

Mercury TMDL for the State of Florida

Appendix E

Impact of Mercury Pollution on Wildlife

Watershed Evaluation and TMDL Section



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Appendices

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E.1. American Alligator

The first report of total mercury (THg) in wild-caught American alligators (*Alligator mississippiensis*) from Florida waters was made by Ogden et al. (1974), who reported on levels in eggs collected from Shark River Slough in the ENP (the southern end of the EPA). They found concentrations of THg in alligator eggs greatly exceeded levels observed in the eggs of their estuarine counterpart, the American crocodile (*Crocodylus acutus*), collected from Florida Bay.

Measurements of THg in tail muscle from wild-caught alligators from Florida waters were first reported by Delany et al. (1988). They found that average concentrations in 32 alligators collected from eight lakes in 1984 ranged from 0.04 to 0.61 ppm. In 1989, responding to findings of elevated levels of THg in fish, the FWC collected 29 harvestable-size alligators from the WCAs and tested for THg in tail muscle. THg levels were well in excess of previous findings from non-Everglades water bodies, with a system-wide range in individual alligators of 0.46 to 3.88 ppm and an average concentration of 2.38 ppm (Hord et al., 1990).

During the same time period, the FWC obtained samples of tail muscle collected by a nuisance-alligator hunter from alligators captured in urban canals in the Fort Lauderdale area. For comparison, an additional 58 samples of tail muscle were collected from licensed meat processors from north, central, and South Florida (Hord et al., 1990). Results for nuisance alligators from the Fort Lauderdale area during May 1989 revealed a wide range of values — individual concentrations ranged from 0.17 to 2.52 ppm with an overall mean of 0.74 ppm. The results for alligators collected from meat processors from north, central, and South Florida (non-WCA locations) revealed lower THg concentrations with a range in county means of 0.13 to 0.90 ppm. The highest county mean, 0.90 ppm (n = 1), was from Franklin County in the panhandle, indicating that problematic levels of THg were not limited to the WCAs.

Concentrations of THg in alligator muscle collected through the 1990s clearly demonstrated THg levels exceeding the existing criteria established for the protection of human health by the FDOH and U.S. Environmental Protection Agency (USEPA, 2001a).

E.2. Florida Panther

The Florida panther (*Puma concolor coryi*) is a state and federally listed endangered species. Environmental stressors (including environmental contaminants), low genetic variability, and habitat loss have all contributed to the decline of this species. Mercury contamination has been suggested as a causative factor in the low densities, poor reproduction, and some reported deaths of panthers from portions of South Florida (Roelke et al., 1991; Facemire et al., 1995); however, factors such as prey abundance and consumption, panther diseases, genetics, and demographic issues are difficult to separate from the influence of mercury when measuring panther fitness and mortality. During a survey of various tissue, blood, and hair samples collected from 52 live and dead free-ranging panthers from 1978–1991, Roelke et al. (1991) found detectable levels of THg in all tissues as well as strong spatial gradients. Similarly, MeHg

was present in all panther hair samples collected from museum specimens dating back to the 1890s (Newman et al., 2004), with significantly higher levels observed in the 1990s than in the late 1800s.

Roelke et al. (1991) reported that the highest mercury concentrations were found in panthers from the Shark River Slough of the ENP (hair = 56.4 ppm; blood = 0.794 ppm) and the lowest concentrations were from north of Alligator Alley (hair = 1.66 ppm; blood = 0.094 ppm), which included northern Fakahatchee Strand, Florida Panther National Wildlife Refuge (FPNWR), and portions of Big Cypress National Preserve (BCNP). Differences were likely influenced by the ambient levels of mercury in the environment as well as prey selection, with panthers feeding on non-hoofed, fish-eating species [i.e., raccoons (*Procyon lotor*)] exhibiting the highest tissue THg concentrations. [Note: Animal tissue (fish, panther, etc.) are usually reported as mg/kg (ppm); blood is mg/L (ppm).]

It was noted that raccoons comprised 70 percent or more of the diet of panthers foraging within Shark River Slough. These panthers also had the highest muscle and liver THg concentrations. Panthers foraging north of Alligator Alley had lower mercury levels and fed primarily on white-tailed deer (*Odocoileus virginianus*) and feral hogs (*Sus scrofa*) — species not tied to the aquatic food web. During the late 1980s, adaptive management strategies by the FWC to modify the prey base available to panthers foraging within the Fakahatchee Strand resulted in declines in panther THg levels, as panthers transitioned from a diet dominated by raccoons to one comprised largely of deer and hogs (Roelke et al., 1991). At that time, raccoons within Fakahatchee Strand had THg values 10–100 times higher than those in deer.

From 2000–2007, the FWC gathered a total of 272 blood samples and 384 hair samples from panthers for mercury analysis. Preliminary results for these collections were reported by Brandon et al. (2009). Blood samples (n = 158) had measurable amounts of mercury, with concentrations ranging from 0.009 ppm to 5.3 ppm. Likewise, hair samples (n = 321) also had measurable concentrations of mercury, with values ranging from 0.086 ppm to 100 ppm. During this period, the panther with the highest mercury concentrations in blood and hair (from samples collected post-mortem), identified as FP 85, was first caught in the Southern Glades Wildlife Management Area in 2003 and then found dead in the ENP in 2004. The cause of death for FP 85 was listed as “unknown” (FWC, 2010).

Although average mercury concentrations in Florida panther blood and hair generally declined between study periods (1978–1991 and 2000–2007) at Big Cypress National Preserve (BCNP) south of I-75, increasing mercury levels in blood and hair were observed in recent years. Mean concentration of mercury in blood rose from 0.259 ppm (n = 6) in 2006 to 0.568 ppm (n = 8) in 2007 and more than doubled in hair from 4.518 ppm in 2006 (n = 9) to 10.847 ppm (n = 13) in 2007. This difference between years was not statistically significant for blood or hair, but because of the few animals left in the wild, any data indicating elevated panther mercury levels are cause for concern.

It is evident that the majority of the current Florida panther population occupies an area where mercury bioaccumulation in aquatic ecosystems remains a significant concern. The FWC continues to collect blood and hair samples for mercury analysis. Analyses will focus on developing a better understanding of potential influential variables contributing to mercury exposure (such as panther age and sex, and regional hydrology). Moreover, correlation analyses of mercury levels with health metrics such as body condition, blood chemistry, and reproductive success should be conducted on the expanding dataset and compared to literature-derived critical tissue concentrations to elucidate the direct and indirect effects of mercury on individuals and regional sub-populations. Finally, special consideration should be

given to regional and individual maximum exposure levels observed in panthers due to their endangered status.

E.3. Fisheating Birds

Experimental exposure of the white ibis (*Eudocimus albus*) to MeHg through diet significantly reduced reproduction. The main loss of reproduction was due to a high rate of MeHg-induced white ibis male-male pairings (up to 55 percent of males), an effect which was dose-related in two of the three study years (Frederick and Jayasena, 2008). In this study, experimental groups of 40 white ibises (even sex ratios) were exposed to 0.05, 0.1, and 0.3 mg MeHg/kg wet weight in diet from 90 days of age through three breeding seasons. No effects were found of MeHg on mass, size, survival, appetite, juvenile hormone levels, or the ability to learn to feed in novel situations. However, all of the mercury-dosed groups had significantly lower reproductive success than the control group in all years, with up to 30 percent reduction in reproductive success. The main loss of reproduction was due to nests not producing eggs, and this stemmed directly from a high rate of male-male pairings (up to 55 percent of males), an effect which was dose-related in two of the three years.

The male-male pairings showed nearly all of the characteristics of male-female pairings, including phenology, courtship, copulation, nest construction, nest attendance, mate defense, and socially monogamous behavior. Male-male pairs were often of longer duration than male-female pairings, and dosed groups all had significantly more time (pair-days) spent in male-male pairings than did the control group. In all years, the majority of the reproductive deficits in dosed groups were attributable to male-male pairing (2006: 75–85 percent, 2007: 82–100 percent, 2008: 50–100 percent). Male-male pairings were not a result of location effects, sex ratio, or constrained mating opportunities. Additionally, male-male pair bonds in all groups were formed relatively early in the breeding season at a time when there were unpaired females available in breeding condition.

Males that were dosed, and especially those that later paired with males, had significantly lower display rates than control males (Frederick and Jayasena, 2010). It seems likely that although females approached them for courtship, the displays of these males may have been substandard. Some homosexual males later formed heterosexual pair bonds in the same or subsequent seasons, and had fertile eggs in all of those situations, demonstrating that they were competent mates. Male-male pairings declined over the three breeding seasons, suggesting that birds were switching mates because of poor reproductive success.

Expression of sex steroids (estradiol and testosterone) were also affected by MeHg exposure, showing a dose-dependent response (Frederick, UF, personal communication). The pattern of altered expression was exaggerated within any group among homosexual males, suggesting that MeHg-induced changes in hormone expression affected sexual behavior such as display rates and pairing preference, and through that mechanism, reproduction was affected. While this experimental evidence strongly links hormones, mercury exposure, and behavior, the physiological mechanisms involved are unknown.

This study suggests that MeHg can function as an endocrine disruptor, resulting in altered sexual behavior and reduced reproductive success. The reduction in reproduction was not trivial — if the normal sex ratio in the wild is 1:1, the reduction in success could be up to 55 percent

(the proportion of males pairing with males in this study). In many studies, effects seen in the lab (or aviary) are exaggerated in the field because of additional stressors in the wild; it is unclear whether effects documented in the aviary would be exacerbated in the Everglades.

At minimum, the implications of this study are that MeHg exposure at ambient levels in the Greater Everglades in the early 1990s could have been enough to affect breeding behavior to the extent that measurable demographic change may have been realized. As mercury exposure declined in the late 1990s, the numbers of breeding pairs of wading birds increased by 3–5X. While some of this increase was clearly due to better hydrological conditions, hydropattern does not explain all of the increase, and mercury is an explanatory variable in nearly all models of population response during this period (Frederick and Jayasena, 2008). While these results are merely correlational, the experimental research demonstrates an effect and a mechanism by which mercury affected populations.

A risk assessment of MeHg exposure to three piscivorous wildlife species (bald eagle, (*Haliaeetus leucocephalus*); wood stork, (*Mycteria Americana*); and great egret, (*Ardea albus*)) foraging at a MeHg hot spot in northern ENP indicated the likelihood was very high, ranging from 98–100% probability, that these birds would experience exposures above the acceptable MeHg dose when foraging in northern ENP. Moreover, the likelihood that these birds would experience exposures above the lowest-observed-adverse-effect level (LOAEL) ranged from a 14% probability for the wood stork to 56% probability for the eagle. Data from this study, along with the results from several other surveys suggest that biota in ENP currently contain the highest MeHg levels in South Florida and that these levels are similar to or greater than other known MeHg hot spots in the United States (Rumbold et al., 2008)

E.4. Pig Frog

The FWC regulates harvest of amphibians and allows year round harvest of frogs for personal consumption. The pig frog (*Rana grylio*) constitutes the majority of harvest in the Everglades and Francis S Taylor Wildlife Management Area (i.e. the WCAs) (Paul Moler, FWC, Personal Communication). A study in 2005 indicated pig frogs in Everglades Water Conservation Areas (WCA) 2 and 3 have elevated levels of mercury in edible portions of leg meat that could constitute a health risk to consumers (Ugarte et al. 2005). In 2006, the FWC collected a total of 135 pig frogs for mercury analyses (Ted Lange, 2006). THg concentrations ranged from 0.005 to 0.78 ppm and the average THg concentration for all pig frogs was 0.17 ppm.

In 2008, a consumption advisory was issued by DOH for pig frogs. For the sensitive population, a limit of one meal per week from WCA 3B and one meal per month from WCA 3A was advised.

E.5. Burmese Python

The Burmese python (*Python molurus bivittatus*) is native to Southeast Asia and has been exported to the United States for the pet trade and ultimately released into the wild. These snakes thrive in the subtropical South Florida climate. Due to increases in their populations, state and federal agencies are working to control pythons. In January 2008, the FWC established a list of Reptiles of Concern (ROC) for nonnative species which includes pythons. In July 2009, a permit program was initiated to allow hunting of ROCs in FWC-managed areas.

There is concern, however, that hunters may consume the python meat, which has high concentrations of mercury.

Mercury data were collected from 24 Burmese pythons in the ENP from 2006–2009 by the U.S. Geological Survey (Krabbenhoft, unpublished data). The mean THg concentration in muscle tissue of 3.6 ppm (range: 0.14–10.75 ppm) was significantly higher than in fish and alligators within the ENP and showed no relationship to python size. Most of the mercury burden in pythons appears to be in the methylated form, with an average MeHg fraction of 80 percent in 11 co-sampled individuals (range: 67–96 percent). Analysis of the digestive tracts of captured pythons in Florida show some of the species consumed are raccoons, wading birds, and alligators (Snow et al., in press), which could account for the high concentrations of mercury since all of these species are fish-eating.



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