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## Mercury Contamination in Waterbirds Breeding in San Francisco Bay

by Dr. Josh Ackerman  
and Dr. Collin Eagles-Smith

References to the neurological effects of mercury exposure date back several centuries. In the 1800s, when mercury was a common ingredient used in the production of felt hats, the term “mad as a hatter” entered the vernacular as a reference to the slurred speech, irritability, tremors, and other odd behavior that mercury exposure could cause. These neurological and behavioral effects were made famous by the delirious Mad Hatter character in Lewis Carroll’s 1865 masterpiece *Alice in Wonderland*.

However, environmental concerns regarding mercury contamination were not widespread until the tragedy in Minamata Bay, Japan in the late 1950s when an estimated 27 tons of mercury-containing compounds were released into the Bay from a plastics factory. The mercury accumulated up the food chain into fish, which comprised a major portion of the fishing town’s diet. The outcome was drastic – the fishery collapsed, several hundred people died, and more than 3,000 others had contracted “Minamata disease” which caused devastating neurological impacts from methyl mercury exposure. Since this and other tragic mercury-related events, extensive research has been undertaken to understand the distribution, cycling, and accumulation of mercury in the environment. These past studies have indicated that mercury is a potent neurotoxin and a common contaminant in aquatic ecosystems throughout the world, and is a significant health threat to both humans and wildlife.

San Francisco Bay has a legacy of mercury contamination from historical mercury mining in the Coast Range and gold extraction in the Sierra Nevadas. An estimated 220 million pounds of mercury were mined in the coastal

mountains from the mid-1800s to the mid-1900s. Additionally, over 26 million pounds of mercury were used for gold recovery in the Sierras. During these mining activities, roughly 10% to 30% of all the mercury used was lost to the surrounding watersheds and has since been making its way, attached to sediment particles, into the San Francisco Bay-Delta. This pollution has resulted in San Francisco Bay being listed as an impaired water body under the Clean Water Act, and a Bay-wide fish consumption advisory has been enacted by the State of California’s Office of Environmental Health Hazard Assessment (for more information visit <http://www.oehha.ca.gov/fish/general/sfbaydelta.html>).

The most sensitive endpoint of mercury toxicity in wildlife is reproductive impairment, thus mercury contamination in San Francisco Bay may reduce the reproductive success of waterbirds breeding within the estuary. Although these effects have been little studied in the estuary, the risk is a concern because San Francisco Bay is a site of hemispheric importance to shorebirds, annually supporting over half a million wintering and



*A radio-marked avocet is readied for release. Subsequently, it is tracked to determine movements and habitat use.*  
Photo by Scott Demers, USGS.

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*A remotely triggered net is set ready to capture a group of roosting black-necked stilts in a San Francisco Bay marsh. Photo by Brooke Hill, USGS.*

migrating shorebirds and more than a quarter million ducks. Current restoration plans to enhance existing wetlands and to convert salt evaporation ponds into tidal marsh could result in accelerated microbial conversion of legacy inorganic mercury to methyl mercury, the form of mercury which is highly toxic and most bioavailable to wildlife and humans.

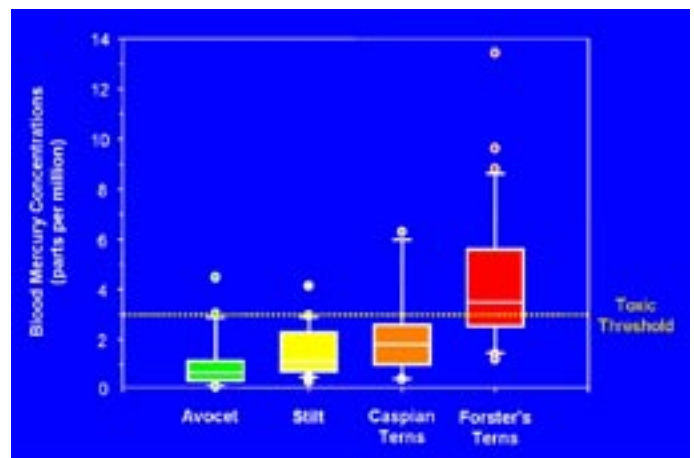
In a large collaborative project funded by the CalFed Ecosystem Restoration Program, biologists of the U.S. Geological Survey, U.S. Fish and Wildlife Service, San Francisco Bay Bird Observatory, and PRBO Conservation Science are investigating the risks of mercury to waterbirds breeding within the estuary. This unprecedented project seeks to assess mercury burden and dietary exposure in waterbirds and, ultimately, the effects that mercury has on avian reproduction within the estuary.

This study is examining several aspects of the biology of five waterbird species that are common residents of San Francisco Bay and associated wetlands. The species being studied include two shorebirds (American avocet and black-necked stilt), two terns (Forster's tern and Caspian tern), and one diving duck (surf scoter). This is a multi-faceted project that includes capturing and radio-marking birds to track their movements and habitat use, sampling bird blood and feathers for mercury concentrations and chemical signatures of diet, monitoring nesting success, and examining chick movements and survival. Although the study was initiated only recently, in 2005, it has already produced several inter-

esting results. For example, it has been determined that mercury concentrations are generally higher in fish-eating birds (terns) than in birds that eat mainly aquatic invertebrates (shorebirds). This is likely due to the fact that methyl mercury bioaccumulates within the environment, such that fish that are eaten by birds already will have accumulated high levels of mercury from consuming large amounts of invertebrate prey.

Furthermore, mercury concentrations are high enough to be a cause for concern, especially in the most southern and northern portions of the Bay. For example, 5% of stilts, 6% of avocets, 10% of Caspian terns, and 58% of Forster's terns breeding in South Bay sites south of the

Dumbarton Bridge (Alviso salt pond complex) were at or above the high-risk category for mercury contamination. The higher mercury levels in the South Bay are likely a consequence of highly contaminated sediments that have been transported through Alviso Slough, the discharge point for the Guadalupe River. This watershed drains from the historic New Almaden quicksilver mine – one of the largest mercury mines in the western U. S. – and residual mercury remains within the environment. High levels of mercury in the North Bay are likely from the Sacramento-San Joaquin Delta, and ultimately from upstream historic gold mining activities in the Sierras. Although it is difficult to detect how mercury toxicity might actually manifest itself in wild birds, mercury usually has its greatest effect on reproduction. These effects can include reduced



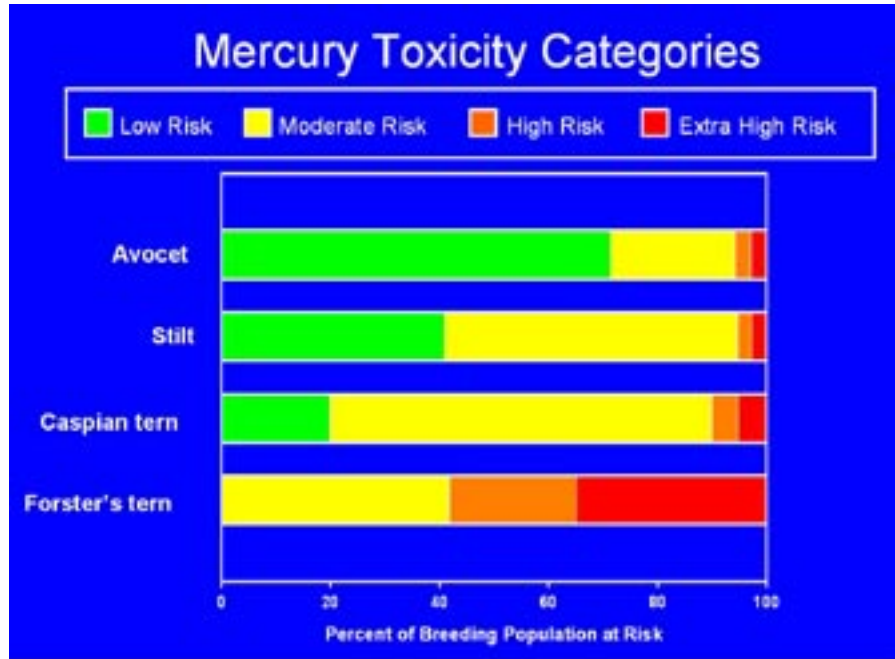
*The percentage of the breeding populations of several waterbird species that are at risk to reduced reproductive success and declining populations due to mercury contamination in the South San Francisco Bay. USGS and USFWS graphic.*

breeding effort, altered breeding behavior, impaired vision, hearing, and motor skills, embryo death and deformities, reduced egg hatchability, and reduced chick survival.

Although mercury will continue to be a problem in San Francisco Bay for the foreseeable future, the benefits of wetland creation for wildlife will likely outweigh many concerns about the potential for increased methyl mercury production. Scientists will continue to conduct research within the San Francisco Bay National Wildlife Refuge Complex to understand mercury's availability to wildlife and its effects on breeding waterbirds.

*Dr. Josh Ackerman is a Research Wildlife Biologist at the U. S. Geological Survey's Davis Field Station and studies waterbird ecology and the ecotoxicological effects of mercury on avian reproduction.*

*Dr. Collin Eagles-Smith is a biologist with the U. S. Fish and Wildlife Service, Environmental Contaminants Division and studies aquatic foodwebs and the bioaccumulation and ecological effects of mercury contamination.*



*Mercury concentrations in the blood of breeding waterbirds approached and surpassed toxic threshold levels in the South San Francisco Bay, especially for fish-eating terns. Bird samples were analyzed for mercury at the USGS Davis Field Station Mercury Lab.*