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Bioaccumulation of Heavy Metals in Two Populations of Mummichog *(Fundulus heteroclitus)*

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In polluted areas, bioaccumulation by an organism can occur when the rate of uptake of a pollutant exceeds its rate of elimination . Gale et al. (1973) reported higher concentration of metals in aquatic organisms from a contaminated area than those from an uncontaminated area. Anderson and Brown (1978) found higher concentrations of Cd and Pb in crayfish (*Orconectes virilis)* collected from a contaminated site than those from an uncontaminated site. Similarly, Khan et al. (1989) reported higher concentrations of Cu, Hg, and Zn in grass shrimp *(Palaemonetes pugio)* collected from a polluted creek than those from a non-polluted creek. However, many aquatic animals under contaminated conditions are able to maintain trace metal concentrations in the body at a normal level. McDermott et al. (1976) reported that Dover sole *(Microstomus pacificus)* collected from contaminated and uncontaminated sites accumulated comparable levels of silver, cadmium, chromium, copper, nickel, lead, and zinc.

This paper reports on the concentrations of Hg, Cd, Cu and Zn in two populations of mummichog *(Fundulus heteroclitus).* One population was from Piles Creek (PC), a polluted tidal creek in a heavily industrialized area in Linden, New Jersey, and the other population was from a pristine area in Southampton, Long Island (LI), New York.

MATERIALS AND METHODS

To study bioaccumulation of Hg, Cd, Cu, and Zn in PC and LI fish, adult fish (5.5 -9.5 cm standard length) were caught during July, October, and November of 1985 from both PC and LI by using minnow traps. At the time of fish collection, a total of 12 surface sediment samples were also collected by Ekman dredge at 10-15 cm depth from 4 stations (5 samples/station) at each site. Both fish and sediment samples were stored at -20^{o}C until analysis. After each collection period, fish were

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measured and sorted by size and sex (except July) and individual livers were excised for analysis. Liver samples were wet-ashed using 0.1-0.2 g in one ml of a 3:1 mixture of ultrapure concentrated HNO_3:$HClO_4$. The residues were redissolved in 10 ml of 10% HNO_3. Sediment samples were oven dried (150°C) for 6 hr and ground in a motar and pestle. Samples were extracted using 0.1 -0.2 g in one ml of a 3:1 mixture of concentrated HNO_3:$HClO_4$ and made up to 10 ml with deionized water. All samples were analyzed for Cd, Cu, and Zn by direct aspiration into air-acetylene flame of a Perkin-Elmer 403 atomic absorption spectophotometer. For each metal 40-138 fish samples were analyzed. Oyster powder (National Bureau of Standards) samples were analyzed for Cd, Cu, and Zn along with fish liver samples. The recoveries were 95, 95, and 96 % for Cd, Cu, and Zn, respectively. Total Hg in sediment and fish liver were analyzed by the Hatch and Ott (1968) cold vapor atomic absorption method in a Coleman MAS-5O mercury analyzer. This procedure uses concentrated H_2SO4: HNO3 (4:1) at 58°C for wet-ashing. USEPA quality control samples "Metals in Fish" were analyzed for Hg along with the fish liver samples and 95% of the Hg was recovered. For data analysis, means and 95% confidence limits were computed (Zar 1984). Concentration factors were calculated by dividing the mean concentration of metals in the fish liver by the mean concentration of metals in the sediments.

RESULTS AND DISCUSSION

Piles creek sediment contained much higher concentrations of Hg, Cd, Cu, and Zn (11.2 ppm Hg, 5.78 ppm Cd, 623 ppm Cu, and 628 ppm Zn) than LI sediment (<0.03 ppm Hg, 0.460 ppm Cd, 41.0 ppm Cu, and 49.4 ppm Zn).

Piles Creek fish contained significantly higher levels of Hg and Cu than LI fish (Table 1). The accumulation of higher levels of Hg and Cu in PC fish may have been related to the concentration of these metals in sediments and in their environment. The association of higher levels of metals in organisms and greater levels in their environment have been reported by Anderson and Brown (1978) in crayfish (*Orconectes virilis*) in freshwater, Frazier and George (1983) in oyster *(Ostrea edulis)* in sea water and Khan et al. (1989) in grass shrimp *(Palaemonetes pugio)* in sediment.

Piles Creek fish, however, had comparable concentrations of Cd and Zn (Table 1) as did the LI fish. This indicates some regulatory ability of the organisms since sediment metal concentrations vary between the two sites. McDermott et al. (1976) also found comparable levels of these metals in Dover sole *(Microstomus pacificus),* collected from unpolluted and polluted areas. Both PC and LI males accumulated significantly

Table 1. Mean bioaccumulation and 95% confidence intervals (in parentheses) of heavy metals (ppm wet weight) in the liver of two populations of mummichog (Total of July, October, and November).

	PC	LI
Hg[a]	0.45 (0.33 - 0.56)	0.06 (0.02 - 0.10)
N	105	93
Cd[b]	0.38 (0.30 -0.45)	0.39 (0.29 - 0.48)
N	134	100
Cu[a]	117 (116 - 118)	66.7 (65.1 - 68.2)
N	140	99
Zn[b]	45.1 (44.8 - 45.3)	43.8 (42.7 - 44.8)
N	138	101

a. significant difference between PC and LI mummichog metal accumulation.
b. no significant difference between PC and LI mummichog metal accumulation.

Table 2. Mean bioaccumulation and 95% confidence intervals (in parentheses) of heavy metals (ppm wet weight) in the males and females of PC mummichog (Total of October and November).

	Males	Females
Hg[b]	0.51 (0.33 - 0.69)	0.41 (0.25 - 0.56)
N	45	50
Cd[b]	0.49 (0.36 - 0.61)	0.37 (0.25 - 0.49)
N	58	58
Cu[a]	118 (115 - 119)	103 (101 - 105)
N	58	58
Zn[b]	37.2 (36.4 - 38.3)	39.8 (38.2 - 40.7)
N	59	58

a. significant difference between males and females mummichog metal accumulation.
b. no significant difference between males and females mummichog metal accumulation.

higher levels of Cu than PC and LI females (Table 2 & 3). Long Island females also accumulated significantly higher levels of Zn than LI males (Table 3). Similar sex differences were also reported for 12 species of freshwater fish in terms of Hg concentration (Hattula et al. 1978), Cd concentration in zebrafish (Rehwoldt and Karimian-Teherani 1975), and Zn concentration in killifish, *F. heteroclitus* (Chernoff and Dooley 1979). Both PC and LI fish showed no correlation between metal levels and standard length of the fish. Similar results were also reported in scorpion

Table 3. Mean bioaccumulation and 95% confidence intervals (in parentheses) of heavy metals (ppm in wet weight) in the males and females of LI mummichog (Total of October and November).

	Males	Females
Hg[b]	0.049 (0.002 - 0.10)	0.07 (0.01 - 0.14)
N	44	50
Cd[b]	0.44 (0.30 - 0.57)	0.43 (0.28 - 0.58)
N	40	43
Cu[a]	74.9 (72.0 - 77.7)	50.4 (48.6 - 52.1)
N	40	43
Zn[a]	38.0 (36.3 - 39.7)	45.05 (43.3 - 46.8)
N	40	43

a. significant difference between males and females mummichog metal accumulation.
b. no significant difference between males and females mummichog metal accumulation.

fish (Renzoni et al. 1973), in blue marlin (Shultz and Crear 1976), in freshwater fish (Hattula et al. 1978), and in pike (Hakanson 1984). However, Walting et al. (1981) found a correlation between Hg and increase of length of mako shark. Singh et al. (1991) reported that Cu and Zn levels in five tropical marine fishes either increased significantly with the size of the fish or stayed essentially same.

Although PC fish showed higher concentrations of Hg and Cu in the liver, their concentration factors were much lower (concentration factors of 0.04, 0.06, 0.18, and 0.07 for Hg, Cd, Cu, and Zn, respectively) than those of LI fish (0.84, 1.62, and 0.88 for Cd, Cu, and Zn, respectively). Khan et al. (1989) also found lower concentration factors for grass shrimp (*Palaemonetes pugio)* collected from PC. Organisms living in contaminated areas can concentrate relatively lower amounts of contaminantants, possibly by excreting more or by reducing permeability and, thus, help them to survive in contaminated areas.

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