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Temporal distribution of accumulated metal mixtures in two feral fish species and the relation with condition metrics and community structure

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A B S T R A C T

The present study investigated temporal influences on metal distribution in gudgeon (*Gobio gobio*) and roach (*Rutilus rutilus*), and its relation to condition metrics and fish community structure. Fish communities were sampled in two seasons (autumn and spring) during two successive years and the Index of Biotic Integrity (IBI) was calculated. Cadmium, Cu, Pb, Zn and As concentrations were measured in gill, liver, kidney and muscle, and condition factor (CF) and hepatosomatic index (HSI) were measured. Cadmium (max. 39.0 μg g^{-1} dw) and Zn (max 2502 μg g^{-1} dw) were most strongly stored in kidney and liver and periodical influences on metal accumulation were observed. CF appeared to be a stable metric related to accumulated metal-mixtures and was best related to hepatic levels, while the HSI was less useful. Relations between single metal accumulation and IBI were influenced by sample period, however, when taking into account multiple metals periodical influences disappeared.

1. Introduction

Metal contamination in aquatic ecosystems can pose a severe threat to resident biological communities (e.g. fish, macroinvertebrates, phytobenthos), eventually resulting in the loss of species diversity (Bervoets et al., 2005; De Jonge et al., 2008). In natural watercourses, metals may occur in mixtures of different concentrations, in which they can interfere with each other both at uptake sites and at the site of toxic action, hampering easy discrimination between single and mixture effects of metals in the field (Borgmann et al., 2008; Norwood et al., 2003).

In order to assess possible impacts related to metal pollution, taking into account bioavailability aspects, bioaccumulation can be measured (Belpaire and Goemans, 2007; Bervoets and Blust, 2003). Quantifying metal concentrations in tissue of resident species represents an integrated and ecologically-relevant image of site-specific metal bioavailability, and may be a valuable alternative for the numerous physical-chemical measurements associated with the monitoring in environmental compartments such as surface water and/or sediment (Bervoets et al., 2005; De Jonge et al., 2012, 2013). Since many fish species are at a high trophic level, they can easily accumulate metals via different exposure routes (via surface water, food and sediment ingestion) and thus represent possible health risks for other fish species, piscivorous birds and mammals including humans (Bervoets and Blust, 2003; Couture and Rajotte, 2003). Moreover, accumulated metal levels in fish tissue can provide an indication of metal-induced toxicological effects (Couture and Rajotte, 2003; Bervoets et al., 2005). Various studies already investigated relations between accumulated metal levels in fish tissue and condition metrics (de la Torre et al., 2000; Bervoets and Blust, 2003; Couture and Rajotte, 2003; Maes et al., 2005; Pyle et al., 2005, 2008; Reynders et al., 2008; Bervoets et al., 2009, 2013) as well as fish community metrics (Bervoets et al., 2005; Van Ael et al., 2014). For example the study of Bervoets et al. (2005) observed that accumulated metal mixtures in gudgeon (*Gobio gobio*) liver were negatively related to the integrity of the fish community structure, measured using the Index of Biotic Integrity (IBI) (Belpaire et al., 2000). Following these relations, metal accumulation in fish tissue can be used to predict impacts of metal mixtures on natural fish communities. Similar approaches have been successfully applied for aquatic invertebrates (see e.g. the studies of Rainbow et al., 2012; De Jonge et al., 2013).

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Nevertheless, metal accumulation in fish tissue can be very variable due to seasonal influences such as shifts in diet items, temperature or activity-driven alterations in metabolic rate and decreasing body mass due to reproduction (Belpaire and Goemans, 2007; Pyle et al., 2008; Couture et al., 2008). Pyle et al. (2008) concluded in their study that relations between metal contamination and condition metrics of yellow perch (*Perca flavescens*) should be interpreted taking into account seasonal and regional influences to avoid drawing erroneous conclusions from one-time fish biomonitoring programs. Therefore it is crucial to account for seasonal variation when interpreting relations between metal accumulation and fish condition and/or fish community indices.

The aims of the present study were twofold: (1) to study temporal influences (i.e. two seasons, autumn and spring, during two successive years) on metal distribution in gill, liver, kidney and muscle tissue of gudgeon (*Gobio gobio*) and roach (*Rutilus rutilus*), and (2) to investigate relations between accumulated metal mixtures and condition metrics as well as community responses for both fish species, and assess whether seasonality can influence these relations. Both gudgeon and roach are widespread feral fish species which have been previously shown to reflect environmental metal contamination in their tissues (Bervoets and Blust, 2003; Reynders et al., 2008).

2. Material and methods

2.1. Study area and fish sampling

The River Dommel is a 145 km long lowland river of second to third order, located in the northeastern part of Flanders (Belgium) flowing from Peer to 's Hertogenbosch (The Netherlands). The river is part of the Meuse basin and is mainly fed by rainwater (Groenendijk et al., 1999). Near Neerpelt, the small tributary Eindergatloop has discharged metal-contaminated water in the Dommel for many years until the beginning of the 1990s, due to the presence of metallurgic industry (Ivorra et al., 2000; De Jonge et al.,

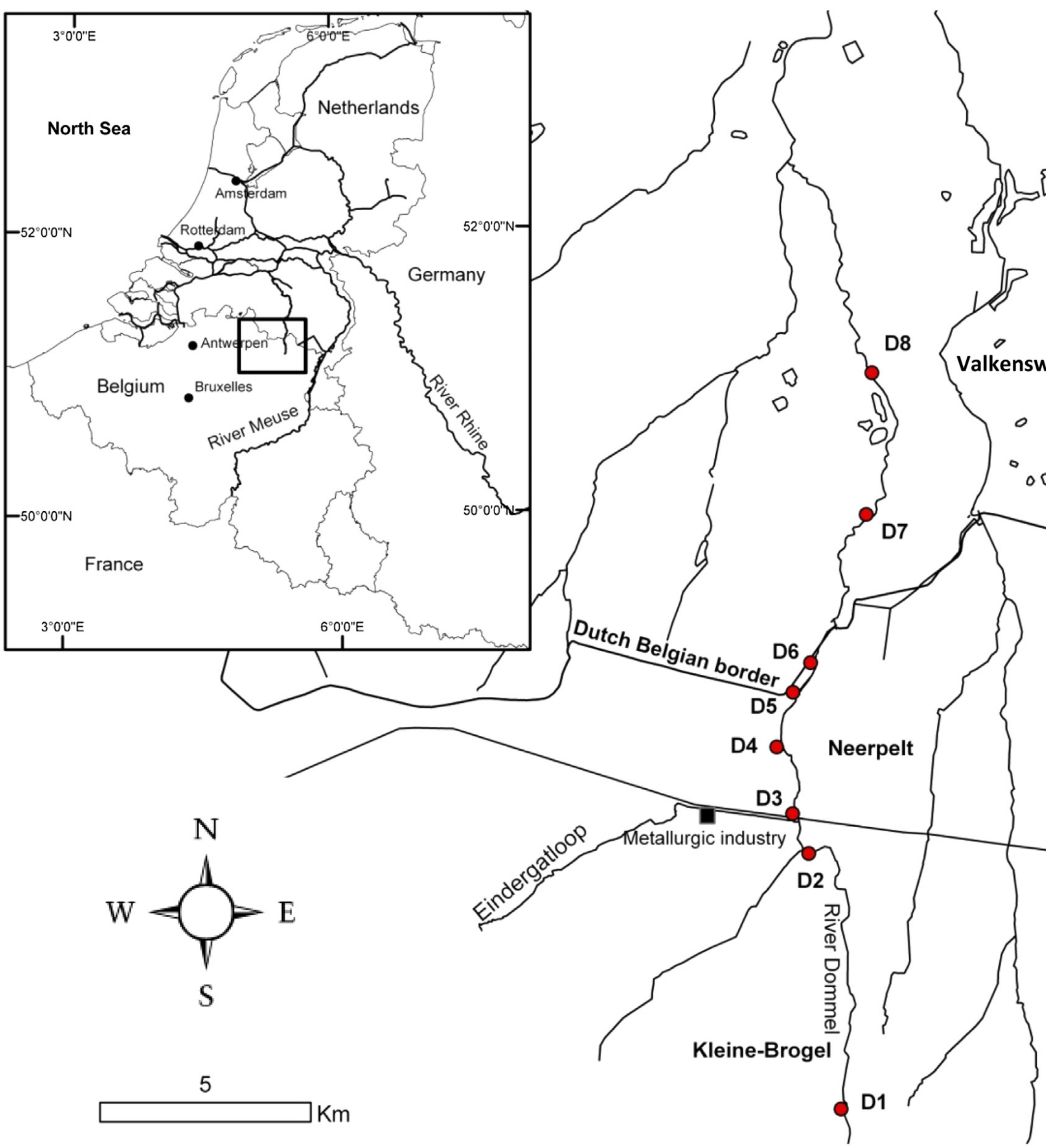

Fig. 1. The River Dommel and its location in Flanders (Belgium). The eight sample sites (D1–D8) are indicated.