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CO-LEAD FOR FATE AND TRANSPORT
GLOBAL MERCURY PARTNERSHIP AREA

GLOBAL MERCURY
MONITORING IN BIOTA
GBMS to date:
1,095 references
>1 million samples
~3,000 locations

Figure 1. Global Biotic Mercury Synthesis (GMBS)
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.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Tissue</th>
<th>Total Mercury Concentrations (ppm, ww or fa free)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharks and Allies (n=10,200)</td>
<td>Muscle</td>
<td>&lt;0.22</td>
</tr>
<tr>
<td>Fish (n=123/996)</td>
<td>Muscle</td>
<td>&lt;0.22</td>
</tr>
<tr>
<td>Marine Mammals (n=8,147)</td>
<td>Muscle</td>
<td>&lt;0.22</td>
</tr>
<tr>
<td>Sea Turtle (n=401)</td>
<td>Eggs</td>
<td>&lt;0.22</td>
</tr>
<tr>
<td>Birds</td>
<td>Blood</td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>Body feathers</td>
<td>&lt;100</td>
</tr>
<tr>
<td></td>
<td>Eggs</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

*Note: fa free = free fraction of mercury.
Fresh Water

5 Top Predators
- Bald Eagle, River Otter

4 Tertiary Consumers
- Northern Pike, Smallmouth Bass, Walleye

3 Secondary Consumer
- Salmon, White Sucker, Yellow Perch

2 Primary Consumers
- Amphipods, Mussels, Zooplankton

1 Producer
- Phytoplankton

Marine

- Blue Marlin, Lemon Shark, Pilot Whale

- Barracuda, Mahi Mahi, Yellowfin Tuna

- Herring, Parrotfish, Sardines

- Conch, Coral, Krill, Zooplankton

- Phytoplankton, Seagrass, Seaweed
A provisional slate of potential bioindicators for evaluating and monitoring environmental Hg loads (Evers et al. 2016 Sci. Total Environ. 569-570:888-903.)

<table>
<thead>
<tr>
<th>Target Terrestrial Biomes</th>
<th>Associated Aquatic Ecosystems</th>
<th>Human and Ecological Health Bioindicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Freshwater Fish</td>
</tr>
<tr>
<td><strong>Arctic Tundra</strong></td>
<td>Arctic Ocean and associated estuaries, lakes, rivers</td>
<td>Arctic Char, Arctic Grayling</td>
</tr>
<tr>
<td><strong>Boreal Forest and Taiga</strong></td>
<td>North Pacific and Atlantic Oceans and associated estuaries, lakes, rivers</td>
<td>Catfish, Pike, Sauger, Walleye</td>
</tr>
<tr>
<td><strong>Temperate Broadleaf and Mixed Forest</strong></td>
<td>North Pacific and Atlantic Oceans, Mediterranean and Caribbean Seas, and associated estuaries, lakes, rivers</td>
<td>Bass, Bream, Mullet, Walleye</td>
</tr>
<tr>
<td><strong>Tropical Rainforest</strong></td>
<td>South Pacific and South Atlantic and Indian Oceans and associated estuaries, lakes, rivers</td>
<td>Catfish, Snakehead</td>
</tr>
</tbody>
</table>
PROPOSED 3-STEP OVERARCHING FRAMEWORK FOR MONITORING MERCURY IN BIOTA ACROSS CONTINENTS AND OCEANS.

**Step 1**
Map ecosystem sensitivity spots for methylmercury availability

**Step 2**
Identify sensitive and at-risk trophic level 4 or higher species

**Step 3**
Select species and ecosystems to model and monitor globally
Figure 3. Sampling strategy for trophic level 4 or higher biota for the Continental Sampling Framework. Listed are the number of intensive sites (with a sample size of 30 at each site), each which should include another three cluster sites (with a sample size of 20 at each site) to account for local variability.

- **Africa**
  - Approximate coverage (%) using existing mercury data and monitoring programs: < 10%
  - 10 overall sites—300 samples from intensive sites; 600 samples in cluster sites*

- **Mexico, Central America, Caribbean Islands**
  - Approximate coverage (%) using existing mercury data and monitoring programs: < 10%
  - 8 overall sites—240 samples from intensive sites; 480 samples in cluster sites

- **Indo-Pacific (including all of Australia and New Zealand)**
  - Approximate coverage (%) using existing mercury data and monitoring programs: < 10%
  - 10 overall sites—300 samples from intensive sites; 600 samples in cluster sites

- **South America**
  - Approximate coverage (%) using existing mercury data and monitoring programs: < 20%
  - 10 overall sites—250 samples from intensive sites; 500 samples in cluster sites

- **Asia**
  - Approximate coverage (%) using existing mercury data and monitoring programs: < 50%
  - 10 overall sites—150 samples from intensive sites; 300 samples in cluster sites

- **Europe**
  - Approximate coverage (%) using existing mercury data and monitoring programs: > 80%
  - 10 overall sites—Samples provided by existing monitoring programs

- **North America (excluding Mexico, Central America)**
  - Approximate coverage (%) using existing mercury data and monitoring programs: > 90%
  - 10 overall sites—Samples provided by existing monitoring programs

*Note: The number of samples is based on 30 samples per trophic level 4 or higher bioindicator for freshwater, nearshore marine, and terrestrial ecosystems.
Figure 4. Sampling strategy for trophic level 4 or greater biota for the Oceanic Sampling Framework. Listed are the number of sites (with an initial sample size of 30 fish at each site) for both objectives of monitoring temporal trends and spatial gradients of mercury.

Approximate coverage (%) using existing mercury data and monitoring programs:

- South Atlantic Ocean: TT—3 sites; 180 samples
  SG—3 sites; 180 samples
- North Atlantic Ocean: TT—3 sites; 180 samples
  SG—3 sites; 180 samples
- South Pacific Ocean: TT—3 sites; 180 samples
  SG—3 sites; 180 samples
- North Pacific Ocean: TT—3 sites; 180 samples
  SG—3 sites; 180 samples
- Caribbean Sea: TT—2 sites; 120 samples
  SG—2 sites; 120 samples
- Indian Ocean: TT—3 sites; 180 samples
  SG—3 sites; 180 samples
- Mediterranean Sea: TT—2 sites; 120 samples
  SG—2 sites; 120 samples
- Arctic Ocean: TT—3 sites; 180 samples
  SG—3 sites; 180 samples
### ARCTIC TUNDRA AND ARCTIC OCEAN BIOME

- **ARCTIC CHAR, YELLOW-BILLED LOONS AND IVORY GULL, BELUGA WHALES AND NARWALS**

- Body burdens exceed thresholds for 13 of 16 toothed whales
- Some species average 10x above thresholds

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**Total Mercury Concentrations in Muscle Tissue from Toothed Whales (Odontoceti)**

<table>
<thead>
<tr>
<th>Toothed Whale</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>False killer whale</td>
<td>46</td>
</tr>
<tr>
<td>Striped dolphin</td>
<td>285</td>
</tr>
<tr>
<td>Rissos dolphin</td>
<td>82</td>
</tr>
<tr>
<td>Bottlenose dolphin</td>
<td>558</td>
</tr>
<tr>
<td>Beaked whales</td>
<td>34</td>
</tr>
<tr>
<td>Pantropical spotted dolphin</td>
<td>61</td>
</tr>
<tr>
<td>Pilot whales</td>
<td>257</td>
</tr>
<tr>
<td>Killer whale</td>
<td>18</td>
</tr>
<tr>
<td>Sperm whale</td>
<td>355</td>
</tr>
<tr>
<td>Beluga</td>
<td>996</td>
</tr>
<tr>
<td>Harbor porpoise</td>
<td>710</td>
</tr>
<tr>
<td>Common dolphin</td>
<td>236</td>
</tr>
<tr>
<td>Narwhal</td>
<td>351</td>
</tr>
<tr>
<td>Spinner dolphin</td>
<td>79</td>
</tr>
<tr>
<td>Gray dolphin</td>
<td>203</td>
</tr>
<tr>
<td>Franciscana</td>
<td>127</td>
</tr>
</tbody>
</table>

**Great Lakes Consortium mercury consumption guidelines ≤ 0.22 ppm**

**WHO mercury consumption guideline level**

![Mercury Concentrations Chart](chart.png)

**Total Mercury (parts per million [ppm]; wet weight [ww])**

![Arctic Tundra and Ocean Biome Image](arctic_image.png)
BOREAL FOREST AND TAIGA AND NORTH ATLANTIC/PACIFIC BIOME

- PILOT WHALE, COMMON LOON, RUSTY BLACKBIRD, NORTHERN PIKE

✓ Body burdens are 10x higher than ~ 2 centuries ago
✓ Most of the population has reduced productivity of 50%

Northeastern Rusty Blackbirds
Blue solid line is log fit where Log(feather MeHg) = 0.02 * Year - 47.2
Rsq = 0.77, P = 0.01, n = 36

Estimated reduction in nest success (Jackson et al. 2011)
50%
20%
10%

(body feather MeHg (ppm))
TEMPERATE BROADLEAF AND CENTRAL OCEAN BASINS BIOME — LEMON SHARK, BARRACUDA, OSPREY, SALTMARSH SPARROW

- Body burdens are 10-15x greater than critical thresholds
- Reduced diversity identified in rice-field wetland areas
TROPICAL RAINFOREST/SOUTH PACIFIC-ATLANTIC BIOME – TIGER SHARK, GOLIATH GROUPER, RINGED KINGFISHER, WANDERING ALBATROSS

- Body burdens average higher than threshold levels for 6 shark families
- Effects from mercury are still relatively unknown
SUMMARY

1. Fish and Wildlife Populations are adversely impacted by Hg

2. Many species are likely declining because of Hg

3. Biodiversity is likely suffering in many biomes for high trophic level species

4. Particular concern is in areas most sensitive to Hg input
Figure 2. Average (+/- 5D; N=sample size) THg concentration in muscle tissue of nine tuna species compared with the FAO harvest estimate in tonnes. See above for mercury consumption guidelines. *FAO harvest is less than 15,000 tonnes.