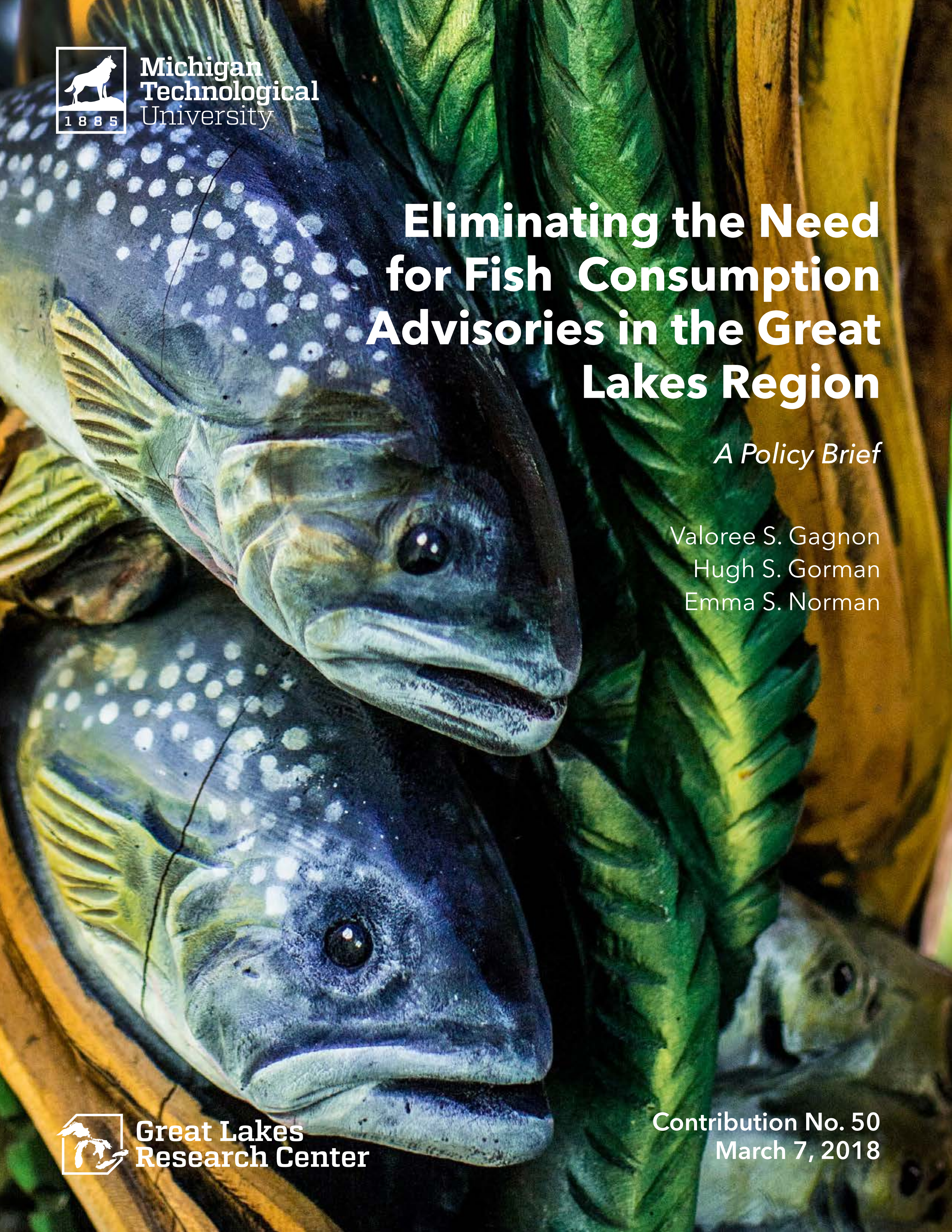

Michigan Technological University

Eliminating the Need for Fish Consumption Advisories in the Great Lakes Region

A Policy Brief

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Introduction

Chemically-contaminated fish is a cross-boundary, global problem with long-term impacts to the ecosystem and human health.[1] Toxic substances associated with this contamination include mercury, industrial chemicals such as polychlorinated-biphenyl (PCB) compounds, and many types of pesticides. When present in fish in relatively small quantities, these substances pose a number of risks to human health. The risk depends on a variety of factors, including the type, size, and quantity of fish in one's diet and one's physical size. Women of childbearing age are an especially sensitive population because of the health risks to developing fetuses and breast-fed infants.

In the Great Lakes region, health officials first issued fish consumption advisories in the early 1970s. At the time, these advisories were considered temporary, necessary to protect the health of the fish-consuming public, until sources of contamination in the Great Lakes basin could be eliminated.[2] However, even after most local sources of contaminants were eliminated, the problem remained.

We know now that the problem is more complex than health officials first assumed. Indeed, the toxic compounds that contaminate fish are more mobile than initially assumed. Once released into the environment, they can be transported globally through cycles of deposition and re-emission. In general, the offending contaminants are "atmosphere-surface exchangeable pollutants" (ASEPs) that share the following characteristics:[3]

1) They are persistent in the environment; they degrade and/or are removed from circulation at extremely slow rates.

2) After being deposited in water bodies and on vegetation, soils, and other surfaces, they can be re-emitted into the atmosphere. These re-emissions facilitate their global dissemination, making it difficult to address the concern of contaminated fish by regional action alone.

3) They biomagnify in food webs, making it possible for fish to contain unsafe concentrations of a contaminant even though the water has a much lower concentration.

Today, almost fifty years after their introduction, fish consumption advisories remain an important policy tool. These advisories are issued by federal agencies, all fifty states, and many Native American tribes.[4] Described as "recommendations" and "guidance," advisories provide information about particular water bodies and fish species, helping fish consumers limit their exposure to contaminants such as methyl-mercury, PCBs, toxaphene, chlordane, dioxins, dichloro-diphenyl-trichloroethane (DDT), and other pesticides and industrial chemicals. Nationwide, mercury advisories for fresh-caught fish are issued in thirty-eight states, including all Great Lakes states. In the United States, over four thousand advisories are now issued, affecting almost half of the nation's lake acreage, river miles, and coastlines. In addition, a nationwide mercury advisory for store-bought and restaurant fish is also in place, issued jointly by the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA).

The purpose of this policy brief is to renew the focus on eliminating the need for fish consumption advisories. Organized around six policy points, this policy brief outlines an approach for achieving that goal. Although this policy brief places the emphasis on the Great Lakes basin, it is relevant to water basins worldwide.

Policy Point 1

Toxic contamination is an invisible health concern made visible by fish consumption advisories. As long as fish contain unsafe levels of contamination, the need for advisories will remain.

Fish consumption advisories, monitoring programs, and epidemiological research make toxic contamination and the associated health risks visible. In fish monitoring programs, officials measure the concentration of compounds in various species of fish to provide people with the information they need to make informed decisions about their fish consumption patterns. Researchers also measure the concentrations of these compounds in the air and water in order to determine whether conditions are improving. Likewise, epidemiological and toxicological studies allow us to quantify the effects of toxic substances on both animal and human populations. As long as monitoring programs and epidemiological studies provide evidence of unsafe levels of contaminants in food webs, fish consumption advisories will continue to be necessary.

The invisible nature of toxic contamination

The presence of toxic substances in fish is largely invisible to humans. In fact, these substances cannot be detected without sensitive measuring devices. Indeed, fish contaminated with compounds such as mercury, PCBs, and/or various types of pesticides can taste and smell fine and the water in which they swim may appear pristine.

In general, these compounds are present in air and water at low concentrations, posing little direct threat to humans. However, these contaminants can biomagnify in food webs. At the lower level of a food chain, aquatic organisms accumulate small quantities of these contaminants as they respire and take in nutrients. Species higher in a food chain then take in and accumulate these contaminants over the course of their lifetime. That contamination can become substantial. For example, the concentration of PCBs in herring gull eggs can reach fifty-thousand times the concentration found in aquatic species from nearby water bodies and many more times greater than the concentration of PCBs in the water itself.[5]

Levels of contamination in fish can vary widely due to a number of factors. One reason is due to differences in the concentration of contaminants in different water bodies. In addition, water bodies host many different ecosystem types and food webs, resulting in different levels of biomagnification.[6] Furthermore, different contaminants biomagnify at different rates and have different levels of toxicity, complicating matters further. Other factors also matter, such as the ratio of land-to-water in a given watershed. Finally, only methylated forms of mercury bioaccumulate, or watersheds with greater opportunities for bacteria-driven methylation to occur, result in with all else being equal, fish with greater levels of mercury contamination.

Unfortunately, human senses cannot detect differences in contamination levels. Therefore, fish consumers have no direct way of determining the quantity of mercury, PCBs, or other toxic compounds that they are taking in or what the health effects of that exposure might be. Those who catch fish in monitored areas within the Great Lakes basin may have some idea of contamination levels, but it is still only a rough estimate. Those who purchase fish from grocery stores and restaurants have much less of an idea.

Predicting the negative health effects that will occur given one's exposure to toxic contamination, even if that exposure could be precisely determined, is also challenging.[7] For example, chemicals that act as endocrine disrupters can affect the development of fetuses and children in complex ways.[8] Lifestyle choices and differences in human physiology also matter. What is clear is that those who are most reliant on fish consumption and those in the developmental stages of life, are also at the greatest risk of adverse effects due to these toxic compounds. While some people eat little or no fish, others—such as members of tribal communities in the Great Lakes region—consume fish several times a week.[9]

Finally, our ability to see the negative health effects that occur due to individuals consuming contaminated fish is limited.[10] Some health effects, such as increased cancer risks, increases in miscarriages, and cognitive impairment, can be linked to fish consumption only at the scale of a population. But every population is made of individuals with unique experiences. Variations in these experiences (including living in many different environments over a lifetime), substantially complicate health studies. Only by following rigorous research procedures can investigators determine the degree to which health problems in a population are due to the consumption of contaminated fish.

Making toxic contamination visible

Efforts to monitor the presence of chemicals in the environment and the effect of those chemicals on human health are important because they help identify which contaminants are present in the environment, the bodies of water that should be avoided, the species of fish that are the most and least contaminated, and how to take advantage of the benefits of fish consumption while minimizing the risks.

Increasing visibility through fish tissue monitoring programs

Since their inception almost five decades ago, advisory programs have evolved substantially.[11] In general, they began with states issuing strict warnings. The first came in 1971 when Michigan issued a "Do Not Eat" warning after researchers discovered unsafe levels of methylmercury in fish taken from the St. Clair River. The programs of other states emerged independently, with little coordination between states.

In the 1990s, health officials in the Great Lake states began developing targeted fish consumption advisories. First, agencies began creating and disseminating advisories for groups of people considered to be most at risk. This strategy was in response to studies that found that those most in need of contaminant information (women of childbearing-age, developing children, and those who's diet relied heavily on fish), were unaware of local advisories, did not understand them, and/or did not trust issuing agencies.[12] Another change involved providing information to help people balance the risks and benefits of consuming fish. As a result of these changes, specific advisory information became available for different groups, such as expecting and nursing mothers, sports and recreational fishers, various cultural groups, and youth.

These changes were followed by the development of uniform advisory protocols, a National Listing of Fish Advisories database, and a basin-wide advisory consortium.[13]

"That's a big challenge for us—it's a very complicated message. So people sometimes just make choices to stop eating fish. So my hope would be that women, particularly of-childbearing-age, would eat fish that are low in contaminants with an emphasis on 'eating fish' because of the benefits to the baby, the developing fetus."

(State Health Department Official 2014)

To assist agency professionals in the management of fish consumption advisories, the USEPA developed *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories*.[14] The intent of this four-part volume was to establish a consistent process for creating and disseminating advisories across jurisdictions. It provided guidance on each step in the process, from fish sampling and risk assessment, to risk management and communication

Fish tissue monitoring programs continue to provide important information to officials who issue fish consumption advisories. The Great Lakes Fish Monitoring and Surveillance Program (GLFMSP), established in 1970 by the U.S. Geological Survey, was one of the first long-term monitoring programs of toxic compounds[15] Currently administered by EPA's Great Lakes National Program Office (GLNPO), GLFMSP is implemented in cooperation with sixteen state-, tribal-, and province-level agencies across the basin.

Each entity's focus depends on their mission.[16] For example, the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), which represents eleven Ojibwe tribes that reserved hunting, fishing, and gathering rights in treaties with the U.S., structures its sampling process to serve the informational needs of its tribal members.[17] Among other things, GLIFWC Mercury Program monitors mercury levels in walleye from inland lakes throughout Minnesota, Wisconsin, and Michigan because harvesting walleye is a priority to the tribes served by this program.

Programs such as these will continue to be of great importance until the need for fish consumption advisories can be eliminated. [18] Although monitoring programs have revealed that concentrations of many contaminants have declined, some concentrations have leveled off above desired targets. In some places within the Great Lakes basin, recent monitoring shows that the concentration of mercury may even be increasing.[19]

Increasing visibility through atmospheric monitoring

Since the 1970s, scientists have learned much about the long-distant transport of toxic compounds.[20] In the 1970s, high levels of some chemicals were detected in some Arctic traditional foods. The presence of these compounds in remote regions strongly suggested that they were reaching distant areas via the atmosphere. These and other findings dramatically changed perceptions about the spatial component of toxic contamination, eventually leading to the realization that these compounds, once in the environment, disseminated globally.[21]

In response to the broad realization that contaminants were reaching remote areas by long-distance atmospheric transport, officials in several parts of the world established air monitoring programs. In the Great Lakes region, an Integrated Atmospheric Deposition Network (IADN) has been monitoring concentrations and fluxes of toxic compounds in the atmosphere since 1990.[22] Established after the 1987 revision of Great Lakes Water Quality Agreement between the U.S. and Canada, IADN includes five master stations, one for each Great Lake, and a variety of satellite stations sited near urban areas. Although concentrations of toxic compounds in the atmosphere are much lower than concentrations in fish tissue, measurements in the air are a more reliable source of data for evaluating long-term changes because they are not affected by changes in the food web.

Air monitoring programs in other parts of the world also provide valuable information about the long-distance transport of contaminants. For example, the Arctic Monitoring and Assessment Programme (AMAP) was established by the Arctic Environmental Protection Strategy and the intergovernmental Arctic Council to learn more about threats to the Arctic's uniquely vulnerable ecosystem. The Council's member nations (Canada, Denmark, Finland, Norway, Russia, Iceland, Sweden, and the U.S.) developed AMAP as part of a plan to remediate, reduce, and prevent toxics in the Arctic. In addition to providing information about the quantity of compounds reaching distant regions, the data generated by AMAP, IADN, and other monitoring networks aid scientists in identifying various sources and trends associated with the global circulation of these toxic compounds.

Increasing visibility with health studies

Health studies make the consequences of exposure to toxic substances visible. Many different types of researchers, including biologists, toxicologists, and epidemiologists, study the effects of contaminants on ecosystems and living species. For humans, dose-response relationships tend to be developed from epidemiological studies. The results of such studies often become the basis for regulatory standards associated with specific compounds. Laboratory toxicological research, on the other hand, provides insight into cause-and-effect relationships. A challenge is that most studies focus on the effects of a single type of contaminant. However, multiple types of compounds are likely to be present in contaminated fish, complicating our efforts to understand the effects of that contamination.

Other forms of human health research also provide health officials important information. For example, in the late 1980s researchers discovered that Inuit mothers in Northern Quebec had PCB concentrations in their breast milk five times higher than Caucasian women in southern Canada.[23] Other studies revealed cognitive impairments to children exposed to PCBs in utero.[24] Investigators also confirmed that many other compounds (DDT, DDD, DDE, dioxin-like chemicals, methyl-mercury, selenium, chlordane, and toxaphene) can cause negative health effects. Research that examines the benefits of consuming fish, such as the health benefits associated with the Omega 3 fatty acids that fish contain, is also important.

The bottom line is that fish consumption advisories will continue to be necessary as long as contamination levels remain high enough to place the health of fish consumers at risk.

Policy Point 2

Fish consumption advisories are not a permanent policy solution to address health concerns associated with fish contamination.

Eliminating the need for fish consumption advisories remains a priority for the Great Lakes region. The U.S.–Canada Great Lakes Water Quality Agreement explicitly identifies the "human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants" as a goal.[25] Since the 1970s, the Great Lakes Water Quality Agreement has guided numerous efforts aimed at preventing toxic contamination in the Great Lakes region. Many national regulations have also led to basin-wide reductions in contamination levels.[26]

Unfortunately, health officials in the Great Lakes cannot control sources of toxic contamination outside the region. Furthermore, environmental quality agencies in Canada and the U.S. have no jurisdiction over global sources of ASEPs—that is, over pollutants (such as mercury and PCBs) that disseminate globally through atmosphere-surface exchange. As a result, to some people, advisories—once viewed as a temporary policy tool—have come to be seen as permanent.

However, the long-term goal must remain on reducing the release of contaminants into the environment and eliminating the need for advisories. Keeping the focus on eliminating the need for advisories is especially important because many groups of people (as well as many animal species) remain dependent on fish consumption regardless of contamination. Restoring and maintaining the ecosystem services associated with harvesting edible fish is essential.

Advisories do not prevent toxic contamination

Fish consumption advisories are an indicator of contamination at harmful levels. Even though they are a valuable policy tool for protecting public health, they do not prevent contamination. That is, the process of creating and disseminating advisories does not reduce environmental contamination. Preventing toxic releases of contaminants that disseminate globally and bioacccumulate in fish is the only way to eliminate the need for fish consumption advisories.

Advisories do not protect everyone's health

Not all individuals follow the recommendations provided by fish consumption advisories. In fact, advisory guidance is minimally effective for some groups of people heavily dependent on fish. In some cases, people are simply unaware of local advisories or have trouble understanding them. In other cases, advisories are ineffective primarily because people are unwilling to forego the many benefits that fishing and consuming fish provide their families and communities. As a result, some sensitive and vulnerable populations remain dependent on fish. In short, many people do not, cannot, or will not follow advisory recommendations. The reliance on fish for economic, social, and cultural well-being increases health risks due contaminants such as PCBs and mercury.[27]

> *For a lot of people, this information is passed down from grandparents. Even though they're not getting the advisory, the hardcopy, they're still getting the information. But they're not going to change their habits. They're going to still eat catfish and carp. So we just try to get them to prepare the fish in a way that gets rid of contaminants. So we understand we're not going to change behavior . . . but if people are going to fish here, then we'll let them know, good or bad.*
>
> *(National Oceanic & Atmospheric Administration Researcher, 2015)*

Advisories conflict with the Treaty Rights of Tribal Nations

In the Great Lakes region, Anishinaabe nations negotiated treaties that explicitly reserve their hunting, fishing, and gathering rights across millions of acres in the basin.[28] Contamination intrudes upon and erodes tribal harvesting practices protected by those treaties. For many U.S. Native American tribes, fishing rights have been severely impacted by fish consumption advisories and toxicants.[29]

Tribes continue to have some of the highest fish consumption rates in the U.S., with Great Lakes tribal populations currently consuming substances such as mercury and PCBs at levels unsafe for human health. In Lake Superior's Keweenaw Bay Indian Community (KBIC), for example, more than seventy-five-percent of tribal members report fish as a primary source of subsistence.[30] As the oldest and largest federally-recognized Indian tribe in Michigan, the KBIC is one of sixteen U.S. tribes that retain treaty-protected fishing rights in the Lake Superior watershed; thus, harvesting and consuming "safe fish" is a priority. For many Native American groups, fishing is a part of their identity as a people.[31]

Birds don't read fish consumption advisories

The Great Lakes ecosystem is home to numerous species that are negatively affected by toxic contamination. Indeed, many of the dangers associated with toxic chemicals were first discovered in wildlife. The ground-breaking book *Silent Spring* by Rachel Carson brought the issue to the public's attention. Writing in the early 1960s, Carson alerted the public to the effects of DDT and other pesticides on ecological systems.[32] The continued use of DDT, Carson warned, could lead to a bird population unable to reproduce and, hence, a "silent spring."

Unfortunately, fish consumption advisories do not protect wildlife from toxic contamination. Birds—and fish, reptiles, mammals, and organisms of every kind—don't read fish consumption advisories. Thus, even if everyone followed advisory guidelines, negative impacts on wildlife remain. A recent report on Great Lakes mercury contamination indicates that the number of wildlife species with unsafe mercury levels has substantially increased and that health effects on fish and wildlife occur at even lower levels of mercury than previously documented.[33]

In summary, wildlife (and many groups of people) remain dependent on fish consumption regardless of advisories. This reality underscores the importance of eliminating the need for fish consumption advisories. It serves as a reminder that fish consumption advisories are not a permanent policy solution to address health concerns associated with toxic contamination.

Policy Point 3

Actions at all geographical scales—regional, national, and international—are essential if we are to eliminate the need for fish consumption advisories.

The need for fish consumption advisories in the Great Lakes basin due to compounds such as mercury, PCBs, and other chemicals cannot be eliminated by regional actions alone. In fact, even nationwide actions by both the U.S. and Canada cannot prevent all contamination that affects the Great Lakes. The release of compounds that travel by atmosphere-surface exchange anywhere in the world negatively affect contamination levels everywhere.

To eliminate the need for fish consumption advisories, global cooperation and actions at all geographic scales are necessary. In other words, tens of thousands of local jurisdictions, thousands of state- and provincial-level governments, and nations throughout the world must be involved if we are to eliminate the need for fish consumption advisories in the Great Lakes region (and elsewhere).

Important actions have already been taken. In the Great Lakes basin, regional policies that call for the virtual elimination of toxic pollution have been in place for several decades. Similar efforts to protect regional water bodies in other parts of the world are also in place. Furthermore, environmental regulations in many countries have significantly reduced new releases of toxic substances to the environment. International actions have also been important. Many countries are currently implementing international agreements designed to reduce releases of bioaccumulative toxic substances. The scientific community—by monitoring and studying the fate and transport of mercury, PCBs, and other compounds—has been important at all scales. All of these efforts and more will be necessary to eliminate the need for fish consumption advisories in the Great Lake basin and elsewhere.

Toxic pollutants do not respect political boundaries

The movement of toxic substances across the globe is largely determined by Earth's natural systems. The process by which atmosphere-surface exchangeable pollutants (ASEPs) travel (illustrated in Figure 3.1) has been termed the "grasshopper effect."[34] This effect results in the long-distance transport of compounds through cycles of deposition and reemission, contributing to the global nature of the contamination problem.

In general, as these compounds disseminate throughout the world, small amounts accumulate in and on all types of surfaces, water bodies (including oceans), soils, and vegetation. Some of these compounds are then re-emitted into the atmosphere and transported elsewhere. Eventually, the concentration of an ASEP in and on all surfaces, soils, and water bodies reaches a dynamic balance with the concentration in the atmosphere, with as much being deposited as is being re-emitted. The level of this atmosphere-surface exchange depends on a number of factors, including temperature, wind, precipitation, the level of solar radiation, and the characteristics of the surface exposed to the atmosphere.

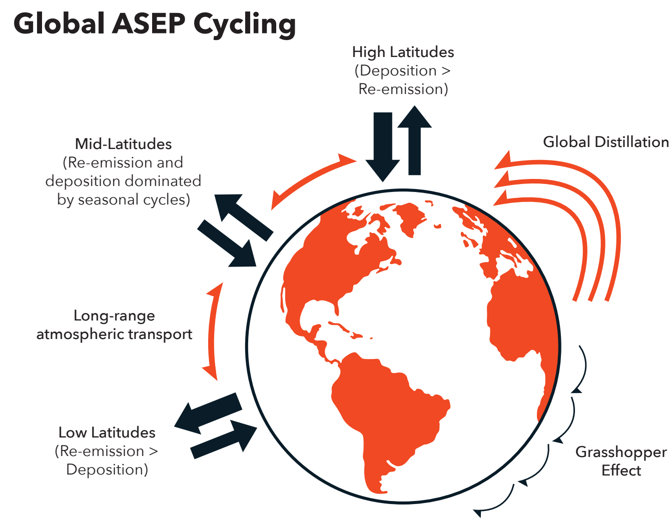

Figure 3.1. Schematic of global atmospheric transport of ASEPs through the 'grasshopper effect' (Wania and Mackay, 1996)

Actions at the regional scale contribute to reducing overall pollutant levels

Regional actions can significantly contribute to the reduction and elimination of toxic releases within a particular water basin. However, as efforts in the Great Lakes basin show, regional reductions of compounds that travel by atmosphere-surface exchange are not sufficient to achieve the goal of eliminating the need for fish consumption advisories.

In the Great Lakes region, new releases of toxic substances have been significantly reduced.[35] The foundation for this success was laid when the U.S. and Canada signed the 1972 Great Lakes Water Quality Agreement (GLWQA), which focuses on the protection and restoration of the Great Lakes ecosystem. Progress toward GLWQA objectives is routinely assessed by the Canada-U.S. International Joint Commission (IJC).

Another important step came in 1991 when U.S. and Canada established the "Bi-national Program to Restore and Protect the Lake Superior Basin."[36] The goal was to develop and implement a strategy to achieve "zero discharge" of toxic chemicals into Lake Superior from the shore. Then, in 1994, the U.S. funded an intensive effort to study the source and fate of mercury, PCBs, and two other ASEPs in Lake Michigan. This six-year "Lake Michigan Mass Balance Study" made clear that the quantity of PCBs and mercury being exchanged between Lake Michigan and the atmosphere was substantially greater than the quantity being directly discharged into the lake from the land.[37] In fact, as the quantity of PCBs in the atmosphere has declined, Lake Michigan has become a net emitter of PCBs to the atmosphere.

To improve efforts to address concerns associated with toxic substances, the GLWQA has been revised several times (1978, 1987, and 2012). The current version of the GLWQA (2012) contains ten annexes, three of which relate to contamination: Annex 1 - Areas of Concern; Annex 2 - Lakewide Action and Management Plans (LAMPs); and Annex 3 - Chemicals of Mutual Concern. These annexes mandate the use of management plans and other tools to coordinate intergovernmental action across the region, with federal, tribal, state, and provincial agencies working together to meet GLWQA annex objectives. However, as GLWQA goals associated with cleaning up hot spots of contaminated sediment and eliminating toxic discharges are achieved, similar actions throughout the world will still be needed. Otherwise, out-of-basin sources may prevent the global background level of atmospheric contamination from significantly changing.

Actions at the national level contribute to reducing global concentrations of pollutants

Decreasing the quantity of bioaccumulative toxic substances in circulation to a point where fish consumption advisories will no longer be needed, depends on all nations reducing or eliminating their uses and releases of those substances. A single nation cannot eliminate the need for all fish consumption advisories within its borders by acting alone.

Efforts to reduce releases of toxic substances are typically coordinated through bodies of environmental law. In the U.S., federal, tribal, and state efforts revolve around a federal regulatory system established in the early 1970s. Several components of that regulatory system govern the production and release of toxic substances (see Table 3.1). State-level and tribal agencies implement many of the programs associated with these federal laws. As a result, tribal and state actions also play a role in reducing releases of toxic compounds to the environment in the U.S.

Some national-level efforts in the U.S. coordinate action across sub-national jurisdictions. For example, the EPA's Great Lakes National Program Office (GLNPO), established in 1978, currently coordinates the Great Lakes-related actions of approximately two hundred federal, state, provincial, and tribal agencies.[38] The Great Lakes Restoration Initiative (GLRI), which funded the cleanup of many heavily contaminated sites, also helped reduce the negative consequences associated with past releases of toxic substances in the Great Lakes basin.

Table 3.1 National-level Environmental Law in the U.S.

The Clean Air Act: sets federal standards for air quality and regulates emissions of pollutants into the air, including toxic compounds. Emissions of mercury from coal-fired power plants are regulated by the Clean Air Act.

The Clean Water Act: regulates the discharge of pollutants into bodies of water, including toxic compounds. When desired uses of a water body are degraded due to contamination, the law requires states to develop and enforce strategies to reduce that contamination.

The Resource Conservation and Recovery Act (RCRA): regulates the disposal of hazardous wastes.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA): requires that pesticides be registered, approved, and labeled—and that uses be consistent with the label.

The Toxic Substances Control Act (TSCA): regulates the use of chemicals in products. (PCBs were banned under TSCA.)

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): governs actions taken when hazardous compounds are discovered at waste sites created before environmental regulations were in place or when spills occur with no clear responsible party.

As important as national efforts are, no single nation can completely control the concentration of ASEPs (including mercury and PCBs) in the atmosphere. For example, both Canada and the U.S. have strong systems of environmental law. Together they have embraced a bi-national program that represents one of the most comprehensive, intergovernmental programs addressing concerns related to chemical pollution. Yet, despite their efforts, these nations have been unable to eliminate the need for fish consumption advisories within their borders.

You emit mercury, you gotta control it. We don't care where it goes because what goes up must come down. We're not trying to track where your emissions go, you know? Mercury is bad—stop it.

(U.S. Federal Regulatory Agency Official, 2015)

Global cooperation through international agreements is necessary for the complete elimination of fish consumption advisories in the Great Lakes and elsewhere

Cooperation at the global scale is imperative for eliminating the need for fish consumption advisories. The vehicle for this cooperation is a set of international conventions designed to govern the flow of hazardous chemicals across political borders.[39] Two of these conventions (Basel and Rotterdam) focus on international shipments of products and wastes that contain hazardous compounds. Both agreements emphasize the importance of the receiving nation providing its consent before any hazardous material enters the country. A third agreement, the Stockholm Convention on Persistent Organic Pollutants (POPs), focuses on eliminating the production of toxic compounds that cross international borders through long-distance atmospheric transport.[40] These compounds include pesticides and industrial chemicals that disseminate in the environment by atmosphere-surface exchange.

A fourth convention, the Minamata Convention on Mercury, aims to protect "human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds."[41] It commits all parties to reducing uses and emissions of mercury within their borders. Emissions from coal-fired power plants and small-scale gold mining account for the majority of all new releases of mercury. Currently, those releases—and, therefore, the amount of mercury accumulating in the world's atmosphere, soils, water bodies, and forests—is increasing.[42]

Eliminating the need for fish consumption advisories in the Great Lakes basin, and in basins throughout the world, will require the participation of nation-states across the globe in the implementation of these conventions. Leadership from nations with the strongest economies is also needed. The U.S., however, has not ratified the Basel, Rotterdam, or Stockholm conventions, which undermines the degree to which the U.S. can actively participate in global efforts to reduce the quantity of toxic substances accumulating in the environment.

Table 3.2 International-level Conventions

The Basel Convention (1989): governs the transport of hazardous wastes (including scrapped equipment) between two countries.

The Rotterdam Convention (1998): governs the transport of products that contain hazardous chemicals (such as pesticides and various industrial compounds) between two countries.

The Stockholm Convention on POPs (2001): addresses the production, use, and disposal of persistent organic pollutants (POPs), which can be transported through atmosphere-surface exchange if released into the environment.

The Minamata Convention on Mercury (2013): commits parties to reducing uses and releases of mercury.

Policy Point 4

Eliminating the need for fish consumption advisories is a long-term goal that will take multiple generations to accomplish.

Eliminating the need for fish consumption advisories requires a long-term commitment. When atmosphere-surface exchange pollutants (ASEPs)—such as mercury, PCBs, toxaphene, and many other industrial chemicals and pesticides—are released into the environment, they remain in circulation for decades, maintaining what can be visualized as a global background concentration. ASEPs are taken out of circulation only when they are sequestered (such as by being buried in sediments) or break down into other compounds, both of which are slow processes.

Even when we stop all new releases of a particular ASEP, the compounds already in the environment continue to circulate for decades. In effect, soils, water bodies, and surfaces become storehouses of past emissions, continually absorbing ASEPs from and releasing ASEPs to the atmosphere. Each new release of a compound only adds to the amount already in circulation. Hence, the longer we delay in reducing or eliminating new releases of problematic compounds, the larger the problem will be for future generations.

New emissions will not stop tomorrow

Eliminating new emissions of all ASEPs worldwide will require changes in practice throughout the world. Rapid reductions in emissions of mercury will be especially difficult to achieve. Coal contains a small amount of mercury and power plants place new quantities of mercury in circulation each year.

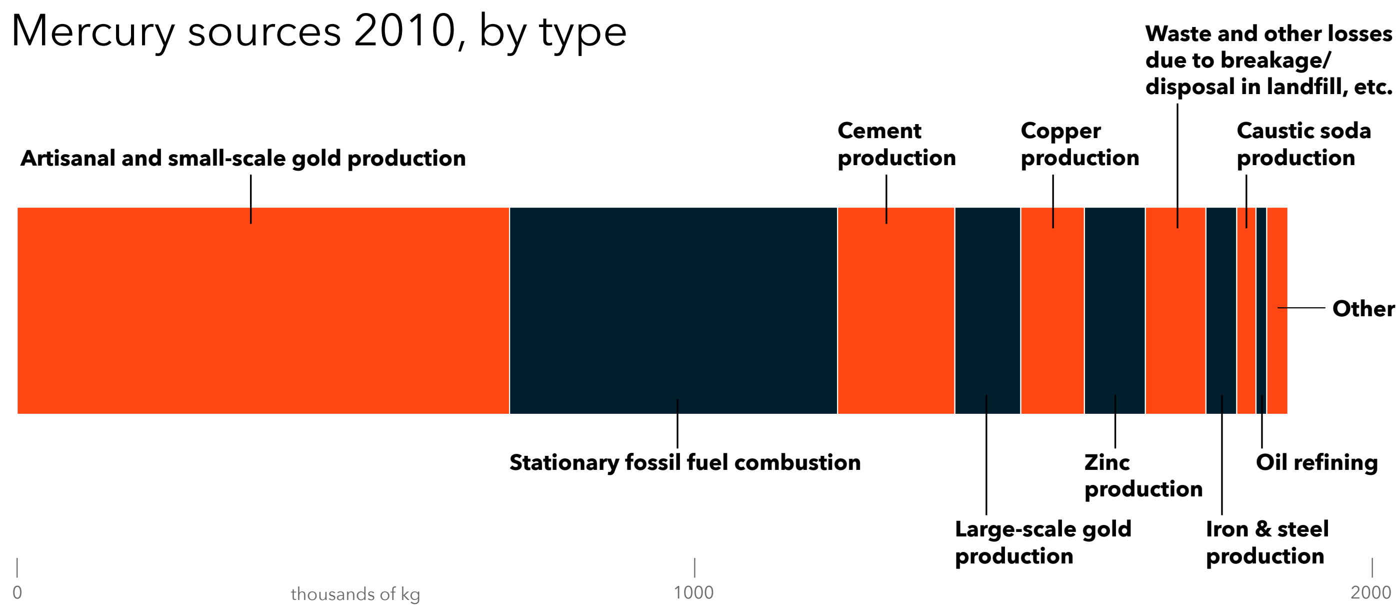

Figure 4.1. Sources of Mercury By Type (from Technical Background Report for the Global Mercury Assessment, 2013)

Pollution control equipment can capture a lot of mercury, but not all countries require such controls.[43] Small-scale gold mining operations also release relatively large quantities of mercury and in poorer countries, some of those operations are likely to continue without controls. Without significant changes in practice, emissions of mercury into the environment could increase.[44]

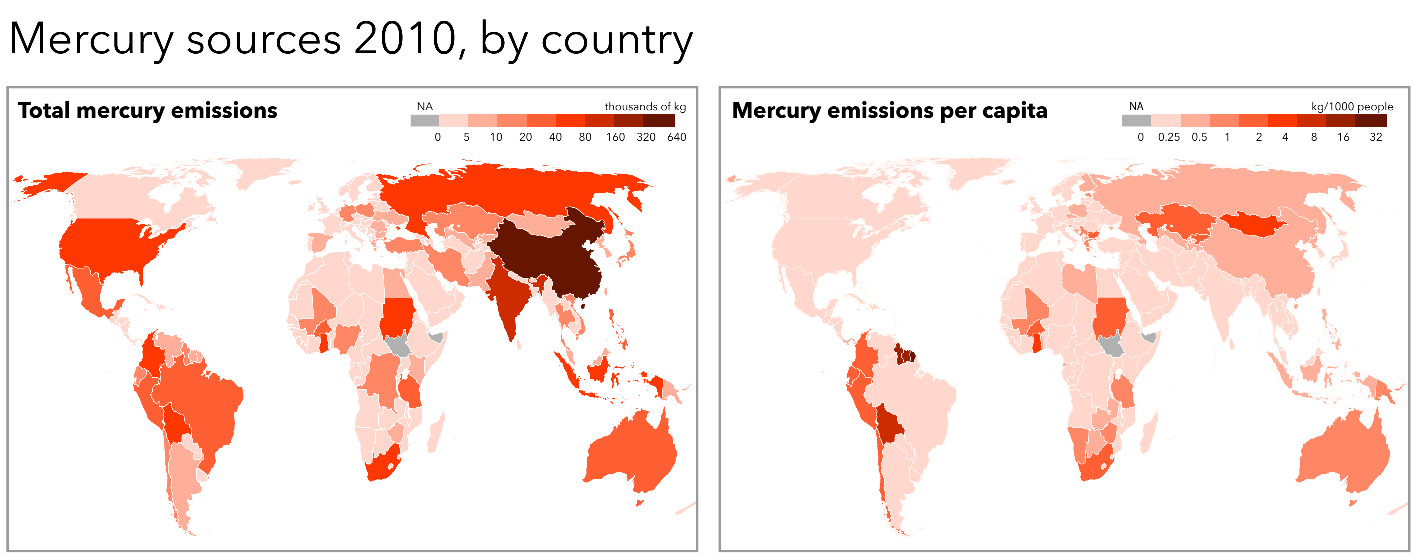

Figure 4.2. Sources of Mercury By Country (*from Technical Background Report for the Global Mercury Assessment, 2013*)

The use and production of many problematic pesticides and agricultural chemicals have already been banned. For banned compounds, new releases still sometimes occur due to leakage from storage, their unintended production as byproducts of other chemical processes, from heavily contaminated soils due to past spills and dumping, and potentially from the illegal production of a compound. For example, new releases of PCBs into the environment still occur when PCBs escape from storage facilities or equipment, such as electrical transformers and capacitors, or when they are produced as the unintended byproducts of various chemical processes.[45]

Another challenge involves preventing the manufacture and widespread use of new products that contain problematic compounds. Systems for identifying problematic products and compounds before they are produced on a large scale are needed.

Toxic substances emitted in the past become sources of secondary emissions

Whether released decades or days ago, toxic substances that disseminate by atmosphere-surface exchange remain available for cycles of reemission and redistribution until they degrade or are sequestered. Indeed, for many ASEPs, secondary emissions from water bodies, soils, and surfaces are a substantial proportion of total emissions.[46] Eventually, as new or primary releases taper and existing molecules break down or are buried and sequestered, secondary emissions—and concentration of these compounds in the atmosphere—gradually decline.

For mercury, secondary emissions represent about two-thirds of the roughly 7,500 Mg/yr of mercury compounds emitted into the atmosphere each year.[47] Ongoing primary emissions (mainly from small-scale gold mining and coal-fired power plants) are adding to the existing quantity in the environment, further increasing the magnitude of secondary emissions.

Eliminating the need for fish consumption advisories due to mercury contamination will require considerable reductions in primary (new) emissions as well as an extended timeframe for secondary emissions to decline. Inaction could easily lead to an increase in fish contamination.

Secondary emissions maintain a background level of atmospheric contamination

Atmospheric concentrations of ASEPs change slowly. Their concentrations in the atmosphere tend to reach a balance with their concentrations in water, soils, and surfaces.[48] When balanced, approximately the same amount of a compound volatizes into the atmosphere as is deposited to or absorbed by water, soils, and surfaces. This tendency toward balance results in a background level of atmospheric contamination that is difficult to change.

Reducing the concentration of an ASEP in a water body below the level at which it is in balance with the background atmospheric concentration is, in the long term, impossible. If concentrations of an ASEP in a water body decrease significantly, deposition from the atmosphere will raise concentrations in the water until balance is reestablished. The only way to permanently reduce contamination levels (in any water body) is to reduce atmospheric levels on a global scale. Doing so requires reducing local inputs, cleaning up heavily contaminated sites everywhere, and waiting for the amount already in circulation to degrade or be sequestered.

The dynamics of atmosphere-surface exchange are complicated, making it difficult to predict what will happen as new emissions of ASEPs decline (or increase) and compounds degrade or are sequestered in sediments. The level of exchange that occurs between the atmosphere and various types of surfaces, soils, and water bodies is dependent on a number of factors, including the specific type of compound involved and the type of surface that is in contact with the atmosphere.[49] Another critical factor is temperature. Higher temperatures can result in greater levels of secondary emissions from oceans and lakes, snowpacks, soils, and vegetation. Solar radiation also promotes the release of ASEPs from surfaces.[50] Wildfire activity, expected to increase in the coming decades, might also result in larger quantities of secondary emissions.[51] Understanding the rates at which compounds degrade and are sequestered in sediments is also critical in determining how atmospheric concentrations will decline (or increase) over time.

Scientists are now studying the environmental factors and chemical characteristics that affect the process of reemission and transport and, hence, how background levels might change over time given different patterns of new emissions.[52, 53] Being able to make such forecasts is essential if we are to assess the rate at which progress is being made toward eliminating the need for fish consumption advisories.

The value of a "Seven Generations" framework

Given that eliminating the need for fish consumption advisories will require significant effort over the long term, approaching the problem with a "Seven Generations" mindset is useful. The concept of a Seven Generations perspective is rooted in Indigenous philosophy and assumes that major decisions should take into account the experiences of past generations, the needs of the present generation, and the consequences on future generations.[54]

> *Our department, our tribal goals, are to protect the community and protect the natural resources for the Seventh Generation. And everything we do is looking into the future, to make sure that the water is high enough quality for people to continue to consume it, or swim in it, or fish out of it for the next seven generations.*
>
> *(Tribal Natural Resources Dept. Official, 2014)*

To some extent, the effort to restore the health of ecosystems in the Great Lakes region, which can be described as a form of adaptive governance, is already being guided by a Seven Generations mindset. That is, the Great Lakes Water Quality Agreement is a framework in which decision makers learn from what has happened in the past, adjust strategies based on what has been learned, and consider how choices being made today will affect people and environments in the future. For example, in the 1970s, officials and scientists believed that the goal of safe fish could be reached relatively quickly and by actions taken within the basin alone. Over time, scientists learned about the phenomenon of atmospheric-surface exchange and realized that the effort to eliminate the need for fish consumption advisories would be more complicated. The challenge now is determining how best to make steady progress toward the goal of safe fish using the tools of adaptive governance on a global scale.

Policy Point 5

Tools of adaptive governance are required to coordinate and sustain the efforts needed to eliminate the need for fish consumption advisories.

Systems of adaptive governance generally include the following components:[55]

- A process for a wide variety of actors to reach consensus on a set of goals and objectives
- The development of science-based strategies for achieving those objectives
- The documentation of those goals, objectives, and strategies
- Efforts to implement those strategies
- Long-term monitoring of progress toward the stated goals and objectives
- A process for periodically reviewing progress and making adjustments based on new scientific knowledge and on what was learned during implementation.

When an objective (such as eliminating the need for fish consumption advisories) requires actions at different geographic scales in jurisdictions throughout the world over multiple generations—all in the context of multiple uncertainties—such an approach is desirable. As previously discussed, a variety of institutional structures relevant to eliminating the need for fish consumption advisories already exist. This section examines the degree to which these efforts support that goal in a coordinated fashion using the tools of adaptive governance.

The Great Lakes Water Quality Agreement (GLWQA) is a regional-scale system of adaptive governance that includes the elimination of fish consumption advisories as an objective

The process embraced by the GLWQA is an example of adaptive governance at the ecosystem or regional level. It includes each of the components associated with a system of adaptive governance.

Setting and documenting goals and strategies

The GLWQA explicitly calls for people to be able to consume Great Lakes fish "unrestricted by concerns due to harmful pollutants."[56] To coordinate efforts to reach such goals, the GLWQA requires the preparation of two general types of management plans. These documents include a Lake Action and Management Plan (LAMP) for each of the five Great Lakes and a Remedial Action Plan (RAP) for multiple Areas of Concern.[57] These documents articulate ecosystem objectives and strategies for achieving those objectives at the scale of each lake and at scale of individual harbors and/or watersheds.

The process for creating LAMPs and RAPs involves the participation of a wide variety of actors. For example, Environment Canada and the U.S. EPA established a working group consisting of representatives from tribal, state, and provincial agencies to create the first Lake Superior LAMP released in 2000. The two federal agencies also established the Lake Superior Bi-National Forum to engage the public and advise the working group. Other working groups developed the first LAMPs for Lake Michigan (2000), Lake Erie (2000), Lake Ontario (2002), and Lake Huron (2004). The GLWQA also requires public participation in the creation of RAPs, which document the actions necessary for restoring the beneficial uses of a local water body impaired by past contamination.

Implementing recommended actions

Securing the funds to implement actions identified in RAPs and LAMPs has been a slow process in both Canada and the U.S. Without an institutional structure such as the GLWQA in place, there is no guarantee that restoration efforts in the Great Lakes, including those associated with eliminating the need for fish consumption advisories, would have remained a priority for policy makers over the last four decades.[58] Since 1987, RAPs have been written for 42 AOCs, with 15 of those areas having since been delisted.[59]

In the case of efforts to reduce the quantity of bioaccumulative toxic substances present in water bodies, the main actions have involved reducing the release of those substances from in-basin sources and cleaning up sediments heavily contaminated by past industrial activity. In the U.S., some of the funding for cleaning up contaminated sites has come from the U.S. Superfund program. In other cases, funding has been obtained from programs such as the U.S. Great Lakes Restoration Initiative. Other funds have come through state-level programs. In Canada, the "Canada–Ontario Agreement on Great Lakes Water Quality and Ecosystem Health" aligns federal and provincial level efforts toward meeting the goals of the GLWQA.[60]

Intergovernmental coordination is really important. Since 1990, we've reduced mercury emissions in the basin by 80%. That's big; that's good. We still have those challenges from global sources, but if we don't do it in our backyard, where is it going to get done? At the same time, restoration is a big need, but it's a whole lot cheaper to protect what we have than have to restore it later. Protection of high quality resources is a huge priority, we need to be devoting resources as much to protection as to restoration.

(GLWQA Superior Working Group, Annex 2, Lakewide Management, 2015)

Measuring and monitoring progress

The GLWQA calls for the Canada-U.S. International Joint Commission (IJC)—a body established to resolve conflicts over water shared by the two nations in order to conduct a periodic assessment of progress toward the goals of the GLWQA. The data the IJC uses to assess progress toward the goal of fish consumption "unrestricted by concerns due to harmful pollutants" comes from a variety of sources, including tribal, state, provincial, and federal fish sampling programs, as well as from air monitoring programs. Additional assessment mechanisms are also in place. One effort, the Cooperative Science and Monitoring Initiative (CSMI) coordinated by the U.S. EPA and Environment Canada, places each of the Great Lakes on a rotational five-year cycle for a process that includes identifying a lake-specific priority, conducting lake-wide sampling, and reporting the results.[61]

Periodically assessing and adjusting

Periodic assessments allow experience and new knowledge to be integrated into the LAMPs and, when necessary, RAPs. This integration of new knowledge is seen in the history of the GLWQA. The initial GLWQA agreement (1972) focused on reducing the amount of phosphorus entering the Great Lakes, and significant progress was made in the first few years of implementation. However, it soon became clear that the issue of fish contamination was also important. Thus, when the Agreement was revised in 1978 to include more focus on toxic contamination. In 1987, after assessments showed little progress in eliminating fish contamination, policy makers revised the agreement again and introduced LAMPs and RAPs.[62] Much has been learned since then as well, including the knowledge that actions outside the basin will be necessary if GLWQA goals associated with safe fish consumption are to be achieved.

U.S. environmental laws support but do not explicitly identify the elimination of fish consumption advisories as an objective to be pursued adaptively

In the U.S., both the Clean Air Act (CAA) and the Clean Water Act (CWA) are strong environmental laws that include adaptive components for achieving explicit goals. These laws, along with laws governing the use of toxic substances in products and laws designed to prevent hazardous wastes from contaminating the environment, support efforts to eliminate the need for fish consumption advisories. However, none of these laws explicitly identify the elimination of fish consumption advisories as a goal.

How national environmental laws contribute to safer fish

In the U.S., environmental laws limit the release of toxic substances to the environment and facilitate the clean up of environments that have been contaminated. For example, the 1979 ban on the manufacture and distribution of PCBs under the Toxics Substance Control Act (TSCA) contributed significantly to the goal of safer fish consumption. A pre-TSCA ban on the pesticide DDT also helped significantly. Today, regulations empowered by the CAA place limits on emissions of mercury from coal-fired power plants and are critical if levels of mercury in Great Lakes fish are to decrease. Without controls and bans such as these, not only in the U.S. but throughout the world, concentrations of these toxic compounds in fish tissue would have increased rather than decreased.[63]

The limits of national environmental laws

One weakness of national environmental laws is that they are not particularly strong at addressing issues associated with boundary-crossing pollutants, especially ASEPs. For example, the U.S.'s CWA calls for states and authorized tribes to enact total maximum daily loads (TMDLs) on pollutants that compromise the desired use of a water body. A TMDL is "the maximum amount of a pollutant allowed to enter a water body so that the water body will meet and continue to meet water quality standards for that particular pollutant."[64] Such a strategy works well for pollutants with local sources only. However, a TMDL simply does not work with ASEPs because concentrations of ASEPs in a water body are in a dynamic balance with the atmosphere. Local and regional jurisdictions cannot stop the atmosphere and water body from maintaining that balance. Similarly, national laws cannot directly affect practices outside national boundaries.

The failure to explicitly identify the elimination of fish consumption advisories as an objective can also limit action. For example, if the goal of eliminating fish consumption advisories were embedded in national law, U.S. participation in international conventions associated with the management of hazardous chemicals might be greater.

International Conventions support but do not explicitly identify the elimination of fish consumption advisories as an objective to be pursued adaptively

International conventions play a crucial role in coordinating efforts to reduce emissions of ASEPs. The Basil and Rotterdam Conventions established a process for identifying the presence of hazardous chemicals in products and wastes being transported over national boundaries, which represented an important step in the responsible management of all hazardous chemicals. Going a step further, the Stockholm and Minamata Conventions establish expectations associated with preventing releases of compounds (POPS and mercury) that are toxic, persistent in the environment, bioaccumulative, and capable of disseminating globally through processes of atmosphere-surface exchange.

How international conventions contribute to safer fish

An important way in which international conventions reduce global levels of ASEPs is by coordinating bans on their production and coordinating reductions in emissions. For example, the Stockholm Convention has helped establish national bans on a variety pesticides and industrial chemicals. The Minamata Convention facilitates national efforts to reduce the use of mercury in products and to reduce emissions of mercury from power plants and small-scale gold mining. International conventions have also been important in mobilizing the scientific community to generate knowledge associated with the fate and transport of ASEPs. For example, the Stockholm and Minamata conventions call for participating nations to support the monitoring and research needed to determine if progress is being made toward the objectives of these conventions.

The limits of international conventions

One limit of international conventions is that they are, to some degree, voluntary. Not all nations sign and ratify these agreements. Furthermore, they depend strongly on the capacity and willingness of individual nations. For example, under the Minamata Convention, individual nations set their own targets for mercury reductions. In addition, these conventions do not explicitly target the elimination of fish consumption advisories as a goal.

Adaptive governance of a local problem with global sources requires a shared objective at all scales and jurisdictions

In summary, the goal of eliminating the need for fish consumption advisories is explicitly specified in the U.S.-Canada Great Lakes Water Quality Agreement and is being pursued adaptively at that scale. However, eliminating the need for fish consumption advisories in the Great Lakes basin and in water basins throughout the world will require the adaptive pursuit of this goal by all nations working together. Although important systems of governance are in place at the national and global scale, they do not explicitly identify the elimination of fish consumption advisories as a goal, making it difficult to coordinate efforts to achieve this goal.

Policy Point 6

The path forward necessitates a global policy framework that links regional, national, and international efforts, and unites ecosystem and chemical-based goals.

The world's capacity to govern the production, use, and/or emissions of chemical compounds that are responsible for fish contamination has increased over the last two decades. Indeed, a significant institutional framework focused on health-related objectives, ecosystem-based objectives, and objectives related to the management of chemicals already exists. All three approaches are important if the world is to make steady progress towards safe fish.

Efforts to eliminate the need for fish consumption advisories would be strengthened if jurisdictions at all scales explicitly adopt a unified objective centered on safe fish and pursue that objective in a coordinated fashion. The tools of adaptive governance, facilitated by the coupling of science and policy, are effective only for reaching goals that are explicitly articulated.

In addition to explicitly articulating the goal of eliminating the need for fish consumption advisories at all scales, the path forward should also include: (a) a global air monitoring program to assess progress; (b) consistent human health criteria across jurisdictions; (c) consistent criteria for cleaning up heavily contaminated soils and sediments; (d) a global "virtual elimination" policy for persistent organic pollutants that can be transported by atmosphere-surface exchange; and (e) a planetary total maximum load for mercury.

A global air monitoring program is desired to assess progress towards safe fish

How can we determine if steady progress is being made toward the goal of safe fish? Monitoring air concentrations is one way to determine if longterm goals are being met. When it comes to chemicals with the characteristics of an ASEP, land and water bodies throughout the world are ultimately connected to each other through the atmosphere.

The implication is sobering: the concentration of an ASEP in a water body cannot deviate too far from being in dynamic balance with atmospheric concentrations and, indirectly, with soils, surfaces, and other water bodies around the world. Hence, if scientists monitor air concentrations at strategic locations, they can determine much about long-term trends associated with amount of mercury in circulation.

The basic infrastructure for developing a global air monitoring program already exists

A number of regional networks that monitor air concentrations of ASEPs already exist. For example, air monitoring programs such as the Great Lakes Integrated Atmospheric Deposition Network (IADN), the Arctic Monitoring and Assessment Program (AMAP), and regional networks in Europe are well established. In addition, a Global Observation System for Persistent Organic Pollutants (GOS4POPS) and a Global Observation System for Mercury (GOS4M) are being created to make use of data generated by such networks to assess the effectiveness of the Stockholm and Minamata conventions.

The scientific community has a role to play in assessing the effectiveness of policies

The data from air monitoring networks have to be interpreted to be useful. For example, what do we expect air concentrations of PCBs to be in 2035 given that the manufacture of this industrial compound has been banned? Forecasting such numbers and comparing the results to measured data allows scientists and officials to track progress and determine if policies are having the desired effect.

This pattern of comparing forecasts with measurements lies at the core of adaptive governance. If future measurements are not in alignment with a past forecast, investigating these discrepancies can produce knowledge that contribute to improved science and/or policy. Hence, a coordinated monitoring program also includes the efforts of scientists who make sense of the data that is generated. Scientists can also use fate and transport models to test policies—that is, to determine if the forecasted outcomes associated with a given set of policies will be sufficient to achieve a desired goal.[65]

Fish tissue monitoring, needed to identify health concerns, is less useful for determining longterm trends

The sampling of fish tissue to detect levels of mercury, PCBs, and other bioaccumulative toxic substances is necessary if health officials are to create meaningful advisories for specific water bodies. However, fish sampling is less reliable than air monitoring for determining longterm contamination trends. The problem is that the concentration of contaminants in fish tissue is influenced by factors that vary by location, which can change over time. These factors include the mix of organisms in the food web (which can also change over time), land uses (which can alter the amount of a compound that reaches a water body, as well as the rate at which mercury is methylated), and the mobility of fish (which complicates their consumption history).[66] Given the variety of factors that influence fish tissue concentrations, air monitoring data is more useful for identifying longterm trends.

Consistent human health criteria for safe fish is desired across jurisdictions

Currently, the human health criteria used to determine the risks posed by consuming contaminated fish varies from jurisdiction to jurisdiction. In essence, the notion of what is "safe" varies throughout the world. Although health officials follow the same general methodology to assess risk, different jurisdictions use different values for various factors important in calculating risk.

One of these factors is the reference dose, which is the quantity of a contaminant that one can safely be exposed to per kilogram of body weight per day (µg/kg/day). The safe reference dose for methylmercury (MeHg) in jurisdictions throughout the world ranges from 0.1 to 0.5 µg/kg/day.[67] Such differences not only complicate efforts to set and interpret progress toward the goal of safe fish, but also can result in different levels of human safety across regions. Arriving at a consistent understanding of what constitutes safe fish is desirable.

Consistent standards for remediating soils and sediments is desirable.

Most soils and sediments contain ASEPs like mercury and PCBs in concentrations that are in dynamic balance with the atmosphere or, in the case of sediments, with the water column. In general, these concentrations are extremely low.

However, soils and sediments that have been heavily contaminated with mercury, PCBs, or other ASEPs through past industrial activity or spills pose a special concern. These soils and sediments act as sources, elevating local concentrations and adding to the amount in circulation. Remediating these sediments reduces the level of contamination in the local area and prevents further increases to the amount in global circulation.[68] Consistent standards for identifying and remediating soils and sediments contaminated with an ASEP are desirable given that, in the longterm, all locations are linked through the atmosphere.

A global "virtual elimination" policy is desirable for persistent organic pollutants that can bioaccumulate and be transported by cycles of atmosphere-surface exchange

The world has reduced environmental releases of the dozen or so compounds identified in the Stockholm Convention on Persistent Organic Pollutants. This accomplishment is significant.

> *We need to stop the flow. The chemical industry comes up with chemicals so fast, and introduces them on the market so fast, that there is no way to keep up with the pace they have. Sure, we can pay chemists to follow existing chemicals but we must stop the flow, too. Chemical industries can't keep producing new chemicals because every time you solve a problem with one, there are ten more.*
>
> *(Arctic Monitoring and Assessment Programme, POPs Expert Group, 2014)*

At the same time, there are relatively few barriers to placing new compounds that have the characteristics of an ASEP on the market. One of the greatest concerns held by people involved in efforts to address toxic contamination is that new pesticides and industrial chemicals will be placed into production that are just as problematic as the ones already banned. By the time such a compound is detected by monitoring networks, its dissemination to water bodies, soils, and other surfaces throughout the world will have already occurred. The potential additive nature of toxic compounds on an individual's health makes it all the more important to keep new synthetic organic compounds with the characteristics of an ASEP out of circulation.

To continue progress towards eliminating fish consumption advisories, a global "virtual elimination" policy is needed for all compounds that have the characteristics of an ASEP. In short, if a compound is persistent, capable of being transported globally through cycles of deposition and re-emission, and has the capacity to bioaccumulate, that compound should not be placed into production.

A planetary total maximum load is desirable for mercury

Mercury is different than most atmospheric surface-exchangeable pollutants. Mercury is not an industrial synthesized compound, but a naturally occurring element able to be released from rock formations or volcanic events. The problem is that releases of mercury from human activities have substantially increased the amount of mercury in circulation.

The focus needs to be on steadily reducing the quantity of mercury released by human activity. Given that the largest anthropogenic sources of mercury are releases from coal-fired power plants and small-scale gold mining, the Minamata Convention calls for countries to require technological controls on processes that release mercury to the atmosphere. The Convention also calls for stringent rules on the disposal of mercury and a limit to its use in products. However, the Convention does not set targets for these reductions. One way to coordinate the reduction of mercury is to identify a total maximum load for mercury at the global scale and have nations commit to targets consistent with that goal. Otherwise, there is no way to guarantee that progress will be made in the direction of safer fish.

Which Scenario?

Today, everyone should follow the guidance of fish consumption advisories so as to minimize potential health risks while taking advantage of the benefits of consuming fish. The question is which scenario will unfold in the future? A proactive one in which the need for fish consumption advisories steadily decreases over time? Or a scenario in which contamination levels continue to pose health risks (or, worse, increase the risks to humans and ecosystems), making fish consumption advisories a permanent part of life?

The purpose of this policy brief is to recognize the importance of fish consumption advisories but to keep the long-term focus on eliminating the need for such advisories in the future.

About this Project

This policy brief was prepared as part of the NSF-sponsored research project "Managing Impacts of Global Transport of Atmosphere-Surface Exchangeable Pollutants (ASEPs) in the Context of Global Change." In the larger project, more than 30 investigators from five universities and 11 organizational partners participated in three primary research efforts: 1) the development of better fate and transport models for compounds that have the characteristics of ASEPs; 2) using those models to "test" policies associated with achieving ASEP-related air- and water-quality goals; and 3) evaluating the existing system of environmental and chemical governance in terms of its capacity to implement the desired policies.

The policy goal of eliminating the need for fish consumption advisories emerged out an effort to provide community partners with an opportunity to shape the research trajectory. As part of that effort, two workshops were held and the question of "when can we eat the fish?" emerged as a priority. This question helped to structure various aspects of the overall project, including efforts to model the fate and transport of mercury and PCBs under different policy scenarios. In essence, the question of "when can we eat the fish?" resulted in an investigation of how long it would take to achieve "safe fish" under different levels of policy action. This community-directed priority was also the impetus for this policy brief: to renew focus on eliminating the need for fish consumption advisories and to outline a framework for achieving such a vision.

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For more information about this project, please visit http://asep.mtu.edu/

Notes

[1] Canada--United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes, April 7, 1997. For text see, archive.epa.gov/greatlakes/p2/web/pdf/bnssign.pdf

[2] C. O'Neill, "Mercury, Risk & Justice," *Environmental Law Reporter News and Analysis 34* (2004): 11070–11115.

[3] J. A Perlinger, H. S. Gorman, E. S. Norman, D. Obrist, N. E. Selin, N. R. Urban, and S. Wu, "Measurements and Modeling Atmosphere-surface Exchangeable Pollutants (ASEPs) to Understand their Environmental Cycling and Planetary Boundaries," *Environmental Science & Technology 50* (2016): 8932–8934.

[4] United States Environmental Protection Agency (EPA), "National Listing of Fish Advisories, Fish and Shellfish Advisories and Safe Eating Guidelines." 8/17/2017, www.epa.gov/choose-fish-and-shellfish-wisely/fish-and-shellfish-advisories-and-safe-eating-guidelines

[5] U.S. EPA, "Report to the International Joint Commission Under the Great Lakes Water Quality Agreement," 2nd Report, 1991.

[6] E. K. Read, V. P. Patil, S. K. Oliver, A. L. Hetherington, J. A. Brentrup, J. A. Zwart, K. M. Winters, J. R. Corman, E. R. Nodine, R. I. Woolway, H. A. Dugan, A. Jaimes, A. B. Santoso, G. S. Hong, L. A. Winslow L.A., P. C. Hanson, and K. C. Weathers, "The Importance of Lake-Specific Characteristics for Water Quality across the Continental United States," *Ecological Applications 25* (2015): 943–955.

[7] State of Michigan, "Michigan Fish Consumption Advisory Program Guidance Document," version 4, 2016.

[8] Colborn, D. Dumanoski, and J. P. Myers, *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival?–A Scientific Detective Story*. (London: Penguin Books, 1997).

[9] National Environmental Justice Advisory Council, "Fish Consumption and Environmental Justice," a report developed from the NEJAC Meeting, Seattle, WA, December 3-6, 2001.

[10] Health Professionals Task Force for the International Joint Commission, "Great Lakes Fish Consumption Advisories: The Public Health Benefits and Risks," discussion paper, 2004. 3/6/2018, http://www.ijc.org/files/publications/ID1540.pdf

[11] P. A. Cunningham, S. L. Smith, J. P. Tippett, and A. Greene, "A National Fish Consumption Advisory Data Base: A Step Toward Consistency," *Fisheries 19* (1994): 14–23.

[12] V. S. Gagnon, "Prolonging Disaster (Un)Recovery: 'Culturally-irrelevant' Fish Consumption Advisories in the Keweenaw Bay Indian Community," *Student Anthropologist 4* (2015): 18–30.

[13] Minnesota Department of Health, "Great Lakes Consortium for Fish Consumption Advisories," 8/18/17, www.health.state.mn.us/divs/eh/fish/consortium

[14] United States Environmental Protection Agency, "EPA Guidance for Developing Fish Advisories," 8/18/2017, www.epa.gov/fish-tech/epa-guidance-developing-fish-advisories

[15] United States Environmental Protection Agency, "Great Lakes Fish Monitoring and Surveillance," 8/18/2017, www.epa.gov/great-lakes-monitoring/great-lakes-fish-monitoring-and-surveillance

[16] United States Environmental Protection Agency, "National Forum on Contaminants in Fish," 8/18/2017, www.epa.gov/fish-tech/national-forum-contaminants-fish

[17] Great Lakes Indian Fish & Wildlife Commission (GLIFWC), "Guidance for safe consumption of walleye from inland lakes within the Ceded Territories of Wisconsin, Michigan, and Minnesota," 9/2016, www.glifwc.org/Mercury/mercury.html

[18] D. L., Carlson and D. L. Swackhamer, "Results from the US Great Lakes Fish Monitoring Program and Effects of Lake Processes on Bioaccumulative Contaminant Concentrations," *Journal of Great Lakes Research 32* (2006): 370–385.

[19] C. Zhou, M. D. Cohen, B. A. Crimmins, H. Zhou, T. A. Johnson, P. K. Hopke, and T. M. Holsen, "Mercury Temporal Trends in Top Predator Fish of the Laurentian Great Lakes from 2004 to 2015: Are Concentrations Still Decreasing?," E*nvironmental Science and Technology 51* (2017): 7386–7394. See also B. A. Monson, D. F. Staples, S. P. Bhaysar, T. M.

Notes

Holsen, C. S. Schrank, S. K. Moses, D. J. McGoldrick, S. M. Backus, and K. A. Williams, “Spatio-temporal Trends of Mercury in Walleye and Largemouth Bass from the Laurentian Great Lakes Region,” *Ecotoxicology 20* (2011): 1555–1567.

[20] W. R. Swain, “Chlorinated Organic Residues in Fish, Water, and Precipitation from the Vicinity of Isle Royale, Lake Superior,” *Journal of Great Lakes Research 4* (1978): 398–407.

[21] F. Wania and D. Mackay, “Tracking the Distribution of Persistent Organic Pollutants,” *Environmental Science & Technology 30* (1996): 390–396.

[22] United States Environmental Protection Agency, “Great Lakes Integrated Atmospheric Deposition Network,” 8/17/2017, www.epa.gov/great-lakes-monitoring/great-lakes-integrated-atmospheric-deposition-network

[23] E. Dewailly, “Case Study Canadian Inuit and the Arctic Dilemma,” *Oceanography 19* (2006): 88–89.

[24] J. L. Jacobson, S. W. Jacobson, and H. E. Humphrey, “Effects of in utero exposure to polychlorinated biphenyls and related contaminants on cognitive functioning in young children,” *Journal of Pediatrics 116* (1990): 38–45.

[25] U.S.-Canada, “Great Lakes Water Quality Agreement (GLWQA) of 2012,” 3/6/2018, https://binational.net/2012/09/05/2012-glwqa-aqegl/

[26] H. Gorman, V. Gagnon, and E. Norman, “Local Impacts, Global Sources: The Governance of Boundary-Crossing Chemicals,” *History of Science 54* (2016): 443–459.

[27] National Environmental Justice Advisory Council. 2002. Fish Consumption and Environmental Justice, a report developed from the NEJAC Meeting of December 3-6, 2001, Seattle, WA.

[28] 7 Stat., 591:Oct. 4, 1842—Treaty with the Chippewa, Proclamation, Mar. 23, 1843; 10 Stat., 1109: Sept. 30, 1854—Treaty with the Chippewa, Proclamation, Jan. 29, 1855.

[29] D. Ranco, C. O’Neill, J. Donatuto, and B. Harper, “Environmental Justice, American Indians and the Cultural Dilemma: Developing Environmental Management for Tribal Health and Well-Being,” *Environmental Justice 4* (2011): 221–230. See also C. O’Neill, “Protecting the Tribal Harvest: The Right to Catch and Consume Fish,” *Justice, Environmental Law, and Litigation 22* (2007): 131–151.

[30] V.S. Gagnon, P. Nankervis, and E. Johnston, “Keweenaw Bay Indian Community Wildlife and Natural Resources Report,” KBIC Natural Resources Dept., Lanse, MI, 2013.

[31] V. S. Gagnon, “Ojibwe Gichigami (‘Ojibwa’s Great Sea’): An Intersecting History of Treaty Rights, Tribal Fish Harvesting, and Toxic Risk in Keweenaw Bay, United States,” *Water History 8* (2016): 365–384.

[32] R. Carson, *Silent Spring*. (Boston: Houghton Mifflin, 1962).

[33] D. C. Evers, J. G. Wiener, C. T. Driscoll, D. A. Gay, N. Basu, B. A. Monson, K. F. Lambert, H.A . Morrison, J. T. Morgan, K. A. Williams, and A. G. Soehl, “Great Lakes Mercury Connections: The Extent and Effects of Mercury Pollution in the Great Lakes Region.” *Biodiversity Research Institute. Gorham, Maine. Report BRI 2011–2018.*

[34] Wania and Mackay, “Tracking the Distribution of Persistent Organic Pollutants.”

[35] U.S. EPA and Environment Canada, Great Lakes Binational Toxics Strategy, Annual Progress Report, 2006.

[36] Lake Superior Work Group, “A Binational Pollution Prevention Strategy for the Lake Superior Basin,” discussion paper, Lake Superior Binational Program, 1996. See also Lake Superior Binational Program, “Lake Superior Zero Discharge Demonstration Program and Critical Chemical Reduction Milestones,” Lake Superior Binational Program, 2012.

[37] H. B. McCarty, J. Schofield, K. Miller, R. N. Brent, Results of the Lake Michigan Mass Balance Study: Polychlorinated Biphenyls and Trans-Nonachlor Data Report, EPA 905 R-01-011, prepared for USEPA GLNPO, April 2004.

[38] U.S. EPA, “Five Year Program Strategy for the Great Lakes National Program Office,” EPA document 905/9/89/001, US EPA, 1989.

Notes

39. Conference of the Parties (COPs), "Synergies Among the Basel, Rotterdam, and Stockholm Conventions," 11/27/2017, www.brsmeas.org

40. H. Selin, G*lobal Governance of Hazardous Chemicals: Challenges of Multilevel Management*. (Cambridge, MA: MIT Press, 2010).

41. UN Environment Program, Minamata Convention on Mercury, 11/27/2017, www.mercuryconvention.org

42. UN Environment Program, Global Mercury Assessment: Sources, Emissions, Releases, and Environmental Transport (UNEP Chemical Branch, 2013).

43. A. Giang and N. E. Selin, "Benefits of Mercury Controls for the United States," *Proceedings of the National Academy of Sciences 113* (2015): 286–291.

44. Samuel J. Spiegel, Sumali Agrawal, Dino Mikha, Kartie Vitamerry, Philippe Le Billon, Marcello Veiga, Kulansi Konolius, and Bardolf Paul, "Phasing Out Mercury? Ecological Economics and Indonesia's Small-Scale Gold Mining Sector," *Ecological Economics 144* (2018): 1–11.

45. Song Cui, Hong Qi, Li-Yan Liu, Wei-Wei Song, Wan-Li Ma, Hong-Liang Jia, Yong-Sheng Ding, Yi-Fan Li, "Emission of Unintentionally Produced Polychlorinated Biphenyls (UP-PCBs) in China: Has this become the major source of PCBs in Chinese air?" *Atmospheric Environment 67* (2013): 73–79. See also Song Cui, Qiang Fu, Wan-Li Ma, Wei-Wei Song, Li-Yan Liu, and Yi-FanLi, "A Preliminary Compilation and Evaluation of a Comprehensive Emission Inventory for Polychlorinated Biphenyls in China," *Science of The Total Environment 533* (2015): 247–255.

46. L. Nizzetto, M. Macleod, K. Borgå, A. Cabrerizo, J. Dachs, A. Di Guardo, D. Ghirardello, K. M. Hansen, A. Jarvis, A. Lindroth, B. Ludwig, D. Monteith, J. A. Perlinger, M. Scheringer, L. Schwendenmann, K. T. Semple, L. Y. Wick, G. Zhang, K. C. Jones, "Past, Present, and Future Controls on Levels of Persistent Organic Pollutants in the Global Environment," *Environmental Science and Technology 44* (2010): 6526–6531.

47. Arctic Monitoring and Assessment Programme and United Nations Environment Programme, Technical Background Report for the Global Mercury Assessment 2013 (AMAP and UNEP Chemicals Branch, 2013).

48. Judith A. Perlinger, Hugh S. Gorman, Emma S. Norman, Daniel Obrist, Noelle E. Selin, Noel Urban, and Shilang Wu, "Measurement and Modeling of Atmosphere-Surface Exchangeable Pollutants (ASEPs) to Better Understand their Environmental Cycling and Planetary Boundaries," *Environmental Science and Technology 50* (2016): 8392–8394.

49. W. H. Schroeder and J. Munthe, "Atmospheric mercury - An overview," *Atmospheric Environment 32* (1998): 809–822.

50. M. S. Gustin, G. E. Taylor, and R. A. Maxey, "Effect of Temperature and Air Movement on the Flux of Elemental Mercury from Substrate to the Atmosphere," *Journal of Geophysical Research-Atmospheres 102* (1997): 3891–3898. See also C. Moore and A. Carpi "Mechanisms of the Emission of Mercury from Soil: Role of UV radiation," *Journal of Geophysical Research-Atmospheres 110* (2005): D24302.

51. D. Obrist, H. Moosmuller, R. Schurmann, L. W. A. Chen, and S. M. Kreidenweis, "Particulate-Phase and Gaseous Elemental Mercury Emissions during Biomass Combustion: Controlling Factors and Correlation with Particulate Matter Emissions," *Environmental Science and Technology 42* (2008): 721–727.

52. J. A. Perlinger, N. R. Urban, A. Giang, N. E. Selin, A. N. Hendricks, H. Zhang, A. Kumar, S. Wu, V. S. Gagnon, H. S. Gorman, and E. S. Norman, "Responses of Deposition and Bioaccumulation in the Great Lakes Region to Policy and Other Large-Scale Drivers of Mercury Emissions," *Environmental Science: Processes & Impacts* (2018), DOI: 10.1039/c7em00547d

53. M. D. Cohen, R. R. Draxler, R. S. Artz, P. Blanchard, M. S. Gustin, Y. Han, T. M. Holsen, D. A. Jaffe, P. Kelley, H. Lei, C. P. Loughner, W. T. Luke, S. N. Lyman, D. Niemi, J. M. Pacyna, M. Pilote, L. Poissant, D. Ratte, X. Ren, F. Steenhuisen, A. Steffen, R. Tordon, S. J. Wilson, "Modeling the Global Atmospheric Transport and Deposition of Mercury to the Great Lakes," *Elementa, Science of the Anthropocene 4* (2016):118, doi.org/10.12952/journal.elementa.000118

Notes

[54] Bergstrom, Amy; Cleary, Linda Miller; Peacock, Thomas D. The Seventh Generation: Native Students Speak about Finding the Good Path (Washington, DC: Office of Educational Research and Improvement, 2003).

[55] Lance Gunderson and Stephen S. Light, “Adaptive Management and Adaptive Governance in the Everglades Ecosystem,” *Policy Science 39* (2006): 323–334.

[56] U.S.-Canada, Great Lakes Water Quality Agreement (GLWQA) of 2012, Article 3(1)(a)(ii).

[57] U.S.-Canada, Great Lakes Water Quality Agreement (GLWQA) of 2012, Annex One and Annex Two.

[58] Velma I. Grover, Gail Krantzberg, eds., *Great Lakes: Lessons in Participatory Governance* (Boca Raton, FL: CRC Press, 2012).

[59] Great Lakes Information Network, “Remedial Actions Plans (RAPs) for the Great Lakes Areas of Concern,” 11/27/2017, www.great-lakes.net/envt/pollution/rap.html

[60] Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health, renewed Dec. 18 2014. For full text see, https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/publications/canada-ontario-agreement-great-lakes.html

[61] Paul Horvatin and Jacqueline Adams, “Partnering for Monitoring and Research across the Great Lakes: The Cooperative Science and Monitoring Initiative,” presentation, Chicago, IL: US EPA Great Lakes National Program Office, 2012.

[62] Lee Botts and Paul Robert Muldoon, *Evolution of the Great Lakes Water Quality Agreement* (East Lansing, MI: Michigan State University Press, 2005).

[63] J. Clarence Davies and Jan Mazurek, *Pollution Control in United States: Evaluating the System.* (Washington, DC: Resources for the Future, 1998).

[64] USEPA, “Clean Water Act Section 303(d): Impaired Waters and Total Maximum Daily Loads (TMDLs),” 11/27/2017, www.epa.gov/tmdl/program-overview-impaired-waters-and-tmdls

[65] A. Giang, L. C. Stokes, D. G. Streets, E. Corbitt, and N. E. Selin, “Impacts of the Minamata Convention on Mercury Emissions and Global Deposition from Coal Fired Power Generation in Asia,” *Environmental Science and Technology 49* (2015): 5326–5335.

[54] Bergstrom, Amy; Cleary, Linda Miller; Peacock, Thomas D. The Seventh Generation: Native Students Speak about Finding the Good Path (Wasington, DC: Office of Educational Research and Improvement, 2003).

[55] Lance Gunderson and Stephen S. Light, “Adaptive Management and Adaptive Governance in the Everglades Ecosystem,” *Policy Science 39* (2006): 323–334.

[56] U.S.-Canada, Great Lakes Water Quality Agreement (GLWQA) of 2012, Article 3(1)(a)(ii).

[57] U.S.-Canada, Great Lakes Water Quality Agreement (GLWQA) of 2012, Annex One and Annex Two.

[58] Velma I. Grover, Gail Krantzberg, eds., *Great Lakes: Lessons in Participatory Governance* (Boca Raton, FL: CRC Press, 2012).

[59] Great Lakes Information Network, “Remedial Actions Plans (RAPs) for the Great Lakes Areas of Concern,” 11/27/2017, www.great-lakes.net/envt/pollution/rap.html

[66] M. T. Bremigan, P. A. Soranno, M. J. Gonzalez, D. B. Bunnell, K. K. Arend, W. H. Renwick, R. A. Stein, and M.J. Vanni, “Hydrogeomorphic Features Mediate the Effects of Land Use/Cover on Reservoir Productivity and Food Webs,” *Limnology and Oceanography 53* (2008): 1420–1433.

P. A. Soranno, K. E. Webster, K. S. Cheruvelil, and M. T. Bremigan, “The Lake Landscape-Context Framework: Linking Aquatic Connections, Terrestrial Features and Human Effects at Multiple Spatial Scales,” *Verhandlungen IVL 30* (2009): 695–700.

[67] G. R. J. Khaniki, I. Alli, E. Nowroozi, and D. Nabizadeh, “Mercury Contamination in Fish and Public Health Aspects: A Review,” *Pakistan Journal of Nutrition 4* (2005): 276–281.

[68] P. Chakraborty, G. Zhang, J. Li, S. Selvaraj, K. Breivik, and K. Jones, “Soil Concentrations, Occurrence, Sources and Estimation of Air–Soil Exchange of Polychlorinated Biphenyls in Indian Cities,” *Science of the Total Environment 562* (2016): 928–934.