is generally presumed that Congress acts intentionally . . . in the disparate inclusion or exclusion").

The legislative framework and history of the 1990 Amendments supports the Act's plain language. First, Congress created a strict framework for effective and expeditious regulation of HAPs, "precisely because it believed EPA had failed to regulate enough HAPs under previous air toxics provisions." Nat'l Lime Ass'n v. EPA, 233 F.3d 625, 634 (D.C. Cir. 2000). Because "very little has been done since the passage of the 1970 Act to identify and control hazardous air

pollutants" Congress greatly restricted EPA's discretion. See S. Rep. No. 101-228, at 3, 1990 U.S.C.C.A.N. at 3389. It is only logical, then, that Congress intended section 112(c)(9) to apply to EGUs once listed as the delisting requirements complement the legislature's desire to limit EPA's discretion and promote regulation of all major sources of HAPs.

Second, section 112(n) was the product of a congressional compromise and introduced only to "determine the nature of utility boiler emissions and whether their control is warranted enacted as part of the 1990 amendments to the Act." S. Rep. 101-228, at 414, 1990 U.S.C.C.A.N. at 3794. EPA's broad claims of discretion to avoid the requirements of section 112(c)(9) must fail as the agency may not interpret the Act "in a way that completely nullifies textually applicable provisions meant to limit its discretion." Whitman v. Am. Trucking Ass'ns, 531 U.S. 457, 458 (2001).

POINT II

EPA'S ACTION VIOLATES THE CAA BY EXEMPTING EGUS FROM SECTION 112 BASED ON AN ERRONEOUS "NEW INTERPRETATION" OF SECTION 112(n) AND CAMR AND CAIR

EPA ignored section 112(c)(9) and removed power plants from the 112(c) List based solely on its rescission of its December 2000 appropriate and necessary determination. 70 Fed. Reg. at 16,002. Even assuming EPA had the authority to take such action, EPA's Delisting Rule must still be vacated because EPA's rescission of the December 2000 determination relies on a "new" interpretation of section 112(n) that is contrary to the language and purpose of the Act. The agency's regulatory conclusion – that CAMR and CAIR obviate the need for EGU regulation – is similarly contrary to clear congressional intent and lacks support in the record.

A. EPA's Interpretation Ignores the Purpose, Structure and Context of Section 112(n).

EPA's Delisting Rule rescinds the agency's listing of EGUs as a source regulated under section 112 based on a new legal interpretation of section 112(n). See 70 Fed. Reg. 15,997-99. According to EPA's new interpretation, two threshold questions must be answered affirmatively before EPA can conclude that regulation of EGUs is appropriate and necessary. The first question is: Are the power plant mercury emissions that remain after the CAA's other requirements have been implemented (the "Remaining Emissions") – standing alone – responsible for causing hazards to human health? See 70 Fed. Reg. at 15,997-16,002 (explaining EPA's new understanding of 42 U.S.C. § 7412(n)(1)(A)); 70 Fed. Reg. at 16,022-25 (concluding that the Remaining Emissions do not result in hazards to human health); 70 Fed. Reg. at 16,028 (insisting that EPA cannot consider the effects of power plant emissions in combination with emissions from other sources). If the answer is "no," EPA concludes that it is not "appropriate" to regulate power plant emissions under section 112 and the inquiry ends. See 70 Fed. Reg. at 16,000.

EPA also concludes that even if regulation of power plant emissions under section 112 is "appropriate," it may not be "necessary." According to EPA, such regulation is "necessary" "only if there are no other authorities available under the CAA that would, if implemented, effectively address the remaining HAP emissions from Utility Units." 70 Fed. Reg. at 16,001 (emphases added).

EPA's approach based on EPA's new legal interpretation contravenes the Act. First, section 112(n) does not limit EPA to consider public health impacts arising solely from EGU

emissions. Rather, the section requires EPA to assess the "hazards to public health reasonably anticipated to occur as a result of emissions from [EGUs]." 42 U.S.C. § 7412(n)(1)(A) (emphasis added). EPA's interpretation therefore inserts a new requirement into the act as it reads "as a result of" to mean "solely as a result of." If Congress had intended EPA to focus on hazards resulting solely as a result of EGU emissions, it would have used the word "solely," as it has numerous times even within section 112. See 42 U.S.C. §§ 7412 (b)(2); 7412(b)(3)(A); 7412(r)(4)(B). Cf. New York v. EPA, 443 F.3d 880, 887 (D.C. Cir. 2006) (rejecting EPA's expansive interpretation as "the court must presume that Congress acted 'intentionally and purposely'" when Congress expressly includes a limitation). This statutory context reinforces the plain meaning of "as a result of" to include results that are caused by EGU emissions acting in concert with other sources of mercury. Cf. Kreindler & Kreindler v. United Tech. Corp., 985 F.2d 1148, 1158 (2d Cir. 1993) (the phrase "based upon" does not mean based "solely" upon).

Second, the Act requires EPA to study the hazards posed by EGU emissions after imposition of the "requirements" of the Act, not those emissions projected to be remaining after "authorities" not yet enacted take effect. See 42 U.S.C. § 7412(n)(1)(A). The plain meaning of "requirement" as something "necessary" or "an essential condition" indicates that Congress wanted EPA to look at existing requirements actually imposed on EGUs by the 1990 Amendments such as the Title IV program for SO_2, not authorities that may be implemented as EPA asserts. See New Webster's Dictionary 815 (1984). Here, EPA identifies CAIR and CAMR as available authorities and then looks to the year 2020 to determine if any EGU emissions then remaining pose a threat. Nothing in section 112(n) suggests that the legislature, in 1990, intended that EPA look ahead thirty years and consider the effects of regulatory programs that

would not be promulgated for fifteen years to determine whether regulating EGUs under section 112 was appropriate and necessary. On the contrary, Congress gave EPA until 1993 to study the health hazards reasonably anticipated to occur as a result of EGU mercury emissions, 42 U.S.C. § 7412(n)(1)(A), and clearly expected an appropriate and necessary determination shortly thereafter. EPA utterly fails to explain how its interpretation can possibly comport with the congressional intent for rapid and stringent HAP regulation found in the 1990 Amendments.

Finally, EPA's interpretation would "abrogate[] the enacted statutory text" of section 112. See Sierra Club v. EPA, 294 F.3d 155, 161 (D.C. Cir. 2002) (citing Appalachian Power Co. v. EPA, 249 F.3d 1032, 1041 (D.C. Cir. 2001)). Rather than considering the purpose, structure and context of Section 112(n), see Chemical Manuf. Ass'n v. EPA, 217 F.3d 861, 864-67 (D.C. Cir. 2000), EPA's new interpretation focuses on one sentence: "The Administrator shall perform a study of the hazards to public health reasonably anticipated to occur as a result of emissions by [EGUs] of [HAPs] after the imposition of the requirements of this chapter." 70 Fed. Reg. at 15,997. From this sentence, EPA "extrapolates" its new questions for determining whether regulation of power plant HAP emissions pursuant to section 112 is "appropriate and necessary." Id.

This new interpretation leads EPA to ignore three critical aspects of section 112. The framework of section 112 establishes that regulation provide for an ample margin of safety for public health, 42 U.S.C. § 7412(d)(4); (c)(9)(B)(ii), and address environmental impacts of HAPs, 42 U.S.C. § 7412(f);(c)(9)(B)(ii), and is generally structured to recognize the contributory impacts of the various sources of HAPs by requiring MACT standards for all major sources regardless of the significance of their respective emissions. EPA, however, determines that, in

assessing whether EGU regulation under section 112 is appropriate and necessary, the agency does not have to provide for an ample margin of safety for public health, 70 Fed. Reg. at 15,998, and does not have to address the environmental impacts of EGU emissions in the Delisting Rule, but rather only public health impacts, 70 Fed. Reg. at 15,997-98. EPA also determines that the Act constrains it to examine only the health effects caused solely by power plant emissions, i.e., in isolation from all other mercury source emissions, and cannot consider the contributory impacts of EGU emissions to overall mercury loading in our waterbodies. See 70 Fed. Reg. at 16,028-29. EPA, in other words, determines that Congress meant for all of the facets of effective regulation under section 112 to be abandoned simply because they are not referenced in the single line of text EPA chose to consider.

Congress, however, does not modify fundamental aspects of a regulatory scheme in vague terms or ancillary provisions. Gonzales v. Oregon, 126 S. Ct. 904, 921 (2006) (quoting Whitman v. Am. Trucking Ass'ns, 531 U.S. at 468). It is also "emphatically not within an agency's authority to set regulatory priorities that clearly conflict with those established by Congress." See Sierra Club v. Johnson, 444 F. Supp. 2d 46, 58 (D.D.C. 2006). The plain language of section 112 exhibits Congress's priorities for the regulation of HAPs that cannot be disregarded on the weight of a single "extrapolated" line of statutory text. See Sierra Club v. EPA, 294 F.3d at 161 ("the most reliable guide to congressional intent is the legislation the Congress enacted").

B. CAMR And CAIR Do Not Obviate The Need For, Or Appropriateness Of, EGU Regulation Under Section 112

EPA's conclusion that EGU regulation is not appropriate under section 112 because of CAMR and CAIR also contravenes the Act and is unsupported by the record such that the Delisting Rule must be vacated. Section 112 provides a regulatory framework evincing congressional priorities for HAP regulation. First, the MACT emission standards of section 112 "require the maximum degree of reduction in emissions." 42 U.S.C. § 7412(d)(2)(emphasis added). Second, MACT standards under section 112 apply to all major sources of the listed pollutants. 42 U.S.C. § 7412(f)(4). These technology-based standards are designed to protect both the environment and public health. See, e.g., 42 U.S.C. § 7412(d) (permitting EPA to create so-called "beyond-the-floor" standards based on "environmental impacts and energy requirements"). Third, after standards are set, section 112 requires the installation of pollution controls and full compliance within three years. 42 U.S.C. § 7412(i)(3). In other words, section 112 is designed to address the pressing public health threat posed by HAPs.

In contrast, CAMR and CAIR fail to effect any of the congressional priorities for HAP regulation. While a MACT standard for power plants under section 112 would require approximately 90% reductions of mercury emissions[6], CAMR requires only a 20% reduction for the next decade. As a cap-and-trade program, CAMR will also only reduce emissions at those power plants that do not buy credits for emission reductions and will do nothing to protect

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[6] MACT standards require emission standards for existing sources to be no less stringent than the average emission limitation achieved by the best performing 12% of existing sources. 42 U.S.C. § 7412(d)(3). Of the eighty EGUs for which EPA has data, the top 12% have an average control efficiency for mercury of more than 93%. See 69 Fed. Reg. at 4,673; EPA Memoranda by Bill Maxwell ("Maxwell Memoranda") (Nov. 26, 2003), OAR-2002-0056-0006 [JA 513] and (Oct. 21, 2005), OAR-2002-0056-6305 [JA 2460].

communities and areas near such plants. In fact, EPA's own modeling predicts mercury emission increases under the plan in sixteen states and numerous individual plants until 2018. Compare http://www.epa.gov/ttn/atw/combust/utiltox/unitxunit2.xls (Column F) (listing EPA's unit-specific 1999 emission data) with EPA's Final CAMR Unit Mercury Allowances (final two columns), OAR-2002-0056-6155 [JA 1781]. Finally, CAMR's timeline for compliance is drastically longer than section 112 regulation as CAMR requires no significant reductions until 2018 when its second-phase cap becomes effective. See 70 Fed. Reg. at 28,606. Compliance with the second-phase cap is expected to be significantly delayed due to the banking of emission credits; a 69% reduction in mercury emissions from EGUs will not likely occur until at least 2025. See 70 Fed. Reg. at 28,619 (EPA estimating that under CAMR, EGU mercury emissions in 2020 will still be 24.3 tons); see also Congressional Research Service, supra note 5.

EPA also asserts that the indirect reduction in mercury emissions from EGUs resulting from CAIR provides an alternative basis for its determination that it is not appropriate to regulate EGUs under section 112. 70 Fed. Reg. at 16,004. CAIR, however, is limited to the establishment of emission budgets for NO_x and SO_2 for twenty-eight states in the eastern portion of the country and the District of Columbia, and EPA expects mercury emissions increases under CAIR in areas not addressed. See 70 Fed. Reg. at 28,639. Furthermore, states may seek to comply with CAIR by regulating sources other than power plants, and even if they do regulate power plants, nothing in CAIR requires states to address mercury emissions. See 70 Fed Reg. at 25,162. Thus, EPA's assertion that CAIR will reduce mercury emissions from power plants to levels protecting public health is based purely on an assumption of the indirect benefits to mercury emissions that EPA speculates will result from control technologies used to reduce NO_x

and SO_2 emissions. This assumption is tenuous at best as there is no guarantee that EGUs, even if they are regulated, will use the pollution controls that EPA expects. In light of the congressional mandate in the 1990 Amendments to rapidly and effectively control HAP emissions such as mercury, EPA's assumptions and speculation provide no basis for removing EGUs from section 112.

In sum, CAMR and CAIR will take decades longer to reach full implementation than section 112, while providing for only a portion of the mercury emission reductions achieved under section 112 and no comparable public health assessment to address lingering threats. While EPA may believe its cap-and-trade plan to be better policy, the agency may not impose such policy choices over the statute's express mandate, and its approach must be rejected. See Sierra Club v. Johnson, 444 F. Supp. 2d at 58.

C. EPA's Public Health Conclusion in the Delisting Rule is Contrary to the Act and Arbitrary and Capricious

Finally, EPA based its "revised" delisting determination on a public health analysis that considered only those impacts on public health that result solely from EGU mercury emissions and only one pathway of exposure. This approach fails to protect the public and defies the plain language of the Act, and must be rejected.

First, as mercury moves from power plants, to waterways, and to fish, the mercury bioaccumulates, getting more concentrated at every level of the food chain, and joins with mercury from other sources such as incinerators. See RTC [JA 122-125], 65 Fed. Reg. at 79,827; Hubbard Brook Comments, at 9 [JA 735]. The impact on an individual is then determined by the cumulative level of mercury in fish consumed, regardless of where that mercury originated. Any

individual who consumes more than 0.1 micrograms of mercury per kilogram of his or her body weight per day is exceeding health safety criteria. See 65 Fed. Reg. at 79827. EPA's limited analysis, however, recognizes a health threat only where this safety level is exceeded solely because of mercury from EGUs.

EPA's approach has been rejected by this Court and must be rejected here. This Court has recognized that "an analysis cannot treat an identified environmental concern in a vacuum," but must address the accumulated impacts of various sources. Grand Canyon Trust v. FAA, 290 F.3d 339, 346 (D.C. Cir. 2002); see also Michigan v. EPA, 213 F.3d 663 (D.C. Cir. 2000). Research indicates that approximately 630,000 U.S. babies are annually born to mothers whose blood levels of mercury exceed safety levels. See Comments of New Jersey et al., Decl. of Alan Stern ¶¶ 7-8, OAR-2002-0056-6282 [JA 2342]. For these babies, each additional increment of utility-attributable mercury carries a predictable risk of additional IQ loss and other neurological effects. Id. at ¶ 10; see also National Research Council, Toxicological Effects of Methylmercury OAR-2002-0056-5927 at 56-60 [JA 1712-1716] and -5928 at 112-117 [JA 1728-1733]. EPA's health analysis fails to address these incremental impacts and consequently, leaves unaddressed these thousands of babies affected by EGU mercury emissions.

Second, EPA considered only a single pathway through which people are exposed to mercury: "freshwater fish caught and consumed by recreational and subsistence anglers." 70 Fed. Reg. at 16,012. Thus, EPA's analysis disregarded all marine fish, commercially caught fish, and fish caught in estuaries such as the Chesapeake Bay. Id. These pathways account for millions of pounds of fish consumed by U.S. citizens annually and are significant pathways through which mercury reaches people. See e.g., EPA Technical Support Document ("TSD") at

24, OAR-2002-0056-6303 [JA 2382] (recognizing that marine fish represent more than four million metric tons of caught fish in the United States annually).

EPA attempts to justify its disregard of other pathways of mercury exposure by claiming that analysis of U.S. EGU mercury impacts on marine and estuarine fish is uncertain, and that commercial fish do not represent a significant dietary pathway of U.S. EGU mercury. See EPA TSD, at 34 [JA 1906]. The statutory responsibility facing EPA, however, is to assess all impacts from EGU emissions that are "reasonably anticipated." 42 U.S.C. § 7412(n)(1)(A). Individuals who ingest mercury through marine and commercial fish can be expected to suffer health impacts by the mercury additionally ingested through the single pathway EPA considered. By excluding the pathways through which individuals are exposed to mercury, EPA has disregarded the plain language of section 112(n) and abdicated its statutory responsibility. EPA's approach must be rejected.

POINT III

CAMR'S REGULATION OF MERCURY UNDER SECTION 111 IS CONTRARY TO THE STATUTE

As EPA concedes, if the Delisting Rule is unlawful, CAMR similarly cannot stand. See Letter from Jeffrey R. Holmstead, EPA, to Peter C. Harvey, Attorney General of New Jersey (June 24, 2005) attached to Comments of New Jersey et al., OAR2002-0056-6282 [JA 2302]("staying the final section 112 rule would necessitate staying the final CAMR rule."); EPA's Opp. to Mot. for Stay Pending Review at 20 (July 18, 2005)(admitting same). Assuming, however, that EPA may exempt EGUs from regulation under section 112 – which EPA may not,

as demonstrated above – EPA still violates the Act by regulating mercury, a potent neurotoxin, under section 111 with a cap-and-trade program.

A. EPA's Attempt to Regulate Mercury Under Section 111 is Contrary to the Plain Language of the Act

Section 111 authorizes EPA to promulgate New Source Performance Standards ("NSPS"), technology-based standards for new sources of "air pollution which may reasonably be anticipated to endanger public health and welfare." 42 U.S.C. § 7411(b)(1)(A). Subsection (d) of Section 111 provides authority for regulation of existing sources, but is explicitly limited to those air pollutants that are not "emitted from a source category which is regulated under section 7412 of this title." 42 U.S.C. § 7411(d)(1). Thus, listed HAPs emitted from source categories regulated under section 112 are not to be regulated under section 111. Id. Mercury is a listed HAP under section 112, 42 U.S.C. §§ 7412(b)(1), 7412(c)(6), and is emitted from a number of source categories currently regulated by section 112. E.g., 71 Fed. Reg. 76,518 (Dec. 20, 2006) (establishing emission standards for HAPs including mercury from Portland Cement manufacturers); 69 Fed. Reg. 55,238 (Sept. 13, 2004) (establishing emission standards for mercury emissions from Industrial, Commercial, and Institutional Boilers and Process Heaters). Therefore, EPA may not regulate mercury emissions from EGUs under section 111, See Arlington Cent. School Dist. Bd. of Educ., 126 S. Ct. at 2459 (statutory construction analysis begins with the statute's plain language).

EPA attempts to avoid this clear limit on the scope of section 111(d) by claiming a conflict between the 1990 House and Senate versions of the amendments to section 111(d). See 70 Fed. Reg. at 16,030. Slightly differing language in the versions, however, does not alter

Congress' expressed intent that section 111 was not meant to regulate HAPs. See 42 U.S.C. § 7411(d)(1). Ambiguity between the amendment versions cannot be relied upon to avoid the plain meaning of the statute, but rather, the versions must be harmonized in light of the Act as a whole. See, e.g., FDA v. Brown & Williamson Tobacco Corp., 529 U.S. 120, 133 (2000); Citizens to Save Spencer County v. EPA, 600 F.2d 844, 851, 890 (D.C. Cir. 1979). Under these established canons of statutory interpretation, EPA's attempt to regulate existing sources of mercury under section 111 must be rejected.

The regulatory framework and legislative history of the Act further support the finding that listed HAPs emitted from source categories regulated under section 112 may not be regulated under section 111. First, the statutory limits on the applicability of section 111(d) demonstrate that it serves a backstop role in the Act to account for existing sources of air pollutants that are not controlled under any other provision. 42 U.S.C. § 111(d)(1). Second, as noted supra, Congress explicitly recognized the differences between sections 112 and 111 and the need to regulate HAPs under the former. See S. Rep. No. 101-228, at 167, 1990 U.S.C.C.A.N. at 3552 ("An emissions limitation based on section 112(d) will, in most cases, be more stringent than a new source performance standard for the same category of sources or pollutants . . . that is appropriate as this program is for the control of extremely harmful air pollutants"). Section 112 was enacted to address the public health threat posed by HAPs and required EPA to set standards at a level providing an ample margin of safety to protect the public health. 42 U.S.C. § 7412(c)(9)(B)(ii). In contrast, section 111 was largely designed as a technology forcing provision to promote long-term economic benefits through nationalized standards. See H.R. Rep.. 95-294,

at 186 (1977), reprinted in 1977 U.S.C.C.A.N. 1077, 1264 ("[T]he best technology requirement [of Section 111] was intended to create incentives for improved technology").

B. Even if EPA Has Authority to Regulate Mercury Emissions from EGUs Under Section 111, CAMR Violates the Requirements of That Section.

Section 111 requires EPA to set a standard of performance defined as an air pollutant emissions standard that "reflects the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated." 42 U.S.C. § 7411(a)(1) (emphasis added). See also 42 U.S.C. §§ 7411(g)(4)(B), 7602. CAMR violates this express mandate of section 111 because: (1) existing sources already utilize control technologies that achieve much greater emission reductions than what CAMR requires; (2) the rule will actually result in future emission increases in many states; and (3) the rule will perpetuate dangerous, local "hot-spots" of mercury severely endangering public health. As CAMR conflicts with the language, purpose and intent of the CAA, and is not supported by a reasoned analysis, the Court should vacate CAMR as an abuse of discretion and arbitrary and capricious rulemaking. 42 U.S.C. § 7607(d)(9)(A); see Nat'l Asphalt Pavement Assoc. v. Train, 539 F.2d 775, 786 (D.C. Cir. 1976).

1. CAMR Violates Section 111 Because Currently Utilized Control Technologies and Source Specific Mercury Controls Achieve Substantially Greater Emission Reductions Than CAMR Requires.

Section 111 requires EPA to propose regulations establishing air pollutant emission standards that, applying the "best system of emission reduction," reflect the degree of achievable

emission limitation. 42 U.S.C. §§ 7411(a)(1) (emphasis added) and (f)(1). CAMR will result in a 21% emission reduction by 2010 through an annual emissions cap of thirty-eight tons from a 1999 base line level of forty-eight tons. In contrast, EPA's estimates predict that existing sources will already have reduced their emissions to thirty-one tons - seven tons better than CAMR's phase one requirement - as of 2010. 70 Fed. Reg. at 28,619. EPA offers no explanation for how a cap set at a level seven tons above what the agency expects EGUs to be emitting at the time it becomes operational can possibly reflect the best system of reduction.

Full implementation of CAMR will ultimately result in reductions of mercury emissions from power plants of 69% somewhere around 2025. See 69 Fed. Reg. at 4,691; 71 Fed. Reg. at 33,395; Congressional Research Service, supra note 5. EPA's data, however, demonstrates that the current best performing power plants reduce their mercury emissions by an average of 93%.[7] EPA in fact concluded that currently available control technologies have shown "mercury capture in excess of 90 percent." 65 Fed. Reg. 79,828. Thus CAMR requires only a fraction of the efficiency achieved by existing and available control technologies. In fact, existing power plants of every category established by EPA currently exceed CAMR's performance standards for new

[7] This percentage is derived from the average of the actual emissions achieved by the top 12% of the eighty coal-fired sources for which EPA has data (ten units, two that are coal-refuse-fired units and eight that are bituminous-fired). See 69 Fed. Reg. at 4,673; EPA Maxwell Memoranda [JA 513].

sources.[8] These weak standards are unsupportable given Section 111's express language. See 42 U.S.C. § 7411(a)(1).

The weak standards are further diluted by EPA's subcategorization scheme in establishing the NSPS. 70 Fed. Reg. at 28,612. Although EPA "may" subcategorize based upon different classes, types, and sizes, 42 U.S.C. § 7411(b)(2), EPA is nevertheless statutorily required to implement standards that "reflect the degree of emission limitation achievable through the application of the best system of emission reduction." 42 U.S.C. § 7411(a)(1). EPA's subcategorization scheme, based on the different types of coal EGUs burn, fails to reflect that "a number of Utility Units co-fire different ranks of coal." 70 Fed. Reg. at 28,612-13. Moreover, EPA further subcategorizes units burning subbituminous coal based upon the type of pollution control that is being utilized. Id. at 28,615 (EPA setting different NSPS limits for subbituminous-coal burning EGUs based on the type of Flue Gas Desulfurization or "FGD"system used); EPA's Response to Significant Public Comments at 265, OAR-2002-0056-6722 [JA 3888]. Subcategorization based on technology, however, defeats the very purpose of establishing NSPS limits, because, as EPA itself acknowledged, subcategorization based on the type of air pollution control device "leads to situations where floors are established based on performance of sources that are not the best performing." 69 Fed. Reg. 394, 403 (Jan. 5, 2004). CAMR presents this situation, as a power plant using a wet FGD system is allowed to emit twice

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[8] For instance, CAMR's new source limit is 74% for plants burning bituminous coal while the best performing bituminous plant (Mecklenberg Co-Gen Facility) achieves 98.8% reductions in its mercury emissions. See October 21, 2005 Memorandum from Bill Maxwell to Robert Wayland at 7-10, OAR-2002-0056-6305 [JA 2466-2469]; 70 Fed. Reg. at 28,610 (establishing emissions limits which were converted to a percentage reduction format).

the amount of mercury as a power plant similar in every other respect except its use of a dry FGD system. 70 Fed. Reg. at 62,216.

2. CAMR Violates Section 111 Because the Rule Will Result in Emission Increases in Some States Even Beyond 2018.

CAMR further violates section 111's requirement that standards reflect the best system of emission reduction achievable because EPA's program will actually result in emission increases in numerous states and individual plants. Comparing CAMR budgets to 2003 actual mercury emissions, sixteen states can increase their mercury emissions between now and 2018 while four states can continue to lawfully increase their emissions even beyond 2018. Compare Unit specific estimated mercury emission rates in 1999, at http://www.epa/gov/ttn/atw/combust/utiltox/unitxunit2.xls with 70 Fed. Reg. at 28,649-50. The difference between the allowed emissions under CAMR and states' actual emissions amounts to eighteen tons of excess mercury for the period between 2010 and 2018, a result that Congress could not have intended in enacting section 111. A program that allows emissions increases clearly violates section 111. See 42 U.S.C. § 7411(a)(1).

3. CAMR Cannot Be The Best System of Emission Reduction Adequately Demonstrated Because EPA Ignored Critical Nonair Quality Health and Environmental Impacts Resulting From the Cap-and-Trade Program

Finally, section 111 requires a standard of performance that takes into account "any nonair quality health and environmental impact." 42 U.S.C. § 7411(a)(1). Well-documented and adverse health and environmental impacts from mercury emissions include mercury "hot-spots," areas where the species living in waterbodies exhibit consistently high levels of mercury contamination. See Mercury Connections: The Extent and Effects of Mercury Pollution in

Northeastern North America (2005), OAR-2002-0056-6490.13 [JA 2664]. At least nine such hot-spots have been identified in the area from New York to Nova Scotia, affecting both the environment and public health in those areas. Id.; see also Decl. of Charles Driscoll ¶ 4, OAR-2002-0056-6280 [JA 2251-2252]; Hubbard Brooks Comments, at 13-14 [JA 739-740].

Research has repeatedly noted that EGU air mercury emissions play a significant role in the creation of these hot-spots. Hubbard Brooks Comments, at 7-15 [JA 733-741]. An EPA-funded study found that approximately 70% of mercury wet deposition in Steubenville, Ohio, which is located in close proximity to several major coal-fired power plants, is attributable to the local sources. See Gerald J. Keeler et al., Sources of Mercury Wet Deposition in Eastern Ohio, USA, 40 Environ. Sci. & Technol. 5874 (2006), OAR-2002-0056-6748.1 [JA 4156]. Emission reductions from local source contributors have also been accompanied by significant decreases in the mercury concentrations in fish in local waterbodies, highlighting the role these local sources play. See Hubbard Brook Comments at 13-14 [JA 739-740]. The record therefore reflects that individual EGUs can have significant impacts on local hot-spots of mercury contamination and a cap-and-trade program allowing individual plants to avoid any reduction can reasonably be anticipated to impact public health and the environment.

EPA has previously recognized the potential impacts of a cap-and-trade system for hazardous pollutants. See EPA, Tools of the Trade, A Guide to Designing and Operating a Cap and Trade Program for Pollution Control at 2-5 (June 2003), available at http://www.epa.gov/airmarkets/international/tools.pdf [JA 4544] (command and control regulations work better than cap-and-trade programs where emissions are toxic and have serious local health impacts). In fact, a cap-and-trade program has never been attempted for a neurotoxin

such as mercury and EPA's Office of Inspector General concluded that CAMR as initially proposed failed to adequately address either the potential for hot-spots or the potential impact on children. See EPA Office of Inspector General, Evaluation Report: Additional Analyses of Mercury Emissions Needed Before EPA Finalizes Rules for Coal-Fired Electric Utilities (Feb. 3, 2005), OAR-2002-0056-5686 [JA 1530].

In the final mercury rules, EPA neglects the potential impacts of a cap-and-trade program for mercury, instead erroneously concluding that the final rule is "not significant" in light of CAIR, 70 Fed. Reg. at 28,639, and referring to the CAMR docket generally for a discussion of any impacts, 70 Fed. Reg. at 28,616. First, EPA's reliance on CAIR is misplaced as the agency acknowledges that CAIR will result in "both increases and decreases in [mercury] deposition" with increases expected in areas not covered by CAIR. 70 Fed. Reg. at 28,639. Thus, CAIR provides no assurance to individuals living in the twenty-two states not under its authority. See 70 Fed. Reg. at 28,618.

Second, the rest of the CAMR docket also fails to address the environmental and public health impacts of the cap-and-trade plan. The rulemaking relied on a modeling program to estimate the levels of mercury deposition in the future and concluded, "we do not currently have any facts before us that would lead us to conclude that utility-attributable hot spots exist."See 70 Fed. Reg. at 16,027-28 (emphasis added). By looking solely for "utility-attributable" hot-spots, however, EPA ignores the threats to public health posed by mercury hot-spots created by EGU emissions acting with other sources of the pollutant. As noted supra, EPA coined the "utility-attributable" term in the context of its flawed interpretation of section 112(n)(1)(A). Just as EPA's interpretation was unlawful for section 112, the interpretation equally contradicts the

mandate by section 111 that EPA consider both the health and environmental impacts resulting from a promulgated performance standard. See 42 U.S.C. § 7411(a)(1).

Finally, EPA's reliance on large-scale modeling to predict future hot-spots is misplaced. Hot-spots are frequently created not by generalized mercury deposition over large areas, but rather by local sources such as those studied in Ohio and watershed characteristics such as the terrain and surrounding ground cover. See Comments of New Jersey et al., Evers Decl., Ex. B at 4, 19 [JA 2251-2252] . EPA's model averages the impacts from mercury emissions over 500 square miles using thirty-six square kilometer grids, and misses the local hot-spots that pose threats to the public and the environment. See Comments of The New Hampshire Department of Environmental Services at 3, OAR-2002-0056-6490.1 [JA 2633].

For these reasons, EPA set standards that contravene Congress' intent that standards of performance in Section 111 drive technology and provide for the best system of emission reduction and must be overturned.

CONCLUSION

Because EPA exceeded its statutory authority and acted arbitrarily and capriciously, Government Petitioners respectfully request that the Court vacate the Delisting Rule, 70 Fed. Reg. 15,994, and vacate CAMR, 70 Fed. Reg. 28,606, with instructions to EPA to promulgate emissions standards for HAPs emitted by EGUs under section 112 of the Act.

Dated: July 23, 2007

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CERTIFICATE REGARDING WORD LIMITATION

Counsel hereby certifies, in accordance with Federal Rule of Appellate Procedure 32(a)(7)(C), that the foregoing Government Petitioners' Initial Opening Brief contains 10,436 words, as counted by counsel's word processing system.

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STATE OF NEW JERSEY, et al., Petitioners, v. UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, Respondent.	)	No. 05-1097, and consolidated cases

AFFIDAVIT OF WILLIAM O'SULLIVAN

I, William O'Sullivan, declare as follows under penalty of perjury:

1. I am Director of the Division of Air Quality of the State of New Jersey ("State"), Department of Environmental Protection ("NJDEP"). I have over thirty-four years of experience in the New Jersey air pollution control program. I have managerial responsibility over the State's air pollution control program for ambient monitoring, stack testing, planning, permitting, rulemaking and administration. I am also an active member of various national and regional organizations of air pollution control officials, including the National Association of Clean Air Agencies ("NACAA"), formerly STAPPA/ALAPCO, the Northeast States for Coordinated Air Use Management ("NESCAUM"), and the Mid-Atlantic Regional Air Management Administrators (MARAMA).

2. I am familiar with the two rules promulgated by EPA that are at issue here: the Delisting Rule and the Clean Air Mercury Rule ("CAMR") (collectively, the "mercury rules"), whereby EPA removed electric utility generating units ("EGUs" or "power plants") from the list of source categories regulated under Section 112 of the Clean Air Act (the "Act"), 42 U.S.C. § 7412, and promulgated a cap and trade program under Section 111 of the Act, 42 U.S.C. § 7411, instead of establishing Maximum Achievable Control Technology ("MACT") emission standards for EGUs under Section 112 of the Act. A proper MACT standard, reflecting the cleanest 12% of existing coal-fired power plans, would require approximately 90% reductions in emissions of mercury from each plant and would not include emission trading.

3. EPA's actions in the mercury rules placed a regulatory burden on the states to either participate in a cap and trade program or obtain mercury reductions through other mechanisms. By November 17, 2006, a number of states submitted their state plans to EPA. See 71 Fed. Reg. 75,117, 75,119 (Dec. 14, 2006). In addition to New Jersey, at least fourteen other states have already determined to not participate in the national

trading program and implement their own programs. See NACAA, State Mercury Programs for Utilities (Dec. 7, 2006), attached hereto as Ex. A.

4. New Jersey determined to not participate in the EPA managed cap and trade program because of the program's weak standards instead of a MACT standard, the program's much delayed deadline by which mercury emissions are to be reduced, and the inability of a trading program to achieve mercury emission reductions at every facility, which results in the inability of a trading program to eliminate the dangers of mercury hot-spots. In the absence of an adequate national program, New Jersey adopted more stringent state mercury control rules to achieve greater mercury emission reductions within the State's borders more expeditiously. New Jersey adopted its plan and encouraged other states to adopt similar plans because of EPA's failure in its mercury rules to promulgate rules that effect sufficient reductions of mercury emissions from EGUs to protect the State's natural resources, e.g., wildlife and ecological systems, and the health of the public. In developing and implementing State standards in place of federal standards, New Jersey has already expended hundreds of thousands of dollars and will continue to absorb administrative and other costs and expend funds to implement its rules.

5. I am also familiar with the findings of the New Jersey Mercury Task Force that, based on results of the Northeast Mercury Study (NESCAUM et al. 1998), the New Jersey Atmospheric Deposition Network, and other available information, concluded that out-of-state sources contribute a substantial portion of the mercury that is deposited in New Jersey. See New Jersey Mercury Task Force, Vol. II, Chap. 3, Atmospheric Transport and Mercury Deposition, pp. 29-34 (Jan. 3, 2002), attached hereto as Ex. B. Mercury deposition in the State has compelled the State to, among other things, study the air deposition problem in New Jersey, monitor mercury levels in precipitation, collect and study data on mercury levels in New Jersey fish, and to develop strategies to further reduce mercury pollution in the State, which is mostly the result of mercury deposition from the air. Many tested water bodies exceed the surface water criterion value of 0.3 ppm in fish tissue promulgated by the U.S. EPA. In about 40% of the waterbodies tested, higher trophic level fish were found to have mercury concentrations exceeding 1.0 ppm. See New Jersey Mercury Task Force, Vol. II, Chap. 8, Impact of Mercury on NJ's Ecosystems, p. 95 (Jan. 3, 2002), attached hereto as Ex. C. Mercury concentrations in lower trophic level fish have also been found to be elevated, in the range of 0.2 to 0.5 ppm. Id.

6. Human exposure to the most toxic form of mercury comes primarily from eating contaminated fish and shellfish harvested from aquatic systems. Mercury in the form of methylmercury is quickly taken up into higher organisms through the food chain, and those organisms retain the mercury in their bodies, a process called bioaccumulation. As higher predators consume these organisms, they accumulate even more mercury. Levels of methyl mercury in fish on average range from 100,000 up to millions of times those in the water in which they swim. This process is called biomagnification. Mercury reaches its highest levels in predatory fish and in birds and mammals that consume fish. Accordingly, mercury poses a severe risk not only to human health, but also to the State's

wildlife. Emissions of mercury to the air account for most of the mercury currently entering water bodies and contaminating fish in New Jersey. Emissions of mercury to the air therefore directly impact and harm the natural resources of the State. New Jersey, among most other states, has imposed fish consumption advisories based upon elevated levels of mercury in fish tissues. Attached as Ex. D is the State's 2006 Guide to Health Advisories for Eating Fish and Crabs Caught in New Jersey Waters. EPA's 2004 National Listing of Fish Advisories, attached hereto as Ex. E, indicates that forty-four (44) states, one (1) territory, and two (2) tribes have issued mercury advisories.

7. The mercury rules further impact the states in terms of states' obligations to meet the fishable and swimmable goals of the Clean Water Act ("CWA"), 33 U.S.C. §§ 1251 – 1376. Section 303(d) of the Clean Water Act, 33 U.S.C. § 1313(d), provides that if a waterbody is not meeting water quality standards, the State must include that waterbody on its list of "impaired waters" and then must prepare a "total maximum daily load" or TMDL to specify pollutant reductions necessary from sources in order for the waterbody to attain standards. The EPA's website indicates that mercury is the cause of impairment of 8,565 waterbodies throughout the nation. See http://oaspub.epa.gov/waters/national_rept.control. In New Jersey, as of 2002, there were ninety (90) such waterbodies on the list of impaired waters because of mercury. See http://oaspub.epa.gov/tmdl/waters_list.control?state=NJ&impairment=MERCURY%20IN%20FISH%20TISSUE. Since EPA's cap and trade program provides no guarantee that upwind sources, for example, nearby out of state power plants, will reduce mercury emissions, New Jersey and the other states promulgating TMDLs face an increased burden of finding additional sources of mercury to regulate in order to meet water quality standards.

8. The EPA mercury rules will harm New Jersey's fishing, tourism and recreation industries because without prompt sufficient reductions of mercury emissions, the mercury in the State's waters will not abate promptly or sufficiently, and recreational fishers will continue to not be able to safely consume the fish caught. Captains who fished for species with more elevated levels of mercury, species that have been highlighted in the press as posing a potential health hazard, identified advisories as affecting their business. See New Jersey Mercury Task Force, Vol. II, Chap. 11, Impact of Mercury on Tourism and Recreation in NJ, p. 144 (Jan. 3, 2002), attached hereto as Ex. F.

9. The mercury rules will also result in continued harm to New Jersey birds that have been found to have mercury levels in their tissues, feathers and eggs close to or above levels anticipated to impair behavior, reproduction, growth, and survival. See Ex. C, New Jersey Mercury Task Force, Vol. II, Chap. 8, Impact of Mercury on NJ's Ecosystems, p. 108.

Date: Jan 10, 2007

William O'Sullivan, P.E., Director
Division of Air Quality, NJDEP

EXHIBIT A

National Association of Clean Air Agencies
State Mercury Programs for Utilities
December 7, 2006

The following table is an overview of state actions directed at reducing mercury emissions from coal-fired electric utility boilers including the responses states will use to meet the federal Clean Air Mercury Rule (CAMR) that become effective on May 18, 2005. The table indicates if a state will participate in EPA's interstate trading program and how each state is planning to distribute the mercury allowances in their state budgets. The status of state laws or regulations is also summarized. Finally, the table indicates the status of the submittal of the state plan to EPA. Note that Idaho, Rhode Island and Vermont did not receive a mercury budget under the CAMR and are not required to develop and implement a state plan.

State Participation in National Trading Program

EPA allows states flexibility in achieving the mercury reductions required under CAMR, including optional participation in a national mercury allowance trading program. Under the national program, owners of coal-fired electric generators must hold one allowance for each ounce of mercury emitted in a given year. Allowances can be readily transferred from one utility to another and may be banked for use in later years. If a state chooses to participate in the national trading program, EPA has an allowance tracking system to manage emission reporting and trading based upon the each participating states' methodology for allocation of allowances. EPA has also developed a model rule for their trading program for states to use as the basis for their state plans to implement the CAMR. Any state that does not participate in the national program must establish regulations that set emission limitations and compliance schedules to meet their mercury budget.

Allocation of Allowances

In EPA's model rule a state's mercury budget is distributed as emission allowances to the affected coal-fired electric utility boilers. States have the flexibility to determine the cost of allowance distribution (free or auction), frequency of allocations, basis for the distribution and the use and size of allowance set asides (e.g. new units, small units, energy efficiency and IGCC development). States may select a higher or lower set aside amount for new sources depending upon expected growth.

NACAA Model Rule

The National Association of Clean Air Agencies (NACAA) – formerly STAPPA/ALAPCO – prepared a model rule that contains options for states that wish to adopt a program that is more stringent than the CAMR. Additional information is available on www.4cleanair.org.

State Contact and Additional Information

Included are state contacts, if available, and links to relevant state web pages.

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
Region 1					
Connecticut	State statute requires 90% reduction or comply with mercury emissions limit of 0.6 lb/TBTU by 7/1/2008, with provision for alternative if controls fail to achieve limitation. More stringent limits possible after 7/1/2012.	No.	No.	Ric Pirolli: (860) 424-4152 Ric.pirolli@po.state.ct.us www.cga.ct.gov/2005/pub/chap446c.htm#Sec221-199.htm	Partial submittal by 11/17/06
Maine	All facilities (including EGUs) in Maine have a mercury emission limit of 50 lbs/yr which drops to 35 lbs/yr in 2007 and to 25 lbs/yr in 2010. A mercury reduction plan is required for facilities emitting more than 10 lbs/yr.			Lisa Higgins Lisa.higgins@maine.gov Only one EGU may be subject to CAMR and it emits less than 4 lbs Hg per year. Maine will let EPA administer the program in Maine. Maine is party to the lawsuit to overturn CAMR.	Will not submit a state plan
Massachusetts	Adopted rule requires 85% capture or 0.0075 lb/GW-hr by 1/1/2008 and 95% capture or 0.0025 lb/GW-hr by 10/1/2012. Averaging between units at the same facility allowed.	No.		Patricio Silva: (617) 654-6575 Patricio.silva@state.ma.us www.mass.gov/dep/air/laws/camrplan.doc	Partial submittal by 11/17/06
New Hampshire	Legislation passed house and Senate, signed by Governor. Calls for 80% reduction of mercury emissions from coal-burning power plants through installation of scrubber technology no later than 7/1/2013. Emission credits for SO_2 for early mercury reductions.	No.		Jeff Underhill junderhill@des.state.nh.us	Submitted by 11/17/06 deadline
Rhode Island	Zero state budget for mercury under CAMR. State submitted a negative declaration.	No.			Negative declaration submitted by 11/17/06 deadline

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
Vermont	Zero state budget for mercury under CAMR. State submitted a negative declaration.	No.			Negative declaration submitted by 11/17/06 deadline
Region 2					
New Jersey	Adopted rule requires control efficiency of 90% or 3 mg/MW-hr by 12/15/2007, for coal-fired boilers of any size. A multi-pollutant approach can reduce the initial reduction required and extend compliance to 12/15/2012.	No.		www.nj.gov/dep/aqm/1997adop.htm	Submitted by 11/17/06 deadline
New York	On 9/6/06, NYSDEC proposed a rule for the control of mercury emissions from coal-fired electric utility steam generating units that incorporates the Phase I emission cap in the federal rule for the years 2010-2014 and beginning in 2015 establishes a unit-based emission limit for each applicable unit. Phase I of the state proposal will impose annual facility-wide mercury emission limitations, based upon the state mercury budget EPA distributed to New York. Applicable facilities will not be permitted to generate and trade mercury reductions with other facilities or states. The annual facility-wide emission limitations will be in effect from 2010 to 2014. Starting in 2015, Phase II, in conjunction with other electric sector regulations such as the Regional Greenhouse Gas	No.		Steve DeSantis sxdesant@gw.state.ny.us Details of the regulation can be found at: www.dec.state.ny.us/website/dar/air_regs.html#recent	Submitted by 11/17/06 deadline

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
	Initiative (RGGI) and the second phase of the Clean Air Interstate Rule (CAIR), the state mercury regulation will establish a unit-based emission limit for each applicable unit.				
Region 3					
Delaware	State plan calls for 2 phases: Phase 1 – 80% capture and control of baseline mercury emissions by 2009 (emission rate of 1.0 lb/TBTU); and Phase 2 – 90% capture and control of emissions by 2013 (emission rate limit of 0.6 lb/TBTU).	No.		Robert Clausen Robert.clausen@state.de.us Regulation No. 1146, "Electric Generating Unit (EGU) Multi-Pollutant Regulation" Development Documents www.awm.delaware.gov/info/regs/aqmmultipreg.htm	Submitted by 11/17/06 deadline
Maryland	Healthy Air Act of 4/6/2006. Phase I reduction of 80% by 2010; Phase II reduction of 90% by 2013.	No.		Maryland Healthy Air Act www.mde.state.md.us/Air/MD_CPR.asp	
Pennsylvania	On October 17, 2006, the Environmental Quality Board approved the final-form regulation. The final-form regulation will require an 80% reduction in mercury emissions by 2010 and a 90% reduction by 2015. The independent Regulatory Review Commission approved the final-form regulation on November 16, 2006. Office of Attorney general and legislative reviews are pending. The Legislation introduced in April 2006 requires compliance with CAMR. On November 6, 2006 Section 111(d) State Plan was submitted to EPA.	No.		Dean Van Orden: (717) 787-9702 dvanorden@state.pa.us Krishnan Ramamurthy:(717) 787-9257 kramamurth@state.pa.us John Slade: (717) 787-4325 jslade@state.pa.us DEP accepted a citizen petition requesting a state rule more stringent than CAMR. www.dep.state.pa.us/dep/deputate/airwaste/aq/regs/mercury_rule.htm	Submitted by 11/17/06 deadline

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
Virginia	Governor signed Clean Smokestacks Legislation, effective 7/1/2006. Requires adoption of CAMR and state-specific rule. Largest operator must meet reductions by 2015 and cannot purchase allowances to comply, but may sell excess credits. Second largest operator may use emission credits generated from other units under common ownership within 200 km of VA's border. Units within a nonattainment area cannot purchase credits to comply, but credits generated at units under common ownership within 200 km of border may be used to comply with state rule.	Participating in interstate trading is limited for three companies operating units within the state. Smaller companies are allowed to fully participate in national trading program.	New source set aside of 5% for the first 5 years of program, then 2% thereafter.	Melissa Porterfield msporterfield@deq.virginia.gov An assessment of mercury deposition in VA will be conducted. More details on the assessment are available http://leg1.state.va.us/cgi-bin/legp504.exe?061+ful+HB1055ER+pdf	To be submitted after 11/17/06
West Virginia	Adopted EPA model trading rule. May 1, 2006 rule effective date. Plan submitted on July 12, 2006.	Yes.	5% set-aside to be sold by state. No adjustment for coal type. Heat input based allocations.	Laura Crowder: (304) 926-0499, ext. 1247 State is conducting a mercury study: www.wvdep.org/daq/ and select the mercury link.	Submitted by 11/17/06 deadline
Region 4					
Alabama	Adopted EPA model rule with minimal adjustments.	Yes.	No new-source set-aside. A unit must retire to "free up" allowances for new units. State is allocating the entire first phase and then in 3-yr increments beginning in 2018.	Lisa Cole leb@adem.state.al.us	Submitted by 11/17/06 deadline

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
Florida	Proposal relies on co-benefits of CAIR, with hold-back of projected surplus allowances to prevent build-up of large bank during Phase 1. Rules approved by state board 6/29/06.	Yes.	Existing units allocated 70% of Phase 1 allowances for 2012-2017 with remaining allowances placed in "compliance set aside" for existing units that exceed their allocations despite add-on controls, and for new units as supplement to 5% new-unit set aside.	Larry George: (850) 921-9555 larry.george@dep.state.fl.us www.dep.state.fl.us/air/rules/regulatory.htm	To be submitted after 11/17/06
Georgia	The Georgia DNR Board was briefed on a strategy that includes four state rules that essentially work together: 1. State Rule adopting CAMR regulation with changes to allocation and 2018 budget. Rule to be submitted as part of CAMR SIP. 2. State Rule only - not submitted as part of CAMR SIP: For new coal-fired units that serve a generator of at least 25 MW - Install and operate BACT. 3. State Rule only - not submitted as part of CAMR SIP: For existing units - schedule promulgated for installation and operation of multi-pollutant controls; require a mercury fish tissue study and monitoring program. 4. State Rule only - not submitted as	Participation in National Trading Program with caveats	Decision Pending.	Susan Jenkins: (404) 362-4598 susan_jenkins@dnr.state.ga.us James Kelly: 404-363-7131 james_kelly@dnr.state.ga.us Jimmy Johnston: 404-363-7014 jimmy_johnston@dnr.state.ga.us www.air.dnr.state.ga.us/airpermit/cair Note: same URL for CAIR & CAMR.	To be submitted after 11/17/06

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
	part of CAMR SIP: Adopt a program very similar to the CAMR Model Rule, except that Georgia sources could only show compliance with Georgia EPD allowance allocations using Georgia EPD allowances. The source would be allowed to bank Georgia EPD allowances.				
Kentucky	Plan to adopt EPA model rule.	Yes.	Plan to develop state specific allocation approach.	John Lyons John.lyons@ky.gov	To be submitted after 11/17/06
Mississippi	Plan to adopt EPA model rule.	Yes.			To be submitted after 11/17/06
North Carolina	EMC adopted mercury rules on Nov. 10, 2006. Rules adopt EPA model rule with provision for the installation of mercury control technology on all units by specified dates. In addition, each utility-owned coal-fired EGU has to reduce mercury emissions by the maximum degree that is technically and economically feasible by 2018 or cease operating without relying on trading. Trading can still be used to meet the federal requirements. Rules could lead to 88% reductions in mercury emissions by 2018.	Yes.	Full allocation is distributed across sources based on historical combustion BTUs. Up to 5% mercury credits for new growth will come from allocations.	Paul Grable: (919) 733-1468 Paul.grable@ncmail.net Thom Allen: (919) 733-1489 Thom.allen@ncmail.net http://daq.state.nc.us/rules/adopted/	To be submitted after 11/17/06
South Carolina	Proposed rule that would adopt EPA model rule with some modifications. Proposed rule published in State Register on October 27, 2006. Comment period ended 11/27/06.	Yes.	Propose to withhold 20% of state budget annually.	Stacey Gardner gardnesr@dhec.sc.gov L. Nelson Roberts robertln@dhec.sc.gov	To be submitted after 11/17/06

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
	Revised rule to be submitted to Board for public hearing on 1/11/07. If approved, rule submitted to legislature, with approval 90 days afterwards. Next, publish final rule in State Register (June or July 2007) and submit final to EPA upon publication.			Each utility may have access to their portion of the annual 20% set-aside if their utility-wide annual emissions exceed their annual utility-wide allocation. Unused portion of the set-aside will continue to roll over and be available until the end of the 2021 control period. The remainder will be retired in 2022.	
Tennessee	Adopted EPA model rule.	Yes.		Travis Blake: (615) 532-0617 Travis.blake@state.tn.us	To be submitted after 11/17/06
Region 5					
Illinois	1/9/2006, Governor's proposal requests Illinois EPA to develop rules for a two-phase reduction approach. 90% reduction with intrastate averaging by 6/09; 75% individual plant reduction by 6/09; 90% individual plant reduction by end of 2012.	No.		www.epa.state.il.us/air/cair/	Submitted by 11/17/06 deadline
Indiana	Drafting a CAMR-based rule for public comment while continuing to work with stakeholders on ways to address the citizen's rulemaking petition and comments received in favor of strengthening the federal rule in Indiana.	Yes.		www.in.gov/idem/air/workgroups/mercury/	To be submitted after 11/17/06
Michigan	4/17/2006, Governor announced proposal to reduce mercury utility emissions beyond CAMR. The first phase would use the reductions from the CAMR and other federal programs by 2010. The second	No.		www.michigan.gov/deq/0,1607,7-135-3310-142890--,00.html	To be submitted after 11/17/06

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
	phase would go beyond, for a 90% by 2015. System-wide averaging would be allowed as long as hot-spots do not result.				
Minnesota	Mercury Emissions Reduction Act of 2006 effective May 2006: • 90% reduction (totaling 1,200 lb.) of annual Hg emissions from existing EGUs greater than 250 MW. • Reductions required by 2009 for dry PM controlled units; 2014 for wet PM controlled units. CAMR remains unchanged by Reduction Act. Presumably reductions create allowances for redistribution.	Yes.		J. David Thornton: (651) 284-0382 J.David.Thornton@pca.state.mn.us www.pca.state.mn.us/air/mercury.html www.house.leg.state.mn.us/bills/billnum.asp?billnumber=HF3712&session_number=0&ls_year=84&year=2005	Not submitting a plan
Ohio	Ohio's draft CAMR rules went out for interested party review on July 24. They are basically the federal model.	Yes.		Lee Burkleca: (614) 728-1344 Lee.burkleca@epa.state.oh.us www.epa.state.oh.us/dapc/page/whatsnew.html www.epa.state.oh.us/dapc/regs/regs.html	To be submitted after 11/17/06
Wisconsin	October 2004 adopted rule requires 40% reduction by 2010 and 75% reduction by 2015. Reductions from a baseline determined from mercury in coal. True-up to CAMR reduction levels and schedule required in the state rule. Governor has directed that	Rule revision process will determine if interstate trading will be allowed.	Rule revision process will establish allocation of allowances.	Jon Heinrich Jon.heinrich@dnr.state.wi.us http://dnr.wi.gov/org/aw/air/reg/mercury/camr.htm	To be submitted after 11/17/06

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
	requirements be added to achieve a 90% mercury emission reduction from coal-fired plants after applying the CAMR schedule and reduction requirements. Public hearing authorization on a draft rule to be requested from Natural Resources Board at their January 2007 meeting. Attempting to have state plan submitted by August 2007.				
Region 6					
Arkansas	Reviewing the model rule as well as alternatives.	Considering participation in interstate trading.		Elizabeth Sartain sartain@adeq.state.ar.us	
Louisiana	LDEQ submitted the EPA model rule in a 111(d) plan to Region 6.	Yes.	Yes.	Jim Orgeron James.orgeron@la.gov	Submitted by 11/17/06 deadline
New Mexico	Proposed rule that would adopt state-specific allocation methodology.	No.	State-specific approach. Proposed new unit set-aside of 5% through 2017, then 3% thereafter.	Andy Berger: (505) 955-8034 andy.berger@state.nm.us	Partial submittal by 11/17/06
Oklahoma	Plan to adopt EPA model rule.	Yes.	Proposing 5% new unit set-aside from 2010 to 2014 and 3% thereafter.	Morris Moffett Morris.moffett@deq.state.ok.us	Partial submittal by 11/17/06
Texas	Adopted the EPA model rule on July 12, 2006. State plan submitted to EPA on August 3, 2006.	Yes.		Kim Herndon kherndon@tceq.state.tx.us www.tceq.state.tx.us/implementation/air/sip/caircamr.html	Submitted by 11/17/06 deadline

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
Region 7					
Iowa	Adopted EPA model rule on July 12, 2006. Submitted to EPA for SIP approval on August 3, 2006.	Yes.	State-specific allocations (based on EPA model rule with only minor modifications).	Christine Paulson Christine.paulson@dnr.state.ia.us www.iowadnr.com/air/prof/caircamr/index.html	Submitted by 11/17/06 deadline
Kansas	Plan to adopt EPA model rule.	Yes. Statutory authority needed; bill passed, effective 7/1/06.	Developing state-specific allocation.	Miles Stotts mstotts@kdhe.state.ks.us	Partial submittal by 11/17/06
Missouri	Plan to adopt EPA model rule. Will be holding a public hearing on draft proposed rule on December 7, 2006.	Yes.	Plan to develop state-specific allocation approach. Proposing full distribution of allowance using EPA's coal weighting and historic heat input.	Rick Campbell: (573) 751-4817 Rick.campbell@dnr.mo.gov www.dnr.mo.gov/env/apcp/cair_camr.htm	To be submitted after 11/17/06
Nebraska	Undecided – EPA model rule or EPA model rule modified.	Yes.		Melissa Woolf Melissa.woolf@ndeq.state.ne.us	To be submitted after 11/17/06
Region 8					
Colorado	Proposed rule that would adopt the EPA model rule with administrative modifications.	Yes.	Plan to develop state-specific allocation approach. Proposing new unit set-aside of 36.6% through 2017, then 5%	Dena Wojtach Dena.wojtach@state.co.us www.cdphe.state.co.us/ap/reg6.html	To be submitted after 11/17/06

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
			thereafter. Proposing to enter into trade agreements with existing units to allocate additional allowances (potentially above CAMR amounts) to units having an allowance deficit in exchange for early reductions. Additional allowances will be given in exchange for installation of Best Available Mercury Control Technology in 2013.		
Montana	The Montana Board of Environmental Review approved final adoption of the MT Mercury Rule on 10/16/06. The rule established an emission limit of 0.9 lbs/TBtu for facilities using sub bituminous coal, and 1.5 lbs/TBtu for plants firing lignite, both on a rolling 12-month average. If a company operates appropriate controls but can't meet its emission limit, it can apply for a temporary alternate emission limit (AEL). The rule establishes ceilings on the AELs of up	Yes, the rule also incorporates the EPA model rule by reference.	Proposing new unit set-aside of 75% until 2018 and 30% thereafter.	Charles Homer: (406)444-5279 chomer@mt.gov www.deq.state.mt.us/ber/index.asp	Submitted by 11/17/06 deadline

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
	to 1.5 lbs/TBtu for new non-lignite facilities, 2.4 lbs/Btu for existing non-lignite facilities, 3.6 lbs/TBtu for new lignite facilities and 4.8 lbs/TBtu for existing lignite facilities. In 2018 these ceilings drop to 1.2 lbs/TBtu for all non-lignite facilities and 2.8 lbs/TBtu for all lignite facilities, or BACT, whichever is more stringent. The rules also require a mercury-specific BACT review every 10 years for each permitted plant.				
North Dakota	Plan to adopt modified EPA model rule.	Yes.	Proposing 5% new unit set-aside from 2010 to 2014 and 3% thereafter.	Tom Bachman tbachman@state.nd.us	Partial submittal by 11/17/06
South Dakota	EPA model rule.	Yes.	Proposing 5% new unit set-aside.		Submitted by 11/17/06 deadline
Utah	Plan to adopt modified EPA model rule.	Yes.	Proposing 5% new unit set-aside from 2010 to 2014 and 3% thereafter.	Bill Reiss breiss@utah.gov	
Wyoming	Plan to adopt modified EPA model rule.	Yes.	New unit set-aside of 10% under consideration. Allocations to existing sources will be made for 5-year blocks.	Tina Anderson tander@state.wy.us	Partial submittal by 11/17/06
Region 9					
Arizona	On November 14, 2006, the	Yes, but facilities	CAMR allocation	Steve Burr	Submitted by

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
	Governor's Regulatory Review Council approved a regulation incorporating CAMR but adopting an additional state standard requiring 90% emission reductions or 0.0087 lb/GW-hr by 12/31/2013.	will be required to purchase allowances on a 2-for-1 basis to the extent their emissions exceed their allocated allowances and the state 90% standard. Emissions in excess of those needed to comply with CAMR will be transferred to the state and retired.	method adopted	Sb5@azdeq.gov	11/17/06 deadline
California	Considering adoption of a rule more stringent than CAMR.	No.	At existing sources, cap mercury emissions at current levels.	Todd Wong: (916) 324-8031 twong@arb.ca.gov	To be submitted after 11/17/06
Hawaii	Plan to adopt modified EPA model rule. Possible revisions to the allocation of allowances	Yes.	Considering shortening the allocation lead time and retaining unused new unit set-asides for undetermined future use.	Scott Takamoto Scott.takamoto@doh.hawaii.gov	To be submitted after 11/17/06
Nevada	Proposing to adopt a modified version of EPA's model rule. The Nevada rule would include incentives that encourage mercury reductions and	Yes.	Plans to develop a state-specific allocation approach allowing	Lori Campbell loric@ndep.nv.gov	Submitted by 11/17/06 deadline

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
	drive state-of-the-art mercury reduction technologies.		for future growth and incentives for low mercury-emitting units.		
Region 10					
Alaska	Plan to adopt EPA model rule. Rule applies to two existing sources in AK.	Yes.	Likely to allocate same as EPA calculated.	Tom Turner: (907) 269-8123 Tom_turner@dec.state.ak.us	To be submitted after 11/17/06
Idaho	Zero state budget for mercury under CAMR. State has decided not to participate in the cap-and-trade program. The state is reserving the right to opt in at a later date after assessing energy needs.	No.		Carl Brown Carl.brown@deq.idaho.gov	Submitted decision by 11/17/06 deadline
Oregon	Proposal of 90% or 0.60 lbs/TBTU by July 1, 2012 with up to a one-year extension possible. Compliance alternative if 90% or 0.60 lbs/TBTU not achieved despite installing best controls.	Considering four trading options from no trading to full trading.	Will propose 10% new-source set aside from 2010-2017 and 20% from 2018 on. Unallocated portions of the new unit set-aside will be retired.	Gerald Ebersole Ebersole.Gerald@deq.state.or.us	To be submitted after 11/17/06
Washington	In drafting stage and subject to change. Considering 0.0087 lb/GWh for all sources beginning in 2013. If controls fail to meet standard, then existing plant would be required to submit a compliance plan by June 2013 to meet controls. Plant must be in compliance by 2017. Anticipate proposing in March; adopting by Sept. 2007. Two different	Yes. Considering trading for first 3 years, then out of trading. Considering intra-state trading during nontrading period.	Trading period: 70% to existing source. Distributed in Feb for preceeding calendar year: 5% new source available for all 5 years; 25% supplemental pool available	Elena Guilfoil: (360) 407-6855 Egui461@ecy.wa.gov Rule development web page: www.ecy.wa.gov/laws-rules/activity/wac173406.html	To be submitted after 11/17/06

State	Rules or Legislation - Proposed or Adopted	Participation in National Trading Program	Allocation of Allowances	State Contact and Additional Information	Submittal of State Plan to EPA (due 11/17/06)
	state agencies regulate these sources in Washington so coordination of state efforts is necessary to propose one state rule. Consideration of energy implications of policy decisions embedded in draft rule continues so rule may change.		first to existing source. Non-trading period: -- Allowance distributed based on .0087 lb/GWh and will be established in permit as hard limit. -- 10% or 15.6 lbs/yr retired as public health measure. -- ~ 3 lbs/yr available for growth.		

EXHIBIT B

Chapter 3 - ATMOSPHERIC TRANSPORT AND MERCURY DEPOSITION

A. Introduction

Mercury is an especially dynamic pollutant because of its unique physical, chemical, and bioaccumulative properties. The volatility of the liquid elemental metal and some of its compounds, in conjunction with its ability to chemically transform under environmental conditions, makes it easily exchangeable across all environmental media including the biosphere where it can bioaccumulate and biomagnify. After release to the environment, mercury enters into what is referred to as the biogeochemical cycle, where it remains chemically, biologically, and environmentally dynamic for a sustained period of time, until it is ultimately sequestered in stable long-term environmental sinks such as the depths of the ocean, deep freshwater lake sediments, and soil (Fitzgerald et al. 1991). Retiring mercury from commerce, by sequestering it in a secure, permanent storage facility is intended to diminish input to the environment.

This section briefly outlines the many components of mercury fate and transport that influence the patterns of accumulation of mercury in the environment and subsequent exposure. These components are described more thoroughly in the first Mercury Task Force Report (NJDEPE 1993). Direct discharges of mercury to land and water will result in increased mercury in the environment, however this section will focus mainly on the fate and transport of emissions to air.

In the past, direct discharges of mercury to land and water were significant in NJ. One such historic example is the Ventron/Velsicol site which discharged as much as two to four pounds of mercury per day into Berry's Creek (see Chapter 7 of this Volume) up until 1974. These sources are much better regulated today, and it is believed that they now represent a very small portion of the new mercury added to the NJ environment each year. Work is still necessary to prevent mercury that is present on land from reaching water bodies in the state.

B. Emissions

The fate of mercury in the environment begins with emissions to air, land or water. Direct emissions to the air in NJ that result from human activities (anthropogenic emissions) have been studied in detail by this Task Force and are discussed in Volume III, of this report. These emissions come from a wide variety of sources including many types of combustion and the processing of mercury-containing wastes. Mercury from emissions elsewhere also contribute to mercury levels in NJ's atmosphere, and estimating the relative contribution of in-state to out-of-state sources is a challenge.

Globally, natural emissions to air are also a significant source category, contributing as much as 2.5 million kilograms per year (Nriagu 1989). Such emissions result from volcanoes, erosion, seasalt spray, forest fires, and particulate and gaseous organic matter emissions from land and marine plants. Nriagu (1989) estimates that natural sources make up about 41% of the total air emissions in the world, with about 40% of natural emissions coming from volcanoes and 30% emitted by marine plants. Other estimates place natural emissions closer to 20%. The contribution of natural sources in NJ is not known but is likely to be small since 1) the state does not have volcanoes within its boundaries, and 2) most of the coastal zone, where seasalt spray may make a contribution, is on the east or downwind coast.

It has been estimated that anthropogenic activities have increased global atmospheric mercury emissions by at least a factor of 3 relative to natural emissions since the beginning of the Industrial Revolution (Andren and Nriagu 1979).

C. Movement Through Air and Between Air and Land

As mercury is emitted to the atmosphere, it is moved and diluted by local winds. Some may be deposited locally, especially during precipitation events. Eventually the remaining mercury plume merges with the general air mass and becomes part of the global atmospheric pool of mercury. This circulates with prevailing air currents, continually receiving newly emitted mercury and losing it through wet and dry deposition on water surfaces or land. Some mercury that falls on land can run off, through rainfall and erosion, into a local water body. Mercury that reaches water bodies either directly or indirectly can be converted by biota into the more toxic methylmercury, which then biomagnifies up the food chain, where it accumulates reaching high concentrations in some of the longer-lived fish (see Figure 2.2).

D. Atmospheric Chemistry & Residence Times

The form in which mercury is emitted and the occurrence of rain and snow influence whether air emissions will be deposited close to a source or will be transported long distances before being deposited on land or water. If a water-soluble form of mercury (such as mercuric chloride) is emitted, it may be deposited close to the emission source during a precipitation event. If not deposited locally, much of this water-soluble mercury is likely to be washed out of the air within a day or two (as soon as a precipitation event is encountered). Non-soluble forms of mercury (such as elemental mercury) will travel much farther. These forms enter the global reservoir where they are slowly converted to soluble forms of mercury, mainly Hg^{++}, and then washed out. The residence time of non-soluble mercury in the atmosphere is about one year (Mason et al. 1994).

E. Deposition

Two types of mercury deposition occur: wet and dry. Wet deposition (via rain and other types of precipitation) is most efficient at removing divalent mercury (a soluble form) from the air. Dry deposition, via settling and scavenging, is more likely to remove particulate forms of mercury from the ambient air and can also remove gaseous mercury forms.

Whether the deposition is to land or water will define the possible pathways to bioaccumulation. The rate of bioaccumulation is dependent on many characteristics of the receiving water body. For example, the bioaccumulation rate in fresh water lakes will be different from the rate in a moving stream, which in turn is different from bioaccumulation in estuarine or marine waters.

1. Estimates of Wet and Dry Deposition of Mercury

Wet deposition of mercury can be measured directly by placing buckets to collect precipitation on a daily, weekly, or event basis. The water that is collected is then analyzed for total mercury, or occasionally even for specific forms of mercury. Reliable techniques for measuring dry deposition of mercury are not available, so indirect means of extrapolating dry deposition from observations of gaseous and particulate mercury in the air must be used. Algorithms have been developed to calculate the amount of mercury in the air that will deposit on the ground and on vegetation in the absence of rainfall.

When estimates of mercury deposition are needed over a large area, models are sometimes used to generate predicted deposition patterns. Some models are used to predict deposition from a single source or small group of sources within one to 50 kilometers of the point of emission. Other models have been developed to predict the transport and deposition of emissions from many sources over large areas. One such large-scale model (RELMAP) was used by USEPA to describe the impact of emissions throughout the country on wet and dry deposition nationwide (USEPA 1997a).

Models such as RELMAP (Regional Lagrangian Model of Air Pollution) and TEAM (Trace Elements Analysis Model), use a series of mathematical equations to represent the movement of mercury through the atmosphere and from the air to land and water. These models use meteorological data collected at hundreds of airports around the country to describe the dispersion of mercury. They also include a series of equations to describe the chemical reactions that convert mercury from one form to another. Assumptions regarding deposition velocity and scavenging rates (i.e., how fast precipitation can remove mercury from the air) are employed to estimate dry and wet deposition, respectively.

2. Estimates of Total Deposition in NJ

At present there are no definitive data that can quantify total wet and dry deposition of mercury in NJ. However, there are modeling and monitoring studies that provide insight into what the deposition is likely to be. These studies include: 1) the Northeast Mercury Study; 2) the Trace Elements Analysis Model; and 3) the NJ Atmospheric Deposition Network. Each of these is described briefly below and the deposition estimates are summarized.

a. Northeast Mercury Study

The Northeast Mercury Study (NESCAUM et al. 1998) includes a modeling analysis of mercury emission sources throughout the country. Using RELMAP, the dispersion of emissions from these sources was predicted for a one-year period using hourly meteorological data from 1989 (e.g. precipitation rates, wind speed and direction). From the predicted concentrations, both wet and dry deposition were estimated at grid squares representing about 1600 square kilometers each (roughly 25 mi x 25 mi).

The model used in this study predicted the total wet and dry deposition rates to be 30 to 100 $\mu g/m^2/yr$ over most of the state of NJ (with a few areas along the coast having predicted rates in the 10 to 30 $\mu g/m^2/yr$ range). When these results are integrated over the whole state (as described below in the discussion of relative contributions), the total deposition is estimated to be 610 to 1740 kg/yr. The Northeast Mercury Study estimates that the relative contribution of wet and dry deposition through the whole Northeastern region (New England, New York and NJ) is about 54% wet and 46% dry.

b. Trace Elements Analysis Model

The model TEAM (Pai et al. 1997) also predicts wet and dry deposition on a national scale. This model uses sophisticated atmospheric chemistry and wet and dry deposition algorithms. The model results (predicted for 10,000 square kilometer grid cells) reported by Pai et al. (1997) are based on 1990 emissions and meteorological data. The model predicts a range of wet and dry deposition rates for NJ, which are summarized below by region. The predicted range for total deposition is 24 to 80 $\mu g/m^2/yr$ (Table 2.2), which is similar to the range of deposition predicted in the Northeast Mercury Study.

Table 2.2. Predictions of Mercury Deposition in NJ from the TEAM Model.

NJ Region	Wet Deposition Rate ($\mu g/m^2/yr$)	Dry Deposition Rate ($\mu g/m^2/yr$)	Total Deposition Rate ($\mu g/m^2/yr$)
North	30-55	26-50	56-80
Central	15-20	8-17	24-32
South	20-30	8-12	24-32

c. NJ Atmospheric Deposition Network

The NJ Atmospheric Deposition Network (NJADN), sponsored in part by NJDEP, is collecting wet deposition and ambient concentration data for a whole suite of pollutants, including mercury, at nine sites around the state. The first site began operating in July 1998. The annual mean wet deposition of mercury, for the four sites in the network measuring wet depostion, is 15 $\mu g/m^2/yr$ (Eisenreich & Reinfelder 2001). This is higher than the value recorded at most of the sites in the National Atmospheric Deposition Program, which reported wet deposition of mercury with a median value of 9 $\mu g/m^2/yr$ and a range across 33 sites of 3.9 to 17.7 $\mu g/m^2/yr$ in 1999 (NADP, 2000). It is also well above the mean wet deposition in the United States and eastern Canada of 10 $\mu g/m^2/yr$ reported by Sweet et al. (1999), but lower than the wet deposition rates predicted by the two models described above. The difference between observed and predicted deposition is most likely due to a combination of two factors: a) conservative assumptions in the models that tend to result in overpredictions of deposition; and b) decreases in emissions from the timeframes used in the models (1990 for TEAM and 1997 for the Northeast Mercury Study) to the present time which is represented by the recent monitored data. Dry deposition estimates based on gaseous and particulate concentrations of mercury measured in the air are still under review. The mercury results of the NJADN are described in more detail in Chapter 7 of this Volume.

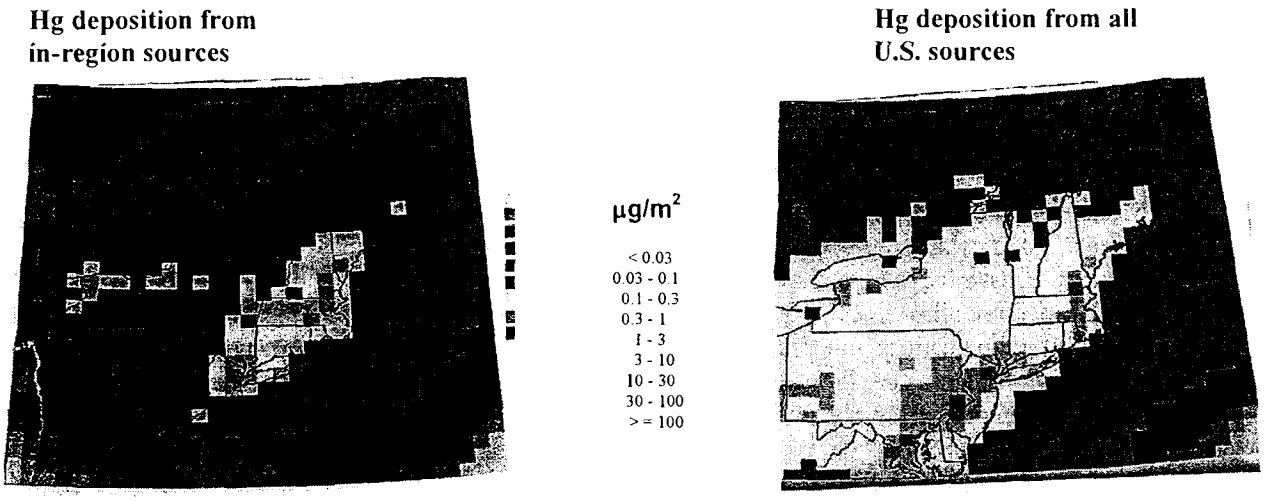
3. Relative Contributions of In-State and Out-of-State Emissions to Deposition in NJ

The Northeast Mercury Study (NESCAUM et al. 1998) provides some rough estimates of the relative contribution of in-state mercury emissions and out-of-state mercury emissions to total mercury deposition in NJ. The study reports the results of three model runs which included: 1) only sources located in the eight northeast states; 2) all other sources in the Unites States; and 3) only the global reservoir of mercury which is present throughout the world. These results are presented in a series of maps which show a range of wet and dry deposition for each grid cell in the region. (A grid cell is about 1600 square kilometers. The total area of NJ is about 21,700 square kilometers.) These results are summarized in Table 2.3.

The deposition estimates for the sources located in the eight Northeast States can be taken as a good representation of deposition in the state from NJ sources alone since this state is generally at the upwind edge of the region. Some of the deposition in the Northeastern grid cells may be influenced by emissions from sources in New York state; however, the impact of other northeast state sources in NJ should be rather slight in this model run. These model predictions (as presented in Figure 2.3, from NESCAUM et al. 1998) can be used to get a rough estimate of total deposition by summing across grid cells the product of the deposition rate ($\mu g/m^2/yr$) and the grid area (km^2). This calculation results in the values in the last column of Table 2.3. This estimated total deposition integrated over the whole state is about

610 to 1740 kg/year. This calculation indicates that the in-state sources could contribute about one-third of the total mercury deposition in the state.

Figure 2.3. Estimated Total Mercury Deposition in the Northeast from In-Region Sources and from All U.S. Sources.



Source: NESCAUM et al. Northeast States and Eastern Canadian Premiers Mercury Study - A Framework for Action. February 1998)

Table 2.3. Deposition Results Reported in the Northeast Mercury Study (NESCAUM et al. 1998).

Source of Mercury Emissions	Range of Wet & Dry Deposition Rates in NJ	Estimated Total Deposition Integrated over NJ
Sources Located in the 8 Northeast States	South: 3-10 µg/m^2 Northwest: 10-30 µg/m^2 Camden: 10-30 µg/m^2 Northeast: 30-100 µg/m^2*	200 – 650 kg/yr
US Sources Located Outside the 8 Northeast States	Southwest: 30-100+ µg/m^2 All other grids: 10-30 µg/m^2	340 – 870 kg/yr
Global Reservoir	Entire State: 3-10 µg/m^2	70 – 220 kg/yr
All Sources Combined	Some Coastal Grids: 10-30 µg/m^2 NE and SW Metro Areas: >100 µg/m^2 All other Grids: 30-100 µg/m^2	610 – 1740 kg/yr

* One grid cell shows deposition greater than 100 µg/m^2. This estimate was most likely influenced by two NJ sources which were modeled but are no longer in existence, so this result is not included in the table. Instead, it is assumed that the maximum deposition in this grid cell was 100 µg/m^2.

4. Uncertainty in deposition estimates

Many uncertainties make it difficult to assess the wet and dry deposition of mercury, either through monitoring of actual values or modeling of the transport and fate of mercury

emissions to the ambient air. However, it is important to note that despite all of this uncertainty, comparisons between modeling and monitoring in many studies (including Pai et al. 1997 and NESCAUM et al. 1998) show a strong correlation between predicted and observed wet deposition rates.

Methods for measuring wet deposition of mercury are limited in their ability to characterize the spatial and temporal distribution of deposition by the investment and maintenance of sampling stations and the cost of analysis. Estimates of dry deposition are even more uncertain because they are extrapolated from air concentrations using various assumptions regarding deposition velocity for the various forms of mercury.

Models of mercury transport begin with a mercury emissions inventory which identifies, estimates and catalogues the mercury emitted from various source types. The quantity of mercury emissions, the location of the emissions, and the chemical form of the mercury when it is emitted are all sources of uncertainty. Although substantial progress has been made in identifying the quantity and location of mercury emissions, there is still a great deal of work to be done in identifying the chemical form. Knowledge of the speciation is especially critical when predicting wet and dry deposition rates since they vary from one species to another. Mercuric chloride, for example, is much more water soluble than elemental mercury and, therefore, is more likely to be absorbed by rainwater and to be deposited close to its source.

Seigneur et al. (1999) have carried out an extensive analysis of the uncertainties associated with model predictions of human exposure to mercury through the consumption of fish. This analysis considered three prediction tools that must be used together to make such estimates of mercury ingestion. These tools are: a) the atmospheric transport and fate model; b) the watershed and biota bioaccumulation model; and c) the model of fish consumption patterns. The atmospheric transport and fate model variables included in their uncertainty analysis were mercury emission speciation, ozone atmospheric concentration, atmospheric precipitation, mercury atmospheric background concentration, mercury deposition velocity, and cloud water pH. Of these variables, mercury emission speciation contributed the most to the model uncertainty.

5. Summary: Transport and Deposition

Some mercury, particularly mercury that is emitted as soluble mercury or as particulates, deposits locally. The remaining mercury eventually enters the global atmospheric pool of mercury. The residence time of non-soluble mercury in the atmospheric is about one year. Eventually atmospheric mercury deposits on surfaces from which it can be transported directly to water bodies.

Total deposition rates for mercury in NJ have been predicted in the Northeast Mercury Study to be on the order of 10 to 100 $\mu g/m^2/yr$ and in the TEAM Study to be about 24 to 80 $\mu g/m^2/yr$. These two studies give comparable total deposition rates. The wet deposition rates observed by the NJADN are on the order of 15 $\mu g/m^2/yr$. This is on the lower end of the wet deposition range predicted by TEAM (15 to 55 $\mu g/m^2/yr$). The Northeast Mercury Study does not break out wet deposition for NJ alone, but it does estimate the relative contribution of wet to dry deposition for the region to be about 46% dry and 54% wet. Using this ratio would give a NJ wet deposition rate of 5 to 54 $\mu g/m^2/yr$, which is about the same range as TEAM and includes the NJADN rate within its bounds. It has been estimated that the NJ emissions account for about one-third of the mercury which deposits in NJ.

F. Recommendations

Maintain and enhance a long-term air deposition monitoring system that incorporates state-of-the-art detection limits and speciation to document temporal and spatial trends in mercury deposition (Recommendation "L" in Volume 1).

Information regarding deposition of mercury in NJ is still quite limited. Both modeling and monitoring approaches should be pursued to fill this gap. The information gathered in this way can be used to assess the current status of deposition in the state and to follow trends as emission reduction programs are put into place. These tools might also be used to provide a rough estimate of the portion of deposition attributable to in-state sources and to out-of-state sources. Recommendations regarding the development of these tools follow.

Air Monitoring: Long-term air deposition monitoring sites should be established in NJ. Some of the sites may be the same as those currently in the NJ Air Deposition Network that is operated by Rutgers and funded, in part, by NJDEP. Site locations should be selected so that deposition of mercury emitted out-of-state can be distinguished from mercury emitted in the state. Sampling frequency for particulate mercury may be every 12^{th} day at some of the sites, but a subset should be enhanced to collect particulate mercury data every 6^{th} day. Weekly samples of wet deposition should be collected.

Deposition: The Department should have access to a state-level version of the EPA model for fate and transport (RELMAP) that can be run using the up-to-date emissions inventory that has been developed by the Mercury Task Force. The results of this modeling effort, combined with new EPA model results for the whole country, thus will provide a better estimate of the relative contribution of in-state and out-of-state sources and can be used in subsequent years to predict the local benefit of reduction strategies.

Since the air emissions of mercury in NJ do not appear to account for the majority of the mercury deposition in the state, it is very important that the NJDEP continue to press for national mercury emission reduction programs.

EXHIBIT C

Chapter 8 - IMPACT OF MERCURY ON NJ'S ECOSYSTEMS

A. Introduction

Determining the impact of mercury or any contaminant on ecosystems is challenging. At high concentrations, some organisms may be severely impacted. At lower concentrations, however, the effects are often subtle and may require years to identify. Moreover, there can be multiple contaminants that co-occur, and identifying the influence of any single contaminant, much less its interactions with other contaminants, can be very difficult. Nonetheless, by combining data from a variety of sources, it is often possible to identify ecosystems or ecological resources that are at risk.

This section examines the levels and impacts of mercury on biota and ecosystems of NJ. NJ studies have played a prominent part in understanding mercury contamination and effects on a national basis. However, it will be apparent from this chapter that there remain many gaps in our knowledge.

B. Impacts of Mercury on Specific NJ Sites

There are a number of NJ hazardous waste sites with sufficiently high mercury levels that impacts on local ecosystems can be identified or anticipated. The NJDEP Site Remediation Program does not currently have a database of contaminated sites which can be sorted by contaminant. However, an informal screening of active sites indicates that the levels and extent of mercury contamination are highly variable. Mercury contamination ranges from limited amounts of contamination with few or no exposure pathways to ecological receptors (e.g., contamination under a building) to low-level, but extensive contamination (e.g., Passaic River) with multiple receptors. Aquatic systems are the principal ecosystems impacted by mercury contamination at these sites. Terrestrial habitat and wildlife species at many of these sites are somewhat limited due to the prior industrial character of the sites, resulting in fewer ecological receptors and exposure pathways. Several impacted sites are discussed below.

1. Berry's Creek-Ventron/Velsicol Site

Berry's Creek-Ventron/Velsicol Site, located in the Hackensack Meadowlands (Borough of Wood-Ridge, Bergen County), is one of the most heavily contaminated mercury sites in the world. The site is known as the Ventron/Velsicol Site and is listed on the National Priorities List (NPL). This site is an important example of the ecological consequences of mercury releases to an aquatic ecosystem. The primary source of mercury to this system was historical discharges (1930 to 1974) from a mercury processing plant. Testing conducted around 1970 indicated that the plant was discharging from two to four pounds of mercury per day into Berry's Creek (Lipsky et. al. 1980). Mercury contamination (primarily inorganic or elemental mercury) was found to be widespread at the site and included soils on and adjacent to the site, and the surface waters, sediments and wetland soils of Berry's Creek. (See Table 2.16) The Ventron/Velsicol Site has been administratively segregated from Berry's Creek and the Responsible Parties are focusing on remediation of the 38-acre site.

An early concern was the potential for mercury to move from this site into the ecosystem through erosion, ground water transport, volatilization, and biological transformation/uptake. Estimates of the amount of mercury contamination beneath the Ventron/Velsicol site have ranged from 30 tons to 289 tons (Lipsky et al. 1980).

Table 2.16. Mercury Concentrations at the Ventron/Velsicol Site and Berry's Creek.

Media	Maximum Mercury Concentration	Maximum Methyl-Mercury Concentration	% MeHg
Surface Soils	13,800 (µg/g)	0.322 (µg/g)	<.001%
Subsurface Soils	123,000 (µg/g)	-	-
Ground Water	8.2 (µg/L)	0.02 (µg/L)	0.2%
Surface Water	15.6 (µg/L)	0.00287 (µg/L)	0.02%
Berry's Creek Sediment (0-2 cm)	11,100 (µg/g)	0.0098 (µg/g)	<.001%
On-site Ditch Sediment (0-2 cm)	97.8 (µg/g)	0.020 (µg/g)	0.02%
On-site Basin Sediment (0-15 cm)	1,290 (µg/g)	0.126 (µg/g)	0.01%
Discharge Pipe (6-9 inches)	89,162 (µg/g)	-	-

Concentrations of total mercury have been detected historically up to 15.6 µg/L in surface waters of Berry's Creek. This compares with the mercury chronic surface water criterion of 0.012 µg/L. Methylmercury concentrations up to 2.87 ng/L have also been detected. More recent limited sampling indicate dissolved mercury concentrations of up to 0.24 µg/L and total mercury concentrations up to 17.6 µg/L adjacent to the site (Exponent 1998). The maximum total mercury concentration detected is greater than the acute and chronic water quality criteria values for mercury. Dissolved mercury concentrations have also exceeded the NJ chronic criteria. The observed mercury concentration indicates that there is potential risk to aquatic organisms from mercury in the surface waters of Berry's Creek.

Three studies were funded by the NJDEP for the period 1978 through 1980 to examine concentrations of mercury in the plants and animals of the general area (Lipsky et al. 1980). A 1978 study found mercury to range from 0.01 to 0.79 µg/g in Mummichogs (Common Killifish), and 0.30 to 1.9 µg/g in White Perch in Berry's Creek. A survey of nine locations in Berry's Creek in 1978 by the NJ Marine Sciences Consortium (NJMSC) found mercury at an average concentration of 0.08 to 0.32 µg/g in Mummichogs. Additional data collected by NJMSC indicated that the average concentration of mercury was 0.52 µg/g in Berry's Creek Mummichogs. The average concentrations of mercury for Grass Shrimp was 0.09 µg/g (Lipsky et al. 1980).

A summary of other tissue analyses (ERM-Southeast 1985) indicated that 51% of the invertebrate samples contained greater than 1 µg/g mercury with a maximum of 150 µg/g in snail tissue. These are extremely high values for lower trophic organisms. Forty-three percent of the bird tissue samples and 6% of the mammal tissues had mercury levels greater than 1 µg/g.

Seven species of plants were analyzed in Berry's Creek for mercury including Common Reed *(Phragmites)*, Cord Grass *(Spartina alterniflora)*, and Cattail *(Typha)*. Tissue levels exceeding 1 µg/g were widespread in the Berry's Creek area (ERM-Southeast 1985). Rhizome (root-like) tissue generally had the highest concentrations of mercury. Speciation was not performed, but other studies have found elevated MeHg levels in salt marsh vegetation (Windhou and Kendall 1978).

Current data suggest that sulfide (e.g., acid volatile sulfide, AVS) and sediment organic carbon are two important factors controlling the concentration and bioaccumulation of methylmercury from mercury-contaminated sediments. Berman and Bartha (1986) suggested that elevated sulfide concentrations (i.e., HgS) were the cause for low mercury methylation

activity in highly contaminated Berry's Creek sediments. Low dissolved oxygen in Berry's Creek indicates anoxic conditions, which favor production of HgS in the sediments. Therefore, the elevated sulfide concentrations in Berry's Creek sediments may be mitigating the impacts of elevated mercury concentrations by minimizing the mercury available for methylation. However, this "equilibrium" could shift if water quality changes. Ongoing studies of these processes are needed.

2. Pierson's Creek -Troy Chemical Company, Inc.

The Troy Chemical Site is located in Newark on an industrial tract that has been active since the early 1900s. Mercury use occurred from 1956 to the late 1980s. Mercury was purchased and reclaimed (via mercury recovery furnaces) for use in the production of organic mercuric compounds such as phenylmercuric acetate, chloromethoxypropyl mercuric acetate, phenyl mercuric sulfide, and phenylmercuric oleates. Pierson's Creek has been grossly contaminated with a number of contaminants including mercury from the Troy Chemical site and other sites in the area. (See Table 2.17) This man-made waterway discharges to Newark Bay just south of the mouth of the Passaic River.

Process discharges from the Troy Chemical site prior to 1965 went directly to Pierson's Creek. Partial treatment occurred from 1965 to 1976 and an on-site wastewater treatment plant was installed in 1976. In 1979 an investigation indicated that an estimated 327 pounds of mercury per day were discharged into the sanitary sewer system. Due to the inefficient primary treatment level of the Passaic Valley Sewage Commission treatment plant at that time, it was estimated that approximately 90% of the mercury were being discharged into Newark Bay with the plant's effluent.

Pierson's Creek has been contaminated with Hg, with maximum concentrations of 607,000 μg/g in sediment, and 886 μg/L in surface water detected by studies conducted in the late 1970's and 1980's. Mercury was detected in 1979 up to 83,200 μg/g in sediment of an adjacent tributary, and a maximum of 25,290 μg/L of Hg was detected in ground water at the Troy Chemical site. More recent data indicates that Hg concentrations are still elevated in all media (Table 2.17).

The impact of this contamination is primarily on the aquatic ecosystem of Pierson's Creek and Newark Bay. The elevated concentrations and mass of contaminants potentially result in toxic impacts on the benthic invertebrate communities. The downstream transport of contaminants can lead to exposure and bioaccumulation by mobile species (e.g., fish) via direct contact and food chain pathways. In addition, cumulative loadings from similar industrial sites result in the widespread distribution of mercury in the surrounding aquatic systems (e.g., Newark Bay).

The City of Newark plans to dredge sections of Pierson's Creek for the purpose of flood control. Dredging has the potential to increase the availability of mercury that is currently sequestered in the sediment. Remediation of the highly contaminated section of the creek adjacent to Troy Chemical is planned but not currently scheduled. Any dredging should include some mechanism for controlling or removing resuspended materials. To date there is essentially no information on either mercury concentrations or impacts on biota in this area.

3. DuPont Chemicals, Pompton Lakes Works

The Pompton Lakes Works (PLW) site is located in Passaic County and was operated by DuPont between 1908 and 1994 for the manufacture of explosives (Exponent 1999). Acid Brook flows

Table 2.17. Mercury Concentrations in Various Media Associated with Pierson's Creek and the Troy Chemical Company Site.

Media/Location	Maximum Hg Concentration – 1997	Average of Hg Concentrations – 1997	Notes
Sediment: Pierson's Creek – Upstream of Troy Chemical site	138 μg/g	64 μg/g	From EMCON 1998. Data reported from 5 samples.
Sediment: Pierson's Creek –Troy Chemical Site	3,030 μg/g	1,470 μg/g	From NJDEP files. Data reported from 6 samples reported.
Sediment: Tributary to Pierson's Creek by Troy Chemical Site	6,200 μg/g	2,110 μg/g	From NJDEP files. Data reported from 4 samples reported..
Sediment: Pierson's Creek – Downstream of site	5,020 μg/g	1,020 μg/g	Data reported from 11 samples reported..
Soil: Troy Chemical Site	4,300 μg/g	Range: 0.6-4,300 μg/g	Data from 5 on-site sampling locations.
Surface Water: Pierson's Creek	5.2 μg/L	Range: ND – 5.2 μg/L	Data from 7 sampling locations.
Ground Water: Troy Chemical Site	2,500 μg/L	Range: ND – 2,500 μg/L	Data from 5 on-site monitoring wells. 25,290 μg/L reported from 1 well in 1982 (NJDEP files).

ND - not detected

through the facility and discharges to Pompton Lake where it has formed a delta (i.e., Acid Brook delta). DuPont has been investigating the site, Acid Brook, and the Acid Brook delta since 1988 under an Administrative Consent Order with the NJDEP. Soil contamination was detected in both on-site and off-site areas affecting both commercial and residential properties. Acid Brook sediments contained elevated levels of mercury. Due to the contamination found, DuPont conducted remediation of on-site and off-site soils, as well as remediation of sections of Acid Brook sediments. Additional remediation is planned in Acid Brook and upland areas.

DuPont conducted a Phase I and Phase II ecological study (Exponent 1999) that examined the impacts of mercury contamination in the Acid Brook delta where it empties into Pompton Lake. Sediments in the delta have maximum levels of mercury of 1,450 mg/kg. Mercury concentrations in algal mats, phytoplankton, zooplankton and benthic invertebrates of the delta are much higher compared to presumably unimpacted reference sites in Pompton Lakes. In addition, fish tissue MeHg concentrations were higher in all seven species of fish (e.g., sunfish, white perch, largemouth bass) captured at the delta as compared to the reference area of the lake. The delta serves as a source for the bioaccumulation of mercury within the food chain of Pompton Lake.

When comparing similar sized fish, average mercury concentrations ranged from 27-33 ng/g for reference Pumpkinseed and 71-140 ng/g for Delta Pumpkinseed. A similar trend was observed for Yellow Perch (130 ng/g versus 440 ng/g) and Largemouth Bass (83-390 ng/g versus 200-1,200 ng/g) for various areas of Pompton Lake.

4. Passaic River Study Area

Another type of site that represents more diffuse contamination of an aquatic system is the lower Passaic River. This section of the river has been subject to multiple point discharges from local industry and non-point discharges for the past one hundred years. The Passaic River Study Area consists of the lower six miles of the river and encompasses the area alongside the Diamond Alkali Superfund Site, a former pesticide manufacturing facility located approximately 2 miles upstream of the river mouth (US EPA 1999c).

Several investigations have collected numerous sediment cores along this reach of the Passaic River. Average mercury concentrations in surface sediments (e.g., $\leq$ 15cm) of the river (452 samples) were 2.1 mg/kg with a range of 0.005 to 15 mg/kg (NOAA 1999). In contrast, sediments at depth (>15 cm to several meters) exhibited a higher average concentration (9.4 mg/kg) and range (0.11 mg/kg to 29.6 mg/kg). These average mercury levels exceed sediment benchmarks for ecological effect (ER-L of 0.15 mg/kg and ER-M of 0.71 mg/kg) indicating potential adverse effects to aquatic biota. Although mercury concentrations may be at a level causing impacts, other contaminants (e.g., dioxin) may be causing equal or more severe impacts (e.g., toxicity) making it difficult to identify specific effects of mercury. This situation is typical of many waterbodies in highly urbanized/industrial areas that have multiple contaminants and sources.

5. Environmental Research Parks

Pioneered by the US Department of Energy in 1971 (USDOE 1994), the National Environmental Research Parks (NERPs) are public lands "open to the researchers for ecological studies and the general public for environmental education". DOE sets aside parts of its large nuclear weapons development sites to study the impact of weapons development, nuclear reactors, and radioactive waste, on surrounding ecosystems. The NERPs address national concern about environmental change, remediation and recovery, and the ability of land to adapt to and recover from contamination. The results from research on NERPs has been used to improve landuse planning, develop site-specific remediation goals and methodologies, and develop an information network for studying biodiversity and managing public lands and improving environmental quality (USDOE 1994).

6. Summary and Conclusions: Impacts of Mercury on Specific NJ Sites

There are a number of sites within the State that are highly contaminated with mercury and which may impact adjacent ecosystems. These include sites with low-level, extensive contamination (e.g., Passaic River) with multiple receptors, and sites with high-level contamination (e.g., Troy Chemical, Berry's Creek). Aquatic systems are the principal ecosystems impacted by mercury contamination at these types of sites. For none of these sites is there adequate characterization of the fate and transport of mercury through the food chain, nor are there adequate studies that would reveal impacts on behavior, biochemistry, reproduction, health, survival, or population dynamics of organisms.

Mercury discharges to the Berry's Creek ecosystem have led to widespread contamination of the soil and sediment in the area. There is evidence of increased bioaccumulation of mercury

in proximity to the site. Paradoxically, more severe impacts may occur if water quality improves, thus allowing a greater utilization of the habitat by higher trophic level aquatic species (e.g., fish). Due to the large quantity of mercury in the Berry's Creek ecosystem and the potential for water quality changes and mercury release, it is recommended that additional study and monitoring of this ecosystem be conducted. Characterization of the transport and bioaccumulation of mercury in Berry's Creek and downstream waters is needed to determine the potential future impacts from the site.

C. Mercury Occurrence and Levels in NJ Fish

The bioaccumulation of mercury in aquatic food chains and most specifically its concentration in higher trophic level fish poses a potential ecological impact to the piscivorous biota and to the fish themselves. This section provides an overview of mercury levels in NJ freshwater and saltwater fish, presents the available data on the impact of those levels to the fish and to their predators.

1. Freshwater Fish

Finfish contamination results primarily from bioaccumulation of pollutants through the food chain. Mercury accumulation is widespread across species and trophic levels, with generally higher levels in larger individuals of any species and higher levels in species higher on the food chain. Data are available mainly on species consumed by humans or those classified as endangered or threatened.

Data on mercury in NJ fish are available through research conducted from the late 1970's to the present. Most of the fish research has been conducted in the state's freshwater rivers, streams, lakes and reservoirs.

Prior to 1994 there was no systematic effort to collect data on mercury levels in NJ freshwater fish that could provide a useful statewide picture. Data that had been collected are limited in coverage and do not necessarily focus on fish from higher trophic levels or fish likely to be consumed by humans. Data from the 1970's and early 1980's (Jacangelo 1977; Ellis et al. 1980), which focused on industrialized areas found evidence of significant elevation of mercury concentrations (> 0.1 ppm). Fish from less industrialized areas, of the state had variable levels of mercury (NYDEC 1981; USFWS 1983, 1990), which tended to be moderately elevated for higher trophic level species while remaining low in fish at lower trophic levels.

NJDEP and the Academy of Natural Sciences of Philadelphia study (ANSP 1994, 1999) reported on results of surveys of mercury contamination in freshwater fish for 1992-94 and 1996-97, respectively, from selected waterways throughout NJ (see Table 2.18). These studies were designed to identify the range of mercury levels for selected fish species. The project design targeted gamefish species from waterbodies via a stratified geographic approach. Sampling locations were selected based on mercury point source inputs, importance of angling at the water body, limnological factors favorable for bioaccumulation (e.g., low pH), recently developed impoundments and reservoirs, and availability of targeted fish species. In the 1992-94 survey, a total of 313 fish from 55 waterbodies were collected. The primary fish species analyzed were Largemouth Bass (n=146) and Chain Pickerel (n=62). Other species sampled in lesser quantities were Smallmouth Bass, White Catfish, Channel Catfish, Yellow Bullhead, Brown Bullhead, Lake Trout, Black Crappie, Hybrid Striped Bass, Rainbow Trout and miscellaneous specimens of Northern Pike, Muskellunge and Walleye.

The study focused on medium or large sized individuals of each species, and all samples were composed of a single edible fillet from an individual specimen. In general, the mercury concentrations varied greatly among lakes, fish species, and with the size of the fish.

Table 2.18. Distribution of Mercury Concentrations in Largemouth Bass and Chain Pickerel in New Jersey Waterbodies Sampled in 1992-94 & 1996-97 (ANSP 1994a, 1999).

	Percent of Sampled Waterbodies			
	Largemouth Bass		Chain Pickerel	
Average Mercury Concentration for each Species	**1992-94***	**1996-97***	**1992-94***	**1996-97***
<0.07 ppm	0 %	0 %	0 %	0 %
0.08 - 0.18 ppm	16.0 %	20.0 %	6.0 %	25.0 %
0.19 - 0.54 ppm	56.0 %	45.5 %	53.0 %	31.5 %
>0.54 ppm	28.0 %	34.5 %	41.0 %	43.7 %

*1992-94 Data (55 Waterbodies Sampled), 1996-97 (30 Waterbodies Sampled)

Tables 2.18 and 2.19 present a summary of these data for the fish species with the highest mercury concentrations. Among the significant findings from this study are the following:

Mercury concentrations greater than 0.5 ppm and 1.0 ppm (FDA Action Level) were seen in fish from a variety of NJ water bodies. Mercury concentrations generally increased with fish size for most species tested and levels > 0.5 ppm were identified primarily in the larger specimens of Largemouth Bass and Chain Pickerel from several lakes and reservoirs. The highest mercury concentrations (3.0 - 8.9 ppm) were found in specimens of Largemouth Bass collected from the Upper Atlantic City Reservoir. High concentrations were also noted in Largemouth Bass from the Manasquan Reservoir (up to 3.9 ppm) and Union Lake (up to 2.0 ppm). Of the 55 waterbodies sampled, 19 (35%) had at least one Largemouth Bass with > 0.5 ppm mercury and 8 (15%) had at least one bass with > 1.0 ppm mercury.

Table 2.19. Percent of Fish Exceeding 0.5 ppm and 1.0 ppm.

	% Exceeding 0.5 ppm	% Exceeding 1 ppm
Largemouth Bass n=146	43% (n=63)	17% (n=25)
Chain Pickerel n=62	56% (n=35)	35% (n=22)
Yellow Bullhead N=9	44% (n=4)	33% (n=3)

The variation of mercury concentration in fish by geographic location probably reflects a number of parameters, including lake morphology, size, and type, as well as variations in pH, and local inputs from industrial activities and wastewater sources. Higher than predicted mercury concentrations in fish were found in recently filled reservoirs and sites from the industrialized northeastern part of the state. Lower than predicted mercury concentrations were observed in small run-of-river impoundments, tidal rivers and small (mainly coastal plain) lakes. Mercury concentrations tended to be higher at sites with lower pH. High

mercury concentrations were measured most frequently in Chain Pickerel from low pH (pH 4-5) lakes and streams in the Pine Barrens region and less acidic lakes (pH 5-6) at the edges of the Pine Barrens. All specimens collected from the Pine Barrens sites had mercury concentrations greater than 0.5 ppm, and 70% had mercury concentrations greater than 1.0 ppm, with a maximum of 2.1 ppm noted.

ANSP (1994b) also conducted a separate study of mercury concentrations in fish collected from rivers and lakes in Camden County, NJ in conjunction with Camden County. A total of five river and seven impoundment sites were sampled. Overall, the mercury levels identified were similar to those previously reported in the 1992-3 statewide ANSP study. The highest mercury concentrations were in samples of Largemouth Bass (1.36 ppm) from Marlton Lake and Chain Pickerel (1.30 ppm) from New Brooklyn Lake, where three of the five Chain Pickerel sampled exceeded 0.50 ppm. Levels in catfish and Black Crappie were low to moderate (generally <0.5ppm).

ANSP (1994c) reported on mercury concentrations in fish collected from three northern NJ reservoirs of the Hackensack Water Supply Company. In this study, samples of Largemouth Bass, Smallmouth Bass, Yellow Bullhead and Common Carp were analyzed. Overall, the concentrations of mercury in fish were low to moderate for all species sampled. However, three Largemouth Bass exceeded 0.50 ppm, with the two highest mercury concentrations, 0.82 ppm and 0.78 ppm, identified from Lake Deforest. Samples of Smallmouth Bass from Lake Tappan averaged 0.07 ppm, while Yellow Bullhead and Common Carp had low to moderate levels (average=0.09 ppm and 0.12 ppm).

NJDEP (1995) reported on results of a pilot project that examined a multi-media profile of three NJ rural, freshwater lakes. The lake profile included collections of surface water, sediments, soil, aquatic vegetation and fish at each lake. The three lakes were located in northern (Mountain Lake, Warren County), central (Assunpink Lake, Monmouth County) and southern (Parvin Lake, Salem County) areas of the state. A total of 15 Largemouth Bass samples (individual edible fillet) and 10 samples of Banded Killifish (individual whole body) were analyzed for total mercury concentrations. Levels of mercury in the Largemouth Bass ranged from 0.14 - 0.40 ppm for the three lakes. The average mercury concentrations in Largemouth Bass from Mountain Lake were 0.23 ppm, Assunpink Lake, 0.31 ppm and Parvin Lake, 0.30 ppm. Forage fish species such as Banded Killifish had mercury concentrations ranging from 0.01 to 0.04 ppm for all three lakes. Interestingly, the mercury concentrations in fish and aquatic vegetation followed a similar pattern for each of the three lakes. Data covering additional fish species and water bodies is expected to be available by 2002.

The results of this study identified an increase in mercury concentrations (through bioaccumulation/biomagnification) across trophic levels in all three of the NJ lakes. The mercury concentrations identified in top trophic level fish (Largemouth Bass) were at least six times greater than the levels identified for forage fish (killifish) and at least ten times greater than for aquatic vegetation. The average mercury concentrations for the Largemouth Bass analyzed for this project were comparable to concentrations of mercury identified in other water bodies (ANSP 1994a, 1994b).

ANSP (1999) reported on mercury in freshwater fish collected from 30 additional waterbodies throughout the state in 1996-97. This project complements the 1992-3 screening project and was designed to fill data gaps in the earlier study, develop trophic transfer information, and to provide additional fish data for selected geographic areas. Samples from 258 fish were analyzed, including 58 Largemouth Bass, 58 Chain Pickerel, and 109 fish of other species. Also, 32 composite samples of several species of forage fish were analyzed.

The results of this study were consistent with those of the 1992-3 study. Mercury concentrations showed a general increase at higher trophic levels. Maximum mercury concentrations were generally highest in piscivorous fish such as Chain Pickerel (average=2.30 ppm) and Largemouth Bass (average=1.68 ppm). Among the lower trophic level species, no clear differences were observed between planktonivores (e.g., Golden Shiners) and invertebrate feeders (e.g., the sunfish). Mercury concentrations for bottom feeding species of bullhead and catfish varied greatly by sampling location and region.

The highest mercury concentrations were in fish from the northern portions of the Pine Barrens (Double Trouble Lake, Ocean County), and on the periphery of the Pine Barrens (Willow Grove Lake and Malaga Lake, Salem County and Success Lake, Ocean County). Dwarf Sunfish had elevated mercury levels compared to other species their size. This may partly explain the elevated levels found in Chain Pickerel in the same lakes. High levels were also seen in fish from the northeastern part of the state where several of the rivers have a history of impacts from industrial activities. Average mercury concentrations in Largemouth Bass, Smallmouth Bass and Yellow Bullhead collected from the Pompton River in Passaic County were 1.17 ppm, 0.96 ppm and 0.80 ppm, respectively. The lowest concentrations were seen in samples from the cold water streams and high pH lakes in the northern part of the state, the Delaware River and in rivers of the southwestern part of the state. In general, the mercury concentrations in most catfish (White and Channel) were less than 0.30 ppm, but some individuals had levels > 0.5 ppm. Mercury concentrations in Yellow Bullhead were much higher than in Brown Bullhead in most waters where both species were collected, with Pine Barrens lakes having the highest levels for both.

Three sunfish species (Bluegill, Redbreast, and Pumpkinseed) were low in mercury concentrations in most areas, except for samples collected from the industrial northeast sites. High levels were identified in individual samples of Redbreast Sunfish (up to 0.41 ppm), Pumpkinseed Sunfish (up to 0.78 ppm) and Rock Bass (up to 0.58 ppm) collected from the Pequannock and Pompton Rivers, in Passaic County.

ANSP (1999) also reported a 1995 analysis of mercury in fish for 15 water bodies for which specific health-based consumption advisories were issued on the basis of the 1992-3 mercury screening study. The project included collections of gamefish species from three trophic levels and a forage fish specie. As in the original ANSP (1994a) project, Largemouth Bass and Chain Pickerel were targeted as the top trophic level species, but other top trophic level species, lower trophic level fish, forage fish, and omnivorous bottom dwelling species were also sampled. Overall, the results paralleled the initial 1992-93 ANSP (1994a) findings, where typically, the largest specimen of gamefish sampled exhibited the highest mercury concentration.

a. Summary and Conclusions

Mercury is a widespread and persistent contaminant in freshwater fish collected throughout the state. Concentrations exceeding 1.0 ppm have been found in higher trophic level fish, particularly Largemouth Bass and Chain Pickerel, in about 40% of the tested waterbodies. Some lakes in industrialized areas of the state which are subject to local mercury pollution had fish with elevated mercury levels, but some lakes in unpolluted areas such as the Pine Barrens also had high levels. Mercury concentrations in lower trophic level fish are also elevated and are commonly in the range of 0.2 to 0.5 ppm. Thus many tested water bodies exceed the recent surface water criterion value of 0.3 ppm in fish tissue promulgated by US EPA (2001). Waters impacted by industrial or municipal discharge, poorly buffered waters

with low pH (e.g., many in the Pine Barrens), and newly created lakes, tend to have fish with elevated mercury levels.

2. Saltwater Fish and Invertebrates

Fishing is a major recreational and economic activity in the estuarine, coastal and offshore waters of NJ. There are an estimated 1.2 million anglers who take about 4.5 million saltwater fishing trips per year, at a value of $1.2 billion. Although the catch-and-release option allows fishermen to enjoy their sport, preserve their resource, and avoid contaminants, the majority of saltwater fishermen eats some or all of their catch or gives it to friends or family. Moreover, upon returning from a successful fishing trip, they may consume fresh fish in large amounts over a period of a few days.

Relatively few data exist on mercury levels in NJ saltwater fish, reflecting the lack of systematic sampling. Ellis et al. (1980) reported the results of a study of metals in aquatic organisms primarily from the estuarine waters along coastal NJ. The data are shown in Table 2.20. A total of 77 species of fish, shellfish and crustacean were collected between 1978 and 1980. Among finfish species, the highest mercury concentrations were identified in eight high trophic level and two lower trophic level species. Samples for this study consisted of a combination of individual (single) edible portions of consumer species and whole body composite samples for lower trophic level samples.

Table 2.20. Mercury Concentration in Selected Saltwater Aquatic Species Collected from
The Lower Hudson River Estuary* (after Ellis et al. 1980).

Sample Type	Species	Average Hg (ppm)
Whole Body	Silversides	2.50
Composite Sample	Soft Clam	2.00
	Blue Mussel	1.90
	Killifish	1.66
Individual Fillet Sample	American eel	2.10
	Striped Bass	1.65
	Bluefish	1.40
	White Perch	1.32
	Summer Flounder	1.16
Composite*	Blue Crab	1.02

** Composite sample of backfin and claw meat from individual specimen*

The USFWS (1990) reported results for a variety of metals, organochlorine pesticides and polychlorinated biphenyls (PCBs) in fish and crabs collected from Deepwater, NJ. Three Blue Crab samples from the Deepwater, NJ site had moderately elevated mercury concentrations. Two of the Blue Crab samples were a muscle/hepatopancreas mixture. These samples revealed concentrations of 0.14 ppm and 0.19 ppm. The other Blue Crab sample was divided into separate muscle (backfin & claw) of 0.19 ppm and hepatopancreas (green gland) tissues with a mercury concentration of 0.13 ppm.

NOAA (Reid et al 1982 and Zdanowicz &Gadboisl 1990) reported on a variety of heavy metal and organochlorine contaminants in four marine fish species (Bluefish, Fluke, Seabass, and Tautog) collected from popular recreational fishing areas along the coast of Monmouth

County and within eight miles of the beach. Samples for metal analyses were composites of fillets from three specimens. The data are shown in Table 2.21. Mercury concentrations for all samples were low and did not exceed 0.11 ppm, and none of the composite fish reached 1.0 ppm. In general, the relative ranking of mercury concentration by species was Tautog = Bluefish > Fluke = Sea Bass. No biological or behavioral features were offered to explain this relationship.

A study by NOAA (Drexel et al 1991) reported on a variety of inorganic and organic contaminants in tissues of American Lobster caught from the New York Bight Apex. A total of 508 lobsters were analyzed for

Table 2.21. Mean Mercury Concentrations of Composite Samples by Species in ppm, Wet Weight.

Species	Site A	Site B	Site C	Site D	Site E	Site F
Bluefish	0.10 (5)	0.11 (5)	0.10 (4)			
Tautog	0.09 (5)	0.08 (4)	0.08 (5)			
Sea Bass	0.06 (4)	0.05 (5)	0.05 (5)			
Fluke	0.04 (2)	0.04 (2)	0.04 (3)	0.04 (3)	0.04(2)	0.03(2)

(n)= Number of composite samples per station

this project. Samples were obtained from commercial lobster fishery operators across a wide area within the New York Bight Apex, including the vicinity of the Mud Dump Site, the Hudson-Raritan estuarine outflow pipe, the Christiansen Basin, and the Hudson Shelf Valley. Samples consisted of composite tissue from five similar size, same sex specimens. A total of 48 muscle (tail) tissue and 48 hepatopancreas tissue and four extruded egg mass tissue samples were analyzed in this project. The remaining lobsters were individually composited and analyzed. All samples were analyzed for organic compounds and ten metals including total mercury. Overall, mercury concentrations for this project did not exceed 0.50 ppm. The maximum composite concentrations of mercury in muscle tissue and composite hepatopancreas tissue samples of five crabs were 0.491 ppm and 0.247 ppm, respectively. Mercury concentrations were below detection limit (<0.004 ppm) in all four of the egg mass samples. Seasonal differences in metal concentrations were observed in hepatopancreas tissue samples. Mercury concentrations in both muscle and hepatopancreas tissues were lowest from specimens collected in the fall (October).

NYSDEC (1996) analyzed total mercury concentrations in edible portions of fish, bivalves, crustaceans and cephalopods taken from the New York - NJ Harbor Estuary including four NJ waters: Upper Bay; The Kills (Arthur Kill, Kill Van Kull and Newark Bay); Lower Bay; and the New York Bight Apex. The species of fish collected were American Eel, Atlantic Herring, Atlantic Tomcod, Bluefish, Butterfish, Cunner, Kingfish, Northern Sea Robin, Porgy, Rainbow Smelt, Red Hake, Sea Bass, Silver Hake, Spot, Spotted Hake, Striped Bass, Striped Sea Robin, Summer Flounder, Tautog, Weakfish, White Perch, Windowpane Flounder and Winter Flounder. The bivalves collected were Blue Mussel, Eastern Oyster, Hard Clam, Horse Mussel, Soft-Shell Clam and Surf Clam. The crustaceans were American Lobster and Blue Crab (both muscle and hepatopancreas tissue). The single cephalopod species was Longfin Squid.

Analyses for total mercury were conducted on 545 samples, and mercury was detected (above the minimum detection level of 0.05 ppm) in 422 samples (77.4%). Two individual Striped Bass samples exceeded 1.0 ppm (1.05 ppm and 1.25 ppm). Mean mercury

concentrations exceeded 0.5 ppm only in Striped Bass measuring 30 inches or more in total length (the largest size group tested). Individual samples of American Eel, Bluefish, Cunner, Striped Bass, Tautog, White Perch and Blue Crab (muscle meat) approached or exceeded 0.50 ppm. Only Striped Bass and Tautog had average mercury concentrations greater than 0.25 ppm. Non-detectable mercury concentrations (<0.05 ppm) were encountered most frequently in the six bivalve species, and in Butterfish, Winter Flounder, the hakes and American Eel. For most species, there were few differences in mercury concentration among the four locations in the harbor estuary.

a. Summary and Conclusions

Data on mercury levels in saltwater fish in NJ are limited and mainly reflect estuarine rather than marine species. Based on the currently available data, most species have moderate mercury concentrations, averaging less than 0.25 ppm. Striped Bass and Tautog, however, may have mercury concentrations in the range of 0.5-1.0 ppm.

Data from 1980 for the Hudson-Raritan Estuary identified relatively high mercury concentrations in both forage base species as well as top trophic level species, while more recent data revealed only a limited number of samples with elevated mercury concentrations. The reason for and the significance of the apparent decline are uncertain due to insufficient data. These waterways have a current and historical record of municipal and industrial discharge activities and the data indicate that these waterways are still impacted.

D. Impacts of Mercury on NJ Fish

1. Introduction

There are two basic approaches that can be taken to assess the impact of mercury in NJ waters on the fish in those waters. One approach can be referred to as a direct approach. This involves making observations of fish health, survival, and performance as a function of mercury exposure. These observations can be supplemented with studies of health, survival and performance under controlled laboratory conditions in which mercury exposure duplicates that experienced in the environment. The other approach can be referred to as an indirect approach. This involves comparing measured concentrations of mercury in water or in fish tissue to toxicity criteria for fish, which were derived specifically for those media. This comparison can provide a prediction of the expected level of impact to the fish exposed to the measured environmental mercury levels.

2. Direct Assessment of Risk to NJ Fish

a. Freshwater Fish

The influence of mercury on the general and reproductive health of wild fish populations has not been well studied in general, and few NJ-specific data are available. Among the measures regularly used to assess the health or condition of fish are the ratio of the liver weight to total body weight (liversomatic index or LSI) and the ratio of gonad to total body weight (gonadsomatic index or GSI). Various researchers have conducted laboratory studies indicating that mercury can produce reproductive impairments in fish. These studies have suggested that mercury exposure can decrease gonadotropin hormone levels and impair spermatogenesis, decrease GSI, and reduce growth in juvenile fish. However, one preliminary field investigation (Friedmann et al. 1996) indicates that such adverse effects on

reproductive health do not occur at levels of tissue mercury four times the United States national average.

In 1997, the NJDEP-DFGW conducted a study to determine overall status, body weight and length, serum androgen levels, GSI, LSI, kidney nuclear diameter, and serum cortisol levels in male Largemouth Bass (NJDEP 1997). The fish were collected from three bodies of water in NJ: Assunpink Lake (containing low levels of mercury), Manasquan Reservoir (containing moderate levels of mercury), and Atlantic City Reservoir (containing high levels of mercury). The mean total mercury content in fish was 0.30 ppm from Assunpink Lake, 1.23 ppm from Manasquan Reservoir and 5.42 ppm from Atlantic City Reservoir (the latter being one of the highest average values recorded for freshwater fish anywhere). Inter-lake and intra-lake analyses demonstrated statistically significant positive associations between mercury levels in fish tissue and 11-ketotestosterone in serum and a negative association between mercury and serum testosterone concentrations. These data are consistent with the hypothesis that mercury influences androgen levels in fish. Other indicators of fish 'health' such as body weight, length, condition factor, and GSI and LSI indices, as well as serum cortisol and cell nuclei diameter were similar for all three lakes. Additional research is required to help understand the implications of the hormone changes.

b. Estuarine/Marine Fish

Killifish were collected from Piles Creek, a mercury-contaminated tidal creek emptying into the Arthur Kill in an industrialized area of NJ, where sediment contained up to 200 mg/kg (average 11.2 mg/kg) of mercury (Khan and Weis 1993). These fish differed biologically from those collected in less polluted areas: Tuckerton, NJ and East Hampton, NY (Weis & Weis, 1989). Piles Creek Killifish had liver concentrations of mercury more than seven times higher, grew more slowly, reached sexual maturity earlier, and did not live as long as those from Tuckerton (Khan & Weis, 1993). Piles Creek Killifish had higher levels of mercury in brain and were slower and poorer in prey capture and predator avoidance than Tuckerton fish (Weis & Khan, 1991; Smith et al. 1995; Smith & Weis, 1997).

Killifish embryos experimentally exposed to 5 or 10 µg/L methylmercury subsequently resulted in slower prey-capture ability in Killifish larvae (Weis & Weis 1995a and 1995b). This effect was transitory and lasted about one week. However, fish exposed in the field would continue to be exposed and might not recover from such deleterious effects (Weis & Weis 1995a and 1995b).

When uncontaminated fish were exposed to conditions similar to those of the polluted creek, this led both to a reduction in their prey capture rate and an increase in brain mercury to levels similar to those of fish native to the creek (Smith & Weis 1997).

c. Summary and Conclusions

There are very few data on the direct effects of mercury on NJ fish. The results of the Weis and Weis research, reported in several papers, demonstrate significant effects on many aspects of biology, behavior and viability of Killifish. Killifish from mercury-contaminated water showed abnormal behavior and reduced viability. A study of androgen levels in largemouth bass also showed the potential for significant reproductive impairment. Much more information is needed to draw conclusions regarding the impact of mercury on fish health and reproductive capacity. Too few data are available to permit generalization of these observations to other NJ species and location, but it is reasonable to expect that analogous situations occur elsewhere and in other species. These findings raise concerns,

and point out the need for research to examine the impact of mercury on the overall viability of fish in impacted NJ estuarine and marine environments.

3. *Indirect Assessment of Risk to NJ Fish*

a. *Freshwater, Estuarine, and Marine Fish*

Given the very limited direct data on the impact of mercury contamination in NJ waters on NJ fish, two indirect approaches were used to estimate risk to NJ fish species. One involved a comparison of surface water concentrations in NJ to published laboratory toxicity data on mercury and water quality criteria. The second method compares tissue concentrations of mercury in NJ fish to published data on mercury effects and Tissue Screening Concentrations (TSCs). Both methods can be characterized as a screening assessment. Additional data and a more rigorous evaluation would be needed to estimate risk to specific fish populations within the State.

With reference to the first method, numerous laboratory studies have been conducted on the toxicity of mercury in water to fish.(Table 2.22) For acute exposures (one to four days), concentrations causing mortality (i.e., LC_{50} values, which are concentrations lethal to 50% of the exposed fish) ranged from 1.24 µg/L for Threespine Stickleback (1-day exposure) to 500 µg/L for Carp (4-day exposure). Other 4-day LC_{50} values for species found in NJ include 90 µg/L for Striped Bass, 110 µg/L for Banded Killifish, 140 µg/L for American Eel, 220 µg/L for White Perch, and 300 µg/L for Pumpkinseed (US EPA 1999a). Chronic exposure to mercury causes effects at much lower concentrations than those causing acute effects due in part to bioaccumulation. Chronic exposure to MeHg reduced growth in Rainbow Trout at 0.04 µg/L (US EPA 1980). Exposure of fish eggs to mercury resulted in high embryo-larval mortality and teratogenesis at concentrations as low as 0.12 µg/L (Birge et al. 1979).

Applicable NJ water quality criteria for mercury in freshwater are 2.1 µg/L (acute; as dissolved mercury) and 0.012 µg/L (chronic; as total recoverable mercury); and for saltwater the criteria are 1.8 µg/L (acute) and 0.025 µg/L (chronic).

Table 2.23 compares chronic toxicity data and water quality criteria to mercury concentrations in NJ surface waters. In 1995-1997, 232 water samples from 78 freshwater stations were collected by NJDEP and USGS. The method detection level was 0.1 µg/L, and 94% of the samples fell below this level (i.e., not detected). A project conducted by NJDEP/DSRT measured average surface water concentrations of 0.0015 to 0.0198 µg/L in three NJ lakes (Stevenson et al. 1995). The maximum value in the DSRT study exceeded NJ's chronic water quality criteria for freshwater (0.012 µg/L). However, only approximately 6% of the 1995-1997 surface water samples exceeded 0.1 µg/L (Table 2.23) and the DSRT study maximum value of 0.0198 µg/L was less than the lowest listed chronic toxicity value (0.04µg/L).

Based on these limited data, it appears that some fish are at potential risk from the toxic effects of mercury in some of NJ's fresh waters.
Lower detection limits will help assess the risk of mercury in aquatic systems. Improvements in analytical capabilities combined with clean laboratory techniques make lower detection limits possible.

There are limited data for marine/estuarine waters. Data for the NY/NJ harbor area probably represent the high end of mercury concentrations in marine waters of NJ. Average concentrations

were 0.0071 µg/L (Raritan Bay), 0.0695 µg/L (Newark Bay), 0.0862 µg/L (Hackensack River), and 0.2499 µg/L (Passaic River)(GLEC 1996).

Table 2.22. Mercury and Methylmercury Acute and Chronic Toxicity Values for Fish.

Species	Exposure Period	Water Concentration of mercury causing Acute Toxicity (LC_{50}) µg/L	Water concentration of mercury causing Chronic Toxicity µg/L	Effect/Reference
Inorganic Mercury				
Striped Bass	4-day	90	-	(US EPA 1999a)
Banded Killifish	4-day	110	-	(US EPA 1999a)
American Eel	4-day	140	-	(US EPA 1999a)
White Perch	4-day	220	-	(US EPA 1999a)
Mummichog	4-day	300	-	(US EPA 1999a)
Pumpkinseed	4-day	300	-	(US EPA 1999a)
Carp	4-day	500	-	(US EPA 1999a)
Egg Exposure	4-day post hatch	0.12-0.21		High embryo-larval mortality; teratogenesis (Birge et al. 1979)
Parental Exposure	400-day	-	0.70-0.79	High embryo-larval mortality; teratogenesis; no detectable adult pathology (Birge et al. 1979)
Methylmercury				
Threespine Stickleback	1-day	1.24	-	(US EPA 1999a)
Rainbow Trout	4-day	31	-	(US EPA 1999a)
Goldfish	1-day	80	-	(US EPA 1999a)
Mummichog	4-day	150	-	(US EPA 1999a)
Rainbow Trout	64-day	-	0.04	Growth reduction (US EPA 1980)
Brook Trout	17-day	-	0.88	Enzyme disruption (US EPA 1980)
Brook Trout	21-day	-	0.79	Organo-Hg; Growth inhibition (US EPA 1980)
Medaka	3-months	-	1.8	Impaired spermatogenesis (Wester 1991)

A comparison of these data to the marine/estuarine surface water chronic criteria of 0.025 µg/L indicates that waters in the more urban areas of the harbor exceeded water quality criteria. This indicates that fish in these waters are at potential risk from the toxic effects of mercury contamination.

Table 2.23. Comparison of NJ Surface Water Criteria with Average Surface Water Concentrations of Mercury.

NJ Surface Water Criteria	Location	Average Surface Water Concentrations	Date
Freshwater			
Acute 2.1 µg/L	78 Water-Quality Stations	0.053 µg/L* (94% of samples below detection limit of 0.1 µg/L)	1995-1997
Chronic 0.012 µg/L	41 Water-Quality Stations	<0.1 µg/L (all samples below detection limit of 0.1µg/L)	1998
	Three NJ Lakes	0.007 µg/L (0.0015 to 0.0198 µg/L*)	1992
Marine/Estuarine			
Acute 1.8 µg/L	Raritan Bay	0.0071 µg/L	1995
Chronic 0.025 µg/L	Newark Bay	0.0695 µg/L*	1995
	Hackensack River	0.0862 µg/L*	1995
	Passaic River	0.2499 µg/L*	1995

** Concentration exceeds the chronic criteria for freshwater or salt water*

The second method for estimating risk to NJ fish species compares tissue concentrations of mercury in NJ fish to published data on mercury effects and Tissue Screening Concentrations (TSCs). However, there is limited information on the relationship between fish tissue concentration and adverse effects. Table 2.24 lists tissue and effects data from several sources for fish in general, and for specific species (e.g., Rainbow Trout). Based on these data, adverse effects are evident at whole body concentrations as low as 1.3 ppm (growth) and at muscle concentrations of 0.232 ppm (behavior). Shephard (1998) recommended the use of tissue screening concentrations (TSCs) to assist in determining the risk of bioaccumulated contaminants. TSCs were defined as "whole body, wet weight tissue residues of chemicals, which if not exceeded, pose little chance of causing adverse toxicological or ecological harm to aquatic biota." These values were derived by applying bioconcentration factors to the ambient water quality criteria. The TSC for mercury is 0.06 µg/g for freshwater (Shephard, 1998). The hazard quotient (HQ) method was used to conduct a screening level risk assessment where:

$$HQ = \frac{\text{Estimated Environmental Concentration}}{\text{Benchmark Concentration}}$$

HQs (see Table 2.25) were generated by comparing NJ fish tissue concentrations of mercury separately to the mercury TSC value and to the lowest observed effect concentration from Table 2.22 (i.e., 0.232 µg/g for adult fish). Exposure was estimated by using the data from the fish collected at 55 locations in NJ (ANSP 1994).

As indicated by the range in HQs, at least some of the fish samples for all of the species exceeded the TSC or effects thresholds (i.e., HQ>1). This indicates that at least some species of fish in some NJ waters are at risk for the effects of mercury. Largemouth Bass and Chain Pickerel are probably at increased risk based on the large HQs for those species.

Table 2.24. Adverse Effects at Observed Fish Tissue Concentrations.

Species	Mercury Concentration (µg/g; wet weight)	Effects	Reference
Brook Trout	5-7 (whole body)	Mortality, decreased growth, sluggishness, deformities	McKim et al. 1976
Rainbow Trout	20-30 (whole body)	Reduced appetite; gill hyperplasia	Niimi and Lowe-Jinde 1984
	4-27 (whole body) 9-52 (muscle)	Appetite & activity loss followed by death	Niimi & Kissoon 1994
	12-23 (muscle)	Reduced growth	Wobeser 1975
Northern Pike	7-9 (muscle)	Emaciation	Lockhart et al. 1972
Walleye	1.7-3.1 (whole body)	Decreased weight, length, & gonadosomatic index	Friedmann et al. 1996
Fathead Minnow	1.3 (whole body)	Decreased weight & length	Snarski & Olson 1982
	4.5 (whole body)	No spawning	
Fish	0.232 (muscle)	Decreased swimming ability	Rompala et al. 1984
Fish	10-30 (whole body)	Toxicity	Spry and Wiener 1991
Juvenile or Adult Fish	9-20 (whole body)	Harmful effects	Wiener 1996
Fish Eggs or Embryo	0.07-0.10	Adverse effects	Wiener 1996

Table 2.25. Hazard Quotients (HQs) Calculated from the Tissue Concentrations (Range of Concentrations) by Species Divided by the Tissue Screening Concentrations (TSC) and Effect Concentration.

NJ Fish Species (no. of samples)	Hazard Quotient	
	Based on TSC	Based on Effects Concentration
Largemouth bass (146)	0.8-149	0.2-38
Chain pickerel (62)	1.5-47	0.4-12
Smallmouth bass (21)	1.3-8.5	0.3-2.2
Channel catfish (12)	1.2-12	0.3-3.1
Brown bullhead (15)	0.3-7.8	0.1-2.0

b. Summary and Conclusions

The limited data, which allow comparison of mercury concentration in NJ fish to published criteria and guidelines, indicate the potential for chronic effects to fish in some waters of the State due to mercury. This potential is reflected in the exceedence of water quality criteria for chronic effects for both freshwater and saltwater fish. In particular, the NY-NJ Harbor area has exhibited mercury water concentrations above water quality criteria. Monitoring using more sensitive (i.e., lower detection limit) methods is needed to assess the levels of mercury in surface waters. It is apparent from both direct and indirect methods that some fish in some NJ waters may be at risk of mercury toxicity.

E. Mercury in NJ Birds

1. Assessment of NJ Species Potentially at Risk

The trophic level and feeding habitats of a bird species will influence its exposure to mercury. Piscivorous bird species are at greatest risk to the effects of mercury due to the biomagnification of mercury through the aquatic food chain. State threatened and endangered species, such as the piscivorous Osprey, Bald Eagle, Black Skimmer, and Least Tern may be at increased risk due to their trophic level and the potential cumulative effects of other contaminants in addition to mercury on reproduction (e.g., DDT/DDE, PCBs). The Peregrine Falcon, another NJ endangered species, may also be at high risk since its diet includes piscivorous birds (such as terns). A variety of large birds including herons and egrets, gulls, terns, and skimmers which typify the NJ shore, may also be at increased risk due to greater mercury exposure from the fish they eat.

Smaller birds that feed at lower trophic levels in the aquatic food chain also may be exposed to increased amounts of mercury due to their high food consumption rate relative to larger birds (US EPA 1997f).

2. Wildlife Criterion Value (Surface Water Concentration)

US EPA (1997d) calculated a wildlife criterion value of 50 pg/L of MeHg in surface water for protection of piscivorous wildlife. Based on this value, they calculated the concentration in fish that would meet this criterion. For trophic level 3 fish (e.g., sunfish) this value is 0.077 μg/g , and for trophic level 4 fish (e.g., Largemouth Bass) this value is 0.346 μg/g. Therefore, concentrations of MeHg in fish would need to be at or below these values to be protective of piscivorous birds and mammals. For example, the MeHg concentration in piscivorous fish species (e.g., Pickerel, Largemouth Bass) would need to be less than or equal to 0.346 μg/g to protect species that feed on them. The MeHg concentration in omnivorous fish (e.g., sunfish) prey would need to be less than or equal to 0.077 μg/g to protect wildlife species including larger predatory fish.

Based on these values, a comparison for the 55 NJ waterbodies sampled in 1992-93, indicates that top trophic level fish exceed the criterion value of 0.346 μg/g for protection of piscivorous wildlife and also exceed the new EPA surface water criterion of 0.3 μg/g (in fish tissue). The data indicate that Largemouth Bass in 70% (23 of 33) and Chain Pickerel in 82% (18 of 22) of the waterbodies exceeded this concentration. Overall, 60% of the Largemouth Bass samples and 74% of the Chain Pickerel samples exceeded this value. This indicates that certain piscivorous wildlife species feeding on these species in these waters are at potential risk from the effects of mercury. Additional data collection and a more comprehensive analysis are recommended for trophic level 3 and 4 fish.

The EPA provided relative ranking of exposure for the species considered: Kingfisher > River Otter > Loon = Osprey = Mink = Bald Eagle. The Belted Kingfisher has a higher daily mercury intake than Osprey, and EPA estimates that 29% of its national range has high atmospheric mercury deposition (5 $\mu g/m^2$). For Osprey and Bald Eagle, 20% and 34% of their national range respectively receives high mercury deposition. Both species were severely impacted by chlorinated hydrocarbon pesticides in the 1950's and 1960's and have recovered through a combination of pesticide bans and aggressive management. Whether mercury currently impairs their survival or reproduction requires additional monitoring.

3. Criteria for Mercury in Birds

US EPA (1997d) concluded, based on a review of laboratory and field data, that adverse impacts on avian populations are possible at mercury concentrations exceeding the following values (fresh weight): feathers - 20 µg/g (Scheuhammer 1991); eggs - 2.0 µg/g (after conversion from dry weight) (Scheuhammer 1991), and liver - 5 µg/g (Zillioux et al. 1993). EPA indicated that these numbers should be used with caution, because the literature contains reported thresholds that are higher than and lower than these values. Some of the NJ data approach these thresholds. Evidence of lower thresholds (e.g., developmental abnormalities in Common Tern chicks [Gochfeld, 1980]) indicate that NJ species may be at potential risk.

Summarizing literature on reproductive and behavioral outcomes, Burger and Gochfeld (1997) identified a level of 0.5 ppm (wet weight) in eggs and 5.0 ppm in feathers as criteria above which adverse effects could be anticipated. Feather levels in the 40-60 ppm range were associated with sterility and total chick mortality, while levels in the 5-40 ppm range were associated with reduced hatchability and behavioral abnormalities (Burger and Gochfeld 1997; Eisler 1987).

4. Mercury Levels in Birds of NJ and the New York Harbor and Bight

Birds have been monitored for mercury since the 1960's and data from NJ, and the New York Bight comprise a significant portion of the contaminants' data compiled in the national database by the US Fish and Wildlife Service (B. Rattner, Personal Comm).

a. Common Loon

The Common Loon (*Gavia immer*), icon of the northwoods, is a species at risk, declining over much of its breeding range. This piscivorous waterfowl breeds on fresh water of Canada and the northern United States. It visits NJ only on migration and as a winter resident between September and April on both fresh and saltwater. Its population has declined, due primarily to acid deposition, but loons have high mercury levels, and Barr (1986) found adverse reproductive effects in loons exposed to 0.3 µg/g of mercury in trophic level 3 fish.

b. Colonial Waterbirds

Species such as gulls and terns, herons and egrets nest in large groups, referred to as "colonies"on islands or other protected habitats mainly along the coast. Chicks are fed by the parents, who fish in the waters within a few kilometers of the colonies. The adults thus "collect" fish from a relatively small area over a period of weeks, thereby integrating exposure over time and space. Several studies of mercury in such species have been conducted in estuarine systems of the New York Bight from Fire Island, NY to Barnegat Bay, NJ.

In a summary of studies of mercury in eggs of nine coastal waterbird species from the New York Bight, Burger and Gochfeld (1997) found that mean mercury levels exceeded 0.5 ppm for Snowy Egrets from Lavalette, NJ; Black Skimmers and Common Terns from NY and NJ; and Forster's Tern and Herring Gulls from Barnegat Bay. Forster's Terns had the highest values. Only Laughing Gulls from Barnegat Bay had a mean less than 0.5 ppm. The same study of feather mercury, however, revealed that most of these colonial species had mean mercury below 5 ppm. Only Snowy Egrets from the Barnegat Light colony and Great Egrets from Lavallette, exceeded an average of 5 ppm. The Great Egret eats relatively large fish,

and Jurczck (1993) concluded that in south Florida this species was exposed to excessive amounts of mercury, thus placing the population at risk. Currently this species has an apparently stable population in NJ that breeds and partly winters in the state.

The insectivorous Cattle Egret also had moderately high levels of mercury, even though it is lower on the food chain. Mercury levels in its feathers averaged 0.60 ppm in the Arthur Kill colonies and 1.6 ppm in the Pea Patch, Salem County colony. These are substantially lower than the 3.5 ppm average at Aswan, Egypt (Burger et al. 1992), but are nonetheless elevated.

In NJ, Herring Gull eggs contained 0.26 μg/g (geometric mean wet weight) of mercury at Shooter's Island, 0.47μg/g at Lavallette, and 0.33 μg/g at Log Creek (Gochfeld 1997). Surprisingly, mercury levels in these two Barnegat Bay colonies were significantly higher than in eggs from the Arthur Kill (geometric mean=0.26 μg/g) and Jamaica Bay (geometric mean=0.29 μg/g) (Gochfeld 1997). The Barnegat Bay levels were comparable to the median for German colonies (about 0.40 μg/g; Lewis et al. 1993) and close to those for highly contaminated Great Lakes colonies (mean=0.51μg/g; Gilman et al. 1977). The source of this elevated mercury has not been identified.

Clearly, with these mean values, some of the birds at the high end would have been at risk of adverse effects. Burger (1997b) compared Herring Gull feather mercury levels in four Long Island, three NJ and one Virginia colony. The highest values (geometric means) were 2.66 μg/g in western Long Island Sound, and 2.45 μg/g in Barnegat Bay. These compare with median values from central Europe of about 5.0 μg/g (Lewis et al. 1993).

Laughing Gulls, mostly from breeding colonies in NJ, were killed at J.F. Kennedy Airport as part of a federal control program to avert aircraft collisions. The carcasses were collected and the tissue analyzed for mecury. Mercury levels averaged 0.55 μg/g in liver, 0.48 μg/g in kidney and 3.5 μg/g in feathers (Gochfeld et al. 1996).

The Roseate Tern (*Sterna dougallii*) is a federal endangered species, which formerly nested at least rarely in NJ. Samples from a Long Island colony revealed a slight decline in mercury in eggs (geometric mean, wet weight) from 1.49 μg/g (1989) to about 1.07 μg/g (1994). Between 1971 and 1982 the geometric mean mercury level in Common Tern eggs (Long Island, NY) declined from 0.61 to 0.25 μg/g (Burger and Gochfeld 1988). Herring Gull feathers from Captree, NY revealed no temporal trend between 1990 and 1993 (values of 0.2 μg/g to 0.4 μg/g in adults) (Burger 1995).

As evidence of biomagnification in Raritan Bay, mercury levels were higher in fish eating Common Terns than in omnivorous Herring Gulls and Greater Scaup or herbivorous Black Ducks (Burger et al. 1984). Some of the highest mercury levels in feathers were found in Black Skimmers from the New York Bight, with up to of 13.0 μg/g (Burger and Gochfeld 1992).

c. Waterfowl

Ducks and geese are prominent features of NJ wetlands, particularly in winter, and ducks have been used as indicators of contaminant levels. Greater Scaup, once the most abundant duck wintering in Raritan Bay, were monitored in 1980-81 (Burger et al. 1984) and again in 1996-97 (Cohen et al. 1999). The mean levels in liver were essentially unchanged (0.73 vs. 0.86 μg/g). Moreover, Cohen et al. (1999) found that mercury levels were higher in Scaup from Sandy Hook than from eastern Long Island or Long Island Sound, suggesting a local source of contamination rather than contamination on the breeding grounds in Canada.

Moreover, mercury levels increased from early winter (when the birds arrived from their Canadian breeding grounds) to early spring (before they departed northward), again indicative of local exposure to mercury in Raritan Bay.

Three species of ducks from Raritan Bay (1980-1981) were analyzed for mercury in liver. Mean levels were 0.53 μg/g (wet weight) in Black Duck, 0.73 μg/g in Scaup, and 0.32 μg/g in Mallards (Burger and Gochfeld 1985; Gochfeld and Burger 1987b). In 1983, Black Ducks, Greater Scaup and Herring Gulls all averaged less than 0.5μg/g of mercury in liver (wet weight) while Common Terns exhibited levels were at 0.7 μg/g.

d. Shorebirds

Many migratory shorebird species feed mainly on Horseshoe Crab eggs and small invertebrates. Average total mercury in Horseshoe Crab eggs from Delaware Bay were 27 ppb (1993), 93 ppb (1994), and 12 ppb (1995) (Burger 1997). Mercury levels were measured in feathers of three shorebird species from Delaware Bay in the early 1990s. Red Knot averaged 1.15 ppm, Sanderling 2.8 ppm, and Semi-palmated Sandpiper 0.021 ppm. These highly migratory species may be exposed in their tropical wintering grounds or their Arctic breeding grounds, as well as along Delaware Bay (Burger 1993).

e. Raptors

The falcons, hawks and eagles (collectively called raptors) are familiar birds to the public. The Osprey is a characteristic feature of the Jersey Shore; the falcon the emblem of the US Airforce, and the Bald Eagle is our national symbol. NJ has invested extensively in protecting raptorial birds. The populations of most species in the eastern United States have recovered. However, the populations of Ospreys, Peregrine Falcons and Bald Eagles has declined precipitously due to the bioaccumulation of chlorinated hydrocarbon pesticides, and the population of Northern Harrier (Marsh Hawk), has declined probably because of habitat loss. NJ has had an aggressive program to restore Eagles and Ospreys and to protect Northern Harrier habitat, as well as the crucial habitat in Cape May County required by migratory hawks. For migratory species such as the Peregrine, chlorinated hydrocarbon exposure in South America continues to be a threat.

Whether mercury has contributed to past declines or may impair future population, is not known. There are few data on mercury levels in NJ raptors (Bald Eagle, Osprey, Peregrine Falcon) but this sparse data show that raptors can accumulate high concentrations of mercury. Comparable data obtained systematically from NJ breeding populations would provide valuable information for a management program. As indicated earlier, piscivorous raptors, such as the Osprey and Bald Eagle, are at greater risk due to increased mercury exposure from their diet.

As of the mid-1990's, the population of Bald Eagles in the Delaware River basin had rebounded from one pair in the early 1970's to 13 pair. Blood mercury levels in 35 Bald Eagle chicks (1993-1996) showed a geometric mean of 140.6 μg/L and were generally below 300 μg/L. The five highest mercury concentrations between 756 and 1549 μg/L were found in 5 of 6 Union Lake nestlings (Clark 1999). These levels are quite high. Additional levels for mercury in NJ raptors are shown in Table 2.7 (Volume II, Chapter 6).

Osprey *(Pandion haliaetus)* and other avian populations have progressively recovered from the adverse effects of widespread pesticide usage. Recovery of several localized populations of Ospreys and Bald Eagles nesting along the Delaware Bay continue to be hampered by

organochlorine pesticides. Results from surveys in 1977 and 1987 contained some of the highest contaminant residues recorded in Bald Eagle eggs from the Delaware Bay region (Steidl et al. 1991).

5. Mercury and Developmental Defects

In the late 1960's and early 1970's, an epidemic of developmental defects was detected in several species of colonial birds in the New York Bight. These included craniofacial abnormalities (anencephaly, cyclopia, micrognathia, crossbill), limb abnormalities (phocomelia, excess limbs and toes), and feather defects. In the 1980's similar defects occurred in birds in the Great Lakes. Total mercury levels in chicks of Common Terns from western Long Island ranged from 165-750 μg/L in blood and 0.8 to 2.6 ppm in feathers, with abnormal chicks having higher levels than normal ones ($p < 0.05$). Developmental abnormalities in Common Tern chicks were associated with significantly higher mercury levels in liver of 2.2 vs. 1.1 μg/g and brain levels of 0.85 vs. 0.42 μg/g (Gochfeld 1980).

Common Terns with developmental defects associated with high levels of mercury also had elevated PCB concentrations (Hays & Riseborough 1971), and an additive or synergistic affect between these pollutants was proposed (Gochfeld 1975).

6. Summary and Conclusions: Mercury in NJ Birds

Mercury levels in tissues, feathers, and eggs of several populations of NJ and New York Bight birds are close to or above levels anticipated to impair behavior, reproduction, growth and survival. Mercury was associated with developmental defects in Common Terns in the 1970's and high mercury levels are considered one of the stressors causing the decline of Common Loons. Mercury in the fish diet of Bald Eagles and Osprey, appears to be elevated in the Delaware Bay region and may be a contributing factor to their relative lack of recovery in these regions.

F. Mercury in Other NJ Biota

Data on mercury levels in animals other than birds and fish are sparse in both the number of observations and the extent of taxonomic coverage.

1. Marine Invertebrates

Blue Mussels (Mytilus edulis) are widely used as an indicator of marine pollution. Mussels have been sampled by NOAA in the Hudson-Raritan estuary from 1986 to 1997 (NOAA 1998). Mercury levels ranged from 0.18 to 0.72 μg/g (dry weight), with the highest values in the Upper Bay and the lowest values in the Hudson River (below Peekskill). The highest value along the NJ portion of the estuary was 0.36 μg/g observed in the Shark River in 1991.

Horseshoe Crab (Limulus polyphemus): Delaware Bay has been the center of abundance of Atlantic Coast Horseshoe Crab, but this population has been jeopardized by over-harvesting, primarily for the conch and eel bait trade. Horseshoe Crab eggs are essential food for migrating shorebirds. Burger (1997) reported that Horseshoe Crab eggs collected in Delaware Bay in 1993, 1994, and 1995 averaged 0.027-0.093 μg/g, while adult Horsehoe Crab muscle averaged 0.053 μg/g (mean, wet weight). At these levels, it seems likely that mercury is not affecting this species.

2. Mammals

Mammals are relatively infrequently sampled for pollutants. Muskrats *(Ondatra zibethicus)* were collected from the Meadowlands and a reference area in NJ in 1975 (Galluzzi 1976). Thirty-six samples of eight species of mammals were collected in the Hackensack Meadowlands in 1978 (Galluzzi 1981). Average mercury concentrations for these mammals are listed in Table 2.26. Mercury concentrations in the Hackensack Meadowlands' Muskrats were generally higher than the Muskrats from the reference location in Morris County. Muskrat muscle, liver, and kidney mercury concentrations were generally higher in the Berry's Creek area as compared to the other two locations in the Meadowlands. The highest mercury concentrations were observed in Opossum *(Didelphis marsupialis)* tissues. The Opossum is an omnivore while several of the other mammal species are generally herbivores (e.g., Muskrat, Vole, and Rabbit). The Opossum's more diverse feeding habits may explain the higher mercury levels (i.e., greater exposure to mercury through food items).

3. Reptiles

Table 2.27 lists a few reptile species that were also collected in the Hackensack Meadowlands in 1978 (Galluzzi 1981). Mercury levels in the Diamondback Terrapin *(Malaclemys terrapin)* muscle and liver tissue were elevated compared to the other reptiles and mammals. This may be due to the Terrapin's diet of aquatic animals, leading to greater mercury exposure. The Garter Snake (*Thamnophis sirtalis*), which feeds on fish, amphibians and invertebrates had mercury levels one order of magnitude higher than the Milk Snake (*Lampropeltis doliata*), which feeds mainly on baby birds and mammals (Smith & Brodie, 1982). However, the sample sizes for all three species are very small and more data are needed before generalizations can be drawn.

The Pine Snake *(Pituophis melanoleucus)* is a threatened species that occupies the increasingly fragmented habitat of the Pine Barrens of southern NJ. Total mercury in body tissue (mainly muscle, bone, and connective tissue) of hatchlings ranged from 0.27 ppm in 1985 to 0.05 ppm in 1990. (Burger 1992)

Table 2.26. Concentrations of Mercury in Mammal Tissue in NJ.

Location	Average mercury Concentration (µg/g; wet weight)	Source
Muskrat *(Ondatra zibethicus)*		
Berry's Creek (West Riser ditch) (n=10)	Muscle=0.024 Liver=0.016 Kidney=0.279	Galluzzi 1976
Berry's Creek (n=10)	Muscle=0.027 Liver=0.036 Kidney=0.176	Galluzzi 1976
Anderson Creek (Secaucus) (n=10)	Muscle=0.006 Liver=0.020 Kidney=0.068	Galluzzi 1976
Sawmill Creek (n=10)	Muscle=0.006 Liver=0.012 Kidney=0.111	Galluzzi 1976
Montville (Morris County) (n=10)	Muscle=0.003 Liver=0.0005 Kidney=0.003	Galluzzi 1976

Hackensack Meadowlands (n=5)	Muscle=0.01 Liver=0.050 Kidney=0.030	Galluzzi 1981
Opossum *(Didelphis marsupialis)*		
Hackensack Meadowlands (n=3)	Muscle=0.17 Liver=1.25 Kidney=1.80	Galluzzi 1981
Norway Rat *(Rattus norvegicus)*		
Hackensack Meadowlands (n=4)	Muscle=0.05 Liver=0.11 Kidney=1.22	Galluzzi 1981
Cottontail Rabbit *(Sylvilagus sp)*		
Hackensack Meadowlands (n=3)	Muscle=ND Liver=0.15 Kidney=0.51	Galluzzi 1981
House Mouse *(Mus musculus)*		
Hackensack Meadowlands (n=11)	Muscle=0.01 Liver=0.06 Kidney=0.34	Galluzzi 1981
Vole *(Microtus sp)*		
Hackensack Meadowlands (n=7)	Muscle=ND Liver=ND Kidney=0.16	Galluzzi 1981
Raccoon *(Procyon lotor)*		
Oakland (Bergen County) (n=1)	Muscle=0.064 Liver=0.248 Kidney=0.227	Galluzzi 1981

4. Vegetation

Measuring mercury levels in terrestrial vegetation and biota may help determine major areas of deposition in the state and may serve as living indicators of mercury contamination through atmospheric deposition. However, there are currently few data on mercury in plants in NJ and no information on adverse impacts. Mercury levels in rye grass and sphagnum moss were measured near the Warren County Resource Recovery Facility (Carpi et. al. 1994). Total mercury in moss exposed at sites within 1.7 kilometers of the incinerator had significantly higher mercury levels (average 206 ng/g, or ppb) compared to samples exposed at greater distances from the facility (average 126 ng/g).

Mercury levels in aquatic vegetation have been measured in NJ. Pond lilies in Mountain Lake, Lake Assunpink, and Parvin Lake were reported to be 7 to 13 ng/g (Stevenson et al. 1995). More information on mercury levels in aquatic vegetation and non-fish biota are needed in order to characterize the extent of mercury pollution and provide baselines for detecting temporal trends.

Table 2.27. Concentrations of Mercury in Reptile Tissue in the Hackensack Meadowlands (Source: Galluzzi, 1981).

Species	Tissue	Average Mercury Concentration (µg/g; wet wt.)
Diamondback Terrapin *(Malaclemys terrapin)* (n=2)	Muscle	Muscle=0.76 Liver=5.6 Kidney=1.8
Garter Snake *(Thamnophis sirtalis)* (n=3)	Muscle	Muscle=0.28 Liver=1.40 Kidney=0.32
Milk Snake *(Lampropeltis doliata)* (n=1)	Muscle	Muscle=0.012 Liver=0.044 Kidney=0.027

5. Summary and Conclusions: Mercury in Other NJ Biota

Very limited data on mercury exposure in NJ plants and animals other than birds and fish are available. The data suggests that omniorous mammalian species have higher mercury levels than hebivorous species. Data on carnivorous species are lacking. For reptiles, elevated levels are associated with the consumption of aquatic biota (fish and invertebrates). Information for evaluating the ecological risk implications of these isolated observations is lacking, and more information on mercury in these animals and in various plant species is needed.

G. Recommendations

To understand the impacts of mercury on biota and ecosystems, it is necessary to systematically collect data on a group of representative species (bioindicators) from a wide variety of ecosystems, stratified by presumed exposure to mercury. A systematic assessment of mercury should be carried out in conjunction with other bioaccumulative pollutants and other heavy metals in NJ plants and animals.

Address critical information gaps concerning the quantities and chemical species of mercury emissions and releases, the fate and transport of mercury in the environment, and the exposure pathways. To accomplish this, NJ should:

- **Consider establishing the mercury-contaminated sites in the Berry's Creek area as an Environmental Research Park, patterned on the National Environmental Research Park system. This could serve as a resource for studies and monitoring of the complex processes governing the fate and transport of mercury in both the terrestrial and estuarine environment.**

(From Recommendation "M.5." in Volume 1).

The massive contamination of the Ventron/Velsicol and Berry's Creek area, provides a unique opportunity to understand the processes controlling the sequestration, availability, and ecological effects of mercury. Since some local residents consume wildlife from this ecosystem, human exposure can also be clarified. The opportunity exists to declare Berry's Creek Environmental Research Park, patterned on the National Environmental Research Park system (DOE 1994), and to fund research studies and monitoring to clarify the complex processes governing the fate and transport of mercury in both the terrestrial and estuarine environment.

Expand and institutionalize routine monitoring for mercury in fish from NJ waters through State-level programs (From Recommendation "G" in Volume 1).

Regular monitoring of freshwater fish, including selected species of recreational and ecological importance, should be conducted to identify temporal and spatial trends in mercury and other bioaccumulative contaminants, to allow the state to keep potential consumers informed of levels, to provide information for updating advisories, and to identify new or unsuspected sources of contaminants.

The scope of sampling should be expanded to additional water bodies to support fish advisories.

There should be regular and systematic monitoring of saltwater species in NJ waters for mercury and other contaminants, in order to provide appropriate consumption advisories. The recent (January 2001) fish consumption advisories issued by FDA and EPA are not NJ-specific.

Address critical information gaps concerning the quantities and chemical species of mercury emissions and releases, the fate and transport of mercury in the environment, and the exposure pathways. To accomplish this, NJ should:

- **Encourage federal agencies to expand existing national research on the ecological effects of mercury, particularly on piscivorous (fish-eating) fish, birds and mammals (particularly marine mammals).**

(From Recommendation "M.3." in Volume 1).

Reduce mercury levels in fish and other biota. Mercury concentrations in freshwater and estuarine fish in New Jersey should, at a minimum, be in compliance with the EPA's recent Surface Water Criterion of 0.3 µg/g methylmercury in tissue. This guidance value, aimed at protecting human health, may not be adequate to protect the health of the fish. Therefore mercury levels in surface water and fish tissue should achieve levels protective of aquatic life and of wildlife (the criterion for which is currently under development). Assessing this criterion requires the use of improved analytic methodologies that lower detection levels by at least an order of magnitude. (From Recommendation "Q" in Volume 1).

Additional research in the domain of aquatic toxicology is needed to understand how mercury effects fish health in terms, not only of survival, but behavior, condition, and reproduction, all of, which are inter-related. The dose-response relationship between mercury exposure measures (mercury in sediment, prey species, or tissue) and fish health need to be established.

Additional data collection and a more comprehensive analysis of fish tissue concentrations and their comparison to effect levels should be carried out especially for tropic levels 3 and 4 fish in NJ, as it appears that these fish are most at risk for adverse effects and are consumed by piscivorous species. Monitoring using more sensitive methods (i.e., lower detection limit) is needed to assess the levels of mercury in surface waters to more precisely estimate the potential for adverse effects on fish on a waterbody-by-waterbody basis.

Develop improved environmental indicators of the impact of mercury on NJ's environment. To accomplish this, NJ should:

- **Develop and apply indicators of trends of mercury in environmental media, including air deposition, mercury concentrations in surface water, mercury**

entry into aquatic food chains, mercury levels in fish tissue, mercury levels in human tissue in the NJ population, and mercury levels in feathers of piscivorous birds nesting in NJ.
(From Recommendation "O.2." in Volume 1).

Establish a monitoring program for mercury and other contaminants in NJ birds, including but not limited to, threatened and endangered species.

EXHIBIT D

2006

Fish Smart, Eat Smart

A Guide to Health Advisories for Eating Fish and Crabs Caught in New Jersey Waters

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Contents

The New Jersey Department of Environmental Protection and the New Jersey Department of Health and Senior Services can provide more information on the advisories and the health effects of chemical contaminants in the fish. To stay current with advisory updates and to request additional information, please contact the NJDEP Division of Science, Research and Technology at 1-609-984-6070 or check the website www.FishSmartEatSmartNJ.org or the NJDHSS at 1-609-588-3123.

Introduction

Fishing provides enjoyable and relaxing recreation. Many people enjoy cooking and eating their own catch. Fish are an excellent source of protein, minerals and vitamins, are low in fat and cholesterol and play an important role in maintaining a healthy, well-balanced diet. The American Heart Association recommends people eat fish regularly. Fish are also one of the few foods that are rich in the omega-3 fatty acids needed for proper development of the brain and nervous system in the fetus and infants, and may reduce the risk of heart attack. Fish are an excellent substitute for other protein foods that are higher in saturated fats and cholesterol. Health professionals recommend that you include fish in your diet.

However, certain fish may contain toxic chemicals, such as polychlorinated biphenyls (PCBs), dioxins and mercury from the water they live in and the food they eat. Therefore, it is a good idea to follow a few precautions in consuming recreationally caught fish and crabs, particularly if you eat them often. The purpose of this booklet is to provide information to you on how to reduce your risk by avoiding or limiting consumption of certain fish, and to guide you in preparing the fish you eat from local waters in ways that reduce your exposure to PCBs, dioxins and mercury.

Since 1982, when research began to show elevated levels of potentially harmful contaminants in certain fish and crabs in some New Jersey waters, fish consumption advisories were adopted to guide citizens on safe consumption practices. Fish consumption advisories are developed through a scientific process that includes collecting samples of fish from waters throughout the state and analyzing them for various chemical contaminants, such as dioxin, PCBs and mercury. The contaminant levels in the fish are then evaluated using federal guidelines for protecting human health. Chemical contaminants such as dioxin and PCBs are classified by the U.S. Environmental Protection Agency as probable cancer-causing substances in humans. Elevated levels of mercury can pose health risks to the human nervous system, particularly to developing fetuses.

The New Jersey Department of Environmental Protection (NJDEP) and Department of Health and Senior Services (NJDHSS) provide advice on consuming those species of fish in which high levels of dioxin, PCBs and mercury have been found. Since levels of contaminants may vary from one location to another, and from one fish species to another, the advisories are also separated by site. So be sure to check which guidelines refer to your fishing location.

Health Effects from Consumption of Contaminated Fish and Crabs

General Advice

Exposure to low levels of some contaminants in the environment may have long lasting health effects on people. Mercury, PCBs and dioxins are among the major contaminants found in some New Jersey fish in portions of the state. These contaminants can be especially harmful to women of childbearing age, pregnant women and nursing mothers. Trace amounts of these contaminants may remain in your body for a period of time after eating. Should you become pregnant during this time, these contaminants can be passed along to your fetus, potentially affecting the development of the nervous system. Children are also at risk of developmental and neurological problems if exposed to these chemicals.

Mercury

Mercury is a toxic metal that has been commonly used in a number of products (e.g., thermometers, electrical switches). There are many sources of mercury in the environment, natural and man-made; primary sources include burning of fossil fuels such as coal, incineration of wastes, and metal processing/manufacturing.

Mercury discharged to the environment can end up in local water bodies. Mercury accumulates in fish muscle tissue through the aquatic food chain from the food that fish eat. Above certain levels, mercury can damage the nervous system, particularly in unborn and young children, resulting in learning and developmental delays. Regular consumption, of even low amounts of mercury may cause subtle effects on the central nervous system in both children and adults. In addition, long-term consumption of fish with elevated levels of mercury by adults and older children may result in adverse health effects, including neurological damage.
For more information go to www.epa.gov/mercury.

PCBs

Polychlorinated biphenyls (PCBs) were commercially produced for industrial application in heat transfer systems, hydraulic fluids and electrical equipment. They were later incorporated into other uses such as printing inks, paints and pesticides. The manufacture of PCBs was stopped in 1979 as a result of evidence that PCBs build up in the environment and cause harmful effects. PCBs tend to stay mostly in soil and sediment, but are also found in the air and water.

Once they enter the food chain, they have a tendency to absorb into fat tissue. PCBs build up in fish to levels that are hundreds of thousands of times higher than the levels in the surrounding water. When people consume fish that have already accumulated PCBs, the PCBs then accumulate in their bodies.

PCBs have been shown to cause cancer in animals, and there is evidence that PCBs may cause cancer in exposed humans. PCBs have also been shown to cause a number of serious health effects besides cancer in humans and animals, including effects on the nervous system of the developing fetus, the immune system, and the reproductive system. Studies have shown that unborn and young children are most at risk to PCB exposure. Because PCBs take a long time to leave the body after they accumulate, women who plan to become pregnant should follow the more restrictive consumption advice before becoming pregnant.
For more information go to www.epa.gov/ebtpages/pollmultimediapollpolychlorinatedbiphenylspcbs.html.

Dioxin

Dioxin is the most toxic member of a large chemical family of related dioxins and furans. Dioxin is an unwanted industrial byproduct formed through numerous processes, including production of chlorinated phenol products such as herbicides, the incineration of municipal solid waste, and creation of paper products using bleach. Most of what we know about dioxin has been obtained through animal toxicity testing in the laboratory and representative wildlife species. Dioxin produces a number of effects in animal testing, including suppression of the immune system, impaired reproduction, birth defects in some species tested, a skin condition called chloracne, alterations in liver function, and cancer. The federal Environmental Protection Agency (EPA) has classified dioxin as a probable human carcinogen.
For more information go to www.epa.gov/ebtpages/pollchemicalsdioxins.html.

General Consumption Guidelines

Fish Species: Contaminant levels may vary from species to species. If possible, eat smaller amounts of several different types of fish rather than a large amount of one type that may be high in contaminants. Try to focus your consumption on those species of fish that have lower levels of contaminants, such as fluke or flounder.

Fish Size: Smaller fish of a species will usually have lower chemical levels than larger fish in the same location because contaminants tend to build up in the fish over time. It is advisable to eat smaller fish (of legal size) more often than larger fish.

High-risk Individuals: Infants, children, pregnant women, nursing mothers and women of childbearing age are considered to be at higher risk from contaminants in fish than members of the general public. People within this category should be particularly careful about following the advisories, because of the greater potential for PCBs, dioxin and mercury to affect the development of the fetus, infant, and young child.

Preparation and Cooking Methods for Fish and Crabs under Advisory

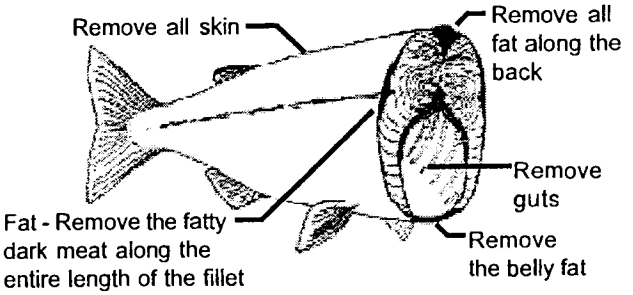
The best way to reduce exposure to contaminants in fish is to learn what fish species are affected and either limit or avoid consumption. However, if you must eat those species under advisories, there are steps you can take to reduce your exposure. Contaminants tend to concentrate in the fatty tissue of the fish you catch. Proper cleaning and cooking techniques, which remove some of the fat from the fish, can significantly reduce levels of PCBs, dioxins and other organic chemicals. **Please note, however, that these techniques will not reduce or remove unsafe levels of *mercury* from these fish.** Mercury occurs in the flesh. There is no way to remove mercury through cooking. The best way to reduce mercury exposure is to select those species of fish which are known to have lower levels of mercury.

Fish Preparation Methods

Proper fish cleaning and cooking techniques may reduce PCB levels by approximately 50 percent when compared to raw fish fillets. A meal size is considered to be an uncooked 8 ounce fillet.

Eat only the fillet portions. Do not eat whole fish or steak portions.

The following diagram illustrates those body portions. Many chemical contaminants, like PCBs and pesticides (but not mercury), are stored in the fatty portions of fish. To reduce the levels of these



chemicals, skin the fish and trim any of the dark meat (lateral line), back strap and belly flap.

Do not eat the heads, guts or liver, because PCBs usually concentrate in those body parts. Also, avoid consumption of any reproductive parts such as eggs or roe.

Fish Cooking Methods

Use a cooking method such as baking, broiling, frying, grilling, or steaming that allows the fats and juices to drain away from the fish. When possible, cook the fish on an elevated rack that allows fats and juices to drain to the pan below.

Avoid batter, breading or coatings that can hold in the juices that may contain contaminants. The juices should be thrown away since they contain the PCBs and other chemicals that were in the fat. Do not pour these juices over the fish as a sauce or to moisten the fish. Butter, margarine or other liquids can be added to the fish for this purpose once the juices have been poured off.

After cooking, **discard all liquids and frying oils**. Do not reuse.

Do not use heads, skin, trimmed fatty portions in soups, stews, chowders, boils, broth or for fish stock. If you make stews or chowders, only use skinless fillet parts.

Raw fish may be infested by parasites. Cook fish thoroughly to destroy the parasites. This also helps to reduce the level of many chemical contaminants.

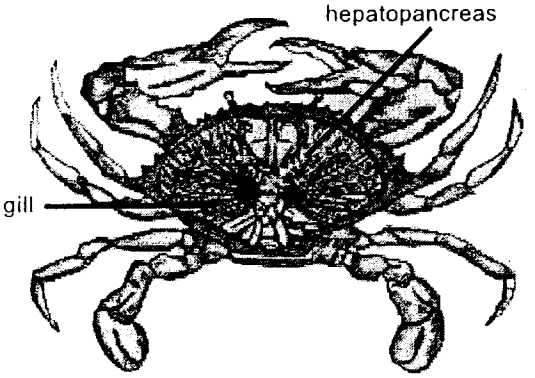
Crab Preparation Methods

Eating, selling or taking (harvesting) blue crabs from Newark Bay Complex and the tidal Passaic River is prohibited. The Newark Bay Complex is located in northeastern New Jersey. It includes the Newark Bay, tidal Hackensack River, Arthur Kill, Kill Van Kull and tidal tributaries. (See chart on page 8.) If blue crabs are taken from water bodies other than the Passaic River/Newark Bay Complex, the following preparation techniques can be followed to reduce exposure to some contaminants.

The highest levels of chemical contaminants are found in the hepatopancreas, commonly known as the tomalley or green gland. It is the yellowish green gland under the gills. This material is found next to the lump meat (backfin) portion of the crab. Chill and break the crabs immediately before cooking. Care must be taken to remove all of the hepatopancreas before cooking.

There is no specific cooking method available to reduce the chemical contaminant levels in blue crabs. The following steps for proper preparation is key to reducing your exposure to harmful chemical contaminants.

- Do not eat the green gland (hepatopancreas).
- Remove green gland (hepatopancreas) before cooking.
- After cooking, discard the cooking water.
- Do not use cooking water or green gland (hepatopancreas) in any juices, sauces, bisques or soups.



Federal Advice on Fish Consumption

The following is provided as general information and advice from the federal government.

Fish and shellfish are an important part of a healthy diet. Fish and shellfish contain high quality protein and other essential nutrients, are low in saturated fat, and contain omega-3 fatty acids. A well-balanced diet that includes a variety of fish and shellfish can contribute to heart health and children's proper growth and development. So, women and young children in particular, should include fish or shellfish in their diets due to the many nutritional benefits.

However, nearly all fish and shellfish contain traces of mercury. For most people, the risk from mercury by eating fish and shellfish is not a health concern. Yet, some fish and shellfish contain higher levels of mercury that may harm an unborn baby or young child's developing nervous system. The risks from mercury in fish and shellfish depend on the amount of fish and shellfish eaten and the levels of mercury in the fish and shellfish. Therefore, the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) are advising women who

may become pregnant, pregnant women, nursing mothers, and young children to avoid some types of fish and eat fish and shellfish that are lower in mercury.

By following these 3 recommendations for selecting and eating fish or shellfish, women and young children will receive the benefits of eating fish and shellfish and be confident that they have reduced their exposure to the harmful effects of mercury.

1. Do not eat Shark, Swordfish, King Mackerel, or Tilefish because they contain high levels of mercury.

2. Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.

   • Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.

   • Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. So, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.

3. Check local advisories about the safety of fish caught by family and friends in your local lakes rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week.

Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions.

Additional information on mercury in seafood can be found at the FDA's web site: http://www.cfsan.fda.gov/~dms/admehg.html

For more information on EPA freshwater fish consumption advisories, go to http://www.epa.gov/ost/fish/

2006 Fish Consumption Advisories for PCBs, Dioxin and Mercury

The following advisory table provides statewide, regional, and water body-specific advisory information for various fish species. The table includes PCB, Dioxin and Mercury Advisories. The table lists the recommended fish consumption frequencies for the **General Population** and **High-risk Individuals** for waters statewide and for specific water bodies.

High Risk Individuals: Includes infants, children, *pregnant* women, nursing mothers and women of childbearing age.

General Population: Includes all others not in the high-risk category. PCB advisories for the General Population are presented in meal frequencies (for example: one meal per month *or* four meals per year). This range is based on an estimated 1 in 10,000 risk of cancer during your lifetime from eating fish at the advisory level. This means that one additional cancer may occur in 10,000 people eating fish at the advisory level for a lifetime.

By using this advisory, you have the necessary information to make an informed choice on the number of meals of fish to consume. You can reduce your risk further by eating less than the advisory meal frequency, however, this needs to be balanced with the health benefits of eating fish.

The limits that follow each species assume that no other contaminated fish are being eaten. If you eat more than one species of fish listed in the advisory, the total consumption of fish should not exceed the recommended frequency as a guideline for consumption. The best approach is to use the lowest recommended frequency as a guideline for consumption. **Example: If you fish Union Lake, you can eat four meals of white perch or you can eat one meal of Largemouth Bass over the course of a month, but not both.**

If your specific fishing location is not mentioned within the advisories on the following pages, this does not mean the fish are free of contamination. Not all New Jersey waters or fish species have been tested, and not all fish species were found in all locations, or in some cases available data were insufficient to list a species for a specific water body. **Follow the statewide advisory for the listed species if your fishing area is not mentioned in the guidelines, or follow the statewide advisory of one meal per week for (general Population) or one meal per month (high-risk individuals) for freshwaters.**

2006 FISH CONSUMPTION ADVISORIES

NOTE: 2006 Advisories marked in **Bold** are New or Revised

STATEWIDE FISH CONSUMPTION ADVISORIES

STATEWIDE ESTUARINE & MARINE WATERS

(All coastal waters except those under Waterbody Specific Advisories)

SPECIES	GENERAL POPULATION EAT NO MORE THAN: [2, 3]	HIGH-RISK INDIVIDUAL [1] EAT NO MORE THAN: [2, 3]
STRIPED BASS	One meal per month	Do Not Eat
BLUEFISH (greater than 6 lbs/24 inches)	Four meals per year	
BLUEFISH (less than 6lbs/24 inches)	One meal per month	
AMERICAN EEL	Four meals per year	
AMERICAN LOBSTER	Do Not Eat the Green Gland (a.k.a., Tomalley or Hepatopancreas)	

GENERAL FRESHWATER ADVISORIES:

(For all freshwater fish species & waterbodies not covered by a consumption advisory)

General Population - Eat No More Than One Meal Per Week

High-risk Individual - Eat No More Than One Meal Per Month

STATEWIDE FRESHWATERS

(All freshwaters except PINELANDS REGION and those listed in Waterbody Specific Advisories)

SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUAL EAT NO MORE THAN:
LARGEMOUTH BASS	One meal per week	One meal per month
SMALLMOUTH BASS		
CHAIN PICKEREL		
YELLOW BULLHEAD	No restrictions	
SUNFISH[4]		
BROWN BULLHEAD		One meal per week

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

REGIONAL FRESHWATER ADVISORIES
PINELANDS REGION

(All waters of the Pinelands Region except Waterbody Specific Advisories listed with a "P" notation)

LARGEMOUTH BASS	One meal per month	Do not eat
CHAIN PICKEREL		
BROWN BULLHEAD	One meal per week	
YELLOW BULLHEAD		
SUNFISH[4]		One meal per month

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

ESTUARINE & MARINE WATERS

WATERBODY	SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUALS EAT NO MORE THAN:
NEWARK BAY COMPLEX Including Newark Bay, tidal Hackensack River, Arthur Kill, Kill Van Kull and tidal tributaries.	Blue Crab*	Do not harvest,[5] Do not eat	
	Striped Bass*	**Four meals per year**	Do not eat
	American Eel*	**Do not eat**	
	White Perch		
	White Catfish	One meal per year	
TIDAL PASSAIC RIVER Dundee Dam to Newark Bay and tributaries.	All Fish & Shellfish*	Do not eat	
	Blue Crab*	Do not harvest,[5] Do not eat	
HUDSON RIVER Downstream of NY-NJ border including the Upper New York Bay	Striped Bass*	Four meals per year	Do not eat
	American Eel*	One meal per year	
	White Perch		
	Winter Flounder	**One meal per month**	
	White Catfish	Do not eat	
	Blue Crab	**One meal of 7 crabs per week** Do not eat green gland (hepatopancreas); Discard cooking liquid	

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

ESTUARINE & MARINE WATERS

WATERBODY	SPECIES	GENERAL POPULATION	HIGH-RISK INDIVIDUALS
		EAT NO MORE THAN:	EAT NO MORE THAN:
RARITAN BAY COMPLEX Includes the Raritan Bay, tidal Raritan River (to Rte. 1 bridge) and the tidal portions of all tributaries.	**American Lobster**	**One meal per week** Do not eat green gland (hepatopancreas) **Discard cooking liquid**	
	Weakfish	**One meal per month**	**Do not eat**
	Striped Bass		
	White Perch	**One meal per year**	Do not eat
	Winter Flounder	**One meal per month**	
	Porgy		
	American Eel	One meal per year	Do not eat
	White Catfish	Four meals per year	
	Blue Crab	**One meal of 7 crabs per month** Do not eat green gland (hepatopancreas); Discard cooking liquid	
COASTAL TRIBUTARIES Navesink River, Shrewsbury River, Shark River, Toms River & Mullica River.	**American Eel**	One meal per month	**One meal per month**
LOWER (TIDAL) DELAWARE RIVER Trenton, NJ to PA/DE line, including all tributaries to the head of tide.	Largemouth Bass	No restrictions	One meal per week
	Hybrid Striped Bass		
	American eel	**One meal per year**	**Do not eat**
	Channel Catfish		
	White Catfish	**One meal per month**	
	Striped Bass	Four meals per year	
	White Perch	**Four meals per year**	
DELAWARE RIVER ESTUARY- DE/NJ/PA border to C&D Canal	All finfish	Do not eat	

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

ESTUARINE & MARINE WATERS

WATERBODY	SPECIES	GENERAL POPULATION	HIGH-RISK INDIVIDUALS
		EAT NO MORE THAN:	EAT NO MORE THAN:
DELAWARE ESTUARY & BAY C&D Canal to the mouth of Delaware Bay	**Bluefish (less than 14 inches)**	**One meal per month**	
	Weakfish		
	Bluefish (greater than 14 inches.)	**One meal per year**	**Do not eat**
	Striped Bass	One meal per year	Do not eat
	White perch		
	American eel		
	Channel catfish		
	White catfish		
DELAWARE BAY TRIBUTARIES	American eel	One meal per month	Four meals per year

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

FRESHWATER ADVISORIES

WATERBODY	SPECIES	GENERAL POPULATION	HIGH-RISK INDIVIDUAL
		EAT NO MORE THAN:	EAT NO MORE THAN:
Alycon Lake (Gloucester Co.) (P)	Black Crappie	No restrictions	One meal per month
Assunpink Creek (Mercer/Monmouth Co.)	Largemouth Bass	No restrictions	One meal per week
Atlantic City Reservoir - (Atlantic Co.) (P) No Fishing Allowed	Chain Pickerel	Do not eat	Do not eat
	Largemouth Bass		
	Yellow Perch		
Batsto Lake (Burlington Co.) (P)	Chain Pickerel	One meal per week	Do not eat
	Largemouth Bass		
	Brown Bullhead	No restrictions	One meal per month
	Yellow Bullhead		

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

FRESHWATER ADVISORIES

WATERBODY	SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUAL EAT NO MORE THAN:
Big Timber Creek (Gloucester Co.)	Channel Catfish	No restrictions	One meal per week
	Largemouth Bass		
	White Catfish		
	Brown Bullhead		No restrictions
Boonton Reservoir (Morris Co.)	Largemouth Bass	Four meals per year	Do Not Eat
	Smallmouth Bass		
	Rock Bass	No restriction	One meal per month
	White Catfish	One meal per week	
	Brown Bullhead	No restrictions	No restrictions
Bound Brook (Entire length including New Market Pond & Spring Lake) (Somerset Co.)	All fish species	Do not eat	Do not eat
Branch Brook Park Newark (Essex Co.)	Largemouth Bass	One meal per week	Do not eat
	Common Carp	One meal per month	
	Bluegill	No restrictions	One meal per week
Budd Lake (Morris Co.)	Northern Pike	No restrictions	One meal per week
	White Catfish		
Butterfly Bogs Pond (Ocean Co.) (P)	Chain Pickerel	One meal per week	Do not eat
	Brown Bullhead	No restrictions	One meal per week
Canistear Reservoir (Sussex Co.)	Chain Pickerel	No restrictions	One meal per month
	Yellow Perch		
	Yellow Bullhead		One meal per week
	Bluegill Sunfish		
Carnegie Lake (Mercer Co.)	Largemouth Bass	One meal per week	Do not eat
	Channel Catfish	No restrictions	One meal per month
	White Perch		
	Bluegill Sunfish		No restrictions
Cedar Lake (Cumberland Co.) (P)	Chain Pickerel	One meal per week	Do not eat
	Largemouth Bass		
Clementon Lake (Camden Co.) (P)	Chain Pickerel	One meal per week	One meal per month
	Largemouth Bass		
Clinton Reservoir (Passaic Co.)	Largemouth Bass	One meal per week	Do not eat
	Yellow Bullhead		One meal per month
	Rock Bass	No restrictions	
	White Sucker		
Cooper River, below Evans Pond (Camden Co.)	Common Carp	One meal per month	Do not eat
	Bluegill Sunfish	One meal per week	One meal per month

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

FRESHWATER ADVISORIES

WATERBODY	SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUAL EAT NO MORE THAN:
Cooper River, Hopkins Pond (Camden Co.)	Brown Bullhead	One meal per month	Four meals per year
Cooper River Lake (Camden Co.)	Largemouth Bass	Four meals per year	Do not eat
	Common Carp		
	Brown Bullhead	One meal per week	One meal per month
	Bluegill Sunfish		
Cranbury Lake (Sussex Co)	Hybrid Striped Bass	One meal per week	One meal per month
Crater Lake (Sussex Co.)	Yellow Perch	One meal per week	Do not eat
	Brown Bullhead		One meal per month
Crosswicks Creek (Mercer Co.)	Largemouth Bass	No restrictions	One meal per week
	White Catfish		
Crystal Lake (Burlington Co.)	Largemouth Bass	No restrictions	One meal per month
	Black Crappie		One meal per week
	Brown Bullhead		No restrictions
DeVoe Lake (Middlesex Co.)	Chain Pickerel	No restrictions	One meal per month
	Largemouth Bass		
Delaware & Raritan Canal @ Bound Brook (Somerset Co.)	Channel Catfish	One meal per week	Do not eat
Delaware River Upstream of Watergap (Warren/Sussex Co)	Channel Catfish	No restrictions	One meal per month
	Muskellunge		
	Smallmouth Bass	**One meal per week**	
	White Sucker	**One meal per month**	
Delaware River Watergap to Phillipsburg (Warren Co.)	White Catfish	One meal per week	Do not eat
	Channel Catfish	No restrictions	One meal per month
	Smallmouth Bass		
	Walleye		One meal per week
Delaware River Phillipsburg to Trenton (Hunterdon/Mercer Co.)	**Channel Catfish**	**Four meals per year**	Do not eat
	White Sucker	**One meal per month**	
	Largemouth Bass	No restrictions	One meal per month
	Smallmouth Bass	**One meal per week**	**One meal per month**
	American Eel	**One meal per month**	Do not eat
	Striped Bass	Four meals per year	
Double Trouble Lake (Ocean Co.) (P)	Yellow Bullhead	One meal per month	Do not eat

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

FRESHWATER ADVISORIES

WATERBODY	SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUAL EAT NO MORE THAN:
East Creek Lake (Cape May Co.) (P)	Brown Bullhead	One meal per month	Do not eat
	Yellow Bullhead		
	Yellow Perch		
Echo Lake Reservoir (Passaic Co.)	Largemouth Bass	No restrictions	One meal per month
	Chain Pickerel		
	Bluegill Sunfish		One meal per week
	Yellow Bullhead		
Evans Pond (Camden Co.)	Brown Bullhead	One meal per week	One meal per month
Green Turtle Lake (Passaic Co.)	Chain Pickerel	No restrictions	One meal per week
	Yellow Perch		
Greenwood Lake (Passaic Co.)	Largemouth Bass	No restrictions	One meal per month
	Walleye		
	White Perch		No restrictions
	Bluegill Sunfish		One meal per week
	Yellow Bullhead		
Grovers Mill Pond (Mercer Co.)	Brown Bullhead	One meal per week	One meal per month
	Chain Pickerel	No restrictions	One meal per week
Hainesville Pond (Sussex Co.)	Largemouth Bass	No restrictions	One meal per month
	Chain Pickerel		One meal per week
Harrisville Lake (Burlington Co.) (P)	Mud Sunfish	One meal per month	Do not eat
	Yellow Bullhead		
Lake Carasaljo (Ocean Co.) (P)	Largemouth Bass	One meal per week	Do not eat
	Chain Pickerel		One meal per month
Lake Hopatcong (Morris/Sussex Co.)	Largemouth Bass	No restrictions	One meal per month
Lake Nummy (Cape May Co.) (P)	Chain Pickerel	One meal per week	Do not eat
	Yellow Perch		
	Yellow Bullhead	No restrictions	One meal per month
Lake Tappan (Bergen Co.)	Smallmouth Bass	No restriction	One meal per month
	Largemouth Bass		
	Bluegill Sunfish		No restriction
	Yellow Bullhead		One meal per week
	Common Carp		
Lenape Lake (Atlantic Co.) (P)	Chain Pickerel	One meal per week	Do not eat
Linden Lake (Camden Co) (P)	Largemouth Bass	No restrictions	One meal per month

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

FRESHWATER ADVISORIES

WATERBODY	SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUAL EAT NO MORE THAN:
Little Timber Creek (Camden Co.)	Brown Bullhead	No restrictions	No restrictions
Manasquan Reservoir (Monmouth Co.)	Largemouth Bass	One meal per month	Do not eat
	Black Crappie	One meal per week	One meal per month
	Chain Pickerel	No restrictions	
	Yellow Perch		One meal per week
Maskells Mill Lake (Salem Co.) (P)	Brown Bullhead	One meal per week	One meal per month
	Chain Pickerel		
	Largemouth Bass		
	Black Crappie	No restrictions	
Merrill Creek Reservoir (Warren Co.)	Largemouth Bass	One meal per month	Do not eat
	Smallmouth Bass	One meal per week	
	Lake Trout		
	Yellow Perch	No restrictions	One meal per month
	Black Crappie		One meal per week
	Bluegill Sunfish		
	Brown Bullhead		
Mirror Lake (Burlington Co.) (P)	Largemouth Bass	One meal per week	One meal per month
	Brown Bullhead	No restrictions	One meal per week
Monksville Reservoir (Passaic Co.)	Smallmouth Bass	No restrictions	One meal per month
	Yellow Bullhead		One meal per week
	Bluegill Sunfish		
	Yellow Perch		
	White Perch	One meal per week	Do not eat
	Walleye		
Mountain Lake. (Warren Co)	Largemouth Bass	One meal per week	Do not eat
Mullica River (Burlington/Atlantic Co) (P)	Brown Bullhead	One meal per week	One meal per month
	White Perch		
	White Catfish	No restrictions	
New Brooklyn Lake (Camden Co.) (P)	Chain Pickerel	One meal per week	Do not eat
	Largemouth Bass		One meal per month
	Pumpkinseed Sunfish	No restrictions	
	Black Crappie		
	Yellow Bullhead		One meal per week
Newton Creek, North (Camden Co.)	Brown Bullhead	No restrictions	No restrictions

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

FRESHWATER ADVISORIES

WATERBODY	SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUAL EAT NO MORE THAN:
Newton Creek, South (Camden Co.)	Largemouth Bass	One meal per month	Do not eat
Newton Lake (Camden Co.)	Bluegill Sunfish	One meal per week	One meal per month
	Brown Bullhead		
	Largemouth Bass	One meal per month	Four meals per year
	Common Carp		Do not eat
Oak Ridge Reservoir (Passaic Co.)	Largemouth Bass	One meal per week	Do not eat
	Chain Pickerel	No restrictions	One meal per month
	Brown Bullhead		No restrictions
Oradell Reservoir (Bergen Co.)	Largemouth Bass	No restriction	One meal per month
	Bluegill Sunfish		No restrictions
	Yellow Bullhead		
	Common Carp		
Overpeck Creek (Branch of the Hackensack River; Bergen Co).	Largemouth Bass	Four meals per year	Do not eat
	Common Carp		
	American Eel		
Passaic River: Rt. 280 to confluence of Pompton R. to Two Bridges (Morris/Essex/Passaic Co.)	Redbreast Sunfish	One meal per week	One meal per month
	Northern Pike		
	Common Carp	One meal per month	Do not eat
	Black Crappie	No restrictions	One meal per month
	Yellow Bullhead		One meal per week
	Pumpkinseed Sunfish		
Passaic River: Elmwood Park to Dundee Lake (Passaic/Bergen Co.)	Largemouth Bass	One meal per week	One meal per month
	Yellow Bullhead		
	Brown Bullhead		Four meals per year
	Redbreast Sunfish		
	Common Carp	One meal per month	Do not eat
	Bluegill Sunfish		
	American Eel		
Pennsauken Creek, Forked Landing (Camden Co.)	Common Carp	Four meals per year	Do not eat
	Largemouth Bass	One meal per month	
	Pumpkinseed Sunfish		Four meals per year
	White Catfish		One meal per year
Pompton Lake (Passaic Co.)	Largemouth Bass	One meal per week	Do not eat
	Common Carp	One meal per month	

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

FRESHWATER ADVISORIES

WATERBODY	SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUAL EAT NO MORE THAN:
Pompton River at Lincoln Park (Passaic/Morris Co.)	Largemouth Bass	One meal per week	One meal per month
	Northern Pike		Do not eat
	Rock Bass		
	Redbreast Sunfish		Four meals per year
	Black Crappie	No restrictions	One meal per month
	Yellow Perch		
	Common Carp	Four meals per year	Do not eat
Ramapo River @ Pompton Feeder (Morris Co.) Site formerly listed as Pompton River @ Pequannock R. (Passaic/Morris Co.)	Largemouth Bass	One meal per week	Do not eat
	Smallmouth Bass		
	Yellow Bullhead		
	Rock Bass		
	Pumpkinseed Sunfish		
	Redbreast Sunfish		One meal per month
	Black Crappie		
Raritan River at Neshanic Station (Somerset Co.)	Largemouth Bass	No restrictions	One meal per week
	Smallmouth Bass		
	Redbreast Sunfish		
	Rock Bass		
Raritan River at Millstone River (Somerset Co.)	Channel Catfish	No restrictions	One meal per week
	Brown Bullhead		No restrictions
Rockaway River @ Powerville (Morris Co.)	Largemouth Bass	One meal per week	Do not eat
	Yellow Bullhead	No restrictions	One meal per week
	Bluegill Sunfish		
	Rock Bass		One meal per month
	Chain Pickerel		
Rockaway River at Whippany (Morris Co.)	Largemouth Bass	One meal per week	Do not eat
	Black Crappie	No restrictions	One meal per month
	Bluegill Sunfish		One meal per week
Round Valley Reservoir (Hunterdon Co.)	Largemouth Bass	No restrictions	One meal per month
	Lake Trout		One meal per week
Saw Mill Lake (Sussex Co.)	Northern Pike	No restrictions	One meal per month
	Brown Bullhead		No restrictions
Shadow Lake (Monmouth Co.)	Largemouth Bass	No restrictions	One meal per week

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

FRESHWATER ADVISORIES

WATERBODY	SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUAL EAT NO MORE THAN:
Shepherd Lake (a.k.a. Sheppards Lake) (Passaic Co.)	Largemouth Bass	One meal per week	Do not eat
	Rock Bass	No restrictions	One meal per week
Speedwell Lake (Morris Co.)	Bluegill Sunfish	No restrictions	One meal per week
	Chain Pickerel		
	Common carp		
Splitrock Reservoir (Morris Co.)	Chain Pickerel	No restrictions	One meal per month
	Yellow Perch		One meal per week
	Bluegill Sunfish		
	Brown Bullhead		No restrictions
Spring Lake (Monmouth Co.) (P)	Largemouth Bass	One meal per week	Do not eat
Spruce Run Reservoir (Hunterdon Co.)	Northern Pike	One meal per week	One meal per month
	Hybrid Striped Bass	No restrictions	
Stafford Forge Main Line (Ocean Co.) (P)	Chain Pickerel	One meal per week	Do not eat
Steenykill Lake (Sussex Co.)	Largemouth Bass	No restrictions	One meal per week
Stewart Lake (Camden Co.)	Largemouth Bass	Four meals per year	Four meals per year
	Bluegill Sunfish	One meal per week	One meal per month
	Brown Bullhead		Do not eat
	Common Carp	One meal per month	
Strawbridge Lake (Burlington Co.)	Largemouth Bass	One meal per month	One meal per year
	Bluegill Sunfish		
	Common Carp	Four meals per year	Do not eat
	Brown Bullhead	One meal per week	Four meals per year
Sunset Lake (Cumberland Co.) (P)	Largemouth Bass	One meal per week	One meal per month
Swartswood Lake (Sussex Co.)	Smallmouth Bass	No restrictions	One meal per month
	Chain Pickerel		One meal per week
Union Lake (Cumberland Co.) (P)	White Perch	One meal per week	Do not eat
Wading River (Burlington Co.) (P)	Yellow Bullhead	One meal per month	Do not eat
	Chain Pickerel	One meal per week	
	White Catfish		

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

WATERBODY SPECIFIC FISH CONSUMPTION ADVISORIES

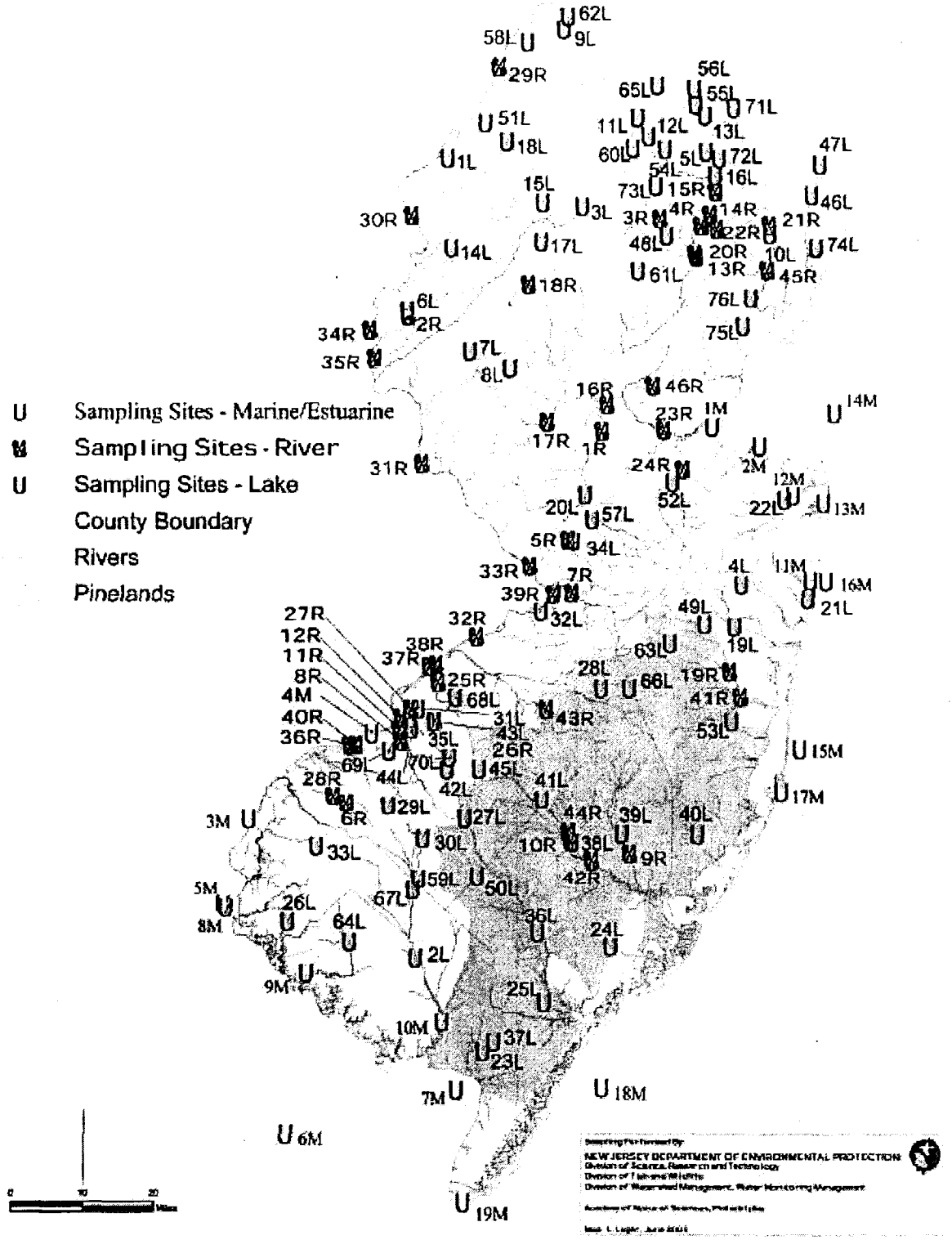
FRESHWATER ADVISORIES

WATERBODY	SPECIES	GENERAL POPULATION EAT NO MORE THAN:	HIGH-RISK INDIVIDUAL EAT NO MORE THAN:
Wanaque Reservoir (Passaic Co.)	Largemouth Bass	One meal per week	Do not eat
	White Perch		
	White Catfish	No restrictions	One meal per month
	Brown Bullhead		No restrictions
	Yellow Bullhead		One meal per week
Wawayanda Lake (Sussex Co.)	Largemouth Bass	One meal per week	Do not eat
	Yellow Bullhead		One meal per month
	Chain Pickerel	No restriction	
Weequahic Lake (Essex Co.)	Largemouth Bass	One meal per month	One meal per month
	Common Carp		Do not eat
	Bluegill	One meal per week	One meal per week
	White Perch	No restrictions	
	Brown Bullhead		No restrictions
Whitesbog Pond (Ocean Co.) (P)	Chain Pickerel	One meal per week	Do not eat
Willow Grove Lake (Cumberland Co.) (P)	Brown Bullhead	No restrictions	One meal per month
Wilson Lake (Gloucester Co.) (P)	Largemouth Bass	One meal per week	Do not eat
	Yellow Perch	One meal per month	
	Chain Pickerel		
	Pumpkinseed Sunfish		
Woodstown Memorial Lake (Salem Co.)	Black Crappie	No restrictions	One meal per month
	Largemouth Bass		

(1)High-risk individuals include infants, children, pregnant women, nursing mothers and women of childbearing age.
(2)One meal is defined as an eight-ounce serving
(3)Eat only the fillet portions of the fish. Use proper trimming techniques to remove fat, and cooking methods that allow juices to drain from the fish (e.g., baking, broiling, frying, grilling, and steaming). See text for full description.
(4)Sunfish includes bluegill, pumpkinseed, and redbreast sunfish.
(5)No harvest means no taking or attempting to take any blue crabs from these waters.
Note: Not all species were found or analyzed in all water bodies, or inadequate data were available to list some species.
(P) = Pinelands Area
* Selling any of these species from designated water bodies is prohibited in New Jersey.

NOTE: To reduce your exposure, eat those fish with the lowest meal restrictions. Do not combine meal restrictions. (For example, If you eat multiple species or catch fish from more than one area, the recommended guidelines for different species and different locations should not be combined.)

New Jersey Fish Tissue Sampling Sites



Lakes

1L	Catfish Pond near Delaware Water Gap
2L	Union Lake
3L	Lake Hopatcong
4L	Manasquan Reservoir
5L	Wanaque Reservoir
6L	Merrill Creek Reservoir
7L	Spruce Run Reservoir
8L	Round Valley Reservoir
9L	Saw Mill Lake
10L	Dundee Lake (Passaic River)
11L	Canistear Reservoir
12L	Clinton Reservoir
13L	Monksville Reservoir
14L	Mountain Lake
15L	Cranberry Lake
16L	Pompton Lake
17L	Budd Lake
18L	Swartswood Lake
19L	Lake Carasaljo
20L	Carnegie Lake
21L	Spring Lake
22L	Shadow Lake
23L	East Creek Lake
24L	Atlantic City Reservoir
25L	Corbin City Impoundment #3
26L	Maskells Mills Lake
27L	New Brooklyn Lake
28L	Mirror Lake
29L	Alcyon Lake
30L	Wilson Lake
31L	Cooper River Park Lake
32L	Crystal Lake
33L	Woodstown Memorial Lake
34L	Assunpink Lake
35L	Newton Lake
36L	Lenape Lake
37L	Lake Nummy
38L	Batsto Lake
39L	Harrisville Lake
40L	Stafford Forge Main Lake
41L	Atsion Lake
42L	Clementon Lake
43L	Evans Pond
44L	Haddon Lake
45L	Marlton Lake
46L	Oradell Reservoir
47L	Tappan Lake
48L	Boonton Reservoir
49L	Butterfly Bogs
50L	Cedar Lake
51L	Crater Lake
52L	De Voe Lake
53L	Double Trouble Lake
54L	Echo Lake

Rivers

1R	Delaware and Raritan Canal
2R	Merrill Creek
3R	Rockaway River
4R	Passaic River - Great Piece
5R	Assunpink Creek
6R	Rancocas Creek
7R	Crosswicks Creek
8R	Big Timber Creek
9R	Wading River
10R	Mullica River
11R	Little Timber Creek
12R	Newton Creek
13R	Passaic River at Hatfield Swamp
14R	Pompton River at Lincoln Park
15R*	Ramapo River at Pompton Feeder
16R	Raritan River at Millstone Creek
17R	Raritan River at Neshanic Station
18R	Raritan River, So. Branch, Clairemont Stretch
19R	Ridgeway Branch of Toms River
20R	Rockaway/Whippany Rivers
21R	Passaic River at Elmwood Park
22R	Passaic River at Pompton
23R	Raritan River Upper at Rt 1
24R	South River at Old Bridge
25R	Pennsauken Creek at Forked Landing
26R	Cooper River at mouth of Evans Pond
27R	Cooper River at Cooper River Lake
28R	Raccoon Creek at mouth near Swedesboro
29R	Delaware River Upstream of Water Gap
30R	Delaware River Phillipsburg to Water Gap
31R	Delaware River at Byram
32R	Delaware River mouth of Neshaminy Creek
33R	Delaware River at Trenton
34R	Delaware River at Easton
35R	Delaware River at Raubsville
36R	Delaware River at Paulsboro
37R	Delaware River at Palmyra
38R	Delaware River at Riverton
39R	Delaware River at Crosswick Creek
40R	Delaware River at Mantua Creek
41R	Toms River
42R	Mullica River between Green Bank and Batsto
43R	Rancocas Tributary between Vincentown/Buddtown
44R	Mullica River from Atsion to Pleasantville
45R	Passaic River at Lyndhurst
46R	Bound Brook

Marine/Estuarine

1M	Raritan River at Rt 35
2M	Raritan Bay Lower at Union Beach
3M	Delaware River at Deepwater
4M	Delaware River at National Park

Lakes

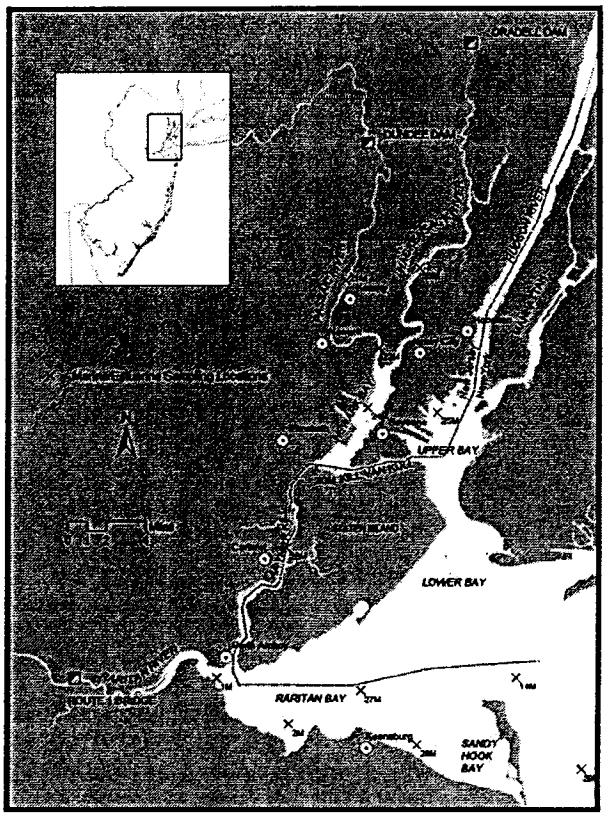
55L Green Turtle Lake
56L Greenwood Lake
57L Grovers Mill Pond
58L Hainsville Pond
59L Malaga Lake
60L Oak Ridge Reservoir
61L Speedwell Lake
62L Steenykill Lake
63L Success Lake
64L Sunset Lake
65L Wawayanda Lake
66L Whitesbog Pond
67L Willow Grove Lake
68L Strawbridge Lake
69L Stewart Lake
70L Linden Lake
71L Sheppard Lake
72L Ramapo Lake
73L Split Rock Reservoir
74L Overpeck Creek Lake
75L Weequahic Lake
76L Branch Brook Park Lake

* Change location name- Ramapo River at Pompton Feeder was listed as Pompton River at Pequannock River.

Marine/Estuarine

5M Delaware Bay at Port Penn
6M Delaware Bay at Bower's Beach, DE
7M Delaware Bay West of Reeds Beach, SE of Thompsons
8M Delaware River/Bay at Reedy Island
9M Cohansey River at Greenwich
10M Maurice River at Mauricetown
11M Shark River at Belmar
12M Navesink River at Fairhaven
13M Shrewsbury River at Oceanport
14M Atlantic Ocean just N of Sandy Hook
15M Atlantic Ocean at Island Beach State Park
16M Atlantic Ocean off Belmar
17M Atlantic Ocean at Barneget Light
18M Atlantic Ocean E of Sea Isle City, S of Ocean City
19M Atlantic Ocean about 1 mile S of Cape May
20M Barnegat Bay at Toms River
21M Passaic River by Kearny
22M Lower Passaic River
23M Hackensack River
24M Newark Bay
25M Upper Bay
26M Arthur Kill
27M Mid-Raritan Bay
28M E. Raritan Bay at Keansburg
29M New York Bight
30M Newark Bay Shooters Island

Northeast New Jersey Waters



The NJDEP and NJDHSS can provide more information on the advisories and the health effects of chemical contaminants in the fish. To stay current with advisory updates and to request additional information, please contact the NJDEP Division of Science, Research and Technology at 1-609-984-6070 or check the website www.FishSmartEatSmartNJ.org or the NJDHSS at 1-609-588-3123.

EXHIBIT E

United States Environmental Protection Agency

Office of Water
4305

EPA-823-F-05-004
September 2005

EPA Fact Sheet

2004 National Listing of Fish Advisories

Summary

Since 1993, EPA has made available to the public its compendium of information on locally issued fish advisories and safe eating guidelines. This information is provided to EPA annually by states, U.S. territories, tribes, and local governments, and EPA makes this information easily accessible to the public every summer on its Web site (http://www.epa.gov/waterscience/fish/). States, U.S. territories, tribes, and local governments issue fish consumption advisories and safe eating guidelines to inform people about the recommended level of consumption for fish caught in local waters. Fish advisories are advice to limit or avoid eating certain fish. Safe eating guidelines are designations of monitored waters where there is no restriction on eating fish. The ***2004 National Listing of Fish Advisories*** *database shows that the number of safe eating guidelines issued continues to rise rapidly. Although states, U.S. territories, tribes, and local governments also continue to issue new fish advisories, most new fish advisories involve mercury and are a result of increased monitoring and assessment rather than increased U.S. releases of mercury. In fact, U.S. mercury emissions have declined by more than 45% since 1990. On March 15, 2005, EPA issued the Clean Air Mercury Rule to permanently cap and reduce mercury emissions from coal-fired power plants.*

The national listing is available on the Internet at http://www.epa.gov/waterscience/fish/.

Background

The states, District of Columbia, U.S. territories, tribes, and local governments (for simplicity, hereafter referred to as states) have primary responsibility for protecting their residents from the health risks of eating contaminated fish caught in local waters. Forty-eight states, the District of Columbia, the U.S. Territory of American Samoa, and three tribes have fish consumption advisories in place. The states have developed their own fish advisory programs over the years, and as a result there is variability among states in the scope and extent of monitoring, in how frequently previously tested waters are sampled again, in how decisions are made to place waters under advisory, and in the specific advice that is provided when contamination is found in fish. Because of this variability, it is difficult to draw national conclusions or to establish national trends in fish advisories; however, through this Technical Fact Sheet, EPA provides an annual summary of fish advisory information submitted by states.

A consumption advisory may include recommendations to limit or avoid eating certain fish and water-dependent wildlife species caught from specific waterbodies or, in some cases, from specific waterbody types (e.g., all lakes) due to contamination by one or more particular contaminants. An advisory may be issued for the general population (i.e., general public), including recreational and subsistence fishers, or it may be issued specifically for sensitive subpopulations, such as pregnant women, nursing mothers, and children. A consumption advisory is not a regulation, but rather a voluntary recommendation issued to help protect public health.

States typically issue five major types of advisories and bans to protect both the general population and specific subpopulations.

- **No-consumption advisory for the general population** – Issued when levels of chemical contamination in fish or wildlife pose a health risk to the general public. The general population is advised to avoid eating certain types of locally caught fish or wildlife.
- **No-consumption advisory for sensitive subpopulations** – Issued when contaminant levels in fish or wildlife pose a health risk to sensitive subpopulations (such as children and pregnant women). Sensitive subpopulations are advised to avoid eating certain types of locally caught fish or wildlife.
- **Restricted-consumption advisory for the general population** – Issued when contaminant levels in fish or wildlife may pose a health risk if too much fish or wildlife is consumed. The general population is advised to limit eating certain types of locally caught fish or wildlife.
- **Restricted-consumption advisory for sensitive subpopulations** – Issued when contaminant levels in fish or wildlife may pose a health risk if too much fish or wildlife is consumed. Sensitive subpopulations are advised to limit eating certain types of locally caught fish or wildlife.
- **Commercial fishing ban** – Issued when high levels of contamination are found in fish caught for commercial purposes. These bans prohibit the commercial harvest and sale of fish and shellfish from a designated waterbody.

In addition to the five major types of advisories, states are increasingly issuing notices of statewide advisories and safe eating guidelines. A statewide advisory is issued to warn the public of the potential human health risks from widespread chemical contamination of certain species of fish from particular types of waterbodies (e.g., lakes, rivers, and/or coastal waters) within the state. An advisory for each waterbody name or type of waterbody may be listed as one advisory, regardless of the number of fish affected or the number of chemical contaminants detected. In contrast, a safe eating guideline is issued to inform the public that fish from specific waterbodies have been tested for chemical contaminants, and the results have shown that specific species of fish from these waters are safe to eat without consumption restrictions. As states increase their monitoring activities, the quantity of available information increases, resulting in better public health protection.

2004 National Listing of Fish Advisories Web Site

The National Listing of Fish Advisories Web site provides information on fish advisories issued by the federal government, all 50 states, the District of Columbia, four U.S. territories, and three tribes. The 2004 National Listing of Fish Advisories Web site lists 3,221 advisories in 48 states, the District of Columbia, 1 territory, and 3 tribes. The Web site includes

- Information on species and size of fish or water-dependent wildlife under advisory
- Chemical contaminants identified in the advisory
- Geographic location of the waterbody
- Lake acreage or river miles under advisory
- Population for whom the advisory was issued
- Meal size and meal frequency (number of meals per week or month) by advisory
- Data on the concentrations of contaminants in fish tissue for 48 states and the District of Columbia
- State and tribal contact information.

The Web site can generate national, regional, and state maps that summarize advisory information. The Web site also includes the names of each state contact, a phone number, a fax number, and an e-mail address.

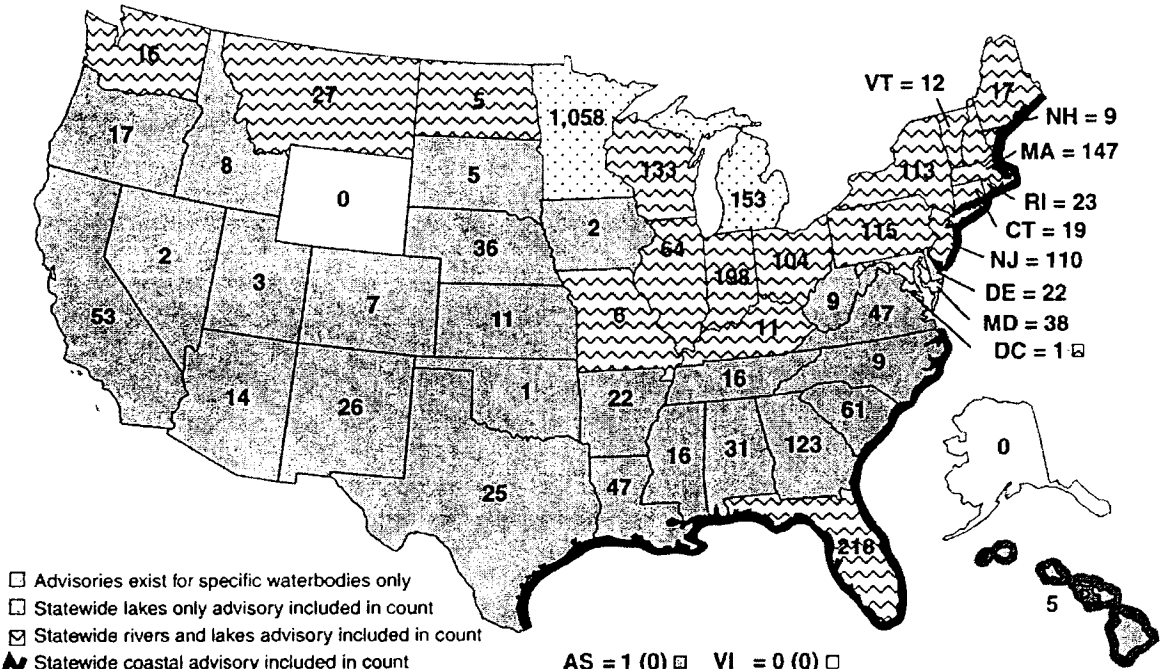
Synopsis of 2004 National Listing of Fish Advisories

In past years, EPA has reported fish advisories based on the number of advisories in effect; however, this does not provide an indication of the geographic extent of the advisory. For example, a waterbody-specific advisory may be issued to cover a single waterbody (e.g., a 20-acre lake), whereas a single statewide lake advisory can cover all lake acres within the state's jurisdiction (up to 12,787,200 acres in one state). Because of the dramatic range in the geographic size of lake acres and river miles affected by a single advisory, the number of advisories does not tell the full story of the geographic extent of waters subject to state advice to limit fish consumption. Thus, EPA is providing information on the total lake acres and total river miles where advisories are currently in effect.

The EPA 2004 National Listing of Fish Advisories indicates that states reported that 395 new fish advisories were issued in 2004 and 65 previous advisories were reactivated, bringing the total number of advisories in effect to 3,221 in 2004 (Figure 1). Currently, the 3,221 advisories in the national listing represent 35% of the nation's total lake acreage and 24% of the nation's total river miles. Approximately 14,285,062 lake acres and 839,441 river miles were under advisory in 2004. This represents less than a 1% increase in the number of lake acres and river miles that were under advisory in 2003, and the lowest percentage increase since the National Listing of Fish Advisories was created in 1993. The percentages of lake acres

Figure 1

Total Number of Fish Consumption Advisories – 2004

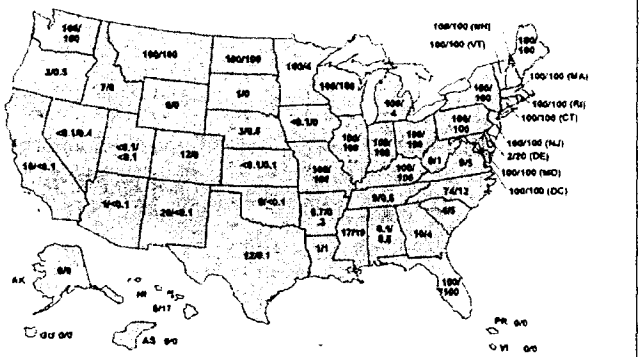


Please note that states may have a different counting method for fish advisories than the national method, so advisory counts in Figure 1 may be slightly different than those reported by individual states.

nd river miles under advisory in each state in 2004 are shown ı Figure 2. All (100%) of the Great Lakes and their connecting /aters were under advisory in 2004 (Table 1). The Great Lakes nd their connecting waters are considered separately from ıther waters and are not included in the above calculations of ɔtal lake acres or river miles.

Figure 2

Percentage of Lake Acres/River Miles Currently Under Advisory



In 2004, approximately 35% of the nation's lake acres and 24% of the nation's river miles were under fish consumption advisories.

Table 1. Fish Advisories Issued for the Great Lakes

Great Lakes	PCBs	Dioxins	Mercury	Chlordane	Mirex	DDT
Lake Superior	●	●	●	●		
Lake Michigan	●	●	●	●		●
Lake Huron	●	●	●	●		
Lake Erie	●	●	●			
Lake Ontario	●	●			●	

The number of lake acres and river miles under advisory is related to the number of assessments of chemical contaminants in fish and water-dependent wildlife tissues, as well as the states' use of statewide advisories.

A statewide advisory is issued to warn the public of the potential for contamination of specific species of fish or water-dependent wildlife (e.g., turtles or waterfowl) in certain types of waterbodies (e.g., lakes, rivers, or coastal waters) across the state. Thirty-one states had statewide advisories in effect in 2004, the same number as in 2003 (Table 2). Indiana reported a new statewide advisory for lakes in 2004.

In addition to the Great Lakes, other large lakes and estuaries are currently under advisory for a variety of contaminants. For example, the main stem of the Chesapeake Bay is under advisory for the first time. The Potomac, James, Back, Anacostia, Piankatank, and Patapsco rivers that connect to the Chesapeake Bay continue to be under advisory. Baltimore Harbor, which also connects to the Chesapeake Bay, is under advisory for chlordane and PCB contamination in fish and blue crabs.

Fifteen states have issued fish advisories for all of their coastal waters (Table 2). Almost 65% of the coastline of the United States (excluding Alaska, which has no advisories) currently is under advisory. Based on coastal size estimates from the National Oceanic and Atmospheric Administration, 92% of the Atlantic coast and 100% of the Gulf coast were under advisory in 2004 as was the case in 2003. The Atlantic coast advisories have been issued for a wide variety of chemical contaminants, including mercury, PCBs, dioxins, and cadmium. All of the Gulf coast advisories have been issued for mercury. No Pacific coast state has issued a statewide advisory for any of its coastal waters, although several local areas along the Pacific coast are under advisory. Hawaii has a statewide advisory in affect for mercury in several marine fish species.

Table 2. Summary of Statewide Advisories by Waterbody Type and Year Issued

State	Lake	Issued	River	Issued	Coastal Waters	Issued
Alabama					Mercury	1996
Connecticut	Mercury	1996	Mercury	1996	PCBs	1993
Dist. of Columbia	PCBs	1993	PCBs	1993		
Florida	Mercury	2002	Mercury	2002	Mercury	1993
Georgia					Mercury	2000
Hawaii					Mercury*	2003
Illinois	Mercury	2002	Mercury	2002		
Indiana	Mercury	2004	Mercury PCBs	1996		
Kentucky	Mercury	2000	Mercury	2000		
Louisiana					Mercury	1997
Maine	Mercury	1994	Mercury	1994	Dioxins Mercury PCBs	1994
Maryland	Mercury	2001	Mercury	2004		
Massachusetts	Mercury	1996	Mercury	1996	PCBs Mercury	1994
Michigan	Mercury	1993				
Minnesota	Mercury PCBs	1999				
Mississippi					Mercury	1998
Missouri	Mercury	2001	Mercury	2001		
Montana	Mercury	2003	Mercury	2003		
New Hampshire	Mercury	1995	Mercury	1995	PCBs Mercury Dioxin	1994
New Jersey	Mercury	1995	Mercury	1995	PCBs Dioxins	1993
New York	PCBs Chlordane Mirex DDT	1994	PCBs Chlordane Mirex DDT	1994	Cadmium Dioxins PCBs	1995
North Carolina					Mercury	2000
North Dakota	Mercury	2001	Mercury	2001		
Ohio	Mercury	1997	Mercury	1997		
Pennsylvania	Mercury	2001	Mercury	2001		
Rhode Island	Mercury	2002	Mercury	2002	PCBs Mercury	1993
South Carolina					Mercury	2001
Texas					Mercury	1997
Vermont	Mercury	1995	Mercury	1995		
Washington	Mercury	2003	Mercury	2003		
Wisconsin	Mercury	2000	Mercury	2000		

* Hawaii has a statewide advisory for mercury in marine fish.

Safe Eating Guidelines

EPA has been encouraging states to issue safe eating guidelines when providing advisory information. In addition to issuing statewide advisories warning the public about chemical contaminants in fish tissue, states are increasingly issuing safe eating guidelines to inform the public that fish from specific waterbodies or certain species of fish have been tested for chemical contaminants and have been shown to contain very low levels of contaminants. By issuing safe eating guidelines, the states are identifying monitored waters or species for the public where no restrictions on eating fish apply, as well as promoting enjoyment of recreational fishing.

In 1993, the first year that the National Listing of Fish Advisories collected data on safe eating guidelines, there were only 20 such guidelines in effect. This number increased very slowly until 2004, when Arkansas, Georgia, and Minnesota reported 827 new safe eating guidelines, increasing the total number of safe eating guidelines to 1,213 in 2004. This 2004 increase represented almost half of all safe eating guidelines issued since 1993. Table 3 shows the trend in the issuance of safe eating guidelines since 1993. As of December 31, 2004, 17 states have issued safe eating guidelines. No tribes have issued safe eating guidelines. The largest numbers of such guidelines have been issued by Minnesota (835), Georgia (159), South Carolina (75), and Texas (45). Three states have issued statewide guidelines. In 2001, Alaska issued a statewide guideline to inform the public that all of Alaska's fish are safe to eat without restrictions. In 2002, Wisconsin issued a safe eating guideline for bluegill and other sunfish, yellow perch, white and black crappie, and bullheads in all lakes statewide. Minnesota issued a similar guideline for panfish in all lakes statewide. There are a few waterbody-specific exceptions to the safe eating guidelines, so consumers are advised to review waterbody-specific information on state Web sites.

Table 3. Total Safe Eating Guidelines Issued Since 1993

Year Issued	New Advisories	Cumulative Advisories
1993	20	20
1994	12	32
1995	35	67
1996	10	77
1997	2	79
1998	25	104
1999	44	148
2000	7	155
2001	20	175
2002	164	339
2003	47	386
2004	827	1,213

In 2004, 2.4% of river miles and 18% of lake acres in the continental United States had safe eating guidelines for at least one fish species. Approximately 76,069 river miles and 5,047,921 lake acres had safe eating guidelines in 2004. Between 2003 and 2004 the area for which there were safe eating guidelines increased by 9,530 river miles and 3,808,605 lake acres. In addition, the number of these guidelines is likely to grow as more states identify safe fishing waters or species (e.g., sunfish and other panfish) that do not tend to accumulate chemical contaminants in their tissues to the same extent as long-lived predatory species (e.g., largemouth bass, walleye, northern pike, catfish). These guidelines will help direct the public toward making more informed decisions about the waterbodies in which they fish, as well as healthier choices about the species that they choose to eat.

Bioaccumulative Contaminants

Bioaccumulative chemical contaminants accumulate in the tissues of aquatic organisms at concentrations many times higher than concentrations in the water. Bioaccumulative chemical contaminants can persist for relatively long periods in sediments, where bottom-dwelling organisms that are low in the food chain can accumulate them and pass them up the food chain to fish. Concentrations of bioaccumulative contaminants in the tissues of aquatic organisms may increase at each level of the food chain. As a result, top predators in a food chain, such as largemouth bass or walleye, may have concentrations of bioaccumulative contaminants in their tissues a million times higher than the concentrations found in the waterbodies.

Although there are advisories in the United States for 36 chemical contaminants, almost 98% of advisories in effect in 2004 involved five bioaccumulative chemical contaminants: mercury, PCBs, chlordane, dioxins, and DDT. In this regard, considerable progress has been made towards reducing the occurrence of these contaminants in the environment. US human-caused emissions of mercury to the air have declined more than 45% since 1990 and EPA has issued regulations that will result in further reduction of mercury emissions. For example, on March 15, 2005, EPA issued the Clean Air Mercury Rule (CAMR) to permanently cap and reduce mercury emissions from coal-fired power plants. CAMR supplements EPA's Clean Air Interstate Rule (CAIR) to significantly reduce emissions from coal-fired power plants. When fully implemented, these rules are estimated to reduce utility emissions of mercury nearly 70 percent. In addition, production of PCBs for use ceased in 1977; chlordane was banned in 1988; DDT was banned in 1972; and known and quantifiable industrial emissions of dioxin in the United States are estimated to have been reduced by approximately 90% from 1987 levels.

Mercury

The total number of advisories for mercury increased from 2,362 in 2003 to 2,436 in 2004, with 44 states, 1 territory, and 2 tribes issuing mercury advisories. Seventy-six percent of all advisories have been issued, at least in part, because of mercury. The increase in the number of mercury advisories in 2004 can be attributed to the issuance of new mercury advisories by 20 states and 1 tribe. Most of these new advisories were issued by Florida and Minnesota. To date, 44 states, 2 tribes and 1 territory have issued mercury advisories. Alaska, District of Columbia, Iowa, Kansas, Oklahoma, Utah, and Wyoming did not issue advisories in either 2003 or 2004. In 2004, the Cheyenne River Sioux Tribe was the only state or tribe to issue a mercury advisory for the first time.

A total of 13,183,748 lake acres and 765,399 river miles were under advisory for mercury in 2004. This represents a decrease of 1,467 river miles under advisory between 2003 and 2004. The decrease is a result of changes in waterbody-specific mercury advisories in several states. The total number of river miles under advisory decreased in Minnesota, Michigan, Louisiana, Nebraska, and Georgia, as well as other states. The number of lake acres under advisory in 2004 represents an increase of 114,758 lake acres between 2003 and 2004. The increase is a result of changes to waterbody-specific advisories in several states as well as the addition of Indiana's statewide advisory for lakes.

Currently, 21 states (Connecticut, Florida, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, New Hampshire, New Jersey, North Dakota, Ohio, Pennsylvania, Rhode Island, Vermont, Washington, and Wisconsin) have issued statewide advisories for mercury in freshwater lakes and/or rivers. Twelve states (Alabama, Florida, Georgia, Louisiana, Maine, Massachusetts, Mississippi, New Hampshire, North Carolina, Rhode Island, South Carolina, and Texas) have statewide advisories for mercury in their coastal waters. Hawaii has a statewide advisory for mercury in marine fish. The Micmac tribe of Maine has two tribal statewide advisories in effect for mercury in freshwater and marine fish (including lobster). In addition, the Cheyenne River Sioux Tribe has one tribal statewide for mercury in rivers, lakes, and stock ponds.

PCBs

In 2004, there were 873 advisories in place for PCBs, with 39 states, American Samoa, and the St. Regis Mohawk Tribe reporting PCB advisories in 2004. This represents a decrease in the number of PCB advisories since 2003 when there were 884 PCB advisories. Although 17 states added new advisories for PCBs in 2004, 55 advisories were rescinded. There were 4,652,401 lake acres and 110,522 river miles under PCB advisory in 2004. Four states (District of Columbia, Indiana, Minnesota, and New York) issued statewide freshwater (river and/or lake) advisories for PCBs, and seven other states (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, and Rhode Island) issued PCB advisories for all of their coastal marine waters in 2004.

Chlordane

Many advisories for the pesticide chlordane have been rescinded in recent years, primarily because all uses of chlordane were banned in the United States in 1988 and the compound continues to degrade in the environment. In 2003, there were 89 chlordane advisories. In 2004, that number decreased to 79 chlordane advisories. Chlordane advisories covered 847,242 lake acres and 54,132 river miles in 2004.

Dioxins

In 2003 there were 90 existing dioxin advisories. In 2004, Massachusetts issued 5 new dioxin advisories; Hawaii issued 1 new dioxin advisory; Maine added dioxin to 7 existing advisories for other contaminants; and Michigan, New Hampshire, New Jersey, Oregon, and Texas also added dioxin to existing advisories, bringing the total number of dioxin advisories to 106.

A total of 22,757 lake acres and 2,335 river miles were under a dioxin advisory in 2004. Although dioxins are one of the five major contaminants that have resulted in the issuance of health advisories, the geographic extent of dioxin advisories is extremely limited compared to that for the other four major contaminants. This is due in part to the limited monitoring of dioxins resulting from the high cost of contaminant analysis. Also, dioxins have been associated primarily with specific locations near some pulp and paper plants that use a bleach kraft process, as well as with other types of chemical manufacturing facilities or incineration facilities.

DDT

Although the use of DDT, an organochlorine pesticide, has been banned since 1975, there were 67 advisories in effect for DDT (and its degradation products, DDE and DDD) in 2004. In 2003 there were 52 advisories in effect. There are currently 843,762 lake acres and 69,010 river miles under advisory for DDT. California had the greatest number of DDT advisories in effect in 2004 (14), followed by Maine (13) and Massachusetts (10). During 2004, Massachusetts issued 10 new advisories for DDT, and New York had an existing statewide advisory for multiple contaminants, including DDT.

Other Contaminants

Although the five bioaccumulative contaminants account for almost 98% of the total number of advisories, the remaining 2% of all fish advisories are caused by other contaminants. These include heavy metals (e.g., arsenic, cadmium, chromium, copper, lead, selenium, and zinc) and organochlorine pesticides (e.g., dieldrin, heptachlor epoxide, kepone, mirex, and toxaphene), as well as a myriad of other chemical compounds, including creosote, polycyclic aromatic hydrocarbons (PAHs), hexachlorobenzene, pentachlorophenol, and diethylphthalate.

In 2004, eight states issued new advisories for these contaminants: Delaware (not specified), Georgia (toxaphene), Indiana (not specified), Massachusetts (pesticides), Maryland (chlorinated pesticides), New York (mirex), Ohio (mirex), and Utah (arsenic). Washington also added diethylphthalate to an existing advisory. In contrast, other states rescinded advisories for aldrin, dichloroethane, gasoline, lindane, trichloroethane, and vinyl chloride.

Although these other chemical contaminants represent only 2% of the total number of advisories, the extent of the area under advisory for these contaminants slightly exceeds the lake acres and river miles under advisory for DDT. In 2004, 2,176,525 lake acres and 102,938 river miles were under advisories for these contaminants. The majority of lake acres and river miles under advisory for other chemical contaminants are the result of a statewide advisory in New York for multiple contaminants, including mirex, a regional advisory in Mississippi for toxaphene, and a statewide advisory in Maine for cadmium.

Wildlife Advisories

In addition to advisories for fish and shellfish, the National Listing of Fish Advisories Web site also contains several water-dependent wildlife advisories. In 2004, no new advisories were issued for water-dependent wildlife. States have issued advisories in previous years that are still in effect. Four states have issued consumption advisories for turtles: Massachusetts (1), Minnesota (6), New York (statewide advisory), and Rhode Island (1). In addition, Massachusetts has an advisory for frogs; New York has a statewide advisory for waterfowl; Utah has an advisory for American coot and ducks; and Maine issued a statewide advisory for cadmium in moose liver and kidneys.

National Advice Concerning Mercury in Fish

In 2004, EPA and the U.S. Food and Drug Administration (FDA) issued advice for women who might become pregnant, women who are pregnant, nursing mothers, and young children. The national advice is not included in the statistics presented in this fact sheet. The following advice is still in effect:

Fish and shellfish are an important part of a healthy diet. Fish and shellfish contain high-quality protein and other essential nutrients, are low in saturated fat, and contain omega-3 fatty acids. A well-balanced diet that includes a variety of fish and shellfish can contribute to heart health and children's proper growth and development; therefore, women and young children in particular should include fish or shellfish in their diets due to the many nutritional benefits.

Nearly all fish and shellfish, however, contain traces of mercury. For most people, the risk from mercury from eating fish and shellfish is not a health concern. Yet some fish and shellfish

contain higher levels of mercury that may harm an unborn baby or young child's developing nervous system. The risks from mercury in fish and shellfish depend on the amount of fish and shellfish eaten and the levels of mercury in the fish and shellfish. Therefore, the FDA and EPA are advising women who may become pregnant, pregnant women, nursing mothers, and young children to avoid some types of fish and to only eat fish and shellfish that are lower in mercury.

By following the three recommendations listed below for selecting and eating fish or shellfish, women and young children will receive the benefits of eating fish and shellfish and be confident that they have reduced their exposure to the harmful effects of mercury.

- Do not eat shark, swordfish, king mackerel, or tilefish because they contain high levels of mercury.
- Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.
  - Five of the most commonly consumed fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.
  - Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. Eat up to 6 ounces (one average meal) of albacore tuna per week.
- Check local advisories about the safety of fish caught by family and friends in local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish caught from local waters, but do not consume any other fish during that week.

Follow these same recommendations when including fish and shellfish in a young child's diet, but serve smaller portions. More information on the joint federal advisory is available at www.epa.gov/waterscience/fish.

For More Information

For more information on specific advisories within a state, contact the appropriate state agency listed on the National Listing of Fish Advisories Web site at www.epa.gov/waterscience/fish. This is particularly important for advisories that recommend that consumers restrict their consumption of fish from certain waterbodies. For restricted consumption advisories, state health departments provide specific information on the meal size and meal frequency (number of meals per week or month) that is considered safe to eat.

For more information on how to reduce exposure, consult EPA's brochure *What You Need to Know About Mercury in Fish and Shellfish*, available in several languages on EPA's fish advisory Web site: www.epa.gov/waterscience/fish.

For more information on the National Fish and Wildlife Contamination Program, contact:

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EXHIBIT F

Chapter 11 - IMPACT OF MERCURY ON TOURISM AND RECREATION IN NJ

A. Introduction

The Task Force was charged to identify the impact of mercury on tourism and recreation in NJ. This is a sizeable task considering the popularity of fishing and the importance of fish as a vector of mercury. Mercury, or any other pollutant, might have a direct impact on a resource by,
1) rendering it unusable, 2) rendering it inaccessible through regulatory restrictions, 3) adherence to advisories reducing fishing or fish consumption, or 4) accurately or inaccurately altering the public's perception of the acceptability of the resource. However, the fact that NJ has taken an aggressive position about issuing fish consumption advisories may also inspire confidence among fishermen and fish consumers.

B. Data and trends in freshwater and marine fishing in NJ

1. Introduction

Freshwater and saltwater fishing are very popular in NJ and contribute substantially to the economy, particularly along the shore. During the past twenty years there have been two countervailing public messages regarding fish consumption emphasizing benefits and risks. The health benefits of fish consumption have generally been emphasized, while issues concerning contaminants in fish have only attracted attention sporadically. There was, however, a great increase in attention to contaminants in fish from November 2000-January 2001 when mercury and related risks from fish consumption were featured on prime time TV news stories.

If people are influenced by such information in deciding whether or not to go fishing, one might expect to see an impact of the information reflected in either an increase or decrease in the number of people fishing in NJ. Several studies cited in the section on Advisories (Vol. II Chapter 9) emphasize that many fisherfolk are unaware of advisories or choose to ignore them. Such data, however, do not identify would-be fishers who chose not to go fishing because of health concerns.

People could react to fish consumption advisories and other information regarding the hazard posed by elevated mercury levels in fish by:
- Remaining unaware
- Being aware but ignoring such information
- Reaching a decision that it is not a problem for them
- Reducing or changing their consumption patterns
- Continuing to fish but catch and release
- Stopping fishing

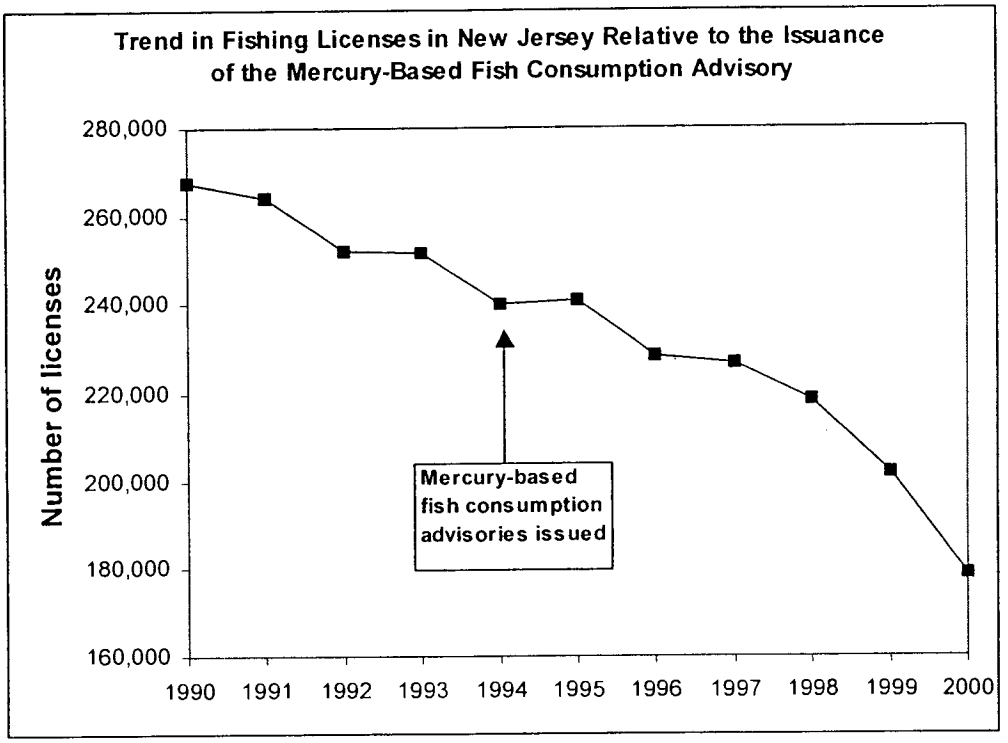
2. *Trends in Fishing Licenses and Fishing Statistics*

a. Freshwater Licenses

For those people for whom fishing is a long-term hobby it is not likely that they would stop fishing solely on the basis of advisories or word-of-mouth information. On the other hand, novices might choose other hobbies.

To assess the impact of advisories pertaining to freshwater fish on freshwater fishing, the Task Force obtained information on the issuance of resident fishing licenses (freshwater only) for the period 1990-1997 from the NJDEP Division of Fish and Wildlife. At the beginning of the period there were more than a quarter million licenses issued annually (Figure 2.9), but this number has declined to just over 200,000. The decline was already evident by 1991. The arrow shows the time when advisories were issued in 1994. Although the decline in licenses continued, there is no evidence that it was accelerated by the advisories.

Figure 2.9. Trend in Fishing Licenses in New Jersey Relative to the Issuance of the Mercury-Based Fish Consumption Advisory.



Saltwater fishing contributes about $2 billion annually to the NJ economy, with about 75% coming from recreational fishing. With an estimated 841,000 saltwater anglers, NJ ranks 4th in the nation.

b. Saltwater Fishing Statistics

The NJDEP Bureau of Marine Fisheries provided the Task Force data from the National Marine Fisheries Service, which conducts a variety of surveys on coastal fishing activities. The statistics show a big dip in the number of fishers between 1990 and 1992, and then an increase with a peak in 1994, followed by another decline. It is possible that this second decline which coincided approximately with the issuance of the advisories was related to mercury, even though the advisories were specifically for freshwater fish, and not for saltwater fish. The number of person-days fishing did not show any consistent trend and was essentially flat across the period.

c. Official Opinions

The Task Force sought opinions from several officials who would be likely to know of an impact of advisories on fishing. The following offered their opinions:

Gilbert H. Ewing Jr., Chair, NJ Marine Fisheries Council, August 1999,
"The Council is not aware of any documented information regarding the changes in fishermen behavior as a result of concern for mercury pollution."

Robert Soldwedel, NJDEP, Chief, Bureau of Freshwater Fisheries, August 1999.
"It is a fact that there has been a continual downward trend in the sale of fishing licenses in NJ, as well as in most of the other states throughout the country. However, it is extremely doubtful that this decline could be tied into the issue of mercury-based fish consumption advisories. ...."

"Fishermen surveys invariably conclude that very few people are interested in taking fish home to eat. Most of the more dedicated fishermen and those in fishing organizations such as the BASS Federation, Trout Unlimited and Muskies Inc wouldn't even consider keeping a fish regardless of its size, because they recognize that it's in the best interest of their future fishing to release all that they catch. Creel censuses have found catch and release rates as high as 95% for Largemouth Bass and Chain Pickerel. ..."

"It has been our perception that the fish consumption advisories for mercury have little impact."

The above statement regarding catch-and-release refers mainly to fresh water fishing, since interviews of estuarine and coastal fishermen in the Arthur Kill, Raritan Bay, and north Jersey shore, indicated that 61% of 119 people fishing from shore and 94% of those fishing from boats, responded yes to "do you eat fish you catch" (May and Burger 1996).

3. Boat Captain Survey

Although subsistence fishing has been examined extensively, relatively little attention has focused on organized recreational fishing, such as party and charter boats. Yet, in many coastal states, these boats play a major role in recreational fishing, particularly for estuarine and marine fish. For saltwater fish, NJ issues advisories based on PCBs, not on mercury. However, to determine whether the information on mercury toxicity and the advisories might have affected recreational fisheries, a study led by Dr. Joanna Burger of Rutgers University (in collaboration with NJDEP Division of Science, Research and Technology staff) interviewed fishing boat captains on their views (Burger et al., 2001). It must be stressed that this study obtained opinions, and did not try to determine the accuracy of these captains' opinions.

The interviews of NJ party and charter boat captains asked about (1) knowledge about consumption advisories; (2) current and potential communications about advisories to clients; and (3) perception of whether advisories affect fishing. Additional information collected from boat captains during the interviews (frequency and nature of fishing activities, etc.) appears in a separate report (Burger et al., 2001).

From March through May 2000, 93 captains were interviewed by telephone. This was 40% of the 231 registered boat captains in NJ. Another 40% could not be contacted. All but eight of the remainder was willing to participate, but could not arrange a mutually convenient time to be interviewed before their intense fishing season started at the end of May. Of the respondents, 55% were full-time boat captains. The main fish sought were Flounder/Fluke, Bluefish, Striped Bass, Weakfish, and Tuna. Only a small percentage of trips were for Swordfish and Shark, predatory species that are likely to have high mercury levels.

The vast majority (94%) of respondents said they had heard about fish consumption advisories, but their knowledge of these was mixed. Of the 82 captains who said what they had heard about health warnings on fish, 35% mentioned PCBs (13% linked the contaminant to Striped Bass, particularly in the Hudson River. Bluefish also were often mentioned as contaminated with PCBs); 29% mentioned mercury. Several captains erroneously cited particular contaminants or affected species, or mentioned erroneous problems (e.g., lesions on fish) and solutions (e.g., proper preparation or storage removes contamination). Only six captains cited limits on the amount of certain species that one should eat. Surprisingly, about 23% had not heard of the *NJ Fish and Wildlife Digest*, which is the DEP's primary means of conveying information about advisories to anglers.

As for current communications, only 12% of captains said that they currently posted advisories. Some 82% of captains said that customers were aware of advisories, but many fewer thought customers were aware of the actual content of the advisories (e.g., only 20% thought customers were aware of mercury advice). About half said customers had asked about the safety of fish (9% often, 40% sometimes).

The responses captains reported providing to these customers were diverse. Eight of the captains mentioned specific species to avoid, usually Bluefish and Striped Bass. Others mentioned general guidelines (e.g., it "depends on the species," "size of the fish", or the "amount one eats") or categories. Some answers were conflicting, such as (avoid or eat only "bottom feeders"). Nine captains gave advice on how to prepare fish to avoid problems (e.g., "don't eat the dark meat," "always remove the blood line," "filet and skin") which is accurate for dealing with PCBs, but not mercury. Two captains said this is a problem only if one fishes in other than "clean" water, although water column pollution is not the primary source of fish contamination, and many contaminated fish migrate. Some 19% of all boat captains interviewed said there was no problem with fish safety at all. About a third (37%) of the boat captains said they would post consumption warnings if they were provided by the State; another 21% were not sure, with most of the latter saying it would depend on the advisories' content and presentation. Captains who felt public health warnings had affected their business were not less likely to say they would post advisories than other captains.

Boat captains were asked to rate the importance of various factors in the quality of their fishing seasons. Fishing management regulations, the strength of the overall economy, fishing success of clients, and business costs were all cited by 80% or more captains. Competition from commercial fishing boats and the declining size of available fish were cited by over two-thirds. Some 47% of captains cited "public health advice/warnings about saltwater fish contaminants" as a strong or moderate factors in the quality of their fishing season, ranking it seventh (of 13

factors) in importance. Just under a third (31%) felt advisories affected business strongly. About 36% of the captains reported that former customers had decided to stop fishing, but advisories were not reported as among the reasons given.

Captains who took more trips for Bluefish, Fluke, Sea Bass, and Thresher Shark were somewhat more likely to think that advisories affected their business than did those who did not seek these species very often. Bluefish is the only one of these species that is subject to advisories, in this case for PCBs, and this species has a moderately elevated concentration of mercury. There were no differences for those who took trips for Swordfish, Marlin, Stripped Bass, Tuna, or other Shark species, all species with moderate to high mercury values. Captains who felt advisories were affecting their businesses worked closer to areas (e.g., Raritan Bay Complex and New York Harbor) subject to PCB advisories than did other captains, and were more prone to respond that management regulations (e.g., size, limits, seasons) and marketing and advertising by the industry or State were strong influences on the success of their seasons.

C. Summary and Conclusions: Impact of Mercury on Tourism and Recreation in NJ

Many social and economic factors affect the popularity of any recreational activity. The Task Force found no clear evidence that the issuance of fish advisories or the rising public concern about mercury have had a major influence on freshwater or saltwater fishing. Although the number of fishing licenses has declined, the decline did not coincide with the issuance of advisories. Although concerns over PCBs (through saltwater advisories) may have impacted fishing, these advisories were not based on mercury.

About a third of party and charter boat captains, particularly in northern NJ, reported that advisories did hurt their business to a greater or lesser degree. The Boat Captain Survey was not able to evaluate the accuracy of these reports. Reporting that advisories affected business, however, was consistent mainly for those captains who fished for Bluefish, in the waters of the northern part of the state. It is notable that although bluefish have moderately elevated levels of mercury, there is no mercury-based advisory for Bluefish. There are, however, PCB-based advisories for Bluefish in the waters of northern NJ (i.e., the Harbor Estuary). Furthermore, captains who fished for species with more elevated levels of mercury, species which have been highlighted in the press as posing a potential health hazard (i.e., Shark, Tuna), did tend to identify advisories as affecting their business. This survey cannot rule out a small impact from fish consumption advisories in general on the recreational fishing industry in NJ. It seems unlikely that mercury-based advisories in particular have any major impact on the industry. These results indicate that fish advisories may have had a modest impact on the popularity of saltwater fishing in NJ. However, the incomplete information reported by captains suggests that an outreach campaign to boat captains and improved media reporting should provide accurate information, and should include the brochures already published by NJDEP. This campaign may increase the popularity of catch-and-release activities.

D. Recommendations

Advisories should be timely, requiring periodic monitoring of mercury levels in different kinds of fish that are sought by recreational fishers.

Boat captains should be encouraged to post advisories relevant to their fishing activities and should be provided with advisory handouts that present balanced information.

ACRONYMS

μg	microgram
ACGIH	American Conference of Governmental Industrial Hygienists
ASMN	Ambient Stream Monitoring Network
ATSDR	Agency for Toxicology and Disease Registry
AVS	Acid volatile sulfide
BBEP	Barnegat Bay Estuary Program
BSDW	Bureau of Safe Drinking Water
CF	Concentration Factor
CSFII	Continuing Survey of Food Intake by Individuals
CWS	Community Water Systems
DELEP	Delaware Estuary Program
DFW	Division of Fish and Wildlife
DSRT	Division of Science, Research and Technology
ER-M	Effects Range-Medium
GIS	Geographical Information System
GSI	Gonadsomatic Index
HEP	Harbor Estuary Program
HQ	Hazard Quotient
Kg	Kilogram
LOAEL	Lowest-observed-adverse-effect-level
LSI	Liversomatic Index
MCL	Maximum Contaminant Level
MeHg	Methylmercury
MRL	Minimum Risk Level
NAWQA	National Water Quality Assessment
NERP	National Environmental Research Parks
NESCAUM	Northeast States for Coordinated Air Use Management
NEWMOA	Northeast Waste Management Officials' Association
NFTDR	National Fish Tissue Data Repository
ng	Nanogram
NHANES	National Health and Nutrition Examination Survey
NJADN	NJ Atmospheric Deposition Network
NJDEP	NJ Department of Environmental Protection
NJDHSS	NJ Department of Health and Senior Services
NJDOH	NJ Department of Health
NJHDG	NJ Harbor Dischargers Group
NJMSC	NJ Marine Sciences Consortium
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-observed-adverse-effect-level
NPL	National Priorities List
NRC	National Research Council
NSCRF	National Study of Chemical Residue
ODES	Ocean Data Evaluation System
PCBs	Polychlorinated biphenyls
PLW	Pompton Lakes Works
PMA	Phenyl mercuric acetate
POET	Point-of-entry-treatment

ppb	Part per billion
ppm	Part per million
ppt	Part per trillion
RELMAP	Regional Langranian Model Air Pollution
R-EMAP	Regional Environmental Monitoring & Assessment Project
RfC	Reference Concentration
RfD	Reference Dose
TEAM	Trace Element Analysis Model
TSC	Tissue Screening Concentrations
US E.P.A.	US Environmental Protection Agency
USFDA	US Federal Drug Administration
USFWS	US Fish and Wildlife Service
USGS	United States Geological Survey
WHO	World Health Organization
WQC	Water Quality Criterion
WQS	Water Quality Standard

REFERENCES AND BIBLIOGRAPHY

Abbasi, S.A., and R. Soni (1983) Stress-induced enhancement of reproduction in earthworms, Octochaetus pattoni, exposed to chromium (VI) and mercury (II) - implications in environmental Management. Int. J. Environ. Stud. 22: 43-47.

Academy of Natural Sciences, Philadelphia (ANSP) (1994a) Preliminary assessment of total mercury in fish from lakes, rivers, and reservoirs of NJ. Report to the NJDEPE, Division of Science and Research, Report No. 93-15F, 92 pp.

Academy of Natural Sciences, Philadelphia (ANSP) (1994b) Preliminary assessment of mercury in freshwater fish from Camden County, New Jersey, Rept. No. 94-22D, 21 pp.

Academy of Natural Sciences, Philadelphia (ANSP) (1994c) Total mercury concentrations in fishes from three Hackensack Water Company reservoirs, Rept. No. 94-16F, 28 pp.

Academy of Natural Sciences, Philadelphia (ANSP) (1999). Phase II 1999 assessment of total mercury concentrations in fishes from rivers, lakes, and reservoirs of New Report to the NJDEP, Division of Science and Research, Report No. 99-.7R, 162 pp.

Adams, D. A., J. S. O'Connor, and S. B. Weisberg (1996) Sediment Quality of the NY-NJ Harbor System. Draft Final Report. USEPA Region 2 and Versar, Inc.

Agocs, M.R., R. Etzel, R. Parrish, D. Paschal, P. Campagna, D. Cohen, E. Kilbourne and J. Heese (1990) Mercury exposure from interior latex paint, New England J. Of Medicine 323:1096-1101.

Anderson, A.C. and Rice, J.C. (1993) Survey of fish and shellfish consumption by residents of the greater New Orleeans area. Bull. Environ. Contam. Toxicol. 51:508-514.

Andren, A. and J.O. Nriagu (1979) The global cycle of mercury. In: The Biogeochemistry of Mercury in the Environment (J.O. Nriagu, Ed.), Elsevier-North Holland, Amsterdam. Pp. 1-21.

Armstrong, F.A.J. (1979) Effects of mercury compounds on fish. Pages 657-670 in J. O. Nriagu (ed.). The biogeochemistry of mercury in the environment. Elsevier/North-Holland Biomedial Press, New York.

Agency for Toxic Substances and Disease Registry (ATSDR) (1993) Toxicological Profile for Lead - Update. US Department of Health and Human Services, Public Health Service, TP-92/12.

Agency for Toxic Substances and Disease Registry (ATSDR) (1999a) Toxicological Profile for Mercury. US Department of Health and Human Services, Public Health Service. March 1999.

Agency for Toxic Substances and Disease Registry (ATSDR) (1999b) Toxicological Profile for Lead. US Department of Health and Human Services, Public Health Service, PB/99/1166704.

Aucott, M. (2000) Personal communication.

Babiart, C.L., S.R. Hoffman, M.M. Shager, J.P. Hurley, A.W. Andren, & D.E. Armstrong (2000). A critical evaluation of tangential-flow ultrafiltration for trace metal studies in freshwater systems, 2. Total mercury and methylmercury, Environ. Science Technol. 34:3428-3434.

Bache C.A., W.H. Gutenmann and D.J. Lisk (1971) Residues of total mercury and methyl mercury in lake trout as a function of age. Science 172:951.

Barr, J.F. (1986) Population dynamics of the Common Loon (*Gavia immer*) associated with mercury-contmainated waters in northwestern Ontario. Occasional Paper No. 56, Canadian Wildlife Service.

Barringer, J.L., C.L. MacLeod, & R.A. Gallagher (1997) Mercury in ground water, soils and sediments of the Kirkwood-Cohansey Aquifer System in the New Jersey Coastal Plain, USGS Open-File Report 95-475, 260 pp.

Barringer, J.L. & C.L. MacLeod (1998) (DRAFT) Relation of mercury to chemical constituents in ground water in the Kirkwood-Cohansey Aquifer System, New Jersey Coastal Plain, and mechanisms for mobilization of mercury from sediments to ground water, Water-Resources Investigations Report 98-DRAFT.

Baumann, J., M.T. Bender and J.M. Williams (2000) Fishing for Trouble: A survey of mercury contamination in America's waterways. Mercury Policy Project and California Communities Against Toxics, and PIRG http://www.pirg.org/reports/enviro/merc.htm

Beijer K, and A. Jernelöv (1979) Methylation of mercury in aquatic environments, pp.203-210 in The Biogeochemistry of Mercury in the Environment (Nriagu JO, ed) Amsterdam: Elsevier/North Holland.

Bemis, J.C., and R.F. Seegal (1999) Polychlorinated biphenyls and methylmercury act synergistically to reduce rat brain dopamine content in vitro. Environ. Health. Perspect. 107:879-885.

Benoit, J.M., W.F. Fitzgerald and A.W.H. Damman (1994) Historical atmospheric mercury deposition in the mid-continental United States as recorded in an ombrotrophic peat bog. In Mercury as a Global Pollutant: Towards Integration and Synthesis. C.J. Watras and J.W. Huckabee, editors. Lewis Press, Boca Raton, FL pp. 187-202.

Benoit, J.M., W.F. Fitzgerald & A.W.H. Damman (1998) A biogeochemistry of an ombrotrophic bog: evaluation of use as an archive of atmospheric mercury deposition. Environmental Research Station, Section A 78, p. 118-133.

Benoit, J.M., Gilmour, C.C. and Mason, R.P. (2001a). Aspects of bioavailability of mercury for methylation in pure cultures of *Desulfobulbus proprionicus (1pr3).* Appl. Environ. Microbiol. 6751-58.

Benoit, J.M., Gilmour, C.C., and Mason, R.P. (2001b). The influence of sulfide on solid-phase mercury bioavailability for methylation by pure cultures of *Desulfobulbus propionicus (1pr3).* Environ Sci Technol. 35:127-132.

Berman M. and R. Bartha (1986a) Levels of chemical versus biological methylation of mercury in sediments. Bull Environ Contam Toxicol 36:401-404.

Berman, M., and R. Bartha (1986b) Control of the methylation process in a mercury-polluted aquatic sediment. Envir. Pollution (Series B) 11: 41-53.

Best, J.B., M. Morita, J. Ragin and J. Best Jr. (1981) Acute toxic responses of the freshwater planarian, Dugesia dorotocephala, to methylmercury. Bull. Environ Contam Toxicol. Jul;27(1):49-54.

Beusterien, K., R. Etzel, M. Agocs, G. Egeland, E. Socie, M. Rouse and B. Mortensen (1991) Indoor air mercury concentrations following application of interior latex paint, Arch. Environ. Contam. Toxicol. 21:62-64.

Beyer, W.N., E. Cromartie, and G.B. Moment (1985) Accumulation of methylmercury in the earthworm, Eisenia foetida, and its effects on regeneration. Bull. Environ. Contam. Toxicol. 35: 157-162.

Bidstrup, L., J.A. Bonnell, D.G. Harvey, and S. Locket (1951) Chronic Mercury Poisoning in Men Repairing Direct Current Meters, Lancet 2:856-861

Biester, H., M. Gosar, S. Covelli (2000) Mercury speciation in sediments affected by dumped mining residues in the drainage area of the Idrija mercury mine, Slovenia, Environ. Sci. & Tech. 34: 3330-3336.

Birge, W.J., J.A. Black, A.G. Westerman, and J.E. Hudson. (1979) The effects of mercury on reproduction of fish and amphibians. In J.O. Nriagu (ed.) The Biogeochemistry of Mercury in the Environment. Elsevier, Amsterdam, The Netherlands, pp. 629-656.

Bloom N.S. (1992) On the chemical form of mercury in edible fish and marine invertebrate tissue. Can J Fish Aquatic Sci 49:1010-1017.

Bodaly, R.A. & R.E. Hecky (1979) Post-impoundment increases in fish mercury levels in the southern Indian Lake Reservoir, Manitoba. Can. Fish. Mar. Serv., Manuscript Rep. 1531, 15 pp.

Bopp, R.F., H.J. Simpson, S.N. Chillrud, D.W. Robinson (1993) Sediment-derived chronologies of persistent contaminants in Jamaica Bay, NY. Estuaries. V. 16. No. 3B: 608-616.

Borg, K., K. Erne, E. Hanko, and H. Wanntorp (1970) Experimental secondary methyl mercury poisoning in the Goshawk (*Accipiter gentilis*) Environ Pollut. 1: 91-104.

Bowerman, W.W. IV, E.D. Evands, J.P. Giesy, and S. Postupalsky (1994) Using feathers to assess risk of mercury and selenium to Bald Eagle reproduction in the Great Lakes region. Arch. Environ. Contam. Toxicol. 27:294-298.

Braune, B.W. and D.E. Gaskin (1987) Mercury levels in Bonaparte's Gull (*Larus philadelphia*) during autumn molt in the Quoddy region, New Brunswick, Canada. Arch. Environ. Contam Toxicol. 16: 539-549.

Brosset, C. and E. Lord (1995) Methylmercury in Ambient Air. Method of Determination and Some Measurement Results. Water, Air, and Soil Pollution 82: 739-750.

Burger, J. (1992) Trace element levels in Pine Snake hatchlings: tissue and temporal differences. Arch. Environ. Contam. Toxicol. 22: 209-213.

Burger, J. (1993) Metals in avian feathers: bioindicators of environmental pollution. Review Environ. Toxicol. 5:203-311.

Burger, J. (1995) Heavy metal and selenium levels in feathers of Herring Gulls (*Larus argentatus*): differences due.

Burger, J. (1997a) Heavy metals in the eggs and muscle of Horseshoe Crabs (*Limulus polyphemus*) from Delaware Bay. Environ. Monitor. Assess. 46: 279-287.

Burger, J. (1997b) Heavy metals and selenium in Herring Gulls (*Larus argentatus*) nesting in colonies from eastern Long Island to Virginia. Environ. Monitor. Assess. 48: 285-296.

Burger, J. (1998) Fishing and risk along the Savannah River: possible intervention, J. Toxicol. Environ. Health 55,405-419.

Burger J., and M. Gochfeld (1985) Comparison of nine heavy metals in salt gland and liver of Greater Scaup (*Aythya marila*), Black Duck (*Anas rubripes*) and Mallard (*A. Platyrhynchos*) Comp. Biochem. Physiol. 81C: 287-292.

Burger, J. and M. Gochfeld (1988) Metals in tern eggs in a New Jersey estuary: a decade of change. Environ. Montor Assess 11: 127-135.

Burger, J. and M. Gochfeld. (1996). Fishing advisories: useful or difficult to interpret? Risk: Health, Safety & Environment 23:23-33.

Burger, J. and M. Gochfeld (1997) Risk, mercury levels, and birds: relating adverse laboratory effects to field biomonitoring. Environ. Research 75: 160-172.

Burger, J., J. Sanchez and M. Gochfeld (1998) Fishing, consumption, and risk perception in fisherfolk along an East Coast Estuary. Environmental Research (A) 77:25-35.

Burger, J. and M. Gochfeld (2001) Effects of chemicals and pollution on seabirds. Pp. 485-526 in Biology of Marine Birds (Schreiber, E.A. and Burger, J. eds) CRC Press, Boca Raton, FL.

Burger, J. and Gochfeld, M. (2001) On developing bioindicators for human and ecological health. Environmental Monitoring and Assessment 66: 23-46.

Burger, J. and J. Snodgrass (1998) Heavy metals in Bullfrog (*Rana catesbeiana*) tadpoles: effects of depuration before analysis. Environ. Toxicol. Chem. 17:2203-2209.

Burger, J., and L. Waishwell (2001) Are we reaching the target audience? Evaludation of a fish fact sheet. Science Total Environ. 277:77-86.

Burger, J., M. Gochfeld, A.A. Rooney, E.F. Orlando, A.R. Woodward and L.J. Guillette, Jr. (2000) Metals and metalloids in tissues of American Alligators in three Florida lakes. Arch. Environ. Contam. Toxicol. 38:501-508.

Burger, J., C.S. Borning, W.L. Stephens, J. Snodgrass, J. and M. Gochfeld (2001a) Mercury and selenium in fish from the Savannah River: species, trophic level, and locational differences. Environ. Research A87:108-118.

Burger, J., K.R. Gaines, and M. Gochfeld (2001b) Ethnic Differences in Risk from Mercury Among Savannah River fishermen. Risk Analysis. In Press.

Burger, J., M. Gochfeld, and C. Leck (1984) Waterbirds on Raritan Bay: a preliminary analysis of their distribution and heavy metal levels. NJ Academy of Sciences.

Burger, J., M. Gochfeld, C.W. Powers, L. Waishwell, C. Warren and B.D. Goldstein, (2001c) Science, policy, stakeholders and fish consumption advisories: developing a fish fact sheet for the Savannah River. Environ. Management 27:501-514.

Burger, J., Pflugh, K.K., Lurig, L., von Hagen L, and Von Hagen S. 1999. Fishing in urban New Jersey: ethnicity affects information sources, perception and complaince. Risk Analysis 19:427-438.

Burger, J., B. Johnson and M. Gochfeld. In press. Perceptions of recreational fishing boat captains: knowledge and effects of fish consumption advisories. Risk Analysis.

Burger, J., R.A. Kennamer, I.L. Brisbin Jr., and M. Gochfeld (1997) Metal levels in Mourning Doves from South Carolina: potential hazards to doves and hunters. Environ Research 75:173-186.

Burger, J., K. Parsons, T. Benson, T. Shukla, D. Rothstein, and M. Gochfeld (1992) Heavy metal and selenium levels in young Cattle Egrets from nesting colonies in the northeastern United States, Puerto Rico, and Egypt. Arch. Environ. Contam. Toxicol. 23: 435-439.

Burger, J., K. Staine, K., and M. Gochfeld. (1993) Fishing in contaminated waters: knowledge and risk perception of hazards by fishermen in New York City. J. Toxicol. Environ. Health 39:95-105.

Burger, J., Sanchez J. & Gochfeld, M. 1998. Fishing, consumption, and risk perception in fisherfolk along an East Coast estuary. Environmental Research 77:25-35.

Burger, J., W. Stephens, C.S. Boring, M. Kuklinski, J.W. Gibbons, and M. Gochfeld (1999) Factors in exposure assessment: ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River, Risk Anal. 19, 421-431.

Callahan, P. and J.S. Weis. (1983) Methylmercury effects on regeneration and ecdysis in fiddler crabs (Uca pugilator, U. pugnax) after short-term and chronic pre-exposure. Arch. Envir. Contam. Tox., 12:707-714.

Carpi, A., Lindberg, S.E., Prestbo, E.M., et al. (1998) Methylmercury contamination and emission to the atmosphere from soil amended with municipal sewage sludge. J. Env. Qual. 26:1650-1655.

Ceccine, G.A., III 1997. Combinations of natural and anthropogenic stressors affect populations of freshwater rotifers. Thesis (Ph.D.) Georgia Institute of Technology. 1997. 137p.

Centers for Disease Control (1996) Mercury exposure among residents of a building formerly used for industrial purposes, NJ 1994. MMWR 45:422-445.

Cernichiari, E., T.Y. Toribara, L. Liang, D.O. Marsh, M.W. Berlin, G.J. Myers, C. Cox, C.F. Shamlaye, O. Choisy, and P. Davidson (1995) The biological monitoring of mercury in the Seychelles study. Neurotoxicology 16:613-628.

Clark, K.E., L.J. Niles (1999) Status and Trends of Contaminant Concentrations in Raptors: Stressor-Condition Indicator Linkages. NJDEP/ESNP. Division of Fish and Game (Unpublished)

Clarkson, T.W., R. Hamada, and L. Amin-Zaki (1984) Mercury. In J.O. Nriagu (ed) Changing metal cycles and human health. Springer-Verlag, Berlin.

Cohen, J.B., J.S. Barclay, A.R. Major, and J.P. Fisher (1999) Wintering Greater Scaup as biomonitors of metal contamination in Federal Wildlife Refuges in the Long Island Sound region. Manuscript.

Cope W.G., J.G. Wiener, and R.G. Rada (1990) Mercury accumulation in Yellow Perch in Wisconsin seepage lakes: relation to lake characteristics. Environ Toxicol Chem 9:931-940.

Costa, H.J. and T.C. Sauer (1994) Distributions of chemical contaminants and acute toxicity in Delaware Estuary sediments. Final Report, DELEP #94-08. For Delaware Estuary Program, US Environmental Protection Agency, by Arthur D. Little, Inc., Cambridge, MA. 89 pp. and appendices.

Cramer, G.M. (1994) Exposure of US consumers to methylmercury from fish. In: DOE/FDA/EPA Workshop on Methylmercury and Human Health. March 22-23, 1994, Bethesda, MD. Biomedical and Environmental Assessment Group, Brookhaven National Laboratory, Upton, NY, Conf-9403156. pp. 103-116.

Cramer, J.S. (ed) (1995) Special Issue: Methylmercury and Human Health. NeuroToxicology 16(4):577-731.

Crump, K.S., T. Kjellstrøm, A.M. Shipp, A. Silvers, and A. Stewart (1998) Influence of Prenatal Mercury Exposure Upon Scholastic and Psychological Test Performance: Benchmark Analysis of New Zealand Cohort. Risk Analysis 18:701-713.

D'Itri, F.M. (1990) The biomethylation and cycling of selected metals and metalloids in aquatic sediments. In: Sediments: Chemistry and Toxicity of In-Place Pollutants. R. Baudo, J. Giesy, and H. Muntau (Eds.) Lewis Publishers, Inc., Ann Arbor. Pp. 164-168.

Davidson, P.W, G.J. Myers, C. Cox (1998) Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment. JAMA 280:701-707.

Day (1991) Autopsy report. NJDEP.

De Jesus, I.M., de Oliveira Santos E.C., da Silva Brabo, E., Loureiro,E.C. de Magalhaes Camara, V., Mascarenhas, A.F., da Silva,D.F. and Cleary, D. (2001) Exposure to elemental mercury in urban workers and gold miners from the Tapajos Region, Para, Brazil. Bull. Environ. Contam. Toxicol. 67:317-323.

Delaware Estuary Program. 1996. Comprehensive Conservation and Management Plan.

Dietz, R., F. Riget, and E.W. Born (2000) Geographical differences of zinc, cadmium, mercury and selenium in Polar Bears (Ursus maritimus) from Greenland. Science Total Environ. 245:25-47.

Dooley, J.H. (1992) Natural sources of mercury in the Kirkwood-Cohansey Aquifer System of the New Jersey Coastal Plain, NJGS Report 27, 19 pp.

Draxler, A.F.J., P. Hauge and A.D. Deshpande (1991) Organic contaminants in hepatic tissues of lobster and flounder at the New York Bight "12-Mile" sewage sludge dumpsite : 1987-88 /: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Region, Northeast Fisheries Science Center Woods Hole, Mass.. 10 pp.

Duvall, S.E. and M.G. Barron (2000) A screening level probabilistic risk assessment of mercury in Florida Everglades food webs. Ecotoxicol. Environ. Safety 47:298-305.

Efroymson, R. A., M. Will and G. W. Suter II (1997) Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision. U. S. Dept. of Energy. ES/ER/TM-126/R2.

Egeland, G.M. and J.P. Middaugh (1997) Balancing fish consumption benefits with mercury exposure, Science 278:1904-1905.

Eisenrich, S.J. & J. Reinfelder (2001) Interim Report to the NJDEP, The NJ Atmospheric Deposition Network (NJADN), Dept. of Environmehtal Sciences, Rutgers Univ., New Brunswick, NJ.

Eisler, R. (1987) Mercury Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review. US Fish and Wildlife Service Biological Report. 85 (1.10), 90 pp.

Electric Power Research Institute (EPRI) (1994) Mercury Atmospheric Processes: A Synthesis Report; EPRI/TR-104214; Workshop Proceedings.

Elliott, J.E., R.J. Norstrom and G.E.J. Smith. (1996) Patterns, trends, and toxicological significance of chlorinated hydrocarbon and mercury contaminants in Bald Eagle eggs from the Pacific Coast of Canada. Arch. Environ. Contam. Toxicol. 31: 354-367.

EMCON (1998) Remedial Investigation Report, Troy Chemical Corporation, Inc., Newark, New Jersey.

Endo, T., S. Nakaya, R. Kimura and T. Murata (1986) Gastrointestinal absorption of inorganic mercuric compounds in vitro. Toxicol Appl Pharmacol. 83:187-196.

Engstrom, D.R. & E.B. Swain (1997) Recent declines in atmospheric mercury deposition in the Upper Midwest. Environ. Sci. Technol. 31:960-967.

ERM-Southeast, Inc. (1985) Berry's Creek Study, Volume 1, Nature of the Problem. Final Report. Task I of the Berrys Creek RI/FS Investigation.

Exponent Environmental Group (1998) Phase I Remedial Investigation Report: Ventron/Velsicol Site, Wood-Ridge/Carlsdadt, New Jersey (Draft), Volume 1 of 3. Prepared for Velsicol Chemical Corporation and Morton International, Inc.

Exponent Environmental Group and The Academy of Natural Sciences (1999a) Acid Brook Delta Ecological Investigation Phase I Report. Prepared for Du Pont Pompton lakes Works, Pompton Lakes, NJ.

Exponent Environmental Group (1999b) Acid Brook Delta Ecological Investigation, Phase 2 Report. Prepared for Du Pont Pompton Lakes Works, Pompton Lakes, New Jersey.

Faber, R.A., R.W. Risebrough and H.M. Pratt (1972) Organochlorines and mercury in Common Egrets and Great Blue Herons. Environ. Pollution 3:111-122.

Fiedler, N. I. Udasin, M. Gochfeld, G. Buckler, K. Kelly-McNeil, and H. Kipen (1999) Neuropsychological and stress evalaution fo a residential mercury exposure, Environ. Health Perspect. 107: 343-347.

Fields, T.W., T.F. McNevin, R.A. Harkov, & J.V. Hunter (1993) A summary of selected soil constituents and contaminants at background locations in New Jersey, NJDEP- Site Remediation Program and Vision of Science & Research, September, 43 pp.

Fields, T. (1999) Background levels of selected contaminants in New Jersey Soils. Site Remediation Program, NJDEP. Unpublished.

Fimreite, N., Fyfe, R.W. and Keith, J.A. (1970) Mercury contamination of Canadian prairie seed eaters and their avian predators. Canadian Field-Nat. 84:269-276.

Fimreite, N., W.N. Holsworth, J.A. Keith, P.A. Pearce, P.A. and I.M. Gruchy (1971) Mercury in fish and fish-eating birds near sites of industrial contamination in Canada. Canadian Field Nat. 85:211-220.

Fimreite, N. and L. Karstad (1971) Effects of dietary methyl mercury on Red-tailed Hawks. J. Wildlife Management, 35: 293-300.

Finley, M.T. and R.C. Stendell (1978) Survival and reproductive success of black ducks fed methylmercury. Environ. Pollut. 16:51-64.

Fitzgerald, W. F., Mason, R. P., and G.M. Vandal (1991) Atmospheric Cycling and Air-Water Exchange of Mercury over Mid-Continental Lacustrine Regions. Water, Air, and Soil Pollution 56: 745-767.

Fitzgerald, W. (1995) Is mercury increasing in the atmosphere? The need for an atmopheric mercury network (AMNET). Water, Air and Soil Pollution 80: 245-254.

Fitzgerald, W.F., C.H. Lamborg, A.W.H. Damman, J.M. Benoit & P. H. Balcom (1999) Contemporary and historical eolian depositional fluxes of mercury: archival records in ombrotrophic bogs and lake sediments from Nova Scotia and New Zealand. Mercury as a Global Pollutant - 5th International Conference. May 23-28, 1999. Rio de Janeiro, Brazil. Pg. 551.

Fitzgerald, W. F., Mason, R. P., and G.M. Vandal (1991) Atmospheric Cycling and Air-Water Exchange of Mercury over Mid-Continental Lacustrine Regions. Water, Air, and Soil Pollution 56: 745-767.

Frakes, R. A., S. L. Lemieux, and K. E. Clark. (1998) Reproductive success and egg contaminant concentrations of southern New Jersey peregrine falcons. U. S. Fish and Wildlife Service, NJ Field Office, Pleasantville, NJ and NJDEP Division of Fish and Wildlife, Trenton, NJ. 35pp+app.

Friedmann, A.S., M.C. Watzin, J.C. Leiter, and T. Brinck-Johnsen (1996) Effects of environmental mercury on gonadal function in Lake Champlain Northern Pike (*Esox lucius*) Bull. Environ. Contam. Toxicol. 56: 486-492.

Frithsen, J.B., D.E. Strebel, S. Schreiner, and T. Schawitsch (1995) Estimates of contaminant inputs to the Delaware Estuary. For the Delaware Estuary Program, U. S. Environmental Protection Agency, by versar, Incl., Columbia, MD. 162 pp. and appendix.

Gaines, K., C.G. Lord, C.S. Boring, I.L. Brisbin Jr., M. Gochfeld and J. Burger (2000) Raccoons as potential vectors of radionuclide contamiantion to humanf ood chains from a nuclear industrial site, J. Wildlife Managmenet 64:199-208.

Galae-Gorchev, H. (1993) Dietary intake in food and estimated intake of lead, cadmium, and mercury. Food Additives and Contaminants 10:115-128.

Galluzzi, P.F. (1976) Mercury concentrations is Muskrats, *Ondatra zibethiscus*, from the Hackensack Meadowlands, New Jersey, Master□s Thesis, Fairleigh Dickinson Univ., New Jersey.

Galluzzi, P.F. (1981) Mercury concentrations in mammals, reptiles, birds and waterfowl collected in the Hackensack Meadowlands, New Jersey. Presented at: The NJ Acaemy of Sciences, March 28.

Ganther, H.E., C. Goudie, M.L. Sunde, M.J. Kopecky, M.J., P.Wagner, P. S.H. Oh and W.G. Hoekstra (1972) Selenium: relation to decreased toxicity of methylmercury added to diets containing tuna. Science 175:1122-1124.

Ganther, H.E. (1980) Interactions of vitamin E and selenium with mercury and silver. Annals NY Acad Sci. 355:212-226.

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

Gerstenberger S.L., J. Pratt-Shelley, M.S. Beattie and J.A. Dellinger (1993) Mercury concentrations of Walleye (Stizostedion vitreum vitreum) in 34 northern Wisconsin lakes. Bull Environ Contam Toxicol 50:612-617.

Gilman, A.P., G.A. Fox, D.B. Peakall, S.M. Teeple, T.R. Carroll, and G.T. Haynes (1999) Reproductive parameters and egg contaminant levels of the Great Lakes Herring Gulls. J. Wildlife Management 41: 458-468.

Gilmour, C.C. & D.G. Capone (1987) Relationship between Hg methylation and the sulfur cycle in estuarine sediments. Ocean Sciences Abstr. Meet., EOS 68: 1718.

Gilmour, C.C. and G.S. Riedel (2000) A survey of size-specific mercury concentrations in game fish from Maryland fresh and estuarine waters. Arch. Environ. Contam. Toxicol. 39:53-59.

Gnamus, A., Byrne, A.R. and Horvat, M. (2000). Mercury in the soil-plant-deer-predator food chain of a temperate forest in Slovenia. Environ. Science Technol. 34:3337-3345.

Great Lakes Environmental Center (GLEC) (1996) Summary of the Phase I metals sampling and analysis program for the New Jersey component of the NY-NJ Harbor Estuary Program. Traverse City, MI 49686.

Gnamus, A., A.R. Byrne and M. Horvat (2000) Mercury in the soil-plant-deer-predator food chain of a temperate forest in Slovania, Environ. Sci. Technol. 34: 3337-3345.

Gochfeld, M. (1971) Pre-mature feather loss---a "new disease" of Common Terns on Long Island, New York. Kingbird 21:206-211.

Gochfeld, M. (1975) Developmental defects in Common Terns of western Long Island, New York. Auk 92:58-65.

Gochfeld, M. (1980) Tissue distribution of mercury in normal and abnormal young Common Terns. Marine Pollution Bull. 11:362-377.

Gochfeld, M. (1997) Spatial patterns in a bioindicator: heavy metal and selenium concentration in eggs of Herring Gulls (Larus argentatus) in the New York Bight. Arch. Environ. Contam.Toxicol 33:63-70.

Gochfeld, M. and J. Burger (1987a) Factors affecting tissue distribution of heavy metals: age effects and the metal concentration patterns in Common Terns, *Sterna hirundo.* Biol Trace Element Res 12: 389-399.

Gochfeld, M., and J. Burger (1987b) Heavy metal concentrations in the liver of three duck species: influence of species and sex. Environ. Pollution 45:1-15.

Gochfeld, M. and Burger, J. (1998) Temporal trends in metal levels in eggs of the endangered Roseate Tern (Sterna dougallii) in New York. Environ Research. 77A:36-42.

Gochfeld, M., J.L. Baland, T. Shukla, T. Benson, and J. Burger (1996) Heavy metals in Laughing Gulls: gender, age, and tissue differences. Environ. Toxixcol. Chem. 15:2275-2283.

Grandjean, P., P. Weihe, R.F. White, F. Debes, S. Araki, K. Yokoyama, K. Murata, N. Sorensen, R. Dahl and P.J. Jorgensen (1997) Cognitive deficit in 7-year old children with prenatal exposure to methylmercury. Neurotoxicol. Teratol. 19:417-428

Grieb T.M., C.T. Driscoll, S.P. Gloss, C.L. Schofield, G.L. Bowie and D.B. Porcella (1990) Factors affecting mercury accumulation in fish in the upper Michigan Peninsula. Environ Toxicol Chem 9:919-930.

Grier, J.W. (1974) Reproduction, organochlorines, and mercury in northwestern Ontario Bald Eagles. Canadian Field-Nat 88:469-475.

Haines T.A., V.T. Komov and C.H. Jagoe (1992) Lake acidity and mercury content of fish in Darwin National Reserve, Russia. Environ Pollut 78:107-112.

Haines T.A., V.T. Komov, V.E. Matey and C.H. Jagoe (1995) Perch mercury content is related to acidity and color of 26 Russian lakes. Water, Air, Soil Pollution 85:823-828.

Hall, R.A., E.G. Zook and G.M. Meaburn, G.M. (1978) National Marine Fisheries Service Survey of Trace Elements in the Fishery Resource. NOAA Technical Report NMFS SSRF-721. National Marine Fisheries Service, March 1978.

Hamilton, A. (1925) Industrial Poisons in the United States. Macmillan, New York.

Hammond, A.L. (1971) Mercury in the Environment: natural and human factors. Science 171:788-790.

Harada, M. (1995) Minamata Disease: Methylmercury Poisoning in Japan Caused by Environmental Pollution. Crit. Rev. Toxicol. 25:1-24.

Hays, H. and R.W. Risebrough (1971) The early warning of the terns. Natural History.

Hecky R.E., R.A. Bodaly, D.J. Ramsey, and N.E. Strange (1991) Increased methylmercury contamination in fish in newly formed freshwater reservoirs, pp. TO GET ORIGINAL. in Advances in Mercury Toxicology. (Clarkson TFW, Suzuki T, Imura A, eds) New York: Plenum.

Hochreiter, J.J., Jr. and J. Kozinski (1985) Quality of water and bed material in streams of Logan Township, Gloucester County, New Jersey, 1984. US Geological Survey Water Resources Investigations Report 85-4300.

Hoffman, R.D. and R.D. Curnow (1973) Toxic heavy metals in Lake Erie Herons. Proc. Conf. Great Lakes Research 16:50-53..

Huckabee J.W., J.W. Elwood and S.G. Hilderbrand (1979) Accumulation of mercury in freshwater biota pp. 277-301 et al. in The Biogeochemistry of Mercury in the Environment (Nriagu J.O., ed) Amsterdam: Elsevier/North Holland.

Hughes, K.D., P.J. Ewins and K.E. Clark (1997) A comparison of mercury levels in feathers and eggs of Osprey (Pandion haliaetus) in the North American Great Lakes. Arch. Environ. Contam. Toxicol. 33:441-452.

Hunter, D. (1974) The Diseases of Occupations. English Universities Press, Ltd, London.

Irwin, R.J., M. VanMouwerik, L. Stevens, M.D. Seese, and W. Basham (1997) Environmental Contaminants Encyclopedia, Mercury Entry, National Park Service, Water Resources Division, Fort Collins, Colorado.

Jackson, T.A. (1991) Biological and environmental control of mercury accumulation by fish in lakes and reservoirs of northern Manitoba, Canada. Can J Fish Aquatic Sci 48:2449-2470

Jacobs, H.L., H.D. Kahn, K.A. Stralka and D.B. Phan (1998) Estimates of per capita fish consumption in the US based on the Continuing Survey of Food Intake by Individuals (CSFII) Risk Analysis 18:283-291.

Jacobson, J.L. and S.W. Jacobson (1996) Intellectual impairment in children exposed to polychlorinated biphenyls in utero. New Engl. J. Med 335:783-789.

Jagoe C.H., P.L. Shaw-Allen, and B.S. Gill (1996) Na+-K+-ATPase activity in largemouth bass (Micropterus salmoides) from three reservoirs with different levels of mercury contamination. Aquatic Toxico. 36:161-176.

Johnston T.A., R.A. Bodaly and J.A. Mathias (1991) Predicting fish mercury levels from physical characteristics of boreal reservoirs. Can J Fish Aquatic Sci 48:1468-1475.

Jurczk, N.U. (1993) An ecological risk assessment of the impact of mercury ocntamiantion in the Florida Everglades. Master□s Thesis, Univ. Of Florida, Gainesville, FL.

Kabata-Pendias, A. and H. Pendias (1984) Trace Elements in Soils and Plants. CRC Press, Boca Raton FL.

Khan, B. and B. Tansel (2000) Mercury bioconcentrations factors in American Alligators (Alligator mississippiensis) in the Florida Everglades. Ecotoxicol. Environ. Safety 47:54-58.

Khan, A.T., and J.S. Weis. (1987) Effects of methylmercury on sperm and egg viability of two populations of killifish (Fundulus heteroclitus) Arch. Envir. Contam. Tox., 16:499-505.

Khan, A.T. and J.S. Weis (1993) Bioaccumulation of four heavy metals in two populations of mummichog, (*Fundulus heteroclitus*) Bull. Enviorn. Contam. Toxicol. 51:1-5.

Kinjo, Y., H. Higashi, A. Nakano, M. Sakamoto and R. Sakai (1993) Profile of Subjective Complaints and Activities of Daily Living Among Current Patients with Minamata Disease After 3 Decades. Environ. Res. 63-241-251.

Kjellstrøm, T., P. Kennedy, S. Wallis and C. Mantell (1986) Physical and Mental Development of Children with Prenatal Exposure Mercury from Fish. Stage 1: Preliminary Tests at Age 4. National Swedish Environmental Protection Board, Report 3080, Solna, Sweden.

Kjellstrøm, T., P. Kennedy, S. Wallis, A. Stewart, B. Lind, T. Wutherspoon and C. Mantell (1989) Physical and Mental Development of Children with Prenatal Exposure to Mercury from Fish. Stage 2: Interviews and Psychological Tests at Age 6. National Swedish Environmental Protection Board, Report 3642, Solna, Sweden.

Komsta-Szumska, E., K.R. Reuhl and D.R. Miller (1983) Effect of selenium on distribution, demethylation, and excretion of methylmercury by the guinea pig. J. Toxicol. Environ. Health.1:775-785.

Kosatsky, T. and P. Foran (1996) Do Historic Studies of Fish Consumers Support the Widely Accepted LOEL for Methylmercury in Adults. Neuro Toxicol. 17: 177-186.

Krabbenhoft, D.P. (1999) Summary Document for the USGS Workshop on Mercury Cycling in the Environment. Golden, CO, July 7-9, 1996. Website: http://toxics.usgs.gov/toxics/pubs/hg/summary.shtml.

Kurland, L.T., S.N. Faro and H. Siedler (1960) Minamata Disease. World. Neurology 1: 370-395.

Lacerda, L.D., E.D. Bidone, A.F. Guimaraes and W.C. Pfeiffer (1994) Mercury concentrations in fish from the Itacaiunas-Parauapebas River system, Carajas region, Amazon. An Acad Bras Cienc. 66:373-9.

Lambertini, M. (1982) Mercury levels in Larus audouinii and Larus michahellis breeding in Capraia Island (Tyrrhenian Sea) Rev. Ital. Ornit. 52:75-79.

Lange T, D. Richard, and H. Royals (2000) Long-term trends of mercury bioaccumulation in Florida's Largemouth Bass, Annual Meeting South Florida Mercury Science Program, Tarpon Springs FL.

Latif, M.A., R.A. Bodaly, T.A. Johnston and R.J. Fudge (2001) Effects of environmental and maternally derived methylmercury on the embryonic and larval stages of walleye (Stizostedion vitreum) Environ Pollut. 111:139-148.

Lawrence, A.L. and R.P. Mason (2001) Factors controlling the bioaccumulation of mercury and methylmercury by the estuarine amphipod Leptocheirus plumulosus. Environ Pollut. 111:217-231.

Lebel, J., D. Mergler, M. Lucotte, M. Amorim, J. Dolbec, D. Miranda, G. Arantès, I. Rheault and P. Pichet (1996) Evidence of Early Nervous System Dysfunction in Amazonian Populations Exposed to Low-Levels of Methylmercury. Neuro Toxicol. 17:157-168.

Lebel, J., D. Mergler, F. Branches, M. Lucotte, M. Amorim, F. Larribe and J. Dolbert (1998) Neurotoxic Effects of Low-level Methylmercury Contamination in the Amazonian Basin. Environ. Res. 79:20-32.

Leggett, R.W., N.B. Munro and K.F. Eckerman (2001) Proposed revision of the ICRP model for inhaled mercury vapor. Health Physics 81:450-455.

Lewis, S.A. and R.W. Furness (1991) Mercurya ccumulation and excretion by laboratory-reared black-headed gull *Larus ridibundus* chicks, Arch. Environ. Contam. Toxicol. 21: 316-320.

Lindberg, P. (1984) Mercury in feathers of Swedish Gyrfalcons, Falco rusticolus in relation to diet. Bul. Environ. Contam. Toxicol. 32:453-459.

Lindberg, P. and T. Odsjö (1983) Mercury levels in feathers of Peregrine Falcon Falco peregrinus compared with total mercury content in some of its prey species in Sweden. Environ. Pollut. 5: 297-318.

Lipsky, D., R.J. Reed, and R. Harkov (1980) Mercury Levels in Berry's Creek. Office of Cancer and Toxic Substances Research. NJDEP. 76 pp.

Lockhart, W.L., J.F. Uthe, A.R. Kenney and P.M. Mehrle (1972) Methylmercury in Northern Pike (*Esox lucius*): distribution, elimination and some biochemical characteristics of contaminated fish. J. Fish. Res. Board Can., 29: 1519-1523.

Lockhart, W.L., R.W. Macdonald, P.M. Outridge, P. Wilkinson, J.B. Delarond, & J.W.M. Rudd (1999) Tests of the fidelity of lake sediment core records of mercury deposition to known historics of mercury contamination. Mercury as a Global Pollutant - 5th International conference. May 23-28, Rio de Janeiro, Brazil.

Lofroth, G. (1970) Methyl Mercury: A review of the health hazards and side effects associated with the emission of mercury compounds into natural systems. Ecological Research Committee Bulletin No. 4, (2nd ed.) Swedish Natural Science Research Council, Stockholm, Sweden.

Malm, O., F.J. Branches, H. Akagi, M.B. Castro, W.C. Pfeiffer, M. Harada, W.R. Bastos and H. Kato (1995) Mercury and methylmercury in fish and human hair from the Tapajos River basin, Brazil. Science Total Environ. 175:141-150.

Marien, K. and G.M. Patrick (2001) Exposure analysis of five fish-consuming populations for overexposure to methylmercury. J. Exposure Anal. Environ. Epidemiol. 11:193-206.

Marsh, DO., M.D. Turner, J.C. Smith, P. Allen and N. Richdale (1995) Fetal methylmercury study in a Peruvian fish-eating population. Neurotoxicology 16:717-726.

Martin-Doimeadios, R.C., Wasserman, J.C., Bermejo, L.F., Amouroux, D., Nevado ,J.J., and Donard, O.F. (2000) Chemical availability of mercury in stream sediments from the Almaden area, Spain. J Environ Monit.2:360-366.

Mason, R.P., W.F. Fitzgerald and F.M.M. Morel (1994) The biogeochemical cycling of elemental mercury: anthropogenic influences. Geochim. Cosmochim. Acta 58/15: 3191-3198.

Matsunaga, T., T. Ueno, R.L.R. Chandradjith, H. Amano, M. Okunura & H. Hashitani (1999) Cesium-137 and mercury contamination in lake sediments. Chemosphere. 39 (2): 269-283.

May, H. And J. Burger (1996) Fishing in a poluted estuary: fishing behavior, fish consumption and potential risk, Risk Analysis 16:459-471.

McFarlane G.A. and W.G. Franzin (1980) An examination of Cd, Cu, and Hg concentrations in livers of northern pike Esox lucius, and white sucker, Catastomus commersoni, from five lakes near a base metal smelter at Flin Flon, Manitoba. Can J Fish Aquatic Sci 37:1573-1578.

McKim, J.M., G.F. Olson, G.W. Holcombe, and E.P. Hunt (1976) Long-term effects of methylmercuric chloride on three generations of brook trout (Salvelinus fontinalis): Toxicity, accumulation, distribution, and elimination. J. Fish. Res. Board Can. 33: 2726-2739.

McLaughlin, M. and R. Hamon (2001). Perspectives on inputs of cadmium to the food chain, pp. 60-65, in Syers, K and M. Gochfeld (eds). Environmental Cadmium in the Food Chain: Sources, Pathways, and Risks. Proceedings of SCOPE Workshop, Belgian Academy of Sciences, September 2000.

Meili, M. (1995) Pre-industrial atmospheric deposition of mercury: uncertain rates from lake sediment and peat cores. 1995. Water, Air, and Soil Pollution 80 (104): p. 637-640.

Miller D.R. and H. Akagi (1979) pH affects mercury distribution, not methylation. Ecotoxicol Environ Safety 3:36-38.

Minnesota Pollution Control Agency (1998) Options and Strategies for Reducing Mercury Releases, Source Reduction Feasibility and Reduction Strategies Committee Report, Minnesota Pollution Control Agency, Policy and Planning Division, Majors Air Unit, 520 Lafayette Rd., St. Paul, MN.

Monmouth County (NJ) Board of Health (1989) Interim report on the nine coastal lakes in Monmouth County.

Murphy, E.A., & M. Aucott (1999) A methodology to assess the amounts of pesticidal mercury used historically in New Jersey, Journal of Soil Contamination 8(1): 131-148.

Murphy, E.A., J. Dooley, H.L. Windom and R.G. Smith Jr. (1994) Mercury species in potable groundwater in southern New Jersey. Water, Air, and Soil Pollution 78: 61-72.

National Atmospheric Deposition Program (NADP) (2000) 1999 Annual Summary, NADP Data Report 2000-02, NADP Program Office, Illinois State Water Survey, Champaign, IL.

National Center for Health Statistics (NCHS) (2001) National Health and Nutrition Examination Survey (NHANES IV), U.S. Public Health Service, Hyattsville, Maryland.

National Center for Health Statistics (NCHS) (1978) National Health and Nutrition Examination Survey (NHANES I), Selected Findings: Food consumption profiles of white and black persons 1-74 years of age in the U.S., 1971-74, Pata 21:1-11.

National Institute of Environmental Health Sciences (NIEHS) (1998) Report on the Workshop on Scientific issues relevant to assessment of health effects from exposure to methylmercury, Brownestone Hotel, Raleigh, NC, Nov. 18-20.

National Research Council (NRC) (2000) Toxicological Effects of Methylmercury. National Academy Press, Washington, D.C.

National Oceanic and Atmospheric Administration (NOAA) (1998) Raw data file. NOAA National Status and Trends Program.

National Oceanic and Atmospheric Administration (NOAA) (1999) Data Base for Newark Bay. Prepared by Hazardous Materials Response and Assessment Division.

National Wildlife Federation (1999) Clean the Rain, Clean the Lakes: Mercury in Rain is Polluting the Great Lakes. National Wildlife Federation Ann Arbor, MI, http://www.nwf.org/greatlakes

National Institute of Environmental Health Sciences (NIEHS) (1998) Scientific Issues Relevant to Assessment of Health Effects from Exposure to Methylmercury. Report of the November 18-20, 1998 Workshop, Raleigh, NC.

NESCAUM, NEWMOA, NEIWPCC and EMAN (1998) Northeast States and Eastern Canadian Provinces Mercury Study: A Framework for Action. Northeast States for Coordinated Air Use Management, Boston, MA.

New Jersey Department of Environmental Protection and Energy (NJDEPE) (1993) Task Force on Mercury Emissions Standard Setting. Final Report on Municipal Solid Waste Incineration. Vol. II: Environmental and Health Issues. July 1993.

New Jersey Department of Environmental Protection (NJDEP) (1995a) A guide to health advisories for eating fish and crabs caught in NJ waters, 4 pp, Division of Science, Research and Technology, Trenton, NJ, 4 pp.

New Jersey Department of Environmental Protection (NJDEP) (1995b) NJ household fish consumption study, Conducted by the Center for Public Interest Poling, Eagleton Institute of Politics, Rutgers Univ. And the NJ Marine Sciences Consortium. Final Report, Trenton, NJ.

New Jersey Department of Environmental Protection (NJDEP) (1998a) Environmental Indicators Technical Report, National Environmental Performance Partnership System (NEPPS).

New Jersey Department of Environmental Protection (NJDEP) (1998b) Guidance for Sediment Quality Evaluations. Site Remediation Program, NJDEP, 28 pp.

New Jersey Department of Environmental Protection (NJDEP) (1996) The Delaware Estuary Program, Comprehensive Conservation and Management Plan. USEPA Region III. Philadelphia, PA. Versar, Inc. 1994. Estimates of contaminant inputs to the Delaware River from nonpoint sources. Contract draft report to the Delaware Estuary Program.

New Jersey Department of Environmental Protection (NJDEP) (1999) Toxics Source Reduction Plan for the NY-NJ Harbor Estuary. Office of Program Coordination. New York-New Jersey Harbor Estuary Program Including the Bight Restoration Plan. 1996. Final Comprehensive Conservation and Management Plan. US Environmental Protection Agency.

New Jersey Department of Environmental Protection (NJDEP), Div. Fish and Wildlife (2000) New Jersey fish and wildlife digest. Vol.13-.2: 24-25pp.

New Jersey Department of Health and Senior Services (NJDHSS) and NJDEP (1997) A guide to eating fish and seafood; what you should know if you are: pregnant, planing to be pregnant or have a young child, Trenton, NJ, 7 pp.

New York State Department of Environmental Conservation (NYSDEC) (1981) Autopsy report on American Kestrel. Unpublished document.

New York-New Jersey Harbor Estuary Program including the New York Bight Restoration Plan (1996) Comprehensive Conservation and Management Plan. USEPA Region II, New York, NY.

Newland, M.C. and E.M. Paletz (2000) Animal studies of methylmercury and PCBs: what do they tell us about expected effects in humans. NeuroToxicology 21:1003-1028.

Newland, M.C. and E.B. Rasmussen (2000) Aging unmasks adverse effects of gestational exposure to methylmercury in rats. Neurotoxicol Teratol. 22:819-28.

Nichols J, S. Bradbury and J. Swartout (1999) Derivation of wildlife values for mercury. J Toxicol Environ Health B Crit Rev. 2:325-355.

Nierenberg, D.W., R.E. Nordgren, M.B. Chang, R.W. Siegler, M.B. Blayney, F. Hochberg, T.Y. Toribara, E. Cernichiari and T. Clarkson (1998) Delayed cerebellar disease and death after accidental exposure to dimethylmercury. New Engl. J. Med. 338: 1672-1676.

Niimi, A.J., and G.P. Kissoon (1994) Evaluation of the critical body burden concept based on inorganic and organic mercury toxicity to Rainbow Trout (*Oncorhynchus mykiss*) Arch. Environ. Contam. Toxicol. 26: 169-178.

Niimi, A.J. and L. Lowe-Jinde (1984) Differential blood cell r atios of Rainbow *Trout (Aslmo gairdneri*) exposed to methylmercury and chlrobenzenes, /arcg, /ebvuirb, /cibtan, /tixucik, 13L 393-311.

Nriagu, J.O. (1979) The biogeochemistry of mercury in the environment/editor, J.O. Nriagu. Publication info: Amsterdam, New York, Elsevier/North-Holland Biomedical Press.

Nriagu, J.O. (1989) A global assessment of natural sources of atmospheric trace metals. Nature 338:47-49

Odsjö, T. 1975. Toxic chemicals in sedentary and migratory birds in Fennoscandia and the Baltic area. Ornis Fenn. 52:74-82.

Olsen, S.F., J. Olsen and Frische, G. (1990) Does fish consumption during pregnancy increase fetal growth? Internatl J. Epidemiology 19: 971-977.

Orloff, K.G., G. Ulirsch, L. Wildes, A. Block, J. Fagliano, & J. Pasqualo Jr. (1997) Human exposure to elemental mercury in a contaminated residential building, Arch. Environ. Health 52:169-172.

Pai, P., P. Karamachandani and C. Seigneur (1997) Simulation of the Regional Atmospheric Transport and Fate of Mercury Using a Comprehensive Eulerian Model. Atmospheric Environment 31: 2707-2732.

Park J-G and L.R. Curtis (1997) Mercury distribution in sediments and bioaccumulation by fish in two Oregon Reservoirs: point-source and nonpoint-source impacted systems.

Peakall, D.B. and R.J. Lovett. (1972) Mercury: its occurrence and effects in the ecosystem. BioScience 22(1):20-25.

Perry, D. M., J. S. Weis and P. Weis (1988) Cytogenetic effects of methylmercury on embryos of the killifish, Fundulus heteroclitus. Arch. Envir. Contam. Tox., 17:569-574.

Pfeiffer, W.C., L.D. de Lacerda, O. Malm, C.M. Souza, E.G. da Silveira and W.R. Bastos (1989) Mercury concentrations in inland waters of gold mining areas in Rondonia, Brazil. Science Total Environ. 87-88:233-240.

Pflugh, K.K., L. Lurig, L.A. von Hagen, S. Von Hagen and J. Burger (1999) Urban anglers' perception of risk from contaminated fish, Sci. Tot. Environ. 228:203-218.

Pillay, K.K.S., C.C. Thomas Jr., J.A. Sondel and C.M. Hyche CM (1972) Mercury pollution of Lake Erie ecosphere, Environ. Res. 5:172-181.

Prestbo, E.M. and N.S. Bloom (1994) Mercury Speciation Adsorption (MESA) Method Intercomparison Results in Combustion Flue Gas. In: Proceedings of the Eleventh Annual International Pittsburgh Coal Conference: Coal-Energy and the Environment, Volume 1. The University of Pittsburgh School of Engineering Center for Energy Research, September 12-16, 1994, pp. 557-562.

Price, P.S; Su, S.H, Gray, M.N. (1994) The effect of sampling bias on estimates of angler consumption rates in creel surveys. J. Exposure Anal. Environ. Epidemiol. 4:355-372.

PTI (1997) Alternative Risk-Based Residential Cleanup Level for Mercury in Hawthorne Site Soil. Vol. 1 - Technical Report. Prepared for Merck & Co. Inc., Somerset, NJ. PTI Environmental Services, Bellevue, WA., March 1997.

Ramazzini, B. 1713. De Morbis Artificum Diatriba. Translation by W.C. Wright. Univ. Chicago Press, Chicago.

Ramprashad, F. and K. Ronald. (1977) A surface preparation study on the effect of methylmercury on the sensory hair cell population in the cochlea of the Harp Seal (Pagophilus groenlandicus Erxleben, 1977) Canad. J. Zool. 55: 223-230.

Rappe, A. (1973) Influence de la pollution par le mercure sur les populations d'oiseaux. L'Oiseau et R.F.O. 43: 196-204.

Redmayne, A.C., Kim, J.P., Closs, G.P. and Hunter, K.A. (2000) Methyl mercury bioaccumulation in Long-finned Eels *Anguilla dieffenbachia,* from three rivers in Otago, New Zealand. Sci. Total Environ. 262:37-47.

Reid, R.N., J.E. O'Reilly & V.S. Zdanowicz (1982) Contaminants in New York Bight and Long Island Sound sediments and demersal species, and contaminant effects on benthos, summer 1980: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center,Woods Hole, Mass., 96 pp.

Ribeyre, F. and A. Bouduo (1994) Experimental study of inorganic and methylmercury bioaccumulation by four species of freshwater rooted macrophytes from water and sediment contamination sources. Ecotoxicol Environ Saf. 28:270-286.

Rice, D.C. (1995) Neurotoxicity of lead, methylmercury, and PCB's in relation to the Great Lakes, Environmehtal Health Persepctive 103(supplement 9): 71-81.

Rice, D.C. (2000) Identification of functional domains affected by developmental exposure to methylmercury: Faroe Islands and related studies, Neuro. Toxicol. 21:1039-1044.

Riley, D.M., C.A. Newlov, T.O. Leal-Almerz & V.M. Thomas (2001) Assessing elemental mercury vapor exposure from cultural and religious practices, Environ. Health Perspect. 109:779-784.

Rissanen T., S. Voutilainen, K. Nyyssonen, T.A. Lakka and J. Salonen (2000) Fish oil-derived fatty acids, docosahexaenoic acid and docosapentaenoic acid , and the risk of acute coronary events: the Kuopio ischaemic heard disease risk factor study. Circulation 102:2677-2679.

Roberts, M. R. and K. E. Clark. (1995) Evaluation of contaminant residues in Delaware Bay bald eagle nestlings. Report by USFWS, NJ Field Office (Pleasantville) and NJDEP, Division of Fish, Game and Wildlife (Tuckahoe).

Rompala, J.M., F.W. Rutosky, and D.J. Putnam (1984) Concentrations of environmehtal contaminants from selected waters in Pennsylvania. US Fish and Wildlife Services Report, State College, PA.

Ronald, K, S.V. Tessaro, J.F. Uthe, H.C. Freeman, and R. Frank. (1977) Methylmercury poisoning in the Harp Seal (Pagophilus groenlandicus) Sci. Total Environ. 8: 1-11.

Rupp, E.M., Miller, F.L., and Baes, C.F. (1980) Some results of recent surveys of fish and shellfish consumption by age and region of U.S, residents. Health Physics 39:169-175.

Salonen J.T, Seppanen K, Nyyssonen K, Korpela H, Kauhanen J, Kantola M, Tuomilehto J, Esterbauer H, Tatzber F, and Salonen R (1995) Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary cardiovascular, and any death in eastern Finnish men. Circulation 1; 9: 645-55.

Santoro, E.D., and S.J. Koepp (1986) Mercury levels in organisms in proximity to an old chemical site (Berrys Creek, Hackensack Meadowlands, New Jersey, USA) Mar. Poll. Bull. 17(5): 219-224.

Schantz, S.L. (1996) Developmental neurotoxicity of PCBs in humans: what do we know and where do we go from here. Neurotox and Teratol. 18217-227, 1996.

Scheuhammer, A.M. 1991. Effects of acidification on the availability of toxic metals and calcium to wild birds and mammals. Environ. Pollut. 71: 329-375.

Schuler, C.A., R.G. Anthony and H.M. Ohlendorf (1990) Selenium in wetlands and waterfowl foods at Kesterson Reservoir, California, 1984. Arch. Environ. Contam. Toxicol. 19:854-853.

Seigneur, C., K. Lohman, P. Pai, K. Heim, D. Mitchell and L. Levin (1999) Uncertainty Analysis of Regional Mercury Exposure. Water, Air and Soil Pollution 112:151-162.

Shephard, B.K. (1998) Quantification of ecological risks to aquatic biota from bioaccumulated chemicals. Pp. 2-31 to 2-52, IN: National Sediment Bioaccumulation Conference Proceedings. September 11-13, 1996, Bethesda, Maryland. USEPA 823-R-98-002, Office of Water.

Simon, O. and A. Boudou (2001a) Direct and Trophic Contamination of the Herbivorous Carp Ctenopharyngodon idella by Inorganic Mercury and Methylmercury. Ecotoxicol Environ Safety. 50:48-59.

Simon, O. and A. Boudou (2001b) Simultaneous experimental study of direct and direct plus trophic contamination of the crayfish Astacus astacus by inorganic mercury and methylmercury. Environ Toxicol Chem. 20:1206-1215.

Sites, A. (1994) Removing mercury using POET systems. Water Conditioning and Purification, October 1994: 94-99.

Sjoblom, A., Meili, M., and Sundbom, M. (2000) The influence of humic substances on the speciation and bioavailability of dissolved mercury and methylmercury, measured as uptake by Chaoborus larvae and loss by volatilization. Science Total Environ. 261:115-124.

Smith, J.C., P.V. Allen and R. Von Burg (1997) Hair methylmercury levels in US women, Arch. Env. Health 52:476-580.

Smith, H.M. and E.D. Brodie, Jr. (1982) A Guide to Field Identification, Reptiles of North America. Golden Press, New York, 240 pages.

Smith, G.M., A.T. Khan, J.S. Weis and P. Weis. (1995) Behavior and brain chemistry correlates in nummichogs (*Fundulus heteroclitus*) from polluted and unpolluted environments. Mar. Environ. Res. 39: 329-333.

Smith, G.M., and J.S. Weis (1997) Predator-prey relationships in mummichogs (Fundulus heteroclitus (L.): effects of living in a polluted environment. J Exper Marine Biol Ecol. 209:75-87.

Snarski, V.M. and G.F. Olson. (1982) Chronic toxicity and bioaccumulation of mercuric chloride in the Fathead Minnow (Pimephales promelas) Aquat. Toxicol. 2: 143-156.

Snodgrass, J.W., Jagoe, C.H., Bryan, L., Brant, H.A. and Burger, J. (2000) Effects of trophic status and wetland morphology, hydroperiod and water chemistry on mercury concentration in fish. Canad. J. Fisher. Aquatic Sci. 57:171-180.

Snyder, N.F.R., Snyder, H.A., Lincer, J.L. and Reynolds, R.T. (1973) Organochlorines, heavy metals, and the biology of North American Accipiters. BioScience, 23: 300-305.

Solonen, T. And M. Lodenius (1990) Feathers of birds of prey as indicators of mercury contamination in southern Finalnd, Holarct Ecol. 13: 229-237.

Solonin and Lodenius. (1984)

Southworth, G.R., M.J. Peterson and M.G. Ryon (2000) Long-term increased bioaccumulation of mercury in Largemouth Bass follows reduction of waterborne selenium, Chemosphere 41:1101-1105.

Spalding, M.G., P.C. Frederick, H.C. McGill, S.N. Bouton and L.R. McDowell (2000a) Methylmercury accumulation in tissues and its effects on growth and appetite in captive Great Egrets, J. Wildlife Diseases 36:411-422.

Spalding, M.G., P.C. Frederick, H.C. McGill, S.N. Bouton, L.J. Richey, I.M. Schumacher, C.G.M. Blackmore and J. Harrison (2000b) Histologic, neurologic, and immunologic effects of methylmercury in captive Great Egrets, J. Wildlife Diseases 36:423-435.

Spronk, N. and G.C. Hartog. (1970) Mercury in birds of prey. Ardea 59:34-37.

Spry, D.J. and J.G. Wiener (1991) Metal bioavailability and toxicity to fish in low-alkalinity lakes: a critical review, Environ. Pollut. 71: 243-304.

Steidl, R. J., C. R. Griffin, and L. J. Niles. (1991) Contaminant levels in osprey eggs and prey reflect regional differences in reproductive success. J. Wildl. Manage. 55(4): 601-608.

Stern, A.H., (1997a) A Review of Merck Submission on Bioavailability of Mercury Contamination at Hawthorne Site " NJDEP Memo from Alan Stern to Barry Frasco, July 28.

Stern, A.H. (1997b) An Estimate of Hg Inhalation Exposure Potential." Memo from Alan Stern to Eileen Murphy. Division of Science and Research, NJDEP, October 15, 1997.

Stern, A.H., M. Gochfeld, C. Weisel and J. Burger (2001) Mercury and methylmercury exposure in the NJ pregnant population, Arch. Environ. Health., in press.

Stern, A.H., Korn, L.R., and Ruppel, B.E. (1996) Estimation of fish consumption and methylmercury intake in the New Jersey population. J. Exposure Analysis Env. Epidemiology 6:503-527.

Stevenson, E., R. England, & B. Ruppel (1995) A pilot study to assess trace levels of mercury in New Jersey lakes and precipitation, NJDEP-DSR Research Project Report, August 1995, 22 pp.

Stoewsand, G.S., C.A. Bache and D.J. Lisk (1974) Dietary selenium protection of methylmercury intoxication of Japaneses quail, Bull. Environ. Contam. Toxicol 11(2):152-156.

Styrishave, B. And M.H. Depledge (1996) Evaluation of mercury-inducted changes in circadian heart rate rhythms in the freshwater crab, *Potamon potarnios*, and the crayfish, *Astacus astacus*, as an early predictor of mortality, Comparative Biochemistry and Physiology A-Physiology 115(4):349-356.

Sutton, C.C., J.C. O'Herron, II, and R. T. Zappalorti (1996) The scientific characterization of the Delaware Estuary. A publication of the Delaware Estuary Program.

Sweet, C., E. Prestbo, and B. Brunette (1999) Wet deposition of mercury in the US and Canada, presented at "Mercury in the Environment Specialty Conference," September 15-17, 1999, Minneapolis, MN, Proceedings published by Air and Waste Mgmt. Assoc., Pittsburgh, PA.

Tejning, S. (1967) Biological effects of methyl mercury dicyandiamide treated grain in the domestic fowl Gallus gallus L. Oikos 1967 Suppl. 8:1-116.

Thompson D.R., R.W. Furness and R.T. Barrett (1992) Mercury concentrations in seabirds from colonies in the northeast Atlantic, Arch Environ Contam Toxicol.23:383-389.

Thompson, D.R. and R.W. Furness (1989) Comparison of the levels of total and organic mercury in seabird feathers, Marine Pollution Bull. 20:577-579.

Thompson, D.R., R.W. Furness and L.R. Monteiro (1998) Seabirds as biomonitors of mercury inputs to epipelagic and mesopelagic marine food chains. Science Total Environ. 213:299-305.

Toxics in Biota Committee (1994) Mercury Contamination in New Jersey Freshwater Fish - Report of the Toxics in Biota Committee. New Jersey Department of Environmental Protection, New Jersey Department of Health, New Jersey Department of Agriculture. July 1994.

United States Geological Survey (USGS) (1997) Mercury in Ground Water, Soils, and Sediments of the Kirkwood-Cohansey Aquifer System in the New Jersey Coastal Plain. Open-File Report 95-475. US Geological Survey, West Trenton, NJ.

US Department of Energy (USDOE) (1994) National Environmental Research Parks. Washington, DC.

US Fish and Wildlife Service (USFWS) 1990. Concentrations of organochlorines and trace elements in fish andBlue Crabs from the Delaware River. Easton to Deepwater. Pennsylvania Field Office, Rept. N. 90:5-05. United States Fish and Wildlife Service, 19 pp.

US Food and Drug Administration (USFDA) (1994) FDA Consumer Report, Consumpiton advice on eating shark and swordfish.

US Environmental Protection Agency (USEPA) 1991. ECOTOX: Ecological Database. Office of Research and Development.

US Environmental Protection Agency (USEPA) (1992) National Study of Chemical Residues in Fish vols. I and II. Report # 823-R-92-008 Washington DC: US Environmental Protection Agency.

US Environmental Protection Agency (USEPA) (1992a) Guidelines for Exposure Assessment. USEPA/600Z-92/001. FR 57: 22888 - 22938

US Environmental Protection Agency (USEPA) (1992b) Characerization of products containing mercury in municipal solid wastes in the US, 1970 to 2000, USEPA 530-R-92-013, USEPA, Office of Solid Waste and Emergency Response.

US Environmental Protection Agency (USEPA) (1993) National Fish Tissue Data Repository, USEPA, Washington, DC.

US Environmental Protection Agency (USEPA) (1995a) Method 669. Sampling ambient water for trace metals at EPA water quality criteria levels. USEPA. 821-R-95034.

US Environmental Protection Agency (USEPA) (1995b) The use of the benchmark dose approach in health risk assessment. Office of Research and Development, Washington, DC: USEPA/630/R-94/007, February, 1995

US Environmental Protection Agency (USEPA) (1998) An SAB Report: Review of the USEPA Draft Mercury Study Report to Congress. USEPA-SAB-EC-98-001. October 1997.

US Environmental Protection Agency (USEPA) (1997c) Mercury Study Report to Congress. Vol. 3: Fate and Transport of Mercury in the Environment, USEPA-452/R-97-003. US Environmental Protection Agency, Washington, DC.

US Environmental Protection Agency (USEPA) (1997b) Mercury Study Report to Congress. Vol. 4: An Assessment of Exposure to Mercury in the United States. USEPA-452/R-97-006.

US Environmental Protection Agency (USEPA) (1997c) Mercury Study Report to Congress, Vol. 5: Health Effects of Mercury and Mercury Compounds. USEPA-452/R-97-007.

US Environmental Protection Agency (USEPA) (1997e) Mercury Study Report to Congress, Vol. 7: Characterization of Human Health and Wildlife Risks from Mercury Exposure in the United States. USEPA-452/R-97-009.

US Environmental Protection Agency (USEPA) (1999b) National Recommended Water Quality Criteria. USEPA 822-Z-99-001. Office of Water.

US Environmental Protection Agency (USEPA) 1999c. Passaic River Study Area. Fact sheet. Web page: ww.epa.gov/region02/superfnd/pass-ou2.htm.

US Environmental Protection Agency (USEPA) (2000) Workshop on Source Emission and Ambient Air Monitoring of Mercury: Bloomington, MN September 13-14, 1999. USEPA/625/R-00/002) June 2000.

US Environmental Protection Agency (USEPA (2001) Water quality criterion for protection of human health: Methylmercury - Final. USEPA-823-R-01-001.

United States Food and Drug Administration (USFDA) (1992) Compilation of Methylmercury Results by Species for FY91 and FY92. Office of Seafood. Washington, D.C.

Vahter M, A. Akesson, B. Lind, U. Bjors, A. Schutz and M. Bergluund (2000) Longitudinal study of methylmercury and inorganic mercury in blood and urine of pregnant and lactating women, as well as in umbilical cord blood. Environ. Research 84:186-194.

Van Metre P.C. & E. Callendar (1997) Study plan for the reconstructed trends project of the National Water Quality Assessment Program. Website: http://tx.usgs.gov/coring/approach.html United States Geological Survey. 1999. National Water Quality Assessment Program.

Varanasi, U., J.E. Stein, K.L. Tilbury, J.P. Meador, C.A. Sloan, D.W. Brown, J. Calambokidis, and S. Chan. (1993) Chemical contaminants in Gray Whale (Eschrichtius robustus) stranded in Alaska, Washington, and California, USA. NOAA Technical Memorandum NMFS-NWFSC-11, 115 p.

Vermeer, K., F.A.J. Armstrong and D.R.M. Hatch (1973) Mercury in aquatic birds at Clay Lake, western Ontario. J. Wildlife Manage. 37:58-61.

Versar, Inc. (1994) Estimates of contaminant inputs to the Delaware Estuary from nonpoint sources. Contract report to the Delaware Estuary Program.

Verta M. (1990) Changes in fish mercury concentrations in an intensively fished lake. Can J Fish Aquatic Sci 47:1888-1897.

Wagemann, R. and D.C.G. Muir. (1984) Concentration of heavy metals and organochlorines in marine mammals of northern waters: overview and evaluation. Canadian Technical Report of Fisheries and Aquatic Sciences 1279.

Wang, A., Barber, D., and Pfeiffer, C.J. (2001) Protective effects of selenium against mercury toxicity in cultured Atlantic Spotted Dolphin (Stenella plagiodon) renal cells. Arch. Environ. Contam. Toxicol. 41:403-409.

Weihe, P., P. Grandjean, F. Debes, and R. White (1996) Health implication for Faroe Islanders of heavy metals and PCBs from Pilot Whales. Science Total Environ. 186:141-148.

Wiener, J.G. (1996) Mercury in fish and aquatic food webs. Paper presetned at US Geological Survey meeting, "Merucyr Cycling in the Environment," USGS, Office of Water Quality, Denver, CO.

Weis, J.S. and A.A. Khan (1990) Effects of mercury on the feeding behavior of the Mummichog, Fundulus heterolcitus, from a polluted habitat. Marine Environ Research 30:243-249.

Weis, J.S., and A.A. Khan (1991) Reduction in prey capture ability and condition in mummichogs from a polluted habitat. Trans. AM. Fish. Soc. 120: 127-129.

Weis, J. S. and P. Weis. (1977a) Effects of heavy metals on development of the killifish, Fundulus heteroclitus. J. Fish Biology, 11:49-54.

Weis, P. and J. S. Weis. (1977b) Methylmercury teratogenesis in the killifish, Fundulus heteroclitus. Teratology, 16:317-326.

Weis, J.S. and P. Weis (1989) Tolerance and stress in a polluted environment: the case of the Mummichog. BioScience 39:89-95.

Weis, J.S. and P. Weis (1995a) Swimming performance and predator avoidance by mummichog (Fundulus heteroclitus) larvae after embryonic or larval exposure to methylmercury. Can J Fish Aquatic science 52: 2168-2173.

Weis, J.S. and P. Weis (1995b) Effects of embryonic exposure to methylmercury on larval prey-capture ability in the Mummichog, Fundulus heteroclitus. Environ Toxicol Chemistry 14:153-156, 1995b.

Weis, J. S., P. Weis, and J.L. Ricci. (1981) Effects of cadmium, zinc, salinity, and temperature on the teratogenicity of methylmercury to the killifish (Fundulus heteroclitus) Rapp. P.-v. Réun. Cons. int. Explor. Mer, 178:64-70.

Wester, P.W. (1991) Histopathological effects of environmental pollutants B-HCH and methylmercury on reproductive organs in freshwater fish. Comp. Biochem. Physiol. 100C: 237-239.

Wiemeyer, S.N., D.M. Bunck, and C.J. Stafford (1993) Environmental contaminants in Bald Eagle eggs - 1980-1984 - and further interpretations of relationships to productivity and shell thickness. Arch. Environ. Contam. Toxicol. 24:213-227.

Wiemeyer, N., R.M. Jurek, and J.F. Moore (1986) Environmental contaminants in surrogates, foods and feathers of California Condors (Gymnogyps californianus) Environ. Monitor. Assess. 6:91-111.

Wiemeyer, S.N., T.G. Lamont, C.M. Bunck, C.R. Sindelar, F.J. Gramlich, J.D. Fraser and M.A. Byrd. (1984) Organochlorine pesticide, polychlorobiphenyl, and mercury residues in Bald Eagle eggs - 1969-1979 - and their relationship to shell thinning and reproduction. Arch. Environ. Contam. Toxicol. 13:529-549.

Wiener, J.G., W.F. Fitzgerald, C.J. Watras and R.G. Rada (1990) Partitioning and bioavailability of mercury in an experimentally acidified lake, Enviorn. Toxicol. Chem. 9:909-918.

Windom, H.L and D.R. Kendall (1979) Accumulation and biotransformation of mercury in coastal and marine biota pp. 303-324. in Nriagu, J.O. (ed) The Biogeochemistry of Mercury in the Environment. Elsevier-North Holland Press, Amsterdam.

Windom, H.L. & R.G. Smith, Jr. (1992) Analysis of mercury species in ground water using inductively coupled plasma - mass spectrometry and gas chromatography, Final Report to NJDEP, September, 30 pp.

Wobeser, G. (1975) Prolonged oral administration of methylmercury chloride to Rainbow Trout (*Salmo giardneri*) J. Fish. Res. Board Can. 32: 2015-2023.

World Health Organization (WHO) (1990) Environmental Health Criteria; 101, Methylmercury. Geneva, Switzerland.

World Health Organization (WHO) (1991) Inorganic Mercury. Environmental Health Criteria 118. Geneva.

Yanochko, G.M., Jagoe, C.H. and Brisbin, I.L. Jr. (1997) Tissue mercury concentrations in Alligators (*Alligator mississippiensis*) from the Florida Everglades and the Savannah River Site, South Carolina. Arch. Environ. Contam. Toxicol. 32:323-328.

Yess, N.J. (1993) US Food and Drug Administration Survey of Methyl Mercury in Canned Tuna. J. AOAC International 76:36-38.

Zallups, R.K. (1997) Renal toxicity of mercury. Pp. 633-652 in Comprehensive Toxicology vol. 7: Renal Toxicology (Sipes I.G., McQueen, C.A. and Gandolfi, A.J., eds) Pergamon Press, New York.

Zdanowicz, V.S. and D. Gadbois (1990) Contaminants in sediment and fish tissue from estuarine and coastal sites of the northeastern United States : data summary for the baseline phase of the National Status and Trends Program Benthic Surveillance Project, 1984-1986. : U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, Mass, 138 pp.

Zillioux, E.J., D.B. Porcella and J.M. Benoit (1993) Mercury cycling and effects in freshwater wetland ecosystems, Environ. Toxicol. Chem. 12: 2245-2264.

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

STATE OF NEW JERSEY, et al.,	:	
	:	
Petitioners,	:	No. 05-1097, and consolidated cases
	:	
v.	:	Complex
	:	
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY,	:	
	:	
Respondent.	:	

DECLARATION OF RAYMOND VAUGHAN
CONCERNING PLAINTIFF STATE OF NEW YORK'S STANDING

Pursuant to 28 U.S.C. § 1746, Raymond Vaughan declares as follows:

Overview

1. I am an environmental scientist employed by the New York State Office of the Attorney General.

2. I submit this declaration in support of the petitions for review filed in these consolidated actions by the States of New Jersey, California, Connecticut, Delaware, Illinois, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, New Mexico, New York, Rhode Island, Vermont and Wisconsin, the Pennsylvania Department of Environment Protection and the City of Baltimore (collectively, the "Government Petitioners").

3. In this declaration, I explain that New York's natural resources have been damaged by mercury contamination and that a substantial portion of that damage appears to have been caused by mercury emissions from coal-fired electric utility steam generating units ("power plants"), some located within New York and others located outside of, and upwind from, the state. I also explain that those mercury emissions will continue at an unduly high level under the regulatory actions that are the subject of this litigation. In the first of those actions, which the Government Petitioners refer to as the "Delisting Action,"[1] the U.S. Environmental Protection Agency ("EPA") has decided not to regulate power plant mercury emissions via the maximum achievable control technology ("MACT") standard approach contemplated by Section 112 of the Clean Air Act ("CAA"), 42 U.S.C. § 7412. In the second action, known as the Clean Air

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[1] See Revision of December 2000 Regulatory Finding on the Emissions of Hazardous Air Pollutants from Electric Utility Steam Generating Units and the Removal of Coal- and Oil-Fired Electric Utility Steam Generating Units from the Section 112(c) List; Final Rule, 70 Fed. Reg. 15994 (March 29, 2005).

Mercury Rule, or CAMR, EPA has promulgated a cap-and-trade plan whereby, in essence, each individual power plant will receive permission to emit a certain amount of mercury, total power plant mercury emissions nationwide will be capped at a certain level and individual power plants will be able to trade their mercury emission allowances.[2] As I explain in paragraphs 15 and 16 below, a proper Section 112 approach would rapidly reduce total domestic power plant emissions of mercury to approximately 6 tons per year. In contrast, EPA itself estimates that it will take at least 13 more years for CAMR to reduce those emissions to 24 tons per year — or 4 times the amount of mercury that would be emitted each year under a proper Section 112 approach. In sum, EPA's regulatory approach will ensure that New York's natural resources are burdened with ongoing and unduly high mercury exposure for many years to come.

Personal Background

4. I am currently employed by the New York State Attorney General's Office as an Environmental Scientist III and I have worked in this office as an environmental scientist since 2000. My responsibilities as an environmental scientist have included, among others, researching and evaluating federal and state laws and regulations that may affect New York State's environment and the health and welfare of New York's citizens.

5. I received a B.S. in Math and Astronomy from Empire State College of the State University of New York in 1975, and I am currently a candidate for a Ph.D. in Geology at the State University of New York at Buffalo. A copy of my resume is attached hereto as Exhibit A.

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[2] See Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units; Final Rule, 70 Fed. Reg. 28606 (May 18, 2005).

Mercury Contamination in New York State

6. According to the New York State Department of Health's listing of fish consumption advisories for 2006-2007, New York currently has 86 rivers, ponds, lakes and/or reservoirs that are subject to fish consumption advisories based on mercury contamination.[3] This number has increased in recent years. NYS DOH's 2005-2006 list included 71 New York State water bodies with advisories based on mercury contamination. And one year before that there were less than 50 New York State water bodies with advisories based on mercury contamination. In addition, mercury contamination is now so pervasive in New York's Adirondacks region that in 2005 the New York State Department of Health warned women of childbearing years and children under the age of fifteen that they should not eat any amount of certain types of fish taken from any Adirondack waters.[4]

7. Additional evidence exists of harm to New York's wildlife, especially common loons inhabiting aquatic habitats within New York State. In particular, a study published in the January 2007 issue of BioScience, a peer-reviewed scientific journal, reports on the existence of a "biological mercury hotspot" in New York's central Adirondack Mountains where 25% of the loons are found to have concentrations of mercury above a level of concern based on

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[3] See NYS DOH, Chemicals in Sportfish and Game, 2006-07 Health Advisories (listing fish advisories) (available at http://www.health.state.ny.us/environmental/outdoors/fish/docs/fish.pdf).

[4] See DOH Press Release, April 15, 2005 (available at (http://www.health.state.ny.us/press/releases/2005/2005-04-15_2005_fish_advisory_release.htm)

physiological, behavioral, and reproductive effects in the birds.[5] A related study by some of the same authors indicates that, "For the common loon, existing Hg concentrations can cause adverse individual (behavioral and reproductive) and population-level effects."[6]

8. Although fish consumption is generally thought of as the primary pathway by which other animals and humans are exposed to mercury, recent evidence indicates that mercury contamination and exposure may, in fact, be much more pervasive. For example, a recent study reportedly indicates that dozens of species of woodland birds in New York State have high mercury levels despite the fact that they do not live on water and do not eat fish.[7] This study suggests that mercury contamination exists not only in New York's aquatic environments, but also its terrestrial habitats.

9. Recent research also appears to indicate that New York is particularly susceptible to mercury deposition. Driscoll et al. find that the northeastern United States, consisting of New England and New York, "receives elevated Hg deposition and contains ecosystems sensitive to Hg inputs."[8] The elevated mercury deposition is due in part to the large proportion of wooded land in the northeastern states and the way in which the large leaf surface area of forests interacts

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[5] D.C. Evers et al., "Biological Mercury Hotspots in the Northeastern United States and Southeastern Canada," 57 BioScience 29 (2007) at 30-32, 33 (Fig. 2), and 34 (Table 2) (Attached hereto as Exhibit B and referred to in subsequent citations as "Evers 2007").

[6] C.T. Driscoll et al., "Mercury Contamination in Forest and Freshwater Ecosystems in the Northeastern United States," 57 BioScience 17 (2007) at 26 (Attached hereto as Exhibit C and referred to in subsequent citations as "Driscoll 2007").

[7] A. DePalma, "Study of Songbirds Finds High Levels of Mercury," New York Times, July 25, 2006.

[8] Driscoll 2007 at 18.

with mercury in the air.[9] Wooded areas in New York include large state-owned tracts such as the 65,000-acre Allegany State Park, the Adirondack Park, and many other state forests and wooded parks.[10] Evers et al. emphasize that "Forests enhance landscape sensitivity to atmospheric Hg deposition."[11]

Power Plants are a Source of New York's Mercury Contamination Problems

10. Certain industrial sources are responsible for a large portion of the mercury emitted into the atmosphere. Approximately 30% of domestic man-made mercury emissions, or well over 40 tons per year, come from coal-fired power plants.[12] Indeed, based on 1999 data, EPA has concluded that domestic coal-fired power plants emit approximately 48 tons of mercury per year.[13] EPA data also shows that several states directly upwind from New York are significant sources of mercury emissions, and that those states emit far more mercury than does New York.[14] This pattern is likely to continue under CAMR because that rule provides that the

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[9] Driscoll 2007 at 20.

[10] More specific descriptions of New York State forests and wooded areas can be found at three websites maintained by New York State agencies: http://www.dec.state.ny.us/website/dlf/publands/regmap.html (maintained by the New York State Department of Environmental Conservation), http://nysparks.state.ny.us/ (maintained by the New York State Office of Parks, Recreation and Historic Preservation), and http://www.apa.state.ny.us/State_Land/index.html (maintained by the New York State Adirondack Park Agency).

[11] Evers 2007 at 35.

[12] 65 Federal Register 79825, 79827-28 (Dec. 20, 2000).

[13] See 70 Federal Register at 28619 (2d Column).

[14] See EPA, Emissions Inventory and Emissions Processing for the Clean Air Mercury Rule (CAMR), OAR-2002-0056-6129, Table 7 (especially the data for the States of New York, Ohio, Pennsylvania, West Virginia and Indiana).

states of Ohio, Pennsylvania, Indiana and West Virginia (among others) all have mercury emission budgets that are much greater than New York's.[15]

11. In a modeling study that looked specifically at the sources of mercury deposited in New York, Seigneur et al. found that 25 to 49% of mercury deposition within the state came from sources within the contiguous United States exclusive of New York, and that these were the "largest sources of total deposition of Hg" for New York.[16] Various authors have identified coal-fired power plants as a substantial contributor to mercury deposition in New York and other northeastern states. For example, Evers et al. identify coal-fired electric utilities as "[t]he largest single source in the United States" and indicate that "Mercury can be deposited locally or travel great distances..."[17] Dastoor and Larocque show the relationship of global weather patterns to the generally eastward transport of mercury across the United States.[18]

12. In a computer modeling study of mercury deposition in the Great Lakes -- including Lakes Ontario and Erie, major parts of which are New York's waters – Cohen et al. found the annual mercury deposition from U.S. and Canadian sources combined (expressed in g/km^2 or in the equivalent measure of $\mu g/m^2$ (micrograms per square meter)) to be about 19 $\mu g/m^2$ for Lake Erie and about 13 $\mu g/m^2$ for Lake Ontario, and they noted that "coal combustion

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[15] See 71 Fed. Reg. 33388, 33398-99 (table setting forth final state mercury emission budgets under CAMR).

[16] C. Seigneur et al., "Contributions of global and regional sources to mercury deposition in New York State," 123 Environmental Pollution 365-373 (2003), at 365, 371.

[17] Evers 2007 at 34.

[18] A. Dastoor and Y. Larocque, "Global circulation of atmospheric mercury: a modelling study," 38 Atmospheric Environment 147-161 (2004), at 154-56 (esp. Figs. 4a-e and Figs. 5c-d).

was generally found to be the largest contributor to atmospheric mercury deposition to the Great Lakes."[19] Total annual mercury deposition from U.S. and Canadian sources combined is about 450 kg/yr for Lake Erie and 250 kg/yr for Lake Ontario, according to their model.[20] For both Lakes Erie and Ontario, they find at least 70% of the modeled deposition is from sources more than 100 km away, and about 25% of the deposition is from sources more than 400 km away.[21] The authors conclude that "Overall, coal combustion in the United States was found to be the most significant source category contributing mercury through atmospheric deposition to the Great Lakes."[22]

13. Using results from its own computer model, EPA finds that the annual mercury deposition in New York from coal-fired power plants alone is 5 to10 $\mu g/m^2$ in the western part of the state, 1 to 5 $\mu g/m^2$ throughout much of the state, and 0 to 1 $\mu g/m^2$ in the northeastern corner of the state.[23] However, EPA may have underestimated the amount of mercury deposited onto forested areas downwind from coal-fired power plants and other emission sources because the interaction between elemental mercury (Hg^0) and the leaves of trees has not been properly understood up to now. As described by Driscoll et al.,

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[19] M. Cohen et al., "Modeling the atmospheric transport and deposition of mercury to the Great Lakes," 95 Environmental Research 247-265 (2004), at 259 (Fig. 10) and 247 (referred to in subsequent citations as "Cohen 2004").

[20] Cohen 2004 at 259 (Fig. 10).

[21] Cohen 2004 at 262 (Fig. 13).

[22] Cohen 2004 at 262-63.

[23] U.S. EPA, Technical Support Document ("TSD"), OAR-2002-0056-6301, at 7 (Fig. 2.2).

> Elemental Hg, which is relatively unreactive and generally slowly oxidized, constitutes by far the largest pool of Hg in the atmosphere because of its relatively long residence time (0.5 to 2 years) and long-range transport potential (tens of thousands of kilometers). However, under some conditions Hg^0 can be rapidly oxidized and deposited locally or regionally, as observations have shown in the Arctic and Antarctic..., at the marine and continental boundary layer, and in areas downwind of urban areas.... Elemental Hg can also be directly deposited to forested ecosystems through stomatal gas exchange.... As a result, the atmospheric lifetime of Hg^0 is probably closer to 0.5 year than to 2 years.[24]

Similarly, Evers et al. state that "Elemental Hg can also interact with the forest canopy, enhancing deposition rates..."[25] In my understanding, this is not a phenomenon recognized in EPA's modeling of mercury deposition. By not taking this phenomenon into account, EPA is likely underestimating the deposition of elemental mercury downwind from coal-fired power plants.

14. EPA expects that reductions in mercury emissions from power plants will result in reduced mercury deposition. See EPA Methodology TSD, OAR-2002-0056-6186, Section 2.

CAMR Will Not Reduce Power Plant Mercury Emissions
as Extensively or as Rapidly as a Proper Section 112 Regulatory Approach

15. Although EPA describes CAMR as setting a cap on power plant mercury emissions of 15 tons per year as of 2018,[26] EPA has concluded that as of 2020, *actual* mercury emissions under CAMR will remain at 24 tons per year.[27] Thus, thirteen years from now, CAMR

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[24] Driscoll 2007 at 19 (internal citations omitted.)

[25] Evers 2007 at 35.

[26] See 70 Federal Register at 28606 (1st Column).

[27] Compare 70 Federal Register at 28606 (1st Column) (setting 2018 cap at 15 tons per year) with id. at 28619 (2d & 3d Columns) (admitting that even with the combined effect of CAMR and a separate rule known as the Clean Air Interstate Rule, mercury emissions in 2020 will be approximately 24 tons per year).

will have reduced power plant mercury emissions by just 50% from their 1999 levels — according to EPA's own estimates.

16. In contrast, the Government Petitioners have estimated (in comments that were submitted to EPA as part of the rulemakings now under review) that a proper Section 112 approach would reduce total domestic power plant mercury emissions to just 6 tons (or less) per year.[28] And because Section 112 MACT requirements take effect within three years after promulgation by EPA,[29] the reductions would be achieved much more rapidly than the reductions contemplated by EPA under CAMR. For example, if a proper MACT standard were to be promulgated in 2010 — three years from now — total domestic power plant mercury emissions would be reduced to approximately 6 tons per year by 2013.

17. Mercury deposition in New York is also likely to remain unnecessarily high under CAMR as compared to a proper MACT approach. EPA's own modeling shows remaining mercury deposition in New York in the year 2020 that can be attributed to coal-fired power plant emissions *after* implementation of CAIR and CAMR, ranging up to 2 to 3 micrograms per square meter in the southwestern part of the state.[30] *Additional* remaining mercury deposition in New York, over and above the amount predicted by EPA's computer model, is also likely because EPA's model does not appear to account properly for the above-described interaction between elemental mercury and forest canopy. New York's waters and lands – including such waters as

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[28] See Comments of New Jersey Attorney General, et al., dated June 28, 2004, Docket Number OAR-2002-0056-2823, pages A12 & A13.

[29] See 42 U.S.C. § 7412(i)(3)(A) (setting deadlines for compliance with MACT standards).

[30] TSD at 8-9 (Figs. 2.4 and 2.5).

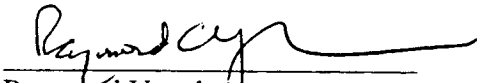
Lake Erie and Chautauqua Lake and such forested lands as Allegany State Park in the southwestern part of the state – would therefore continue to be impacted by this remaining mercury deposition, amounting to several micrograms per square meter, even after the full implementation of CAMR many years from now. By contrast, a proper MACT approach would reduce the mercury deposition in New York from coal-fired power plants more quickly and more completely. I reach this conclusion based on my own general knowledge of the relationship between emission and deposition, including the concept of transfer coefficients,[31] and on my review of studies that have assessed the emission-deposition relationship at different levels of emission reduction.[32]

Conclusion

18. Based on the evidence indicating that power plant mercury emissions are a significant source of mercury contamination in New York, and based on the contrast between the power plant emissions reductions that will be achieved under a proper MACT standard and the CAMR, I conclude that New York State's natural resources are being, and will continue to be, harmed by the Delisting Action and the CAMR.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on January 11, 2007.



Raymond Vaughan

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[31] Cohen 2004 at 255-57.

[32] For example, C. Seigneur et al., "Modeling the atmospheric fate and transport of mercury over North America: power plant emission scenarios," 85 Fuel Processing Technology 441-450 (2004), at 448-49 (Figs. 3-5).

State of New Jersey, et al., v. U.S. EPA, No. 05-1097, and consolidated cases

Exhibit A to
Declaration of Raymond Vaughan

RAYMOND C. VAUGHAN

135 East Main Street - Hamburg, NY 14075 - (716) 648-5861

SUMMARY

Environmental Scientist III with specialties in geology, hydrogeology, public policy, technical communication, numerical methods, environmental testing, site remediation, development of soil cleanup standards, chemical fate and transport (esp. mercury, dioxin, and other persistent bioaccumulative toxic chemicals), Great Lakes protection, aquatic invasive species policy and ballast water management technology, wetlands protection, climate change and carbon sequestration, bioassay and analytical methods, and research and development. Excellent working knowledge of physics, physical chemistry, electrochemistry, rheology, and properties of materials. Volunteer experience in technical and regulatory aspects of nuclear waste management, health effects of radiation, land-use planning, etc. Ph.D. candidate in geology at University at Buffalo. Five U.S. patents.

PROFESSIONAL EXPERIENCE

New York State Attorney General's Office, Environmental Protection Bureau, Buffalo, NY **1999-present**

Environmental Scientist	2000-present
Science Aide in Environmental Protection Bureau	1999-2000

- Part of multi-state legal/technical team to challenge inadequate federal mercury emission standards.
- Development of comments, petitions, and case preparation re: aquatic invasive species in Great Lakes.
- Site characterization and remediation projects, esp. in Livingston, Monroe, Genesee, and Orleans Counties.
- Field investigation, record review, and interagency consultation on wetlands policy and enforcement.
- Communication with experts for identification of litigation opportunities or case preparation.
- Consultation with various environmental organizations to identify possible issues of mutual interest.
- Creation and administration of Environmental Protection Bureau science intern program in Buffalo.

Graphic Controls Corporation, Buffalo, NY **1976-1998**

Senior Research Technician	1981-1998
Research Technician	1976-1981

- Development of EKG electrode products including Quikset, Q-Trace, and Meditrace 5700.
- Development of silver/silver chloride and graphite inks and conductive substrates.
- Development of hydrogels and conductive adhesives.
- Design, construction, and operation of prototype equipment for coating, curing, and printing.
- Product and component testing, including pH, viscoelastic properties, conductivity, and other electrical properties.

Carborundum Company, Niagara Falls, NY **1965-1975**

Research Technician

- Development of ceramic (boron nitride) fibers, high-temperature plastic fibers, and textile processes for converting fibers to yarn and cloth.

EDUCATION/AFFILIATIONS

- Ph.D. candidate in Geology, University at Buffalo, 1999-present
- B.S. in Math and Astronomy, State University of New York, 1975
- Massachusetts Institute of Technology, 1962-1964
- Steering Committee, Coalition on West Valley Nuclear Wastes, 1978-2006
- Member, West Valley Citizen Task Force, 1997-present
- Member, Town of Hamburg Conservation Advisory Board, 1980-1999
- Board of Directors, Western New York Land Conservancy, 1991-2002

PUBLICATIONS/PRESENTATIONS

R.C. Vaughan, K.B. Boomer, D.R. Simpson, "Examining EPA's Environmental Emission Limits for Mercury," in preparation.

R.C. Vaughan, T.D. Wood , D.J. Higbee, J.R. Olson, Y. Tondeur, S.J. Lupton, B.P. McGarrigle, "Applying an Effect-Directed Strategy to the Search for Unrecognized Toxic Chemicals," submitted to *Chemosphere*, 2006.

R.C. Vaughan, T.D. Wood , D.J. Higbee, J.R. Olson, Y. Tondeur, "Chromatographic Separation Strategy for Isolating and Characterizing Compounds with High Bioassay Response," presented at Dioxin 2005 conference, Toronto; published in *Organohalogen Compounds* **67**, 208 (2005).

R.C. Vaughan, "State Options for Controlling Aquatic Invasive Species in the Great Lakes," *National Environmental Enforcement Journal* **18**, 3 (2003).

R.C. Vaughan, "Ranking the Bioassay TEFs and REPs," presented at Dioxin 2003 conference, Boston; published in *Organohalogen Compounds* **60**, 165 (2003).

R.C. Vaughan, "Fending Off Orthodoxy with Ink and Umbrage: Church and State Controversy in Western New York, 1815-1837," presented at Conference on New York State History, Buffalo, 1998.

R.C. Vaughan (editor and coauthor), *'Low-Level' Radioactive Waste: The Siting Process in New York State*, 3rd ed., Norwich, NY, 1990.

State of New Jersey, et al., v. U.S. EPA, No. 05-1097, and consolidated cases

Exhibit B to
Declaration of Raymond Vaughan

Biological Mercury Hotspots in the Northeastern United States and Southeastern Canada

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Biological mercury (Hg) hotspots were identified in the northeastern United States and southeastern Canada using a data set of biotic Hg concentrations. Eight layers representing three major taxa and more than 7300 observations were used to locate five biological Hg hotspots and nine areas of concern. The yellow perch and common loon were chosen as indicator species for the human and ecological effects of Hg, respectively. Biological Hg hotspots receive elevated atmospheric Hg deposition, have high landscape sensitivity, and/or experience large reservoir fluctuations. In the Merrimack River watershed, local Hg emissions are linked to elevated local deposition and high Hg concentrations in biota. Time series data for this region suggest that reductions in Hg emissions from local sources can lead to rapid reductions of Hg in biota. An enhanced Hg monitoring network is needed to further document areas of high deposition, biological hotspots, and the response to emissions reductions and other mitigation strategies.

Keywords: biological mercury hotspots, mercury sources, common loon, mercury monitoring, yellow perch

Mercury (Hg) is a local, regional, and global pollutant that affects fish, wildlife, and human health. Recently, 71 scientists from New England, New York, and eastern Canada compiled and analyzed more than 30,000 observations of Hg levels in biota, including 40 fish and 44 wildlife species (Evers and Clair 2005). The resulting database is a powerful tool to quantify spatial patterns of Hg in biota across the northeastern United States and southeastern Canada (referred to here collectively as the Northeast).

We focus on biological Hg hotspots in the Northeast because the spatial heterogeneity of Hg deposition and methylmercury (MeHg) in biota is an issue of international concern. For example, fish consumption advisories concerning Hg contamination exist in each of the eastern Canadian provinces and 44 states in the United States, including all states within our study area. This pattern of advisories demonstrates that Hg contamination is widespread.

Current state and national policies to control Hg emissions from point sources include the consideration of cap-and-trade options. Trading allows the providers of coal-fired electric utilities to purchase pollution credits in order to meet a national cap, rather than requiring reduced emissions for all facilities. Thus, trading has the potential to lead to static or increased emissions in some areas of the United States, which may produce changes in Hg deposition, cycling, and biological uptake. Increased deposition near areas that are highly sensitive to Hg or already affected by Hg deposition could increase Hg contamination in fish, and may increase the risk to people and wildlife that consume fish. An understanding of the mechanisms contributing to biological Hg hotspots is important when Hg trading policies are considered.

Given the growing scientific evidence of Hg contamination (Evers et al. 2005, Kamman et al. 2005) and the public policy interest in identifying specific geographic areas that are disproportionately elevated in Hg, it is important to develop a common definition for the term "biological mercury hotspot." We define a biological Hg hotspot as a location on

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the landscape that, compared to the surrounding landscape, is characterized by elevated concentrations of Hg in biota (e.g., fish, birds, mammals) that exceed established human or wildlife health criteria as determined by a statistically adequate sample size.

There are important considerations in defining and identifying biological Hg hotspots. The sources of Hg contamination are not easily differentiated in ecosystems. Therefore, the identification of biological Hg hotspots, based on the effects of Hg pollution, should not be constrained to those areas where high Hg concentrations can be attributed to a single source or sector. Rather, multiple sources from multiple sectors can contribute to a hotspot, and as a result we do not limit the definition of a hotspot to a single source or sector.

Biological Hg hotspots can occur in diverse locations across the landscape, and are not restricted to areas of high Hg deposition. Landscapes have critical characteristics that influence Hg transport to surface waters, the methylation of ionic Hg, and the bioaccumulation of MeHg in biota, thereby modifying sensitivity to Hg inputs (Driscoll et al. 2007). These characteristics include land cover, oxidation–reduction conditions, hydrologic flow paths, and nutrient loading. Modifications of the landscape, such as changes in land disturbance, can alter the supply of Hg to downstream aquatic ecosystems.

To further define and identify biological Hg hotspots in the Northeast, we analyzed the extensive existing database developed for Hg in fish and wildlife (Evers and Clair 2005). Although these summarized data are comprehensive, some areas within the Northeast remain poorly characterized for Hg, and additional biological Hg hotspots may exist. We also hypothesize mechanisms that contribute to the formation of the biological Hg hotspots. We use a case study of the lower and middle Merrimack River watershed, located in northeastern Massachusetts and southern New Hampshire, to estimate the impact of local emissions and assess the extent to which biota may respond to changes in local Hg emissions and deposition. Finally, we describe the need for increased long-term monitoring, process-level science, and improved Hg models to fill data gaps critical to locating hotspots, tracking changes in Hg levels, following emission controls, and assessing the impact of policy decisions.

Study area and methods

Regional databases of Hg in biota were gathered during a four-year effort by the Northeastern Ecosystem Research Cooperative (NERC) and published in a series of papers describing the distribution of Hg and MeHg in northeastern North America (Evers and Clair 2005). We used a subset of 7311 observations for seven species, in three major taxonomic groups that represent eight data layers, to quantify the spatial heterogeneity in tissue Hg concentrations (table 1, figure 1). Spatial data for Hg concentrations in biota were used to identify areas where the tissue burdens of Hg exceeded levels known to result in adverse effects.

The primary data layers for Hg concentrations in fillets of yellow perch (*Perca flavescens*) and in the blood and eggs of the common loon (*Gavia immer*) were used to locate biological Hg hotspots. Secondary data layers for whole-fish analysis of yellow perch and for Hg concentrations in large-mouth bass (*Micropterus salmoides*), brook trout (*Salvelinus fontinalis*), bald eagle (*Haliaeetus leucocephalus*), river otter (*Lontra canadensis*), and mink (*Mustela vison*) were used to locate areas of concern. All data are presented in terms of wet weight (ww) unless otherwise described as fresh weight (fw), which includes biotic material such as feathers and fur. All means are arithmetic. We also used data on surface water chemistry and land cover to evaluate the factors contributing to the spatial heterogeneity of Hg in biota.

Data preparation. To develop a common measure across the data set, we calculated standardized conversions of Hg concentrations for different tissue types in yellow perch and common loons. We used the Hg concentrations of standard-length (20-cm) yellow perch (Kamman et al. 2005), relying on whole-fish concentrations as an indicator of ecological risk and on fillet concentrations as an indicator of human health risk. Where only whole-fish concentrations were available, we converted these values to fillet equivalents using a regression of average-age mean Hg concentrations for fillets against mean whole-fish Hg concentrations developed from a set of statistically randomized lakes (fillet Hg = [1.63 • whole-body Hg] + 0.06; $F_{41,1} = 46.6$, $p < 0.001$, $r^2 = 0.54$; Kamman et al. 2004). This regression is similar to one performed for Hg levels in fish analyzed from lakes in the western United States (Peterson et al. 2005). Similarly, Hg values for the eggs of the common loon were converted to equivalent values for the blood of the adult female loon (female loon blood Hg = [1.55 • loon egg Hg] + 0.22; $r^2 = 0.79$; Evers et al. 2003).

Impact thresholds. The effects of MeHg exposure are difficult to measure. The US Environmental Protection Agency (USEPA) bases human health criteria on consumption models. We used the USEPA suggested advisory level of 0.30 μg Hg per g (ww) in fish muscle tissue to identify biological Hg hotspots of human health concern (USEPA 2001). This level triggers advisories of one or fewer fish meals per month for sensitive groups, such as pregnant women, women of childbearing years, and children less than 12 years of age.

To identify biological Hg hotspots that pose risks to ecological health, we used accepted thresholds for adverse effects from Hg in several wildlife species, as derived from the literature. One of the more comprehensive data sets for assessing the adverse effects of Hg on wildlife is from studies on the common loon.

Blood and egg Hg concentrations have been linked to demonstrated adverse effects in the common loon. The level of 3.0 μg Hg per g ww, which was developed *in situ*, is based on (a) physiological effects, such as higher average corticosterone levels and increased developmental instability (Evers et al. 2004); (b) behavioral effects, such as lethargy in chicks

Table 1. Summary statistics of biological data layers for mercury (Hg) concentrations in fish and wildlife (μg per g) in the northeastern United States and southeastern Canada.

Category/species	Sample size	Data layer designation	Hg concentrations: Mean ± standard deviation	Hg concentrations: Range	Hg level of concern (tissue type)	Percentage of samples with concentrations > level of concern
Human health						
Yellow perch[a]	4089	Primary	0.39 ± 0.49	< 0.05–5.24	0.30 (fillet)	50
Largemouth bass[b]	934	Secondary	0.54 ± 0.35	< 0.05–2.66	0.30 (fillet)	75
Ecological health						
Brook trout	319	Secondary	0.31 ± 0.28	< 0.05–2.07	0.16 (whole fish)	75
Yellow perch[c]	(841)[d]	Secondary	0.23 ± 0.35	< 0.05–3.18	0.16 (whole fish)	48
Common loon[e]	1546	Primary	1.74 ± 1.20	0.11–14.20	3.0 (blood)	11
Bald eagle	217	Secondary	0.52 ± 0.20	0.08–1.27	1.0 (blood)	6
Mink	126	Secondary	19.50 ± 12.1	2.80–68.50	30.0 (fur)	11
River otter	80	Secondary	20.20 ± 9.30	1.14–37.80	30.0 (fur)	15

Note: All data are in wet weight except for fur, which is on a fresh-weight basis.

a. Fillet Hg in yellow perch is based on individuals with a standardized length of 20 cm.

b. Fillet Hg in largemouth bass is based on individuals with a standardized length of 36 cm.

c. Whole-fish Hg in yellow perch is based on individuals with a standardized length of 13 cm. Whole-fish Hg for yellow perch was converted to fillet Hg.

d. The sample population of 841 yellow perch examined for whole-fish Hg is included with the 4089 fillets (i.e., the total number of all biotic data layers does not double-count yellow perch).

e. Egg Hg for the common loon was converted to the adult blood equivalent.

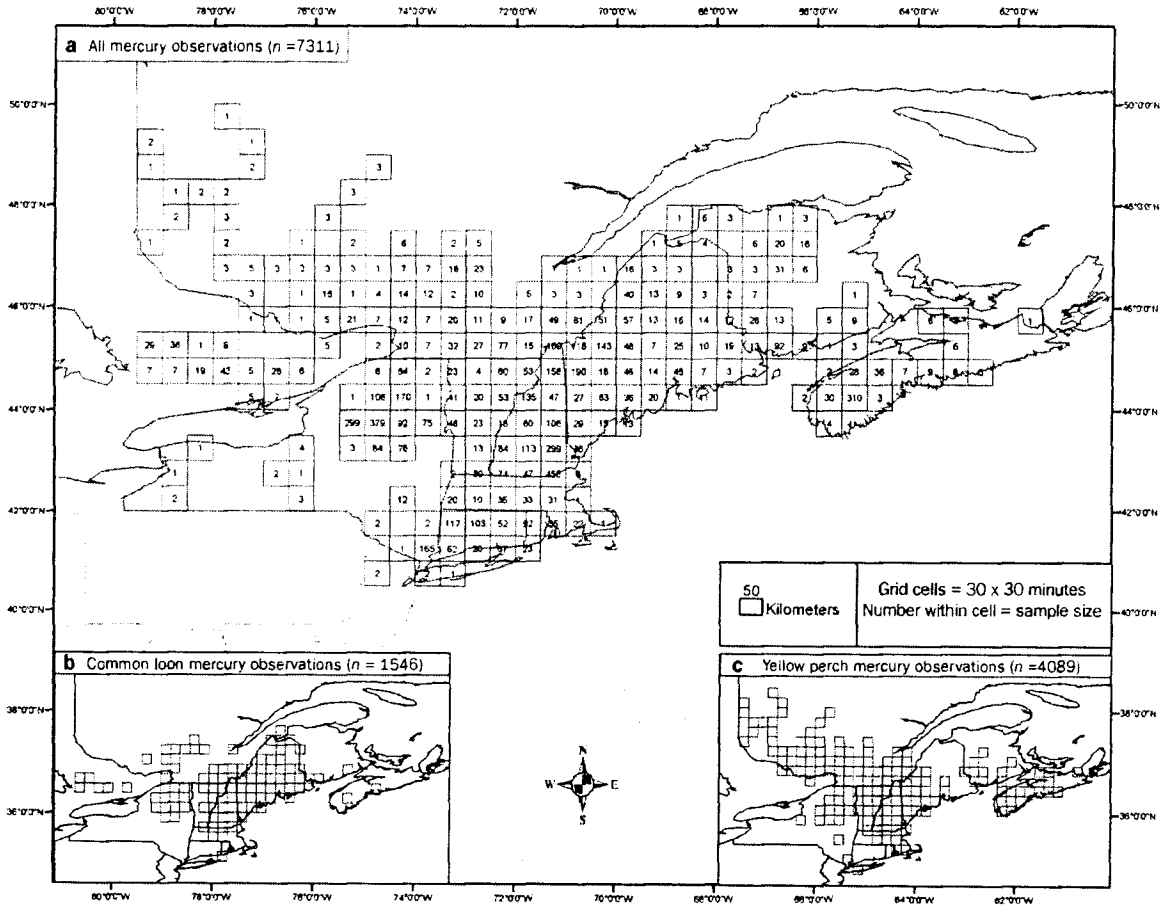

Figure 1. (a) Distribution of biotic mercury (Hg) observations across the northeastern United States and southeastern Canada, and specific distribution of Hg observations for (b) the common loon and (c) yellow perch.

(Nocera and Taylor 1998) and abnormal incubation patterns (Evers et al. 2004); and (c) reproductive effects, such as fewer fledged young from a territorial pair (Barr 1986, Burgess et al. 1998, Evers et al. 2004). Based on this level of concern and on estimates of nesting success, productivity levels can be modeled to determine population sinks and sources for loons (Evers et al. 2004, Nacci et al. 2005). Stage-based models indicate that when more than 25% of a loon population produces 40% fewer fledged young, a population sink occurs.

A second group of human health and ecological indicators was selected to identify areas of concern in the region. These secondary indicators are largemouth bass, brook trout, yellow perch (whole-fish concentrations), bald eagle, river otter, and mink. In this analysis, a whole-fish Hg concentration of 0.16 μg per g (ww) for yellow perch and brook trout was used as an adverse-effect level for piscivores, reflecting the documented risk to loons foraging on fish with whole-body concentrations above this level (Evers et al. 2004, Seiler et al. 2004). A blood Hg concentration of 1.0 μg per g (ww) in bald eaglets was selected as the adverse-effect level that is related to significant negative effects on reproductive success in Maine (DeSorbo and Evers 2006). Because of uncertainties in the accepted level of adverse effects for furbearers, a value of 30 μg per g (fw) in fur was used for river otter and mink, rather than the 20 μg per g (fw) used in some studies (Thompson 1996).

Spatial analysis. The biotic Hg data layers were plotted using a 30' × 30' polygon grid interval (or 0.5° × 0.5° grid) to summarize the data and provide a relevant geographic coverage using GIS (geographic information system) techniques. The grid size was selected on the basis of our understanding of the NERC data, reflecting the trade-offs between spatial detail and the number of sites with biotic Hg data within a cell. Grid interval size varied according to latitudinal and longitudinal position but averaged approximately 2200 to 2300 km^2. We employed power analyses to determine the minimum acceptable number of yellow perch and loon samples needed within any given grid cell to maintain a likelihood of detecting biological threshold limits ($p \pm 0.01$ and $\beta = 0.80$ for yellow perch; $p \pm 0.001$ and $\beta = 0.95$ for common loons). These analyses indicate that a minimum sample size of 10 independent sites per grid cell for yellow perch, and 14 for common loons, is needed to characterize Hg concentrations accurately.

The perch data were queried to display standardized Hg concentrations of at least 0.30 μg per g (ww), with each data point representing an independent sampling site. These data were joined to a 30' × 30' polygon grid, and the resulting grid was queried for a sample size of at least 10. We verified this analysis by converting the entire NERC fish Hg data set of more than 15,000 observations (Kamman et al. 2005) to a data set for standard-length yellow perch using the model created by Wente (2004). These data showed agreement with the spatial analysis, demonstrating that the yellow perch database was a robust indicator for biological Hg hotspots. The loon data were joined to a 30' × 30' polygon grid. These data were then queried to display (a) cells with a sample size of at least 14 and (b) cells with at least 25% of the data showing 3.0 or more μg Hg per g (ww).

For those grid cells that did not meet the sample size requirements for yellow perch and common loons, we examined Hg concentrations in the six secondary biotic data layers (table 1). Independent of sample size, those grid cells that had two or more biotic data layers with mean Hg concentrations that exceeded associated adverse-effect levels were identified as areas of concern. Locations of major historic and current Hg discharges at industrial sites (e.g., mercury-cell based chlor-alkali facilities, textile plants) were also identified (figure 2).

To help ascertain possible mechanisms responsible for biological Hg hotspots, we examined land-use and water-chemistry attributes of water bodies within each grid cell based on standardized data sets, such as those available through the USEPA Environmental Monitoring and Assessment Programs (both national and regional versions). Land-use percentages for forested, wetland, and agricultural areas were extracted from the US Geological Survey's National Land Cover Dataset, while total phosphorus (TP), dissolved organic carbon (DOC), pH, and acid neutralizing capacity (ANC) in surface waters were summarized in relation to sensitivity thresholds established by Driscoll and colleagues (2007) using NERC data (TP < 30 μg per L, DOC < 4 mg carbon [C] per L, pH < 6, and ANC < 100 microequivalents [μeq] per L).

Spatial analysis based on multiple data layers of mercury

Mercury concentrations within the two primary and six secondary data layers were available for 234 grid cells covering an area of 513,471 km^2. Five biological Hg hotspots were identified in the study region, based on the two primary data layers (yellow perch and common loon). A total of 663 sites, with 4089 measurements of yellow perch Hg concentrations, were analyzed for 147 grid cells representing an area of 336,723 km^2. A total of 101 grid cells (approximately 70% of the study region) had mean Hg concentrations for yellow perch that exceeded the USEPA human health criterion at one or more sites. Nine grid cells had mean Hg concentrations for yellow perch at 10 or more independent sites that exceeded the criterion, resulting in five biological Hg hotspots with a total area of 20,616 km^2 (figure 2).

In general, where standard-length yellow perch exhibited Hg concentrations in excess of 0.30 μg per g, other larger, more predatory, and more sought-after game fish, such as largemouth bass, also had elevated Hg concentrations. Mean perch Hg concentrations were highest in the western Adirondack Mountains of New York (H1a) and the middle part of the Merrimack River watershed in New Hampshire (H3a), followed by the lower part of the Merrimack River watershed

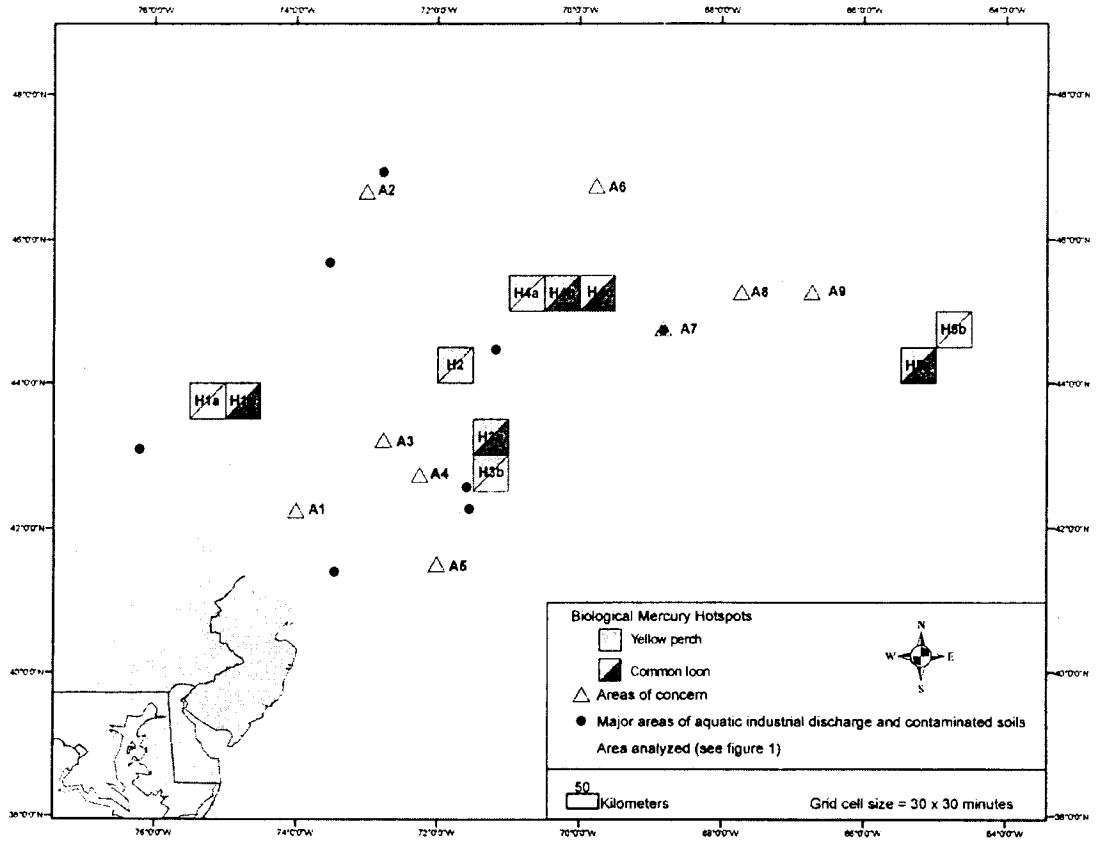

Figure 2. Distribution of biological mercury hotspots (H1a–H5b) and areas of concern (A1–A9). Areas of concern: A1, Catskill Mountains, New York; A2, LaMauricie region, Quebec, Canada; A3, Deerfield River, Vermont; A4, north-central Massachusetts; A5, lower Thames River, Connecticut; A6, upper St. John River, Maine; A7, lower Penobscot River, Maine; A8, Downeast region, Maine; A9, Lepreau region, New Brunswick, Canada. Hotspots: H1a, western Adirondack Mountains, New York; H1b, central Adirondack Mountains, New York; H2, upper Connecticut River, New Hampshire and Vermont; H3a, middle Merrimack River, New Hampshire; H3b, lower Merrimack River, Massachusetts and New Hampshire; H4a, upper Androscoggin River, Maine and New Hampshire; H4b, western upper Kennebec River, Maine; H4c, eastern upper Kennebec River, Maine; H5a, Kejimkujik National Park, Nova Scotia, Canada; H5b, central Nova Scotia.

in Massachusetts (H3b), the central Adirondack Mountains (H1b), and Nova Scotia, Canada (H5a and H5b).

Of the 1546 loons sampled in 102 grids, representing an area of 226,503 km^2, 33 grid cells met the minimum sample size requirement. Biological Hg hotspots associated with loons occur in five grid cells within four of the biological hotspots, covering an area of 11,027 km^2 (table 2, figure 2). In these grid cells, 25% to 93% of the sampled loon population had Hg concentrations above adverse-effect levels. In these biological Hg hotspots, common loons therefore are most likely to experience significant adverse effects at the population level. Mean loon blood Hg concentrations were highest in the upper Kennebec River region of Maine (H4b and H4c) and in Kejimkujik National Park in Nova Scotia (H5a).

Nine areas of concern were identified based on the six secondary data layers. These areas include the Catskill Mountains, New York (A1); the LaMauricie region, Quebec, Canada (A2); Deerfield River, Vermont (A3); north-central Massachusetts (A4); the lower Thames River, Connecticut (A5); the upper St. John River, Maine (A6); the lower Penobscot River, Maine (A7); the Downeast region, Maine (A8); and the Lepreau region, New Brunswick, Canada (A9; figure 2).

Identification and interpretation of biological mercury hotspots

To understand the mechanisms that may contribute to these biological Hg hotspots, it is necessary to consider Hg sources, atmospheric processes, landscape characteristics, and human disturbance to the landscape (figure 3). We hypothesize that three factors amplify the effects of regional and global atmospheric Hg emissions and deposition and are the likely major mechanisms contributing to the biological Hg hotspots identified here: (1) elevated atmospheric Hg deposition from local sources, (2) high landscape sensitivity, and (3) large

Table 2. Summary of data layers for mercury (Hg) concentrations (μg per g, wet weight) in yellow perch and common loons for each biological Hg hotspot in the Northeast.

Biological Hg hotspot	State/province	Hg concentrations: mean ± standard deviation (*n*, range)		Percentage of loons with Hg concentrations > level of concern
		Yellow perch	Common loon	
H1a: Adirondack Mountains (west)	New York	0.73 ± 0.15 (10, 0.57–0.96)	1.5 ± 0.3 (6, 1.1–2.1)	0
H1b: Adirondack Mountains (central)	New York	0.54 ± 0.15 (12, 0.39–0.80)	2.0 ± 1.2 (44, 0.3–4.1)	25
H2: Upper Connecticut River	New Hampshire, Vermont	0.35 ± 0.13 (17, 0.14–0.58)	1.1 ± 0.7 (45, 0.1–2.9)	0
H3a: Merrimack River (middle)	New Hampshire	0.78 ± 0.99 (38, 0.05–5.03)	2.6 ± 1.8 (39, 0.7–7.1)	28
H3b: Merrimack River (lower)[a]	Massachusetts, New Hampshire	0.65 ± 0.78 (17, 0.23–3.81)	NA (no loons sampled)	NA
H4a: Upper Androscoggin River	Maine, New Hampshire	0.44 ± 0.27 (12, 0.21–1.25)	1.9 ± 1.0 (92, 0.15–5.47)	14
H4b: Upper Kennebec River (west)	Maine	0.40 ± 0.09 (11, 0.24–0.52)	3.1 ± 2.1 (77, 0.6–14.2)	43
H4c: Upper Kennebec River (east)	Maine	0.38 ± 0.30 (3, 0.14–0.72)	2.2 ± 1.0 (31, 0.6–4.1)	26
H5a: Kejimkujik National Park	Nova Scotia	0.50 ± 0.18 (27, 0.14–0.85)	5.5 ± 1.4 (14, 2.9–7.8)	93
H5b: Central Nova Scotia	Nova Scotia	0.58 ± 0.86 (16, 0.14–3.79)	NA (no loons sampled)	NA

NA, not applicable.
a. *Source:* Hutcheson et al. 2003.

water-level manipulations (table 3). Atmospheric deposition is the major Hg input to the region (Fitzgerald et al. 1998), and both local sources and long-range transport of Hg are likely to be important in the formation of biological Hg hotspots. Although biological Hg hotspots may also originate from local sources of Hg-contaminated soils and waters, the impacts from these sources are less pervasive, and we therefore focus here on biological Hg hotspots originating from atmospheric deposition.

Mercury is emitted to the atmosphere from a variety of sources. The largest single source in the United States is coal-fired electric utilities. Mercury can be deposited locally or travel great distances, depending mostly on its oxidation state (i.e., 0, +2). Mercury is present in the atmosphere in several forms: elemental Hg, or Hg^0; gaseous divalent Hg, or Hg(II); and particulate Hg, or Hg(p). Elemental Hg has an approximately 0.5- to 2-year residence time in the atmosphere, so it constitutes the majority of airborne Hg. Gaseous divalent Hg and Hg(p) are generally deposited much more rapidly than

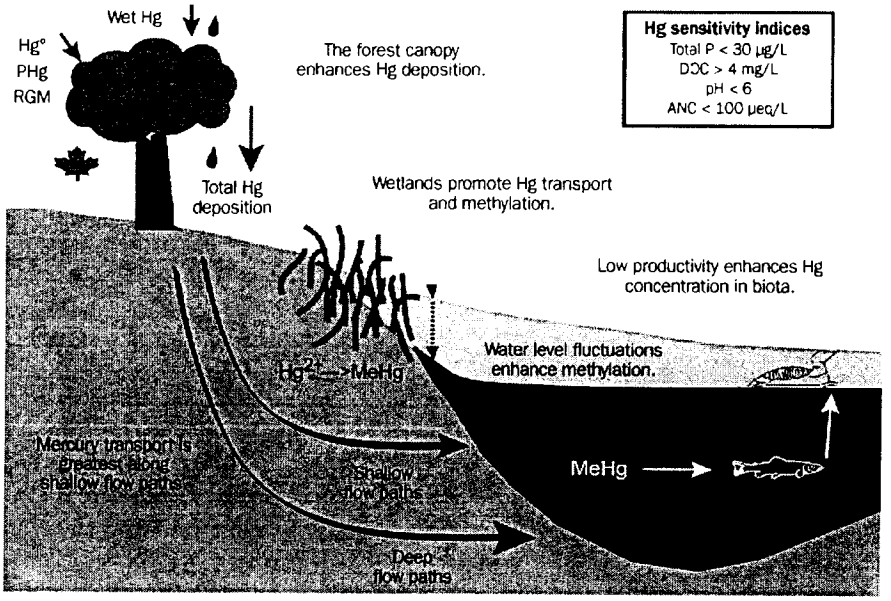

Figure 3. Conceptual figure illustrating important processes controlling the sensitivity of forest and linked aquatic ecosystems to atmospheric mercury (Hg) deposition and artificial water level regulation. The forest canopy enhances dry Hg deposition. Water transported along shallow flow paths supplies greater quantities of Hg than water in deep flow paths. Wetlands are important in the supply of dissolved organic carbon (DOC), which enhances the transport of ionic Hg and methylmercury (MeHg), and are important sites for the production of MeHg. The nutrient status and productivity of surface waters also control concentrations of MeHg in aquatic biota. Indicators of lakes sensitive to Hg inputs are shown in the insert (after Driscoll et al. 2007). Reservoir creation and water-level fluctuation will stimulate MeHg production in the littoral region. Abbreviations: ANC, acid neutralizing capacity; Hg^0, elemental Hg; P, phosphorus; PHg (i.e., Hg[p]), particulate Hg; RGM (i.e., Hg[II]), reactive gaseous Hg.

Table 3. Hypothesized mechanisms for presence of biological mercury (Hg) hotspots in the Northeast.

		Hypothesized mechanisms of Hg contamination				
Biological Hg hotspot	State/ province	Regional and global atmospheric deposition	Water-level management	Landscape sensitivity	Local air emissions	Local soil contamination
H1a: Adirondack Mountains (west)	New York	x	–	x	–	–
H1b: Adirondack Mountains (central)	New York	x	–	x	–	–
H2: Upper Connecticut River	New Hampshire, Vermont	x	x	–	–	–
H3a: Merrimack River (middle)	New Hampshire	x	–	–	x	–
H3b: Merrimack River (lower)	Massachusetts, New Hampshire	x	–	–	x	–
H4a: Upper Androscoggin River	Maine, New Hampshire	x	x	–	–	–
H4b: Upper Kennebec River (west)	Maine	x	x	–	–	x
H4c: Upper Kennebec River (east)	Maine	x	x	–	–	–
H5a: Kejimkujik National Park	Nova Scotia	x	–	x	–	–
H5b: Central Nova Scotia	Nova Scotia	x	–	x	–	–

Hg^0 and therefore have much shorter residence times. These oxidized species make up a small fraction of the total atmospheric Hg (less than 5% at remote sites) but can be responsible for a significant fraction of the total deposition. Gaseous divalent Hg and Hg(p) make up 50% to 90% of the Hg emitted from coal-fired electric utilities in the northeastern United States (NESCAUM 2005, NHDES 2005).

Although Hg^0 generally has a low deposition velocity, under some conditions Hg^0 can be rapidly converted to gaseous Hg(II) and deposited locally and regionally (Wang and Pehkonen 2004). Elemental Hg can also interact with the forest canopy, enhancing deposition rates (discussed below). Gaseous Hg(II) and Hg(p) have high deposition velocities; therefore, proximity to sources and the form of Hg emitted from sources play key roles in determining the amount of Hg deposited to a given area.

We hypothesize that once Hg has been emitted to the atmosphere and deposited to the landscape, the potential for biological Hg hotspots to develop depends on several factors, including the rate of deposition as well as site-specific characteristics such as landscape sensitivity, water-level management in reservoirs, and direct Hg input from water discharges and contaminated soils. Examples of how these factors affect organisms at higher trophic levels are provided below.

Landscape-driven biological mercury hotspots. Ecosystems vary in their sensitivity to Hg inputs; models predicting ecosystem sensitivity can be developed using environmental indicators (Roué-Legall et al. 2005). Mercury that is deposited from the atmosphere may be reemitted to the atmosphere, sequestered in soil or sediments, or transported with drainage waters to aquatic ecosystems, where it can potentially be methylated and bioaccumulate in aquatic organisms. Generally only a small fraction of atmospheric Hg deposition is transported to aquatic ecosystems (Grigal 2002). Nevertheless, the extent to which Hg is transmitted to surface waters varies greatly, and is controlled by multiple processes in the watersheds that connect atmospheric deposition to Hg fate in surface waters (figure 3). Ecosystems with enhanced Hg deposition, transport to surface waters, methylation, and bioaccumulation are considered Hg sensitive (Driscoll et al. 2007).

Forests enhance landscape sensitivity to atmospheric Hg deposition. Canopy trees scavenge atmospheric Hg (Rea et al. 1996). Atmospheric Hg(p), gaseous Hg(II), and oxidized Hg^0 may be adsorbed by foliage and subsequently leached in throughfall (Lindberg et al. 1995). Elemental Hg also enters foliage by the stomata and can ultimately be deposited to the forest floor via leaf litter. In northeastern North America, dry deposition associated with the canopy may provide 60% to 75% of total Hg inputs to forest ecosystems (Miller et al. 2005).

Landscape characteristics including shallow hydrologic flowpaths (Grigal 2002, Galloway and Branfireun 2004), the presence of wetlands (St. Louis et al. 1994), and unproductive surface waters (Chen et al. 2005) facilitate the transport, methylation, and bioconcentration of Hg in surface waters, thereby increasing an ecosystem's sensitivity to atmospheric Hg deposition (Driscoll et al. 2007). Moreover, acidic deposition has affected forested watersheds across eastern North America (Driscoll et al. 2001). It exacerbates ecosystem sensitivity to Hg because the addition of sulfate stimulates production of MeHg (Jeremiason et al. 2006) and the acidification of surface waters enhances concentrations of Hg in fish tissue (Hrabik and Watras 2002).

Two of the biological Hg hotspots in the Northeast, located within the Adirondack Mountains (H1a and H1b) and Nova Scotia (H5a and H5b), appear to be associated with watersheds that are highly sensitive to atmospheric Hg deposition (table 3); the H5a grid cell is of especially high concern because of demonstrated negative Hg impacts on common loon reproductive success (Burgess et al. 1998, 2005). The grid cells in these biological Hg hotspots have forested and wetland cover above the 80th percentile of all grid cells, and are in the lowest 10th percentile for agricultural land uses. These same

grid cells were characterized by water chemistry within the sensitive ranges for attributes associated with high fish Hg in the Northeast (Driscoll et al. 2007). The mean values for 28 water bodies contained in these grid cells are as follows: TP = 9.5 μg per L; DOC = 4.7 mg C per L; ANC = 75 μeq per L; pH = 6.1.

Biological mercury hotspots associated with water-level management. Mercury concentrations in biota are elevated in reservoirs of the Northeast relative to other aquatic environments (Evers et al. 2004, Kamman et al. 2005). We identified two biological Hg hotspots representing four grid cells that appear to be associated with water-level manipulations in reservoirs: the upper Connecticut River in New Hampshire and Vermont (H2) and the upper Androscoggin River watershed (H4a) and upper Kennebec River watershed of Maine (H4b, H4c).

Generally, elevated Hg levels can be attributed either to reservoir creation or to water-level manipulations within existing reservoirs. The initial saturation of soils resulting from the creation of a reservoir yields a large flux of Hg and other detrital material to overlying waters (Bodaly et al. 2004). The resultant decompositional environment of the soil–water interface favors bacterial methylation of recently deposited or legacy Hg adsorbed on soil and vegetative particles. The MeHg forms complexes with various DOC compounds, and several factors, including the composition of the DOC itself, mediate subsequent bioaccumulation (Bodaly et al. 2004, Driscoll et al. 2007). Methyl Hg concentrations have been shown to increase up to 30% above initial values within the first 13 years after reservoir creation (Schetagne and Verdon 1999).

Increases in fish Hg concentrations of 1.5 to 4 times natural lake background levels have been observed in new reservoirs, with concentrations peaking approximately 10 to 15 years postconstruction and declining thereafter (Schetagne and Verdon 1999). Where reservoirs are not further manipulated or managed, fish Hg concentrations typically decline to natural lake background levels 20 to 40 years after initial flooding (Anderson et al. 1995, Schetagne and Verdon 1999).

In addition to reservoir creation, water-level fluctuation influences fish Hg concentrations. Water-level fluctuation has been identified as a key variable in explaining elevated Hg concentrations in fish tissue (Verta et al. 1986). Shallow depth and variable hydroperiods are strongly associated with increased fish Hg concentrations in southeastern US ponds (Snodgrass et al. 2000). The sediments of dewatered and reinundated littoral zones are prime environments for methylation because of their transitioning reduction–oxidation conditions, which promote bacterial sulfate reduction. Methylmercury formed in the littoral zone can be transported to the remaining open-water portion of the reservoir either during rain events or when the reservoir is refilled. The availability of MeHg to reservoir biota is likely to vary in relation to the ratio of dewatered area to reservoir size. Steep-sided reservoirs with organic-poor substrates can be expected to display less efficient MeHg production, lower ambient MeHg concentrations, and less bioaccumulation than reservoirs with wide basins and large littoral areas with more organic matter.

Several reservoir systems in the Northeast illustrate the effects of water-level manipulations (figure 4). In one study in north-central Maine, the ratio of MeHg to Hg in samples from sediment cores was shown to increase considerably, and then remain elevated, after the onset of reservoir fluctuation (Haines and Smith 1998). In another Maine study of five interconnected reservoirs, Hg concentrations in loon tissue increased with greater reservoir fluctuation. In reservoirs that had large summertime (June through September) drawdowns (> 3 m), Hg concentrations in adult loon blood were significantly higher than in reservoirs with small drawdowns (< 1 m) (figure 4). Similar patterns in fish Hg concentrations were documented in an interconnected system of three Connecticut River reservoirs for smallmouth bass (*Micropterus dolomieu*) and yellow perch (figure 4). In Minnesota, dampening water-level fluctuations resulted in significantly improved fish Hg concentrations (Sorensen et al. 2005).

Biological mercury hotspots associated with direct water discharges and contaminated soils. In contrast to sources of Hg from air emissions, direct Hg discharges (e.g., industrial wastes, wastewater, stormwater overflow) and land-based contamination (e.g., landfills, former mining and industrial facilities) tend to affect discrete drainage areas. Eight well-known sites of Hg discharges into lakes and rivers were identified, though they are not considered biological Hg hotspots under our definition, since the data for Hg in biota are currently insufficient to make such determinations (figure 2). The influence of these sources on streams is well studied; generally, streams can rapidly transport and diffuse Hg from a site (Whyte and Kirchner 2000). However, some land-based Hg sources, such as those on rivers with extensive emergent, shrub, and forested floodplains, can have significant downstream biological impacts that may reach 30 km (Wiener and Shields 2000) to 130 km or more (Hildebrand et al. 1980) from the source, decades after termination of active Hg discharges. Mercury-cell chlor-alkali plants are well-known sources of Hg contamination (Hildebrand et al. 1980), and in some cases they may influence biotic Hg levels in lakes that are downwind (A7; figure 2). Other less-described sources include landfills with Hg-containing leachate (Niebla et al. 1976), historical mining activities (Seiler et al. 2004), and municipal wastewater treatment plants (Gilmour and Bloom 1995). Storm water discharges, particularly from areas associated with impervious cover in urban and suburban footprints, also can enhance Hg supply to surface waters (Rule et al. 2006). Estuaries and other wetlands are common end points of urban watersheds, and the potential exists for negative impacts to avian reproductive success from Hg runoff (Schwarzbach et al. 2006). To further assess potential ecological impacts, monitoring and remediation efforts need to be continued long after Hg discharges to surface water from

point sources or contaminated soils are terminated.

Biological mercury hotspots associated with local atmospheric emissions and deposition: A case study. Several studies have shown that the high ambient concentrations of gaseous Hg(II) typically observed in the vicinity of high-emission areas increase dry and wet Hg deposition (USEPA 1997, Bullock and Brehme 2002) and Hg concentrations in soils and sediments (Biester et al. 2002). Here we estimate emissions and deposition in southern New Hampshire and parts of northeastern Massachusetts in order to assess the linkages among local Hg emissions, deposition, and concentrations in biota.

The industrial source complex short-term air dispersion model, or ISCST3 (USEPA 1995), was used to examine the hypothesis that the biological Hg hotspot in the middle and lower Merrimack River watershed (H3a and H3b; figure 2) is associated with high deposition from local emissions sources.

The ISCST3 model is a steady-state Gaussian plume model, which is used to assess pollutant concentrations from sources at the local scale (within 50 km). It assumes that deposition of Hg^0 from anthropogenic emissions is balanced by the reemission of previously deposited Hg^0, because of its large vapor pressure and low solubility (Bullock and Brehme 2002, Cohen et al. 2004), so only deposition of Hg(II) and Hg(p) was simulated in this analysis (table 4). The Henry's law constant and molecular diffusivity used in the USEPA *Mercury Study Report to Congress* (USEPA 1997) were adopted for Hg(II). Following Landis and colleagues (2002), it was assumed that the fine fraction (0.68 μm) accounted for 70% and the coarse fraction (3.5 μm) 30% of the Hg mass.

The model was run using a 5-km grid based on the 1996 National Emissions Inventory (USEPA 1996) for Hg and the 2002 revised emissions inventory for the Northeast states (NESCAUM 2005). The input-modeling domain was defined as New Hampshire and several counties within the adjacent states of Maine, Massachusetts, and Vermont. The output-modeling domain was limited to New Hampshire and northeastern Massachusetts. Meteorological data from Concord, New Hampshire, and Portland, Maine, were used as the surface and upper air data for 2002, respectively.

The ISCST3 results indicate that a biological hotspot (H3a and H3b) exists within an area of elevated deposition that receives considerable Hg input from local and regional sources (figure 5). Model estimates show total Hg deposition associated with local and regional sources of 17 to 804 μg per m^2 per year in 1996 and 7 to 76 μg per m^2 per year in 2002. There are two possible reasons for this area of high Hg deposition: (1) The predominant wind direction has a westerly compo-

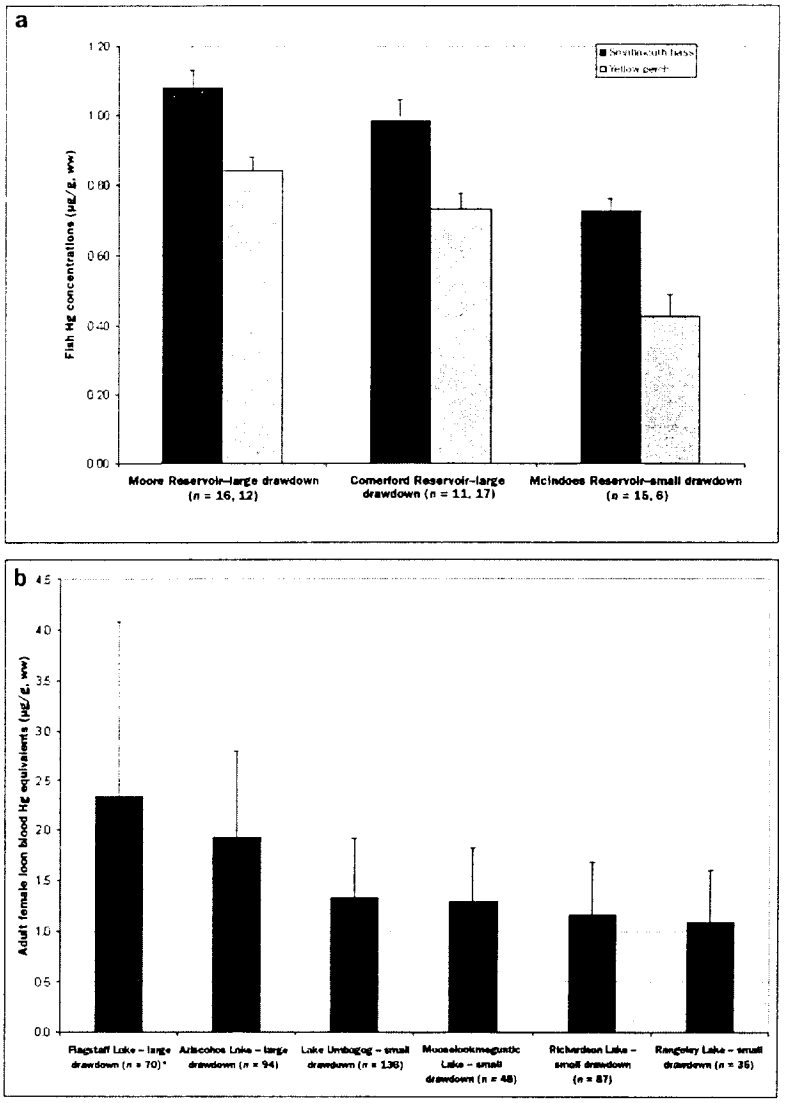

Figure 4. (a) Fillet mercury (Hg) concentrations for smallmouth bass and yellow perch (mean ± standard deviation [sd]) at three interconnected Connecticut River reservoirs in Vermont and New Hampshire and (b) blood Hg concentrations for the common loon (mean ± sd) at five interconnected Androscoggin River reservoirs in Maine and New Hampshire and one reservoir (Flagstaff Lake) in the upper Kennebec River watershed, Maine. (Although it is not hydrologically connected to the grid in the upper Androscoggin River watershed, Flagstaff Lake is illustrative of headwater reservoirs in that region that have large drawdowns.) Reservoir drawdowns from June through September that are less than 1 m are considered small, and those greater than 3 m are considered large. Kruskal-Wallis tests indicate significant differences between reservoirs with large and small drawdowns.

nent, and (2) major Hg sources are located in southern New Hampshire and Massachusetts. Of the total modeled deposition in 2002, Hg(II) deposition contributes the dominant fraction (90%) compared with Hg(p) (10%), primarily because the dry and wet deposition velocities for Hg(II) are higher than for Hg(p). In addition, the emissions of gaseous Hg(II) and Hg(p) from point sources contribute approximately 76% and 58% of the totals in the Hg(II) and Hg(p) categories, respectively (table 5). The ISCST3 results also show that dry deposition contributed more than wet deposition for Hg(II), while the opposite was true for Hg(p).

The USEPA estimated Hg deposition in the United States for 2001 using the community multiscale air quality (CMAQ) model. For the study area in northeastern Massachusetts and southern New Hampshire, they report a range in total deposition of 15 to 20 μg per m^2 per year (USEPA 2005). Miller and colleagues (2005) estimated regional Hg deposition for the study area using a "big-leaf" model and reported a range in total Hg deposition of 19 to 21 μg per m^2 per yr, with wet deposition of 5 to 6 μg per m^2 per year and dry deposition of 14 to 15 μg per m^2 per year. The values from the CMAQ model include local sources, but the emissions are averaged over a large grid cell, and therefore the model appears to underpredict total Hg deposition in the immediate vicinity of large emission sources. The big-leaf model represents regional and global deposition sources; the impact of large local emission sources was not directly accounted for. The local deposition estimates from the ISCST3 model represent an additional Hg input above the deposition estimated by the big-leaf model and therefore suggest that approximately 25% to 65% of total Hg deposition from all sources in the southern New Hampshire region is attributable to local emission sources.

Table 4. Deposition parameters of mercury (Hg) used for this study.

Form	Properties	Values used in this study
Divalent Hg	Molecular diffusivity[a]	0.045 cm^2 per s
	Solubility enhancement factor[a]	10^9
	Pollutant reactivity[a]	800
	Mesophyll resistance[a]	0
	Henry's law constant[a]	2.7×10^{-7}
	Liquid scavenging ratio[b]	2.5×10^{-4} (s-mm per hr) $^{-1}$
	Frozen scavenging ratio[b]	5.0×10^{-5} (s-mm per hr) $^{-1}$
Particulate Hg	Liquid scavenging coefficient (0.68 μm)[b]	7.0×10^{-5} (s-mm per hr) $^{-1}$
	Frozen scavenging coefficient (3.5 μm)[b]	2.8×10^{-4} (s-mm per hr) $^{-1}$

a. Adopted from USEPA 1997.
b. Adopted from Sullivan et al. 2004.

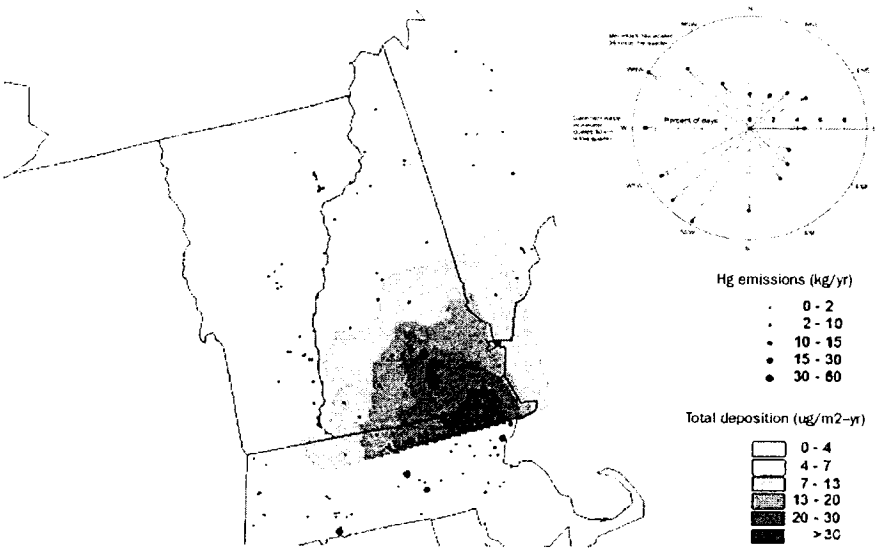

Figure 5. Left, map showing total mercury (Hg) deposition for 2002, estimated using the industrial source complex short-term model, or ISCST3; right, wind rose showing the direction of air flow for May through August 1999 to 2002 in southern New Hampshire, based on weekly wind roses from the NOAA (National Oceanic and Atmospheric Administration) Air Resources Laboratory's READY (Real-time Environmental Applications and Display System) analyses (NOAA 2006).

Table 5. Emission rates used in model domain in 2002.

Emission sources	Emission rates (kg per yr) Particulate mercury	Divalent mercury	Elemental mercury
Point sources	82.4	264.8	135.8
Area sources	60.4	90.6	245.0
Total emissions	142.8	355.4	380.8

Temporal patterns in biotic mercury. Historical data from the Merrimack River watershed biological hotspot (H3a and H3b) suggest that biotic Hg can change rapidly in response to changes in atmospheric emissions and deposition from local and regional sources. From 1997 to 2002, Hg emissions in southern New Hampshire declined 45 percent, largely as a result of restrictions on incinerators (table 6). Meteorological data from Concord were used to determine the dominant wind direction in the area of the Merrimack River watershed biological hotspot and to identify a group of study lakes downwind from major Hg sources. The average wind direction was calculated in grid cell H3a (latitude –43.08 N, longitude –71.16 W) for 1999 to 2002 using the months of May through August (a period of loon blood Hg measurements). The results show that airflow to grid cell

H3a had a westerly component during approximately two-thirds of this period (figure 5).

Based on the meteorological analysis, we selected 10 study lakes within grid cell H3a that were downwind of major Hg emission sources and, when pooled together, provided time series data for Hg in common loons. The study lakes are: Ayers, Canobie, Jenness, Massabesic, Mendums, Onway, Northwood, Pawtuckaway, Swains, and Tower Hill. Mean loon Hg concentrations in these lakes declined 64% from 1999 to 2002 (figure 6a), commensurate with the reduction in Hg emissions of 45% from upwind sources in southern New Hampshire (table 6). Recent data show no appreciable change in mean loon Hg concentrations from 2003 to 2005 (figure 6a). The grid cell immediately north of grid cell H3a, outside the area of highest Hg deposition within the middle Merrimack River watershed, provides a reference area for comparing the magnitude and temporal trends of loon Hg concentrations. This area has similar watershed cover and water chemistry to grid cell H3a. Here, mean loon Hg concentrations were 1.3 to 2.7 times lower than in grid cell H3a during the 1999 to 2002 time period, but still declined 30%. From 1999 to 2002, mean loon Hg concentrations in grid cell H3a exhibited a significant negative trend (using the Mann-Kendall test for normalized approximations; $s = -6$, $n = 4$, $z = -1.70$), and the grid cell immediately north of grid cell H3a did not exhibit a significant negative trend ($s = -4$, $n = 4$, $z = -1.02$).

Negative mercury trends in other taxa were observed within the lower Merrimack River watershed biological hotspot and demonstrated other lines of evidence during the same time period. In yellow perch, there was a significant decrease in fillet Hg concentrations between 1999 and 2004, based on individuals normalized to 24.3 cm in length within northeastern Massachusetts, which overlaps with grid cell H3b; comparatively, throughout the rest of Massachusetts, perch exhibited decreases approximately half as large as those in the Merrimack River watershed (C. Mark Smith and Michael Hutcheson, Massachusetts Department of Environmental Protection, Boston, personal communication, 7 July 2006). Mercury concentrations in zooplankton samples taken from three lakes in grid cell H3a declined between 1996 and 2002, compared with three study lakes outside grid cell H3a, in which the trend in total Hg in zooplankton did not decline (Chen et al. 2000; Carol Folt, Department of Biological Sciences, Dartmouth College, Hanover, New Hampshire, personal communication, 20 June 2006).

The consistency between the timing and magnitude of Hg emissions reductions and the declines in Hg concentrations in common loons, fish, and zooplankton could be related to several factors. A substantial amount of gaseous Hg(II) was removed from the

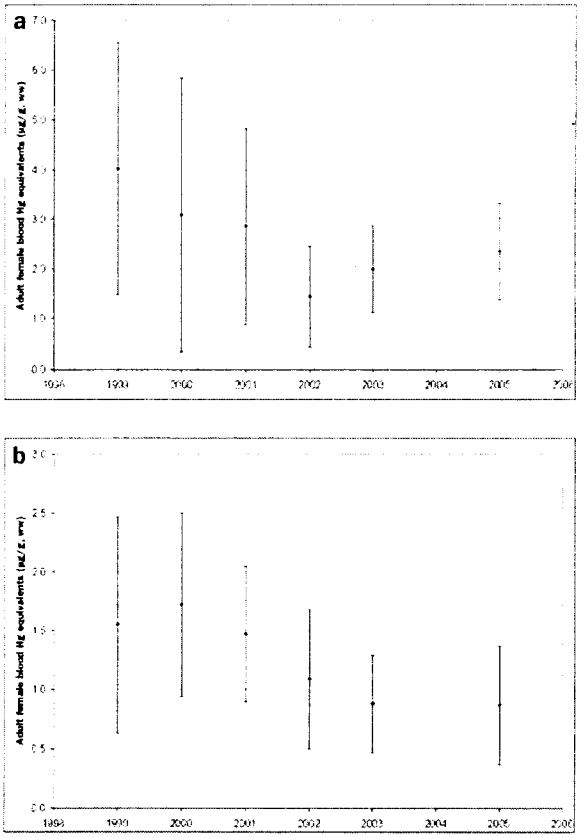

Figure 6. Temporal patterns for adult loon blood mercury (Hg) equivalents (μg per g, wet weight; mean ± standard deviation) in (a) the middle Merrimack River watershed (n = 53) and (b) the upper Merrimack River watershed (n = 43), New Hampshire. Note: The magnitude of the y axis, adult female blood Hg equivalents, differs between figure 6a and 6b.

Table 6. Values of mercury (Hg) emissions, deposition, and biotic concentrations in the middle Merrimack River watershed, New Hampshire, for 1996–1997, 1999, and 2002.

Measure	Year	
	1996–1997 and 1999	2002
Emissions in model domain	1515.3 kg	879.0 kg
Maximum annual deposition[a]	810 μg per m^2 per yr	76 μg per m^2 per yr
Area of elevated deposition	50 km^2	20 km^2
Average adult common loon blood equivalent[b]	4.02 μg per g	1.45 μg per g
Average zooplankton (45–202 μm)	5.14 ng per g	0.59 ng per g
Average zooplankton (> 202 μm)	1.72 ng per g	0.17 ng per g

a. Deposition estimates are based on monitoring data from the Mercury Deposition Network and ISCST3 (industrial source complex short-term) model analysis.

b. Common loon tissue Hg equivalents were determined from 10 lakes in southeastern New Hampshire from 1999 to 2005. The decline from 1999 to 2002 represents a statistically significant change ($t = 2.1$, df = 16, $p = 0.008$). Loon blood and egg Hg concentrations were collected starting in 1999.

Table 7. Emission reduction scenarios considered in this analysis.

Location of coal-fired electric utilities	Emissions (kg per yr)		
	Current	50% reduced	90% reduced
Merrimack Station	62.4	31.20	6.24
Schiller Station	5.00	2.50	0.50
Salem Harbor Station	8.80	4.40	0.88
Mount Tom Station	1.93	0.97	0.19

Figure 7. Total differences in mercury (Hg) deposition (μg per m² per year) statewide in New Hampshire (a) with 50% emission reduction and (b) with 90% emission reduction from four coal-fired utilities in New England. Power plant Hg emission sources: (1) Merrimack Station, (2) Schiller Station, (3) Salem Harbor Station, (4) Mount Tom Station.

local atmosphere and most likely reduced local Hg deposition, and this "new" Hg is generally thought to be more readily bioavailable than Hg that has been in the ecosystem for some time (Gilmour et al. 2003). Moreover, most of the study lakes have characteristics that are considered conducive to rapid response: They exist in close proximity to the emission sources, have small watershed-to-lake-area ratios (Grigal 2002), and have limited shoreline wetlands. Wetland areas less than 150 m from lake shoreline are predictive of loon blood Hg concentrations (Kramar et al. 2005), and therefore their extent influences the production of MeHg in the food web.

Links between local emission sources and birds have been measured elsewhere. In Britain, downward trends in piscivorous bird Hg levels were associated with reductions in local industrial air emissions (Newton et al. 1993). In the United States, recent downward trends in the Hg concentrations of Florida's wading birds were linked to reductions in Hg emissions and deposition from local sources (Frederick et al. 2004). Varying sulfate loads may also be a factor in the extent of MeHg production and availability in the Everglades (Bates et al. 2002).

Predicted future changes related to power plant emissions. The ISCST3 model was also used to evaluate two scenarios: a 50% and a 90% reduction in emissions from the four active coal-fired utilities located in the input modeling domain (table 7). The difference in deposition between the current and reduced emissions scenarios is evident in grid cells H3a and H3b (figure 7a, 7b). The average difference in deposition across all cells was 5% for the 50% reduction scenario and 9% for the 90% reduction scenario. However, the reduction in deposition was much greater in the areas of highest deposition; the model cells with the greatest percent decrease between current and projected deposition (23% for the 50% reduction and 41% for the 90% reduction) are located within 20 km of the Merrimack Station in New Hampshire, which is the largest coal utility in the modeling domain.

The scenario results indicate that a large portion of Hg(II) and Hg(p) is deposited within a short distance of these large sources, causing elevated deposition. Similarly, the results show that emissions from four coal-fired utilities in the area contribute approximately 40% of total Hg deposition attributed to local sources, and that decreased Hg emissions will result in substantial decreases in Hg deposition. The magnitude of the decreases in Hg deposition from local sources illustrated in these calculations (figure 7) should be viewed in the context of the additional Hg deposition from regional and global sources (19 to 21 μg per m² per year; Miller et al. 2005).

These results are based on the NESCAUM (Northeast States for Coordinated Air Use Management) inventory, which assumed that coal-fired utilities emit 70% of Hg as gaseous Hg(II) and Hg(p), on average. Recent stack-testing data for the Merrimack Station in New Hampshire suggest that gaseous Hg(II) emissions may constitute up to 92% of total Hg emissions at this facility (NHDES 2005). Under these conditions, we would expect baseline deposition to be higher than estimated here, and the decline in deposition associated with these emission reduction scenarios to be much greater.

Conclusions

Current levels of Hg deposition in the Northeast are 4 to 6 times higher than the levels recorded in 1900 (Perry et al. 2005). We identified five biological Hg hotspots in the region and hypothesized that these hotspots occur where the impacts of atmospheric Hg deposition are amplified by large reservoir fluctuations, highly sensitive landscapes, or elevated Hg deposition associated with large local emission sources.

Model estimates suggest that emissions from coal-fired power plants in the study region account for a large fraction of the total Hg deposited in the Merrimack River watershed hotspot, and that decreased emissions from these sources will result in decreased deposition. Significant and rapid improvements in Hg concentrations in common loons and other biota within this deposition-associated biological Hg hotspot (H3a, H3b) were documented for 1997–2002. Our analysis of the importance of local emission sources also emphasizes that emission trading rules must take local deposition and ecological conditions into account. Other management activities linked to potential reductions in biotic Hg concentrations include minimizing summertime water-level fluctuations on some reservoirs and creating suitable catchments for storm water runoff.

While existing data provide a strong basis for identifying biological Hg hotspots, large gaps in data and understanding continue to hamper our ability to quantitatively analyze sources and fully characterize the spatial and temporal patterns of deposition and biological availability across the United States and Canada. We suggest the development of comparable and linkable data sets for the primary and secondary data layers used here across North America; such data sets will further facilitate the identification of biological Hg hotspots. Developing novel indicator species, such as songbirds and bats, will enhance the ability to identify potential terrestrial biological Hg hotspots for invertivores that may or may not be directly associated with aquatic food webs.

At present, only 92 Hg wet deposition sites operate in the United States and Canada, and no coordinated national system exists to systematically collect and analyze Hg samples for dry deposition and biota in either country. A comprehensive Hg monitoring network has been developed (Mason et al. 2005) and, if employed, can be used to (a) better quantify wet and dry Hg deposition, particularly near high-emission sources; (b) detect additional deposition or biological Hg hotspots; (c) quantify the ecological and human health risks associated with existing biological Hg hotspots; and (d) track the resulting changes in management and policy actions. Ongoing process research and model development can be used to guide this monitoring network.

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References cited

Anderson MR, Scruton DA, Williams UP, Payne JF. 1995. Mercury in fish in the Smallwood Reservoir, Labrador, twenty one years after impoundment. Water, Air, and Soil Pollution 80: 927–930.

Barr JF. 1986. Population Dynamics of the Common Loon (*Gavia immer*) Associated with Mercury-Contaminated Waters in Northwestern Ontario. Ottawa (Canada): Canadian Wildlife Service. Occasional Paper 56.

Bates AL, Orem WH, Harvey JW, Spiker EC. 2002. Tracing sources of sulfur in the Florida Everglades. Journal of Environmental Quality 31: 287–299.

Biester H, Muller G, Scholer HF. 2002. Estimating distribution and retention of mercury in three different soils contaminated by emissions from chlor-alkali plants: Part I. Science of the Total Environment 284: 177–189.

Bodaly RA, et al. 2004. Experimenting with hydroelectric reservoirs. Environmental Science and Technology 38: 347A–352A.

Bullock OR, Brehme KA. 2002. Atmospheric mercury simulation using the CMAQ model: Formulation description and analysis of wet deposition results. Atmospheric Environment 36: 2135–2146.

Burgess NM, Evers DC, Kaplan JD. 1998. Mercury and reproductive success of common loons breeding in the Maritimes. Pages 104–109 in Burgess NM, Beauchamp S, Burn G, Clair T, Roberts C, Rutherford L, Gordon R, Vida O, eds. Mercury in Atlantic Canada: A Progress Report. New Sackville (Canada): Environment Canada, Atlantic Region.

———. 2005. Mercury and other contaminants in common loons breeding in Atlantic Canada. Ecotoxicology 14: 241–252.

Chen CY, Stemberger RS, Klaue B, Blum JD, Pickhardt PC, Folt CL. 2000. Accumulation of heavy metals in food web components across a gradient of lakes. Limnology and Oceanography 45: 1525–1536.

Chen CY, Stemberger RS, Kamman NC, Mayes BM, Folt CL. 2005. Patterns of Hg bioaccumulation and transfer in aquatic food webs across multi-lake studies in the northeast US. Ecotoxicology 14: 135–147.

Cohen M, et al. 2004. Modeling the atmospheric transport and deposition of mercury to the Great Lakes. Environmental Research 95: 247–265.

DeSorbo CR, Evers DC. 2006. Evaluating Exposure of Maine's Bald Eagle Population to Mercury: Assessing Impacts on Productivity and Spatial Exposure Patterns. Gorham (ME): BioDiversity Research Institute. Report no. BRI 2006-02.

Driscoll CT, Lawrence GB, Bulger AJ, Butler TJ, Cronan CS, Eagar C, Lambert KF, Likens GE, Stoddard JL, Weathers KC. 2001. Acidic depo-

sition in the northeastern United States: Sources and inputs, ecosystem effects, and management strategies. BioScience 51: 180–198.

Driscoll CT, Han Y-J, Chen CY, Evers DC, Lambert KF, Holsen TM, Kamman NC, Munson RK. 2007. Mercury contamination in forest and freshwater ecosystems in the northeastern United States. BioScience 57: 17–28. doi:10.1641/B570106

Evers DC, Clair TA. 2005. Mercury in northeastern North America: A synthesis of existing databases. Ecotoxicology 14: 7–14.

Evers DC, Taylor KM, Major A, Taylor RJ, Poppenga RH, Scheuhammer AM. 2003. Common loon eggs as indicators of methylmercury availability in North America. Ecotoxicology 12: 69–81.

Evers DC, Lane OP, Savoy L, Goodale W. 2004. Assessing the Impacts of Methylmercury on Piscivorous Wildlife Using a Wildlife Criterion Value Based on the Common Loon, 1998–2003. Gorman (ME): BioDiversity Research Institute. Report no. BRI 2004-05.

Evers DC, Burgess NM, Champoux L, Hoskins B, Major A, Goodale WM, Taylor RJ, Poppenga R, Daigle T. 2005. Patterns and interpretation of mercury exposure in freshwater avian communities in northeastern North America. Ecotoxicology 14: 193–221.

Fitzgerald WF, Engstrom DR, Mason RP, Nater E. 1998. The case for atmospheric mercury contamination in remote areas. Environmental Science and Technology 32: 1–7.

Frederick PC, Hylton B, Heath JA, Spalding MG. 2004. A historical record of mercury contamination in southern Florida (USA) as inferred from avian feather tissue. Environmental Toxicology and Chemistry 23: 1474–1478.

Galloway ME, Branfireun BA. 2004. Mercury dynamics of a temperate forested wetland. Science of the Total Environment 325: 239–254.

Gilmour CC, Bloom NS. 1995. A case study of mercury and methylmercury dynamics in a Hg-contaminated municipal wastewater treatment plant. Water, Air, and Soil Pollution 80: 799–803.

Gilmour CC, Heyes A, Mason RP, Miller C, Rearick M. 2003. Response of methylmercury production to changes in Hg loading: A comparison of Hg isotope addition studies. Workshop Abstracts. STAR Mercury Fate and Transport Final Progress Review Workshop; 21 November 2003, Washington, DC.

Grigal DF. 2002. Inputs and outputs of mercury from terrestrial watersheds: A review. Environmental Review 10: 1–39.

Haines T, Smith AM. 1998. Determination of the Influence of Impoundments on Bioavailability of Mercury to Fish, Wildlife, and Humans in the Penobscot River Watershed, Maine. Orono: University of Maine.

Hildebrand SG, Strand RH, Huckabee JW. 1980. Mercury accumulation in fish and invertebrates of the North Fork Holston River, Virginia and Tennessee. Journal of Environmental Quality 9: 393–400.

Hrabik TR, Watras CJ. 2002. Recent declines in mercury concentration in a freshwater fishery: Isolating the effects of de-acidification and decreased atmospheric mercury deposition in Little Rock Lake. Science of the Total Environment 297: 229–237.

Hutcheson MS, Rose J, Smith CM, West CR. 2003. Fish Mercury Levels in Northeastern Massachusetts Lakes. Boston: Massachusetts Department of Environmental Protection, Office of Resolution Standards.

Jeremiason JD, Engstrom DR, Swain EB, Nater EA, Johnson BM, Almendinger JE, Monson BA, Kolka RK. 2006. Sulfate addition increases methylmercury production in an experimental wetland. Environmental Science and Technology 40: 3800–3806.

Kamman NC, Lorey PM, Driscoll CT, Estabrook R, Major A, Pientka B, Glassford E. 2004. Assessment of mercury in waters, sediments, and biota of New Hampshire and Vermont lakes, USA, sampled using a geographically randomized design. Environmental Toxicology and Chemistry 23: 1172–1186.

Kamman NC, et al. 2005. Mercury in freshwater fish of northeast North America—a geographic perspective based on fish tissue monitoring databases. Ecotoxicology 14: 163–180.

Kramar D, Goodale WM, Kennedy LM, Carstensen LW, Kaur T. 2005. Relating land cover characteristics and common loon mercury levels using geographic information systems. Ecotoxicology 14: 253–262.

Landis MS, Stevens RK, Schaedlich F, Prestbo EM. 2002. Development and characterization of an annular denuder methodology for the measurement of divalent inorganic reactive gaseous mercury in ambient air. Environmental Science and Technology 36: 3000–3009.

Lindberg SE, Kim K-H, Meyers TP, Owens JG. 1995. A micrometeorological gradient approach for quantifying air/surface exchange of mercury vapor: Tests over contaminated soils. Environmental Science and Technology 29: 126–135.

Mason RP, Abbott ML, Bodaly RA, Bullock JOR, Driscoll CT, Evers D, Lindberg SE, Murray M, Swain EB. 2005. Monitoring the response to changing mercury deposition. Environmental Science and Technology 39: 15A–22A.

Miller EK, Vanarsdale A, Keeler GJ, Chalmers A, Poissant L, Kamman NC, Brulotte R. 2005. Estimation and mapping of wet and dry mercury deposition across northeastern North America. Ecotoxicology 14: 53–70.

Nacci D, et al. 2005. An approach to predict risks to wildlife populations from mercury and other stressors. Ecotoxicology 14: 283–293.

[NESCAUM] Northeast States for Coordinated Air Use Management. 2005. Inventory of Anthropogenic Mercury Emissions in the Northeast. Boston: NESCAUM.

Newton I, Wyllie I, Asher A. 1993. Long-term trends in organochlorine and mercury residues in some predatory birds in Britain. Environmental Pollution 79: 143–151.

[NHDES] New Hampshire Department of Environmental Services. 2005. Comments Regarding Proposed National Emissions Standards for Hazardous Air Pollutants; and, in the Alternative, Proposed Standards of Performance for New and Existing Stationary Sources: Electric Utility Generating Units; Notice of Data Availability. Environmental Protection Agency Docket ID no. OAR-2002-0056.

Niebla EE, Korte NE, Alesh BA, Fuller WH. 1976. Effect of municipal landfill leachate on mercury movement through soils. Water, Air, and Soil Pollution 5: 399–401.

[NOAA] National Oceanic and Atmospheric Administration. 2006. NOAA Air Resources Laboratory READY (Real-time Environmental Applications and Display System). (2 November 2006; *www.arl.noaa.gov/ready.html*)

Nocera JJ, Taylor PD. 1998. *In situ* behavioral response of common loons associated with elevated mercury (Hg) exposure. Conservation Ecology 2: 10–17.

Perry E, Norton SA, Kamman NC, Lorey PM, Driscoll CT. 2005. Deconstruction of historic mercury accumulation in lake sediments, northeastern United States. Ecotoxicology 14: 85–99.

Peterson SA, Van Sickle J, Hughes RM, Schacher JA, Echols SF. 2005. A biopsy procedure for determining filet and predicting whole-fish mercury concentration. Archives of Environmental Contamination and Toxicology 48: 99–107.

Rea AW, Keeler GJ, Scherbatskoy T. 1996. The deposition of mercury in throughfall and litterfall in the Lake Champlain watershed—a short-term study. Atmospheric Environment 30: 3257–3263.

Roué-Legall A, Lucotte M, Carreau J, Canuel R, Garcia E. 2005. Development of an ecosystem sensitivity model regarding mercury levels in fish using a preference modeling methodology: Application to the Canadian boreal system. Environmental Science and Technology 39: 9412–9423.

Rule KL, Comber SD, Ross D, Thornton A, Makropoulos CK, Rautiu R. 2006. Diffuse sources of heavy metals entering an urban wastewater catchment. Chemosphere 63: 64–72.

Schetagne R, Verdon R. 1999. Mercury in fish of natural lakes of Northern Quebec (Canada). Pages 235–258 in Lucotte M, Schetagne R, Therien N, Langlois C, Tremblay A, eds. Mercury in the Biogeochemical Cycle: Natural Environments and Hydroelectric Reservoirs of Northern Quebec. Berlin: Springer.

Schwarzbach SE, Albertson JD, Thomas CM. 2006. Effects of predation, flooding, and contamination on the reproductive success of California Clapper Rails (*Rallus longirostris obsoletus*) in San Francisco Bay. The Auk 123: 45–60.

Seiler RL, Lico MS, Wiemeyer SN, Evers DC. 2004. Mercury in the Walker River Basin, Nevada and California—Sources, Distribution, and

Potential Effects on the Ecosystem. Carson City (NV): US Geological Survey. Scientific Investigations Report no. 2004-5147.

Snodgrass JW, Jagoe CH, Bryan AL, Brant HA, Burger J. 2000. Effects of trophic status and wetland morphology, hydroperiod, and water chemistry on mercury concentrations in fish. Canadian Journal of Fisheries and Aquatic Sciences 57: 171–180.

Sorensen JA, Kallemeyn LW, Sydor M. 2005. Relationship between mercury accumulation in young-of-the-year yellow perch and water-level fluctuations. Environmental Science and Technology 39: 9237–9243.

St. Louis VL, Rudd JWM, Kelly CA, Beaty KG, Bloom NS, Flett RJ. 1994. Importance of wetlands as sources of methyl mercury to boreal forest ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 51: 1065–1076.

Sullivan TM, Bowerman B, Adams J, Lipfert DD, Morris SM, Bando A. 2004. Local Impacts of Mercury Emissions from Coal Fired Power Plants. Washington (DC): US Department of Energy. Report no. BNL-73967-2005.

Thompson DR. 1996. Mercury in birds and terrestrial mammals. Pages 341–356 in Beyer WN, Heinz GH, Redmon-Norwood AW, eds. Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. Boca Raton (FL): Lewis.

[USEPA] United States Environmental Protection Agency. 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Report no. EPA-454/B-95-003a. (6 December 2006; *www.epa.gov/scram001/dispersion_alt.htm#isc3*)

———. 1996. National Emissions Inventory database (1996 NEI Point Source Facility Summary). (12 December 2006; *www.epa.gov/ttn/chief/net/*)

———. 1997. Mercury Study Report to Congress, vols. 1–8. Washington (DC): Office of Air Quality Planning and Standards and Office of Research and Development. Report no. EPA-452/R-97-005.

———. 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. Final. Washington (DC): Office of Science and Technology and Office of Water. Report no. EPA-823-R-01-001.

———. 2005. Technical Support Document for the Final Clean Air Mercury Rule. Washington (DC): Office of Air Quality Planning and Standards.

Verta M, Rekolainen S, Kinnunen K. 1986. Causes of increased fish mercury levels in Finnish reservoirs. Publications of the Water Research Institute of Finland 65: 44–71.

Wang Z, Pehkonen SO. 2004. Oxidation of elemental mercury by aqueous bromine: Atmospheric implications. Atmospheric Environment 38: 3675–3688.

Wente SP. 2004. A Statistical Model and National Data Set for Partitioning Fish-Tissue Mercury Concentration Variation between Spatiotemporal and Sample Characteristic Effects. US Geological Survey Science Investigation Report 2004-5199. (3 November 2006; *http://pubs.usgs.gov/sir/2004/5199/*)

Whyte DC, Kirchner JW. 2000. Assessing water quality impacts and cleanup effectiveness in streams dominated by episodic mercury discharges. Science of the Total Environment 260: 1–9.

Wiener JG, Shields PJ. 2000. Mercury in the Sudbury River (Massachusetts, U.S.A.): Pollution history and synthesis of recent research. Canadian Journal of Fisheries and Aquatic Sciences 57: 1053–1061.

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Exhibit C to
Declaration of Raymond Vaughan

Mercury Contamination in Forest and Freshwater Ecosystems in the Northeastern United States

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Eastern North America receives elevated atmospheric mercury deposition from a combination of local, regional, and global sources. Anthropogenic emissions originate largely from electric utilities, incinerators, and industrial processes. The mercury species in these emissions have variable atmospheric residence times, which influence their atmospheric transport and deposition patterns. Forested regions with a prevalence of wetlands and of unproductive surface waters promote high concentrations of mercury in freshwater biota and thus are particularly sensitive to mercury deposition. Through fish consumption, humans and wildlife are exposed to methylmercury, which markedly bioaccumulates up the freshwater food chain. Average mercury concentrations in yellow perch fillets exceed the Environmental Protection Agency's human health criterion across the region, and mercury concentrations are high enough in piscivorous wildlife to cause adverse behavioral, physiological, and reproductive effects. Initiatives are under way to decrease mercury emissions from electric utilities in the United States by roughly 70%.

Keywords: atmospheric deposition, bioaccumulation, methylmercury, mercury contamination, northeastern United States

Mercury (Hg) is a potent neurotoxin of significant ecological and public health concern. Human and wildlife exposure to Hg occurs largely through the consumption of contaminated fish. It is estimated that over 410,000 children born each year in the United States are exposed in the womb to methylmercury (MeHg) levels that are associated with impaired neurological development (Mahaffey 2005). Eight percent of US women of childbearing age have blood Hg levels in excess of values deemed safe by the US Environmental Protection Agency (USEPA; Schober et al. 2003). Studies have also linked elevated Hg in the blood or tissue of fish, birds, and mammals with negative effects such as reduced reproductive success, hormonal changes, and motor skill impairment (Wiener and Spry 1996, Nocera and Taylor 1998, Evers et al. 2004).

To protect human health, the USEPA set a fish tissue criterion for MeHg at 0.3 μg per g under section 304(a) of the Clean Water Act (USEPA 2001). Similar criteria for wildlife are under development or promulgation in several states (e.g., Maine, New York). As of 2004, fish consumption advisories regarding Hg contamination have been issued for 44 states, including 21 statewide advisories for fresh waters and 12 for coastal waters. These advisories represent more than 53,000 km^2 of lakes and 1,230,000 km of rivers. The extent of fish consumption advisories underscores the extensive human and ecological health risk posed by Hg pollution.

Important sources of Hg to the environment include electric utilities, incinerators, industrial manufacturing, wastewater treatment plants, and improper disposal of consumer products (e.g., batteries, fluorescent light bulbs, Hg switches). Considerable public policy attention is directed toward airborne Hg emissions, since they constitute the largest source

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of Hg in the United States and globally (UNEP 2002). Although estimates suggest that US emissions of Hg peaked in the 1970s and have since declined (Pirrone et al. 1998), atmospheric concentrations remain approximately three times higher than preanthropogenic levels (Mason et al. 1994).

Neither atmospheric Hg emissions nor ambient concentrations of Hg in water constitute a direct public health risk at the levels of exposure usually found in the United States. The risk to humans and wildlife occurs as Hg is transported to watersheds and accumulates in the aquatic food chain. Airborne Hg is transported over variable distances (i.e., local to global scales), depending on the speciation of Hg emissions and reaction pathways, and is deposited to the Earth's surface.

Following deposition, ionic Hg (i.e., oxidized mercuric species, including complexes and particulate forms) may be reduced and reemitted to the atmosphere or converted to a more bioavailable form, MeHg. Through a bioaccumulation factor of about 10 million, MeHg accumulates to toxic levels at the top of the aquatic food chain. This Hg linkage, from air to water to fish and other biota, challenges the state and federal regulators charged with controlling airborne emissions and with decreasing Hg deposition to levels that meet standards for concentrations in water and in fish tissue.

To improve understanding of the Hg air–water–biota connection, the Hubbard Brook Research Foundation convened a team of eight scientists to synthesize scientific information concerning (a) Hg sources and inputs; (b) Hg transport, transformations, exposure, and environmental effects; and (c) Hg policy impacts in the Northeast. This synthesis includes the analysis of a large Hg data set compiled for eastern North America as part of a NERC (Northeastern Ecosystem Research Cooperative) initiative (Evers and Clair 2005). The NERC Hg project published summaries for water, sediment, and major taxonomic groups. Here we distill these studies into a regional overview with policy applications.

Efforts have been under way at state, regional, national, and global scales to reduce Hg emissions. Notably, in May 2005 the USEPA adopted a rule pertaining to Hg emissions from coal-fired power plants (the Clean Air Mercury Rule, or CAMR). This rule calls for a two-phase reduction in emissions through a cap-and-trade approach that is predicted to produce by approximately 2025 a 70% decrease in total US emissions from electric utilities. Rather than imposing an emission rate limit or requiring the use of maximum achievable control technology, the cap-and-trade approach allows facilities to purchase Hg allowances in order to comply with the regulations.

Mercury emissions and deposition in the northeastern United States

The northeastern United States (i.e., New England and New York) is an important region in which to investigate Hg, because it receives elevated Hg deposition and contains ecosystems sensitive to Hg inputs. Mercury-sensitive areas are typically forested areas with shallow surficial materials, abundant wetlands, and low-productivity surface waters. In the Northeast, the fish in many lakes and streams and the associated wildlife have elevated Hg, which in some instances is high enough to constitute a "biological Hg hotspot," which requires special attention from both a scientific and a policy perspective (Evers et al. 2007). A biological Hg hotspot is a location on the landscape that, compared with the surrounding landscape, is characterized by elevated concentrations of MeHg in biota (e.g., fish, birds, mammals) in excess of established human health or wildlife criteria as determined by a statistically adequate sample size.

Mercury emissions. Globally, approximately 6600 metric tons of Hg are emitted to the atmosphere annually, with 33% to 36% attributed to direct anthropogenic emissions. The remainder originates from natural sources or from past anthropogenic emissions that are rereleased (Mason and Sheu 2002). These values suggest that about two-thirds of atmospheric Hg emissions are derived from either direct or reemitted anthropogenic sources. Coal-fired power plants are the largest single category of Hg emissions, with 1450 metric tons per year, comprising about 50% of anthropogenic sources (Pacyna et al. 2003).

Total anthropogenic Hg emissions from all sources in the United States are calculated to be 103 metric tons per year, with the Northeast contributing about 4.7 metric tons per year (USEPA 1999). Mercury emissions in the United States have declined markedly over the past decade (table 1) as a result of federal regulations that mandated large reductions in Hg emissions in medical waste incinerators and in municipal incinerators (USEPA 2005). Unlike incinerator emissions, emissions from electric utilities have remained largely unchanged, and their relative contribution to total US emissions has increased from 25% to 40%. Municipal waste incinerators (23%) and electric utilities (16%) are the largest point-source categories in the Northeast.

Mercury is emitted to the atmosphere from point sources in three forms: elemental Hg (Hg^0), gaseous ionic Hg (reactive gaseous mercury, or RGM), and particulate Hg (PHg). This speciation exerts significant control over the fate of atmospheric Hg emissions and varies widely among sources (table 2). Therefore, Hg can be a local, regional, or global pollutant, depending on the speciation of the emissions and the associated residence times in the atmosphere (Dastoor and Larocque 2004).

In 1999, 57% of calculated point-source Hg emissions in the Northeast occurred as Hg^0, 33% as RGM, and 10% as PHg (USEPA 1999). Studies indicate that emissions from coal combustion in the United States are roughly 50% Hg^0, 40% RGM, and 10% PHg (Pacyna et al. 2003). However, emissions from coal combustion in the northeastern states have a higher percentage of RGM (68%) and a lower percentage of Hg^0 (30%) and PHg (2%; NESCAUM 2005). The actual Hg emission speciation profile for a specific power plant depends on the type of coal used and the air pollution control technology employed (NESCAUM 2003).

Table 1. Mercury (Hg) emissions (in metric tons per year), by source category, in the United States from 1990 through 2002 and in the Northeast region in 2002.

Source	Emissions (metric tons per year) United States 1990	1996	1999	2002	Northeast, 2002
Utility coal boilers	54	46	44	45	0.74
Medical waste incinerators	46	36	3	0.3	0.015
Municipal waste combustors	52	29	5	4	1.1
Industrial/commercial/ institutional boilers and process heaters	13	11	11	10	0.33
Chlorine production	9	7	6	5	0
Electric arc furnaces	7	–	–	10	–
Hazardous waste incineration	6	4	6	5	0.001
Total	222	168	109	103	4.7

Note: Individual source categories do not sum to the totals because area sources and minor point-source categories are not shown.
Source: USEPA 2002, 2005, NESCAUM 2005.

Elemental Hg, which is relatively unreactive and generally slowly oxidized, constitutes by far the largest pool of Hg in the atmosphere because of its relatively long residence time (0.5 to 2 years) and long-range transport potential (tens of thousands of kilometers). However, under some conditions Hg^0 can be rapidly oxidized and deposited locally or regionally, as observations have shown in the Arctic and Antarctic (Lindberg et al. 2002), at the marine and continental boundary layer, and in areas downwind of urban areas (Weiss-Penzias et al. 2003). Elemental Hg can also be directly deposited to forested ecosystems through stomatal gas exchange (Grigal 2002). As a result, the atmospheric lifetime of Hg^0 is probably closer to 0.5 year than to 2 years.

Reactive gaseous Hg consists predominantly of gaseous chloride and oxide forms of ionic Hg. This species is highly soluble in water and readily deposits to surfaces within tens to a few hundreds of kilometers from emission sources. Because of RGM's short atmospheric residence time (0.5 to 2 days), elevated Hg deposition can occur near RGM emission sources.

The atmospheric residence time of PHg is also relatively short (0.5 to 3 days). Although the fraction of PHg in ambient air in remote areas is generally less than 5% of total atmospheric Hg (Horvat 1996), concentrations may be higher near Hg emission sources and under certain atmospheric conditions (Lu et al. 2001).

Atmospheric deposition. Atmospheric deposition of Hg occurs in two forms: wet deposition (the deposition of Hg associated with rain and snow) and dry deposition (the deposition of PHg and RGM, cloud and fog deposition, and stomatal uptake of Hg^0). Although some areas have been contaminated by land disposal of Hg or discharge of Hg in wastewater effluent, the predominant input of Hg to most watersheds is atmospheric deposition. Fitzgerald and colleagues (1998) systematically rule out alternate hypotheses, such as natural weathering, as a significant cause of the observed widespread Hg contamination.

Judging from global models (Hudson et al. 1995), reconstructions of mass balances (Mason et al. 1994), and paleolimnological techniques (Engstrom and Swain 1997), it appears that deposition of Hg has increased two- to threefold over the past two centuries, following increases in Hg emissions associated with industrialization and Hg use. Paleolimnological studies in the Northeast typically show Hg deposition starting to increase in the late 1800s or early 1900s and increasing 2.5- to 15-fold by the late 20th century (1970s to 1990s) (figure 1; Kamman and Engstrom 2002). Decreases in sediment Hg deposition in the Northeast (approximately 25%) have been evident in recent years, coincident with reductions in US emissions and with static global emissions. Because inventories of Hg emissions have been limited, it is not clear what is responsible for the declines in Hg deposition

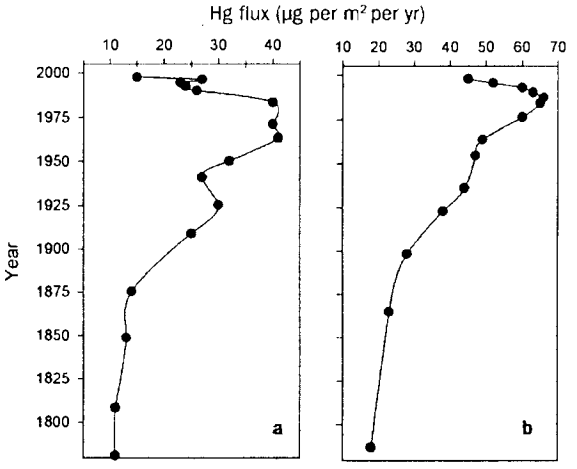

Figure 1. Changes in historical deposition of mercury (Hg) to sediments in (a) Spring Lake and (b) Wallingford Pond, Vermont, from 1820 to the present (after Kamman and Engstrom 2002). The sediment patterns reflect changes in Hg emissions and deposition over time.

Table 2. Percentage of mercury species emitted, by source category.

Source	Particulate mercury (percentage)	Reactive gaseous mercury (percentage)	Elemental mercury (percentage)
Coal-fired electric utilities (United States)	10	40	50
Coal-fired electric utilities (Northeast)	2	68	30
Utility oil boilers	20	30	50
Municipal waste combustors	20	58	22
Medical waste incinerators	20	75	5
Pulp and paper production	20	30	50
Chlorine production	0	5	95
Hazardous waste incinerators	22	20	58
Primary and secondary metal production	10	10	80
Municipal landfills	10	10	80

Source: USEPA 1999, Pacyna et al. 2003, NESCAUM 2005.

over the past few decades. However, it seems likely that controls on particulate matter and sulfur dioxide from electric utilities, and reductions in consumer and industrial Hg use, are important factors (Engstrom and Swain 1997).

In the eastern United States, Hg deposition is high (USEPA 1997), but it is difficult to identify its specific sources. Of the estimated 52 metric tons of Hg deposited per year in the United States from US sources, 24 metric tons (46%) are likely to originate from domestic utility coal boilers (half of the 48 metric tons of Hg that the coal-fired utilities emit each year is likely to be deposited within the United States; USEPA 1997). Likewise, for regions of New York it is estimated that 11% to 21% of the Hg deposited is derived from emissions within New York, 25% to 49% originates from other US sources, and 13% to 19% originates from Asia (Seigneur et al. 2003). Given that most coal-fired utilities emit 50% to 70% of Hg as RGM and PHg (table 2), local sources are most likely an important component of the deposition in areas within 50 km of these sources. An analysis of emissions and deposition in southern New Hampshire shows a local region of high deposition associated with local electric utility emissions (Evers et al. 2007).

In the United States and Canada, measurements of wet Hg deposition, which are largely made through the Mercury Deposition Network (MDN), show that wet Hg deposition is highest in the Southeast (e.g., Florida, Mississippi) and lowest in the West. There are currently seven MDN sites in the Northeast, with average annual wet deposition ranging from 3.8 to 12.6 μg per m^2 per year (*http://nadp.sws.uiuc.edu/mdn/*). There do not appear to be broad spatial patterns in wet Hg deposition across the region, but the network is sparse. Because of the placement of collectors in rural areas, the deposition values for the region do not include elevated deposition that would be expected near Hg sources and in urban areas.

Estimates of dry Hg deposition are highly uncertain because of the complex interrelationships of atmospheric conditions, collection surface characteristics and terrain, and chemical properties of the contaminants. Several modeling efforts have been used to estimate dry deposition of Hg, however. In regions of New York, estimated dry Hg deposition was 4 to 10 μg per m^2 per year (Seigneur et al. 2003). Another model estimate specifically for the Northeast suggests that dry deposition of RGM plus Hg^0 was 37 μg per m^2 per year (Xu et al. 2000). Both studies indicate that dry deposition provides a significant pathway of Hg inputs (50% to 75% of total deposition) and agree with USEPA predictions that Hg dry deposition in the Northeast is the highest in the country, in part as a result of the abundant forests whose canopies effectively collect Hg from the atmosphere.

Because of the large surface area associated with canopy foliage, atmospheric deposition of contaminants is elevated in forests compared with other types of ecosystems. Forest studies have indicated that total atmospheric Hg deposition may be estimated using fluxes of throughfall (precipitation that passes through the canopy) plus litterfall (plant material that falls to the forest floor; Rea et al. 2001). Grigal (2002) suggests that the ratio of Hg fluxes resulting from wet deposition, throughfall, and litterfall, respectively, is 1.0 to 1.8 to 2.2. So for the 5 μg per m^2 per year of wet deposition that might be typical of the Northeast, anticipated throughfall would be 9 μg per m^2 per year, and litterfall would be 11 μg per m^2 per year, resulting in total Hg deposition of 20 μg per m^2 per year and dry deposition of 15 μg per m^2 per year (75% of total).

Some portion of the Hg deposited to Earth's surface is reemitted to the atmosphere. However, rates of volatilization vary widely in association with differences in vegetation, soil moisture, temperature, solar radiation, and landscape characteristics. In general, volatilization rates from soil are high immediately after inputs of ionic Hg to the soil (Schluter et al. 1995). On the basis of a review of the literature, Grigal (2002) estimated a mean rate of Hg^0 volatilization from soil of approximately 11 μg per m^2 per hour. This rate is more than adequate to reemit most of the atmospheric Hg deposition. The magnitude and uncertainty of this process demonstrate the acute need for additional research on Hg reemissions.

Transport and transformation of mercury in forest–wetland–lake ecosystems

Following deposition to the landscape, Hg may be sequestered in soil, reemitted to the atmosphere, or transported through the watershed, with a fraction of these inputs ultimately supplied to surface waters. Watershed and water chemistry characteristics influence the transport of Hg to surface waters. Anoxic zones in wetlands and lakes provide suitable conditions for the methylation of ionic Hg to MeHg. The extent to which MeHg is biomagnified in the freshwater food chain depends on the nature and length of the food chain and on water chemistry characteristics.

Mercury transport and fate in upland forest ecosystems. Although there have been few direct studies of soil sequestration of Hg, immobilization of Hg in forest soil is known to correspond with the retention of organic carbon (Schwesig et al. 1999). Pools of Hg in upland soil in northern temperate regions are about 7 mg per m^2, although higher levels have been reported in central Europe (Grigal 2003).

The export of Hg by waters draining upland soils to surface waters is generally low. Concentrations and fluxes of Hg in soil waters, as in soil, are closely related to dissolved organic carbon (DOC; Schwesig et al. 1999). In northern forests, concentrations of total Hg are highest in waters draining the upper soil, coinciding with high concentrations of DOC. Concentrations and fluxes of total Hg decrease as DOC is immobilized with depth in mineral soil (Grigal 2002).

Limited studies suggest that MeHg concentrations in upland soils and groundwaters are generally low, although higher concentrations occur in upper soil waters and decrease with soil depth (Grigal 2002). Low concentrations and fluxes of MeHg in drainage waters suggest that rates of methylation are low, and freely draining upland soils are generally not important in the supply of MeHg to downstream surface waters, with the possible exception of recently harvested forests (Porvari et al. 2003).

Transport and transformation of mercury in wetlands. Wetlands are important features of the landscape that influence the supply of different Hg species to adjacent surface waters. Wetlands are typically net sinks of total Hg and sources of MeHg (Grigal 2002, 2003). Rates of total Hg accumulation are greater in wetlands than in upland soils because of the strong association of Hg with organic matter (Grigal 2003). Annual rates of MeHg production in wetlands are approximately 0.1 to 1 μg per m^2 per year (Galloway and Branfireun 2004). The factors controlling methylation of Hg in wetlands are not completely understood, but they most likely involve the amounts and types of organic matter, hydrologic flow paths, and rates of microbial activity (Galloway and Branfireun 2004). Wetlands are also a major source of DOC. Organic matter produced in wetlands forms complexes with both ionic Hg and MeHg, enhancing the transport of these Hg species to surface waters but decreasing their bioavailability (Hudson et al. 1994). An elevated supply of DOC to downstream surface water could also stimulate methylation and limit photodegradation of MeHg and photoreduction of ionic Hg. Furthermore, wetlands support sulfate-reducing bacteria, which appear to be largely responsible for Hg methylation (Benoit et al. 2003). Concentrations of MeHg in wetland porewaters (waters filling the spaces between solid material in sedimentary deposits) and surface waters vary seasonally, with the highest concentrations evident during the late summer, presumably as a result of warmer temperatures, higher rates of microbial activity, and longer hydraulic residence times (Galloway and Branfireun 2004).

Mercury concentrations and transformations in surface waters. Freshwater ecosystems are among the most sensitive to Hg pollution. Total Hg concentrations in surface waters in the Northeast vary by more than an order of magnitude, from less than 0.5 to 12.7 nanograms per liter (5th to 95th percentile; figure 2; Dennis et al. 2005). Most of the Hg in surface water occurs as ionic Hg, with MeHg ranging from 1% to 35% of total Hg (figure 3). Under conditions of high total Hg loading, MeHg production can vary widely, depending on the methylation efficiency of a particular ecosystem (Krabbenhoft et al. 1999).

Mercury enters remote surface waters through direct atmospheric deposition and through soil water, wetland, or groundwater drainage. Streams and rivers can exhibit marked temporal variation in Hg concentrations, which is associated with variations in concentrations of DOC or suspended matter. Large increases in Hg concentrations can occur during high flow events (Shanley et al. 2005).

Some inputs of Hg to lakes are removed from the water column by the volatilization of Hg^0 and by sediment deposition. In freshwater lakes, photochemical processes are largely responsible for the reduction of ionic Hg to Hg^0 (Amyot et al. 1997). Microbial reduction has been observed in laboratory studies, but only at higher than ambient concentrations of Hg (Morel et al. 1998). Biogeochemical processes in lakes also result in net production of MeHg due to methylation in anoxic sediments and in the water column.

The geographic distribution of average surface water Hg concentrations in the Northeast (figure 2) shows landscape-level heterogeneity in lake and river Hg concentrations, and areas where concentrations are elevated across several contiguous 18-minute grid cells. Areas of elevated Hg concentrations in surface waters can be explained by high concentrations of DOC, as in the Adirondacks; by high inputs of suspended solids, from rivers along Lake Champlain, related to high flow events; and by elevated atmospheric Hg deposition, as in lakes in southeastern New Hampshire and eastern Massachusetts. A large portion of the variation in total Hg and MeHg across the region can be explained by variation in DOC (Dennis et al. 2005). Areas with the highest mean surface water Hg concentrations also have the greatest range in Hg concentrations (figure 2). This variation may be attributed to heterogeneity in watershed characteristics or to high flow events (Shanley et al. 2005).

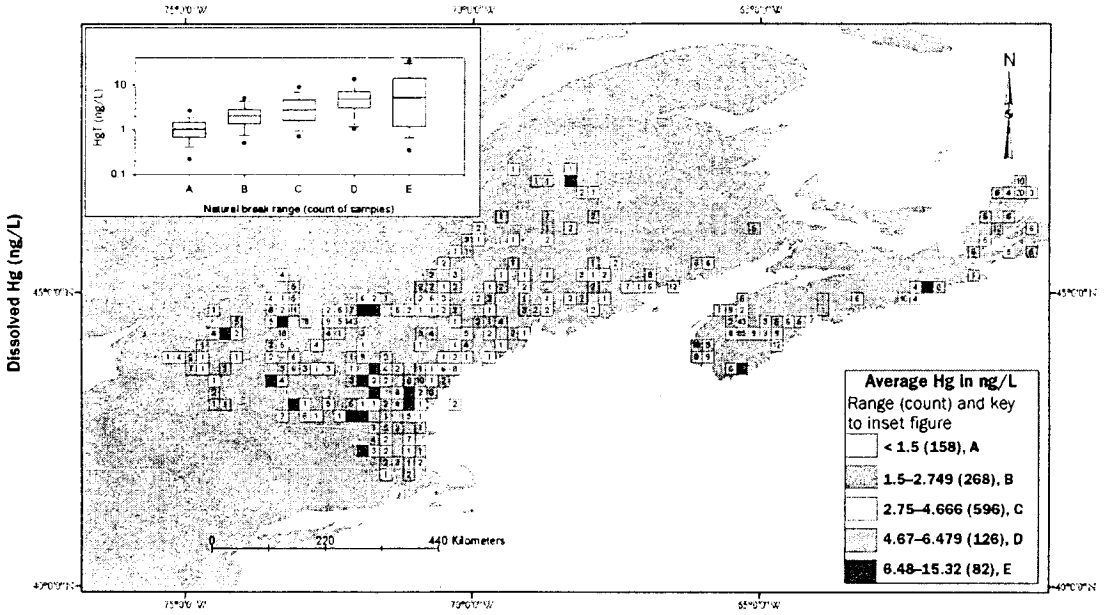

Figure 2. Average water mercury (Hg) concentrations within 18-minute grid cells for lakes and streams across northeastern North America. Inset shows the distribution of Hg concentrations comprising the mean for each quintile.

Other factors controlling mercury dynamics in surface waters. Other factors, such as water chemistry, land cover and land use, and watershed disturbances, alter the transport, transformation, and bioavailability of Hg in surface waters.

The Northeast receives elevated loading of acidic deposition as well as Hg deposition, and contains a relatively large number of acidified surface waters. Acidic deposition and the associated sulfur alter the acid–base status of surface waters, thereby influencing Hg transformation and accumulation in fish. Sulfur transformations are closely coupled with Hg dynamics. The solubility of Hg increases with increasing sulfide concentrations in anoxic waters through complexation reactions, potentially increasing the pool of Hg available for methylation (Benoit et al. 2003). Experimental observations show that when sulfate is added to wetlands or lakes, sulfate reduction is enhanced, leading to increased methylation and MeHg export (Branfireun et al. 1999, Watras et al. 2006).

Widespread observations show an inverse relationship between fish Hg concentrations and surface water pH (e.g., Kamman et al. 2004). Hrabik and Watras (2002) used reference data and observations from a lake experimentally acidified with sulfuric acid to examine the relative contribution of atmospheric Hg deposition and acidic deposition to Hg concentrations in fish. They found that half of the decrease in fish Hg over a six-year period during which the lake was recovering from acidification could be attributed to decreases in sulfuric acid loading.

In a study of 21 river basins nationwide, watersheds with mixed agriculture and forest land cover had the highest methylation efficiency, even where these watersheds had low total Hg in sediments (Krabbenhoft et al. 1999). Some waters draining largely agricultural lands have relatively high concentrations of total Hg and MeHg, but lower concentrations in fish, presumably due to algal "bloom dilution" associated with high phosphorus loading (Kamman et al. 2004; see below) or elevated DOC concentrations (which could stimulate methylation but limit bioaccumulation), or both.

Land disturbance influences Hg export and availability for methylation. Forest harvesting has been shown to increase export of total Hg and MeHg (Porvari et al. 2003). Fire results in a complex pattern of Hg loss from watersheds. During and shortly after fire, elevated Hg losses are associated with volatilization and drainage losses (Grigal 2002). Over the longer term, Hg transport to surface waters is reduced in burned areas as a result of decreases in soil carbon and DOC concentrations.

In reservoirs, rates of Hg methylation can be altered by water level fluctuation associated with hydropower production or flood control. Many large bodies of water in the Northeast are impounded to increase their storage or daily peaking capacity, and these water bodies may fluctuate tens of centimeters on a daily basis or several meters over the course of a summer. As the littoral zone experiences periodic wetting and drying, varying cycles of reduction and oxidation may enhance the production of MeHg, depending on a variety of factors (Sorensen et al. 2005, Evers et al. 2007).

Trophic transfer of mercury in surface waters of the Northeast. Concentrations of total Hg or MeHg in surface waters often do not correlate well with the Hg content of freshwater biota, such as fish. There are many physical, chemical, ecological, and land-use factors controlling the trophic transfer

of MeHg, which are key to predicting MeHg concentrations in fish and other freshwater organisms.

Trophic transfer of Hg in freshwater food webs begins with the bioaccumulation of ionic Hg and MeHg by primary producers. Bioaccumulation factors in the transfer of Hg from water to algae are by far higher (approximately 10^5 to 10^6) than at subsequent trophic levels (figure 3). Although both ionic Hg and MeHg are taken up by aquatic organisms, MeHg is assimilated four times more efficiently than ionic Hg (Mason et al. 1994). However, the absolute and relative assimilation efficiencies of ionic Hg and MeHg vary with trophic level, uptake pathway, and water chemistry conditions. Freshwater grazers and predators acquire MeHg mainly from their food rather than from water (Harris and Bodaly 1998). Methylmercury is efficiently transferred to the higher levels of the food web and largely incorporated within proteins, as in muscle tissue.

The NERC data show that MeHg increases in concentration and comprises a greater percentage of the total Hg in freshwater consumers and predators as it progresses up the food chain (figure 3). Thus organisms consuming prey at higher trophic levels are exposed to higher concentrations of total Hg and MeHg (Vander Zanden and Rasmussen 1996). Fish Hg occurs almost entirely as MeHg.

A variety of physical, chemical, and biological factors influence the biomagnification of MeHg. Fish Hg concentrations tend to vary positively with lake or watershed area and negatively with pH, acid neutralizing capacity (ANC), nutrient concentrations, zooplankton density, and human land use (Chen et al. 2005). Furthermore, the Hg added to the lake surface each year appears to be more available for conversion to MeHg than Hg that has been in the ecosystem for longer periods (Gilmour et al. 2003).

Both experimental and field studies show that nutrient enrichment diminishes Hg bioaccumulation in phytoplankton through the biodilution of Hg under algal bloom conditions (Pickhardt et al. 2002). Mercury concentrations in zooplankton also decrease with increasing zooplankton densities that in turn are correlated with lower Hg concentrations in fish (Chen and Folt 2005). Growth dilution in fish, also under conditions of high productivity and food availability, may be related to lower Hg concentrations in fish (Essington and Houser 2003).

Within given fish populations, Hg burdens increase with the age and size of individuals in part because of the slower rates of elimination and longer exposure in larger individuals, and in part because of the consumption of higher-trophic-level foods by older and larger individuals (Wiener and Spry 1996). Mercury concentrations in top predator fish are higher in food webs with longer chain lengths and less omnivory (Stemberger and Chen 1998).

Indicators of mercury sensitivity. Four simple and common measures of water quality—DOC, ANC, pH, and total phosphorus—have been shown by Chen and colleagues (2005) and many others to be related to fish Hg concentrations. To develop indicators of Hg sensitivity, we combined data from two stratified, random-probability surveys of northeastern lakes (USEPA EMAP [Environmental Monitoring and Assessment Program], Northeast Lakes Program, 1991–1994, and Vermont–New Hampshire REMAP [Regional EMAP], 1998–2000) with the survey data sets of Chen and colleagues (2005) to examine these four water-chemistry characteristics in lakes with standard-age yellow perch (*Perca flavescens*) whose tissue contained mean concentrations of Hg above and below the USEPA criterion (0.3 μg per g; figure 4). The standard age for yellow perch examined in this analysis was 4.6 years (Kamman et al. 2004). This analysis showed that lakes with Hg levels above 0.3 μg per g in yellow perch had significantly higher DOC (t = −3.099, p = 0.003) and lower pH (t = −6.282, $p < 0.001$), ANC (t = 2.835, p = 0.007), and total phosphorus (t = 3.840, $p < 0.001$) than lakes with fish Hg concentrations below 0.3 μg per g. As yellow perch have low to moderate Hg concentrations, these thresholds are conservative and help identify the most sensitive lakes.

Twenty percent of lakes in the region had total phosphorus concentrations above 30 μg per L. In those lakes, Hg concentrations in yellow perch were below 0.3 μg per g. In the remaining 80%, we found that most lakes (75%) had yellow perch Hg concentrations exceeding 0.3 μg per g when surface waters had a DOC level of more than 4.0 mg carbon per L, a pH of less than 6.0, or an ANC of less than 100 microequivalents (μeq) per L. These commonly monitored indicators provide natural resource managers with a useful tool for evaluating the likelihood of high fish Hg concentrations in individual lakes.

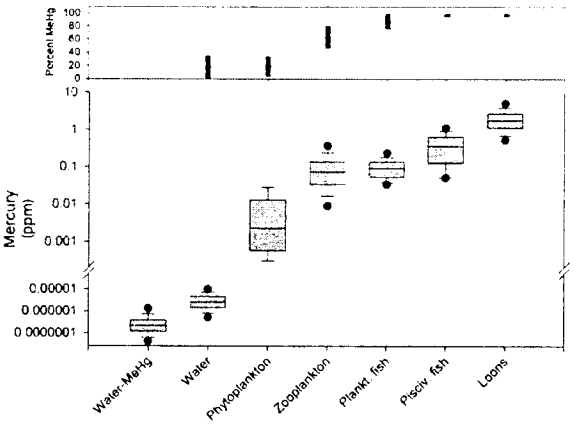

Figure 3. Box and whisker plots of mercury (Hg) concentrations in water and aquatic biota in eastern North America. Also shown are the ranges for the percentage of total Hg occurring as methylmercury (MeHg). All values were obtained from NERC (Northeastern Ecosystem Research Cooperative) data and represent wet weight, except those for phytoplankton, which were obtained from Watras and colleagues (1998).

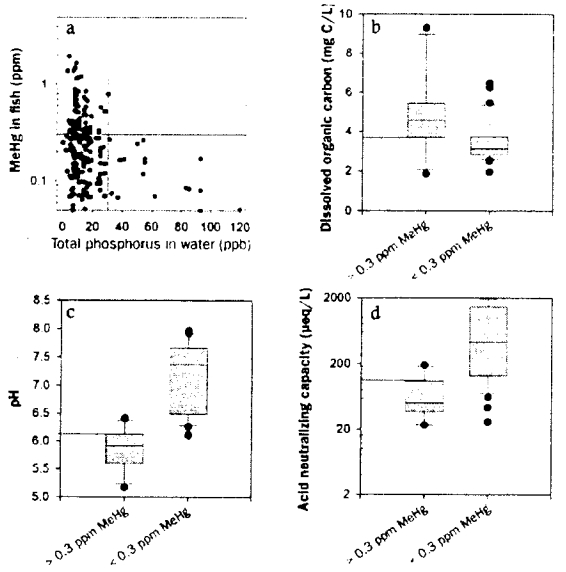

Figure 4. Relationship between methylmercury (MeHg) concentrations in standard-length yellow perch and total phosphorus concentration in lakes (a), and box and whisker plots of concentrations of dissolved organic carbon (b), pH (c), and acid neutralizing capacity (d) for lakes in the northeastern United States containing average concentrations of standard-age yellow perch with MeHg concentrations less than and greater than 0.3 μg per g.

Taxonomic patterns of mercury exposure

Biota are exposed to MeHg primarily through fish and insect consumption. The NERC data establish robust Hg exposure profiles for fish, birds, and mammals (table 3; Evers and Clair 2005), and highlight the importance of habitat type, foraging guild, trophic structure, and demographics on MeHg exposure (Evers et al. 2005).

In general, Hg concentrations vary by taxonomic group, with a higher proportion of MeHg at higher trophic levels. Mercury in benthic invertebrates and larval insects has been extensively studied in northeastern lakes and reservoirs, and is found to increase with trophic level (odonates > hemipterans and coleopterans > trichopterans > dipterans and ephemeropterans; Tremblay et al. 1996). The NERC data on Hg in over 15,000 fish show that the mean fillet Hg levels in 10 of the 13 species are above 0.3 μg per g, with the highest levels in large predatory fish such as walleye (*Sander vitreus*) and lake trout (*Salvelinus namaycush*; figure 5; Kamman et al. 2005).

Habitat type also has an important influence on MeHg concentrations. Data for two-lined salamanders (*Eurycea bislineata*) suggest that amphibians found in headwater streams have significantly higher MeHg concentrations than those in lakes (Bank et al. 2005). Larval insects in reservoirs have total Hg concentrations that are 3 to 10 times higher than those in natural lakes (Tremblay et al. 1996). Northern crayfish (*Orconectes virilis*) in headwater streams have Hg concentrations up to five times greater than those in lakes (Pennuto et al. 2005).

Comprehensive bird studies illustrate differences in MeHg exposure in foraging guilds. Piscivorous species with particularly high MeHg levels include the common loon (*Gavia immer*; Evers et al. 2005), wading birds (Frederick et al. 1999), and the bald eagle (*Haliaeetus leucocephalus*; Bowerman et al. 2002). Exposure studies in common loons have shown hormonal changes, reduced reproductive success, and motor skill impairment, resulting in the establishment of a wildlife criterion for blood Hg of 3.0 μg per g (Evers et al. 2004).

Table 3. Mercury exposure for selected biota in representative habitats in the Northeast.

Major habitat and organism	Sample size	Tissue sampled	Mercury level (μg per g) Mean ± SD	Mercury level (μg per g) Range	Reference
Lakes					
Yellow perch	841	Whole body	0.29 ± 0.07	< 0.05–3.17	Kamman et al. 2005
	2888	Fillet	0.35 ± 0.20	< 0.05–5.03	Kamman et al. 2005
Common loon	770	Adult blood	2.04 ± 1.39	0.05–8.63	Evers et al. 2005
	660	Egg	0.78 ± 0.60	0.01–9.00	Evers et al. 2005
Estuaries					
Saltmarsh sharp-tailed sparrow	108	Adult blood	0.63 ± 0.26	0.18–1.68	Lane and Evers 2005
Rivers					
Belted kingfisher	117	Adult blood	0.99 ± 0.82	0.07–4.57	Evers et al. 2005
Mountains					
Bicknell's thrush	242	Adult blood	0.08 ± 0.38	0.03–0.80	Rimmer et al. 2005
General aquatic					
Bald eagle	108	Juvenile blood	0.30 ± 0.27	0.01–1.20	Evers et al. 2005
Tree swallow	53	Adult blood	0.41 ± 0.21	0.11–1.00	Evers et al. 2005
Mink	126	Fur	20.7	1.78–68.5	Yates et al. 2005
Otter	160	Fur	18.0	1.14–73.7	Yates et al. 2005

SD, standard deviation.

Exposure to MeHg is not limited to piscivorous birds. Data for insectivorous songbirds, such as the northern waterthrush (*Seiurus noveboracensis*) and red-winged blackbird (*Agelaius phoeniceus*), show blood Hg levels that can exceed levels in piscivorous birds (Evers et al. 2005). Moreover, elevated MeHg has been measured in several breeding populations of saltmarsh sharp-tailed sparrows (*Ammodramus caudacutus*) in some New England estuaries (Lane and Evers 2005), and in terrestrial species such as Bicknell's thrush (*Catharus bicknelli*) and other montane songbirds (Rimmer et al. 2005).

Terrestrial mammals, particularly mink (*Mustela vision*) and river otter (*Lontra canadensis;* table 3), also experience elevated MeHg in the Northeast. Yates and colleagues (2005) found that Hg levels tend to be higher in mink than in otter, in interior than in coastal populations, and in females than in males. Recent evidence for MeHg exposure in insectivores has led to ongoing investigations in bats and other nonpiscivorous mammal species.

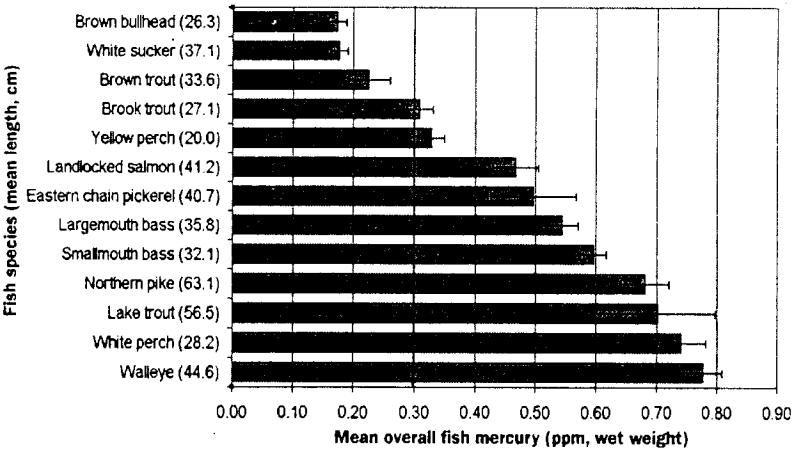

Figure 5. Mean and standard deviation of mercury (Hg) concentrations of 13 species of fish in eastern North America (Kamman et al. 2005). The downward-pointing arrow indicates the US Environmental Protection Agency's criterion for fish Hg concentrations.

Comprehensive data on fish and wildlife exposure are being used to identify species, habitats, and regions that are likely to be at the highest risk for MeHg contamination, and will be useful for measuring progress resulting from future management actions.

Evaluating reductions in mercury emissions

At present, most state and national policy attention is focused on Hg emissions from electric utilities (i.e., coal-fired power plants). Although controlling other sources (e.g., emissions from incinerators, discharges from wastewater treatment plants) and implementing other management options (e.g., biomanipulation, land-use management) may also hold promise for reducing and mitigating Hg bioaccumulation, we focus on the potential effect of reducing Hg emissions from electric utilities, because they are the largest single source of airborne emissions in the United States and the second largest source in the Northeast, and because their emissions have remained unchanged both regionally and nationally over the past decade (NESCAUM 2005). Although municipal waste combustors are the largest Hg emission source in the Northeast, effective strategies for reducing their emissions are under way, as evidenced by the decline of approximately 80% in emissions from this source between 1998 and 2003 (NESCAUM 2005).

Many proposals have been introduced at both the federal and the state level to control Hg emissions from electric utilities. The main differences among them include (a) the level and timing of the cuts, (b) the existence of an emissions cap or emissions rate limit, and (c) whether or not trading is allowed. In general, the level and timing of Hg emission reductions are likely to control the extent and rate of recovery in the region, and the use of trading has prompted questions regarding the persistence or expansion of biological Hg hotspots (Evers et al. 2007).

Here we estimate the changes in emissions and deposition that are associated with the CAMR and discuss the potential effect of these changes on freshwater ecosystems using field data. The USEPA estimates that the CAMR will result in a 70% decrease in Hg emissions from electric utilities by 2025. We estimate that the CAMR, when fully implemented, would result in a decrease of approximately 18% to 30% in deposition in the northeastern United States. This estimate is based on an analysis of US emissions and deposition that assumes (a) that current and reemitted anthropogenic emissions each constitute one-third of the emissions in the United States, and (b) that electric utilities account for 50% of each of these two emission categories. It follows that if electric utilities reduce their emissions by 70%, current and reemitted anthropogenic emissions would each decrease by 35%.

We further assume that US emissions are responsible for 40% to 65% of Hg deposition in the Northeast (Seigneur et al. 2003) and that reemitted US emissions contribute another 10% to 20%. If deposition attributed to these emission categories were reduced by 35% as a result of the CAMR, then total deposition would decline by approximately 18% to 30%. These predictions are consistent with the decrease of approximately 25% in sediment Hg deposition that occurred coincident with decreases in Hg emissions in the United States between 1970 and 1999.

An 18% to 30% decrease in Hg deposition is likely to provide significant ecological benefits in the region. Detailed biological data from a group of nine lakes in New Hampshire show that the Hg concentrations in the blood and eggs of the common loon declined 50% between 1999 and 2002 as emissions in the vicinity were cut 45% between 1997 and 2002, suggesting that some ecosystems in close proximity to large

emissions sources may experience rapid improvement (Evers et al. 2007). Hrabik and Watras (2002) found that Hg fish concentrations declined 30% between 1994 and 2000 as a result of decreased atmospheric Hg loading to a lake in northern Wisconsin; they concluded that modest changes in Hg or acidic deposition can significantly affect Hg bioaccumulation over short timescales. The range and rate of ecosystem response are most likely related to the variation in the physical, chemical, and biological characteristics of lakes and watersheds.

We expect that the CAMR will produce important results, but these changes may not be sufficient to protect human and environmental health. Given that *average* fish Hg concentrations sampled across the region currently exceed the USEPA human health criterion by 10% to 88%, depending on the species, significant additional reductions in Hg emissions from other US and global sources will probably be necessary to bring about widespread recovery to Hg levels that are below this criterion in most fish species in the northeastern United States.

Conclusions

A large Hg database produced by the NERC Hg working group was used to document and examine the widespread Hg contamination across eastern North America. From this synthesis, it is evident that the Northeast receives elevated Hg deposition derived mostly from direct emissions and reemissions of anthropogenic sources. Paleolimnological studies suggest that Hg deposition is substantially influenced by US emissions and responds to reductions in these sources.

Direct anthropogenic emissions of Hg originate largely from electric utilities, incinerators, and industrial processes. Current understanding of speciation and deposition processes suggests that, while speciation exerts important influence over patterns of atmospheric transport and deposition, all forms of Hg have the potential to deposit locally or regionally.

Forest regions are particularly sensitive to Hg inputs as a result of numerous factors: the filtering effects of the canopy and the associated elevated deposition; the prevalence of wetlands, which are critical in the transport of Hg and the production of MeHg; and low-productivity lakes, which promote high concentrations of Hg in fish. Although Hg is highly variable in surface waters across the region, we have identified several chemical thresholds to predict high fish Hg: total phosphorus concentrations of less than 30 μg per L; pH of less than 6.0; ANC of less than 100 μeq per L; and DOC of more than 4 mg carbon per L. Freshwater food chains are characterized by marked bioaccumulation of MeHg (10^6 to 10^7), with the largest increase occurring from water to plankton (10^5). Many freshwater and terrestrial animals in the Northeast exhibit high concentrations of Hg. For the common loon, existing Hg concentrations can cause adverse individual (behavioral and reproductive) and population-level effects.

Our analysis suggests that (a) cuts in Hg emissions from electric utilities in the United States will decrease Hg deposition in the region; (b) decreased Hg deposition will result in lower Hg levels in biota, although significant time lags may exist in many ecosystems; and (c) widespread recovery to Hg levels that no longer pose a human health risk or population risk to the common loon will be a long-term process that is likely to require additional reductions in Hg emissions.

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References cited

Amyot M, Gill GA, Morel FMM. 1997. Production and loss of dissolved gaseous mercury in coastal seawater. Environmental Science and Technology 31: 3606–3611.

Bank MS, Loftin CS, Jung RE. 2005. Mercury bioaccumulation in northern two-lined salamanders from streams in the northeastern United States. Ecotoxicology 14: 181–191.

Benoit JM, Gilmour C, Heyes A, Mason RP, Miller C. 2003. Geochemical and biological controls over methylmercury production and degradation in aquatic ecosystems. Pages 262–297 in Chai Y, Braids OC, eds. Biogeochemistry of Environmentally Important Trace Elements. Washington (DC): American Chemical Society. ACS Symposium Series no. 835.

Bowerman WW, Roe AS, Gilbertson M, Best DA, Sikarskie JG, Summer CL. 2002. Using bald eagles to indicate the health of the Great Lakes environment. Lake and Reservoir Management 7: 183–187.

Branfireun BA, Roulet NT, Kelly CA, Rudd JWM. 1999. *In situ* sulphate stimulation of mercury methylation in a boreal peatland: Toward a link between acid rain and methylmercury contamination in remote environments. Global Biogeochemical Cycles 13: 743–750.

Chen CY, Folt CL. 2005. High plankton biomass reduces mercury biomagnification. Environmental Science and Technology 39: 115–121.

Chen CY, Stemberger RS, Kamman NC, Mayes BM, Folt CL. 2005. Patterns of Hg bioaccumulation and transfer in aquatic food webs across multilake studies in the Northeast US. Ecotoxicology 14: 135–147.

Dastoor A, Larocque Y. 2004. Global circulation of atmospheric mercury: A modeling study. Atmospheric Environment 38: 147–162.

Dennis IF, Clair TA, Driscoll CT, Kamman NC, Chalmers A, Shanley JB, Norton SA, Kahl S. 2005. Distribution patterns of mercury in lakes and rivers of northeastern North America. Ecotoxicology 14: 113–123.

Engstrom DR, Swain EB. 1997. Recent declines in atmospheric mercury deposition in the upper Midwest. Environmental Science and Technology 31: 960–967.

Essington TE, Houser JN. 2003. The effect of whole-lake nutrient enrichment on mercury concentration in age-1 yellow perch. Transactions of the American Fisheries Society 132: 57–68.

Evers DC, Clair TA. 2005. Mercury in northeastern North America: A synthesis of existing databases. Ecotoxicology 14: 7–14.

Evers DC, Lane OP, Savoy L, Goodale W. 2004. Assessing the Impacts of Methylmercury on Piscivorous Wildlife Using a Wildlife Criterion Value Based on the Common Loon, 1998–2003. Gorham (ME): Maine Department of Environmental Protection, BioDiversity Research Institute. Report no. BRI 2004-05.

Evers DC, Burgess NM, Champoux L, Hoskins B, Major A, Goodale WM, Taylor RJ, Poppenga R, Daigle T. 2005. Patterns and interpretation of mercury exposure in freshwater avian communities in northeastern North America. Ecotoxicology 14: 193–221.

Evers DC, Han Y-J, Driscoll CT, Kamman NC, Goodale MW, Lambert KF, Holsen TM, Chen CY, Clair TA, Butler T. 2007. Biological mercury hotspots in the northeastern United States and southeastern Canada. BioScience 57: 29–43. doi:10.1641/B570107

Fitzgerald WF, Engstrom DR, Mason RP, Nater EA. 1998. The case of atmospheric mercury contamination in remote areas. Environmental Science and Technology 32: 1–7.

Frederick PC, Spalding MG, Sepulveda MS, Williams G, Nico L, Robins R. 1999. Exposure of egret (*Ardea albus*) nestlings to mercury through diet in the Everglades ecosystem. Environmental Toxicology and Chemistry 18: 1940–1947.

Galloway ME, Branfireun BA. 2004. Mercury dynamics of a temperate forested wetland. Science of the Total Environment 325: 239–254.

Gilmour CC, Heyes A, Mason RP, Miller C, Rearick M. 2003. Response of methylmercury production to changes in Hg loading: A comparison of Hg isotope addition studies. Pages 23–24 in US Environmental Protection Agency, National Center for Environmental Research, Proceedings: STAR Mercury Fate and Transport Final Progress Review Workshop, November 21, 2003, Washington, DC. (27 November 2006; *http://es.epa.gov/ncer/publications/workshop/pdf/2003star_mercury_fate_transport_proceedings.pdf*)

Grigal DF. 2002. Inputs and outputs of mercury from terrestrial watersheds: A review. Environmental Review 10: 1–39.

———. 2003. Mercury sequestration in forests and peatlands: A review. Journal of Environmental Quality 32: 393–405.

Harris RC, Bodaly RA. 1998. Temperature, growth, and dietary effects on fish mercury dynamics in two Ontario lakes. Biogeochemistry 40: 175–187.

Horvat M. 1996. Mercury analyses and speciation. Pages 1–31 in Baeyens W, Ebinghaus R, Vasiliev O, eds. Global and Regional Mercury Cycles: Sources, Fluxes and Mass Balances. Dordrecht (The Netherlands): Kluwer Academic.

Hrabik TR, Watras CJ. 2002. Recent declines in mercury concentration in a freshwater fishery: Isolating the effects of de-acidification and decreased atmospheric mercury deposition in Little Rock Lake. Science of the Total Environment 297: 229–237.

Hudson RJM, Gherini SA, Watras, CJ, Porcella DB. 1994. Modeling the biogochemical cycle of mercury in lakes: The mercury cycling model (MCM) and its application to the MTL study lakes. Pages 473–523 in Watras CJ, Huckabee JW, eds. Mercury Pollution: Integration and Synthesis. Boca Raton (FL): Lewis.

Hudson RJ, Gherini SA, Fitzgerald WM, Porcella DB. 1995. Anthropogenic influences on the global mercury cycle: A model-based analysis. Water, Air, and Soil Pollution 80: 227–233.

Kamman NC, Engstrom DR. 2002. Historical and present fluxes of mercury to Vermont and New Hampshire lakes inferred from ^{210}Pb dated sediment cores. Atmospheric Environment 36: 1599–1609.

Kamman NC, Lorey PM, Driscoll CT, Estabrook R, Major A, Pientka B, Glassford E. 2004. Assessment of mercury in waters, sediments, and biota of New Hampshire and Vermont lakes, USA, sampled using a geographically randomized design. Environmental Toxicology and Chemistry 23: 1172–1186.

Kamman NC, et al. 2005. Mercury in freshwater fish of northeast North America—a geographic perspective based on fish tissue monitoring databases. Ecotoxicology 14: 163–180.

Krabbenhoft DP, Wiener JG, Brumbaugh WG, Olson ML, DeWild JF, Sabin TJ. 1999. A national pilot study of mercury contamination of aquatic ecosystems along multiple gradients. Pages 147–160 in Morganwalp DW, Buxton HT, eds. US Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, Charleston, South Carolina, March 8–12, 1999, vol. 2. Contamination of Hydrologic Systems and Related Ecosystems. US Geological Survey Water-Resources Investigations Report no. 99-4018B. (18 December 2006; *http://toxics.usgs.gov/pubs/wri99-4018/Volume2*)

Lane OP, Evers DC. 2005. Developing a Geographic Exposure Profile of Methylmercury Availability in Salt Marshes of New England. Gorham (ME): BioDiversity Research Institute. Report no. BRI 2005-04.

Lindberg SE, Brooks SB, Lin C-J, Scott KJ, Landis MS, Stevens RK, Goodsite M, Richter A. 2002. The dynamic oxidation of gaseous mercury in the Arctic atmosphere at polar sunrise. Environmental Science and Technology 36: 1245–1256.

Lu JY, Schroeder WH, Barrie LA, Steffen A, Welch H, Martin K, Lochard L, Hunt RV, Boila G, Richter A. 2001. Magnification of atmospheric mercury deposition to polar regions in springtime: The link to tropospheric ozone depletion chemistry. Geophysical Research Letters 28: 3219–3222.

Mahaffey KR. 2005. Update on recent epidemiologic mercury studies. Pages 31–33 in Proceedings of the 2004 National Forum on Contaminants in Fish; 25–28 January 2004, San Diego, California. Report no. EPA-823-R-05-006.

Mason RP, Sheu G-R. 2002. Role of the ocean in the global mercury cycle. Global Biogeochemical Cycles 16: 1093.

Mason RP, O'Donnell J, Fitzgerald WF. 1994. Elemental mercury cycling within the mixed layer of the equatorial Pacific Ocean. Pages 83–97 in Watras CJ, Huckabee JW, eds. Mercury Pollution: Integration and Synthesis. Boca Raton (FL): Lewis.

Morel FMM, Kraepiel AML, Amyot M. 1998. The chemical cycle and bioaccumulation of mercury. Annual Review of Ecology and Systematics 29: 543–566.

[NESCAUM] Northeast States for Coordinated Air Use Management. 2003. Mercury Emission from Coal-fired Power Plants: The Case for Regulatory Action. Boston: NESCAUM.

———. 2005. Inventory of Anthropogenic Mercury Emissions in the Northeast. Boston: NESCAUM.

Nocera JJ, Taylor PD. 1998. *In situ* behavioral response of common loons associated with elevated mercury (Hg) exposure. Conservation Ecology 2: 10–17.

Pacyna J, Pacyna E, Steenhuisen F, Wilson S. 2003. Mapping 1995 global anthropogenic emissions of mercury. Atmospheric Environment 37 (suppl. 1): S-109–S-117.

Pennuto CM, Lane OP, Evers DC, Taylor RJ, Loukmas J. 2005. Mercury in the northern crayfish, *Orconectes virilis* (Hagen), in New England, USA. Ecotoxicology 14: 149–162.

Pickhardt PC, Folt CL, Chen CY, Klaue B, Blum JD. 2002. Algal blooms reduce the uptake of toxic methylmercury in freshwater food webs. Proceedings of the National Academy of Sciences 99: 4419–4423.

Pirrone N, Allegraini I, Keeler GJ, Nriagu JO, Rossmann R, Robbins JA. 1998. Historical atmospheric mercury emissions and depositions in North America compared to mercury accumulations in sedimentary records. Atmospheric Environment 32: 929–940.

Porvari P, Verta M, Munthe J, Haapanen M. 2003. Forestry practices increase mercury and methylmercury output from boreal forest catchments. Environmental Science and Technology 37: 2389–2393.

Rea AW, Lindberg SE, Keeler GJ. 2001. Dry deposition and foliar leaching of mercury and selected trace elements in deciduous forest throughfall. Atmospheric Environment 35: 3453–3462.

Rimmer CC, McFarland KP, Evers DC, Miller EK, Aubry Y, Busby D, Taylor RJ. 2005. Mercury concentrations in Bicknell's thrush and other insectivorous passerines in montane forest of northeastern North America. Ecotoxicology 14: 223–240.

Schluter K, Alstad J, Seip HM. 1995. Mercury translocation in and evaporation from soil, I: Soil lysimeter experiments with ^{203}Hg-radiolabeled compounds. Journal of Soil Contamination 4: 327–353.

Schober SE, et al. 2003. Blood mercury levels in US children and women of childbearing age, 1999–2000. Journal of the American Medical Association 289: 1667–1674.

Schwesig D, Ilgen G, Matzner E. 1999. Mercury and methylmercury in upland and wetland acid forest soils of a watershed in NE-Bavaria, Germany. Water, Air, and Soil Pollution 113: 141–154.

Seigneur C, Lohman K, Vijayaraghavan K, Shia R. 2003. Contributions of global and regional sources to mercury deposition in New York State. Environmental Pollution 123: 365–373.

Shanley JB, Kamman NC, Clair TA, Chalmers A. 2005. Physical controls on total and methylmercury concentrations in streams and lakes of the northeastern USA. Ecotoxicology 14: 125–134.

Sorensen JA, Kallemeyn LW, Sydor M. 2005. Relationship between mercury accumulation in young-of-the-year yellow perch and water-level fluctuations. Environmental Science and Technology 39: 9237–9243.

Stemberger RS, Chen CY. 1998. Fish tissue metals and zooplankton assemblages of northeastern US lakes. Canadian Journal of Fisheries and Aquatic Sciences 55: 339–352.

Tremblay A, Lucotte M, Rheault I. 1996. Methylmercury in a benthic food web of two hydroelectric reservoirs and a natural lake of northern Quebec (Canada). Water, Air, and Soil Pollution 91: 255–269.

[UNEP] United Nations Environment Programme. 2002. Global Mercury Assessment. (27 November 2006; *www.chem.unep.ch/mercury/Report/Final%20Assessment%20report.htm*)

[USEPA] US Environmental Protection Agency. 1997. Mercury Study Report to Congress, vols. 1–8. Washington (DC): Office of Air Quality Planning and Standards and Office of Research and Development. Report no. EPA-452/R-97-005.

———. 1999. 1999 National Emission Inventory Documentation and Data—Final Version 3.0; Hazardous Air Pollutants Inventory—Final NEI Version 3; HAPS Summary Files. (12 December 2006; *www.epa.gov/ttn/chief/net/1999inventory.html*)

———. 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. Washington (DC): Office of Water. Report no. EPA-823-R-01-001.

———. 2002. 2002 National Emissions Inventory Data and Documentation. Inventory Data. Point Sector Data: National Files and Nonpoint Sector Data: National Files. (12 December 2006; *www.epa.gov/ttn/chief/net/2002inventory.htm*)

———. 2005. EPA Fact Sheet 2004: National Listing of Fish Advisories. Washington (DC): Office of Water. Report no. EPA-823-F-05-004.

Vander Zanden MJ, Rasmussen JB. 1996. A trophic position model of pelagic food webs: Impact on contaminant bioaccumulation in lake trout. Ecological Monographs 66: 451–477.

Watras CJ, Back RC, Halvorsen S, Hudson RJM, Morrison KA, Wente SP. 1998. Bioaccumulation of mercury in pelagic freshwater food webs. Science of the Total Environment 219: 183–208.

Watras CJ, Morrison KA, Regnell O, Kratz TK. 2006. The methylmercury cycle in Little Rock Lake during experimental acidification and recovery. Limnology and Oceanography 51: 257–270.

Weiss-Penzias P, Jaffe DA, McClintick A, Prestbo EM, Landis MS. 2003. Gaseous elemental mercury in the marine boundary layer: Evidence for rapid removal in anthropogenic pollution. Environmental Science and Technology 37: 3755–3763.

Wiener JG, Spry DJ. 1996. Toxicological significance of mercury in freshwater fish. Pages 297–340 in Beyer WN, Heinz GH, Redmon-Norwood AW, eds. Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. Boca Raton (FL): Lewis.

Xu X, Yang X, Miller DR, Helble JJ, Thomas H, Carley RJ. 2000. A sensitivity analysis on the atmospheric transformation and deposition of mercury in northeastern USA. Science of the Total Environment 259: 169–181.

Yates DE, Mayack DT, Munney K, Evers DC, Major A, Kaur T, Taylor RJ. 2005. Mercury levels in mink (*Mustela vison*) and river otter (*Lontra canadensis*) from northeastern North America. Ecotoxicology 14: 263–274.

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