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Impact of urbanization on the ecology of Mukuvisi River, Harare, Zimbabwe

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A B S T R A C T

The main objective in this study was to compare the physico-chemical characteristics and biota of a river (Mukuvisi) passing through an urban area to that of a non-urbanised river (Gwebi). Five sites in the Mukuvisi River and five sites in the Gwebi River were sampled for water physico-chemical parameters (pH, conductivity, DO, BOD, TDS, ammonia, Cl, SO_4^{2-}, PO_4^{2-}, NO_3^{3-}, F^-, Pb, Cu, Fe, Mn, Zn and Cr) once every month between August, 2012–August, 2013. Cluster analysis based on the physico-chemical parameters grouped the sites into two groups. Mukuvisi River sites formed their own grouping except for one site which was grouped with Gwebi River sites. Principal Component Analysis (PCA) was used to extract the physico-chemical parameters that account for most variations in water quality in the Mukuvisi and Gwebi Rivers. PCA identified sulphate, chloride, fluoride, iron, manganese and zinc as the major factors contributing to the variability of Mukuvisi River water quality. In the Gwebi river, sulphate, nitrate, fluoride and copper accounted for most of the variation in water quality. Canonical Correspondence Analysis (CCA) was used to explore the relationship between physico-chemical parameters and macroinvertebrate communities. CCA plots in both Mukuvisi and Gwebi Rivers showed significant relationships between macroinvertebrate communities and water quality variables. Phosphate, ammonia and nitrates were correlated with *Chironomidae* and *Simulidae*. Gwebi River had higher ($P < 0.05$, ANOVA) macroinvertebrates and fish diversity than Mukuvisi River. *Clarias gariepinus* from the Mukuvisi River had high liver histological lesions and low AChE activity and this led to lower growth rates in this river.

1. Introduction

Urbanization puts unprecedented pressure on lentic and lotic ecosystems. The susceptibility of lotic systems is made worse by their unidirectional nature. Any activity within a river catchment has the potential to cause environmental change and pollutants entering a river are likely to exert effects for a large distance downstream. There has been a substantial increase in nutrient concentrations throughout the world and, globally, fewer than 10% of the rivers can be classified as pristine in terms of their nitrate status as defined by World Health Organisation (i.e. <0.1 mg/l NO_3-N) (Malmqvist and Rundle, 2002).

Streams in urban areas are severely impaired by industrial and sewage effluent. Urban streams are functionally less diverse than undisturbed streams (Meyer et al., 2005). However, information on anthropogenic impacts on streams and rivers in developing countries is patchy. There is a great disparity between fundamental knowledge of riverine ecology in developed and developing countries with only 2% of papers published in international limnological journals between 1987 and 2013 originating from scientists in developing countries.

The city of Harare lies within its catchment area and the Mukuvisi River which passes through the city, is polluted from both point and non-point sources. The limited work done on the ecology of the Mukuvisi River focused on the analysis of physicochemical conditions of water (Zaranyika et al., 1993; Jawarazi, 1997; Mathuthu et al., 1997). The effect of pollution on the biota in Mukuvisi River has generally been ignored with the exception of Moyo and Phiri (2002). Nyamangara et al. (2008) investigated the effect of sewage and industrial effluent on zinc, copper, lead and cadmium concentrations in water and sediment of the Mukuvisi River. They concluded that accumulation of heavy metals is better monitored using sediments than water. The main problem with their approach is that, chemical analysis of water and sediment

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cannot provide direct indications of the effect of contaminants on the biota. Macroinvertabrates have been widely used in Southern Africa to monitor organic pollution (Chutter, 1994; Dickens and Graham, 2002). Moyo and Phiri (2002) looked at the effect of sewage effluent on macroinvertebrates in the Mukuvisis River. Although this approach focuses on biota, it has been criticized for only indicating severe stress that has already occurred (Adams et al., 2005). Biomarkers have been proposed as a way of detecting stress in biota before community level (e.g. macroinvertebrates) responses (Adams et al., 2005). In this study, the use of liver histopathology and the acetylcholinesterase assay as a biomarker is used for the first time in assessing pollution of the Mukuvisi River. The scarcity of information on a river that is being seriously degraded prompted this study. This study compares the water quality, macroinvertebrate fauna and fish species of two rivers, one heavily polluted (Mukuvisi River) and the other relatively unpolluted (Gwebi River). The Gwebi River has not been affected by industrial activities as it flows along the northern boundaries of the city mainly through commercial agricultural land.

2. Materials and methods

The Gwebi and Mukuvisi originate close to the city of Harare. The Gwebi River rises from the northern boundary of the city while the Mukuvisi rises to the east of the city. Five sampling sites were chosen along both rivers (Fig. 1). Seventeen physicochemical parameters were determined at each of the sites. Temperature, pH, conductivity and total dissolved solids (TDS) were measured on site with a conductivity meter (TSI Model 33). The Winkler method was used to determine dissolved oxygen, iron (Fe), manganese (Mn), Chromium (Cr), lead (Pb), copper (Cu) and zinc (Zn) were determined by atomic absorption spectrophotometry (AAS). Chloride (Cl^-) was determined by a precipitation titrimetric procedure using 0.01 M silver nitrate with a potassium chromate indicator. An ion selective electrode using a total ionic strength-adjusting buffer was used to determine fluoride (F^-). A turbidimetric procedure, using a conditioning reagent and barium chloride dehydrate to precipitate the sulphate from the water was used to measure the concentration of sulphate (SO_4^{-2}). The methods used to determine nitrate (NO_3), ammonia (NH_4) and phosphate (PO_4) are explained in Madera et al. (1982). A hierarchical method, average linkage cluster analysis, was applied to the mean values of the physical and chemical variables for each site using the IBM SPSS version 20.0 statistical package.

Principal component analysis (PCA) was used to determine the water quality parameters that contribute to the water quality variation between the two rivers. Canonical correspondence analysis (CCA) was used to explore the relationship between macroinvertebrates and water quality parameters. Both PCA and CCA were run using the statistical package CANOCO 5. Shannon–Wiener diversity was used to determine the diversity of macroinvertebrates between the two rivers.

Invertebrates were sampled using a hand net, with a mesh size of 2 mm, secured to a 30 cm square frame. A maximum stretch of 20 m was sampled at each site. Most of the macroinvertebrates were identified to the family level using keys from Thirion et al. (1995).

A South Rot VI-A electrofisher powered by a Honda EZ 4500 generator was used to capture fish along the two streams. Each station was fished for 10 min and relative abundance was expressed as catch per effort (no. min^{-1}). Liver tissues from 22 *Clarias gariepinus* individuals caught in the Mukuvisi River and 22 from Gwebi River were embedded in paraffin wax. The liver tissues were then sectioned into 5 μm slices before staining with haematoxylin and eosin. Each slide was scored between 0 and 4 according to methods adapted from Van Dyk et al. (2003). AChE activity was determined in the brain tissue of *C. gariepinus* from the two rivers, following the methods of McLoughlin et al. (2000).

The aticular otoliths were embedded in clear polyester casting resin and then sectioned (0.4 mm). The sections were used to determine the age of *C. gariepinus* from the two river systems. The von Bertallanffy model was used to describe the growth of *C. gariepinus* in the Mukuvisi and Gwebi rivers:

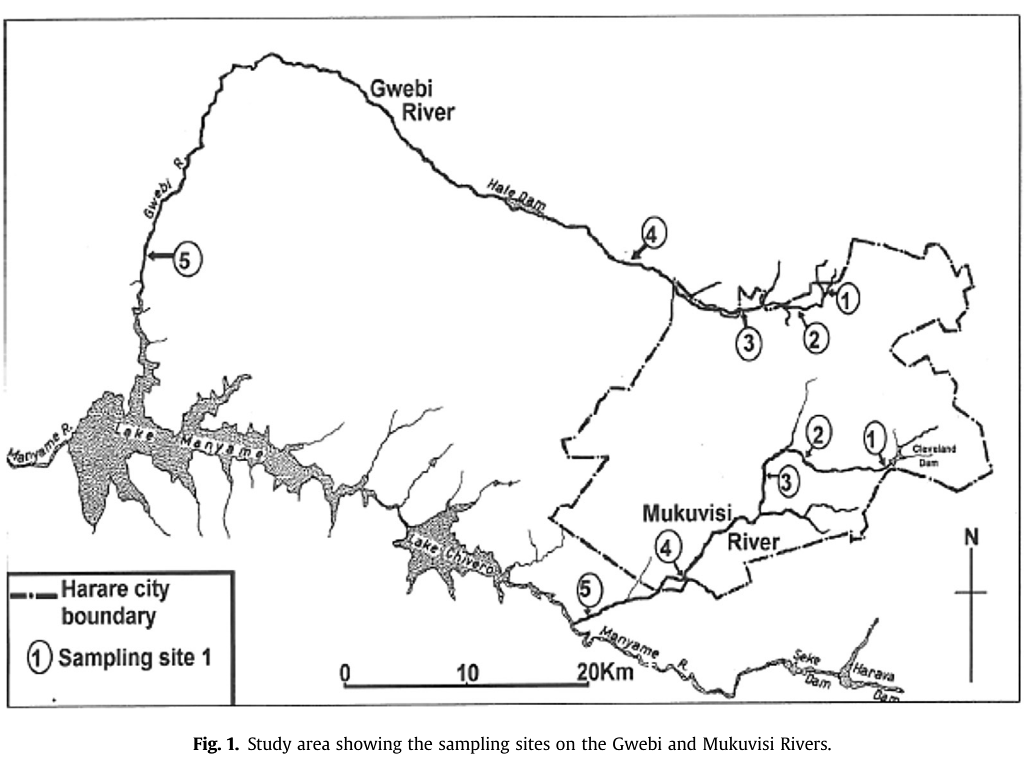

Fig. 1. Study area showing the sampling sites on the Gwebi and Mukuvisi Rivers.