Mercury Monitoring

Belize

A Series Publication for the Caribbean Region Mercury Monitoring Network

Introduction

In response to opportunities for ratifying the Minamata Convention on Mercury, Belize is conducting a Minimata Initial Assessment (MIA). Through funding from the Global Environment Facility (GEF) and guidance by the United Nations Environment Programme (UNEP), Belize is making great strides toward meeting the obligations of the Convention. These efforts provide a better understanding of the mercury sources, uses, releases, use of biota for mercury monitoring (Evers et al. 2016).

Approximately 62 percent of Belize is forest land. The coast is characterized by one of the world's largest coral reef systems— the MesoAmerican Barrier Reef. The fisheries sector plays an important role in the economy (3 percent of GDP; FAO 2018). The local catch is primarily from the reef shelf and, to a lesser degree, inland waters. This domestic production contributes a substantial amount of the estimated 13.8 kg per capita annual fish consumption level and serves as an important source of protein.

Mercury in the Environment

Mercury is released into the atmosphere mainly in elemental or inorganic forms, but can be converted into methylmercury by complex microbial processes, primarily in aquatic systems (Podar et al. 2015). Methylmercury is a potent neurotoxin that impairs physiological and neurological functioning and causes reproductive harm (Evers, 2018). Methylmercury bioaccumulates in individual organisms and biomagnifies up through the food web and has been documented in wildlife both in close proximity to, and distant from, point sources (Driscoll et al., 2013). Human exposure to methylmercury is known to cause adverse health effects particularly in young children and developing fetuses (Basu et al., 2018).

Fishing communities are an important part of Belize society.

Environments that are sensitive to mercury can lead to higher than otherwise expected mercury concentrations in the food web, including for humans. Human exposure occurs most often through diet, primarily consumption of seafood, with methylmercury the predominant form of mercury found in fish muscle (Sunderland, 2007).

Caribbean Region Mercury Monitoring Network (CRMMN)

A network of integrated laboratories for the Caribbean Region will be developed over the next few years, with the focal lab based in Antigua and Barbuda. These labs will serve as the regional hub for mercury analyses of abiotic and biotic samples often used for assessing human and environmental health. Standardized protocols for biological sampling, handling, and shipping of samples to the regional lab hubs will be developed during regional workshops. Belize, a Party to the Minamata Convention on Mercury, is also now a member of the CRMMN.

As part of the MIA in the Caribbean region, researchers conducted a study of ecosystem sensitivity and evaluated fish and wildlife exposure in Belize. The study was designed to identify patterns of mercury on three levels:

1. Identify spatial patterns of mercury sensitivity—We used landscape-scale environmental indicators to identify areas that may be disproportionately sensitive to mercury contamination. We identified spatial patterns of potential mercury sensitivity at a watershed level using widely available geospatial data.
2. Quantify mercury exposure levels in wildlife and humans—In order to address mercury exposure, we: 1) tested fish available and intended for human consumption; 2) identified locations from where contaminated fish were distributed; and 3) used opportunistic sampling of birds and bats as indicators for assessing mercury exposure to wildlife.
3. Evaluate biomonitoring assessments—To improve tracking for future monitoring efforts, we assessed patterns of mercury in biota to begin developing a plan for future mercury biomonitoring using fish and wildlife.

Biomonitoring in Belize

This publication highlights the results of the mercury assessments in Belize. Of particular note is the pattern between watershed mercury sensitivity rankings and the presence of potentially contaminated sites as well as wetland and water body coverage.

The mercury sensitivity mapping and the biotic sampling results together indicate that there is likely high variation in mercury exposure to fish, wildlife, and humans across Belize. Although the patterns and mechanisms of mercury's path through the environment are complex, these results highlight the importance of continued sampling efforts to further elucidate the patterns of mercury exposure across the landscape.

The Methylation Process

Once in the environment, elemental mercury can be converted to an organic form, methylmercury, by bacteria and other microbes. Methylmercury is toxic and can accumulate to high concentrations in the tissues of fish, wildlife, and humans, causing negative health effects.

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 repeated wet-dry cycles (Evers et al. 2007).

The complexity of the mercury cycle makes it challenging to predict effects levels in upper trophic level fish and wildlife from air, sediment, and water mercury concentrations alone. Identifying appropriate bioindicators based on their relationship with sensitive ecosystems is a critical first step in assessing risk to ecological and human health through long-term mercury monitoring.

Belize Ecosystem Sensitivity

The mercury sensitivity map of Belize (right) shows considerable variation among watersheds. Spatial analysis indicates that mercury sensitivity patterns are strongly driven by the combination of wetlands and contaminated sites.

The Belize River was the only watershed in the highest sensitivity classification. This watershed forms a corridor of developed areas, including Belize City, Belmopan, and San Ignacio. Due to these populated areas, the watershed contains multiple potentially contaminated sites and wastewater treatment plants, which increase mercury in puts to an already sensitive watershed. How the Chalillo Reservoir contributes to downstream mercury inputs is being closely monitored through mammal and fish monitoring. Findings are currently inconclusive.

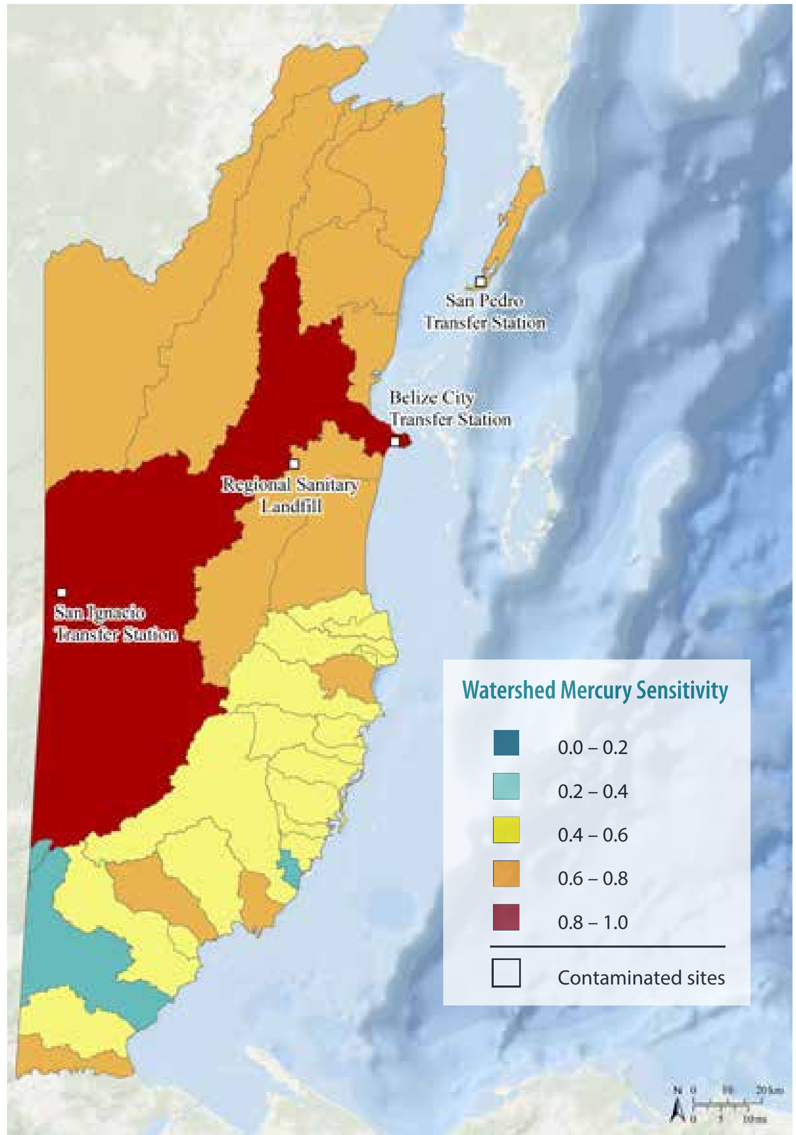

Figure 1. Watershed mercury sensitivity in Belize. The data show that there are no sites with the lowest mercury sensitivity in Belize.

To learn more, download BRI's publication: *Ecosystem Mercury Mapping—Belize*

www.briloon.org/mercury

The Role of Bioindicators

Fish mercury concentrations provide important information on the potential for human exposure through their consumption from freshwater, estuarine, and marine ecosystems. This is of particular importance to vulnerable populations including children, pregnant women, and indigenous communities that rely on fish as a major protein source.

Fish and wildlife also serve as important bioindicators of 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, are of greater significance for human health. These bioindicators can also be used to assess impacts to piscivorous wildlife (e.g., seabirds and otters).

Belize and the CRMMN

As a member of this newly formed initiative, Belize will work with other countries in the region to form a standardized monitoring program and data set that can be used for understanding and developing regional spatial and temporal patterns.

Marine bioindicators identified so far for the region include four species that are often fished in Belize (see box). Freshwater fish indicators are yet to be chosen.

Red snapper, a popular food source in the Caribbean region, are used as targeted bioindicators for mercury.

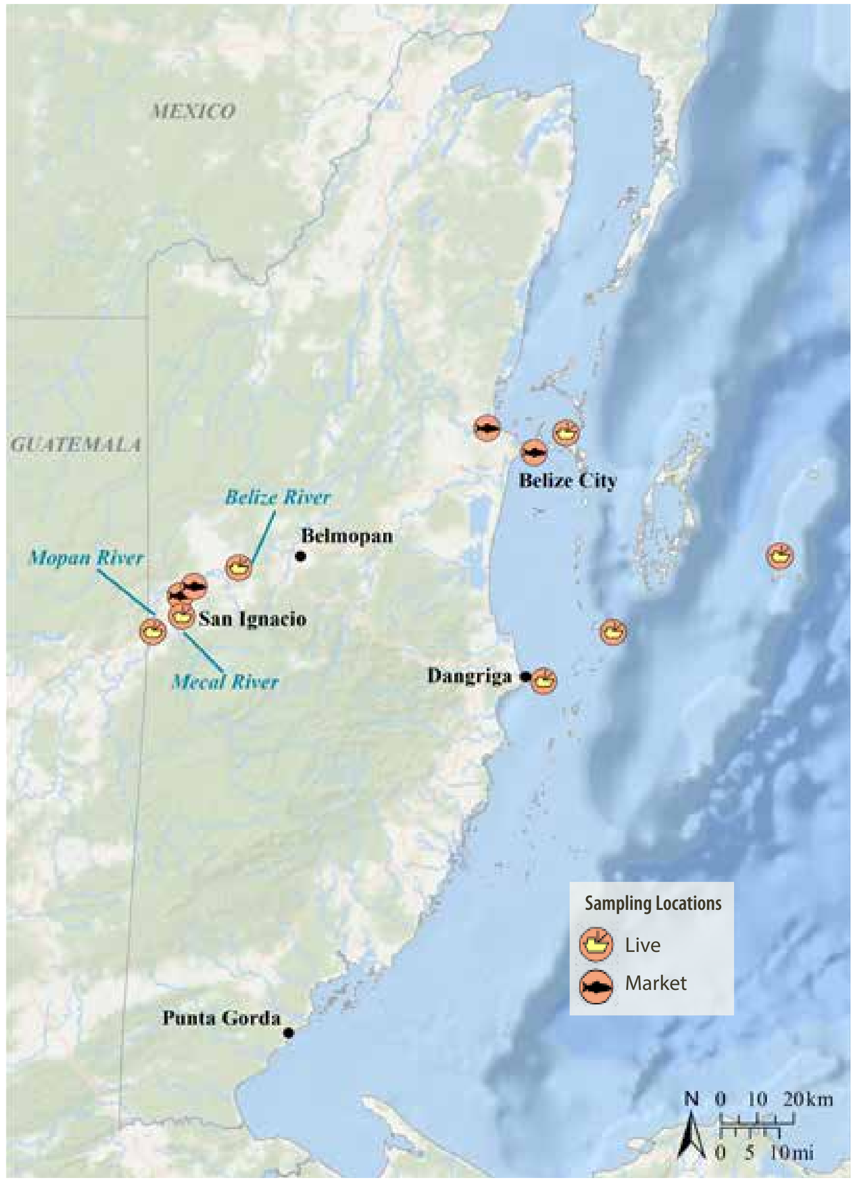

Figure 2. Fish sampling locations in Belize 2019..

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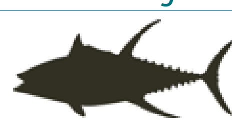
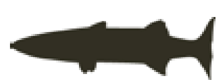
Target Fish Bioindicators

Yellowfin Tuna



Tuna, a popular fish group for exporting to the European Union (EU), may have elevated mercury levels.

Barracuda



While the barracuda is a common species, it’s popularity as a local food item is dictated by the incidence of ciguatera fish poisoning. Barracuda regularly have elevated mercury levels.

Mahi Mahi

Mahi mahi is a popular food item for local consumption and younger individuals tend to have safe mercury levels.

Red Snapper

Red snapper are abundant and widespread. They have relatively low mercury levels and are regularly used for local consumption.

Belize Fish Monitoring

Biodiversity Research Institute (BRI) has conducted multiple studies on mercury in fish throughout coastal and inland waters in Belize. Initial studies, from 2005 to 2012, emphasized estuarine and marine habitats and resulted in the collection of 505 fish samples.

Many Small Island Developing States and other coastal countries such as Belize depend on shellfish and fish with safe levels of environmental contaminants.

Those data contributed to a better knowledge of the goliath grouper (Evers et al. 2009) and multiple species, and broader relationships of Belize with other parts of the world (Buck et al. 2019). In 2019, BRI conducted fish sampling surverys, in coordination with the MIA process. BRI sampled fish from rivers as well as coastal systems.

Study Findings from 2019

A detailed assessment of total mercury concentrations in species regularly consumed by Belizeans was conducted. Findings include:

- Species of greatest concern with mercury levels greater than 0.5 ppm include sharks, catfish, mackerel, barracuda, and jacks.
- Species of concern to the most sensitive populations (e.g., children under 12 and pregnant women) include the above species plus groupers, cichlids, snappers, and snooks.
- The Belize River watershed appears to be highly sensitive to mercury contamination and had higher than expected concentrations in fish caught for human consumption. Due to the population density in this corridor and the reliance on fish for protein, the potential for human exposure indicates further monitoring is warranted. The relationship of the Belize River mercury loads and the Chalillo Reservoir are still not well understood.

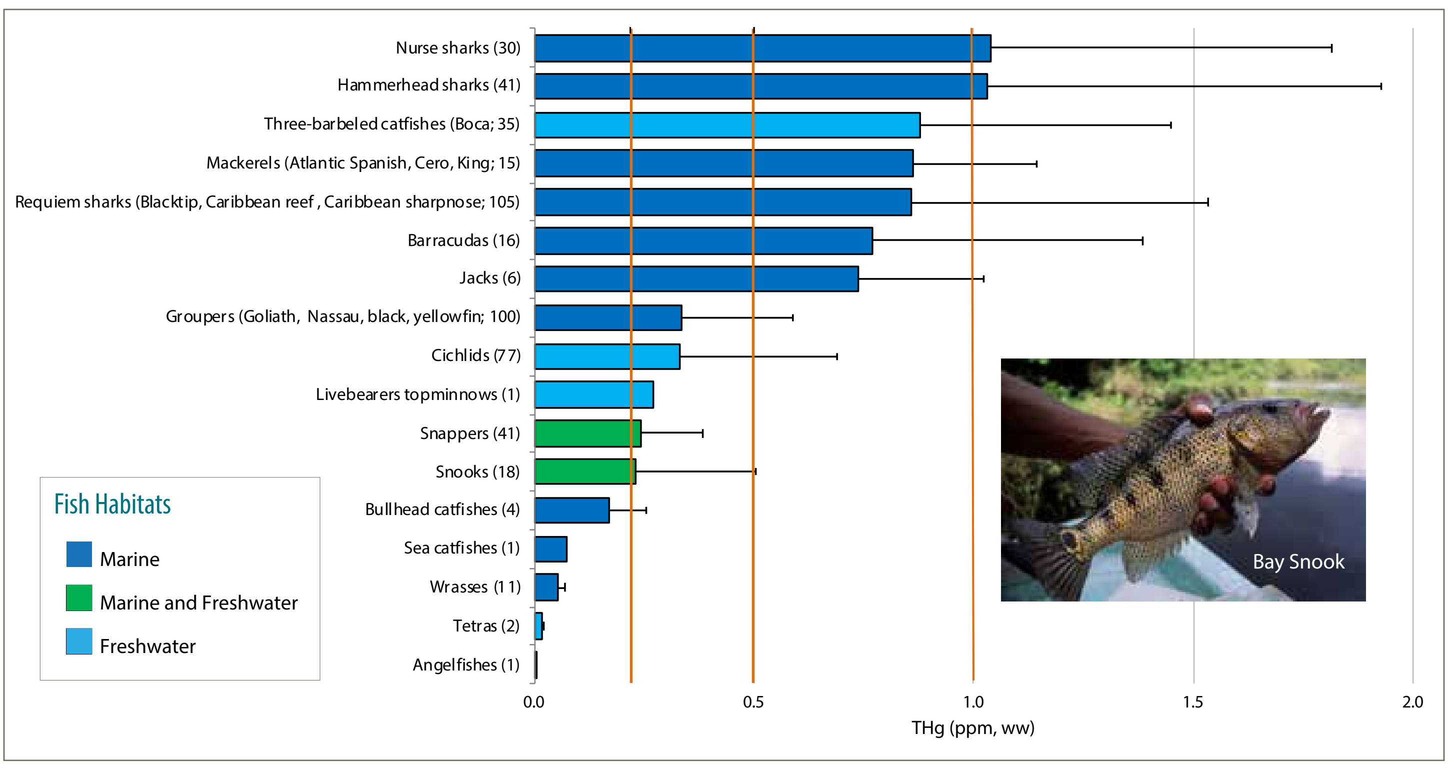


Figure 3. Unadjusted mercury concentrations in fish by family from the waters of Belize. Common names for each family are shown on the Y axis. The three reference lines correspond to mercury in fish consumption guidelines established by the Great Lakes Fish Advisory Workshop (2007) of 0.22 ppm, ww and the World Health Organization of 0.5 ppm, ww and 1.0 ppm. The highest threshold is used by the EU for billfish, tuna, and other predatory fish.

Why Monitor Birds

Birds are excellent bioindicators for measuring the availability of methylmercury in aquatic and terrestrial environments. Hundreds of studies from around the world have documented mercury body burdens in birds—often using nonlethal tissues such as eggs, blood, and/or feathers.

The physiological, behavioral, and reproductive effects of methylmercury on birds viewed through these and other tissues can be confidently identified while using a scalable outcome, such as reproductive success. Mercury concentrations and associated toxicity thresholds vary by species, particularly among foraging guilds (e.g., piscivores [fish-eating] and invertivores [invertebrate-eating]; Evers 2018).

Piscivores can have elevated mercury levels and while not measured during this study, they will be part of a group of bioindicators used by the CRMMN.

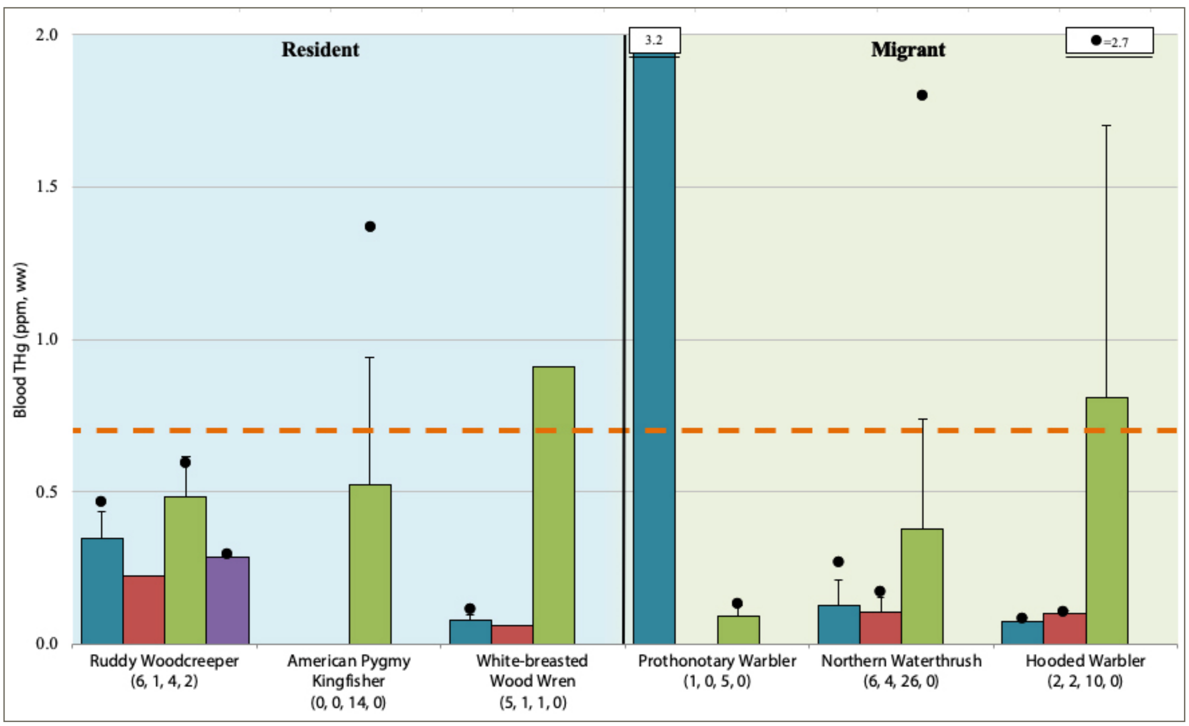
Since 2007, BRI biologists have worked closely with Belizean biologists to measure mercury in landbirds—389 individuals and 73 species have been assessed. Specific resident bird groups (e.g., kingfishers, wrens, and woodcreepers) and neotropical migrants have been identified as bioindicators of highest mercury body burdens.

Kingfishers are good bioindicators in Belize.

Figure 4. Blood mercury concentrations (ppm) in landbirds* (residents and neotropical migrants) for four stations in Belize:

- Belize Foundation for Research and Environmental Education
- Chaa Creek Nature Preserve
- Runaway Creek Nature Preserve
- Tropical Education Center

** sample sizes in parentheses*



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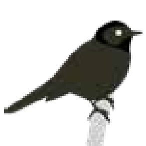
Target Bird Bioindicators

American Pygmy Kingfisher

The five species of kingfishers in Belize are good bioindicators of rivers.



Hooded Warbler

Certain species of neotropical migrants that breed in the U.S. and Canada, such as this warbler, can have elevated blood mercury levels (which reflect on-site dietary uptake of methylmercury in Belize within the prior few days of sampling).

White-breasted Wood Wren

Wood wrens and other wrens often forage on invertebrates with elevated methylmercury levels (e.g., spiders).

Ruddy Woodcreeper

The nine woodcreeper species in Belize often have the highest levels of mercury body burdens for resident species.

Seabird Bioindicators

The **CRMMN** Network will include seabirds for monitoring. Target species are undetermined at this time.

Why Monitor Bats

Bats are critical contributors to mammalian biodiversity, particularly in the neotropics where they comprise more than 50 percent of the terrestrial mammal fauna.

The ecological services that bats provide include: pollinating fruit trees; dispersing seeds for nuts, figs, and cacao; controlling insect populations; and excreting nutrient-rich guano used for farm crops. In addition, research on bats has led to important advances in medicines and vaccines.

Bats also have potential as bioindicators of methylmercury loads in the environment. Insect-eating bats can occupy high trophic levels and are particularly problematic in ecosystems sensitive to mercury input (e.g., Belize River watershed).

Bat Study Findings:

- Captured and released 190 individual bats comprising 24 species (Figure 5)
- Recordings at eight acoustic survey sites resulted in 3,922 acoustic data files, representing 17 species
- 57 bats were sampled for mercury for 14 species (Figure 6)
- Based on lowest observed adverse effect levels, 43% of those 14 species were over thresholds set for mice and 29% set for mink.
- Overall, Belize bat mercury concentrations are elevated and are of high conservation concern.

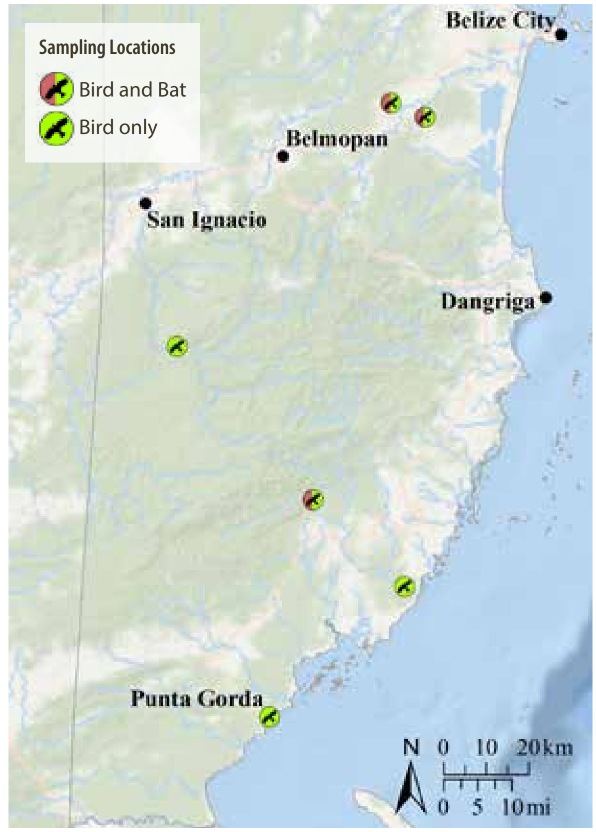
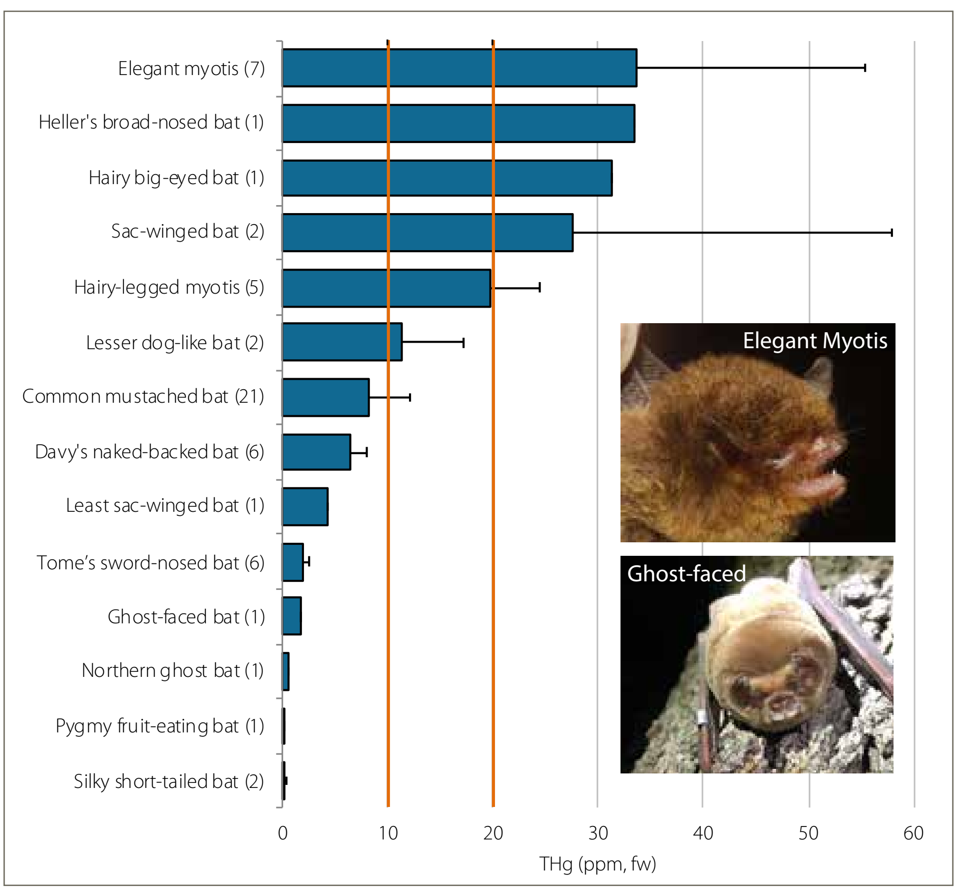


Figure 5. Sampling locations in Belize for birds and bats.



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Target Mammal Bioindicators

Bats

Bats are good bioindicators of mercury in the invertivore food web for freshwater systems.

Neotropical River Otter

Otters are good bioindicators of freshwater systems based on the fish food web.

Pilot Whale

Pilot whales are good bioindicators of marine ecosystems and are sometimes related to human health.

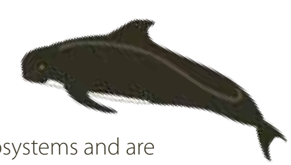

Figure 6. Mercury levels in bats. Threshold levels determined from experiments with mice (10 ppm, fw; Burton et al. 1977) and mink (20 ppm, fw; Basu et al. 2007) with supporting evidence from bat studies (Nam et al. 2012; Yates et al. 2014).

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Barracuda are fished in Belize. Older individuals can have elevated mercury levels.

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