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Mercury threatens wildlife resources
and human health in Everglades National Park

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In recent decades, National Park Service (NPS) areas have faced a previously unrecognized threat - the introduction of contaminants from sources external and often distant from park boundaries. The effects of long-range transport of contaminants, which contribute to acidic deposition, ozone damage, and impairment of scenic resources, have become obvious to park employees and visitors alike. NPS areas have also suffered the impacts of point- and non-point source pollutants entering parks through waters shared by cities, industry, and agriculture. The Service has responded by instituting many research and monitoring programs with the guidance and participation of the Air Quality and Water Resources divisions. NPS has been a major player in the National Atmospheric Deposition Program, and individual parks, to maintain their air and water quality standards as required by the Clean Air and Clean Water Acts, often work closely with other federal and state agencies to monitor physicochemical parameters. Although NPS has programs to monitor the status of air and waters in park areas, the chemical contamination episode reported here strongly indicates that present monitoring programs are inadequate to detect ecotoxins that accumulate in park biota. This specific case history deals with mercury but applies as well to other bioaccumulatory heavy metals and pesticides. We hope that the mercury case history in the Everglades will demonstrate the need for periodic contaminants testing of the biota to detect a problem before symptoms occur.

Mercury (Hg) is a heavy metal found naturally in air, water, and earth in a number of chemical forms. It is very volatile, easily entering the atmosphere where it may be dispersed widely (Swain, 1989). The biota accumulate mercury in body tissues, through which it is passed to higher trophic levels in the food web (Johnels et al., 1967). Top-level carnivores may accumulate loads at which toxic effects, such as nerve damage, convulsions, and death, become evident. The U.S. Food and Drug Administration presently sets a maximum limit of 1.0 ppm Hg in human foods. Methylmercury is the most toxic and accumulatory mercury compound which is probably produced by the microbial methylation of Hg in aquatic systems (National Academy of Sciences, 1978).

The first hint that Hg was present in Everglades National Park (EVER) came during the DDT-scare of the early 1970's. Ogden et al. (1974) presented the results of screening a variety of wildlife for pesticides and heavy metals. They expressed concern about the biotic effects of Hg because levels in some freshwater fishes averaged between 0.6 and 0.9 ppm. Levels in wading birds eggs and alligator eggs ranged from 0.4 to 0.5 ppm, and exceeded 1.0 ppm in some wading bird tissues. Ogden et al. (1974) suggested that the biota be monitored for contaminants every two or three years, but their suggestion was not heeded.

In 1989, a statewide sampling program for Hg in freshwater gamefish by the Florida Game and Fresh Water Fish Commission revealed that largemouth bass (Micropterus salmoides) filets from the Everglades had the highest levels ($x > 1.0$ -1.5 ppm) in the state (Hand and Friedemann, 1990). Consumption advisories for fishermen were issued by the Florida Department of Health and Rehabilitative

Services. EVER cooperated with the U.S. Fish and Wildlife Service (USFWS) to analyze bass and yellow bullhead catfish (Ameiurus natalis) samples at their Columbia, Missouri lab. Bass from Shark Slough, downstream of the Water Conservation Areas, had the highest levels ($x = 1.706 - 1.847$ ppm); Taylor Slough drainage bass had lower levels ($x = 0.511 - 0.603$ ppm)(Fig. 1). Park managers responded by issuing a brochure explaining the threat to human health, and by prohibiting consumption of bass from Shark Slough and restricting consumption elsewhere. Signs warning of contamination were posted at popular angling sites (Fig. 2). Because the greatest fishing activity and harvest occur in saltwater areas, higher order gamefishes like spotted seatrout (Cynoscion nebulosus) and gray snapper (Lutjanus griseus) were tested next. Fortunately, mercury levels were lower than in the freshwater fishes ($x = 0.112 - 0.587$ ppm), and posed no human health threat.

Until late in 1989, the emphasis for action focused on the human-health issue. This changed when the situation with the Florida Panther (Felis concolor coryi) arose (See Park Science 10(4):15). In the summer of 1989, Panther #27 from Shark Slough died (Fig. 3). Autopsy results were inconclusive but revealed that the cat had regurgitated prior to death. Results of the of the liver scan revealed an incredible 110.0 ppm of Hg, much higher than liver values from panthers killed by automobiles or other causes. Again the Shark Slough link was evident. Blood and hair samples taken from free-living cats captured for radio-collaring showed a similar pattern of high Hg in cats using Shark Slough (Fig. 1). Bioaccumulation of Hg through the panther diet was suggested as the source for the high levels in some cats. Panthers in Shark Slough feed heavily on raccoons

(Procyon lotor) and alligators (Alligator mississippiensis), which in turn feed on fishes and invertebrates. Panthers in other areas prey on whitetail deer (Odocoileus virginianus) as a staple, and deer have been found to have very low Hg levels (Roelke et al., 1992). The next step in the investigation was to determine Hg levels in raccoons. Those from Shark Slough had the highest levels (Table 1). Alligator samples await analysis, but in the northern Everglades the state closed the alligator hunting season because of unsafe Hg levels. Most recently, Great Egrets (Casmerodius albus) and other waders from Shark Slough had the highest Hg levels of samples tested from south Florida (M. Spalding, Univ. of Florida, pers. comm.).

The major questions raised in this episode are the sources of Hg contamination and the factors responsible for its mobilization and cycling in the environment. An obvious correlate of high Hg levels in animal samples from Shark Slough is the presence of peat or muck soils in the central depression of the Everglades. In studies of Hg contamination in Scandinavia and the northern U.S. (Swain, 1989; Hand and Friedemann, 1990), correlations between peat substrates and high Hg levels have been indicated, especially when the peats were mixed or disturbed in some way. Presumably, disturbances liberate Hg stored over time in the peats, making it available for methylation and food-web transfer. The northern quarter of the original Everglades system, known as the Everglades Agricultural Area (EAA), was converted to agriculture decades ago. Two major farming activities in the EAA may release Hg by disturbing the soils. Before the sugarcane harvest begins, thousands of hectares of fields are burned, sending huge plumes of smoke skyward. The processing mills are also fueled by burning cane wastes.

A recent report showed that sugarcane tissues contain Hg at levels of 0.03-1.2 ppm (Simons, 1991). As part of the growing cycle, the fields are alternately flooded and dried, leading to rapid oxidation of the peats and the release of stored Hg. Sod and vegetable production in the EAA also result in peat disturbance and loss. The liberation of either natural or anthropogenically produced Hg from storage in peats may be a major source of contamination elsewhere in the system.

The metropolitan and agricultural areas on the east coast from Palm Beach to Homestead are home to more than four million people who use Hg in products such as batteries, dental materials, and fungicides in latex paints. All of those uses represent non-point sources for a volatile metal easily transported by winds. There also exist point emissions for Hg such as fossil fuel-fired power plants (Joensuu, 1971) and waste incinerators. A study contracted by the NPS Air Quality division estimated that one of the power plants may emit several thousand kg of Hg annually (Gough et al., 1986). Another study which modeled wind tracks over the Everglades in summer and winter demonstrated that Hg emitted along the east coast would be transported over the Everglades (Segal et al., 1986).

Biocontaminant sampling and research is costly; most parks do not have the fiscal resources to address this issue. EVER is participating with the state task force assigned to address and manage the episode, but the task force suffers from insufficient funds to address the problem. To continue periodic monitoring and research, NPS must fund some of the work. The implications of mercury biocontamination are frightening. If we do not understand the sources or the processes, there will be no way to mitigate the episode, leaving the region with a

chronic contamination situation. Because of the potential threat to the few remaining wild panthers in the Everglades, the Florida Panther Interagency Committee had recommended the removal of all at-risk panthers into captivity; no action has yet been taken. With alligators and wading birds, the past few years have seen notable reproductive failures and some developmental anomalies. Interpretation of those findings is confounded by the coincidence of several years of extreme drought, but the synergy of Hg must also be considered.

National parks are not immune to the waste products of the society that surrounding them. The lesson of the Hg incident is clear. Even if air- and water-quality monitoring are intended to measure heavy metal or pesticide levels in the environment, those levels may be so low that their potential impacts on wildlife are not appreciated. We believe NPS must fund periodic monitoring for contaminants in biota to catch the problem before symptoms appear. The most efficient means is by sampling indicator organisms near the top levels of system food webs, where symptoms are most likely to be manifested. The price of ignoring biocontaminant monitoring is the potential to discover that biotic resources of a park are being quietly but inevitably poisoned.

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FIGURE LEGENDS

- Figure 1. Extreme southern Florida, showing the major drainage areas in and near Everglades National Park. High (closed symbols) or low (open symbol) mercury levels in tissues from fishes, raccoons, and the Florida Panther show the pattern of association with Shark Slough.
- Figure 2. Warning sign posted at a freshwater fishing area in the Taylor Slough drainage area of Everglades National Park.
- Figure 3. Remains of Florida Panther # 27 found dead in Northeast Shark Slough.