Biodiversity Research Institute

Center for Mercury Studies

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About Biodiversity Research Institute

Biodiversity Research Institute (BRI), headquartered in Portland, Maine, is a nonprofit ecological research group whose mission is to assess emerging threats to wildlife and ecosystems through collaborative research, and to use scientific findings to advance environmental awareness and inform decision makers. BRI supports ten research programs within three research centers including the Center for Mercury Studies.

Mercury Center Co-directors

David C. Evers, Ph.D., *BRI Founder, Executive Director, and Chief Scientist*
Since 1990, Dr. Evers has specialized in the investigation of mercury exposure and effects in fish and wildlife. He is the co-lead for UN Environment's Transport and Fate Partnership Advisory Group, has served as an international technical expert for the United Nations for over 30 countries since 2015, has served as a steering committee member of the International Conference on Mercury as a Global Pollutant (ICMGP) since 2009, and has published more than 100 peer-reviewed papers on the topic of mercury in the environment.

Celia Y. Chen, Ph.D., *BRI Adjunct Scientist*
Dr. Chen, an ecotoxicologist, is a research professor at Dartmouth College and the director of the Dartmouth Toxic Metals Superfund Research Program. Her work has focused on the fate and effects of metal contaminants in aquatic food webs. She has studied the bioavailability and bioaccumulation of mercury and other metals in benthic and pelagic invertebrates and trophic transfer to fish. She has conducted metal bioavailability studies using freshwater and estuarine crustaceans and fish, and has also investigated metal bioaccumulation and trophic transfer in field studies in lakes and estuaries in the Northeast United States. She has served on the steering committee of the ICMGP since 2013, and co-chaired the 13th ICMGP in 2017.

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Contents

BRI's Center for Mercury Studies

BRI is Engaged in Mercury Projects and Initiatives Around the World

BRI's Wildlife Mercury Lab

BRI operates two labs. One lab has a Direct Mercury Analyzer and is certified with a Biosafety Lab 2 status that permits international samples to be accepted without special treatment. The second lab contains a necropsy table and the ability to process samples. Tissues most commonly analyzed include egg, fish muscle, blood, feather, fur, and hair. Because > 95% of the mercury in these tissues is in the methyl form, BRI can analyze as total mercury, but interpret the data as methylmercury. BRI follows laboratory methods approved by the US Environmental Protection Agency (US EPA).

BRI's collaboration with IPEN and others has resulted in mercury analyses of human hair and/or fish sample from more than 74 countries (see pages 16-17).

Biodiversity Research Institute (BRI) is a leader in research designed to understand the risks of exposure to and the effects of mercury in ecosystems. Since its inception, BRI has focused on providing accurate and neutral science to help inform the development and implementation of policies related to reducing the impacts of mercury exposure on human health and the environment.

In 2011, we created the **Center for Mercury Studies** as a way to consolidate science and policy-related projects led and conducted by BRI scientists around the world. The Center is engaged in projects and initiatives that range from the global-scale monitoring of mercury in aquatic ecosystems to detailed monitoring of mercury exposure in single species and at-risk populations.

These programs fall into three major categories: global initiatives, global mercury monitoring, and North American and Caribbean Region mercury assessments.

BRI United Nations Initiatives

Mercury is a pollutant of global importance, affecting ecosystems and human populations around the world. The Minamata Convention on Mercury (see page 6) draws worldwide attention to the risks of mercury exposure. BRI is involved in several projects supporting the ratification and implementation of the Convention that include innovative ways to share global-scale data on mercury in the environment.

Global Mercury Monitoring

BRI's scientists have extensive experience monitoring the exposure and effects of mercury in fish and wildlife. This experience is broad across taxa, geographic areas, and time, ranging from assessing mercury in fish-eating birds in northeastern North America over the past 25 years to discovering elevated mercury exposure in insect-eating bats in the Amazon Basin. These projects provide insight into long-term patterns in the transport and fate of mercury in the environment.

North American and Caribbean Region Mercury Assessments

BRI collaborates with local, state, and national governmental agencies in North America and the Caribbean Region to synthesize disparate mercury data and quantify "injury" related to mercury exposure in fish and wildlife.

These projects focus on providing information to decision makers in an effective manner and often include the coordination of multiple teams of researchers. Results from these assessments are published in peer-reviewed literature and also translated into booklets and pamphlets that summarize the findings.

BRI Science Communications

BRI has developed an effective approach for disseminating scientific findings to policymakers, resource managers, and other stakeholders. Our communications pieces summarize available science and are used in governmental agency briefings, by the media, and by the general public (see page 34).

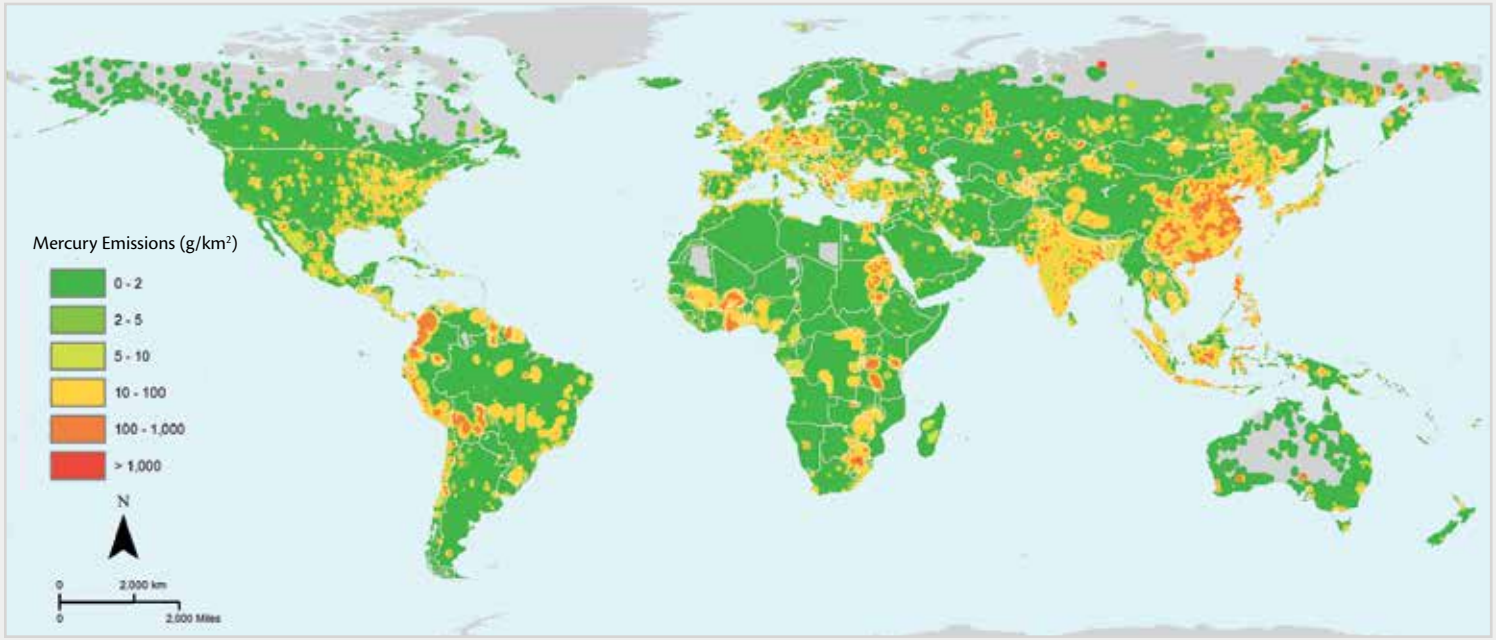


Figure 1. Distribution of Global Anthropogenic Mercury Emissions (Data Source: UN Environment's 2013 Global Mercury Assessment)

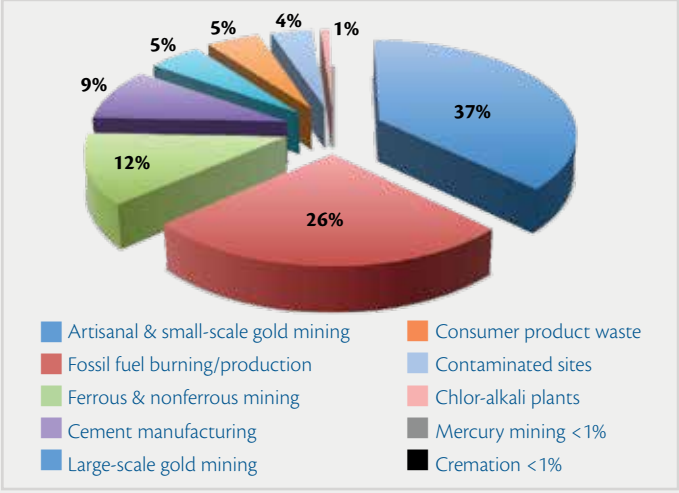


Figure 2. Global Anthropogenic Mercury Emissions by Sector (Data Source: UN Environment's 2013 Global Mercury Assessment)

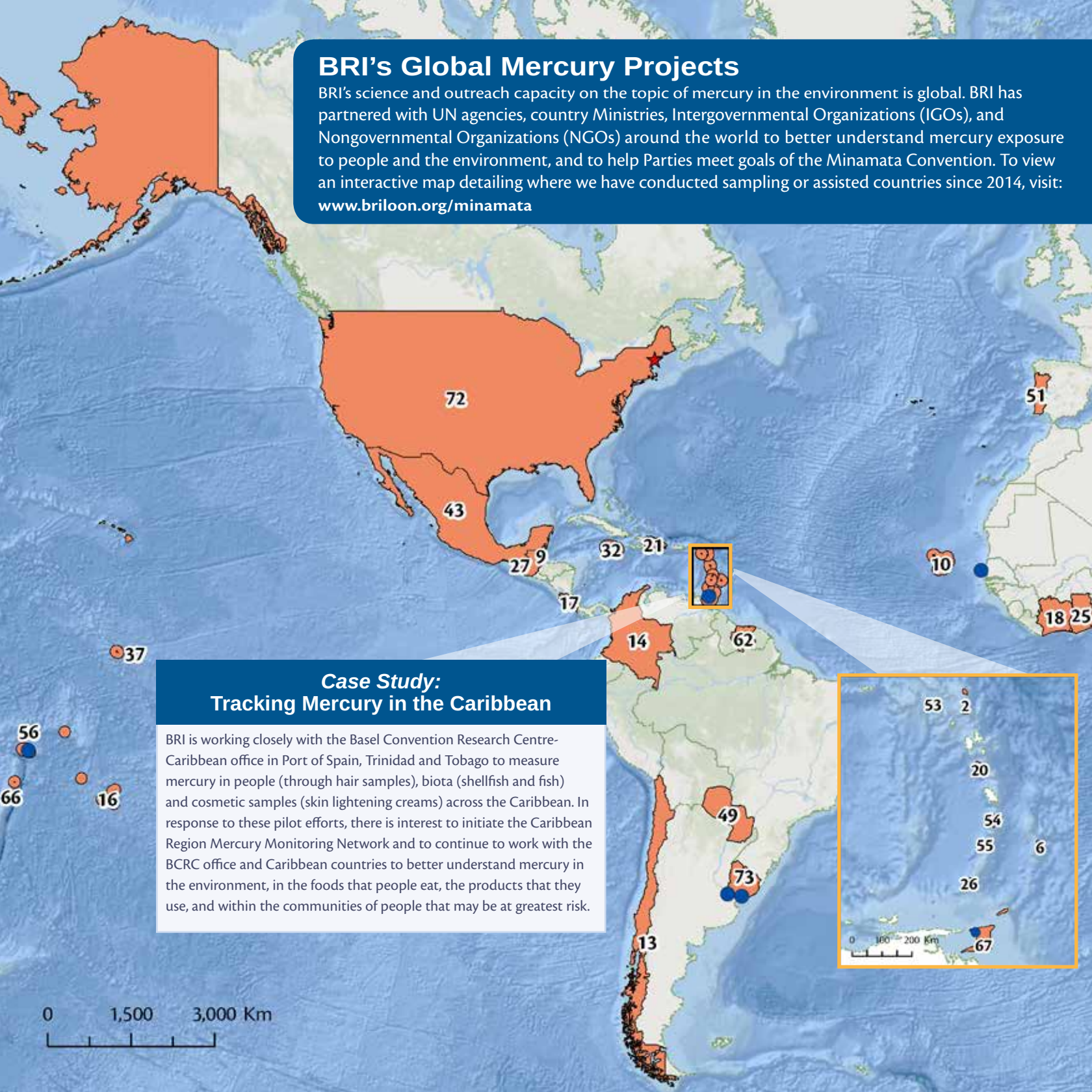
Mercury in the Global Environment

Mercury concentrations in the global environment have increased almost three-fold as a result of human activities. While industrial emissions have declined in North America and Europe during the past two decades, emissions have increased in other regions, including northern South America, India, and East Asia (Figure 1).

Fossil fuel combustion has long been considered the primary source of mercury emissions into the atmosphere. However, the rapid expansion of artisanal and small-scale gold mining (ASGM) in many countries has made this sector the largest single source of mercury emissions in the world—representing approximately 37 percent of all global emissions (Figure 2). Other sectors, including ferrous and nonferrous mineral smelting and cement manufacturing, can be locally and regionally significant. In addition, legacy effects related to contaminated sites and chlor-alkali facilities are also locally important sources of mercury emissions.

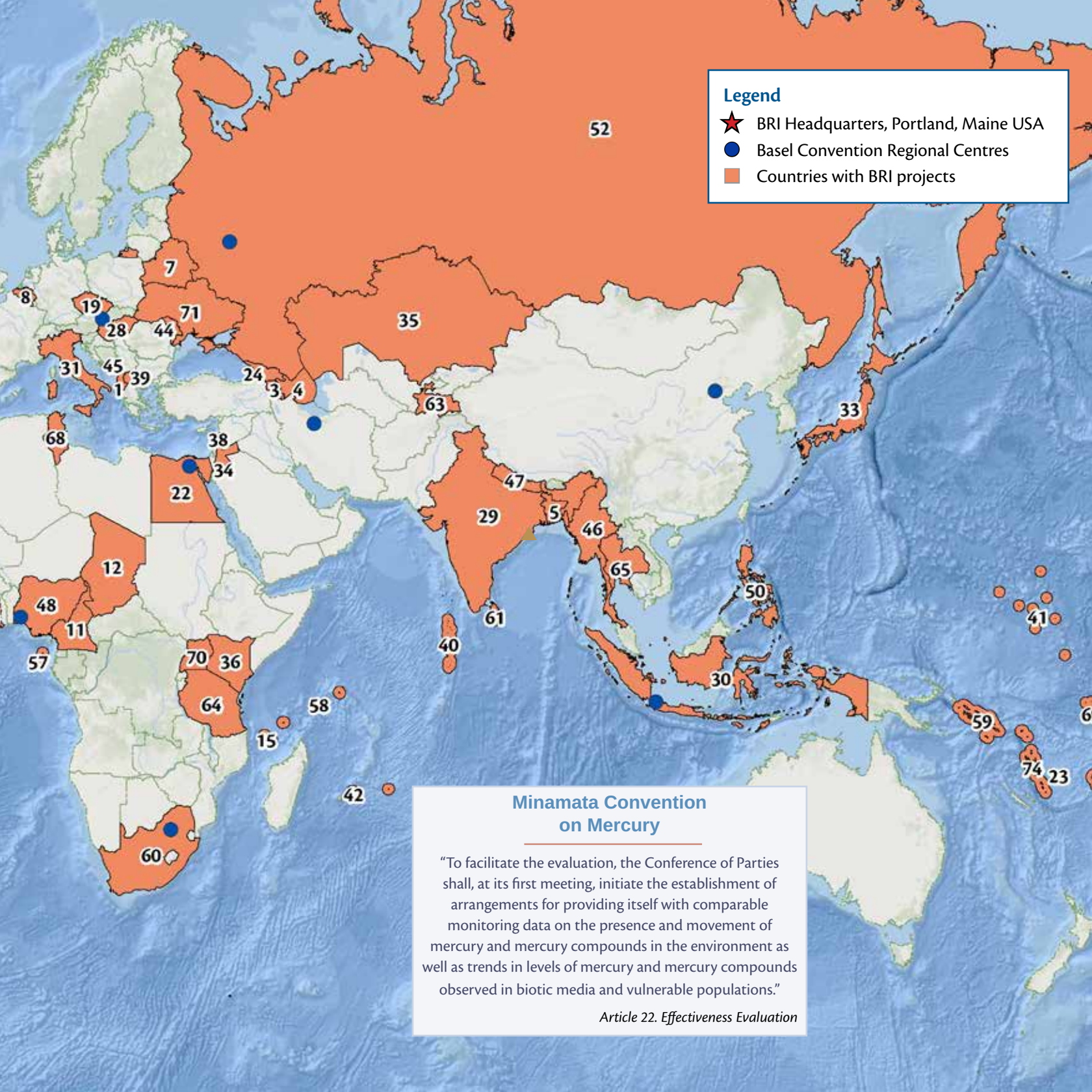
BRI's Global Mercury Projects

BRI's science and outreach capacity on the topic of mercury in the environment is global. BRI has partnered with UN agencies, country Ministries, Intergovernmental Organizations (IGOs), and Nongovernmental Organizations (NGOs) around the world to better understand mercury exposure to people and the environment, and to help Parties meet goals of the Minamata Convention. To view an interactive map detailing where we have conducted sampling or assisted countries since 2014, visit: **www.briloon.org/minamata**



Case Study: Tracking Mercury in the Caribbean

BRI is working closely with the Basel Convention Research Centre-Caribbean office in Port of Spain, Trinidad and Tobago to measure mercury in people (through hair samples), biota (shellfish and fish) and cosmetic samples (skin lightening creams) across the Caribbean. In response to these pilot efforts, there is interest to initiate the Caribbean Region Mercury Monitoring Network and to continue to work with the BCRC office and Caribbean countries to better understand mercury in the environment, in the foods that people eat, the products that they use, and within the communities of people that may be at greatest risk.



Minamata Convention on Mercury

"To facilitate the evaluation, the Conference of Parties shall, at its first meeting, initiate the establishment of arrangements for providing itself with comparable monitoring data on the presence and movement of mercury and mercury compounds in the environment as well as trends in levels of mercury and mercury compounds observed in biotic media and vulnerable populations."

Article 22. Effectiveness Evaluation

Minamata Convention on Mercury

Linking Mercury Science with Policy

The Minamata Convention on Mercury, opened for signature in October 2013, is a global agreement specifically designed to address contamination from a heavy metal. The Convention also becomes the first major global environmental treaty since the Kyoto Protocol came into force in 2005.

The Minamata Convention seeks to address issues related to the use and release of mercury including trade, industrial uses, and major sources of atmospheric emissions and releases of mercury into the environment, as well as long-term storage and disposal of mercury and mercury compounds.

BRI's Scientific Research Informs International Policy

As experts in the field of mercury science, BRI researchers were invited by U. government officials to participate as an NGO during the negotiation process of the Minamata Convention.

The meetings of the Intergovernmental Negotiating Committee (INC) that preceded the adoption of the Convention included delegates from more than 140 countries and numerous NGOs interested in reducing mercury pollution. BRI participated in the last six meetings of the INC and is now participating in the Conference of Parties (COP).

BRI currently serves as co-lead of UN Environment's Mercury Air Transport and Fate Research partnership area. As a co-lead, BRI is assisting with the development of a globally coordinated mercury monitoring and observation system and with the synthesis of the mercury inventories of the Minamata Initial Assessments (MIA). BRI is also a partner organization in the ASGM partnership area (see page 14 for more details).

More than 100 countries have ratified the Convention.

Helping Countries Prepare for Ratification

In addition to participating in the INC/COP process as an active member in the partnership areas, BRI currently serves in several capacities to assist countries with developing strategies for ratifying and ultimately implementing the Convention. See page 8 for more details.

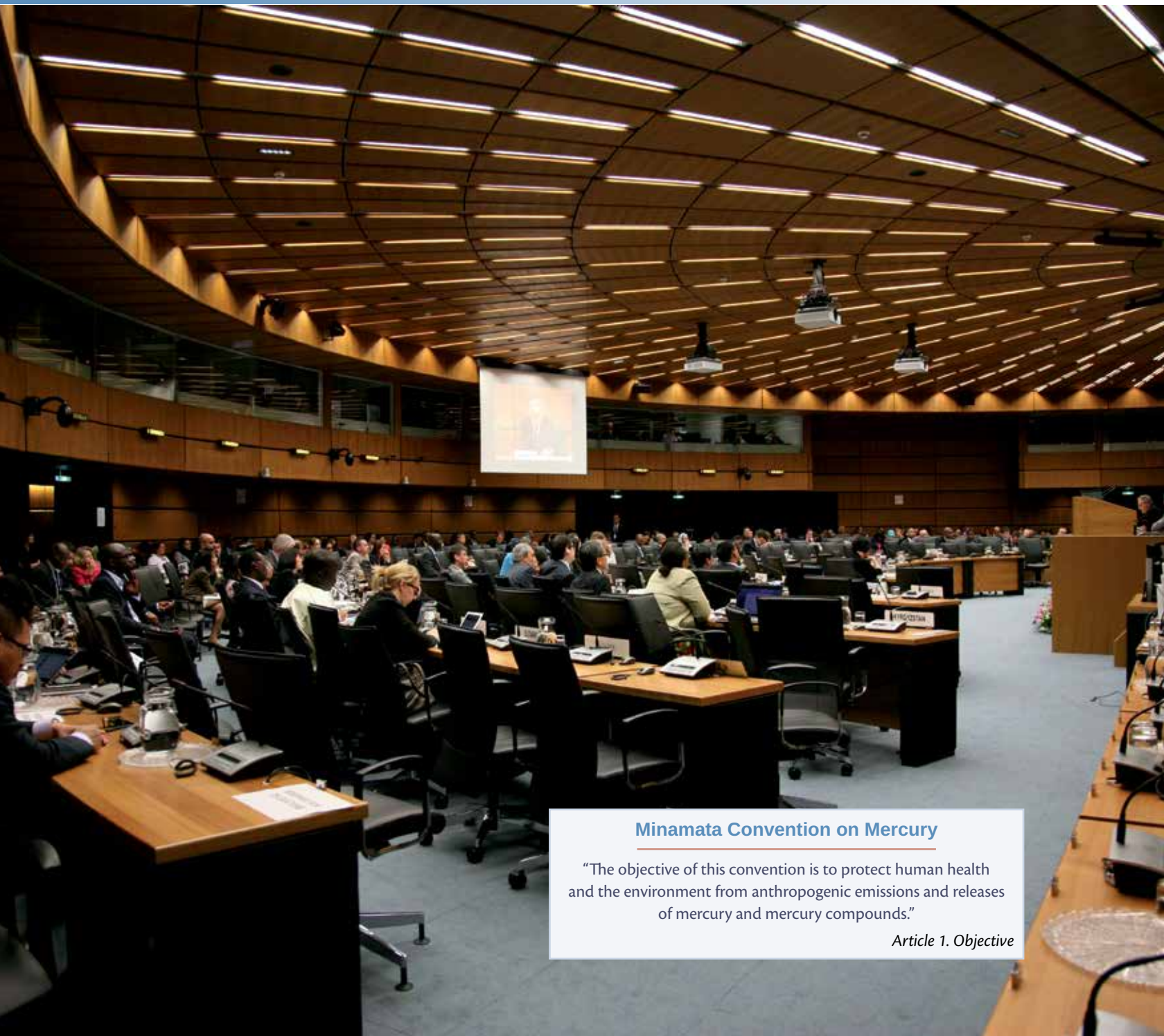
International Conference on Mercury as a Global Pollutant

The International Conference on Mercury as a Global Pollutant (ICMGP) provides a venue for mercury scientists and policymakers to present and exchange information. Topics range from remediation strategies in contaminated sites to the biogeochemistry of mercury and new policy interventions designed to reduce the risks of mercury pollution.

BRI scientists have been members of the ICMGP steering committee for meetings held in:

- Halifax, Nova Scotia, Canada (2011)
- Edinburgh, Scotland (2013)
- Jeju, Korea (2015)
- Providence, Rhode Island, USA (2107)

BRI is a member of the steering and host committees for the 2019 ICMGP (to be held in Kraków, Poland).



Minamata Convention on Mercury

"The objective of this convention is to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds."

Article 1. Objective

Minamata Convention Initial Assessments

Helping Countries Prepare for Ratification and Implementation of the Minamata Convention

Under the Convention, individual countries are charged with protecting human health and the environment from the risks of mercury exposure by systematically controlling mercury emissions and releases, including phasing out the use of mercury in certain products and processes.

The INC and the Global Environmental Facility have developed a series of preratification activities, called Minamata Convention Initial Assessments (MIAs), that are designed to prepare countries for ratification and implementation of the Convention.These activities focus on three primary steps:

1. Establishment of a national steering committee to coordinate activities related to the Convention;
2. Review and identification of gaps in existing national legislation related to mercury; and
3. Development of a national mercury profile that includes major sectors that use mercury as well as a summary of major emission and release source types.

In addition, MIAs assist countries with the development of communications tools and strategies for informing governmental agencies, NGOs, and the general public on activities related to the Convention.

BRI's Collaboration with UN Agencies

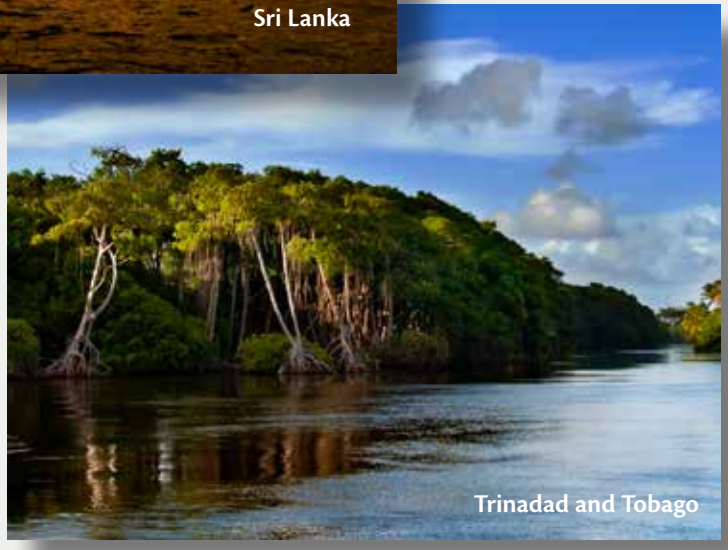
BRI serves as an Executing Agency for the United Nations Industrial Development Organization (UNIDO), and as an International Technical Expert for UN Environment and the United Nations Development Programme (UNDP) to lead or help complete MIAs for more than 30 countries (17 of which are now complete).

Partnering with BCRC-Caribbean

BRI is now closely partnering with the Basal Convention Regional Centre–Caribbean office in Port-of-Spain, Trinidad and Tobago, West Indies. BCRC-Caribbean and BRI are working together on MIA projects for nine Caribbean countries and monitoring mercury in people, fish, and cosmetics, and mapping biological mercury hotspots in the region.

BASEL CONVENTION

Concentrations of mercury in the global environment have increased nearly three-fold due to human activities especially from releases of mercury into the air and water from coal-fired power plants, chlor-alkali facilities, and ASGM activities.



BRI Global Mercury Projects

BRI has partnered with UN agencies, country ministries, IGOs and NGOs around the world (n=74 countries; examples shown here) to better understand mercury exposure to people and the environment, and to help Parties meet goals of the Minamata Convention. To view an interactive map detailing where we have conducted sampling or assisted countries since 2014, visit:

www.briloon.org/minamata

UNE Mercury Air Transport and Fate Resear

Evaluating the Effectiveness (EE) of the Minamata Convention

GLOBAL MERCURY PARTNERSHIP

As a member of UN Environment's Mercury Air Transport and Fate Research Partnership Area, BRI is a also a member of the EE ad hoc group to develop methodologies for evaluating the effectiveness of the Minamata Convention. This group is working to provide a platform to help countries monitor mercury in air, biota, and people, based on recent meetings in Rome, Italy, Ottawa, Canada, and Geneva, Switzerland.

BRI is Developing a Regional Pilot Project to Monitor Mercury

BRI is partnering with several countries, the BCRC-Caribbean office and UN Environment to develop the Caribbean Region Mercury Monitoring Network (CRMMN). Pilot efforts to date have included collaboration with 14 Caribbean countries to design projects that collect, analyze, and interpret mercury exposure in people and the shellfish and fish they eat as well as the cosmetics they use.

Additionally, to help understand how contaminated sites and ecosystem sensitivity contribute to methylmercury availability to biota in their countries, researchers are mapping biological mercury hotspots.

For more information on the mercury monitoring work BRI is doing around the globe, visit:

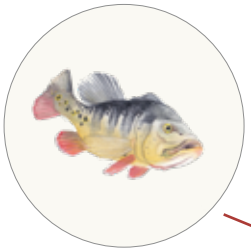
www.briloon.org/minamata

Minamata Convention on Mercury

"Modeling and geographically representative monitoring of levels of mercury and mercury compounds in vulnerable populations and in environmental media, including biotic media such as fish, marine mamals, sea turtles and birds, as well as collaboration in the collection and exchange of relevant and appropriate samples."

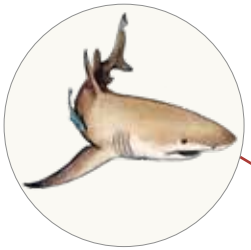
Article 19. Research, Development and Monitoring

Ecosystem Type: Oxbow Ponds
Bioindicator: Fishing Bat



Ecosystem Type: River
Bioindicator: Peacock Bass

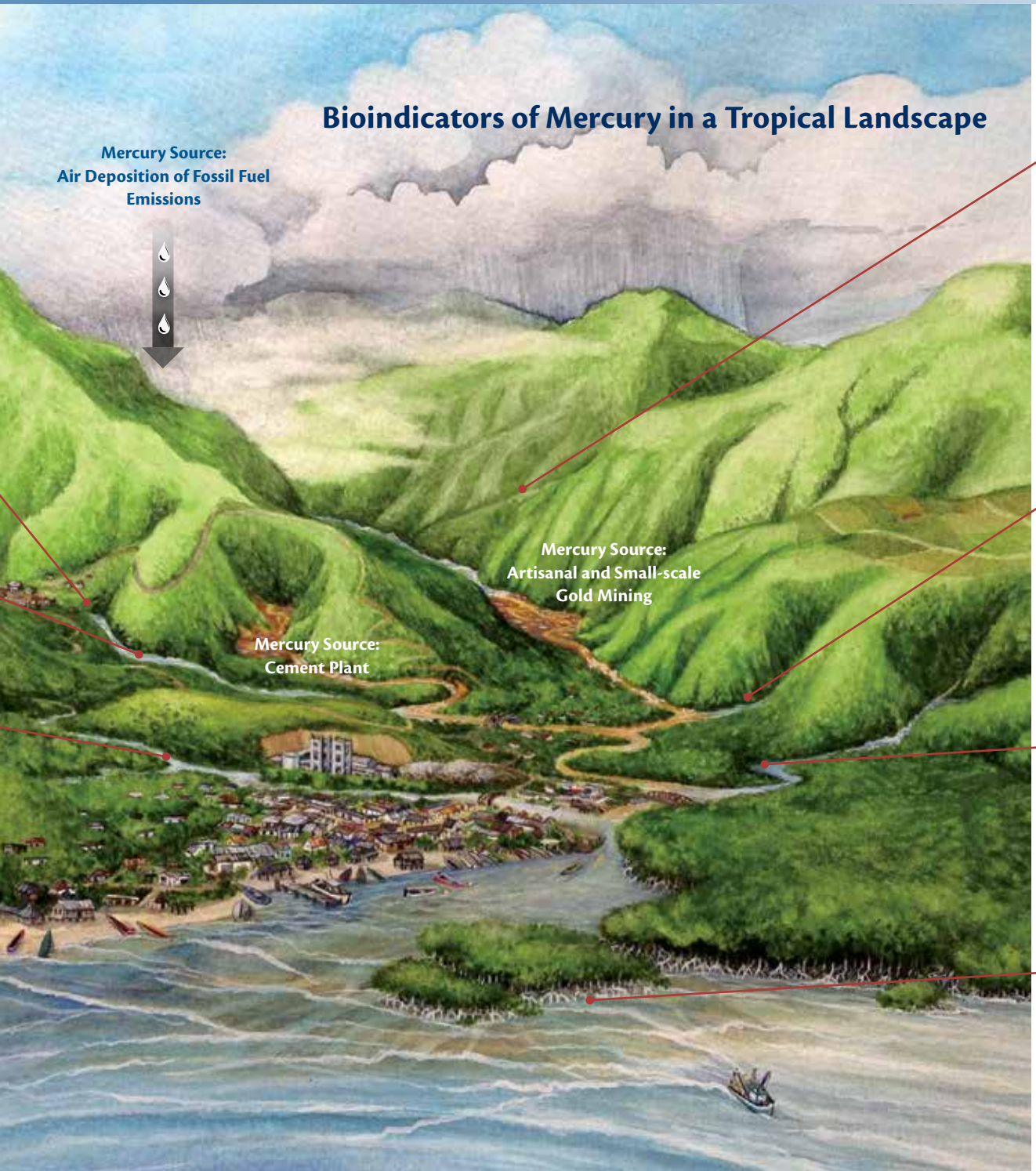
Ecosystem Type: River
Bioindicator: Giant River Turtle



Ecosystem Type: Coral Reef and Open Ocean
Bioindicator: Lemon Shark

ch Partnership Area: EE Ad Hoc Group

Bioindicators of Mercury in a Tropical Landscape



Ecosystem Type: Mountain Forest
Bioindicator: Olive-sided Flycatcher

Ecosystem Type: River Tributaries
Bioindicator: Ringed Kingfisher

Ecosystem Type: Lowland River
Bioindicator: Giant River Otter

Ecosystem Type: Mangroves and Coral Reef
Bioindicator: Goliath Grouper

UNE Mercury Air Transport and Fate Resear

Developing a Mercury Platform for the World to Use

GLOBAL MERCURY PARTNERSHIP

Communicating information on the risks and impacts of mercury in the environment is an important aspect of information exchange under Article 17 of the Convention.

Since 2013, BRI has collated biotic mercury data from peer-reviewed publications and governmental reports into one database—the **Global Biotic Mercury Synthesis** (GBMS).

GBMS data are standardized; derived from peer-reviewed published accounts, they have undergone a level of quality control and quality assurance.

In response to the need for countries to utilize such data, UN Environment's Regional Office of North America funded BRI to further expand the GBMS database to potentially prepare it for use on a searchable website.

Access to these data will help countries better understand the spatial patterns and gaps in knowledge of biotic mercury concentrations around the world.

Global Health Trade-off for Mercury and Omega-3 in Seafood

Milligrams of Omega-3 Fatty Acids/4 Ounces of Cooked Fish →

Total Mercury in Muscle Tissue µg/g (ww) ↓

Meal Frequency Recommendations[1]	<500 mg	500-1,000 mg	1,000-2,000 mg	> 2,000 mg
Unrestricted meals (< 0.05 µg/g)	Catfish (temperate waters), Clams, Crab* (most species), Croaker, Haddock, Scallops, Shrimp, Tilapia*	Blue Mussels,* Pink Salmon, Sockeye Salmon	Coho Salmon, Oysters	Sardines, Shad
1-2 meals per week (0.05–0.22 µg/g)	Atlantic and Pacific Cod, Grenadier, Hake, Lobster,* Scad, Snapper, Sole	Atlantic Pollock, Mahi Mahi, Mullet, Squid, Skipjack Tuna, (light canned tuna)	Atlantic Horse Mackerel, Atlantic and Pacific Mackerel, Chinook Salmon,* European Sea Bass, Rays, Skates, Trout	Anchovies,* Atlantic Salmon, Herring
1 meal per month (0.22–0.95 µg/g)	Catfish (tropical waters) Flounder, Grouper, Orange Roughy, Seabream	Amberjack, Barracuda, Big-eye Tuna, Bluefish, Halibut, Jack, Tilefish, Trevally, Yellowfin Tuna, Wahoo (white canned tuna[2])	Albacore Tuna,* Atlantic Bluefin Tuna, Chilean Sea Bass (white canned tuna[2])	Mercury concentrations vary widely across shark species. To learn more, visit: www.briloon.org/hgcenter
No consumption (> 0.95 µg/g)	King Mackerel	Marlin, Sailfish	Dogfish, Ground, and Mackerel Sharks; Pacific Bluefin Tuna, Swordfish*	

Healthier Choices

Riskier Choices

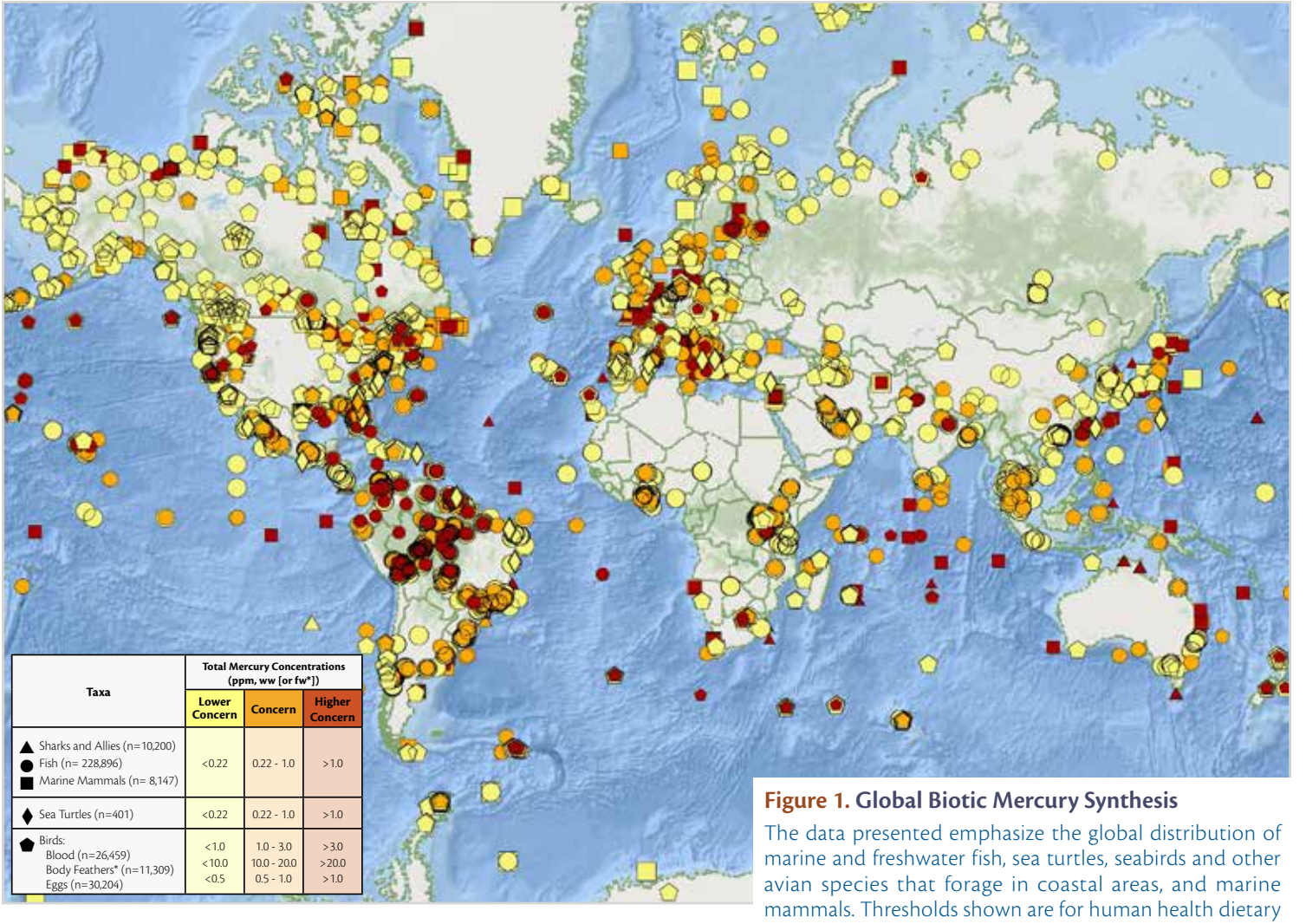
Data Sources: BRI's GBMS Database; U.S. Environmental Protection Agency; U.S. Food and Drug Administration, University of Maryland Medical Center website

[1] Based on human health guidelines from US Great Lakes Advisory Council, European Commission and World Health Organization

[2] white canned tuna can be albacore or yellowfin

* Species that are pictured

ch Partnership Area: GBMS



Taxa	Total Mercury Concentrations (ppm, ww [or fw*])		
	Lower Concern	Concern	Higher Concern
▲ Sharks and Allies (n=10,200) ● Fish (n= 228,896) ■ Marine Mammals (n= 8,147)	<0.22	0.22 - 1.0	>1.0
♦ Sea Turtles (n=401)	<0.22	0.22 - 1.0	>1.0
⬟ Birds: Blood (n=26,459) Body Feathers* (n=11,309) Eggs (n=30,204)	<1.0 <10.0 <0.5	1.0 - 3.0 10.0 - 20.0 0.5 - 1.0	>3.0 >20.0 >1.0

Figure 1. Global Biotic Mercury Synthesis

The data presented emphasize the global distribution of marine and freshwater fish, sea turtles, seabirds and other avian species that forage in coastal areas, and marine mammals. Thresholds shown are for human health dietary purposes, except for birds which reflect reproductive harm. Data are presented in parts per million (ppm) on a wet weight (ww) or fresh weight (fw) basis.

Minamata Convention on Mercury

"Each party shall facilitate exchange of...information from intergovernmental and nongovernmental organizations with expertise in the area of mercury, and from national and international institutions with such expertise."

Article 17. Information Exchange

Learn more in *Mercury in the Global Environment: Patterns of Global Seafood Concentrations and their Relationship with Human Health and the Environment*

UNE Artisanal and Small-scale Gold Mining P

Working to Create a Sustainable Artisanal and Small-scale Gold Mining Sector

Artisanal and small-scale gold mining (ASGM) is the single largest anthropogenic source of mercury. Reducing mercury use within this sector requires a multidisciplinary approach to address technical, social, economic, and ecological issues.

BRI's International Partnerships

As a member of the UN Environment's ASGM partnership area, BRI collaborates with multiple agencies and organizations to reduce and, where possible, eliminate the use of mercury in the ASGM sector. These projects, conducted on local and global levels, include:

Development of Miner Training Resources for Peru, Columbia, and Ecuador
Funding Agency: US Department of State (2015-2017)
Collaborator: Artisanal Gold Council

Training modules for small-scale miners introduce appropriate technologies to improve efficiency, increase gold recovery, and reduce reliance on mercury.

Integrated Assessment of ASGM in Ghana
Funding Agency: University of Michigan (2015-2016)
Collaborators: McGill University, Ghanaian governmental ministries

The integrated assessment identifies policy-relevant solutions that will encourage economic development in the ASGM sector without compromising environmental and human health.

National Action Plan Guidance for Countries with ASGM
Funding Agency: US Environmental Protection Agency (2014-2015)
Collaborators: Natural Resources Defense Council, Artisanal Gold Council, BanToxics

Under the Minamata Convention, countries with significant ASGM activities in their territories must develop a National Action Plan. BRI continues to work with teams of experts in mining and policy development to provide recommendations for ASGM activities that reflect requirements under the Convention.

Reducing Mercury Supply and Availability in Indonesia (2018-2022)

Funding Agency: US Department of State

Collaborators: BaliFokus, IPEN, Global Initiative against Transnational Organized Crime

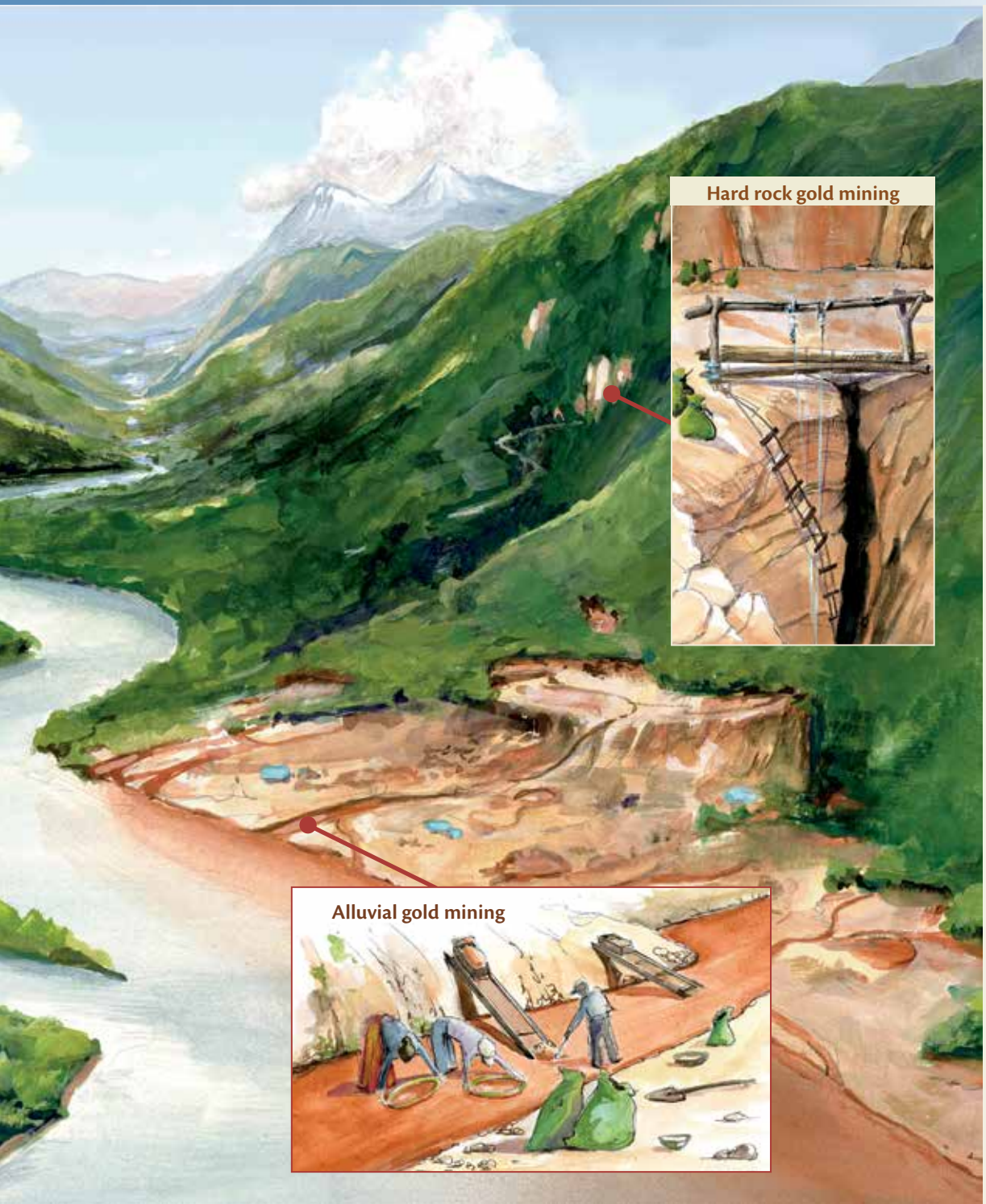
The purpose of this project is to support the government of Indonesia in restricting mercury supplies, especially for the ASGM sector, through amending the draft National Implementation Plan, and by securely storing confiscated mercury, mercury by-products, and recovered mercury from the oil and gas (OG) sector at the local level. This includes (1) legal/regulatory/policy action to restrict mercury supplies from primary mining and mercury by-products from OG; (2) developing and piloting Local Action Plans to reduce and eliminate mercury in ASGM, that include safe handling, interim or temporary storage, and long-term storage of mercury and cinnabar ore to demobilize them/prevent them from being recirculated to the market; and (3) monitoring implementation of both actions.

Minamata Convention on Mercury

"Each party that has aristanal and small-scale gold mining and processing…within its territory shall take steps to reduce, and where feasible eliminate, the use of mercury and mercury compounds in, and the emissions and releases to the environment of mercury from, such mining and processing."

Article 7. Artisanal and Small-scale Gold Mining

artnership Area



Under Annex C of the Minamata Convention, several ASGM practices are considered "actions to eliminate" including whole ore amalgamation and open burning of amalgam.

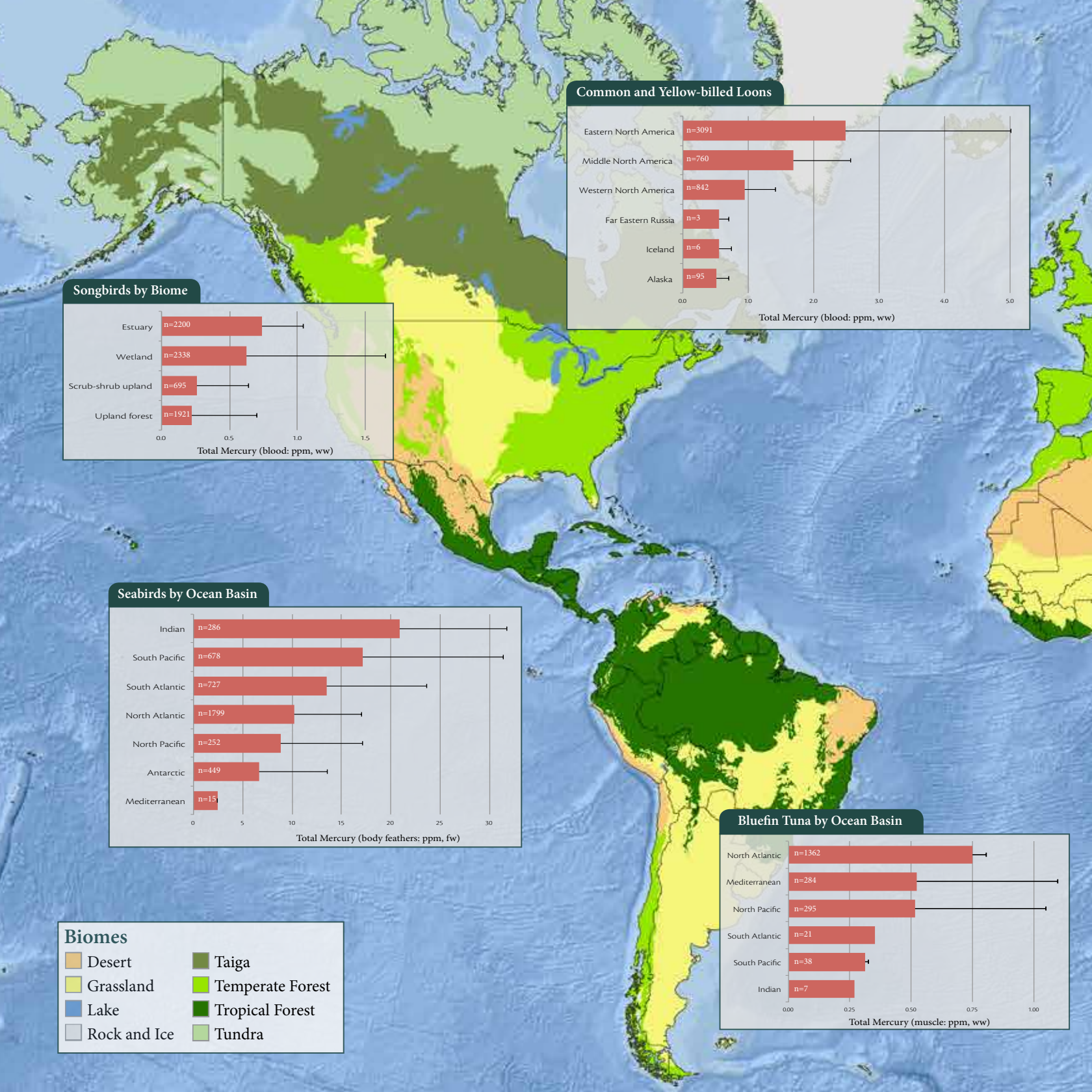
Whole Ore Amalgamation

Mercury is added to the entire ore, without any previous steps to concentrate the gold from the rest of the ore.

Mercury use is high and inefficient, often resulting in large amounts of mercury being lost to the mine tailings.

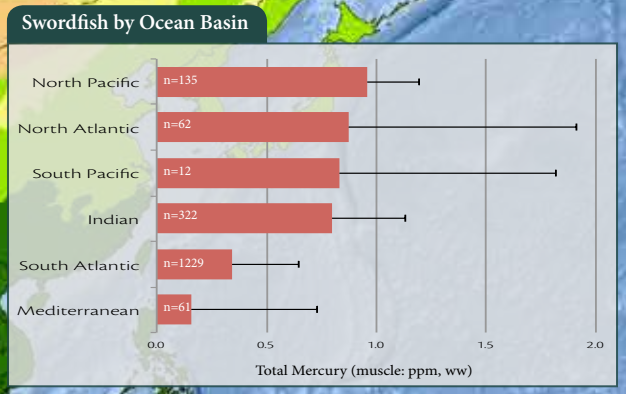
Open Burning of Amalgam

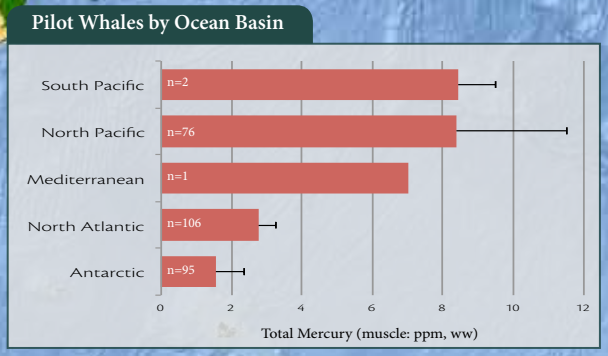
Mercury and gold form an amalgam, which is heated to evaporate the mercury. Mercury vapor released from the burning is highly toxic, impacting miners and people living in adjacent communities.


Common and Yellow-billed Loons
Eastern North America
n=3091
Middle North America
n=760
Western North America
n=842
Far Eastern Russia
n=3
Iceland
n=6
Alaska
n=95
0.0
1.0
2.0
3.0
4.0
5.0
Total Mercury (blood: ppm, ww)
Songbirds by Biome
Estuary
n=2200
Wetland
n=2338
Scrub-shrub upland
n=695
Upland forest
n=1921
0.0
0.5
1.0
1.5
Total Mercury (blood: ppm, ww)
Seabirds by Ocean Basin
Indian
n=286
South Pacific
n=678
South Atlantic
n=727
North Atlantic
n=1799
North Pacific
n=252
Antarctic
n=449
Mediterranean
n=15
0
5
10
15
20
25
30
Total Mercury (body feathers: ppm, fw)
Bluefin Tuna by Ocean Basin
North Atlantic
n=1362
Mediterranean
n=284
North Pacific
n=295
South Atlantic
n=21
South Pacific
n=38
Indian
n=7
0.00
0.25
0.50
0.75
1.00
Total Mercury (muscle: ppm, ww)
Biomes
Desert
Grassland
Lake
Rock and Ice
Taiga
Temperate Forest
Tropical Forest
Tundra

Global Mercury Monitoring

Long-term monitoring of mercury in biota provides an understanding of meaningful spatial and temporal changes. Fish and wildlife at upper trophic levels are the best bioindicators for measuring the exposure and potential risk to biota and human across the world's ecosystems. For nearly 30 years, BRI field sampling efforts have yielded > 50,000 mercury data points from around the world (more than 70 countries). BRI has identified key taxa for monitoring the exposure and effects of mercury in fish, birds, and mammals.





Monitoring Mercury in People

A Primary Goal of the Minamata Convetion is to Protect Human Health

At the top of the global food web, humans are subject to a substantial risk due to the presence of methylmercury in aquatic ecosystems.

Methylmercury is a potent neurotoxin that has been associated with harmful effects such as impaired motor function and vision, unhealthy fetal development, and learning disabilities. Acute methylmercury poisoning is often referred to as Minamata disease, named after a tragic contamination event in Minamata Bay, Japan.

The primary goal of the Minamata Convention on Mercury is to protect human health and the environment from anthropogenic sources of mercury contamination.

Communities Most at Risk

Communities such as the Inuit of North America and the Faroese are often viewed to be at risk because they subsist on marine mammal species, such as toothed whales, that tend to have elevated methylmercury concentrations.

Fishing communities from Small Island Developing States and coastal communities that rely on top trophic-level fish species that include barracuda, tuna, sharks, and swordfish are also at risk of accumulating potentially harmful levels of methylmercury.

BRI-IPEN Studies: Mercury Monitoring in Women of Childbearing Age

BRI and the global NGO network IPEN have collaborated to conduct several global mercury studies in response to strong public interest and governmental negotiation of the Minamata Convention. The partnership between IPEN and BRI provides a rare opportunity to compile new and standardized mercury concentrations on a global basis that reflect the potential impacts of mercury on human populations around the world. Two studies in this collaboration focused on monitoring mercury in women of childbearing age across the globe:

Mercury in Women of Childbearing Age in 25 Countries (2017), measured the prevalence of mercury body burden at levels that can cause neurological and organ damage. Mercury in a mother's body can be transferred to her fetus during pregnancy, exposing the developing fetus to the potent neurotoxin. The study, the first of its kind to collect samples from as many countries or regions and to spotlight women of childbearing age, found significantly elevated mercury concentrations in the hair of women in numerous regions of the world related to three predominant causes of mercury pollution: coal-fired power plants; artisanal small-scale gold mining; and local contaminated sites from various industries releasing mercury to soil, water, and air.

Mercury Monitoring in Women of Childbearing Age in the Asia and the Pacific Region (2017), a study supported by UN Environment and jointly conducted by BRI and IPEN, reveals that women of childbearing age living in four Pacific Island countries (Cook Islands, Marshall Islands, Tuvalu, and Kirbati) have elevated levels of mercury in their bodies.

The study found 96 percent of the women sampled contained significantly elevated hair mercury levels. The participants may have a higher mercury body burden than other locations due to their relatively high consumption of predatory fish species shown to have elevated mercury concentrations in previous studies.

For more information, visit:
www.briloon.org/mercuryinhumans

Fish and Wildlife as Bioindicators of Mercury

Understanding the Threat of Environmental Mercury Loads Requires Biotic Sampling

Identifying appropriate bioindicators is a critical first step in long-term mercury monitoring. Fish and wildlife provide important information on the environmental impacts of mercury pollution and potential risks related to human health.

Some ecosystems are considered more sensitive to mercury inputs than others. In particular, freshwater and coastal wetlands can have elevated biotic mercury concentrations because of unique chemical and physical characteristics. Conversely, in less sensitive ecosystems such as upland areas, heavy inputs of mercury may create little to no significant health threats.

Under Article 19 of the Minamata Convention, organisms that should be monitored include "fish, sea turtles, birds, and marine mammals."

Fish are one of the best bioindicators of environmental mercury loads. Young fish (<1 year) can reflect rapid changes, while long-lived fish and those that are at high trophic levels are of particular concern. Fish species commonly found with elevated mercury body burdens include bass, pike, and walleye in lakes, and tuna, mackerel, billfish, and sharks in the ocean.

In terrestrial ecosystems, birds are accessible and effective bioindicators of mercury pollution. Birds are also of high interest to the general public and can help highlight environmental concerns.

High trophic birds (i.e., predators) are generally at greatest risk. This includes fish-eaters and species foraging within extended invertebrate food webs (e.g., those that include spiders). Fish-eating birds commonly found with elevated mercury body burdens include loons, seabirds, eagles, and herons. Invertebrate-eaters (invertivores) such as rails, shorebirds, and some songbirds are excellent bioindicators.

Mammals can represent both aquatic and terrestrial ecosystems. Some groups are highly relevant for human health purposes (e.g., toothed whales), while others are relevant indicators of ecological integrity, such as fish-eaters (e.g., otters) or invertebrate-eaters (e.g., bats).

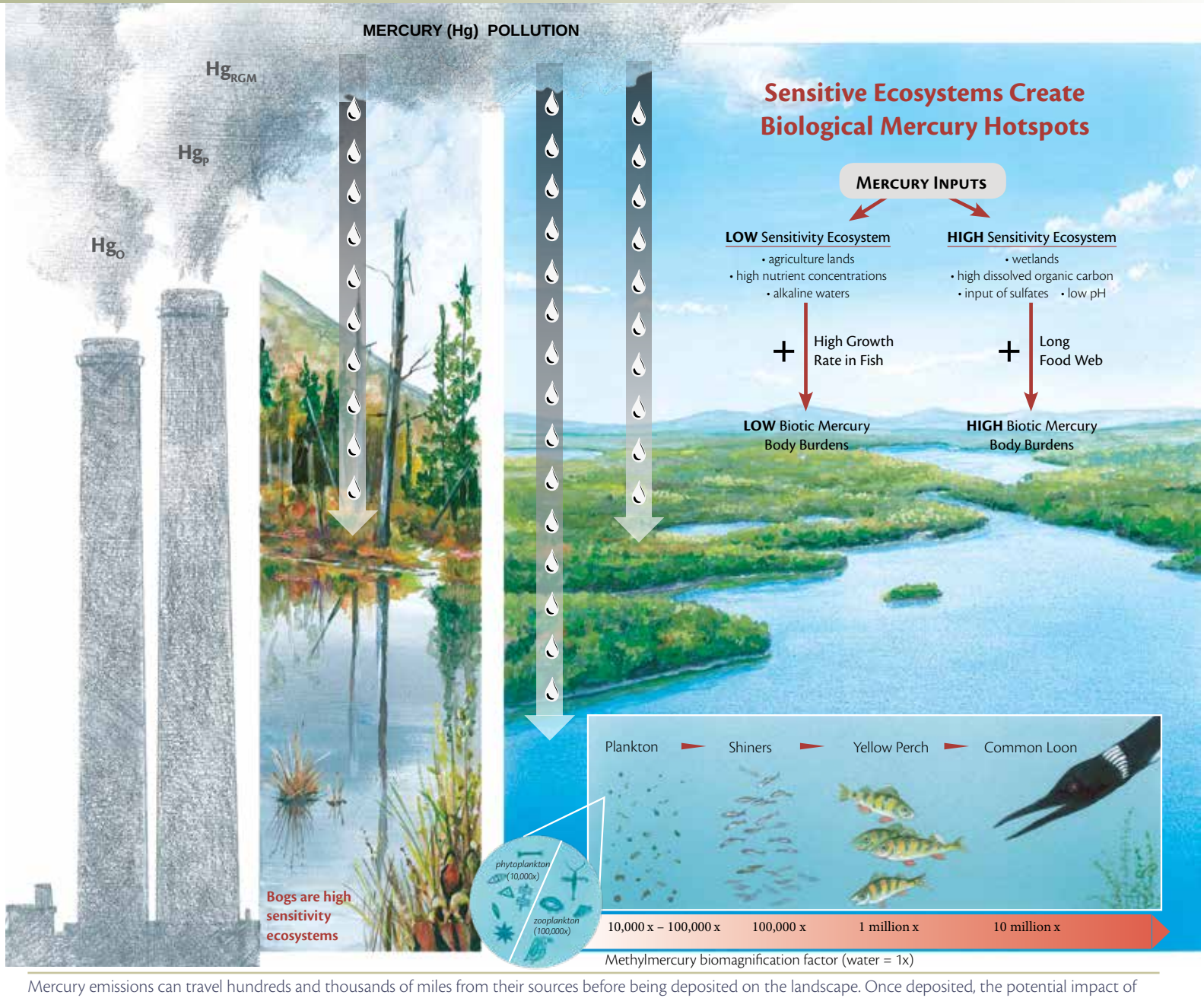
Identifying Biological Mercury Hotspots

Mapping mercury emissions and deposition only partly explains the spatial story of mercury pollution. Elemental mercury is converted to a more toxic and persistent organic form through the process of methylation, which occurs with the help of bacteria found primarily in wet areas.

Larger variations in methylmercury concentrations may happen in the food web depending on the sensitivity of the habitat to mercury input. Where methylmercury availability is elevated, biota such as fish and wildlife may have harmful mercury concentrations.

Such areas are called biological mercury hotspots; they represent the places that will require the most attention by countries and global monitoring programs. These hotspots are especially key if they represent important sources of food for people or if they contain threatened and endangered species. A pilot study in the Caribbean Region is identifying such hotspots for nine countries.

Bald Eagles are well known fish-eaters across North America.



Mercury emissions can travel hundreds and thousands of miles from their sources before being deposited on the landscape. Once deposited, the potential impact of mercury on the environment depends largely on ecosystem sensitivity. Understanding which ecosystems are most susceptible and also which organisms can serve as appropriate bioindicators is a critical component of effective mercury monitoring.

Monitoring Mercury in Freshwater and Marine

Monitoring Mercury in Fish to Understand Risks to Human Health and the Environment

How Much Mercury in Fish Is Too Much?

Mercury can have significant negative impacts on fish and fish-eating wildlife. In addition, the primary route of mercury exposure in humans is through fish consumption. High levels of mercury in commercially important fish often result in fish consumption advisories for humans.

- Studies have shown that mercury concentrations above 0.30 parts per million (ppm) in fish can have negative impacts on fish growth, behavior, and reproduction.
- Fish-eating wildlife, such as the Common Loon, are shown to have decreased reproductive success when mercury concentrations in fish 10–20 cm in length reach 0.16 ppm.
- Human health criteria for mercury concentrations in fish ranges from 0.22 ppm (US Great Lakes Advisory Council) to 0.5 or 1.0 ppm (European Commission and World Health Organization).

Aquatic ecosystems are considered some of the most sensitive ecosystems to mercury pollution. Once mercury is deposited, it can rapidly bioaccumulate and biomagnify. The process (*illustrated at right*) includes:

(1) Mercury may be deposited in sediments, converted to methylmercury, and enter the benthic (bottom dwelling) food web.

(2) Mercury and methylmercury can be directly absorbed from the water column by phyto- and zooplankton, a process called biomagnification.

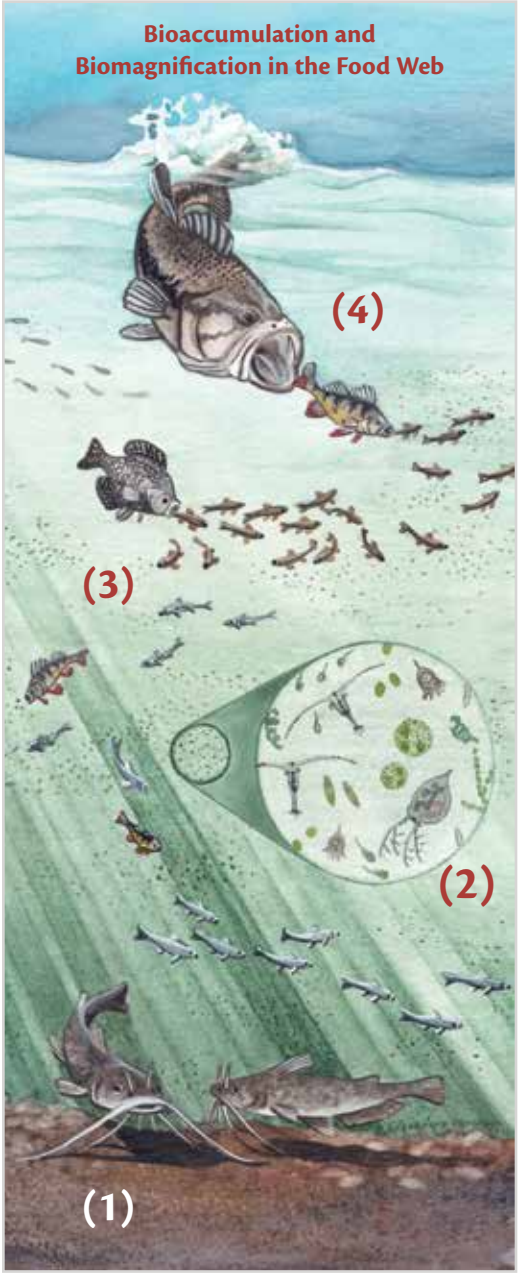
(3) Mercury can bioaccumulate in individual organisms as they grow and age.

(4) The biomagnification, or enrichment, of mercury and methylmercury continues up the aquatic food chain to top-level consumers.

BRI Fish Mercury Studies

BRI conducts research and monitors fish mercury concentrations in freshwater and marine ecosystems. Projects include:

- Assisting government regulators: The Federal Energy Regulatory Commission requires monitoring of mercury concentrations related to water quality.
- Establishing wildlife and human health criteria: BRI has assisted New York and Maine in the development of models and criteria for mercury concentrations in fish.
- Identifying biological mercury hotspots: BRI is measuring mercury in key fish bioindicators for many countries in the Caribbean Region—from the Lesser Antilles to Belize to Suriname.



Fishes

Monitoring Mercury in Avian Piscivores: Loo

Piscivores are Excellent Bioindicators of Mercury Contamination

Avian piscivores include several species of birds that rely on fish as the dominant part of their diet. These birds, including loons, seabirds, and fish-eating raptors, are important bioindicators because of their obvious connection to aquatic ecosystems and because of their high conservation value.

BRI's Loon Research on Mercury

In 1990, BRI began studying the exposure and effects of mercury on the Common Loon. Overall research goals for tracking mercury in loons include:

(1) the identification of biological mercury hotspots;

(2) conducting risk and injury assessments for the U.S. federal government; and

(3) developing the use of loon species as bioindicators in response to regulatory and other policy needs.

BRI annually samples Common Loon blood and feathers for mercury from sites across its North American breeding (in 12 states and 8 provinces) and wintering ranges (13 states). To date, more than 5,000 Common Loons have been captured and monitored for mercury, creating one of the most robust mercury data sets for birds in the world.

The standardized data platform provides a unique ability to track environmental mercury loads through time. Holarctic species are also monitored, including the Yellow-billed and Red-throated Loons, which provides an ability for intercontinental comparison.

BRI's Raptor Research on Mercury

In 2000, BRI initiated mercury monitoring in raptors. Initial work emphasized breeding populations, including Bald Eagle chicks from their nests (more than 730 eaglets by 2014).

BRI's Raptor Program is also engaged in monitoring mercury in breeding adult Bald Eagles, as well as summering populations of Osprey and the federally endangered Snail Kite. A project monitoring mercury in migrant raptors includes multiple partners, especially Hawk Ridge Bird Observatory in Duluth, Minnesota, and Cape May Bird Observatory in Cape May, New Jersey that have produced 3,000 feather Hg concentrations..

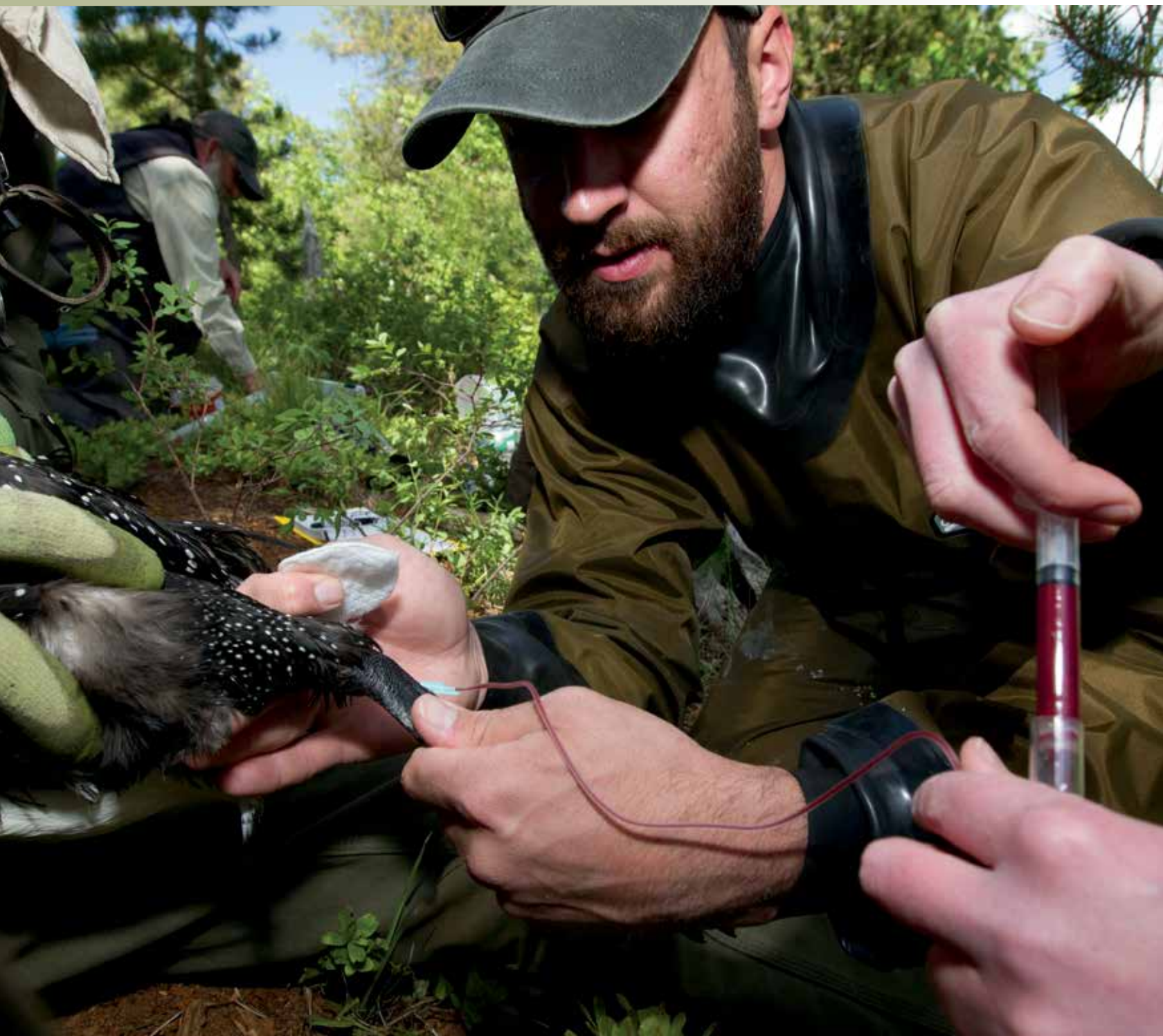
Above: Ospreys are obligate piscivores breeding across much of the northern hemisphere on lakes, rivers, estuaries, and ocean coasts. *Right:* Field biologists take blood samples from the tarsus of a Common Loon.

NYSERDA Mercury Monitoring Program

Supported by the New York State Energy Research and Development Authority (NYSERDA), BRI's Songbird and Loon programs monitor the biotic impacts of mercury pollution and acid deposition to New York's aquatic ecosystems. This long-term monitoring effort provides state-level policymakers with a valuable scientific foundation to help assess the effectiveness of recent regional, national, and global mercury emission regulations at decreasing the ecological impacts of airborne mercury pollution in New York.

Special Issue of Ecotoxicology

ns, Seabirds, and Raptors



Monitoring Mercury in Invertivores: Songbird

Invertivores are Excellent Bioindicators of Mercury Contamination in Wetlands

Recent studies have shown that insect-eating birds and bats can bioaccumulate high amounts of mercury in their bodies and therefore are good bioindicators of mercury contamination. During their summer breeding season, many birds rely on insects and other invertebrates (e.g., spiders) as food for their young.

Invertebrates that spend some of their early developmental stages in aquatic ecosystems are a particularly important link to the aquatic ecosystems most affected by mercury pollution. A similar pattern of mercury exposure affects invertebrate-eating bats.

BRI Studies of Mercury in Songbirds

BRI scientists initially discovered the potential for mercury exposure in songbirds when conducting a risk assessment of a US EPA Superfund Site on the Sudbury River in Massachusetts. There, invertebrate-eating birds (i.e., the Red-winged Blackbird) were found to have blood mercury concentrations four times higher than associated fish-eating birds (e.g., the Belted Kingfisher).

Such findings led to a paradigm shift in how governmental agencies assessed the risk and injury of mercury contamination in ecosystems. The potential risk mercury poses to wildlife was no longer considered a problem for fish-eating wildlife alone, but also for wildlife feeding on invertebrates.

Since that initial study on the Sudbury River, BRI has captured, sampled, and analyzed more than 10,000 songbirds for mercury concentrations (mostly using blood and feather tissues). These data provide critical information on species sensitivity, as well as geographic areas and habitats of greatest concern.

BRI's studies of the Saltmarsh Sparrow show that mercury exposure represents a significant threat to this and other vulnerable species that depend on estuarine habitats.

Published findings indicate wetland songbirds are at greatest risk, especially species that are mostly invertivores during the breeding season and that forage by gleaning invertebrates from vegetation.

Species of greatest concern in the northeastern United States include: the Carolina Wren; Northern and Louisiana Waterthrushes; Rusty and Red-winged Blackbirds; and Nelson's, Saltmarsh, and Seaside Sparrows.

Using Museum Bird Skins to Track Mercury

Methylmercury is naturally bound in the feathers of birds. Therefore, analyzing methylmercury in the feathers of bird skins from museum specimens offers a novel way to determine the change in environmental mercury loads over time, often as far back as the late 1800s.

BRI is conducting this retrospective of mercury with the Harvard Museum of Natural History.

Newly published findings indicate significant increases of feather Hg concentrations over the last 140 years in the Rusty Blackbird and increases in other target songbird species.

Special issue in Ecotoxicology
Mercury in Songbirds (2018)

s and Bats

BRI Studies of Mercury in Bats

Bats are integral components of terrestrial ecosystems, providing critical ecosystem services related to insect management and plant pollination. However, because of their nocturnal nature, they are often overlooked.

BRI has become a leader in bat research and has been monitoring mercury concentrations in bats since 2005. In a recent, first-of-its-kind study, BRI researchers characterized mercury exposure in nearly 1,500 individual bats from 10 species across the northeastern United States.

Results show that bats captured near point sources of mercury pollution had higher mercury concentrations in blood and fur than bats from sites not impacted by point source pollution. Important differences were observed between male and female bats, with females having higher concentrations of mercury.

Recognizing the risk of mercury exposure in bats provides a more comprehensive perspective on the impacts of mercury on the environment. Results from BRI's research highlight the utility of bats as important bioindicators of mercury in terrestrial ecosystems.

Future research will focus on improving our understanding of the long-term impacts of mercury on bat behavior and reproductive success.

Learn more in *Hidden Risk: Mercury in Terrestrial Ecosystems of the Northeast*

Mercury Impacts Endangered Bats

Because bats are long-lived, they have the potential to bioaccumulate high concentrations of mercury over time. High mercury concentrations may lead to multiple problems such as compromised immune systems, which makes it more difficult for animals to fight infections such as white-nose syndrome.

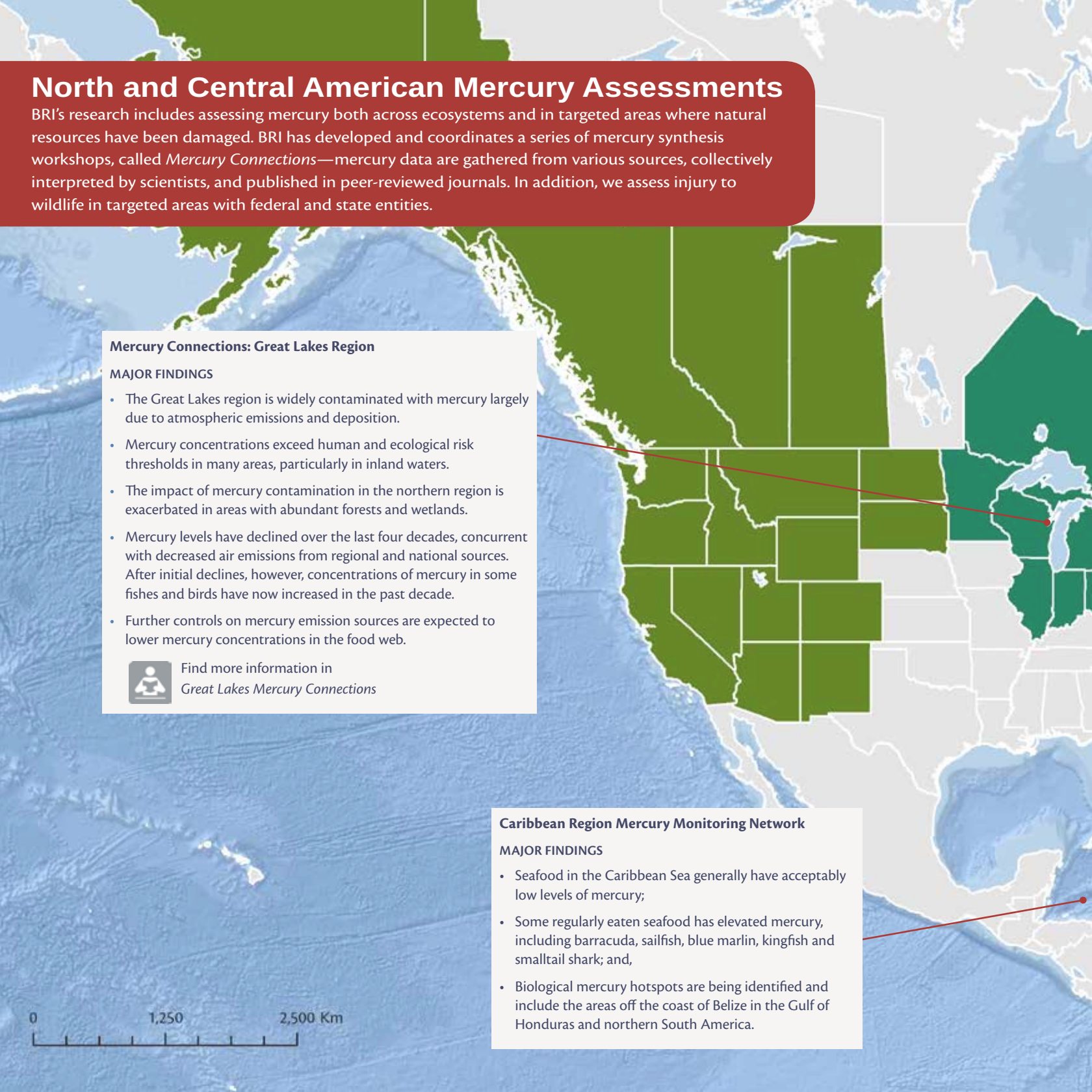
Wind farms present another potential risk to these animals because bats approaching the wind turbine blades may suffer pulmonary death (i.e., capillaries bursting). The ability of bats with elevated mercury body burdens to avoid wind turbines requires further investigation.

Bat species federally listed as threatened or endangered and with known elevated concentrations of mercury include the Indiana bat, the gray bat, the Virginia big-eared bat, and the northern long-eared bat.

BRI's studies on the northern long-eared bat (pictured left) comes at a crucial time as this species is now listed as threatened under the US Endangered Species Act.

North and Central American Mercury Assessments

BRI's research includes assessing mercury both across ecosystems and in targeted areas where natural resources have been damaged. BRI has developed and coordinates a series of mercury synthesis workshops, called *Mercury Connections*—mercury data are gathered from various sources, collectively interpreted by scientists, and published in peer-reviewed journals. In addition, we assess injury to wildlife in targeted areas with federal and state entities.



Mercury Connections: Great Lakes Region

MAJOR FINDINGS

- The Great Lakes region is widely contaminated with mercury largely due to atmospheric emissions and deposition.
- Mercury concentrations exceed human and ecological risk thresholds in many areas, particularly in inland waters.
- The impact of mercury contamination in the northern region is exacerbated in areas with abundant forests and wetlands.
- Mercury levels have declined over the last four decades, concurrent with decreased air emissions from regional and national sources. After initial declines, however, concentrations of mercury in some fishes and birds have now increased in the past decade.
- Further controls on mercury emission sources are expected to lower mercury concentrations in the food web.

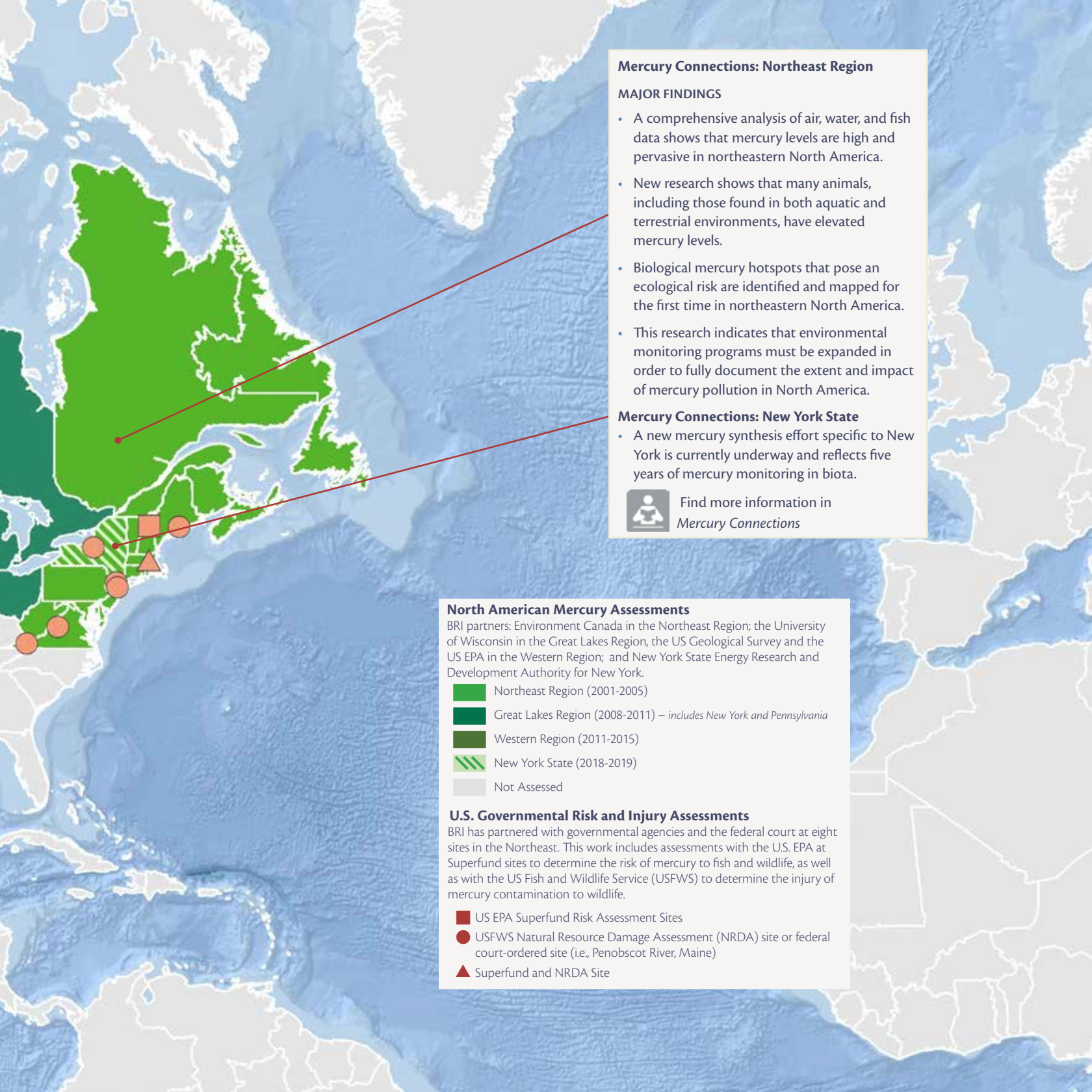
Find more information in
Great Lakes Mercury Connections

Caribbean Region Mercury Monitoring Network

MAJOR FINDINGS

- Seafood in the Caribbean Sea generally have acceptably low levels of mercury;
- Some regularly eaten seafood has elevated mercury, including barracuda, sailfish, blue marlin, kingfish and smalltail shark; and,
- Biological mercury hotspots are being identified and include the areas off the coast of Belize in the Gulf of Honduras and northern South America.

0 1,250 2,500 Km



Mercury Connections: Northeast Region

MAJOR FINDINGS

- A comprehensive analysis of air, water, and fish data shows that mercury levels are high and pervasive in northeastern North America.
- New research shows that many animals, including those found in both aquatic and terrestrial environments, have elevated mercury levels.
- Biological mercury hotspots that pose an ecological risk are identified and mapped for the first time in northeastern North America.
- This research indicates that environmental monitoring programs must be expanded in order to fully document the extent and impact of mercury pollution in North America.

Mercury Connections: New York State

- A new mercury synthesis effort specific to New York is currently underway and reflects five years of mercury monitoring in biota.

Find more information in *Mercury Connections*

North American Mercury Assessments

BRI partners: Environment Canada in the Northeast Region; the University of Wisconsin in the Great Lakes Region, the US Geological Survey and the US EPA in the Western Region; and New York State Energy Research and Development Authority for New York.

- Northeast Region (2001-2005)
- Great Lakes Region (2008-2011) – *includes New York and Pennsylvania*
- Western Region (2011-2015)
- New York State (2018-2019)
- Not Assessed

U.S. Governmental Risk and Injury Assessments

BRI has partnered with governmental agencies and the federal court at eight sites in the Northeast. This work includes assessments with the U.S. EPA at Superfund sites to determine the risk of mercury to fish and wildlife, as well as with the US Fish and Wildlife Service (USFWS) to determine the injury of mercury contamination to wildlife.

- US EPA Superfund Risk Assessment Sites
- USFWS Natural Resource Damage Assessment (NRDA) site or federal court-ordered site (i.e., Penobscot River, Maine)
- Superfund and NRDA Site

Mercury Connections: Translating Science fo

Understanding the Extent and Effects of Mercury Pollution across North America

Mercury Connections provides a model that fosters research collaboration among scientists and policymakers from governmental agencies, academic institutions, and NGOs across North America. BRI developed this model based on the need to synthesize disparate data on environmental mercury concentrations that often are otherwise compartmentalized by matrix or taxa. Synthesized data are analyzed and published in peer-reviewed manuscripts. Our outreach materials provide critical information to the media, governmental regulators, and lawmakers.

Northeastern United States and Eastern Canada (2001–2005)

Funded by the Northeastern State Research Cooperative and in partnership with Environment Canada, BRI led a comprehensive effort to compile mercury data representing air, sediment, water, plankton, invertebrates, fish, birds, and mammals. A database of more than 60,000 data points was used by 72 scientists to generate 21 peer-reviewed manuscripts that were published in the journal *Ecotoxicology*. BRI published an outreach report to present to federal regulatory agencies, U.S. Congressional Committees, and state regulatory and policymakers.

Great Lakes Region (2008–2011)

The mercury data synthesis effort in the Great Lakes built on BRI's landmark study in the Northeast and included most relevant governmental stakeholders and several major universities in both the US and Canada. Through funding from the Great Lakes Commission, and in partnership with the University of Wisconsin, a database of more than 500,000 mercury data points was amassed with the help of 144 co-authors; 35 peer-reviewed papers were published in the journals *Ecotoxicology* and *Environmental Pollution*. BRI distributed a communications piece to highlight the results for a general audience.

Western North America (2011–2015)

For the third North American regional synthesis, BRI teamed with the US Geological Survey and the US EPA to develop a mercury data synthesis effort for western North America. This work includes hundreds of thousands of data points. In an effort to link matrices across various disciplines, an emphasis is placed on incorporating landscape-level GIS-based data to better understand and interpret the complex relationships of mercury in western ecosystems where pollution sources regularly include past and present mining activities. A special issue in the journal *Science of the Total Environment* served as the platform for the publication of 18 peer-reviewed manuscripts.

New York State (2018-2019)

BRI is further leading a synthesis effort in partnership with the New York State Energy Research and Development Authority (NYSERDA) to synthesize mercury data in the state of New York, with an emphasis on the statewide data gathered over the past five years. A special issue is forthcoming in the journal, *Ecotoxicology*, as well as a science-policy publication, *Mercury Connections*, to be distributed in Washington, D.C.

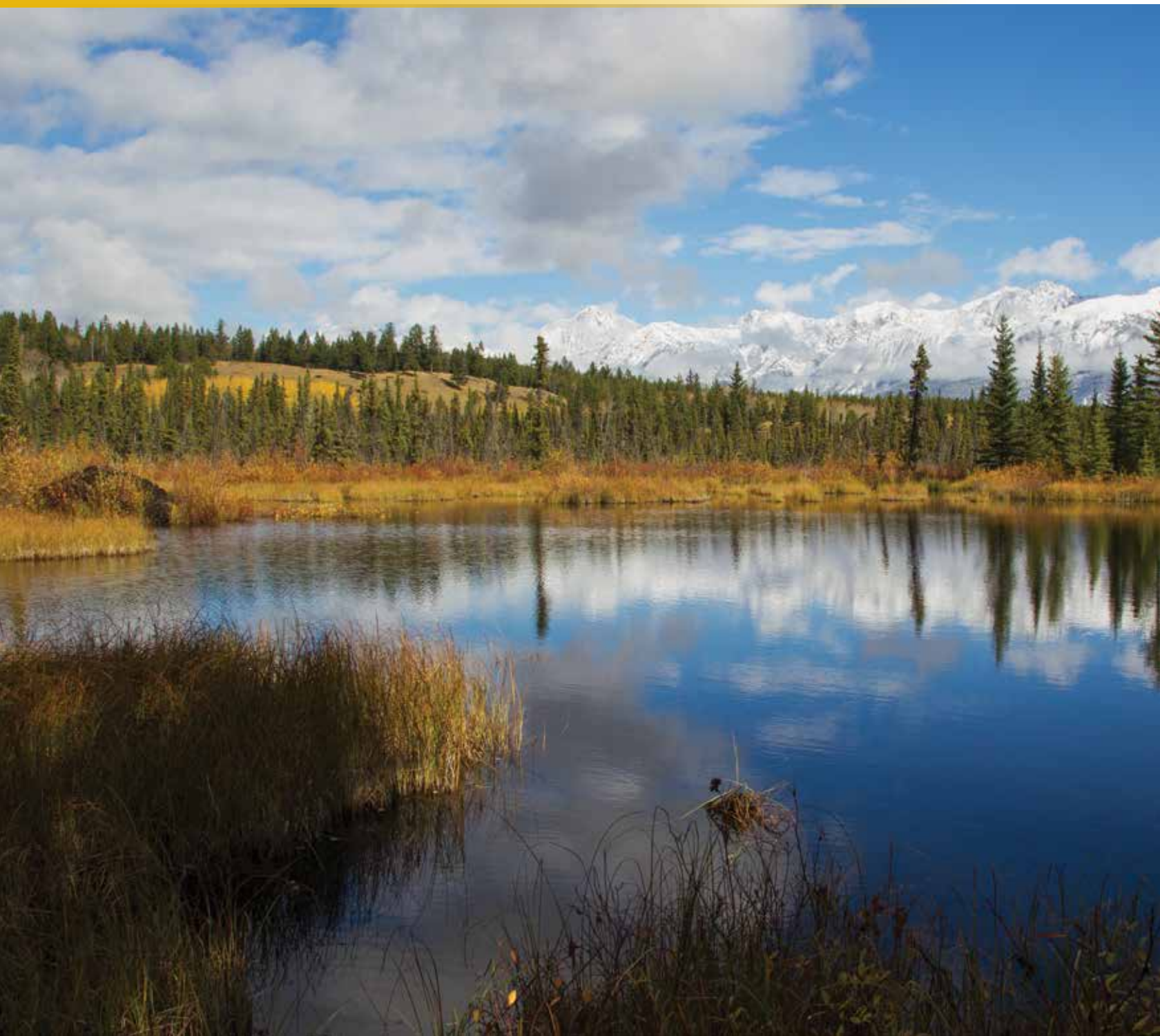
MercNet

Led by the US EPA, a broad cross-section of governmental agencies and institutions are working together to coordinate mercury-monitoring activities in the US.

MercNet is a proposed long-term monitoring program to comprehensively track mercury in air, water, land, fish, and wildlife. The methodologies and geographic areas for monitoring have been identified and specific implementation will be based on the initial synthesis of the Mercury Connections process. A legislative bill was reintroduced to the US Senate in 2018.

Learn more in the publication *MercNet*

r Policy



Assessing Risk and Injury to Wildlife from M

The U. S. Government is a Leader in Mercury Assessments

Economizing NRDAR

The process of determining injury due to mercury or other contaminants requires field sampling and modeling. Once the total impact of an event, such as an oil spill, can be measured—often in terms of individual animal loss or lowered reproductive success—an injury unit is created.

For birds, injuries are often quantified using "bird-years" (the number of birds missing from a population multiplied by the number of years they are absent). Bird-years may be calculated for a species such as the Carolina Wren or a group such as neotropical migrants. Once calculated over time (e.g., since the start of the Oil Pollution Act of 1981 and then 100 years forward) and across the contaminated area (which can be more than 80 miles downstream of a mercury point source), there is a counter calculation to determine how to regain (or restore) the number of bird-years lost. Restoration is often calculated in a way that would enhance species numbers or retain current populations that may otherwise be lost to habitat degradation or destruction.

The United States government has a unique approach for assessing risk, quantifying injury, and restoring damages caused by the impacts of contaminants, such as methylmercury, on fish and wildlife. Two programs provide the legal platform for such assessments: the US EPA's Superfund Program and the US Fish and Wildlife Service's (USFWS) Natural Resource Damage Assessment and Restoration (NRDAR) Program. Both provide the ability for state, federal, and tribal governments to work with the responsible parties, such as chemical companies, to jointly quantify the exposure and potential effects of mercury on fish and wildlife.

Typically, the risk of mercury is determined through models (led by US EPA) while the injury is measured through field sampling with a scalable endpoint, such as reproductive output or individual survival, over time and space (led by the USFWS). If risk is demonstrated to fish, wildlife, or people, then the US EPA conducts remediation and the USFWS proceeds to quantify the injury. Once the overall injury has been calculated, the restoration of fish and wildlife populations adversely impacted by mercury is determined.

Above: The Carolina Wren is a key indicator species for measuring the effects of mercury in songbirds. *Right:* BRI researches mercury exposure on bats such as the little brown bat.

Quantifying the level of restoration for impacted ecosystems is based on economizing the loss of species-years or species' productivity—usually across an agreed upon time period and footprint of the impacted area. Restoration is often through habitat enhancement or protection.

BRI's Contribution to Superfund and NRDAR Studies

For more than a decade, BRI has been working closely with federal agencies on wildlife assessments. The mercury-related projects usually last multiple years and require extensive efforts to determine wildlife species with the greatest risk and injury. At first, emphasis was placed on fish-eating wildlife, but since methylmercury can biomagnify through any food web, BRI discovered that species in invertivore food webs can also be at high risk from elevated mercury concentrations. Therefore, in addition to such commonly studied fish-eating species such as mink, river otter, Bald Eagles, Belted Kingfishers, and Common Mergansers, BRI has also studied invertivores such as Indiana, northern long-eared, little brown, and big brown bats, Tree Swallows, Carolina and Marsh Wrens, Song Sparrows, and Red-winged Blackbirds for multiple Superfund and NRDA projects.

ercury

BRI's Science Communications

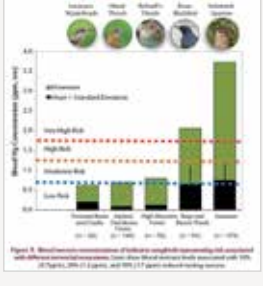
Translating Science

Scientific Expertise

BRI's distinguished team of research and conservation biologists conducts innovative wildlife science around the world.

Mercury Data

We have developed an integrated approach to organize disparate databases on mercury and analyze and share those data.



Workshops/Meetings

International collaborations with other leading scientists, government agencies, and nonprofits help us understand mercury exposure and effects on a global scale.

Publishing Scientific Findings

Most, if not all, of the environmental challenges we face today require more and better science to identify and assess emerging threats, and innovative technology to identify and recommend solutions. At BRI, we also recognize that we need to provide the results of our scientific research to a wide audience. BRI is dedicated to providing unbiased scientific information to policymakers and resource managers that helps to inform critical decisions regarding environmental health and integrity.

Peer-reviewed Journal Articles

BRI consistently publishes the results of our applied wildlife studies in professional journals. The integrity of our scientific research is critical to our mission.

BRI's Science Communications and Public Outreach

We translate our published findings into succinct, clear language, engaging readers who are not experts in the field with our wildlife photography and infographics that convey complex scientific concepts. Our outreach materials serve as a foundation for:

- press conferences
- policy development workshops
- legislative hearings
- public events

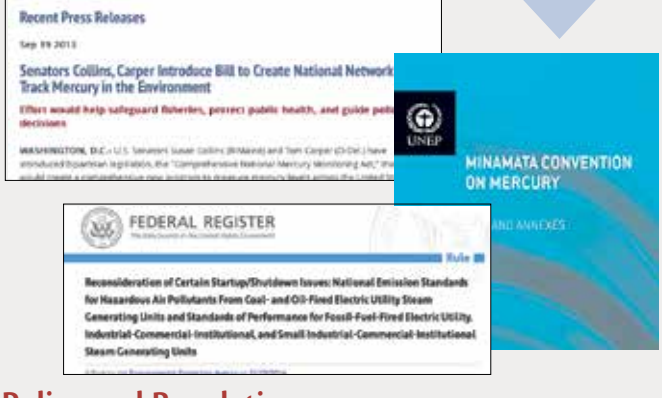
Raising Public Awareness

Media Coverage

Our media campaigns have generated coverage in most of the major news outlets worldwide such as *The New York Times, Audubon Magazine, National Public Radio, British Broadcast Corporation (BBC), The Guardian,* and many others. This exposure both informs the public and promotes positive action.

Providing a Platform for Public Discussion

Informing the Policy Process



Policy and Regulations

The results of our outreach have included contributions to the Minamata Convention on Mercury, the US EPA MATS rule, and the mercury bills currently in progress in the US Congress.

Publications

BRI Published Science Communications

Mercury in the Global Environment: Patterns of Global Seafood Mercury Concentrations and their Relationship with Human Health and the Environment

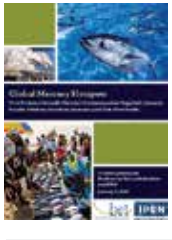
Highlights marine organisms with the greatest concentrations of mercury. Data are compared to global seafood capture data for insight into the potential risks associated with consumption of seafood with high mercury concentrations. (2018)

Mercury in the Global Environment: Marine Mammals

This report illustrates the impacts of methylmercury biomagnification and bioaccumulation on marine mammals, and features five groups that are particularly affected including: toothed whales; baleen whales; pinnipeds (seals and walruses); people; and the polar bear. (2017)

Mercury in the Global Environment: Tuna

Commercial tuna fishing is a $42+ billion industry globally. Despite the high demand for tuna, many of these fish pose a risk to human health due to mercury contamination. This report summarizes mercury levels found in nine tuna species that are popular for human consumption. (2018)



Global Mercury Hotspots: New Evidence Reveals Mercury Contamination Regularly Exceeds Health Advisory Levels in Humans and Fish Worldwide.

This IPEN-BRI project is the first of its kind to identify, in one collaborative effort, global biological mercury hotspots, which are of particular concern to human populations and the ecosystems on which they depend. (2014)

BRI's Multimedia Library

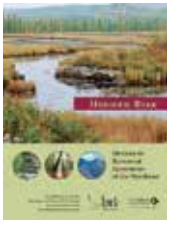
Our online library provides access to BRI's scientific literature including peer-reviewed scientific publications, project reports, posters and presentations, science communications pieces, books, maps, videos, and news articles.
www.briloon.org/library

Local, Regional, and Global Biomonitoring

This publication describes BRI's biomonitoring efforts as for fish, sea turtles, birds, marine mammals, and humans. (2018)

Phasing Out/Phasing Down Mercury-added Products

This publication features information about phasing out and phasing down consumer and commercial products that contain mercury. (2018)



Hidden Risk: Mercury in Terrestrial Systems of the Northeast

Highlights BRI's scientific findings on levels of mercury contamination in songbirds and bats. Mercury accumulation, previously considered a risk for aquatic ecosystems, is also found in many wildlife species living on the land. Published in partnership with The Nature Conservancy. (2012)

Great Lakes Mercury Connections: The Extent and Effects of Mercury Pollution in the Great Lakes Region

This report distills key results from 35 peer-reviewed papers and represents the work of more than 170 scientists, researchers, and resource managers who used more than 300,000 mercury measurements to document the impact of mercury pollution on the region. (2011)

Mercury Connections: The Extent and Effects of Mercury Pollution in Northeastern North America

In this landmark mercury research, carried out over a four-year period (2001-2005), BRI and Environment Canada led a comprehensive effort to compile mercury data from across the northeastern United States and eastern Canada. (2005)

MercNet: Establishing a Comprehensive National Mercury Monitoring Network

BRI was a major contributor to this US EPA publication about the need for an integrated national mercury monitoring network to provide accurate standardized information about mercury in the environment. (2008)

Special Issue Journal Publications

Science of the Total Environment
Eighteen papers are presented on the findings for the Western North America Mercury Synthesis in this Virtual Special Issue of Science of The Total Environment: Mercury in Western North America—Spatiotemporal Patterns, Biogeochemistry, Bioaccumulation, and Risks. **(2016)**

Ecotoxicology
Mercury in the Great Lakes Region **(2011)**

Environmental Pollution
Mercury in the Laurentian Great Lakes Region

In a regional study that encompassed the largest freshwater ecosystem in the world, BRI collaborated with the Great Lakes Commission and the University of Wisconsin-La Crosse to compile a wide variety of mercury data. **(2011)**

Environmental Research
Mercury in Marine Ecosystems: Sources to Seafood Consumers

Led by Dartmouth College's Toxic Metals Superfund Research Program, this special issue includes nine scientific papers that report on mercury in marine ecosystems and cover topics such as biogeochemistry, biotic uptake and climatology. **(2012)**

Ecotoxicology
Biogeographical Patterns of Environmental Mercury in Northeastern North America **(2005)**

Mercury in Songbirds (scheduled for **2018 or 2019** publication)

Synthesis of Environmental Mercury Loads in New York State (scheduled for **2019** publication)

BRI Featured Mercury Scientific Papers

The Effects of Methylmercury on Wildlife: A Comprehensive Review and Approach for Interpretation. In: Dominick Della Sala, Michael Goldstein (ed) Encyclopedia of the Anthropocene, 1st Edition edn. Elsevier, pp 2280

David C. Evers (2018)

Evaluating the effectiveness of the Minamata Convention on Mercury: Principles and recommendations for next steps.

David C. Evers et al. **(2016)**

Science of the Total Environment. 569-570:888-903

Setting Limits: Using Air Pollution Thresholds to Protect and Restore U.S. Ecosystems

Mark E. Fenn et al. **(2011)**

Issues in Ecology 14

Integrated Mercury Monitoring Program for Temperate Estuarine and Marine Ecosystems on the North American Atlantic Coast

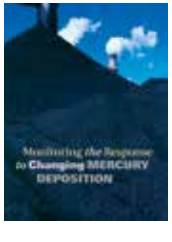
David C. Evers et al. **(2008)**

EcoHealth 5:426-441

Biological Mercury Hotspots in the Northeastern United States and Southeastern Canada

David C. Evers et al. **(2007)**

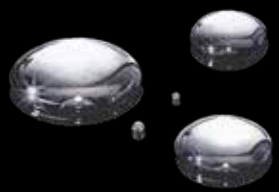
BioScience 57:29-43



Monitoring the Response to Changing Mercury Deposition

Robert Mason et al. **(2005)**

Environmental Science and Technology 39:14A-22A



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