MERCURY IN INDONESIA

REDUCING SUPPLY AND AVAILABILITY

2022

Reducing Mercury in Indonesia

The Minamata Convention on Mercury

Mercury is a pollutant of global importance that adversely affects human health and the environment. Environmental concentrations of mercury have increased three-fold globally due to human industrial activities, and the world's freshwater ecosystems, estuaries, and oceans are primary reservoirs where mercury is deposited.

The goal of the Minamata Convention on Mercury is to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. In support of this goal, the Convention contains provisions that relate to the entire life cycle of mercury, including controls and reductions across a range of products, processes, and industries where mercury is used, released, or emitted. The Convention also addresses the direct mining of mercury, its export and import, its safe storage, and its disposal.

Mercury in the Environment

Mercury is a naturally occurring element that can be released to the environment from fires, volcanic eruptions, or geothermal activities—but mercury is primarily released through human activities (Figure 1). Of the estimated 5,500-8,900 tons of mercury currently emitted and re-emitted each year to the atmosphere, only about 10 percent is attributed to natural sources (UNEP 2013).

Due to its unique properties, mercury has been used in various products and processes for centuries. The largest contributor to global emissions is artisanal small-scale gold mining (ASGM; Figure 1). ASGM is by far the largest contributor in Indonesia (Figure 1a) in amounts so substantial that as a single country its contribution is measurable at the global scale (Figure 1b).

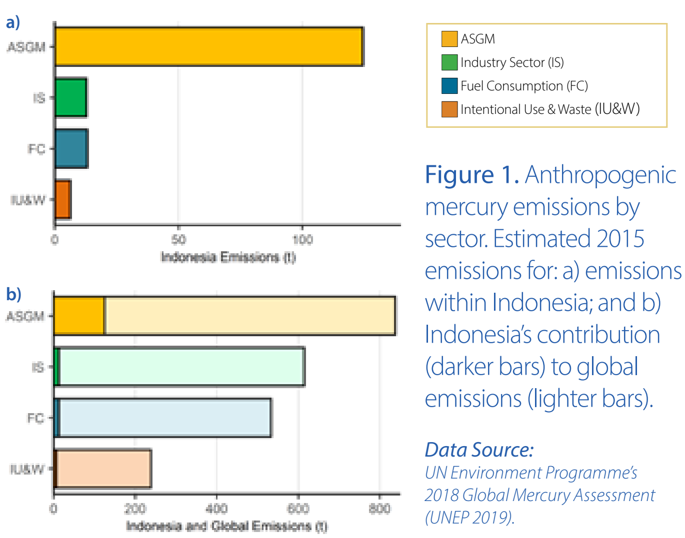


Figure 1. Anthropogenic mercury emissions by sector. Estimated 2015 emissions for: a) emissions within Indonesia; and b) Indonesia's contribution (darker bars) to global emissions (lighter bars).

Data Source:
UN Environment Programme's 2018 Global Mercury Assessment (UNEP 2019).

Based on the results of a new mercury inventory (Dewi and Ismawati, 2019), the main source of mercury contamination (52 percent or 158 tons) came from ASGM gold production using mercury amalgamation, where approximately 32 percent of the contamination was emitted to the air.

How are People and Wildlife Exposed to Mercury?

People are commonly exposed to mercury through the consumption of fish, birds, and marine mammals. In addition, people are exposed to mercury from emissions and releases to land, water, and air through industrial processes. ASGM mercury contamination occurs directly at the mining site via releases to the water and soil, as well as into the air at processing areas where mercury is burned off from gold and pollutes the air. Local mercury air pollution can harm people and the environment unrelated to the mining activity.

A Collaborative Project to Reduce Mercury

Biodiversity Research Institute (BRI), in collaboration with Nexus3 and other nongovernmental organizations, is leading this three-year project, the purpose of which is to support the Government of Indonesia in restricting mercury supplies, especially for the artisanal small-scale gold mining sector.

Project efforts include four major components:

1. Legal/regulatory/policy actions to restrict mercury supplies produced by mining and mercury by-products from other activities.
2. Develop and implement a plan to reduce the trade in illegal import/export of mercury.
3. Develop and implement a plan to securely store elemental mercury waste, mercury added medical devices, and cinnabar.
4. Monitor mercury to determine the magnitude of human and ecological health impacts and prioritize generation and site selection of Local Action Plans (LAPs) to ultimately track project effectiveness.

Study Sites

Four sites to initiate LAPs that would include monitoring to evaluate environmental and human health:

- Bombana in Sulawesi
- Landak in Kalimantan
- Mandailing Natal in Sumatra
- West Sumbawa and West Lombok

See map on page 7

1–Legal/Regulatory/Policy Actions

The Indonesian Government ratified the Minamata Convention in 2017. Following the ratification, the Indonesian President issued a Decree No. 21/2019 on the National Action Plan on Reduction and Elimination of Mercury.

To improve the regulatory framework in order to control and eventually eliminate the importation, exportation, and distribution of mercury, we recommend:

- Revising the category of mercury in the attachment of Government Regulation No. 74/2001 on Hazardous and Toxic Substance from restricted use to prohibited;
- Stipulating mercury as a prohibited substance to be traded under the Larangan dan Pembatasan/prohibition and restriction policy and provide criminal sanctions for the violations;
- Listing the Harmonized Customs (HS) code for mercury in the Indonesia National Single Window (INSW) as a substance prohibited from being imported/exported, and integrating the INSW procedure with the B3 notification based on Government Regulation No. 74/2001; and
- Prohibiting cinnabar mining and the use of mercury in ASGM and providing administration and criminal sanctions for violations, which can be done through the revision of the Mineral and Coal Mining Law and/or the issuance of Regional Regulations.

PROJECT COMPONENTS (including Trade)

Our goals include assisting the development of national plans and policy to restrict mercury supplies from primary mining and to restrict mercury by-products from oil and gas. The project team will pursue five objectives:

- Prepare and adopt needed amendments to the National Implementation Plan and Roadmap for Mercury to include prohibitions on cinnabar mining, recirculation of mercury from oil and gas and mining sectors, and export of mercury. (Yr 1)
- Develop and adopt policy guidance prohibitions on cinnabar mining throughout the country, and on recirculation of mercury recovered from by-products of oil and gas and mining sectors to the market. (Yr 1)
- Develop policy guidance and/or legislation to prohibit export of elemental mercury and cinnabar ore from the country. (Yr 1)
- Advise relevant ministries to revise/update regulations to support the recommendations of this project. (Yr 3)
- Assist Government with implementation and monitoring of policies and/or legislation. (Yrs 2-3)

Existing law enforcement pertaining to cinnabar mining and distribution could be more effective. Therefore, we recommend:

- Strengthening law enforcement by targeting the head of illegal activities in relation to cinnabar mining, import, export, distribution, and use of mercury in artisanal mining rather than focusing on smaller players. Based on our study, criminal sanctions imposed were minimal and the current approach fails to capture the mastermind;
- Strengthening the procedure for the execution of the court orders pertaining to mercury;
- Providing guidelines regarding the treatment and handling of the confiscated mercury and/or cinnabar to implement Ministry of Environment and Forestry Regulation No. P.26/ 2017 Article 7 (k), Article 41, Article 42 and Article 43.

Cinnabar, the most common source ore for refining elemental mercury, is associated with recent volcanic activity. Cinnabar mines are used for supplying mercury in the country for ASGM activities. *Right:* A smelter to refine cinnabar for useable mercury.

2–Mercury Trade

Mercury has been used in Indonesia since the 1990s. Specifically, it is widely used in the artisanal and small-scale gold mining (ASGM) sector. Since the early 2000s illegal gold mining has increased in Indonesia, driven in part by the exponential increase in global gold prices. Various studies have shown an increase in the activity of ASGM and mercury-induced pollution in several provinces in Indonesia.

Globally, UNEP (2019) identifies the ASGM sector as a major contributor to global mercury emissions (38 percent); Dewi and Ismawati (2012) identified mercury emissions from the ASGM sector as the main source of mercury emissions (57.5 percent) in Indonesia.

Until 2014, Indonesia imported mercury from various countries. However, following the adoption of the Minamata Convention in 2013, exporters, such as the European Union and the United States, imposed bans on mercury exports. By 2016, global mercury production and export had shifted from the Northern Hemisphere to East Asia and South America. In 2016, Indonesia became one of the largest mercury producers and exporters in the world, exporting 311 tonnes of mercury to 11 countries.

Today many of these current mercury supply chains are illicit. Indonesia's Ministry of Trade has prohibited the import, trade, and use of mercury in the mining sector. However, mercury continues to be widely used in the Indonesian ASGM sector and large amounts of mercury are reported to be smuggled out of the country to other gold producing nations.

From these known mining locations (Figure 2), ore is transported to Java, in particular Jakarta and Sukabumi in West Java and Surabaya in East Java, where it is processed into usable mercury. Mercury is then sold to the Indonesian ASGM sector or exported.

Illegally traded mercury is confiscated by local police. The mercury trade uses a variety of containers for transport.

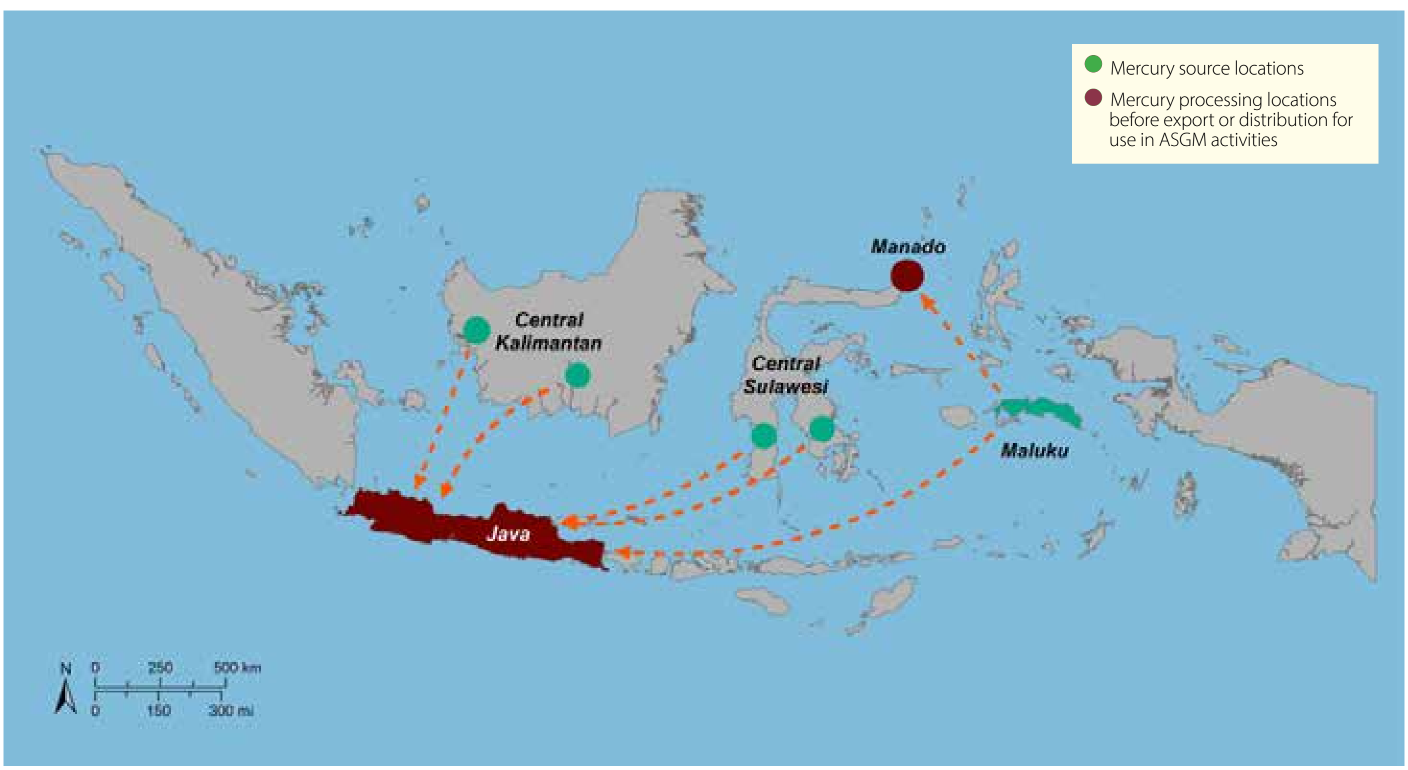


Figure 2. From these known mining locations, ore is transported to Java where it is processed into usable mercury.

3–Mercury Contaminated Sites, Storage, and Waste Management

Contaminated Sites

Mercury contaminated sites in Indonesia are primarily created by ASGM activity when mercury is released to the environment. Mercury contamination can be expected around ball-mill processing areas, tailings disposal sites, cyanidation of mercury processed ore, and even locations where amalgamation is regularly practiced.

Even if all mercury use is stopped in ASGM, the existing contaminated sites will present a significant human health and environmental hazard until they are identified and remediated.

As part of this project, we will provide guidance on the identification, assessment, and management options for mercury contaminated sites. The guidance will focus on rapid, inexpensive screening methods to identify high-risk sites and inventory development to allow prioritization of resource allocation to the highest risk sites. Options for self-financing remedial options that recover gold and mercury from ASGM tailings are also explored.

Storage

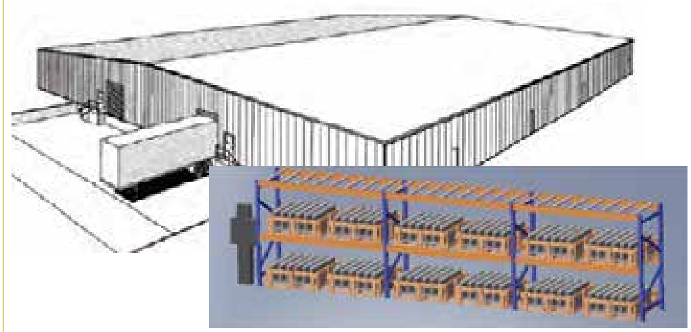
Elemental mercury confiscated from gold mining, illegal imports, and other sources requires a secure tracking and storage system. This includes a decentralized multi-tier storage system that allows police to safely and securely store confiscated mercury and cinnabar in the field. Once secured, mercury can be repackaged at interim storage sites pending transfer to final storage in Indonesia or export as waste.

Recommendations can be made in relation to the long-term storage/disposal of mercury and the need to convert it to safe, stabilized compounds that cannot be readily transformed back into commodity grade mercury.

Top: The panning process of cinnabar and gold in Luhu Village coastline, West Seram Regency, Maluku.

Left: Washed and dried cinnabar ores ready to be transferred to mercury smelters in Java.

Diagram of one type of mercury storage facility



Mercury should be retired from commercial sale and stored in special flasks in an interim storage facility until it can be stabilized (in a process using sulphur) for long-term disposal.

Waste Management

Mercury waste is present in very large volumes in the form of ASGM tailings and, to a lesser extent, through obsolete products and industrial waste. Significant quantities of mercury contaminated waste are rising through the oil and gas sector in Indonesia.

While several mercury waste treatment and stabilisation facilities exist in the region (e.g., Australia and Thailand), it would be preferable for Indonesia to establish its own mercury waste treatment and/or stabilization plant with a final disposal site to avoid export of mercury, manage its industrial mercury waste and ensure mercury is not diverted back to ASGM.

PROJECT COMPONENTS

The work of this component is to develop and implement multiple local plans for handling, interim storage, and final storage of mercury and cinnabar ore. Project team will collaborate with the Government of Indonesia's authorities to achieve these objectives:

- Elaborate the National Implementation Plan into multiple LAPs to reduce and eliminate mercury to include safe handling, interim storage, and final storage of mercury and cinnabar ore. (Yr 1-2)
- Build central and local government capacity, including law enforcement agencies, to handle and store mercury that has been removed from ASGM activities as part of LAPs. (Yr 2)
- Implement one or more LAPs as pilot projects to test for wider implementation throughout Indonesia in potential sites to be determined. (Yrs 2-3)

4–Mercury Monitoring: ASGM Hotspots

Identifying ASGM Hotspots

The four locations—Bombana, Landak, Mandailing Natal, and West Sumbawa—were chosen based on the following criteria:

- Sites that contain active mines and use mercury intensively;
- Sites with ASGM activities near or in ecosystem sensitive areas, national parks, or protected areas;
- Sites where strong initiatives exist to rehabilitate the degraded land, and plans are in place to characterize and remediate mercury contaminated sites;
- Sites where there appears to be strong political will.

Top: Liquid mercury is added to silt in the ball-mill. Excess mercury may end up in local waterways during disposal. ***Inset:*** Heating the amalgam vaporizes the mercury, which pollutes the air.

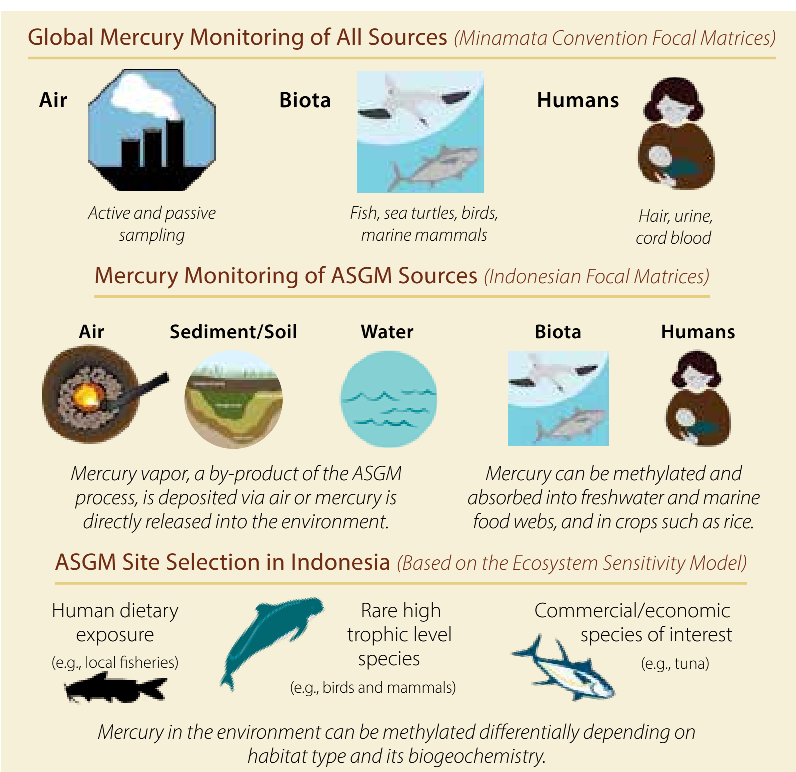


Figure 3. Mercury monitoring priorities of sources and ASGM sites in Indonesia.

Mercury: Spatial Distribution and Temporal Patterns

The compilation of existing biotic mercury data is an important approach to understand broad spatial gradients and temporal patterns. Recent global modeling efforts show 49 percent of global mercury deposition occurs over the tropical oceans (UNEP Global Mercury Assessment 2018).

The equatorial Pacific region is an essential commercial harvesting location for many large pelagic species, such as tuna, that are responsible for a large fraction of human exposure to methylmercury (the organic form of mercury that enters the food web). Recent global modeling efforts show 49 percent of global mercury deposition occurs over the tropical oceans (UNEP 2019).

In freshwater ecosystems, a global meta-analysis suggested that mercury biomagnification through food webs is highest in cold and low productivity systems, however large contaminated sites (e.g., ASGM areas) are likely important drivers of variability in tropical freshwater biota concentrations. Indonesia has many ASGM sites (Figure 5).

Our understanding of how mercury released from ASGM, and associated conversion to methylmercury, exposures, and impacts on human and ecological health is now one of the more important data gaps to fill.

Establishing and understanding patterns of ASGM-derived mercury and other sources of mercury over time and space are critical to developing appropriate strategies to reduce contamination, and are essential for sustaining biomonitoring activities to track progress in a time-efficient and cost-effective manner.

Mercury contaminates the environment, which in turn impacts people via the food they eat. Ideally, mercury monitoring programs sample abiotic (nonliving) and biotic (living) components of our natural world. The Minamata Convention has identified sampling priorities for all (Figure 3).

Monitoring mercury in people can uncover how mercury is contaminating local populations, and help determine solutions to reduce negative impacts. Noninvasive methods (i.e., collecting hair or urine samples) can reveal a great deal about where and how the mercury gets into people (Figure 4).

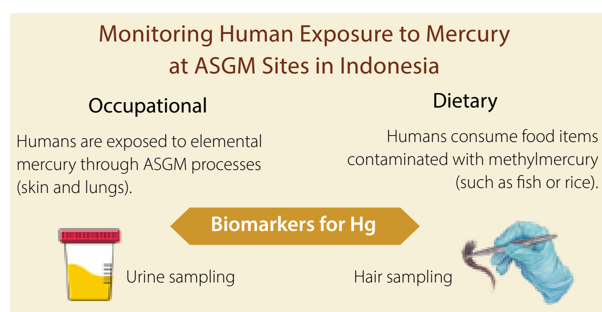


Figure 4. Different biomarkers are used for human monitoring depending on the source of mercury.

ASGM Sites in Indonesia

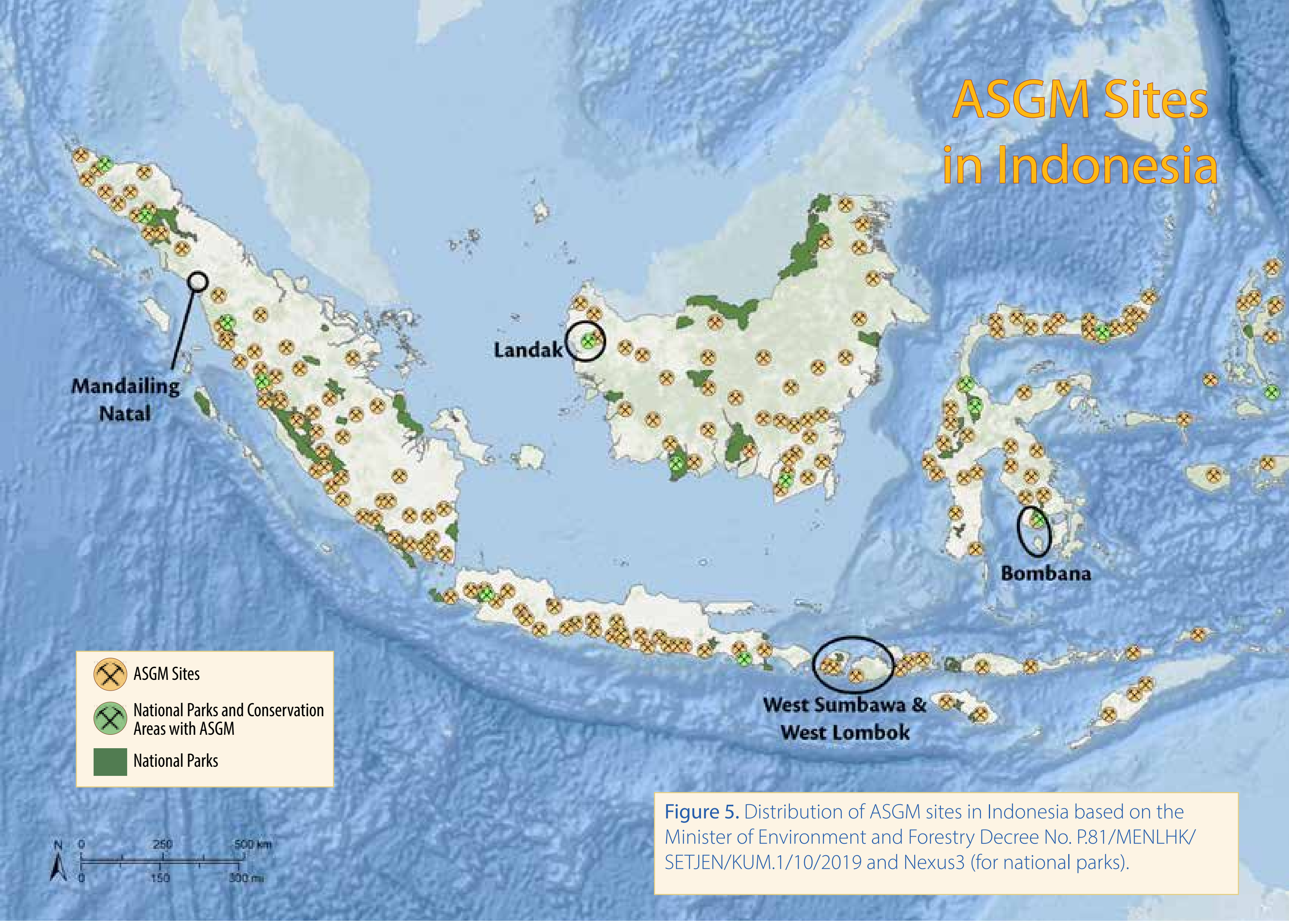


Figure 5. Distribution of ASGM sites in Indonesia based on the Minister of Environment and Forestry Decree No. P.81/MENLHK/SETJEN/KUM.1/10/2019 and Nexus3 (for national parks).

Bombana in Sulawesi

Mandailing Natal in Sumatra

Landak in Kalimantan

West Sumbawa and West Lombok

A Two-pronged Approach

Mercury emissions, deposition, and releases into the environment explain only part of the spatial story of mercury pollution. Ecosystem sensitivity and food web relationships help further define the actual risks to human and ecosystem health.

Elemental mercury is converted to a more toxic organic form of mercury through the process of methylation, which occurs with the help of bacteria found primarily in wet areas. Large variations in methylmercury concentrations may occur in different parts of the food web depending on the sensitivity of the ecosystem to mercury input.

Where methylmercury availability is elevated, fish and wildlife may exhibit harmful mercury concentrations and represent the places that will require the most attention by countries and global monitoring programs.

The threat of mercury contamination can be understood by mapping the combination of these two factors— the risk of mercury contamination from multiple sources and ecosystem sensitivity to mercury methylation. A new global mercury threat assessment was constructed (maps to the right), and Indonesia emerged as highly threatened, as the majority of Indonesia occurs in the highest risk and sensitive areas on the globe (Figure 6).

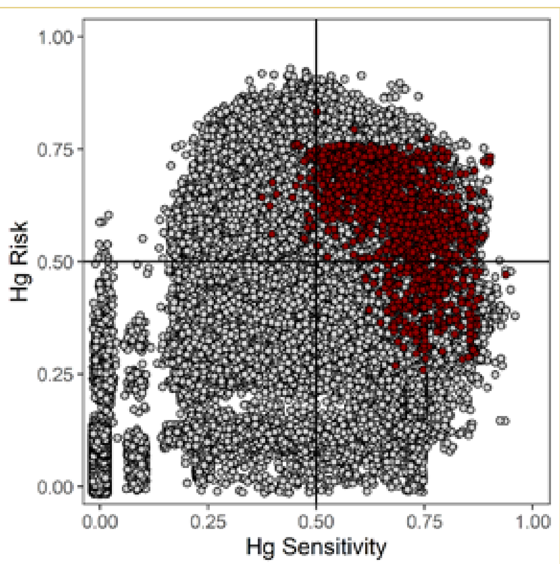
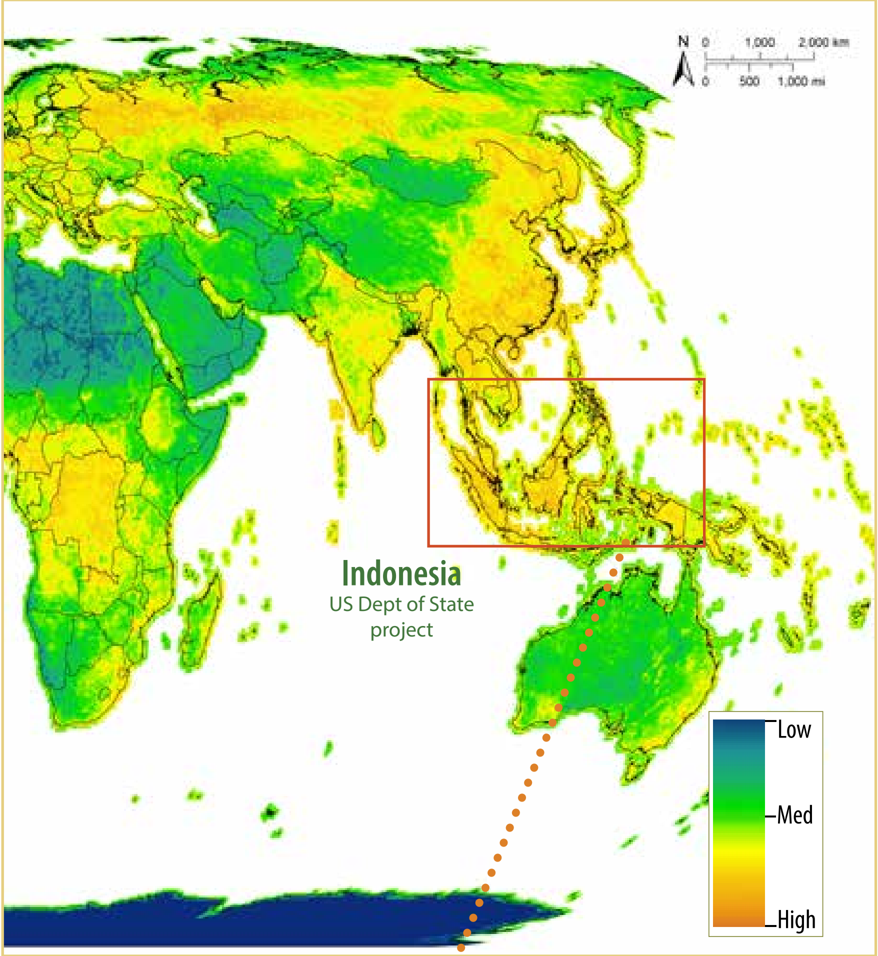
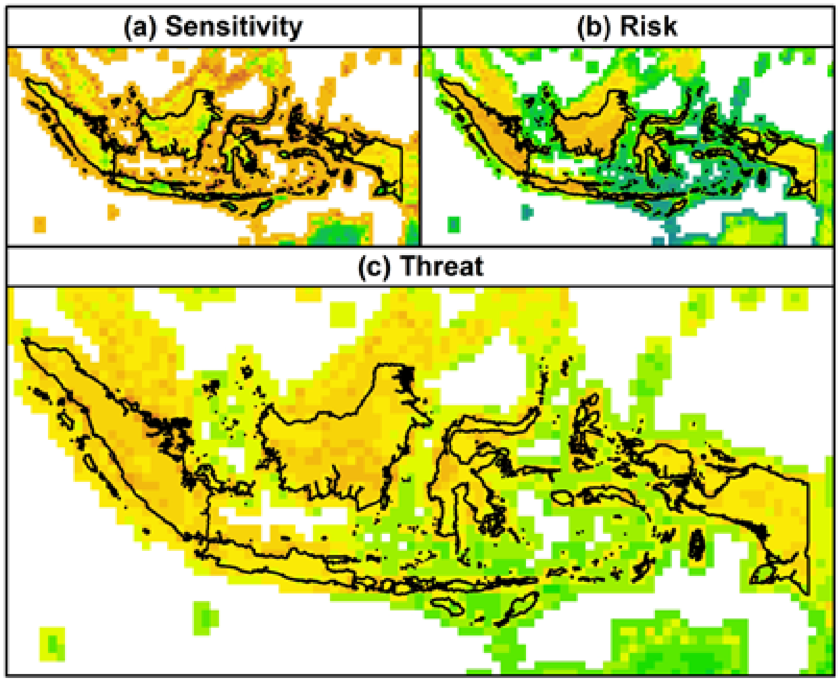


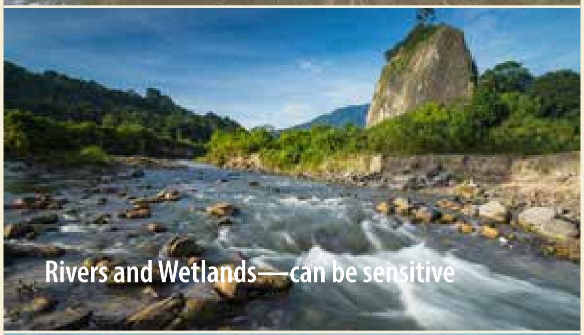
Figure 6. Global mercury risk and sensitivity fingerprint. Indonesia's pixels are colored red; the rest of the world is depicted with gray pixels. The vast majority of Indonesia's pixels are in the highest risk and sensitivity (upper right) quadrant.

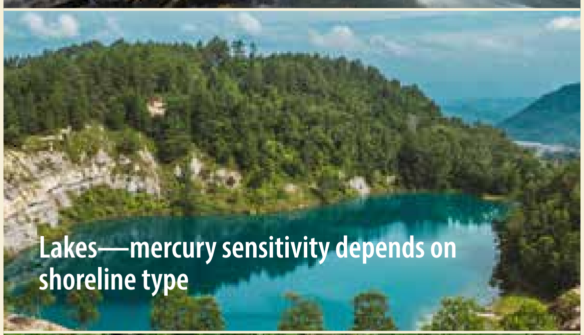




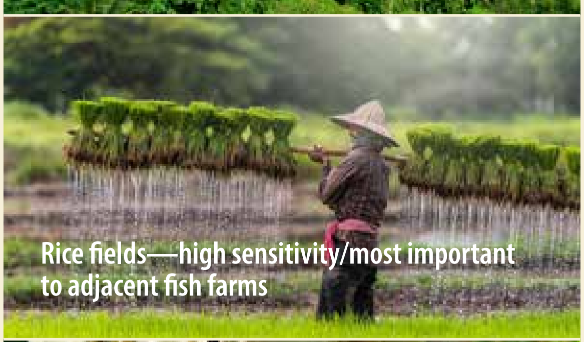
Enlargement of Indonesia to illustrate the spatial distribution of high mercury risk and ecosystem sensitivity that contribute to the overall high threat rating.


Mangroves—highly sensitive


Rivers and Wetlands—can be sensitive


Lakes—mercury sensitivity depends on shoreline type


Forests—can be sensitive


Rice fields—high sensitivity/most important to adjacent fish farms


Agriculture—low sensitivity

Mercury can pose a significant threat to freshwater ecosystems. Increased availability due to human disturbances and the management of natural resources (e.g., dams and reservoir management) may exacerbate mercury's availability to enter food webs. Much of the contamination of people and natural resources in the terrestrial environment is derived from mercury cycling through nearby freshwater ecosystems (UNEP 2019).

Factors Affecting Mercury Sensitivity in Indonesia

Landscapes factoring into mercury sensitivity are often related to either enhancing (+) or dampening (-) methylation abilities by bacteria within most ecosystems. Habitats with wetlands that are often identified as having great sensitivity include:

- Mangrove areas (++)
- Identified RAMSAR* wetlands (+): these areas are protected by the RAMSAR Convention and tend to be large and of high quality;
- Waterbodies (+) and their associated shorelines are generally areas of moderate to high mercury methylation and include lakes, ponds, rivers, and streams
- Forest Cover (+) contributes to capturing more dry mercury deposition and ultimately more methylation abilities on the forest floor
- Rice Fields (+) are generally good areas for mercury methylation because of their regularly occurring wet-dry cycles, which can remobilize methylmercury generated in anaerobic areas of the pore water of soils
- Agriculture areas (-) generally dampen methylation abilities of the bacteriam sometimes through a process of biodilution.

Why is Ecosystem Sensitivity Important?

Ecosystem sensitivity explains the relationship between the amount and type of mercury entering an ecosystem and that environment's ability to methylate mercury (Figure 5). Methylation is the process by which elemental mercury is converted to organic methylmercury by bacteria and other microbes. Methylmercury is toxic and can accumulate to high concentrations in the tissues of fish, wildlife, and humans, causing numerous negative health effects.

Because a small amount of mercury in a highly sensitive ecosystem is likely to be more damaging than a large amount of mercury in an ecosystem with relatively little sensitivity, it is important to identify and work on those systems that are the most sensitive.

How Do We Determine Ecosystem Sensitivity?

The extent to which mercury is methylated and made available in the environment is complex and can be influenced by numerous factors. Specific ecosystem conditions can facilitate the production and bioavailability of methylmercury, such as moderate amounts of sulphate and low oxygen conditions that often occur in wetlands.

**The Convention on Wetlands of International Importance holds the unique distinction of being the first modern treaty between nations aimed at conserving natural resources. The signing of the Convention on Wetlands took place in 1971 at the small Iranian town of Ramsar. Since then, the Convention on Wetlands has been known as the Ramsar Convention. The Ramsar Convention's broad aims are to halt the worldwide loss of wetlands and to conserve, through wise use and management, those that remain. This requires international cooperation, policy making, capacity building, and technology transfer.*

Environmental Monitoring—Next Steps

As illustrated so far, at a global scale, ASGM activity appears to highly threaten Indonesia. But can we actually see these impacts, and if so, how bad are they?

Environmental monitoring plays a valuable role in quickly assessing not only the threat of mercury contamination, but its impact as well. In Figure 7, we see the results of recent (2019) environmental monitoring efforts. The average mercury value for each of the abiotic indicators (i.e., water, soil, sediment, and air) were contaminated well above human health safety thresholds—most by more than 10 times. Humans were also highly contaminated, whether measured by noninvasive (hair and urine) or invasive (blood) methods. From a biotic perspective, plants were also highly contaminated.

Surprisingly, fish were not highly contaminated; this is likely because the number of samples was low (only 35), which was not enough to provide a complete picture if we look solely at the average values. However, there is evidence that both freshwater and marine species are highly contaminated (Figure 8).

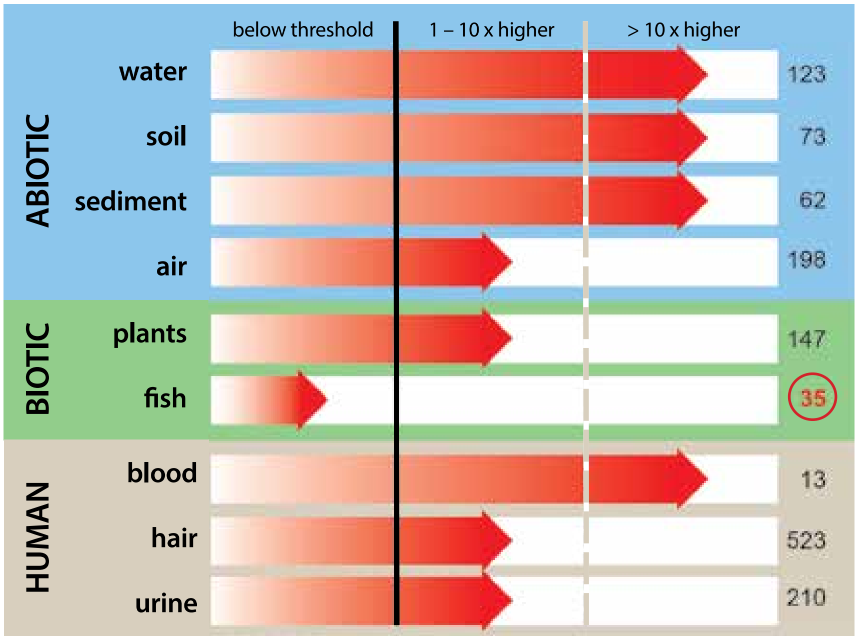


Figure 7. Average mercury contamination levels of various abiotic, biotic and human biomarkers in relation to human health safety thresholds, and the number of samples that these mean values were derived from.

Adaptive Management

There are gaps in our understanding about the relationship between anthropogenic releases of mercury and its subsequent bioaccumulation and biomagnification in freshwater and marine food webs, and how that may translate to exposure and risk at the local, regional, and global scale to fish, wildlife, and humans.

Identifying populations at risk, boosting medical care, and better training of healthcare professionals in identifying and treating mercury-related effects will contribute toward successful implementation of the Convention.

Adaptively managing our approach to reducing mercury contamination must be informed by a well-developed monitoring program (Figure 9). In this way we can learn to improve our efforts to reduce mercury contamination, and improve the health of people and nature at home and across the globe.

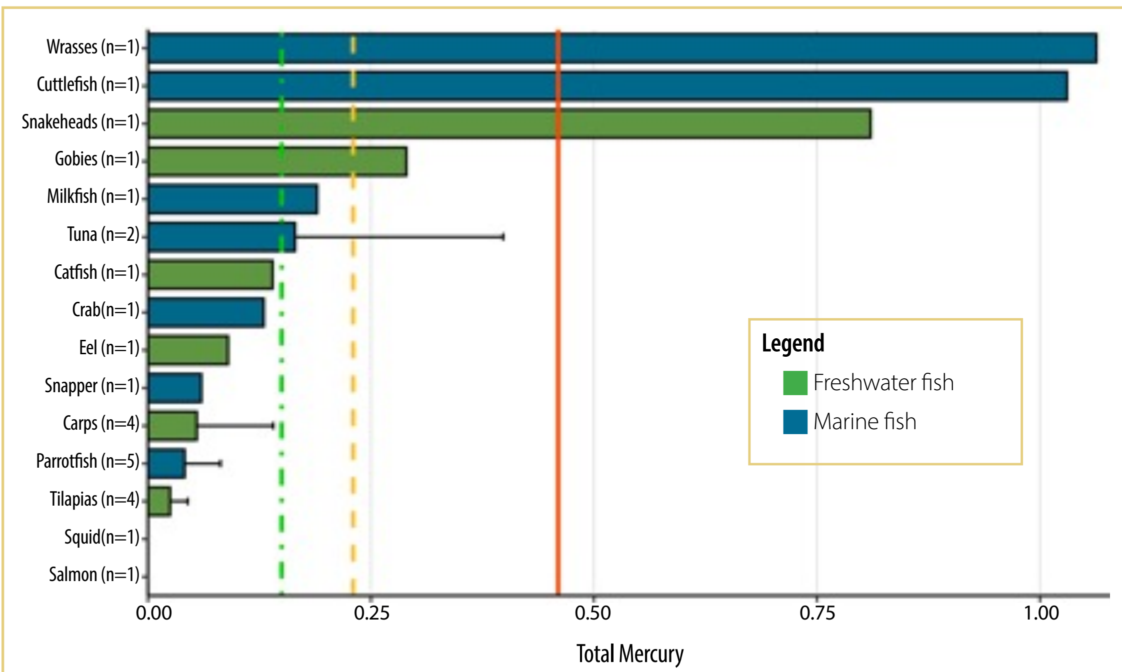
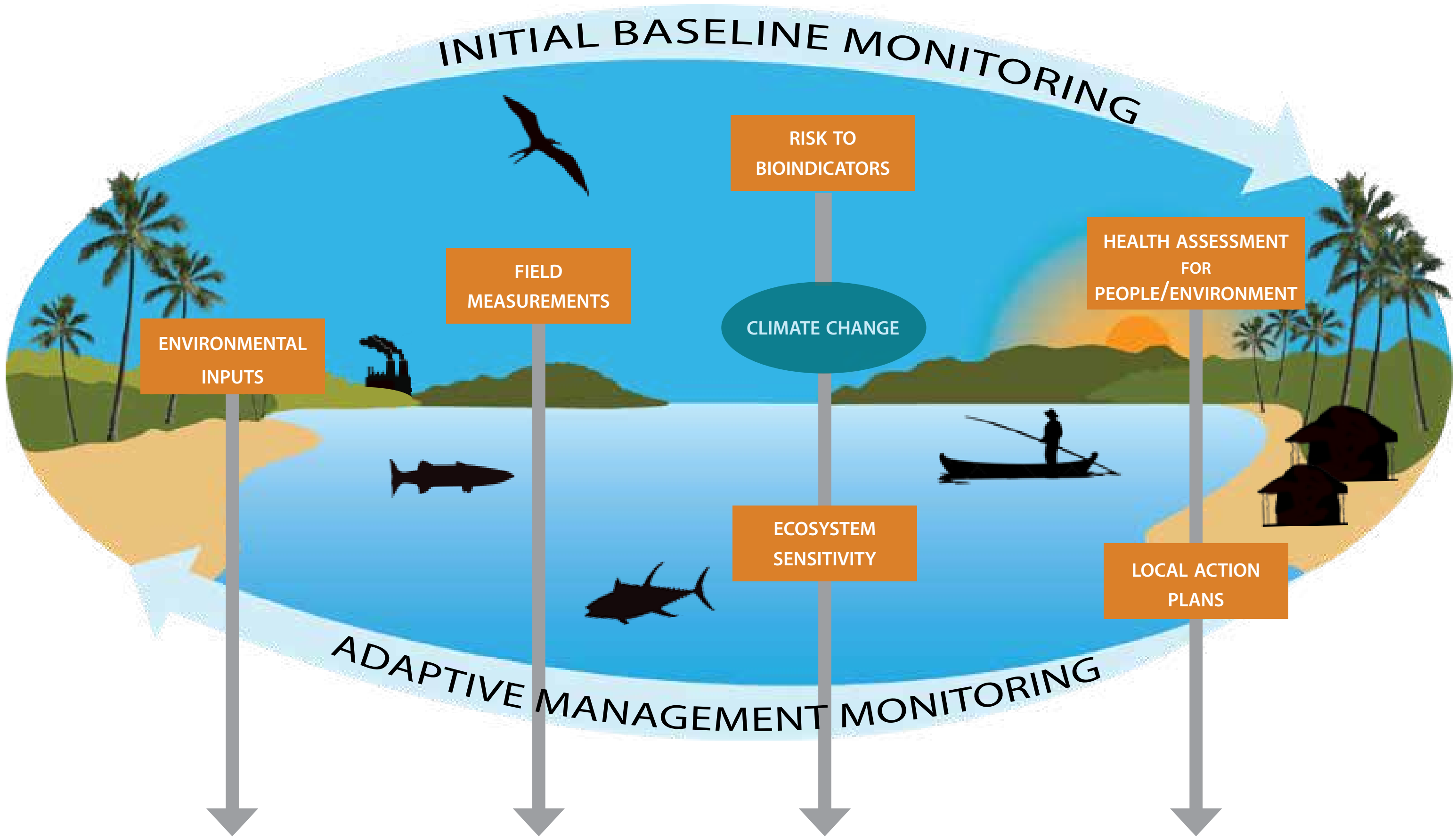


Figure 8. Mercury levels in freshwater (green) and marine (blue) fish species in relation to public health safety thresholds.

Levels above the red solid line indicate species that should not be eaten.

Levels below the green dashed line are safe for consumption.

Levels between the green dashed line and red line represent various levels of caution (above or below the yellow dashed line).



Mercury Sources

- Gold mining—artisianal and commercial
- Cement production
- Coal combustion
- Oil and gas drilling and refineries
- Mercury-added product waste—burning in landfills
- Nonferous metal production

(Mercury can be remobilized from erosion and fire)

Ecosystem Components

- Mercury source inputs through air deposition and effluents
- Wetland types— e.g., peatland, mangrove, rice fields
- Water quality—e.g., pH, DOC
- Temperature/precipitation
- Percent forest cover
- Percent agricultural land
- Soil type
- Wetting/drying cycle
- Food web length—biomagnification

Mercury Biomonitoring

FISH

- Carnivores or Piscivores (tuna)
- Carnivores or Piscivores (barracuda)

BIRDS

- Piscivores (frigatebirds)
- Invertivores (songbirds)

MAMMALS

- Piscivores (otters)
- Invertivores (bats)

HUMANS

- Subsistence/fishing communities
- Children, pregnant women

Addressing the Issue

- Assessement/interpretation of environmental condition as related to inorganic mercury impacts to humans (through occupational use) and organic mercury impacts in the food web to biota and humans.
- Identification of actions to reduce the use and waste of mercury in communities due to ASGM activities
- Follow-up (adaptive) monitoring to evaluate success.

Figure 9. Environmental Monitoring. To best interpret bioindicator mercury exposure over time and space, ecosystem components sensitive to methylation rates need to be identified, collected, and interpreted. While such metadata are critical for high quality interpretation, the changing climate creates increasing urgency. With the volume of information on effects thresholds available for major biota groups and humans, risk assessments can be more confidently generated.

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