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2nd Edition

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Mercury's Pathway from Rain to Fish in the Environment

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2nd Edition
This edition updates some incorrectly calculated data that appeared in the first edition. These updated calculations are not significantly different and do not change the findings in the first edition.

The National Wildlife Federation (NWF) is a non-profit conservation and education organization with national headquarters in Reston, Virginia. Founded in 1936, NWF, its members and supporters, and a national network of affiliated organizations, work to educate citizens about the need for sustainable use and proper management of our natural resources.

The mission of the National Wildlife Federation is to educate, inspire and assist individuals and organizations of diverse cultures to conserve wildlife and other natural resources and to protect the earth's environment in order to achieve a peaceful, equitable and sustainable future.

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Foreword

I have spent many vacations fishing the scenic lakes and rivers in our country's southeastern and Mid-Atlantic States. However, there's a problem looming over these waterways like a thundercloud. My family and yours cannot safely eat the fish we catch because the rivers, lakes and streams are contaminated with mercury, and so are the fish they sustain.

High mercury levels in the inland waters of 44 states have forced health officials to issue advisories warning people to restrict or entirely avoid eating fish caught from thousands of inland lakes and streams. Mercury is a powerful neurotoxin that can cause irreversible harm to the brain and nervous system of children when they are developing in the womb. It is particularly dangerous for sport fishermen, subsistence anglers, Native Americans and others who eat freshwater fish as a dietary mainstay. Wildlife such as otters, eagles, herons and loons are susceptible to mercury, too. Fish-eating animals exhibit reproductive and behavioral problems when their food supply is contaminated with the toxic metal.

Air pollution is the major cause of mercury in our lakes and streams. Coal-fired power plants, waste incinerators, and other industries emit mercury into the air and it falls back to earth in rain and snow. The very precipitation that should be a source of cleansing waters has been shown to increase toxic mercury in waterways across the country.

This report is part of the National Wildlife Federation (NWF) Clean the Rain campaign to educate Americans about the risk mercury poses and give concerned citizens the information and tools to protect themselves and their environment. NWF is working with local partners and communities to sample rain falling over a range of U.S. states, to highlight the threat, and begin tackling the airborne sources of mercury pollution.

We hope this report will inspire citizens, businesses, and policy leaders to act on the solutions we know exist. By cleaning up the nation's coal-fired power plants, promoting clean, renewable energy sources, and eliminating the intentional use of mercury in products and manufacturing, we can protect ourselves and our wildlife from a host of environmental threats that include mercury pollution.

Mark Van Putten
President and CEO

Executive Summary

Water. About 70% of the Earth's surface is covered with it. About 3,100 cubic miles of water in the form of water vapor is circling above us in the atmosphere. Sixty thousand cubic miles of water are stored as fresh water in lakes, inland seas, and rivers.[1] Our own bodies are made up of 75% water. Water is essential: it's the building block of life, it nourishes the land, quenches thirst, and provides a home to millions of aquatic species—yet we allow this precious gift of life to be polluted at an ever-increasing rate.

Every day, chemically reactive mercury is released into the atmosphere by coal-fired power plants, cement manufacturers, incinerators, chlor-alkali plants and a host of other sources and then deposited with rain or snow. This toxic heavy metal falls all around us, contaminating our rivers, lakes and streams. The rain is poisoning our fish and all the other species that rely on these basic ecosystems for survival. Mercury from rain can accumulate in our fish to levels that can poison wildlife and humans that eat them. It can fall hundreds of miles from its original source, contaminating pristine areas as far away as the North Pole—areas far from industrial pollution. Like PCBs, dioxins, and some other environmental contaminants, mercury can travel through the atmosphere and fall out with rain or snow.

In this third series of multi-state Clean the Rain reports, National Wildlife Federation analyzed mercury precipitation data collected in twelve different states from 1995 to 2001. The data show that precipitation throughout the Southeast, Gulf States, and mid-Atlantic, contains mercury in sufficient concentrations to make aquatic organisms toxic to wildlife and humans that consume them. Mercury concentrations in precipitation are compared to the level defined as safe by the U.S. Environmental Protection Agency for mercury in lakes and streams.[2] This comparison is intended to illustrate the potential for rainfall and snow to be a source of mercury for aquatic organisms in lakes and streams. The extent of mercury accumulation in aquatic organisms depends upon local conditions. That those conditions are met throughout the states included in this report is shown by the need for human health warnings about fish consumption, which are based on actual measurements of mercury in fish.

Mercury in precipitation is widespread, and measured levels are consistently elevated:

- Over 97 percent of the rain samples in Louisiana had mercury levels exceeding the EPA safe level for lakes, contributing to mercury contamination in over 35,000 acres of lake water.

- Mercury levels measured in Georgia rain were as high as 78 times the EPA safe level for mercury in lakes.
- Over 96 percent of the precipitation samples in New York exceeded the EPA safe level for mercury, adversely affecting close to 60,000 acres of lake water.

The impact of mercury-contaminated rain is enormous as it enters an ecosystem. Methylmercury is formed in aquatic systems from the reactive mercury getting in to it, bioaccumulates in aquatic organisms and increases in concentration up the food chain. It is a potent neurotoxin. Even at low levels, it can cause subtle but permanent harm in the human brain. The developing human fetus is especially susceptible. Mercury's effects on wildlife are similar. Forty-four states, including all of the states discussed in this report, have issued formal advisories due to mercury contamination, warning people to restrict or avoid consumption of certain species of fish caught from local lakes, streams, rivers, and coastal waters. Indiana, Maryland, North Carolina, Pennsylvania, Texas, Connecticut, Florida, Illinois, Kentucky, Massachusetts, Maine, Michigan, Minnesota, Missouri, North Dakota, New Hampshire, New Jersey, Ohio, Rhode Island, Vermont and Wisconsin all have *statewide* fish consumption advisories due to mercury contamination.[3]

Mercury in water contaminates fish. Deposition data confirms that rainwater is the primary source of this contamination, dispelling the popular notion that rainwater will clean our lakes and streams.

Mercury contaminated rain is a call to action. The leading sources of mercury emissions are well known—coal-burning power plants are currently the principal source. In order to reduce mercury contamination, all known and suspected atmospheric sources must drastically cut mercury emissions, and eventually eliminate them altogether. While regulations for some of these industries have been proposed or are in progress, enforcement limits have been weak and timetables slow. It is clear that strong action is needed in the coming years to reduce atmospheric mercury emissions to levels that protect the health of wildlife and humans that eat fish. In addition to strong action at the federal level, states and localities should implement programs to phase out the release of mercury to the environment. The challenge is before us: we must do no less than clean the rain.

To meet the challenge of eliminating mercury, National Wildlife Federation (NWF) launched the Clean the Rain Campaign in 1999.

The Clean the Rain Campaign is pressing for the control and elimination of mercury emissions and the phase-out of mercury use in products. We are calling for the implementation of the following actions nationally. State-specific challenges and actions are summarized in Chapter 4 as well as in each of the 12 state profiles found in the Appendix.

National Policy Recommendations for Eliminating Mercury Pollution

1. **Use existing regulatory authority to decisively reduce major remaining sources of mercury pollution**

   EPA must use its existing authority under the Clean Air Act and propose stringent mercury emission limits for coal-fired power plants, the largest source of uncontrolled mercury emissions in the nation. EPA is required to finalize maximum achievable control technology standards by December 2004 that could reduce emissions by up to 90 percent.

   Similarly, EPA should promulgate stringent final rules under the Clean Air Act for the chlor-alkali industry and iron and steel industry to sharply reduce or eliminate mercury emissions from these sectors. EPA is currently working on weak proposals in each of these areas.

   EPA should use its authority under the Toxics Substances Control Act to phase out non-essential uses of mercury in commerce. The Act states that EPA has adequate authority to "regulate chemical substances and mixtures which present an unreasonable risk of injury to health or the environment, and to take action with respect to chemical substances and mixtures which are imminent hazards."

   EPA should list all mercury-containing products under the Universal Waste Rule. This would ensure that all mercury-containing waste go to appropriate treatment or recycling facilities that are licensed to manage hazardous waste, as opposed to being disposed of in municipal solid waste landfills or incinerators.

2. **Reject the Bush Administration's Clear Skies Initiative**

   The Bush Administration has proposed power plant legislation that would allow utilities to emit five times as much mercury through 2017 and three times as much mercury every year thereafter compared to what is achievable under the current Clean Air Act.

   Local constituents through grassroots action should place pressure on their elected officials to reject Clear Skies, and to preserve the existing mercury power plant provisions of the Clean Air Act.

3. **Implement comprehensive mercury phase-out programs**

   EPA should assist states to enact legislation, rules, or other initiatives to eliminate mercury pollution by a date certain. Such phase-outs are technically and economically feasible for most sources.

   Congress should enact comprehensive mercury product legislation that would lead to the virtual elimination of mercury products by a date certain.

   Consumers should pressure manufacturers to discontinue reliance on mercury for their production processes and products.

4. **Require appropriate waste management and recycling of mercury products where no alternative yet exists**

   Manufacturers must phase out their use of mercury in products. In the interim, all mercury-containing products should be labeled to allow consumers to make informed purchasing decisions and to facilitate the separation and removal of mercury-containing products from the waste stream.

   As a first step, Congress should mandate manufacturers to implement a lifecycle approach for mercury in products that would require them to track, dispose of, and recycle mercury throughout the product's life.

   Hospitals, dentists and other medical facilities should practice "Mercury-Free Medicine" by eliminating mercury from medical and dental waste streams and avoiding waste incineration or disposal into the water system.

   EPA and states should manage combustion and other mercury-laden wastes in such a way that ensures the mercury is not re-released.

5. **Practice mercury-free purchasing**

   Federal and state institutions, hospitals, corporations and individuals should practice mercury-free purchasing, prohibiting the purchase of mercury-containing products through their procurement standards, for example.

6. **Set standards and monitoring processes to educate the public about mercury risks and responses**

   An extensive monitoring program to track the amount of mercury being released into the environment should be established, including expansion of the current Mercury Deposition Network along with ambient monitoring around facilities. This would require significant improvements over current efforts.[4]

   EPA needs to develop more protective standards for mercury in ambient water, and make the public aware of these standards.

   States, EPA, and the U.S. Food and Drug Administration should work together to coordinate fish consumption advisories for ocean and freshwater fish, and put more effort into educating consumers about the risks from fish contaminants, in particular for the most sensitive populations and high-end consumers of freshwater fish and seafood.

Chapter 1

Mercury Cycling in the Environment

Mercury is a highly volatile, naturally occurring metal found in small amounts throughout the environment: in rocks, soils, lakes and the oceans. Mercury is an element, never breaking down, persisting in the environment, cycling among the land, air, and water (See Figure 1). Mercury can circulate in the atmosphere for one year or more before falling to the ground, and can be re-released into the atmosphere after it deposits. Because mercury can be transported over long distances and cycle through the environment for a very long time, it may take decades for mercury releases to be buried by sediments and removed from the long cycle of evaporation, transport, transformation, and deposition.

Although mercury is a naturally occurring metal, its concentration in our environment has increased dramatically over the past 150-200 years due to mining and industrial activities—particularly coal combustion and incineration of wastes containing mercury.[5] During this time, these and other human activities have caused the rate of mercury deposition around the world to increase by two to 10 times over pre-industrial levels.[6]

Mercury can take on different chemical forms in the environment, which are categorized into three "species": elemental, inorganic, and organic mercury. Elemental mercury is the pure metal, and is also the form most commonly found in low concentrations in the air. The inorganic species involves a combination of mercury with one or more elements, forming compounds such as mercuric chloride, mercuric oxide, and mercuric sulfide. Combustion of coal and wastes containing mercury produces both inorganic and elemental mercury emissions. In addition, elemental mercury can be converted in the atmosphere to the inorganic species, which is more readily deposited from the air to land or water. Recent research has also linked ozone pollution (smog) to mercury deposition. Ozone and certain reactive compounds containing chlorine or bromine can oxidize elemental mercury to form inorganic mercury, which can then deposit locally.[7]

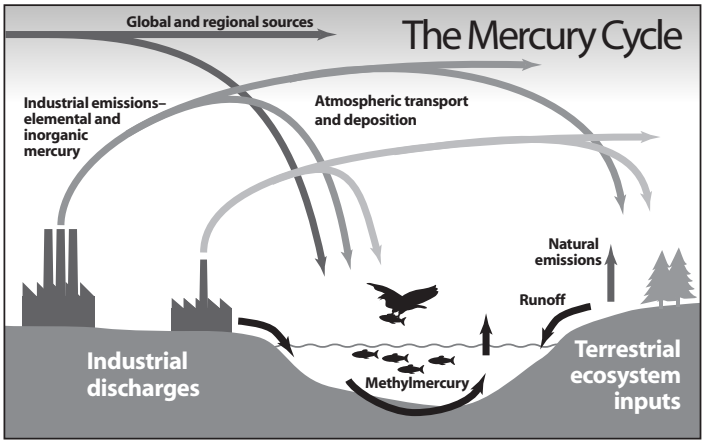


Figure 1

Once mercury is deposited onto the water, it can be converted by certain bacteria in the lake or river sediments from inorganic mercury to methylmercury, an organic form of mercury. The amount of methylmercury produced and taken up by organisms is influenced by a number of factors, including organic carbon concentrations, pH, and sulfate levels.[8] Methylation and mercury buildup in fish is often more significant in lakes with lower pH (i.e., more acidic). Combustion processes—in particular the burning of fossil fuels such as coal and oil—that form acid gases, such as sulfur dioxide and nitrogen oxides, can exacerbate the mercury problem by increasing acid deposition in watersheds, leading to acidification of surface waters and increased methylmercury production.

Accumulation of Mercury in the Food Chain

All forms of mercury can be very dangerous if inhaled or ingested in sufficient quantity. However, organic mercury, specifically methylmercury (MeHg), is of special concern to people and wildlife because it is easily absorbed. The concentration of methylmercury builds in each link of the food chain in contaminated systems, a process called bioaccumulation (see Figure 2).

The first and most important step in this process is the uptake of inorganic mercury by bacteria in a lake or stream.[9] Some of these bacterial organisms, which form the base of the food chain, convert inorganic mercury into methylmercury. While there is still much to learn about the transformation process, research has shown that sulfate-reducing bacteria found in sediments are key in affecting this change. Algae (phytoplankton) can then take up the methylmercury produced in the sediments and released to the water. When zooplankton consume the phytoplankton, they gain not only energy, but stored methylmercury as well. Zooplankton and other organisms are consumed in large quantities by amphibians and small fish, which in turn become food for larger predator fish. Through this process, top predator fish such as lake trout, pike, or walleye can harbor mercury concentrations in their tissues that are over one million times higher than in surrounding water. When people or animals like otters and loons eat these fish, the accumulated methylmercury is transferred to their bodies.

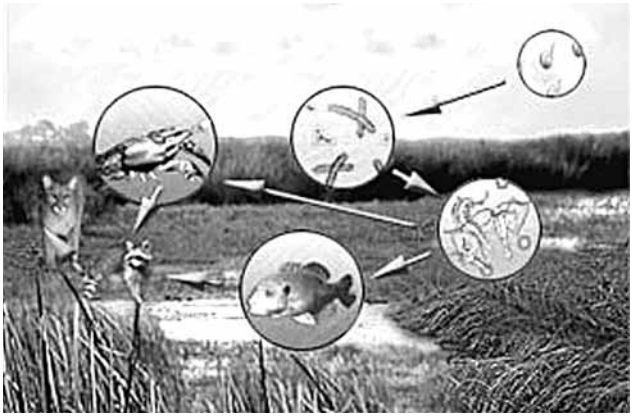


Figure 2

For most watersheds, deposition of mercury from the air is the primary pathway by which mercury enters the water, building up to levels that threaten wildlife and people. Mercury can be transported long distances in the air, resulting in elevated mercury levels even in wildlife found in remote areas.[7, 10]

Although there have not been massive wildlife poisoning incidents recently in the U.S. due to mercury contamination, [11] the mercury threat is nevertheless widespread and insidious, due to the potential for mercury to bioaccumulate and cause harmful effects at low, chronic exposure levels.

Mercury Cycling in the Environment: Old vs. New Mercury

Mercury can enter a lake or river from the atmosphere directly through wet deposition (precipitation), influxes from streams that flow into the lake and from mercury that is already present in the soil. In many cases, the majority of deposited mercury falls in the surrounding watershed, rather than directly on the lake or river. Mercury can also attach itself to plant surfaces and soil organic matter. Through runoff mercury makes its way into the lake or river, transported either in particle form or in liquid form (dissolved in water).

Research currently underway is shedding light on a previously unanswered question, namely, whether the mercury being deposited in watersheds today has a more immediate impact on an ecosystem than mercury deposited months or many years earlier. The METAALICUS (Mercury Experiment To Assess Atmospheric Loading In Canada and the U.S.) study currently underway in the Experimental Lakes Area in Ontario, Canada is examining the effects of mercury deposition on an entire watershed. The main objective of the study is to determine how mercury levels in various components of the ecosystem (in particular, fish) respond to changes in mercury loadings (i.e., inputs to different parts of the watershed). The research involves adding different stable isotopes of mercury (i.e., different forms that can be analyzed to identify unique contributions) to uplands, wetlands, and the water surface to track the relative importance of different mercury sources and to estimate the time lag between deposition, methylation, and accumulation in fish tissue. Preliminary results suggest that mercury newly deposited on lakes and wetlands transforms more rapidly into methylmercury than mercury already present in the system or mercury deposited several years earlier. [12] Follow-up monitoring is planned to assess how long the deposited mercury remains in the biota.

This is the first study of its kind that is able to distinguish methylation rates and bioaccumulation depending on when deposition occurred. The significance of these findings should not be underestimated. These preliminary findings offer compelling evidence to support the need for swift action to reduce ongoing sources of atmospheric mercury. It suggests that mercury reduction at the source can lead to relatively rapid results in the reduction of methylmercury in the environment.

Chapter 2

Mercury Contamination: Threats to People and Wildlife

Mercury and Human Health

Mercury is a dangerous reproductive and neurological toxicant. It can affect the brain, spinal cord, kidneys and liver. Mercury poisoning (i.e., high exposure levels) can affect the ability to feel, see, taste and has the potential to limit mobility. In serious contamination incidences in Minamata and Niigata, Japan, infants exposed to high levels of methylmercury *in utero* had a cerebral palsy-like condition as well as blindness and deafness. [13] Adults can be affected by high mercury exposures as well, with effects on the nervous system (e.g., numbing and tingling of the extremities), and impaired vision and hearing.

Fetuses, infants, and young children are at greatest risk for impacts from more chronic, lower level mercury exposure. Mercury can pass through the placenta, where it can harm the fetus by interfering with proper brain and nervous system development. Children exposed to mercury levels may show signs of attention deficit, impaired visual-spatial skills and poor coordination.[14] Affected children may have lower scores on intelligence tests and exhibit symptoms of delayed verbal and motor skills. A recent study released by the Centers for Disease Control and Prevention found that approximately eight percent of women of childbearing age in the U.S. had mercury levels exceeding the level considered safe by the U.S. EPA for protecting the fetus. This translates into approximately 320,000 babies born each year in the U.S. at risk of developmental harm due to mercury exposure in the womb.[15]

Several recent studies also report that lower level chronic mercury exposures can cause harm in adults. A study published in the Journal of Obstetrics & Gynaecology found that elevated mercury exposures associated with seafood consumption could be linked to an increased risk of infertility in both men and women.[16] A study of middle-aged European and Israeli men found a direct association between measured mercury levels in toenails and first heart attack. Researchers concluded that high mercury levels may diminish the

cardioprotective effect of fish intake.[17] Other research has found a two-fold increased risk of both heart attack and mortality from coronary artery disease, as well increased progression of atherosclerosis (thickening of artery walls) in Finnish men associated with elevated mercury exposures.[18]

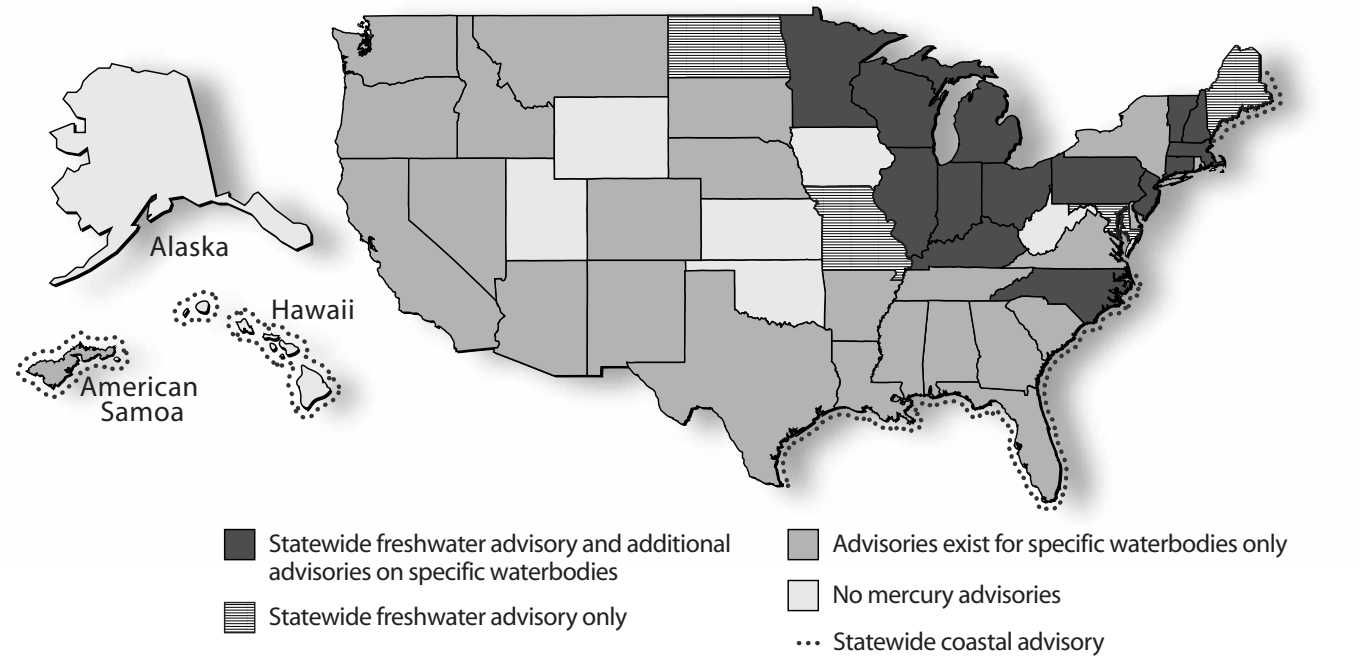
Mercury Fish Advisories

Given the clear impact of mercury contamination on human health and wildlife, there are two necessary approaches for reducing and eliminating these threats—reducing mercury levels in the environment, and reducing the consumption of mercury contaminated fish. While there has been some progress in reducing mercury releases from some industrial sources, much remains to be done. In the meantime, it is critical to protect those most vulnerable to mercury contamination by reducing mercury exposure through fish consumption. Fish are a valuable source of protein and provide many health benefits. There are also cultural and social benefits associated with eating fish. Eliminating fish from diets is an unrealistic and unsatisfactory risk management option over the long term. Therefore, the long-term goal needs to focus on reducing mercury emissions in order to make the fish safe to eat.

State health departments and some Native American tribes issue fish and wildlife consumption advisories to limit exposure to mercury and other chemicals found in fish and wildlife.[19] Forty-four states and American Samoa currently have fish consumption advisories due to mercury. The map below summarizes mercury fish consumption advisories in the country, and the table on the following page summarizes advisories for the states featured in this report.

Mercury advisories by type

US EPA, 2002. National Listing of Fish and Wildlife Advisories, 2001.



A Comparison Chart of Fish Consumption Advisories for Selected States[3]

	River Advisories	Lake Advisories	Coastal Advisories	Statewide Advisories
Alabama	*1*	*4*	*1*	*No*
Florida	*25*	*51*	*8*	*No*
Georgia	*75*	*42*	*1*	*No*
Indiana	*100*	*64*	*-*	*Yes*
Louisiana	*16*	*6*	*4*	*No*
Maryland	*All are covered under statewide*			*Yes*
Mississippi	*7*	*3*	*1*	*No*
New York	*2*	*27*	*-*	*No*
North Carolina	*3*	*6*	*1*	*Yes*
Pennsylvania	*42*	*28*	*-*	*Yes*
South Carolina	*36*	*17*	*1*	*No*
Texas	*1*	*7*	*1*	*Yes*

Economics of Sport Fishing

A study commissioned by the Maryland Department of Natural Resources in 2002 sought to estimate the economic losses assumed by recreational and commercial fishing industries due to the issuance of fish consumption advisories. Recreational costs included lost number of fishing days, lost number of locations, and lost number of species available for safe consumption. Commercial costs included lost purchases from consumers. The study estimated that recreational fishing could sustain an economic loss of about $9 million annually, and commercial fisheries about $0.5 million.[20]

Data from a national survey on numbers of anglers and their expenditures for the states covered in this report are given in the table below.

State	Total Expenditures Residents & non-residents (rounded)	Total Number of Anglers, freshwater and marine (rounded)
Alabama	*$723 million*	*851,000*
Florida	*$4 billion*	*3,104,000*
Georgia	*$544 million*	*1,086,000*
Indiana	*$519 million*	*874,000*
Louisiana	*$703 million*	*970,000*
Maryland	*$480 million*	*701,000*
Mississippi	*$211 million*	*586,000*
New York	*$1 billion*	*1,550,000*
North Carolina	*$1 billion*	*1,287,000*
Pennsylvania	*$580 million*	*1,266,000*
South Carolina	*$559 million*	*812,000*
Texas	*$2 billion*	*2,000,000*

Source: U.S. Fish and Wildlife Service, 2001 National Survey of Fishing, Hunting, and Wildlife—Associated Recreation, October 2002..

It should be emphasized that states and tribal health departments all have different methods for issuing advisories. The protocols and extent of fish sampling programs can differ significantly between states, so the lack of a large number of advisories does not necessarily mean a lack of significant mercury problems in a given state. The conclusion is clear, however: widespread fish advisories indicate that a direct, deliberate and extensive mercury reduction strategy needs to be implemented to combat and reduce the amount of mercury entering our water bodies. By reducing mercury emitted by large sources, such as coal-fired power plants, we can reduce the amount of mercury available for atmospheric deposition. NWF has previously published a report entitled *Getting Serious About Mercury: A Guide for Developing Comprehensive Mercury Reduction Programs*, which details how such strategies can be implemented.

Harm to Wildlife

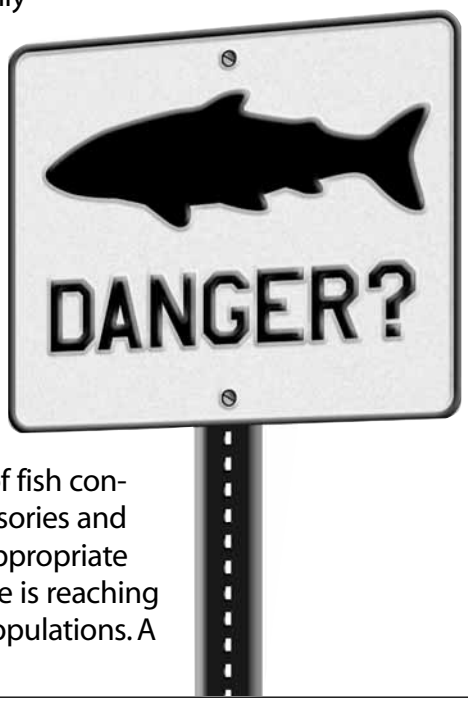
As is the case with people, methylmercury has particular impacts on both the central nervous and reproductive systems in wildlife.

In fish, most of the mercury exists as methylmercury. While inorganic mercury can concentrate more readily than methylmercury in organs such as the kidney, liver and spleen, most of the mercury in fish is in the muscle tissue or filet portion of the fish. As with humans, early life stages are more sensitive to mercury toxicity. Fish exposed to mercury can suffer impaired growth and development, reduced reproduction, behavioral

Are fish consumption advisories doing their job?

Every state featured in this report has issued fish consumption advisories for numerous species and water bodies. But are these advisories accomplishing their goal?

A study along the Savannah River in Georgia near the U.S. Department of Energy's Savannah River Site examined whether the general public, and anglers in particular, were aware of fish consumption advisories and heeding their advice. Shockingly, 82% of the anglers thought the fish were safe to eat, even though 62% of them admitted hearing about some sort of advisory warning of the dangers of eating some fish.[21] Out of the 258 people interviewed only one knew that children and pregnant women should limit their intake of fish.



This study raises serious issues about the effectiveness of fish consumption advisories and whether the appropriate health message is reaching the affected populations. A study conducted among Great Lakes sport anglers in the mid-1990s found similar results. While the Great Lakes study was more concerned with polychlorinated biphenyl's (PCBs) and DDT, the findings are analogous to mercury advisories. The survey found that fish consumption advisories were less effective in reaching women, nonwhites, and people with lower levels of education. Only 50% of the total number of people surveyed (adults who had eaten sport fish caught from the Great Lakes) were aware of the advisories and only 39% of women surveyed were familiar with the consumption advisories. The study concluded that fish consumption advisories could decrease the exposure among fish consumers if "effective communication programs are used."[22]

Mercury Levels in Alligator Meat

In the Southeast, alligator meat is consumed much like fish, and large quantities are processed for domestic and overseas markets. Several studies conducted in Florida found that mercury levels in alligator muscle exceeded state and federal allowances for safe human consumption.[27] Despite these studies there has been no national standard set for mercury levels in wildlife consumed by humans. In one study, if the less conservative 0.5 milligram per kilogram wet weight standard were used, all of the alligators sampled in the Florida Everglades would be considered unsafe to eat.[10] Not only are there health concerns surrounding mercury levels in alligators, but the economic impact of the issuance of advisories is of concern. In Louisiana alone the potential loss of revenue would range from $3-$4 million per year if a consumption advisory for alligators were put in place.[27]

abnormalities, and altered blood chemistry. Walleye may be particularly sensitive to the reproductive toxicity of mercury in the environment.[23]

In mammals, smaller carnivores are more sensitive to methylmercury than larger species. As in people, methylmercury is readily absorbed from the gastrointestinal tract, and crosses the blood-brain barrier more readily than other mercury forms. The average half-life of methylmercury in mammals (i.e., the time it takes for the concentration following a single exposure to drop by one-half) is approximately 70 days. Effects of methylmercury poisoning in fish-eating mammals (such as otters and mink) can include involuntary muscle action and problems with movement, impaired vision and hearing, tremors, loss of consciousness, and death.

In birds, methylmercury is a potent embryo and nervous system toxicant. Acute effects of high mercury exposure in birds can include reduced food intake and weight loss, progressive weakening in wings and legs, difficulty flying, walking and perching, and inability to coordinate muscle movements. Impacts of chronic, lower level mercury exposures in birds include reduced hatchability, eggshell thinning, reduced clutch size, increased numbers of eggs laid outside the nest, aberrant behavior of juveniles, and potentially impaired hearing of juveniles.[24]

Some of the wildlife affected by mercury contamination in the U.S. include raccoons, alligators, otters, mink, panthers, osprey, wood storks, egrets, great white herons, bald eagles, black skimmers, Forster's terns and common loons.

A number of studies have examined the risks that wildlife face in specific locations or regions in the country. A study conducted within the New York Bight (an area incorporating Long Island Sound south to Barnegat Bay) compared the adverse effects of mercury on laboratory birds to wild birds and found that mercury "may be playing a role in decreasing reproductive success of some species nesting in the New York Bight."[25] A separate study examining the effects of mercury on the survival rate of great egrets showed that mercury may reduce the amount of white blood cells and thus weaken the birds' immune systems.[26]

In the southeastern United States, the American alligator *(Alligator mississippiensis)* is an important predator found in many freshwater ecosystems. Because of their longevity, diet and habitat (in particular swamps and reservoirs where production of methylmercury can be more intense), alligators have the potential to amass substantial amounts of mercury. In one risk assessment, all alligators in one section of the Florida Everglades exceeded the chronic reproductive threshold for mercury exposure.[10]

Where Have All the Mink Gone?

According to the South Carolina Wildlife and Marine Resources Department, mink populations in the Atlantic coastal plain states (Virginia, North Carolina, South Carolina, Georgia and Florida) have been declining since the 1960's.[28] According to state biologists, mink are completely absent in certain portions of the Atlantic coastal plain where historically they have thrived. Recent studies on mink populations in South Carolina link population declines to mercury exposure.[29] In addition to the risks from mercury exposure, the additional exposure to PCBs may put the mink at even greater risk, due to the ability of the chemicals to act synergistically (i.e., the combined impacts are greater than simply the sum of the impacts of both mercury and PCBs).[30]

Florida Panther: 60 and Counting

The Florida panther is the last remaining native cougar that resides east of the Mississippi River. Restricted to the southern end of Florida due to human expansion, these magnificent cats have been driven to the brink of extinction. Along with habitat loss, lack of genetic diversity, motor vehicle collisions and prey scarcity, environmental contaminants such as mercury may be contributing to the loss of the remaining panthers. They are exposed to mercury through their diet. Panthers are found at the top of the food chain and consequently are more susceptible to the bioaccumulative effects of mercury.

A study published in 1995 found that mercury in blood samples taken from 24 panthers measured at levels sufficient to contribute to reproductive impairments.[31] With only about 60 panthers remaining, the loss of one breeding panther plays a significant role in the survival of the species.

Chapter 3

Mercury in Precipitation

This report presents data on mercury in precipitation collected largely from the Mercury Deposition Network (MDN) from 1995 to 2001. The MDN became an official network of the National Atmospheric Deposition Program in 1996, with over 50 sites now in operation. The objective of the MDN is to monitor the levels, as well as temporal (e.g., seasonal, annual) and geographic variation of total mercury in precipitation falling in the U.S. and Canada. The sites are generally placed in areas where other data already are being obtained, such as temperature, wind speed and direction, nitrogen and sulfur deposition, etc. Samples are collected on a weekly basis with wet-only samplers (i.e., the samplers do not measure dry deposition of particles), and results are made publicly available at roughly six-month intervals.

For this report, NWF analyzed mercury precipitation samples collected from 1995 to 2001 at 35 rain samplers in 12 states. NWF focused on these 12 states primarily because they covered regions of the country where mercury rain data has not previously been analyzed and presented to the public. In most states we evaluated, one to three rain samplers were operational for the entire period. Several other states have much more extensive networks, most notably Pennsylvania, which has eight active rain samplers including one that was launched in November 2002. Maryland disabled its MDN rain samplers due to funding shortages after being operational sporadically for three years—all available data were included in this report.

Understanding the data: What do the numbers mean?
Mercury levels in rain are measured in nanograms per liter (or parts per trillion). One nanogram is one billionth of a gram. The amount of mercury is so small that one part per trillion is roughly akin to one marble in a container the size of the Louisiana Superdome filled with marbles. Though the concentrations in precipitation may seem small, mercury easily bioaccumulates to levels that threaten people and wildlife. At one lake, researchers found that the amount of mercury deposited over a year's time was about 1 gram. But, due to mercury's high level of bioaccumulation, even this amount was enough to account for all of the mercury in the fish in this 25-acre lake.[32] Thus, even seemingly small concentrations of mercury are significant in terms of their impact on a receiving water body.[33]

In this report, NWF compares mercury levels measured in precipitation to surface water quality standards set by EPA. The purpose of this analysis is simply to illustrate the significance of precipitation as a source of contamination, and its potential effect on the receiving water body. In this comparison, we assume that as long as mercury concentrations in rain are higher than water quality standards, it will be difficult to reduce the mercury concentrations in a lake or river to levels that don't pose risks to people and wildlife.

Water Quality Standards for Protecting Wildlife and Human Health

Water quality standards are established by states and tribes to protect fish, other aquatic life, wildlife and people from the threats of chemical and biological contamination. The EPA periodically issues guidelines for water quality standards; states and tribes then have the discretion to either adopt the suggested standards or adopt their own, subject to EPA approval.[34]

EPA has issued various standards over time for different categories (aquatic life, human health, wildlife) and regions. In the 1980's, EPA issued a recommended water quality guideline of 12 nanograms/liter (ng/l) intended to protect aquatic life. This level was considered by EPA to protect not only fish but also, to some extent, wildlife that fed on the fish. The 12 ng/l standard was adopted by nearly all states. But in 1999, EPA set a much more relaxed standard for aquatic life (770 ng/l).[34] In the meantime, in 1995 EPA set a true mercury wildlife standard (not an interim benchmark) of 1.3 ng/l for the Great Lakes and its tributaries.[35] The Great Lakes mercury wildlife standard is the only mercury standard EPA has developed explicitly for wildlife.

EPA also has set human health standards for mercury in fish. In the 1995 Great Lakes standards, EPA established a human health standard of 3.1 ng/l. Then in 2001, EPA issued a new national water quality criterion for mercury. Although the human health value was expressed as an allowable level of mercury in fish tissue, it translates into a water concentration value of approximately 7.9 ng/l for rivers and 3.5 ng/l for lakes, the latter value close to the EPA's Great Lakes standard.[36]

States have set standards largely based on the EPA standards. The table on the following page compares water quality standards adopted by the twelve states featured in this report to EPA's national and Great Lakes standards.

Mercury Water Quality Criteria Comparison Chart

Jurisdiction	**Aquatic Life – Chronic (ng/l)**		**Wildlife & Human Health (ng/l)**	
	Freshwater	*Saltwater*	*Wildlife*	*Human Health*
EPA	*770*	*940*	*12 (unofficial—see text for explanation)*	*3.5 ng/L for lakes (see footnote 36)*
Great Lakes	*908*	*—*	*1.3*	*3.1*
Alabama	*12*	*25*	*Narrative**	*120*
Florida	*12*	*25*	*Narrative*	*Narrative*
Georgia	*12*	*25*	*Narrative*	*Narrative*
Indiana(other waters)	*12*	*—*	*—*	*150*
Louisiana	*12*	*25*	*Narrative*	*Narrative*
Maryland	*770*	*940*	*—*	*51*
Mississippi	*12*	*25*	*Narrative*	*151*
New York	*770*	*NA*	*2.6*	*0.7*
North Carolina	*12*	*25*	*Narrative*	*Calculated*
Pennsylvania	*770(GL Basin) 12(other waters)*	*—*	*1.3(GL Basin)*	*4(GL Basin) 144(other waters)*
South Carolina	*910*	*1100*	*—*	*50*
Texas	*1300*	*1200*	*Narrative*	*12.2*

Source: http://www.epa.gov/waterscience/standards/states/
** A narrative criteria is issued when there is no actual number for the criterion, but instead a narrative statement is issued, such as: Water bodies should be free from substances that may cause adverse effects to aquatic life.*

States have taken several different approaches for establishing water quality criteria to protect aquatic life, wildlife, and human health. In general, states either:

1. Use EPA's earlier 12 ng/l standard, with a narrative standard for wildlife and/or human health. They are likely working under the assumption that the more stringent aquatic life standard is sufficient to protect wildlife and human health. However, EPA has acknowledged that 12 ng/l is protective neither of wildlife nor of human health. Furthermore, there are difficulties in enforcing a narrative standard (see Florida, Georgia, Louisiana).
2. Adopted the 770 ng/l aquatic life standard as EPA did in 2001 (and in some cases exceeding EPA's standard), but failed to adopt a protective wildlife or human health standard. The combination of a less protective aquatic life standard, a non-existent wildlife standard, and a weak human health standard means that there are no protective enforceable water quality criteria in place (see Maryland, South Carolina, Texas).
3. Adopted the higher aquatic life standard, and adopted a more protective wildlife and/or human health standard. New York is an

example of this approach. Pennsylvania adopted the Great Lakes standards (or a value slightly above the EPA value for human health) for waters in the basin, but not for other inland waters.

While not a focus of this report, the standards summarized in the table indicate the urgent need for states to adopt more protective water quality standards for mercury, and for EPA to develop a protective national standard for wildlife.

Mercury Levels in Rain—What the Data Show

For each state featured in this report, NWF compared mercury rain levels to EPA's new human health standard of 3.5 ng/l for lakes. (See individual state profiles for bar charts and scatter plots of the rain data.) In the table below, we also compared the rain data to EPA's Great Lakes wildlife standard of 1.3 ng/l. These standards are the most recent, most scientifically defensible EPA standards for mercury in water. As noted above, the EPA's Great Lakes wildlife standard is the only standard EPA has ever developed specifically for wildlife. The EPA national human health standard was promulgated in 2001 and is more consistent with (although weaker than) the EPA's Great Lakes human health mercury standard.

Key state findings are summarized below:

	# of precipitation samples	% above EPA's human health std for Hg in lakes (3.5 ng/l)	% above the Great Lakes wildlife std for Hg in lakes (1.3 ng/l)
Gulf States			
Alabama	*134*	*93.3*	*100*
Florida	*642*	*97.5*	*100*
Louisiana	*438*	*97.9*	*99.8*
Mississippi	*73*	*97.3*	*100*
Texas	*175*	*98.3*	*99.4*
Southeast			
Georgia	*268*	*94.4*	*100*
North Carolina	*373*	*88.8*	*99.2*
South Carolina	*200*	*97*	*99.0*
Northeast			
*Maryland**	*316*	*96.2*	*99.7*
New York	*106*	*84.0*	*99.1*
Pennsylvania	*792*	*92.0*	*99.6*
Great Lakes			
Indiana	*236*	*95.8*	*100*

Source: Calculations based on data from Mercury Deposition Network, http://nadp.sws.uiuc.edu/mdn/
**Data source: Personal communication with R. Mason*

Over a six-year period, mercury concentrations consistently exceeded EPA's national and Great Lakes water quality standards. In some cases, mercury concentrations varied greatly depending on the weather and other factors. The following chart compares the variability of the maximum, minimum and average concentrations measured in each state over the entire period for which precipitation data were available:

	Maximum Hg Conc. (ng/l)	Minimum Hg Conc. (ng/l)	Average Hg* Conc. (ng/l)
Gulf States			
Alabama	*67.8*	*2.4*	*8.4*
Florida	*81.2*	*1.3*	*12.6*
Louisiana	*337.9*	*1.2*	*10.4*
Mississippi	*43.7*	*2.5*	*8.8*
Texas	*200.2*	*0.2*	*11.0*
Southeast			
Georgia	*275.6*	*1.3*	*10.7*
North Carolina	*167.7*	*0.7*	*8.3*
South Carolina	*161.3*	*0.3*	*10.4*
Northeast			
Maryland	*270.4*	*1.4*	*17.7*
New York	*29.9*	*1.3*	*6.8*
Pennsylvania	*159*	*0.8*	*9.9*
Great Lakes			
Indiana	*115.6*	*1.4*	*10.9*

**Volume-weighted mean concentrations*

Chapter 4

Conclusions and Recommendations

This is the third in a series of reports by NWF analyzing mercury levels in precipitation in different regions of the country. The findings are consistent: Rainfall and snow consistently exceed the EPA's human health criteria for mercury in lakes, and the concentrations are such that wildlife and human health will continue to be at risk if loadings aren't curtailed significantly.

National and state actions are needed to address mercury deposition, as emissions cross state borders and can drift anywhere from several miles to several hundred miles downwind. Mercury deposition monitoring should be expanded in states with limited or no monitors. Deposition monitors in conjunction with robust mercury emission inventories will improve our ability to monitor progress in reducing mercury contamination nationwide.

Below is a set of national policy recommendations to reduce and eventually eliminate the threat mercury poses to human health and wildlife. There is room for individual states to take action to combat mercury pollution within their borders, and to set a precedent for national action. Specific state recommendations are summarized below and can also be found in each state profile in the Appendix.

National Policy Recommendations for Eliminating Mercury Pollution

1. **Use existing regulatory authority to decisively reduce major remaining sources of mercury pollution**

   EPA must use its existing authority under the Clean Air Act and propose stringent mercury emission limits for coal-fired power plants, the largest source of uncontrolled mercury emissions in the nation. EPA is required to finalize maximum achievable control technology standards by December 2004 that could reduce emissions by up to 90 percent.

   Similarly, EPA should promulgate stringent final rules under the Clean Air Act for the chlor-alkali industry and iron and steel industry to sharply

reduce or eliminate mercury emissions from these sectors. EPA is currently working on weak proposals in each of these areas.

EPA should use its authority under the Toxics Substances Control Act to phase out non-essential uses of mercury in commerce. The Act states that EPA has adequate authority to "regulate chemical substances and mixtures which present an unreasonable risk of injury to health or the environment, and to take action with respect to chemical substances and mixtures which are imminent hazards."

EPA should list all mercury-containing products under the Universal Waste Rule. This would ensure that all mercury-containing waste go to appropriate treatment or recycling facilities that are licensed to manage hazardous waste, as opposed to being disposed of in municipal solid waste landfills or incinerators.

2. **Reject the Bush Administration's Clear Skies Initiative**

   The Bush Administration has proposed power plant legislation that would allow utilities to emit five times as much mercury through 2017 and three times as much mercury every year thereafter compared to what is achievable under the current Clean Air Act.

   Local constituents through grassroots action should place pressure on their elected officials to reject Clear Skies, and to preserve the existing mercury power plant provisions of the Clean Air Act.

3. **Implement comprehensive mercury phase-out programs**

   EPA should assist states to enact legislation, rules, or other initiatives to eliminate mercury pollution by a date certain. Such phase-outs are technically and economically feasible for most sources.

   Congress should enact comprehensive mercury product legislation that would lead to the virtual elimination of mercury products by a date certain.

   Consumers should pressure manufacturers to discontinue reliance on mercury for their production processes and products.

4. **Require appropriate waste management and recycling of mercury products where no alternative yet exists**

   Manufacturers must phase out their use of mercury in products. In the interim, all mercury-containing products should be labeled to allow consumers to make informed purchasing decisions and to facilitate the separation and removal of mercury-containing products from the waste stream.

   As a first step, Congress should mandate manufacturers to implement a lifecycle approach for mercury in products that would require them to track, dispose of, and recycle mercury throughout the product's life.

Hospitals, dentists and other medical facilities should practice "Mercury-Free Medicine" by eliminating mercury from medical and dental waste streams and avoiding waste incineration or disposal into the water system.

EPA and states should manage combustion and other mercury-laden wastes in such a way that ensures the mercury is not re-released.

5. **Practice mercury-free purchasing**

   Federal and state institutions, hospitals, corporations and individuals should practice mercury-free purchasing, prohibiting the purchase of mercury containing products through their procurement standards, for example.

6. **Set standards and monitoring processes to educate the public about mercury risks and responses**

   An extensive monitoring program to track the amount of mercury being released into the environment should be established, including expansion of the current Mercury Deposition Network along with ambient monitoring around facilities. This would require significant improvements over current efforts.[4]

   EPA needs to develop more protective standards for mercury in ambient water, and make the public aware of these standards.

   States, EPA, and the U.S. Food and Drug Administration should work together to coordinate fish consumption advisories for ocean and freshwater fish, and put more effort into educating consumers about the risks from fish contaminants, in particular for the most sensitive populations and high-end consumers of freshwater fish and seafood.

Getting Serious About Mercury

NWF's report, *Getting Serious About Mercury: A Guide for Developing Mercury Reduction Programs,* is a roadmap to assist individuals, policy-makers, businesses and communities in developing, implementing and strengthening mercury reduction initiatives. The report identifies elements that can help move a program in a positive direction. The guide offers suggestions for overcoming the challenges that can undermine even the best initiatives. Copies of the report are available at www.nwf.org/cleantherain or by contacting the Great Lakes Natural Resource Center at (734) 769-3351.

State Recommendations/Challenges

NWF's state partners developed the following state recommendations. State contacts, where applicable, are included in the individual state profiles located in the Appendix.

State	Recommendation
Gulf States	
Alabama	• *Require Occidental Chemical Corporation's chlor-alkali plant to convert to a mercury-free diaphragm process by a date certain* • *Develop a comprehensive mercury reduction program to phase out the use and disposal of mercury-containing products, and reduce emissions from coal combustion by a date certain* • *Adopt protective wildlife and human health water quality standards, similar to those established for the Great Lakes* • *Expand fish monitoring program.*
Florida	• *Build upon existing mercury products legislation by adopting a comprehensive mercury phase-out plan* • *Adopt protective wildlife and human health water quality standards, similar to those established for the Great Lakes.*
Louisiana	• *Require chlor-alkali plants to convert to a mercury-free diaphragm process by a date certain* • *Develop comprehensive mercury reduction program to phase out the use and disposal of mercury-containing products, and reduce emissions from coal combustion by a date certain* • *Expand fish monitoring program: promulgate a state-wide fish consumption advisory for all inland waters* • *Adopt protective wildlife and human health water quality standards, similar to those established for the Great Lakes.*
Mississippi	• *Develop comprehensive mercury reduction program to phase out the use and disposal of mercury-containing products, and reduce emissions from coal combustion by a date certain* • *Expand fish monitoring program: adopt a dedicated budget to fund program* • *Adopt protective wildlife and human health water quality standards, similar to those established for the Great Lakes.*
Texas	• *As a first step, pass HB 2967 which creates a program to properly dispose of electronic equipment, including mercury containing components.* • *Adopt HB 2719 which requires more testing of fish for mercury and improves public notification of fish consumption advisories.* • *Develop comprehensive mercury reduction program to phase out the use and disposal of mercury-containing products, and reduce emissions from coal combustion by a date certain* • *Regulate coal combustion waste to prevent re-release of mercury.* • *Adopt protective wildlife and human health water quality standards similar to those established for the Great Lakes.*
Southeast	
Georgia	• *Require chlor-alkali plants to convert to a mercury-free diaphragm process by a date certain* • *Develop comprehensive mercury reduction program to phase out the use and disposal of mercury-containing products, and reduce emissions from coal combustion by a date certain*

	• *Improve public outreach on the threats associated with fish consumption*
	• *Adopt protective wildlife and human health water quality standards, similar to those established for the Great Lakes.*
North Carolina	• *Improve public outreach on the threats associated with fish consumption*
	• *Adopt protective wildlife and human health water quality standards, similar to those established for the Great Lakes.*
	• *Strengthen the Clean Smokestacks Act by including specific mercury reduction targets*
	• *Develop comprehensive mercury reduction program to phase out the use and disposal of mercury-containing products.*
South Carolina	• *Develop comprehensive mercury reduction program to phase out the use and disposal of mercury-containing products, and reduce emissions from coal combustion by a date certain*
	• *Expand mercury deposition monitoring program*
	• *Develop a statewide protocol for sampling toxins*
	• *Increase public awareness on the dangers of mercury*
	• *Adopt protective wildlife and human health water quality standards, similar to those established for the Great Lakes.*

Northeast

Maryland	• *Adopt protective wildlife and human health water quality standards, similar to those established for the Great Lakes*
	• *Build on existing mercury legislation by adopting a comprehensive mercury reduction program to phase out the use and disposal of mercury-containing products; in the interim, legislation should require labeling products that contain mercury*
	• *Enact legislation to reduce emissions from coal combustion by a date certain through either additional pollution controls or an increased use of renewable energy.*
	• *Improve monitoring of mercury deposition by increasing the number of monitoring sites, and placing them downwind of significant sources of airborne mercury compounds*
	• *Expand mercury monitoring program for all state waters.*
	• *Adopt a stringent and consistent standard for fish consumption advisories for all Chesapeake Bay states (MD, VA, PA, DC).*
New York	• *Fully fund monitoring program to test New York's nearly three thousand lakes and streams for mercury*
	• *Act on the mercury bills that have been introduced, such as A.5932 (Solid Waste and Water Discharge), A.479 (Mercury Air Emissions), A.3633 (Electronic Equipment Recycling Act), A.6096 (Electronic Waste Handling), A.6259 (Mercury-free Vehicle Act of 2004), A.6219 (Statewide Ban on Sale of Mercury Thermometers), A.6416 (Mercury-free Schools Bill).*
Pennsylvania	• *Improve monitoring of mercury deposition by placing monitoring sites downwind of significant sources of airborne mercury compounds*
	• *Adopt a more stringent standard for issuing fish consumption advisories, such as those employed in the neighboring states of Ohio and New Jersey*
	• *Develop comprehensive mercury reduction program to phase out the use and disposal of mercury-containing products, and reduce emissions from coal combustion by a date certain*
	• *Adopt protective wildlife and human health water quality standards for all non-Great Lakes basin waters.*

Great Lakes

Indiana

- *Reduce mercury air emissions from all significant Indiana mercury emissions sources by 90% by 2010, and "virtually eliminate" Indiana mercury air pollution by 2020*
- *Clean up 90% of the mercury hotspots on land and in sediments by 2010, and clean up remainder by 2020*
- *Reduce mercury discharges to lakes and streams to levels below those set to protect water quality, with exceptions as needed for municipal wastewater treatment plants*
- *Adopt protective wildlife and human health water quality standards for all non-Great Lakes basin waters.*

Notes

1 U.S. Geological Survey, 1984, The Hydrologic Cycle (Pamphlet)

2 The numeric levels to which rain data are compared represent the appropriate levels of mercury in water that are deemed safe for human health, wildlife, or aquatic life. NWF describes these levels as the mercury "standard" or "criteria" for surface water quality; they are the levels recommended by EPA that form the basis for state enforceable standards.

3 U.S. Environmental Protection Agency, 2003, National Listing of Fish and Wildlife Advisories

4 EPA compiles information on emissions of mercury and certain other hazardous air pollutants through the National Toxics Inventory, but there are continuing uncertainties about actual emissions in most sectors due to limited stack testing. Also, better information on actual releases to water and land is also needed, through the Toxics Release Inventory reporting program.

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