INVERTEBRATES AS BIOINDICATORS OF MERCURY IN THE OKEFENOKEE 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; Vaithiyanathan, 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 (Rolfhus & 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 bioaccumuation 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 OKEFENOKEE SWAMP

The Okefenokee Swamp is one of the largest freshwater wetlands in North America. It is approximately 3781 km^2 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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