# In Search Of The Smoking Gun

*We know that mercury is poisonous to wildlife and to ourselves ... but where's it coming from? And what can we do about it?*

by Geoff Patton

Mercury is an environmental contaminant whose role in human and animal ecology is very hard to understand. Although technological advances allow us to measure chemicals in minute amounts, this information may be meaningless without broader understanding of biological roles and environmental pathways.

Mercury exists naturally throughout the biosphere. How can we determine when levels become problematic? We know that mercury is contaminating our panthers, dolphins, sharks, eagles and bass. We know that human activities introduce additional mercury into the environment and that, to a degree, these additions may be controllable. But how much of the mercury is from man-made sources ... and at what point would the cost of control outweigh the benefits?

In 1989, warnings were issued by the Florida Game and Fresh Water Fish Commission that fish in Florida waters, as in the Great Lakes, were accumulating enough mercury that eating bass needed to be restricted. This move was necessary to protect Seminole Indians, pregnant women and anyone who might have the opportunity to eat more than three pounds per week of Florida bass.

Historically, mercury poisoning in humans first became widely recognized by the brain deficits associated with the English "mad-hatters" of *Alice in Wonderland* fame. Arguably, the real-life characters were hat blockers who used mercury to help form the felt hats popular at the time. Inhaled elemental mercury vapors were absorbed through the lungs into the bloodstream. Within the blood, the elemental mercury either became methylmercury or bound to sulfhydryl groups of proteins which could then cross cellular membranes and interfere with normal trans-membrane export of ions. In either case, this allowed mercury to cross the "blood-brain" barrier that normally protects the brain from undesirable chemical species. The adverse effects included dementia and early death.

In 1952, sudden sickness and death of Japanese who had eaten fish and shellfish from Minamata Bay at first were attributed to poisoning from selenium, a trace element nutritionally necessary in small amounts but poisonous if consumed in excess. The affected individuals showed elevated selenium levels. However, later analyses for heavy metals revealed mercury poisoning to be the direct cause of death.

Recently, the Florida Everglades has become the focus of much attention because of the high mercury levels found in bass, raccoons, opossums and panthers. The death of one panther was directly attributed to mercury poisoning with a second animal's death suspected to have been largely from eating too much mercury-laden prey in the form of raccoons and opossums, primary food sources for these top carnivores. Mercury has long been known to bioaccumulate

Photo: Geoff Patton

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from one trophic level to the next. This fact underscores our need to monitor animals high in the food web if we are to protect them and ourselves.

Certainly, there is plenty of mercury to go around. Fossil-fueled power plants and municipal solid waste incinerators in Florida emit tons of mercury into the air annually. The issue is what can and should be done, if anything, to target specific sources for control or elimination.

Herein lies the current problem. Even the best reports to date have insufficient information on which to base regulatory decisions that impact energy utilities, solid waste management and waste-to-energy recycling efforts. Mercury is volatilized when fossil fuels and solid waste are burned. Many people assume that electrostatic precipitators and "scrubbers" remove most of the mercury, but only low levels of mercury occur in the fly ash. Smoke stack temperatures are often higher than the 356° C boiling point of mercury, and some inorganic mercury compounds decompose to constituent elements below that temperature.

While it is simple to calculate that a large power plant consuming a million tons of coal per year at an average of 0.2 parts per million of mercury releases nearly 800 pounds of mercury annually into the atmosphere, the specific transport routes for that mercury to aquatic and terrestrial systems has never been demonstrated. Many reports repeat claims that the metal occurs on airborne particulates or is dissolved in falling rain — but these claims are not supported by any definitive studies that actually locate mercury in air or rain samples that might be attributable to any specific source.

Another critical issue on which we lack sufficient information for credible regulation is the exposure levels that cause adverse effects. Phillipus Aureolus Paracelsus, the 16th-century physician who introduced the use of drugs made from minerals, claimed that the dose is the poison … meaning that small levels will normally be tolerated, but above some level, concentrations of anything are hazardous. It is clear that mercury in its various chemical forms (elemental, inorganic and organic) equilibrates differently in different animal species at different concentrations in different organs. In other words, each species, given the same dose, will achieve different dynamic balances of the various chemical forms in the major organs. The effects and symptoms show similar differences. For example, humans and some other mammals can exhibit distinctive mercury deposits in kidney, gut and brain, while bottlenose dolphins and other marine

Photo: Mote Marine Laboratory

*(Left and below) Marine mammals seem to have an effective ability to neutralize at least some mercury toxicity by forming an inert compound of mercury with the nutritional trace element selenium. It is believed that this process "archives" the mercury (mostly in the liver) and isolates it from the rest of the animal's normal physiological functions.*

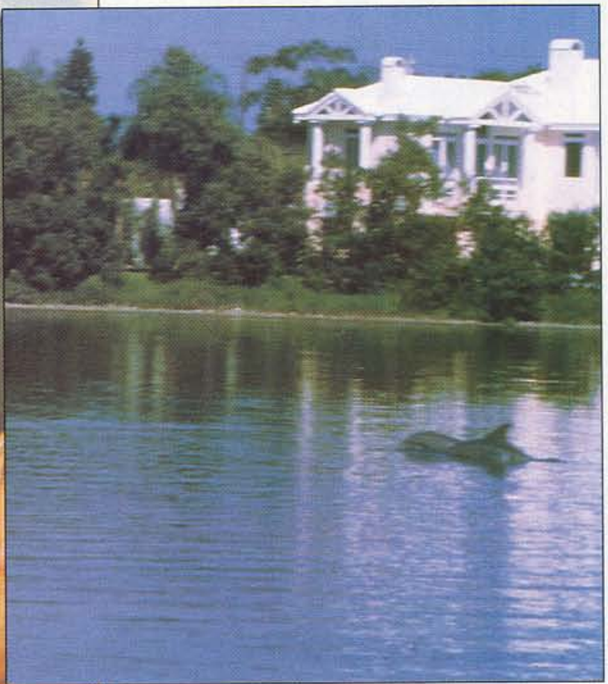

Photo: Mote Marine Laboratory

mammals show the most mercury in liver.

How do these differences manifest themselves in symptoms? In humans, mercury poisoning can damage the kidneys with alterations in the frequency of urinations and changes in water balance. Although mercury is persistent and accumulated throughout life, the kidney damage can be reversed if it is not too severe. Marine mammals seem to have an effective ability to neutralize at least some mercury toxicity by forming an inert compound of mercury with the nutritional trace element selenium. It is believed that this process "archives" the mercury (mostly in liver) and isolates it from the rest of the animal's normal physiological functions. While this idea appears reasonable within current, albeit limited, understanding of these special creatures, it remains to be shown if the material might become remobilized under stresses of blood acidosis, liver disease, or exposure to natural biotox-

Photo: Geoff Patton

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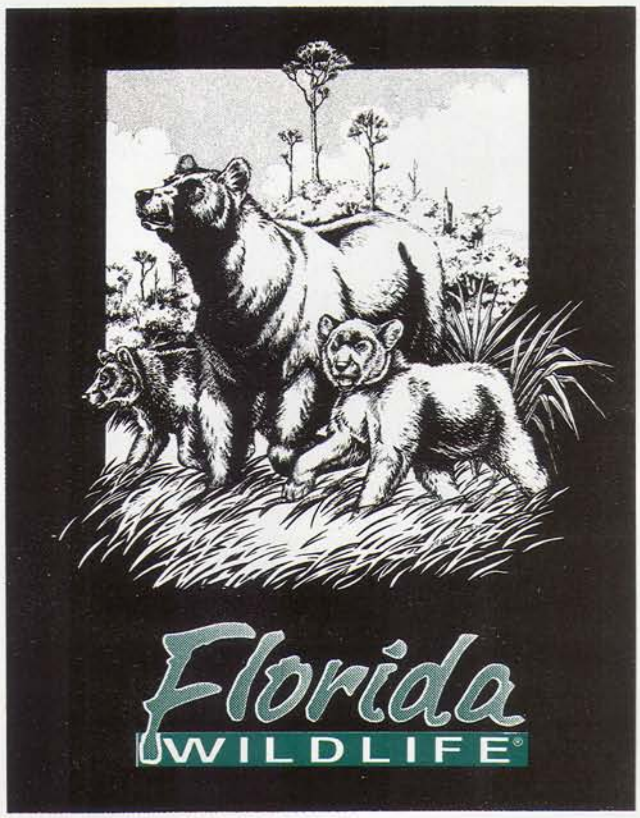

ins like bacterial endotoxin or brevetoxin (red tide). As mentioned in relation to the tragedy of Minamata Bay, humans with high mercury loads also can exhibit high selenium levels but it remains unclear if selenium can or does help protect all mammals from some degree of mercury poisoning.

Scientists (including the author) at Mote Marine Laboratory in Sarasota became interested in the problem of mercury as an air pollutant in 1991, after publishing the first report of evidence of air pollution (soot and other particles) in marine mammals. A colleague, Dr. Daniel K. Odell, suggested that we try to further characterize the soot so that we might discover the source. We haven't accomplished that, yet. However, using analytical electron microscopic techniques, Dr. John Bradley (then of McCrone Associates and now with MVA, Inc. in Norcross, Ga.) found substantial amounts of mercury selenide (HgSe) on the soot. He immediately raised two questions we continue to try to answer: One, was the HgSe formed within the animal by the known process of selenium neutralization of mercury? Or, two, was the HgSe already on the soot when it was inhaled by the dolphins?

It has been known for some time that the levels of total (organic + inorganic) mercury dolphins carry comes predominantly from their food fish. However, the possibility that some mercury may be accumulated from inhaled airborne particulates prompted us to examine a number of air sample filters collected by Hillsborough County's Environmental Protection Commission under the U.S. EPA's Air Quality Monitoring Program. Using the latest analytical electron microscopy equipment in the laboratory of Alicia Slater-Haase of the University of South Florida's College of Engineering, we were able to confirm John Bradley's findings of mercury selenide on soot. However, we were unable to find any mercury or selenium on nearly 100 air filter particles in the respirable 0.25-10 micron size range. No smoking gun.

So, where do mercury emissions go from the five area power plants and four municipal solid waste incinerators? No one seems to know. Did we look at too few particles? Too small or too large? Should we be looking at rain? Or is there actually so little mercury in the air that our present tools are inadequate to find it? Or was John Bradley's first question about the dolphins being able to neutralize ingested mercury with selenium actually most important?

And how will we determine the cost/benefit ratio of efforts to limit emissions of environmental contaminants? Do the answers lie in monitoring contaminant levels in wildlife? Can laboratory studies help provide insight? Do we know enough about the biogeochemical cycles? Or are we asking the wrong questions?

The animals "want" to tell us. All we have to do is listen. Further study is paramount to our protecting the balance of our ecosystems, our natural food supplies and our own health.

*Geoff Patton was a senior biologist with Mote Marine Laboratory in Sarasota for 14 years. He is now a doctoral candidate at the University of South Florida.*