Local, Regional, and Global
biomonitoring

Understanding Mercury Exposure through Monitoring At-risk Species

November 2018

bri

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About Biodiversity Research Institute

Biodiversity Research Institute (BRI), headquartered in Portland, Maine, USA, 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.

About BRI's Center for Mercury Studies

BRI staff have worked on the topic of mercury in the environment for the past 29 years and endeavor to collect original field data, interpret their results in scientific outlets, and relay information to decision makers in an understandable format. For more information visit: www.briloon.org/mercury.

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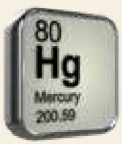
What is Biomonitoring?

Fish and wildlife provide important information on the environmental impacts of mercury pollution and potential risks related to human health. Biomonitoring is the process of assessing the health of organisms and ecosystems and tracking changes in mercury risk and exposure over time.

What Do you Need to Know about Biomonitoring?

The objective of the **Minamata Convention on Mercury**, which entered into force on August 16, 2017, is to “protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.” This publication describes the *who*, *what*, *how*, *why*, and *where* of biomonitoring efforts as outlined in **Articles 16 and 19** of the Convention, which lists those organisms that should be monitored including fish, sea turtles, birds, marine mammals, and humans.



Throughout this booklet, we use the terms mercury (Hg) and methylmercury (MeHg).

For analytical techniques we specify wet weight (ww), fresh weight (fw), or dry weight (dw).

CONTENTS

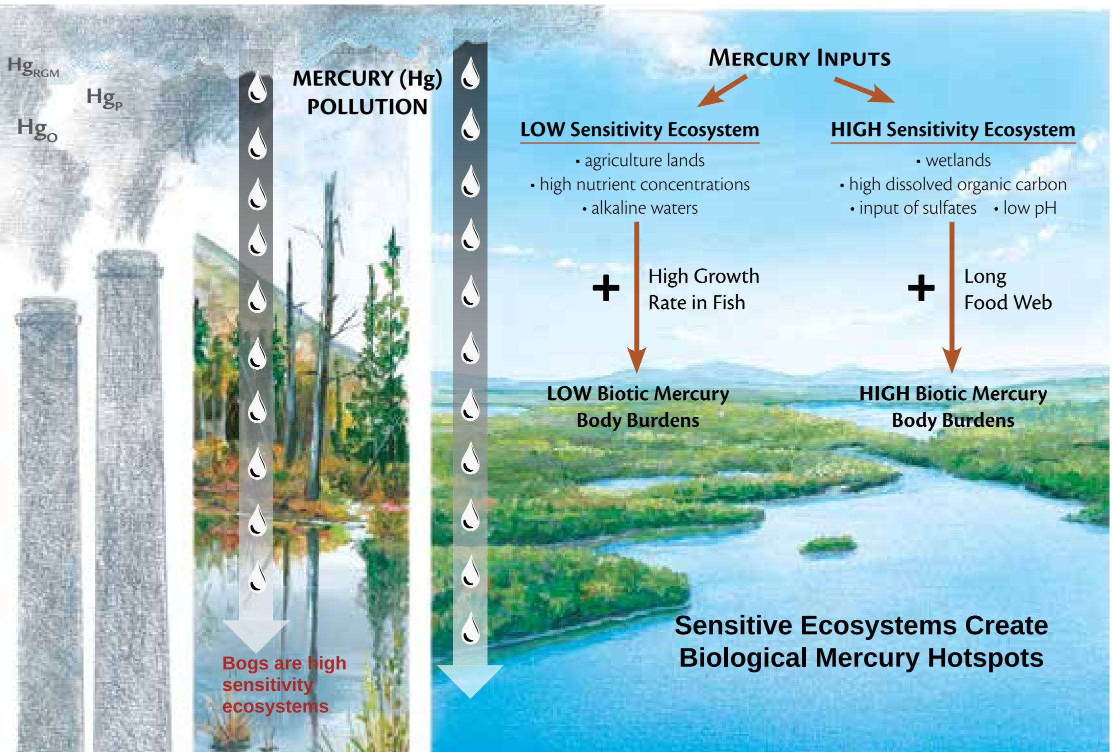
Understanding Environmental Mercury Requires Biotic Sampling

Mapping mercury (Hg) 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.

Methylmercury (MeHg) can then be bound in the food web where it can biomagnify and contaminate ecosystems.

Ecosystem Sensitivity is Key

Methylmercury concentrations in the food web depend on the sensitivity of the habitat to mercury input. Areas of high sensitivity and high mercury exposure are called ***biological mercury hotspots*** *(illustrated below)*; they represent the places that will require the most attention by countries and global monitoring programs. These hotspots are crucial to identify, especially if they represent important food sources for people or if they contain threatened and endangered species.

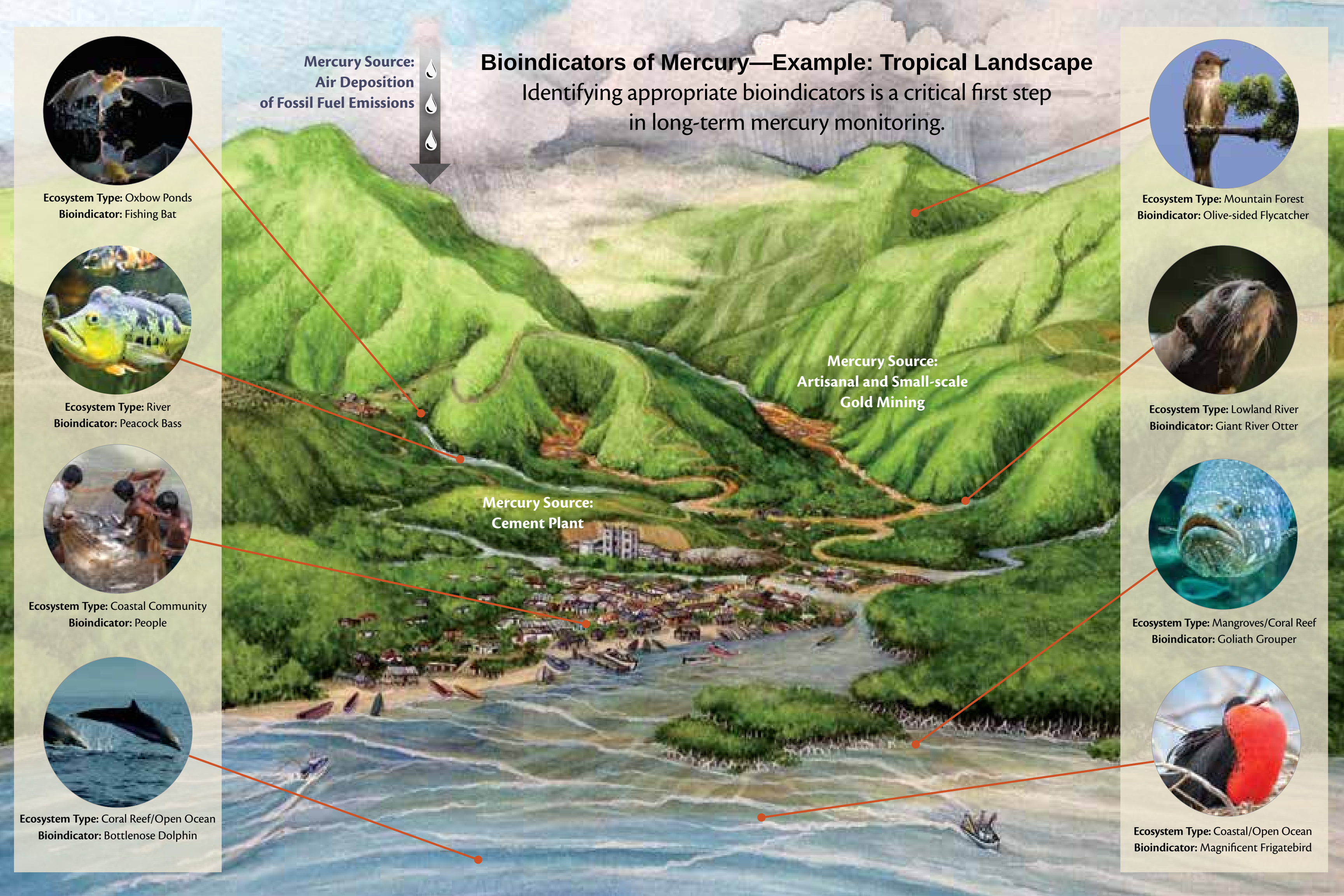


The Role of Bioindicators

Fish and wildlife provide important information on the environmental impacts of mercury pollution and potential risks related to human and ecological health. Young fish (<1 year) can reflect rapid changes of environmental mercury loads, while long-lived predatory fish commonly consumed by humans may indicate concern for human health.

In terrestrial ecosystems, birds are effective bioindicators of mercury pollution. Their public appeal can also help highlight environmental concerns and convey complex messaging.

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).



Bioindicators of Mercury—Example: Tropical Landscape
Identifying appropriate bioindicators is a critical first step in long-term mercury monitoring.
Mercury Source: Air Deposition of Fossil Fuel Emissions
Mercury Source: Artisanal and Small-scale Gold Mining
Mercury Source: Cement Plant
Ecosystem Type: Oxbow Ponds
Bioindicator: Fishing Bat
Ecosystem Type: River
Bioindicator: Peacock Bass
Ecosystem Type: Coastal Community
Bioindicator: People
Ecosystem Type: Coral Reef/Open Ocean
Bioindicator: Bottlenose Dolphin
Ecosystem Type: Mountain Forest
Bioindicator: Olive-sided Flycatcher
Ecosystem Type: Lowland River
Bioindicator: Giant River Otter
Ecosystem Type: Mangroves/Coral Reef
Bioindicator: Goliath Grouper
Ecosystem Type: Coastal/Open Ocean
Bioindicator: Magnificent Frigatebird

Steps in the Biomonitoring Process

1. Select Study Site and Target Species

The choice of bioindicators depends on many criteria such as the ability to capture and sample individuals and the monitoring objectives.

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.

Humans are exposed to methylmercury mainly through fish consumption. It is important to monitor mercury pollution in developing and transition countries where fish is a main dietary item.

2. Collect Samples* (Tissue Types)

Collect fish and marine mammal muscle tissue samples through nonlethal biopsies.

For bird studies, blood helps understand short-term exposure; adult feathers indicate long-term exposure; eggs provide information about short- and long-term issues.

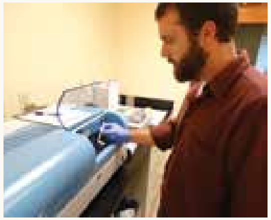
Hair is an easy and meaningful tissue type to test for mercury exposure in humans.

**With proper permits*

3. Prepare Samples — Transport/Storage

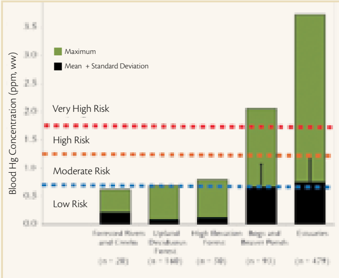
Proper labeling and storage of samples is imperative to ensure quality results. Researchers should adhere to protocols that may vary according to sample type and national permits.

4. Analyze Samples — Toxicology Lab



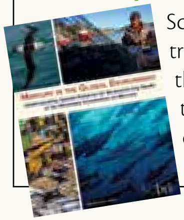
Toxicology lab capabilities should include: 1) total mercury analysis (using a Direct Mercury Analyzer or similar instrument); 2) tissue moisture determination (using a freeze dryer); 3) tissue homogenization (using a cryogrinder); and 4) an analytical balance to measure mass of small samples (e.g., 0.00001 g).

5. Analyze and Manage Data



Analysts should strive for the highest quality in data preparation and standardization, ensuring quality control of data processing and management. An integrative approach that includes field-based measures and data synthesized from disparate databases on mercury concentrations helps to improve confidence in findings.

6. Report Results — Translate the Science



Science communications pieces and web pages translate findings into succinct, clear language that engage readers who are not experts in the field; photography and infographics help convey complex scientific topics.

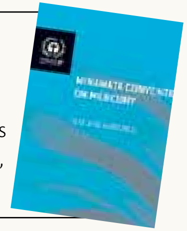
7. Increase Capacity and Raise Stakeholder Awareness through Public Outreach

Outreach materials, such as science communications, presentations, and websites, serve as a foundation for:

- local workshops tailored to the specific country or region
- policy development workshops
- legislative hearings
- public events
- press conferences

8. Meet the Obligations of the Minamata Convention

There are many ways that the scientific activities in this biomonitoring process can help countries, especially with Articles 14, 16, 17, 18, 19 and 22.



SPOTLIGHT ON RESEARCH:
Biomonitoring and the Minamata Convention on Mercury

BRI has partnered with agencies, countries, and NGOs around the world to study mercury exposure to people and the environment, and to help meet goals of the Minamata Convention. To view an interactive map of our study sites, visit:

www.briloon.org/minamata

Atlantic Bluefin Tuna
(Thunnus thynnus)

Quick Notes

- **Focal taxa:** Barracuda, billfish, bluefish, cod, flounder, groupers, haddock, halibut, mackerel, mullet, salmon, sharks, snapper, tuna
- **Field sampling techniques:** For human health purposes, use a fillet or, for nonlethal method, a muscle biopsy. To assess ecological health use either muscle biopsy or the whole fish.
- **Lab analytical techniques:** Fillets (or muscle tissue) can be analyzed on a ww or dw basis. While much of the literature uses ww Hg concentrations, dw is a preferred analysis to avoid the tissue being compromised by loss of moisture. For either ww or dw analysis, it is key to completely homogenize the sample. A dw analysis can either use the measured moisture or a rule of thumb moisture content of 80% to convert dw to ww Hg concentrations.
- **Collaborative projects:** BRI worked with IPEN on *The Global Fish and Community Mercury Monitoring Project*, the first of its kind to identify, in one collaborative effort, global biological mercury hotspots (see Buck et al. 2019 and GBMS in *Resources and References*, page 21).

Illustration opposite: Lemon Shark

Marine Fish

Why Monitor Marine Fish?

Environmental concentrations of mercury have increased approximately three-fold as a result of anthropogenic emissions—the world's oceans are primary reservoirs for this mercury. Mercury emissions enter marine ecosystems through rivers and estuaries, or via direct atmospheric deposition. As a result, marine ecosystems are sensitive to localized inputs of mercury and also serve to integrate larger-scale changes in mercury emissions and releases.

Mercury present in the marine environment can bioaccumulate in fish as they age. In addition, mercury biomagnifies within marine food webs; top-level predators such as swordfish often contain elevated levels of mercury in their tissue. Because mercury is persistent in the marine environment, there can be a lag time between reductions in mercury emissions and releases and actual reductions in mercury concentrations in marine fish.

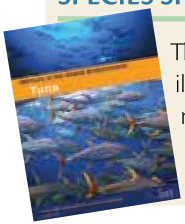
Where to Monitor Marine Fish?

Marine fish should be monitored on a global scale. Understanding mercury concentrations in marine fish is important because of the potential human health risks associated with fish consumption.

According to the UN's Food and Agriculture Organization approximately three quarters of the global fishery is harvested from the marine environment. This harvest includes a wide range of species—from sardines and herring to apex predators such as swordfish and several large tuna species.

Consumption of estuarine and marine fish is the primary pathway for methylmercury exposure in humans. This is of particular importance to vulnerable populations including children, pregnant women, and indigenous communities that rely on fish as a major protein source.

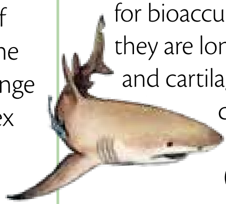
SPECIES SPOTLIGHT: *Tuna*



This new BRI publication helps illustrate the impacts of methylmercury on nine species of tuna, To download this visit: **www.briloon.org/hgcenter**.

PUBLISHED PAPERS

BRI International Studies



SOUTH ATLANTIC AND PACIFIC OCEANS: Sharks are at greater risk for bioaccumulation of mercury because they are long-lived predators. Shark fins and cartilage also contain a ubiquitous cyanobacterial toxin linked to neurodegenerative diseases. (Hammerschlag et al. 2016)

FLORIDA BAY, USA: Study shows bioaccumulation and biomagnification of mercury and methylmercury in coastal sharks in a protected subtropical lagoon (Matulik et al. 2017).

BELIZE: Mercury concentrations in the goliath grouper of Belize: an anthropogenic stressor of concern (Evers et al. 2009).

MEDITERANNEAN SEA: Spatial and taxonomic variation of mercury concentration in low trophic level fauna from the Mediterranean Sea. (Buckman et al. 2018).


Largemouth Bass
(Micropterus salmoides)

Quick Notes

- **Focal taxa:** Bass, catfish, perch, pike, piranha, snook, walleye, wolffish
- **Field sampling techniques:** For human health purposes, use a fillet or muscle biopsy/plug. To assess ecological health the tissue type can be either muscle or the whole fish.
- **Lab analytical techniques:** Fillets (or muscle tissue) can be analyzed on a ww or dw basis. While much of the literature uses ww Hg concentrations, dw is a preferred analysis to avoid the tissue being compromised by loss of moisture. For either ww or dw analysis, it is key to completely homogenize the sample.
- **Collaborative projects:** BRI worked with IPEN on *The Global Fish and Community Mercury Monitoring Project*, the first of its kind to identify, in one collaborative effort, global biological mercury hotspots (see Buck et al. 2019 and GBMS in *Resources and References*, page 21).

Illustration opposite: Peacock Bass

Freshwater Fish

Why Monitor Freshwater Fish?

Freshwater fish are widely used as a monitoring and assessment tool for mercury contamination because of their relative ease of collection and identification. Yearling fish (<1 year old) can serve as good indicators of short-term changes in the input of mercury to freshwater ecosystems while adult fish provide information on long-term patterns of mercury inputs and processes related to bioaccumulation.

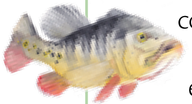
Fish communities also represent multiple trophic levels within aquatic ecosystems and community-wide assessments can provide information on biomagnification of toxic substances within aquatic food webs.

As with marine fish, mercury concentrations in freshwater fish are also closely linked to human health because of human consumption patterns.

Where to Monitor Freshwater Fish

Identifying contaminated waterbodies and fish species that are sensitive indicators of mercury in the environment can help reduce the risk of exposure in humans through the development of fish consumption advisories for specific waterbodies and species of fish.

Freshwater ecosystems provide habitat for nearly half of the world's fish species. Human health may be at risk from the consumption of contaminated fish. Recreational fishing activites and commercial fisheries may be at risk due to the potential of reduced reproductive success of fish populations esposed to elevated levels of mercury.



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BRI International Studies

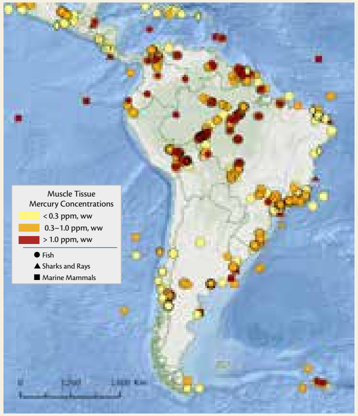
AFRICA: A review of mercury concentrations in freshwater fishes of Africa: Patterns and predictors (Hanna et al. 2015).

GLOBAL: A rapid assessment of fish mercury concentrations at the global scale—incorporating site-specific and taxonomic variables to predict biological mercury hotspots (Buck et al. 2019).

SPOTLIGHT ON RESEARCH:

Mercury Monitoring in South America

BRI's Global Biotic Mercury Synthesis (GBMS) database (see page 21) includes 214 references, totaling 28,940 samples of fish mercury concentrations from inland and near-shore locations in South America. Data are updated regularly. Numerous references have also been identified that document mercury concentrations in humans, particularly from rural, riverine communities living within the Amazon Basin.



Map: The distribution of methylmercury in biota, specifically fish and marine mammals, varies across South America.

Hawksbill Sea Turtle
(Eretmochelys imbricata)

Quick Notes

- **Focal taxa:** Flatback, green, hawksbill, Kemp's ridley, leatherback, loggerhead, and olive ridley sea turtles
- **Field sampling techniques:** Focus on nonlethal sampling of young and adults using blood and scutes and use inviable whole eggs. Proper comparison of sea turtle Hg concentrations should include data on morphometrics and, ideally, age.
- **Lab analytical techniques:** Analyze whole blood as ww and scutes as fw and whole eggs as either ww or dw. All tissues can be analyzed for total Hg as >95% is comprised of MeHg.
- **Collaborative projects:** Currently, BRI is not collaborating on any sea turtle biomonitoring studies.

Illustration opposite page: Loggerhead Sea Turtle

Sea Turtles

Why Monitor Sea Turtles?

Sea turtles have inhabited the Earth's oceans since the time of the dinosaurs. They swim across all warm and temperate waters, often migrating hundreds of miles between nesting and feeding grounds, where they are exposed to mercury pollution.

Extremely long-lived and slow growing, sea turtles can bioaccumulate methylmercury (the organic and more toxic form of mercury) over time and can be important bioindicators of short-term (e.g., blood sampling) and long-term changes (e.g., scute sampling) of environmental mercury loads in marine ecosystems.

Where to Monitor Sea Turtles?

Areas where sea turtles may need to be monitored for elevated levels of mercury include the Caribbean Sea, Mediteranean Sea, Arabian Sea, and other relatively contained ocean basins.

Sea turtles and their eggs may be consumed and their mercury concentrations can have adverse impacts on human and ecological health. While all sea turtle species are protected by various national and international laws, consumption

of their eggs remains a common practice in some communities and countries. Turtle eggs (*pictured left*) can contain elevated levels of methylmercury and may pose a threat to human health if regularly consumed.

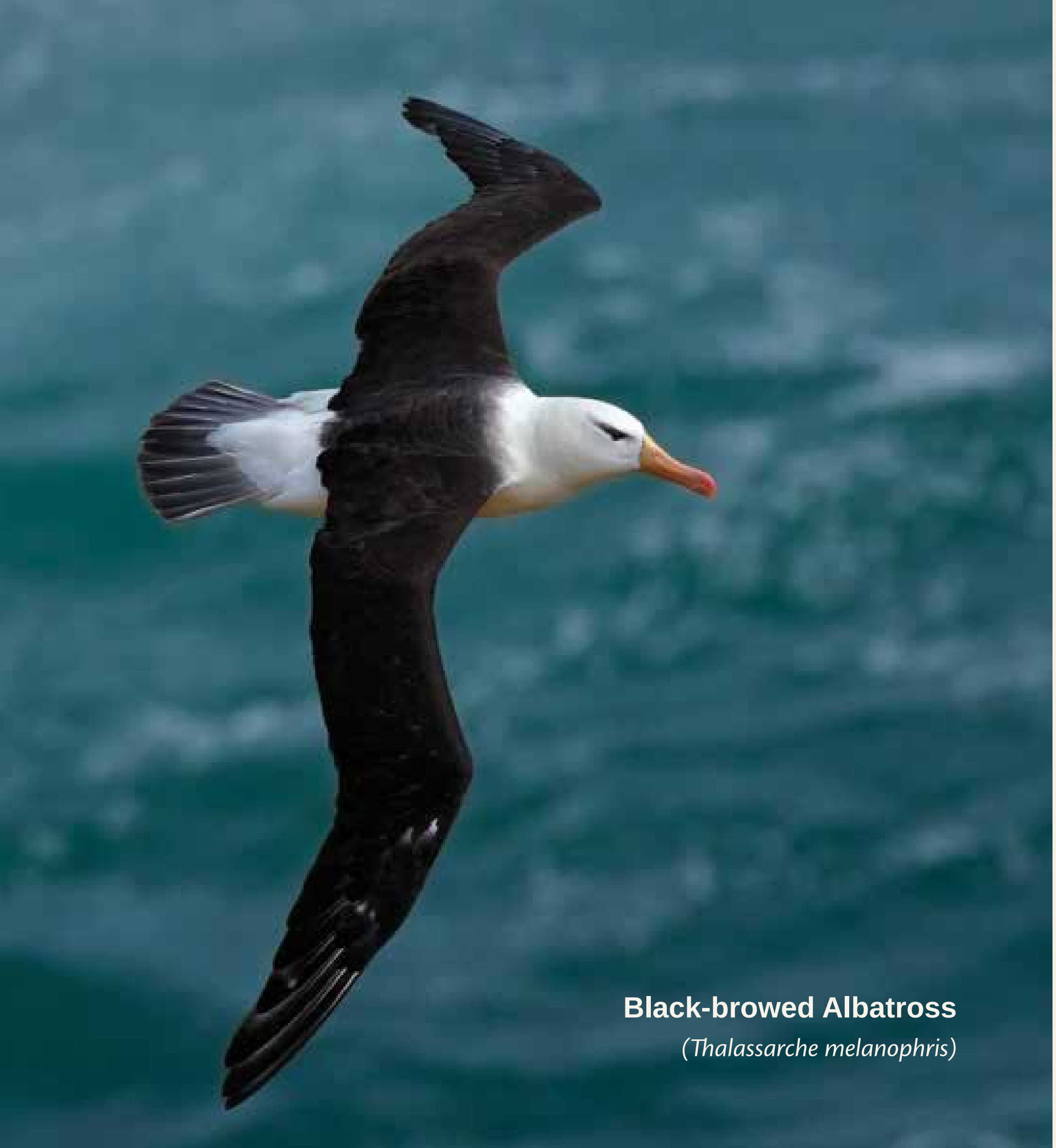
SPOTLIGHT ON RESEARCH:
Identifying Biological Mercury Hotspots in the Mesoamerican Barrier Reef System

The Mesoamerican Barrier Reef System is the largest coral reef in the Western Hemisphere and extends more than 1,000 km along the coastlines of Mexico's Yucatán Peninsula, Belize, Guatemala, and Honduras.

This reef system supports a diverse and active fishery that is affected by contaminant pollution, including mercury. In earlier research studies, BRI and collaborating scientists documented high mercury concentrations in marine fishes.

Current research focuses on measuring fish mercury concentrations sampled from the Gulf of Honduras and associated major watersheds in an effort to identify potential terrestrial sources of mercury that are delivered to the coastal zone and out onto the reef. Mercury concentrations in sea turtles were not determined in these studies.

The Great Blue Hole, comprising the Belize Barrier Reef, is home to approximately 80 percent of the Mesoamerican Barrier Reef System.



Black-browed Albatross
(Thalassarche melanophris)

Quick Notes

- **Focal taxa:** Shorebirds (e.g., plovers and sandpipers), long-legged waders (e.g., egrets and herons), sea ducks (e.g., eiders and scoters), seabirds (e.g., auks, frigatebirds, gulls and terns, pelicans, penguins, and petrels and shearwaters), and loons.
- **Field sampling techniques:** Use nonlethal tissues such as blood, feather, and inviable eggs.
- **Lab analytical techniques:** Analyze all tissues for total Hg because the form of Hg is primarily MeHg (>95%). Blood should be tested as ww; feathers do not need to be dried and should be measured as is unless external contamination is of concern (e.g., museum skins); and eggs can be tested as ww as long as they are fresh, if not they should be freeze dried and tested as dw. Complete homogenization of eggs is key for replicable comparisons.
- **Collaborative projects:** BRI is working with multiple US partners to better understand the best marine birds for monitoring spatial and temporal Hg trends. With a broad coalition of partners, BRI has also carried out several focused studies on marine bird groups, such as shorebirds, loons, and waterfowl, across large regions of North America.

Illustration opposite page: Common Eider

Marine Birds

Why Monitor Marine Birds?

Marine birds are useful bioindicators of coastal and marine ecosystem health—they are conspicuous, easily observed, long-lived, and wide ranging. These birds often live at the top of their food web where pollutants are accumulated over time, and some travel broadly over large swaths of ocean in search of prey, making them efficient samplers of broad scale environmental mercury. Studying contaminants in conjunction with tracking the movements and migrations of marine birds can highlight problem geographical areas or indicate mercury exposure at particularly critical life stages.

SPECIES SPOTLIGHT: *Black-browed Albatross*

Some marine birds are true ocean wanderers that can roam over vast areas of the globe. This puts them at great risk of consuming high levels of pollutants that build up in marine food webs, including mercury. Albatrosses can live more than 60 years, allowing mercury to accumulate with age. Their slow molt patterns and slow rate of reproduction—they only lay one egg at a time, and some species only breed every other year—limit opportunities to reduce their mercury burden.

Where to Monitor Marine Birds?

Body burdens of methylmercury vary considerably and elevated mercury levels may be the result of various anthropogenic activities. Highly colonial marine bird species are generally easy to locate during breeding and relatively easy to capture; marine birds are often sampled at colonies, where they leave to forage and return regularly to feed chicks.

Marine birds that are solitary nesters disperse widely across large expanses of habitat (e.g., coastal tundra), which makes monitoring them a challenge. Collaborative research studies can tap into existing networks to gain samples from a broad geographic region. Many marine birds spend much of the year at sea. Although access during winter can be more difficult, sampling is feasible if their migratory routes and regular stopover sites are known.

PUBLISHED PAPERS
BRI International Studies

RUSSIA, US, and CANADA: The Yellow-billed Loon (*Gavia adamsii*) is one of the rarest breeding birds in North America. Because of the small population size and patchy distribution, any stressor to its population is of concern. (Evers et al. 2014; Solovyeva et al. 2017).

UNITED STATES and CANADA: Contaminant exposure has been identified as one of five leading factors that may be limiting global shorebird populations. (Perkins et al. 2016).

UNITED STATES: Sea ducks are important indicators of ecological health and inshore marine pollution. In the northeastern United States, we compared concentrations of total mercury in Common Eider (*Somateria mollissima*) blood at several New England locations between 1998 and 2013 (Meattey et. al. 2014).


Northern Waterthrush
(Parkesia noveboracensis)

Quick Notes

- **Focal taxa:** General groups include blackbirds, flycatchers, rails, sparrows, swallows, warblers, woodcreepers, and wrens.
- **Field sampling techniques:** Use nonlethal tissues such as blood, feather, and inviable eggs.
- **Lab analytical techniques:** Analyze all tissues for total Hg because the form of Hg is primarily MeHg (>95%). Blood should be tested as ww; feathers do not need to be dried and should be measured as is unless external contamination is of concern (e.g., museum skins); and eggs can be tested as ww as long as they are fresh, if not they should be freeze dried and tested as dw. Homogenization of eggs is key for replicable comparisons.
- **Collaborative projects:** BRI is working with multiple US partners to better understand the best landbirds for monitoring spatial and temporal Hg trends. A new international study is planned within Indonesia with local universities and bird conservation groups.

Illustration opposite: Chestnut-headed Tesia

Landbirds

Why Monitor Landbirds?

Monitoring mercury in landbirds, specifically those that eat invertebrates such as spiders, is a relatively new phenomenon.

Recently, BRI discovered certain landbirds that fed on spider-influenced food webs within sites prone to high mercury methylation are exposured to dietary methylmercury that may equal or exceed associated fish-eating birds.

Because key landbird species (such as wetland songbirds) are generally more numerous and easier to capture, they can be more efficiently used as bioindicators of environmental mercury loads compared to other birds.

Where to Monitor Landbirds?

Landbird body burdens of methylmercury are greatest in certain habitats and elevated mercury levels may be a response to various anthropogenic activities. Mercury methylation is greatest in areas associated with water, therefore, wetlands are key habitats for determining mercury exposure in landbirds. Such habitats include bogs, marshes, estuaries, floodplains, and swamps. In some cases, montane habitats can be important areas for monitoring (because of consistent foggy conditions), especially in areas associated with wet soils.

Human-caused activities that may create even higher body burdens of mercury in landbirds include areas related to frequent or intense water level fluctuations, forest fires, erosion through degradation of vegetated areas, acid rain, and general impacts from climate change (e.g., greater number of intense storm events or warmer climates).

SPECIES SPOTLIGHT: *Northern Waterthrush*

Migration accounts for nearly 75 percent of all annual mortality rates in some songbirds; the added burden of toxic MeHg exposure may make long distance movements even more challenging.

For example, the Northern Waterthrush can receive elevated MeHg loads throughout its life cycle, from breeding areas in northeastern North America, in its staging areas in southern Florida, as well as its wintering grounds in Belize.

PUBLISHED PAPERS

BRI International Studies

CHINA: Landbirds in rice fields near to and distant from mercury contaminated areas in China have some of the highest mercury body burdens known in the world (Abeysinghe et al. 2017).

NICARAGUA: Tropical species such as rails, wrens, and blackbirds in Nicaragua showed elevated mercury body burdens (Lane et al. 2013).

GLOBAL: Effects thresholds were summarized and established for birds and mammals that have application for interpreting wildlife mercury exposure worldwide (Table 1; Evers 2018).

Table 1. Estimated effects thresholds related to a 10% loss in reproductive success.

	Tissue Type (ppm)		
Avian Forage Guild	Egg (ww)	Adult Blood (ww)	Adult Feather (fw)
Invertivores (e.g., songbirds)	0.11	0.7	2.4
Piscivores (e.g., loons)	0.48	1.5	10.0

Beluga Whale
(Delphinapterus leucas)

Quick Notes

- **Focal taxa:**
  Ecological health bioindicators: Toothed whales (e.g., beaked, beluga, bottlenose dolphin, narwhal, orca, pilot, and sperm)

  Human health bioindicators: Toothed whales (e.g., beluga, narwhal, and pilot) and pinnipeds (various seal species)

- **Field sampling techniques:**

  Nonlethal sampling should use skin biopsies, where skin can be correlated with muscle tissue and other tissues if needed for comparative purpose).

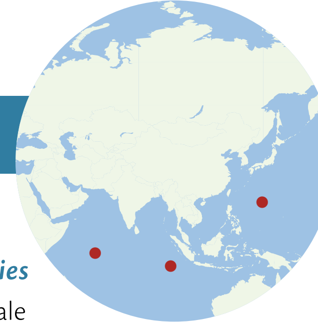
  Lethal sampling or sampling from carcasses can use liver/kidney, muscle, skin, and brain tissues.

- **Lab analytical techniques:** Skin tissue can be analyzed as total Hg, but should be analyzed on a dw basis (% moisture is 75% if there is a need to convert to a ww basis). Muscle, organ, and brain tissues can be analyzed on a dw or ww basis.

- **Collaborative projects:** BRI collaborated with a 5-year study to use the sperm whale as a global bioindicator of mercury and other contaminants (see next page).

  Illustration opposite page: Sperm Whale

Marine Mammals



Why Monitor Marine Mammals?

From the Antarctic to the Arctic, marine mammals move across great expanses of water and are adversely affected by mercury pollution accumulating in the world's oceans.

Marine mammals are a traditional component of the diet of many subsistence communities around the world, particularly in the Arctic. Research suggests that mercury emissions originating at lower latitudes are regularly transported to and deposited in the Arctic, and there is now added concern that warmer temperatures may be rapidly remobilizing formerly bound mercury stores from thawing glaciers, sediment, and permafrost.

Connecting Marine Mammals to Human Health

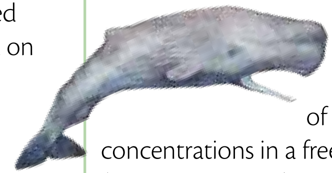
Based on data from our GBMS database, average marine mammal muscle tissue mercury concentrations are generally above safe consumption levels in all ocean basins, except the Antarctic Ocean. Because human communities within the Arctic Ocean can depend greatly on marine mammals, mercury concentrations in those mammals are of special concern.

Beluga whales (*opposite*), narwhals, and pilot whales are commonly harvested and often have muscle mercury concentrations that exceed human health consumption guidelines of one meal per month (based on mercury concentrations between 0.22 and 0.95 ppm, ww). The effect thresholds for bottle-nosed dolphin are poorly understood, but based on effect thresholds for terrestrial mammals, mercury exposure could be having significant adverse impacts on the reproductive success of marine mammals.

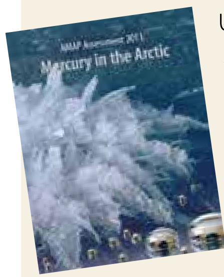
PUBLISHED PAPERS

BRI International Studies

GLOBAL: The sperm whale (*Physeter macrocephalus*) is a sentinel of ocean health due to its wide distribution, longevity, and high trophic level. Researchers surveyed mercury concentrations worldwide in the skin of free-ranging sperm whales considering region, gender, and age. These data provide the first global analysis of mercury and selinium concentrations in a free-ranging cetacean (Savery et al. 2013).



SPOTLIGHT ON RESEARCH: *Arctic Monitoring and Assessment Programme*



Under the direction of the Arctic Council, the Arctic Monitoring and Assessment Program (AMAP) conducts science-based assessments that support future actions in order to improve the conditions of Arctic ecosystems. The *AMAP Assessment 2011: Mercury in the Arctic* provides a detailed synthesis of the current study of mercury science in the North, as well as a number of science-based recommendations for future actions.

A new assessment on the exposure and potential impacts of mercury in the Arctic is also now available. To learn more, visit: **www.amap.no**

Quick Notes

- **Focal communities:** Arctic, Small Island Developing States, tropical ecosystems associated with ASGM
- **Field sampling techniques:** Hair is most commonly used; finger nails and urine are also occasionally used. Hair should be taken from back of head. Use the first two inches. Hair samples can be placed in an envelope or bag. Small blood samples (>50uL) are sufficient.
- **Lab analytical techniques**: Hg concentrations in both hair and blood tissues are primarily MeHg (>95%) so analyses of total Hg is sufficient. Hair samples are analyzed on a fw basis and blood samples on a ww basis. Hair samples can have external contamination (e.g., from ASGM, confined industrial settings, or use of hair products). In those cases, hair may not be primarily comprised of MeHg and will require analyses of MeHg (not only total Hg).
- **Collaborative projects:** In collaboration with UN Environment, BCRC-Caribbean, and IPEN, BRI is helping countries meet the goals of the Convention by coordinating field sampling of dozens of countries, analyzing tissue samples (mostly hair), and compiling a new and standardized global database on Hg concentrations in people around the world (n=74 countries).

People

Why Monitor People for Mercury?

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.

Where to Monitor People

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.

However, Arctic peoples are not the only populations burdened with potentially hazardous bioaccumulation of dietary methylmercury, as evidenced by hair mercury concentrations measured in humans from around the world.

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

PUBLISHED PAPERS

BRI International Studies

GLOBAL: A BRI-IPEN study based on mercury concentrations in human hair indicates developing countries are most likely to benefit from the implementation of the Minamata Convention on Mercury (Trasande et al. 2017).

GLOBAL: A review of mercury in humans worldwide demonstrated great variability of exposure with dietary sources for indigenous people of highest concern (Basu et al. 2018).

SPOTLIGHT ON RESEARCH: *Mercury Monitoring in Women of Childbearing Age in the Asia and the Pacific Region*

A recent study, supported by UN Environment and jointly conducted by BRI and the global NGO network 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% 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. Visit: **www.briloon.org/mercuryinhumans**

BRI's Contributions to the Minamata Convention on Mercury

Scientific Research Informs Policy

BRI has been a participant in the meetings of the Intergovernmental Negotiating Committee (INC) that preceded and have continued since the adoption of the Convention.

As co-lead of UN Environment's Mercury Air Transport and Fate Research partnership area, BRI is assisting with the development of a globally-coordinated mercury monitoring and observation system in association with leading a team to develop a chapter in the 2018 Global Mercury Assessment (AMAP/UN Environment; In Prep).

Helping Countries Prepare for Ratification

The INC and the Global Environmental Facility have developed a series of pre-ratification activities, called Minamata Initial Assessments (MIAs), that are designed to prepare countries for ratification and early implementation of the Convention.

BRI currently serves or will serve as an executing agency for more than 35 countries as part of the Convention's MIA activities.

Collaboration with UN Agencies

BRI is assisting three UN agencies to implement MIA activities around the world as: (1) an Executing Agency with the UN Industrial Development Organization; (2) an International Technical Expert with the UN Development Programme; and (3) an International Technical Expert with UN Environment.

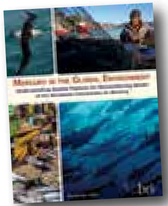
In addition to assisting these UN agencies with their MIAs, BRI is working to help with the implementation of the Minamata Convention by providing guidance to countries for biomonitoring (Table 2).

Table 2. A provisional slate of some potential bioindicators for evaluating and monitoring environmental mercury loads for ecological and human health purpose in four target biomes.

Terrestrial Biomes and Associated Aquatic Areas	Ecological Health Bioindicators			Human and Ecological Health Bioindicators		
	Freshwater Birds	*Marine Birds*	*Marine Mammals & Sea Turtles*	*Freshwater Fish*	*Marine Fish*	*Marine Mammals*
Arctic Tundra and Arctic Ocean	Loons	Fulmars, Murres	Polar Bears, Seals	Arctic Char, Arctic Grayling	Halibut, Cod	Beluga, Narwhal
Boreal Forest-Taiga and N. Pacific and Atlantic Ocean	Loons, Eagles, Osprey, Songbirds	Osprey, Petrels	Mink, Otter, Seals	Catfish, Pike, Walleye	Flounder, Snapper, Tuna	Pilot Whale
Temperate Mixed Forest and Pacific and Atlantic Ocean	Loons, Grebes, Egrets, Herons, Osprey, Terns, Songbirds	Cormorants, Osprey, Terns	Otter, Sea Turtles, Seals	Bass, Bream, Mullet, Walleye	Barracuda, Mackerel, Sharks,Tuna	
Tropical Rainforest and S. Pacific and Atlantic and Indian Ocean	Egrets, Herons, Kingfishers, Songbirds	Albatrosses, Frigatebirds, Noddy, Shearwaters, Terns, Tropicbirds	Otter, Sea Turtles, Seals	Catfish, Snakehead	Barracuda, Grouper, Sharks, Snapper, Swordfish, Tuna	Pilot Whale

Resources and References

BRI Science Communications



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The symbol Hg is derived from the Latin *hydrargyrum* (meaning watery silver).

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