

# INVERTEBRATES AS BIOINDICATORS OF MERCURY IN THE OKEFENOCKE SWAMP OF SOUTHEAST GEORGIA

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**Abstract.** Concerns have developed about elevated levels of mercury in wetland vertebrates. It is suspected that mercury moves through wetland food webs and bioaccumulates in top predators. The objective of this study was to examine mercury concentrations in the Okefenokee Swamp of southeast Georgia, focusing on levels in invertebrates. We collected amphipods, odonates, and crayfish, three groups that are important in the Okefenokee food webs, and determined mercury levels in their tissues. Although amphipods are lower on the food chain, higher levels of mercury were detected in amphipod tissues than in odonates or crayfish.

## INTRODUCTION

Wetlands are often classified as sinks that are also responsible for sequestering heavy metals from surrounding habitats. Elemental mercury and methyl mercury are two forms of mercury that are cause for concern. Elemental mercury poses little risk but it becomes an issue when it is methylated into methyl mercury. This form of mercury is a neurotoxin that poses serious problems to ecosystems. Methyl mercury is produced at high rates in wetlands (St. Louis et al., 1994).

The bioavailability of mercury appears to be dependent on several factors. High temperatures reduce dissolved oxygen levels, which in turn enhance methylation. Methyl mercury bound to sediment is released into the water column when oxygen levels are low (Henry et al., 1995). Alternatively, if high dissolved oxygen levels are maintained it can reduce the release of methyl mercury from sediment (Henry et al., 1995). Mercury levels were highest in fish collected from wetlands that were shallow and had frequent fluctuations in water levels (Snodgrass et al., 2000). Intermittent or shallow flooding may increase methyl mercury bioavailability to organisms.

## SOURCES OF MERCURY

Although mercury is often found in wetlands the source of contamination is not easily determined. Both anthropogenic and natural processes are possible sources of bioavailable mercury. In the Okefenokee Swamp, decomposition of peat is considered to be one natural source of methyl mercury (Porter et al., 1999). The greatest contaminant loads of mercury detected from wetlands are in the Everglades (Facemire, 1995; Rood, 1995). Peat and natural mineral deposits are possible sources of mercury contamination there (Rood 1995; Vaithyanathan, et al., 1996). Possible anthropogenic inputs of mercury into wetlands include burning of fossil fuels, medical waste incineration, agricultural practices, and mining (Rood, 1995).

There is increasing evidence that anthropogenic emissions significantly increase mercury levels in precipitation (Rolffhus & Fitzgerald, 1995; Keeler et al., 1995). Although levels of atmospheric mercury are increased by anthropogenic emissions, this does not necessarily increase levels of methyl mercury in the ecosystem (Bloom & Watras, 1989). In precipitation methyl mercury constitutes a small part of total mercury, with levels varying between 0.8% - 0.9% of total mercury concentrations (Bloom & Watras 1989; Downs et al., 1998). Besides input in precipitation, some mercury may enter wetland habitats via runoff. A positive correlation has been found between sediment mercury concentrations and watershed area (Wiener et al., 1990). However, once in the water column mercury can be methylated into methyl mercury (if conditions permit) and this form of mercury can enter food webs and will ultimately affect vertebrates.

## MERCURY CYCLING IN WETLANDS

In aquatic habitats mercury is most closely bound to sediments or particulate matter in the water column.

Sediment is suggested to be the major source of methyl mercury to vertebrates (Larsorsa & Allen-Gill, 1995; Tremblay et al., 1996). Various factors affect sediment mercury concentrations. In lakes an increase in pH enhances release of mercury found in the sediment, (French 1999). Variations in temperature, dissolved oxygen, depth and pH all affect the uptake of mercury by various organisms (Downs et al., 1998; Rood, 1996).

Studies have concluded that mercury in diets has more influence on bioaccumulation of mercury in vertebrates than exposure to mercury the water column (Bhattacharya & Sarkar, 1991; Downs et al., 1998). Top predators depend either directly or indirectly on plants and invertebrates. Several wetland plants sequester mercury and various levels have been identified from plant tissues. The uptake of mercury by plants may contribute to increase of sediment mercury bioavailability (Rood, 1996). Submerged species of aquatic plants sequester higher levels of mercury (Thompson-Roberts et al., 1999). Bryophytes, both feather and *Sphagnum* mosses, sequester the highest levels of mercury. Common wetland species such as the yellow water lily commonly do not sequester mercury their plant tissues (Thompson-Roberts et al., 1999). The lowest levels of mercury are found in the leaves of trees and shrubs (Moore et al., 1995). Decaying aquatic vegetation also plays a role in increasing mercury levels in wetlands. As plant tissues decompose under anoxic conditions methyl mercury is released (Heyes et al., 1998). It is suspected that this increase is the result of methylation of inorganic mercury within the tissues (Heyes et al., 1998).

Relatively little research has been conducted on bioaccumulation of mercury in insects (Hall, 1998; Odin, et al, 1995; Visman et al., 1995). However, certain non-insect invertebrates are used frequently as bioindicators of heavy metal contamination. For example, mollusks are used as bioindicators of contamination of various heavy metals (Eiseman et al., 1997). Under laboratory conditions amphipods bioaccumulate mercury most efficiently from algae and sediment (Lawrence, 2000). Bioaccumulation of mercury by invertebrates allows mercury to become bioavailable to organisms higher in the food chain.

Wetland fish can bioaccumulate high levels of methyl mercury (Bloom, 1992; Mason et al., 1994; Kannan et al., 1997; Wong et al., 1997; Hall et al., 1998). As a result piscivorous birds are susceptible to bioavailable mercury (Gariboldi et al., 1997). Bioaccumulation of mercury in large predators is of considerable concern. Since alligators are long-lived predators, they have the potential to bioaccumulate

mercury in their tissues (Kahan & Tuansel 1999). Much of the furor about mercury in the Everglades resulted because high levels were detected in the liver of an endangered Florida panther (Roelke et al., 1991).

#### MERCURY IN THE OKFENOKEE SWAMP

The Okefenokee Swamp is one of the largest freshwater wetlands in North America. It is approximately 3781 km<sup>2</sup> and provides habitat for a variety of organisms (Porter et al., 1999). Recently restrictions have been placed on the consumption of two species of fish (bowfin and flyer) found in the Okefenokee due to high levels of mercury. As a result concerns have developed about what role invertebrates play in the biomagnification of mercury through the food web of the Okefenokee Swamp. We initiated a project to study the problem in 1998.

Thirty-two sites in the Okefenokee were chosen that occurred across the range of hydrological units and vegetative communities present in the swamp. They include sites centered around Grand Prairie, Double Lakes, Durden Prairie, Chase Prairie, Floyds Prairie, and the Suwannee River Sill. At each site samples were collected in shrub, prairie (lily and/or sedge) and cypress habitats. Additionally, samples were collected in any deepwater habitats present such as lakes, rivers, canals, and managed boat trails. Sampling was conducted in December, May, and August (from 12/1998-8/2000). We collected amphipods, odonates, and crayfish as available for thirty minutes with sweep nets. Individuals were placed in vials and transported on ice back to the laboratory, and then frozen. Samples were sent to Clemson Institute of Environmental Toxicology where total mercury analyses were conducted.

Significant differences were found in total concentrations of mercury among the invertebrates (unpublished results; data based manuscript, in preparation). Despite being lower on the food chain, amphipods contained significantly more mercury than odonates or crayfish. Mercury levels in amphipods routinely exceeded 1 ppm and levels >20ppm were detected in several samples. Even though odonates and crayfish are higher on the food chain they may not be as important as amphipods in the biomagnification of mercury through the food web of the Okefenokee Swamp. Spatial and temporal variations of total mercury in invertebrates are currently being analyzed.

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## LITERATURE CITED

- Bhattacharya, B., Sakar, S.K., 1996. Total Mercury Content in Marine Organisms of the Hoghly Estuary. *Chemosphere*, 33:147-158.
- Bloom, N.S., Watras, C.J., 1989. Observations of Methyl Mercury in Precipitation. *The Science of the Total Environment*, 87:199:207.
- Bloom, N.S., 1992. On the Chemical form of Mercury in Edible Fish and Marine Invertebrate Tissue. *Canadian Journal of Fisheries and Aquatic Sciences*, 49:1010-1017.
- Downs, S.G., McLeod, C.L., Lester, J.N., 1998. Mercury in Precipitation and its Relation to Bioaccumulation in Fish. *Water Air Soil Pollution*, 108:149-187.
- Eisemann, J.D., Beyer, W.N., Bennets, R.E., Morton, A., 1997. Mercury Residues in South Florida Apple Snails, *Environmental Contamination and Toxicology*, 58:739-743.
- Facemire, C., Augspurger, D., Batemand, D., Brim, M., Conzelmann, P., 1995. Impacts of Mercury Contamination in the Southeastern United States. *Water, Air, Soil Pollution*, 80:923-926.
- French K.J., Scruton, D.A., Anderson, M.R., Schneider, D.C., 1999. Influences of Physical and Chemical Characteristics on Mercury in Aquatic Sediment. *Water, Air, Soil Pollution*, 110:347-362.
- Gariboldi, C.H., Jagoe, A.L., Bryan, A., 1997. Dietary Exposure to Mercury in Nestling Wood Storks. *Archives Environmental Contamination and Toxicology*, 34:398-405.
- Hall, B.D., Rosenburg, D.M., Wiens, A.P., Methyl Mercury in Aquatic Insects from an Experimental Reservoir. *Canadian Journal of Fish and Aquatic Sciences*, 55:2036-2047.
- Henry, E.A., Dodge-Murphy, L.J., Bigham, G.N., Klein, S.M., Gilmour, C.C., 1995. Total Mercury and Methyl Mercury Mass Balance in an Alkaline Hypereutrophic Urban Lake. *Water Air Soil Pollution*. 80:915-921.
- Heyes, A., Moore, T.R., Rudd, J.W.M., 1998. Mercury and Methyl mercury in Decomposing Vegetation of a Pristine and Impounded Wetland. *Journal of Environmental Quality*. 27:591-599.
- Khan, B., Tansel, B., 2000. Mercury Bioconcentration Factors in American Alligators. *Ecotoxicology and Environmental Safety*. 47:54-58.
- Kannan, K., Smith, R.G., Lee, R.F., Windom, H.L., Heitimuller, P.T., 1997. Distribution of Total Mercury and Methyl Mercury in Water Sediment, and Fish from South Florida Estuaries. *Archives of Environmental Contamination and Toxicology*, 34:109-118.
- Keeler, G., Glinsorn, G., Pirrone, N., 1995. Particulate Mercury in the Atmosphere: Its Significance, Transport, Transformation and Sources. *Water Air Soil Pollution*, 80:159-168.
- Lasora, B., Allen-Gil S. 1995. The Methyl Mercury to Total Mercury Ratio in Selected Marine, Freshwater, and Terrestrial Organisms. *Water Air Soil Pollution*, 80:915-921.
- Lawrence, A.L., Mason, R.P., 2000. Factors Controlling the Bioaccumulation of Mercury and Methyl Mercury by the Estuarine Amphipod *Leptocheirus plumulosus*. *Environmental Pollution*, 111:217-231.
- Mason, R.P., Reinfeldler, J.R., Morel, F.M., 1994. Bioaccumulation of Mercury and Methyl Mercury. *Water Air Soil Pollution*. 80:915-921
- Moore, T.R., Bubier, J.L., Heyes, A., Flett, R.J, 1995. Methyl and Total Mercury in Boreal Wetland Plants, Experimental Lake Area, Northwestern Ontario. *Journal of Environmental Quality*. 24:845-850.
- Odiun, F.M., Feurtet-Mazel, A., Ribeyre, F., 1995. Temperature, pH, and Photoperiod Effects on Mercury Bioaccumulation by Nymphs of the Burrowing Mayfly. *Water Air Soil Pollution*, 80:1003-1006.
- Porter, K.G., Bergstedt, A., Freeman, M.C., 1999. Riverine Floodplain Forests of the Southeastern United States. *Invertebrates in Freshwater Wetlands of North America; Ecology and Management*. Ed. D.P Batzer, R.B Rader, & S.A Wissinger. John Wiley & Sons, Inc. Ch. 6, 121-136.
- Roelke, M.E., Schultz, D.P., Facemire, C.F., Sundaolf, S.F., Royals, H.E., 1991. Mercury Contamination in Florida Panthers. Report by the Technical Subcommittee of the Florida Panther Interagency Commission. Florida Game and Freshwater Fish Commission, Gainesville, Florida.
- Rolfhus, K.R., Fitzgerald, W.F., 1995. Linkages Between Atmospheric Mercury Deposition and the Methyl Mercury Content of Marine Fish. *Water Air Soil Pollution*. 80:915-921.

- Rood, B.E., 1996. Wetland Mercury Research: A Review with Case Studies. *Current Topics in Wetland biogeochemistry*, 2:73-108.
- St. Louis, V.L., Rudd, J.W., Kelly, C.A., Beaty, K.G., Bloom, N.S., Flett, R.J., 1994. Importance of Wetlands as Sources of Methyl Mercury to Boreal Forest Ecosystems. *Canadian Journal of Fisheries and Aquatic Sciences*, 51:1065-1076.
- Snodgrass, J.W., Jagoe, C.H., Bryan, A.L., Brant, H.A., Burger, J., 2000. Effects of Trophic Status and Wetland Morphology, Hydroperiod, and Water Chemistry on Mercury Concentrations in Fish. *Canadian Journal Fish and Aquatic Sciences*, 57:171-180.
- Thompson-Roberts, E.S., Pick, F.R., Hall, G.E.M., 1999. Total Hg in Water, Sediment, and Four Species of Aquatic Macrophytes in the St. Lawrence River, near Cornwall Ontario. *Journal of Great Lakes Research*, 25:294-304.
- Tremblay, A., Lucotte, M., Rheault, I. 1996. Methyl Mercury in a Benthic Food Web of Two Hydroelectric Reservoirs and a Natural Lake of Northern Quebec. *Water Air Soil Pollution*. 91:255:269.
- Wiener, W.F., Fitzgerald, W., Watras, C.J., Rada, R.G., 1990. Partitioning and Bioavailability of Mercury in an Experimentally Acidified Wisconsin Lake. *Environmental Toxicology and Chemistry*, 9:900-918.
- Wong, A.H., McQueen, D.J. Williams, D.D., Demers, E., 1997. Transfer of Mercury from Benthic Invertebrates to Fishes In Lakes with Contrasting Fish Community Structures. *Canadian Journal of Fisheries and Aquatic Sciences*, 54:1320-1330.
- Vaithyanathan, P., Richardson, C.J., Kavanuagh, R.G., Craft, C.B., Barkay, T., 1996. Relationships of Eutrophication to the Distribution of Mercury and to the Potential for Methyl mercury Production in the Peat of the Everglades, *Environmental Science and Technology*, 30:2591-2597.
- Visman, V., Mierle, G., McQueen, D.J., Uptake of Aqueous Methyl Mercury by Larval Chaoborus americanus. *Water Air Soil Pollution*. 80:1007-1010.