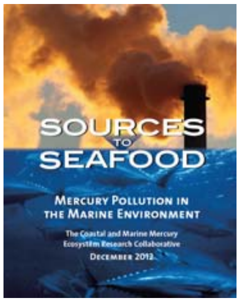

Sources to Seafood: Mercury Pollution in the Marine Environment

The Coastal and Marine Mercury Ecosystem Research Collaborative (C-MERC)
Coordinated by Dartmouth College Toxic Metals Superfund Research Program

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About C-MERC

The Coastal and Marine Mercury Ecosystem Research Collaborative (C-MERC) was established by the Research Translation Core of the Dartmouth College Toxic Metals Superfund Research Program and is comprised of more than 70 marine mercury researchers. C-MERC participants worked for two years to produce a series of scientific papers on mercury pollution in the marine environment from sources to seafood. The resulting 11 papers were published in November 2012 in the peer-reviewed journal *Environmental Research* and in June 2012 in *Environmental Health Perspectives*. The summary report, *Sources to Seafood: Mercury Pollution in the Marine Environment*, provides a scientific synthesis of C-MERC results.

Summary of "Sources to Seafood"

Mercury pollution is ubiquitous in the world's oceans and coastal waters.
Mercury pollution contaminates fish and other seafood that are important sources of protein and nutrition for people worldwide. For the general U.S. population, approximately 85% of their methylmercury exposure via fish consumption comes from estuarine and marine fish. Despite declines in mercury inputs in some regions of the world, methylmercury in commonly consumed marine fish continues to exceed human health guidelines in most marine waters. And, globally, the amount of mercury released to the environment each year from human activities is on the rise.

Mercury pollution has distinct pathways that are linked to different mercury sources.
By examining data from nine different coastal and ocean regions, we classified marine waters into four types of mercury systems based on their dominant mercury inputs. The four system types are: open ocean, ocean current, watershed, and mixed input systems. "Open ocean systems" receive ~90% of their mercury loading from atmospheric deposition. Atmospheric deposition results from mercury emissions from current anthropogenic sources (e.g., fossil fuel combustion, mining), natural sources (e.g., volcanoes), and previously deposited mercury from both natural and anthropogenic sources. Many large gulfs are "ocean current systems" that receive a large fraction of their mercury loading from atmospherically deposited mercury that is transferred into the gulfs by ocean currents (e.g., Gulf of Maine, ~56%; Gulf of Mexico, ~90%). "Watershed systems" and "mixed input systems" both receive substantial river inputs of mercury in addition to mercury from atmospheric deposition.

We used a simple linear model to estimate the general direction and magnitude of change in fish mercury levels in response to decreased mercury inputs. Similar to published findings from a number of marine ecosystems, the model results indicate that controlling atmospheric deposition of mercury (by curbing mercury emissions from global anthropogenic sources) will result in lower mercury concentrations in marine fish harvested from the open oceans. Specifically, our model calculations suggest that a 20% cut in atmospheric deposition of mercury would result in roughly a 16% decline in fish mercury in the North

Atlantic Ocean over time, assuming current environmental conditions. Given the on-going contribution of historic mercury emissions, reaching a given deposition target is likely to require that current anthropogenic emissions be cut by at least twice that amount. Prior modeling efforts suggest that declines in fish mercury levels in the open ocean will begin very quickly after declines in atmospheric deposition are achieved, but may take decades or longer to fully respond.

We classified nearshore coastal waters as watershed systems or mixed input systems. For watershed systems, mercury loading originates largely from the upstream sources and from atmospheric deposition of mercury to the watershed. This mercury is discharged to rivers and carried downstream to bays and estuaries. For example, watershed runoff of mercury in rivers supplies approximately 80% of the total mercury inputs to Long Island Sound (LIS, NY) and San Francisco Bay (SFB, CA). The specific sources of mercury in watershed systems vary but include wastewater treatment plants, legacy sources such as former gold mines and chlor-alkali plants, and atmospheric emission sources. Coastal waters are an important source of fish and seafood to local anglers and to some commercial markets. Coastal fisheries supply > 85% of the methylmercury intake from seafood for local anglers and seafood consumers in the Arctic and in SFB.

We expect that controlling discharges of mercury from watershed sources will result in a proportional response in fish mercury levels. Consistent with other studies, our model calculations for several watershed systems suggest that a 20% cut in watershed inputs delivered by rivers would yield roughly a 15-20% decrease in mercury levels in fish over the long term. Controls on mercury emissions to the atmosphere would bring additional improvements. The fisheries response to controls on watershed inputs is likely to be a two-phased response. The response to cuts in direct discharges is expected to be rapid and the response to declines in indirect inputs via watershed runoff is expected to be slower. If large legacy sources of mercury persist, as in systems like SFB, fisheries may require decades or even centuries to respond.

Some coastal waters, such as Chesapeake Bay, receive both direct atmospheric deposition of mercury (~49%) and river inputs of mercury (~44%). For these mixed input systems, no single approach to controlling mercury pollution will be adequate for cutting mercury levels in fish.

These mercury pollution pathways and seafood consumption patterns have important policy implications.

- Open ocean fisheries supply a large fraction of both the fish consumed and the associated methylmercury intake for the general U.S. population. Reducing atmospheric deposition of mercury by controlling global anthropogenic mercury emissions is important for stemming mercury inputs to the open oceans which supply most of the commercial fish harvested for human consumption.

- Decreasing river inputs of mercury by controlling direct discharges from watershed sources and by managing legacy sources of mercury has already provided important benefits for coastal fisheries that can be continued with ongoing source reductions. Coastal fisheries typically supply a large fraction of the methylmercury intake from fish consumption by recreational and subsistence anglers.

- Over the long term, research suggests that methylmercury concentrations in marine fish will decline roughly in proportion to decreases in mercury inputs, though the timing the response will vary from years to centuries depending on environmental conditions and on the extent to which inputs are controlled.

Citation for full report: Chen, C.Y., C.T. Driscoll, K.F. Lambert, R.P. Mason, L. R. Rardin, C.V. Schmitt, N.S. Serrell, and E.M. Sunderland. 2012. Sources to Seafood: Mercury Pollution in the Marine Environment. Hanover, NH: Toxic Metals Superfund Research Program, Dartmouth College.