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# A dominance shift from the zebra mussel to the invasive quagga mussel may alter the trophic transfer of metals

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ABSTRACT

Bioinvasions are a major cause of biodiversity and ecosystem changes. The rapid range expansion of the invasive quagga mussel (*Dreissena rostriformis bugensis*) causing a dominance shift from zebra mussels (*Dreissena polymorpha*) to quagga mussels, may alter the risk of secondary poisoning to predators. Mussel samples were collected from various water bodies in the Netherlands, divided into size classes, and analysed for metal concentrations. Concentrations of nickel and copper in quagga mussels were significantly lower than in zebra mussels overall. In lakes, quagga mussels contained significantly higher concentrations of aluminium, iron and lead yet significantly lower concentrations of zinc*66*, cadmium*111*, copper, nickel, cobalt and molybdenum than zebra mussels. In the river water type quagga mussel soft tissues contained significantly lower concentrations of zinc*66*. Our results suggest that a dominance shift from zebra to quagga mussels may reduce metal exposure of predator species.



## 1. Introduction

Bioinvasions are one of the major, and growing, causes of biodiversity loss (European Commission, 2013). The EU Biodiversity Strategy (European Commission, 2011), and the International Union for Conservation of Nature (IUCN) guidelines for the prevention of biodiversity loss caused by invasive non-native species, stress the need to identify the most harmful invaders (ISSG, 2000; Katsanevakis et al., 2013). Currently, the rapid range expansion of the quagga mussel (*Dreissena rostriformis bugensis*) is resulting in a dominance shift from the established zebra mussel (*Dreissena polymorpha*) to the quagga mussel (Diggins, 2001; Bonhof et al., 2009; De Rooij et al., 2009; Bij de Vaate, 2010; Heiler et al., 2012; Matthews et al., 2014; Bij de Vaate et al., 2014). Both dreissenid freshwater bivalves appear to be invasive in Western Europe and North America (Neumann and Jenner, 1992; Mitchell et al., 1996; Watkins et al., 2007; Gonzalez and Downing, 1999; Ward and Ricciardi, 2010; Matthews et al., 2014), and are an important source of food for native water birds, fish, crayfish and crabs (Kelly et al., 2010; Mörtl et al., 2010; Van Eerden and De Leeuw, 2010; Bij de Vaate, 2010; Noordhuis et al., 2010; Matthews et al., 2014). Some waterfowl species have been reported to alter their dietary intake and migration patterns in response to the ready availability of zebra mussels (Petrie and Knapton, 1999).

The ability of both these mussel species to filter large quantities of water allows them to accumulate toxicants, which may lead to the secondary poisoning of native predator species (Rutzke et al., 2000; Kwon et al., 2006; Hogan et al., 2007; Mueting and Gerstenberger, 2010). Accumulation of toxicants may lead to mortality and sub-lethal effects such as altered growth, reproduction, and behaviour (Flemming and Trevors, 1989; Custer and Custer, 2000; Santore et al., 2002; Custer et al., 2003; Petrie et al., 2007). Metal accumulation has been implicated in many of these effects. For example, cadmium transfer from zebra mussels to the tufted duck (*Aythya fuligula*) has resulted in behavioural disturbances in adults, growth retardation, and embryonic mortality (De Kock and

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Bowmer, 1993). Selenium toxicity impacts staging, winter body condition and health of lesser and greater scaup (*Aythya affinis* and *Aythya marila*), diving ducks that feed primarily on dreissenids (Custer and Custer, 2000; Custer et al., 2003; Petrie et al., 2007). Accumulation of copper may cause mortality and sub lethal effects such as altered growth, reproduction, and behaviour in fish and macroinvertebrate species (Flemming and Trevors, 1989). High concentrations of zinc may result in calcium uptake inhibition in certain fish species (Santore et al., 2002). Moreover, lead has long been considered one of the most significant metals from the standpoint of environmental contamination and toxicology (Scheuhammer, 1987).

However, metal concentrations in mussel soft tissues may vary, depending on species-specific factors such as reproduction cycle, filtration rate, and ventilation rate (Kraak et al., 1991; Veltman et al., 2008). Therefore, a shift in dominance from established to newly invading mussel species may alter the trophic transfer of metals to native predators. Peer reviewed literature focussing on potential differences in accumulation of metals between the soft tissues of the quagga and zebra mussel is scarce, often inconclusive and limited to North America (Johns and Timmerman, 1998; Rutzke et al., 2000; Richman and Somers, 2005; Le et al., 2011). Moreover, studies reporting metal concentrations in quagga mussels are particularly rare. This article aims to (1) identify potential inter-species differences in metal concentrations between the invasive quagga and established zebra mussel; (2) identify potential intra-species differences in metal concentrations in the soft tissues of quagga mussels in relation to shell size and water type (i.e., river or lake); (3) discuss the possible implications of these inter- and intra-species differences in relation to a dominance shift from zebra mussels to invading quagga mussels for the trophic transfer of metals.

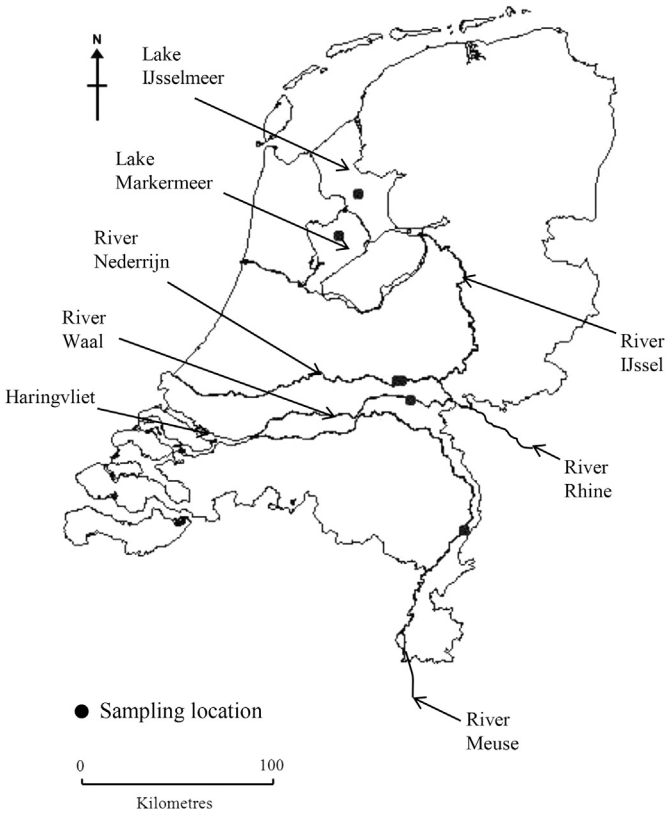


**Fig. 1.** Locations sampled during field surveys.

## 2. Materials and methods

### 2.1. Field survey and chemical analyses

Zebra and quagga mussels were collected by hand from groyne stones from four river locations and with a trawl net from two lake locations in the Netherlands (Fig. 1, Table 1). These sites were selected based on available evidence on the co-existence of the two species. Mussels were separated according to species and size class (small: <15 mm, medium: 15–22 mm, and large: >22 mm). The mussels were not depurated prior to extraction from their shells as this more accurately reflects metal exposure to predators. Mussel predators consume the entire mussel and are therefore exposed to both stomach contents and mussel tissue. Metal concentrations in dreissenid shells have been found to be orders of magnitude lower than in mussel soft tissue (Van der Velde et al., 1992). Therefore, metal concentrations in mussel shells were considered negligible and shells were not included in the analysis. The soft tissue was extracted from mussel shells and subsequently dried at 70 °C for 24 h. Dried samples were then weighed using a Sartorius LA310s micro balance (Sartorius AG, Göttingen, Germany) to produce replicates of 0.2 g dry weight. The dried samples were digested with 4 ml $HNO_3$ 65% and 0.5 ml $H_2O_2$ in a Milestone Ethos D microwave. Following digestion, 100 ml of high quality deionized water was added to each sample. In addition, blanks were prepared to allow for corrections to metal concentrations determined from mussel samples. Analysis of metal concentrations was undertaken using inductively coupled plasma mass spectroscopy (ICP MS) for aluminium (Al), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn*66* and Zn*68*), arsenic (As), selenium (Se), molybdenum (Mo), cadmium (Cd*111* and Cd*112*), tin (Sn), mercury (Hg), and lead (Pb). We considered the complete range of metals measured by ICP-MS as this gives the most complete insight into possible changes in metal exposure of predator species resulting from a dominance shift in prey species.

### 2.2. Data analysis

A number of comparisons were made to identify inter-species and intra-species differences in soft tissue metal concentrations (Tables 2 and 3). Data on metal concentrations were aggregated and compared according to mussel species, size class and origin of sampled material (water type and water body). Water bodies included in the analysis were the lakes IJsselmeer and Markermeer, and rivers Waal, Nederrijn, and Meuse (Fig. 1). In the inter-species comparisons, only paired samples were used (same location and time period). The number of samples for each species included in these analyses was, therefore, the same. Inter-species comparisons consisted of analyses (1) combining all size classes and locations, (2) per water type (river or lake) and combining size classes, and (3) per size class and combining all water types (Table 2). Intra-specific comparisons were made for the quagga mussel. In order to reduce possible bias due to differences in sampling period, only samples taken in 2009 and 2010 were used for this comparison. To obtain sufficient statistical power, concentrations were aggregated either by size class or by sampling location. This was done (1) per size class combining all locations, (2) for lake and river water types combining all size classes and aggregating data for all water bodies within each water type, (3) individual rivers combining all size classes, and (4) individual lakes combining all size classes (Table 3).

### 2.3. Statistical analysis

Potential differences between groups were tested for statistical