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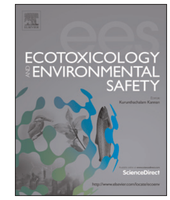

Sharptooth catfish shows its metal: A case study of metal contamination at two impoundments in the Olifants River, Limpopo river system, South Africa

Antoinette Jooste, Sean M. Marr*, Abraham Addo-Bediako, Wilmien J. Luus-Powell

Department of Biodiversity, University of Limpopo, P/Bag X1106, Sovenga 0727, South Africa

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ABSTRACT

Clarias gariepinus is increasing in importance as a global aquaculture species with a 100 fold increase in production over the past decade but this species still remains one of the most important wild harvested freshwater food fish throughout rural Africa. However, this species has been shown to accumulate metals from contaminated inland waters. In this paper, the metal concentrations in muscle tissue of *C. gariepinus* from two main-stem impoundments in the Olifants River, Limpopo Basin, were measured and a desktop risk assessment based on the US-EPA methodology completed to evaluate whether long-term consumption of *C. gariepinus* from these impoundments may pose a health risk to rural communities.

Our results show that metals are accumulating in the muscle tissue of *C. gariepinus* and have appeared to have increased in the last two decades. Risk assessment generated Hazard quotients (HQ) greater than 1 indicate that long term consumption of fish from these impoundments may cause adverse health impacts. We found that lead (HQ=9), antimony (HQ=14), cobalt (HQ=2) and chromium (HQ=1) at one impoundment and lead (HQ=2) at the other impoundment were above acceptable levels for weekly consumption of 150 g *C. gariepinus* muscle tissue.

1. Introduction

The sharptooth catfish *Clarias gariepinus* (Burchell, 1822) is becoming an important aquaculture species and analysts predict that it might follow the aquaculture success of *Oreochromis* spp. (FAO, 2013); currently the most widespread freshwater aquaculture species (FAO, 2014) accounting for about 2% of global aquaculture production. The global production of *C. gariepinus* has increased from 2000 to about 200,000 t from 2000–2010 (Anchor Environmental, 2012; FAO, 2013), although this remains a fraction of the global freshwater finfish aquaculture production of 40 million tons (FAO, 2014). Nigeria is by far the largest producer of farmed *C. gariepinus,* but the Netherlands, Hungary, Kenya, the Syrian Arab Republic, Brazil, Cameroon, Mali and South Africa also produce significant quantities (FAO, 2013). *Clarias gariepinus* is probably the most widely distributed indigenous freshwater fish species in Africa (Cambray, 2003). Its native range extends from central South Africa northwards into West Africa and the Middle East (Skelton, 2001). It has been widely introduced in South Africa, Europe, South America, India and China for aquaculture (de Moor and Bruton, 1988; Cambray, 2003; Vitule et al., 2006; Economou et al., 2007; Gherardi et al., 2008; Radhakrishnan et al., 2011; FAO, 2013). Sharptooth catfish inhabit all freshwater habitats and can survive in extreme conditions (Skelton, 2001; FAO, 2013). *Clarias gariepinus* are omnivorous, predominantly nocturnal, feeding on any available food source, relying on scavenging as well as active hunting (Skelton, 2001).

The wide distribution, large size, extreme hardiness, and high fecundity of *C. gariepinus* make it one of the most important freshwater food fish for rural communities throughout Africa. However, a number of studies have confirmed that *C. gariepinus* bio-accumulate metals from the environment (du Preez et al., 1997; Avenant-Oldewage and Marx, 2000a, 2000b; Coetzee et al., 2002; Farombi et al., 2007; Crafford and Avenant-Oldewage, 2010, 2011). Communities who regularly consume fish from contaminated water bodies are at risk to the genotoxic health impairment of long-term exposure to toxic contaminants (du Preez et al., 2003). Freshwater ecosystems are becoming increasingly polluted and it has become necessary to assess whether fish from degraded river systems are suitable for human consumption (du Preez et al., 2003; Heath et al., 2004).

In South Africa, many of the river systems have been contaminated due to increases in mining, agricultural, industrial and

* Corresponding author.
E-mail addresses: Antoinette.Jooste@ul.ac.za (A. Jooste), sean.marr@ul.ac.za (S.M. Marr), Abe.Addo-Bediako@ul.ac.za (A. Addo-Bediako), Wilmien.Powell@ul.ac.za (W.J. Luus-Powell).

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domestic releases into freshwater bodies. The Olifants River, a tributary of the Limpopo River in eastern South Africa (Fig. 1), has been systemically impaired by acidification, mining, industrial, agricultural and domestic pollution and is now one of the most polluted river systems in South Africa, particularly the Upper Olifants River sub-catchment (Heath et al., 2010; Ashton and Dabrowski, 2011). Acid mine drainage from abandoned mines in the upper catchment is resulting in the acidification of river water and the mobilisation of metals from the bedrock and sediment (McCarthy, 2011; Netshitungulwana and Yibas, 2012). The sulphate concentration in the of the Olifants River system provides an indication of the impact of acid mine drainage in the catchment (de Villiers and Mkwelo, 2009). The annual median sulphate concentration at Loskop Dam has exceeded the 100 mg/L threshold value for aquatic ecosystem health since the year 2000 and is approaching the 200 mg/L threshold for human consumption (Fig. 2). The median sulphate concentration has increased at a rate of 2.76 mg/L per annum at Loskop Dam over the last five decades. Although the sulphate concentrations decrease downstream as a result of dilution by tributaries, the median sulphate concentrations are nevertheless increasing at 1.32 and 0.59 mg/L per annum at Flag Boshielo Dam and the Phalaborwa Barrage respectively. At Flag Boshielo Dam the annual median sulphate concentration is approaching the 100 mg/L threshold value for aquatic ecosystem health whereas at the Phalaborwa Barrage it is approaching 50 mg/L (Fig. 2). There is now a growing concern regarding the long-term impact of water pollution on the aquatic ecosystem and the health of rural communities, especially those still reliant on untreated water and aquatic resources from the Olifants River and its impoundments (Oberholster et al. 2010, 2012).

In South Africa, many rural communities rely on fish harvested from local lakes, rivers and impoundments by subsistence fishers to supplement their dietary protein (Ellender et al., 2009; McCafferty et al., 2012). Previous studies have shown that metal bioaccumulation in fish muscle tissue could pose health risks to communities consuming fish from impoundments in the Olifants River system (Addo-Bediako et al., 2014a, 2014b; Jooste et al., 2014b). However, these studies have not reported on the risks associated with consuming *C. gariepinus*, which is widely consumed in the Olifants River catchment. The aim of this study was to measure the metal concentration in the muscle tissue of *C. gariepinus* at two impoundments in the middle and lower Olifants River System, Limpopo province, South Africa and provide a preliminary assessment of the potential risk to human health posed by consuming fish from these impoundments. Due to resource limitations, the human health risk assessment was limited to a desktop study based on the US Environmental Protection Agency risk assessment methodology (US-EPA, 2000) as revised for South Africa by Heath et al., (2004). Should the result of this study highlight that consuming fish from these impoundments poses a potential risk to human health a more rigorous risk assessment should be performed.

2. Materials and methods

2.1. Study site

Four major impoundments, Witbank, Loskop and Flag Boshielo dams, South Africa, and Massingir Dam, Mozambique, and a water

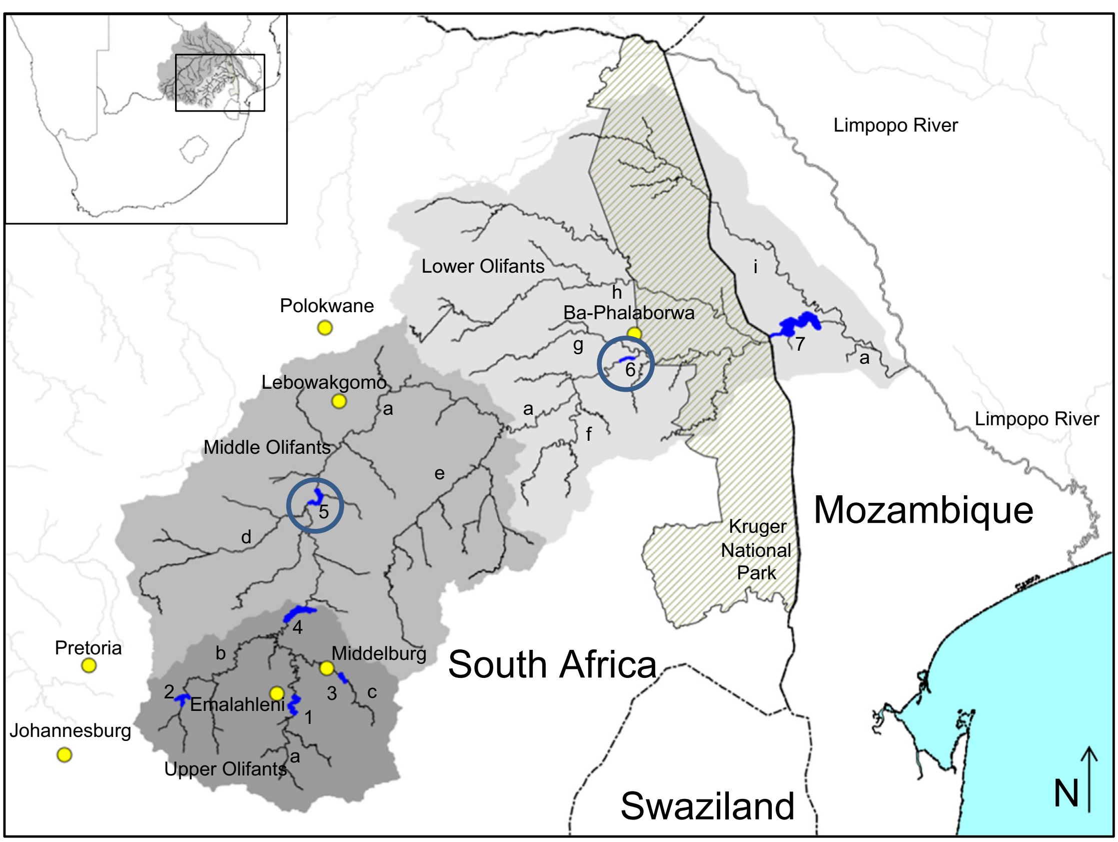

Fig. 1. Map of the Olifants River system showing the location of major towns, impoundments and tributaries. Major impoundments are depicted by numbers: (1) Witbank Dam, (2) Bronkhorstspruit Dam, (3) Middelburg Dam, (4) Loskop Dam, (5) Flag Boshielo Dam, (6) Phalaborwa Barrage and (7) Massingir Dam. The Olifants River and its tributaries are depicted by letters: (a) Olifants mainstem, (b) Wilge, (c) Klein Olifants, (d) Elands, (e) Steelpoort, (f) Blyde, (g) Ga-Selati, (h) Letaba and (i) Shingwedzi. The study sites, Flag Boshielo Dam and the Phalaborwa Barrage, are circled.