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Editorial

History of *Dreissena* research and the ICAIS gateway to aquatic invasions science

Alexander Y. Karatayev¹*, Renata Claudi² and Frances E. Lucy³

- 1 Great Lakes Center, Buffalo State College, 1300 Elmwood Avenue, Buffalo, NY 14222, USA
- 2 RNT Consulting Inc., 823 County Road 35 RR#2, Picton, Ontario K0K 2T0, Canada
- 3 Department of Environmental Science, Institute of Technology, Sligo, Ash Lane, Sligo, Ireland

E-mail: karataay@buffalostate.edu (AYK), rnt@kos.net (RC), lucy.frances@itsligo.ie (FEL)

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Abstract

Research on the ecology and impacts of the zebra mussel (*Dreissena polymorpha*) has developed in parallel with the long history of their spread across Europe and to North America. There is less scientific knowledge however about the quagga mussel (*Dreissena rostriformis bugensis*). The recent spread of both zebra and quagga mussels to the Western states of the USA, has spurred on dreissenid research. The 17th International Conference on Aquatic Invasive Species (ICAIS), was held in San Diego, California in September 2010. This special edition of *Aquatic Invasions* includes topical research presented at ICAIS and also extra subsequent papers on ecology, risk assessment and control of various aquatic invasive species in different parts of the globe.

Key words: Dreissena polymorpha, Dreissena rostriformis bugensis, history of research

Since the initial description of the zebra mussel (Dreissena polymorpha (Pallas)) in 1771 and the quagga mussel (Dreissena rostriformis bugensis Andrusov) in 1897, these two Ponto Caspian invasive species have been studied intensively both in Europe and more recently in North America, following their introduction to the Great Lakes in the 1980s (Mills et al. 1993; Carlton 2008). Research has largely focused on two key areas, firstly on the ecology and the role of dreissenids as ecosystem engineers (Karatayev et al. 2002) and secondly on the infrastructural impacts of biofouling and the development of appropriate control methods (Mackie and Claudi 2010).

The first scientific attention zebra mussels received was in the 19th century, when they started spreading exponentially across Europe through canals built for commerce, resulting in cross-continental connections (reviewed in Kinzelbach 1992; Karatayev et al. 2007, 2011). Soon interest spread outside the scientific community, as the new invaders systematically clogged municipal water systems (e.g. Budapest in 1878, Hamburg in 1886, Paris in 1890s) power stations (e.g. Denmark in 1909) and other facilities using

raw water supply (reviewed in Zhadin 1946). Serious economic problems caused by the zebra mussels led to the development of a variety of methods to control this pest, some as early as the middle of the 20th century (Zhadin 1946; Clarke 1952; Greenshields and Ridley 1957).

In contrast to the zebra mussel, the quagga mussel did not follow the spread of zebra mussels into Western Europe. In fact, it remained restricted to its native range 150 years longer. However, soon after 1940, the quagga mussel began to spread through the Dnieper River and its tributaries utilizing newly constructed reservoirs as the stepping stones for further spread. By the early 1990s, the quagga mussel had colonized reservoirs along the Volga River, then it spread to the Moscow River within the city of Moscow in 2003 and the Rhine River in The Netherlands in 2006 (reviewed in Karatayev et al. 2007, 2011; Mollov et al. 2007; bij de Vaate 2010). Although both Dreissena species were introduced to North America in the 1980s (Mills et al. 1993; Carlton 2008) spreading steadily outwards from the Great Lakes (USGS 2011), they were not reported in the western United States until the new millennium. Quagga

^{*}Corresponding author

mussels were discovered in Lake Mead, Nevada in January 2007 (reviewed in Wong and Gestenberger 2011) and zebra mussels were reported from San Justo Reservoir in central California in 2008 (USGS 2011).

The recent rapid spread of both Dreissena species in Europe and North America and the subsequent impacts created by these species instigated an exponential increase in Dreissena research efforts, resulting in hundreds of publications on the vectors and mechanisms of environmental limits, spread, biology, physiology, ecological and economic impacts and control methods of these invaders. Many of these dreissenid studies were summarized in several books published over the last 20 years (Neumann and Jenner 1992; Nalepa and Schloesser 1993; Claudi and Mackie 1994; Starobogatov 1994; Van der Velde et al. 2010; Mackie and Claudi 2010). Since 1990, many important milestones in *Dreissena* research were first presented at the International Zebra Mussel Research Conferences. In 1995, this conference evolved into the International Zebra Mussel and Other Aquatic Nuisance Organisms Conference eventually became the International Conference on Aquatic Invasive Species (ICAIS) (http://www.icais.org). This evolution meant that studies on other invasive species could be accommodated (reviewed in Lucy and Muckle-Jeffs 2010). Numerous presentations on all the various aspects of aquatic invasive species are presented at this conference, making a timely valuable contribution towards knowledge of the various important invaders. The 17th ICAIS Conference was held in San Diego, California. This venue was chosen due to the recent arrival of dreissenids in the American western states. Of all the aquatic invasive species, both *Dreissena* species are among the most aggressive freshwater invaders in the northern hemisphere causing serious ecological and economic impacts and representing a novel ecological type in European and North American freshwaters (reviewed in Nalepa and Schloesser 1993; Karatayev et al. 1997, 2002, 2007). Dreissenid mussels have all of the properties of ecosystem engineers altering the environments they invade, affecting both ecosystem structure and function (Karatayev et al. 1997, 2002, 2007). While changing existing habitat, the mussels provide new opportunities for other organisms. They affect trophic interactions and, the availability of food for both pelagic and benthic species. At the same time, dreissenids affect the rates of other ecosystem processes including mineralization of nutrients, oxygen availability and sedimentation rates. These changes or impacts may be local or system wide as well as direct or indirect in action.

Although both species have similar life history characteristics, they differ in the timing and rates of spread, habitat requirements, growth, and population dynamics (Karatayev et al. 2012). While the zebra mussel is among the best studied freshwater invertebrates, we do not always have comparable information for the guagga mussel. This limits our ability to predict the spread and ecological impacts of this important freshwater invader. There is very little information on the lower pH and calcium limits quagga mussels to establish sustained populations, making accurate prediction of their potential for spread uncertain. We do not have reliable information on the longevity and fecundity of the quagga mussel, which are critical if we are to predict potential population sizes in newly invaded waterbodies and long term population dynamics. Finally, we do not have enough data on the ecological effects of invasion by D. r. bugensis. The effects may be similar to those of the zebra mussel, or they may be greater. Quagga mussels may succeed in more diverse habitats within lakes than do zebra mussels and thus may be capable of attaining much larger overall population sizes, especially in lakes with large profundal zones. Because the vast majority of observations of quagga mussel impacts on aquatic communities and environments have been conducted in waterbodies previously colonized by zebra (Fahnenstiel et al. 2010; Mida 2010), it is very difficult to disentangle the effects of quagga mussels from those of zebra mussels. We need more data on the impacts of quagga mussels alone to be able to determine their ecological effects. In 2011 Aquatic Invasions published a special edition on 'Quagga mussels in the Western United States', based on early invasion research presented at a 2010 conference on monitoring, ecology and control (Editors: Wong and Gerstenberger 2011). A more recent study on settlement and growth of quagga mussels in Lake Mead was presented at ICAIS 2010, and is contained in these proceedings (Wong et al. 2012). Spread of the dreissenids to the western states has accelerated research in this region and should lead to an increase in knowledge on quagga mussels, particularly in field studies where they occur independent to zebra mussels.

Control of dreissenids and other aquatic invasive species employs a variety of chemical, biological and physical treatments, so as to mitigate biofouling and other infrastructure damage. The fundamental need for reliable water supplies for power plants, industrial facilities and municipal water supplies was pivotal in the provision of research funding and moreover in both the political and public perception of the importance of aquatic invaders, particularly zebra mussels. This resulted in the publication of many research papers and two books providing the relevant biology, engineering concepts and management advice (Claudi and Mackie 1994; Mackie and Claudi 2010). The ICAIS conference series has always included a number of conference sessions on diverse control methods. represented here by papers on impact of pH on survival and settlement of dreissenid mussels (Claudi et al. 2012); re-growth of potential invasive phytoplankton following UV-based ballast water treatment (Liebich et al. 2012) and on in-situ tests of sound-bubble-strobe light barrier technologies to prevent range expansions of Asian carp (Ruebesh et al. 2012).

Detection methods and risk analysis are fundamental to management and control at the early stages of invasion. This research area is represented here by two ICAIS papers. The first is on risk classifications of aquatic non-native species; application of contemporary European assessment protocols in different biogeographical settings (Verbrugge et al. 2012). From the other side of the world, there is a New Zealand short communication on the development of single and multispecies detection methods for the surveillance and monitoring of marine pests (Mountfort at al 2012). Another paper included in this edition, focuses on the development of ensemble forecasting of potential habitat for three invasive fishes (Poulos et al 2012).

Other bivalve invaders are also the focus of international research including the recent spread of the Asian clam within Europe (Elliott and Ermgassen 2008; Caffrey et al. 2011). Schmidlin et al. (2012)'s paper on *Corbicula* in Swiss lakes highlights the increased use of biomolecular techniques to investigate the propagule source and pathways of spread by identifying the genetic strain. On the other side of the Atlantic, Simard et al. (2012) record a new northern limit for the Asian clam on the St Lawrence River (Quebec, Canada). In South America, the golden mussel, *Limnoperna fortunei* (Dunker, 1857) has created widespread ecological and biofouling

impacts since its detection in 1991 (Boltovskoy 2009). The presented research on the impacts on phytoplankton and nutrient cycling in an Argentinian reservoir (Cataldo et al. 2012) are an important contribution to increased knowledge on this aquatic invader.

Crustacean invaders are represented in this edition by three American studies; an ecological study on invasive copepods in Oregon (Bollens et al. 2012); one on environmental factors influencing the dynamics of Chinese mitten crab zoae in the San Francisco Bay Delta (Blumenshine et al. 2012) and lastly a study on the threat posed by the invasive ringed crayfish on the conservation status of the native coldwater crayfish in a Missouri river drainage (Imhoff et al. 2012).

Aquatic invasive plants often follow the same pathways of spread as invertebrates; this is particularly true in the case of recreational boating (Johnson et al. 2001) with education and outreach programmes often targeting fishermen and other water-users to prevent spread of invasive plants and animals. Many organizations distribute educational material and extensive resources available to the public including; Ontario Federation of Anglers and Hunters (http://www.invadingspecies.com), US Seagrant (http://www.sgnis.org), International Joint Commission (http://www.ijc.org) available, USGS (USGS 2011), US Bureau of Reclamation (http://www.usbr.gov/research/science-and-tech/ highlights/pdfs/09-3rdQtrhigh.pdf). In this ICAIS conference proceedings, Jerde et al. (2012) researched fitness loss and invasion potential following dessication of Eurasian milfoil caused by simulated overland transport. Another paper by Masoodi and Khan (2012) investigates the invasion of alligator weed (Alternanthera philoxeroides) in Kashmir, India.

It is now internationally recognized that invasive species are a major threat to habitat loss in terms of threats to biodiversity. Therefore the research presented by scientists at ICAIS is important in the formation of international policy, legislation and conventions on aquatic invasive species, e.g. the IMO ballast water convention. The conference series is attended by international organizations stakeholders, providing an important platform for networking and information-sharing towards future research and management. Aquatic *Invasions* is an important part of this process, by providing peer-reviewed proceedings of the conference series.

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