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Coefficient of Condition in Relation to Copper Levels in Muscle of Serranochromis Fish and Sediment from the Kafue River, Zambia

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The Kafue River is the major source of drinking water and commercial fish for most towns and cities in Zambia. Unfortunately, all the industrial, domestic, and agricultural effluents from these towns, cities and surrounding areas are discharged either directly or via tributaries into the Kafue River. These discharges if not well controlled have a potential of polluting the river and negatively affecting the health of humans, fish and all flora and fauna that depend on it. There are a few studies that have reported high levels of heavy metals in the Kafue River. Levels of copper, cobalt and zinc (Syakalima *et al* 2001a) and lead (Syakalima *et al* 2001b) in water, fish, grass and Kafue Lechwe liver from the Kafue Flats varied from trace to above normal. On the other hand water and sediment from the Kafue River around the Copperbelt mining area has been reported to contain high levels of heavy metals (Mwase *et al* 1998 and Norrgren *et al* 2000).

Few reports exist concerning toxic effects of pollutants on organisms dependent on the Kafue River. The reported toxicity cannot be conclusively linked to anthropological discharges. Cattle deaths due to suspected copper poisoning have been reported (Zambia Consolidated Copper Mines 1982). Mwase *et al* 1998 reported pathological features such as reproductive abnormalities, and granulomas in fish reared in cages containing sediment from the Copperbelt region of the Kafue River. Therefore, discharges from the Copperbelt mining area of Zambia into the Kafue River are considered to be among the main sources of pollutants. Thus, more studies on pollutants in the Kafue River and their toxic effects on flora and fauna are required in order to justify strict pollution control measures.

The coefficient of condition of fish is the length-weight relationship used to express relative plumpness or robustness of fish. This is in turn related to environmental conditions (APHA, AWWA, WPCF 1985). Healthy fish are more plump or robust and have a higher coefficient of condition than unhealthy fish. The genus of Serranochromis fish are important commercial fish in Zambia which can be caught throughout the year. They are found in a broad range of habitats from mainstream margins to floodplain channels and lagoons. They prey on insects and small fish (Utsugi and Mazingaliwa 2002) such as *Brycinus lateralis*

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and *Micralestes acutidens* (Skelton 1993). The objective of this study was to determine the coefficient of condition and copper levels in muscle of Serranochromis fish and sediment from the Kafue River.

MATERIALS AND METHODS

A total of eight sampling sites were identified along the Kafue River. These were, Chimfunshi Wildlife Orphanage and Lukobeko fishing camp in Chingola area but upstream before the Kafue River enters the Copperbelt mining area. These were sites with the least anthropological contamination. Sites expected to have the highest contamination were at Chipata Township and Kumasamba Lodge within the Copperbelt area. Kafue Hook bridge and Highland Fishing Camp were sampling sites in the Kafue National Park while Kasaka Fisheries College and Kafue bridge were site in Kafue Town and these were all downstream from the copper mining area (Figure 1).

Sample collection was done once a week for four weeks in September in the hot dry season and in March during the warm rainy season. Water and sediment samples were collected from the same spots at each site all the time in glass bottles and glass jars respectively. A 600 mL composite surface water sample was made up of 200 mL of water collected approximately two meters from the edge of one river bank, 200 mL approximately two meters from the edge of the other bank, plus 200 mL from the middle of the river. Similarly a 300 g composite sediment sample was made of 100 g of the top layer of the sediment sampler grab sample collected approximately two meters from the edge of one river bank, 100 g approximately two meters from the edge of the other bank and 100 g from the middle of the river. Since water and sediment samples were collected once a week for four weeks in each season, there was a total of four composite water samples ($n = 4$) and four composite sediment samples ($n = 4$) per site per season.

Fish were caught using both seine and 3 inch gill nets. The common fish at all sampling sites in both the rainy and dry seasons were of the genus Serranochromis mainly *S. macrocephalus*, *S. angusticeps* and *S. altus*. From each site 20 Serranochromis fish were randomly collected from a weekly catch for 4 weeks giving a total of 80 fish per site per season. For the purpose of calculating the coefficient of condition, all fish were individually weighed and the standard length (L) which is the length from the tip of the upper lip to the bending point of the caudal fin was measured. The Coefficient of Condition was later calculated for each of the eighty fish ($n = 80$) using the formula, $K = Wx10^5/L^3$, where, K = Coefficient of condition, W = weight in grams, and L = standard length in millimetres (APHA, AWWA, WPCF 1985). For the purpose of determining copper levels in the edible portions of fish, scales were removed and 25 g of muscle including the belly flap and skin were cut from each fish that were collected in a given week and pooled giving a total of four ($n = 4$) 500 g pooled samples per site per season. Pooled fish tissues were packed in histopacks and

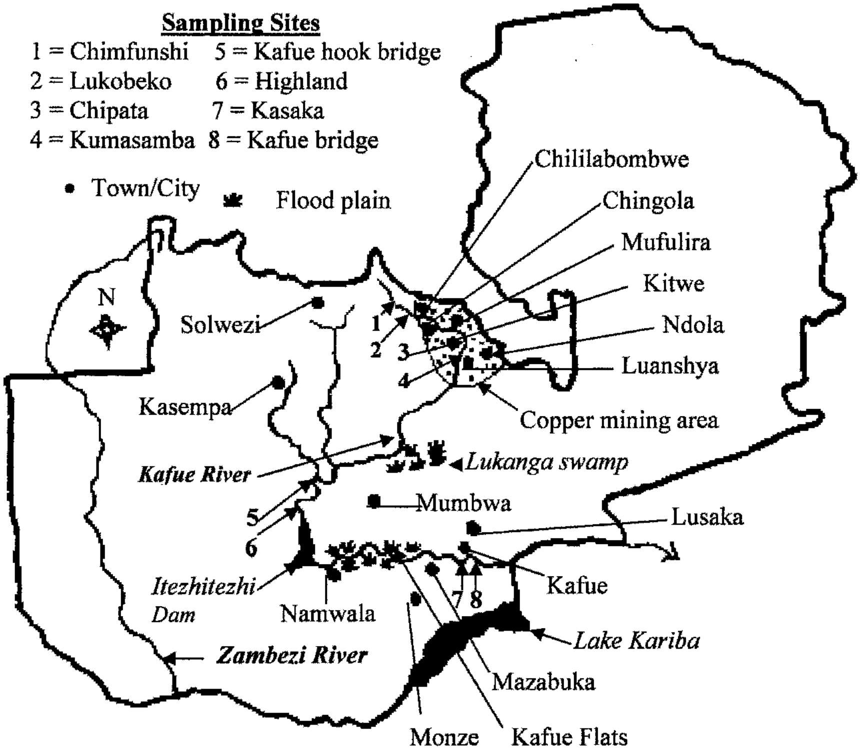

Figure 1: Map of Zambia showing sampling sites and towns/cities discharging directly or via tributaries into Kafue River.

transported together with sediment and water samples in cooler boxes containing ice packs to a deep freezer at the laboratory.

Processing and analysis of all samples for copper was done in duplicate. Pooled fish samples from each site were minced in a blender and dried at 120°C in an oven overnight. Each sample was then ground to powder and 1g was added to 10 mL of concentrated nitric acid and digested on a hot plate at 250°C until all the organic matter was dissolved. It was then cooled and mixed with 10 mL of distilled water followed by 10 mL of perchloric acid. The solution was digested further on a hot plate until the solution was clear or until white fumes emerged. After cooling 24 mL of distilled water was added and boiled on a hot plate. The solution was once again cooled and the volume made up to 100 mL with distilled water. The resulting solution was used for copper analysis on flame atomic absorption spectrophotometer (AAS) (Perkin Elmer 2380). The concentration of copper in mg/L was obtained by calculation in comparison to a standard over a suitable concentration range. The concentration in mg/kg sample was obtained by multiplying mg/L by 100 because the dilution factor in the extraction process was 1g in a total of 100 ml of extraction solution (i.e. 1:100). For copper analysis in sediment, 20 g of each sediment sample was dried by blowing air through a 2 mm sieve over the sample. It was put in a 250 mL conical flask and 40 mL of Diethylentriamminepenta acetic acid penta -sodium-Triethanolamine (DPTA-TEA) solution were added. The suspension was shaken for 1 hour and filtered. Copper was read on AAS in mg/L which were converted to mg/kg sample by multiplying by 2 because the dilution factor was 20g in 40 mL (1:2).

A one-way analysis of variance (ANOVA) was used to test the difference in mean values among sampling sites or seasons. When ANOVA yielded a p value less than 0.05, Bonferroni t tests were conducted to test for significant differences between the means of particular pairs. This was performed using a statistical software called GraphPAD Instat® (1990), version 1.13, C.T.V.M, University of Edinburgh, United Kingdom.

RESULTS AND DISCUSSION

The levels of copper in water from all sites either in the dry or rainy seasons were below the detection limit of 0.001 mg/L. This was low compared to the average concentration of copper in lakes and rivers of 4 ppb or 0.004 mg/L (EBI 2004).

In the rainy season there was no significant difference in levels of copper in sediment among all sites ($p > 0.05$). However, in the dry season levels of copper in sediment were significantly higher ($p < 0.001$) at Chipata and Kumasamba sites (Figure 2). Copper levels in sediment were significantly lower ($p < 0.001$) in the rainy season compared to the dry season at Chipata and Kumasamba. This was mainly a result of the increased dilution effect and the high water current in the rainy season which disperses copper containing particles further down stream and beyond the study area. In addition the low copper levels in sediment at sites down stream to the mining area could have also been a result of the sediment trapping effect of materials downstream e.g. in the Lukanga swamp and Itezhitezhi dam. Copper levels in fish muscle were significantly higher ($p < 0.001$) at Chipata and Kumasamba compared to other sites.

Fish from Chimfunshi and Lukobeko upstream had a significantly better ($p < 0.001$) coefficient of condition than fish from Chipata and Kumasamba and downstream to Hook bridge, Highland, Kasaka and Kafue bridge. However, fish from Chipata and Kumasamba had the lowest coefficient of condition (Figure 3). There was no significant seasonal difference ($p > 0.05$) in the pattern of copper levels in muscle and the coefficient of condition among most sites.

The relatively better coefficient of condition for fish at Hook bridge, Highland, Kasaka and Kafue bridge though downstream could be due to the variability of contaminant toxicity as influenced by physico-chemical processes of e.g. dilution, diffusion, adsorption, precipitation etc. For example it has been shown that the LC_{50} value of copper for rainbow trout is 0.05 mg/L at water hardness of less than

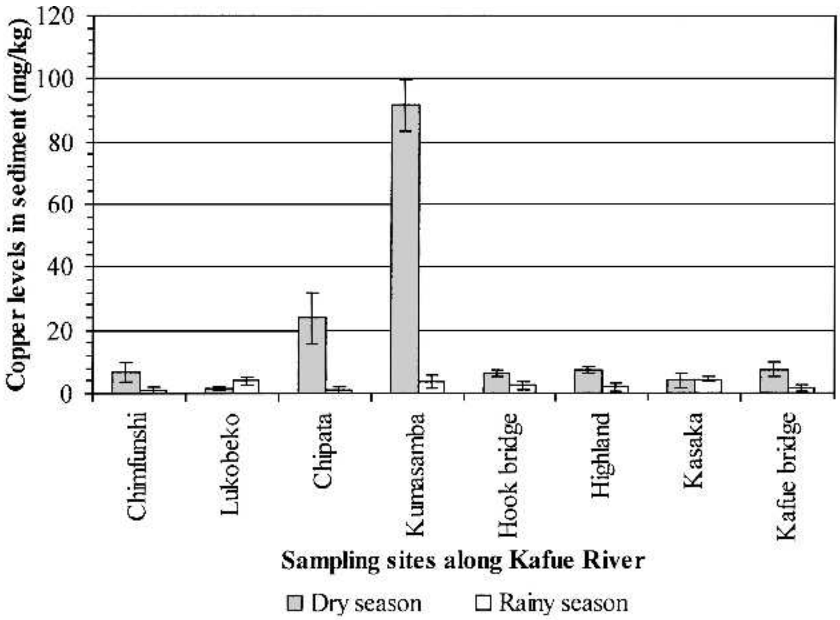

Figure 2: Copper levels in sediment from Kafue River in the dry and rainy season.

100 mg/L and increases to 0.15 mg/L at water hardness greater than 100 mg/L (EBI 2004). The coefficient of condition in fish from Chimfunshi and Lukobeko upstream was significantly higher ($p < 0.001$) than that for fish from sites downstream to copper mining area while copper levels were almost the same. This implies that either other pollutants were involved or that the levels of copper were not high enough to accumulate in muscle although they could have been high enough to suppress normal growth.

Copper is a commonly occurring element in natural water and sediment. At low concentrations it is an essential element for both plants and animals. At slightly higher but sub-lethal concentrations it causes chronic toxicity to aquatic life. Chronic toxic effects may include poor growth or condition, poor immune responses, shortened life span, reproductive problems, lower fertility and changes in appearance and behaviour. A study by Shiau and Ning 2003 showed that the adequate dietary copper requirements for growing *Oreochromis niloticus* was 4 mg/kg diet. Dietary copper levels of 20 mg/kg significantly reduced the weight gain of growing tilapia. Bioaccumulation of copper in fish tissues such as the kidney, liver, spleen and muscle is directly proportional to exposure concentration. Copper levels in the liver are usually higher than those in muscle (Arellano *et al* 1999) because copper and other heavy metals are bound to metallothioneins in the liver (Dallinger 1995). The accumulation of heavy metals including copper in the liver is associated with low levels of contamination, but when organisms exposed are to higher metal concentrations, the liver cannot regulate hepatic levels and an

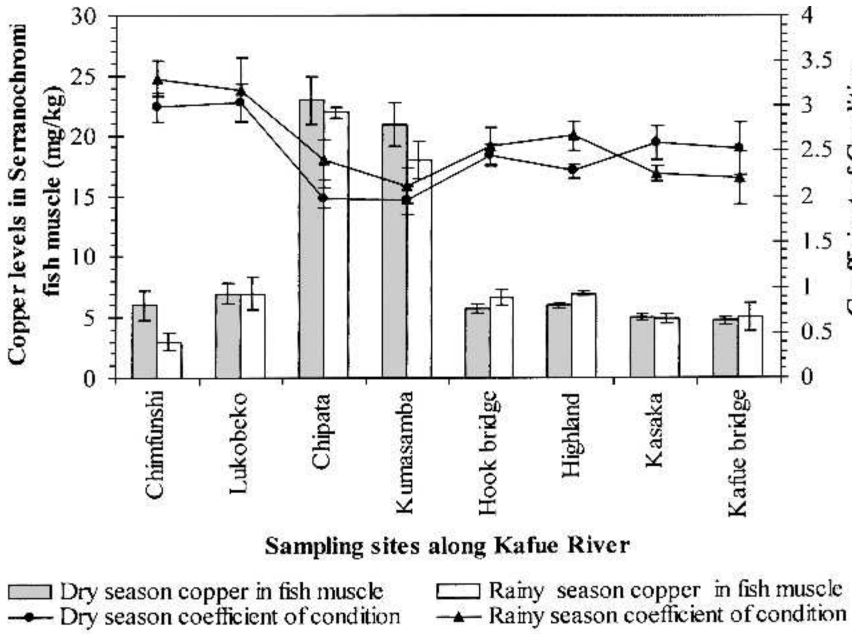

Figure 3: Copper levels in Serranochromis fish in relation to the Coefficient of Condition

increase is observed in other tissues (Benedetti *et al* 1988) such as muscle tissue. These results show that measuring the coefficient of condition for fish is a good indicator for monitoring the effects of contaminants on fish. But since there are many contaminants in the Kafue River detailed studies are required to determine specific causes so that pollution control can be more specific. Copper mining and processing being the largest industry on the Copperbelt needs independent monitoring because of the adverse effects copper can have on the environment.

In conclusion, the coefficient of condition for Serranochromis fish from the Copperbelt region and downstream was lower than for the control sites of Chimfunshi and Lukobeko. In addition the high copper levels in sediment and fish muscle at Chipata and Kumasamba sites implies that copper contributed to the low coefficient of condition in Serranochromis fish. However, more investigations are required to determine the real cause or causes of poor coefficient condition for Serranochromis from the Copperbelt region and downstream.

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