

Editorial

Twenty-year anniversary of the ICAIS: progress and challenges towards a better understanding of aquatic invasions

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In 2017, the International Conference for Aquatic Invasive Species (ICAIS) marked its 20th anniversary. The conference was hosted in Fort Lauderdale, Florida from Oct 22 to 26, and brought together more than 350 participants representing a broad audience including representatives from academia, industry, governmental and non-governmental organizations. Indeed, the participation of such diverse stakeholders has always added a modicum of pragmatism to this forum where both basic and applied research are presented in an attempt to address the problematic issue of aquatic invasions. ICAIS is the most comprehensive forum of its kind, encompassing all aspects of invasion biology in both freshwater and marine biomes. The last two conferences explored topics such as impacts of invasive species, developing tools for early detection of non-indigenous taxa, understanding how biotic drivers facilitate the invasion process, and methods for controlling invasive species which includes citizen science, outreach and policy (Lucy and Panov 2014; Leuven et al. 2017). For the practitioner, there were specific sessions that explored control and management strategies of aquatic invasive species. The 2017 meeting saw a continuation of these science and management themes in both oral and poster presentations. Research from these sessions are represented by 14 papers which were recently published in a special issue of *Management of Biological Invasions*, the sister journal of *Aquatic Invasions* (Bailey et al. 2018; Caffrey et al. 2018; Champion 2018; Coughlan et al. 2018; Davis et al. 2018; First et al. 2018; Luoma et al. 2018; Moser et

al. 2018; Pucherelli et al. 2018; Schloesser et al. 2018; Shannon et al. 2018; Smith et al. 2018; Waller and Bartsch 2018; Wyman-Grothem et al. 2018).

This special issue of *Aquatic Invasions*, titled “Biological Invasions in Inland Waters”, includes 6 research articles presented at ICAIS-2017, and 7 additional papers on bioinvasions in inland waters. These supplementary papers cover many of the issues mentioned at the ICAIS, such as invader impact variability and drivers facilitating the establishment process. A study by Garcia et al. (2018) demonstrated how feeding habits of non-native fishes can vary between lentic and lotic habitats, implying variation in their potential impacts on the recipient systems. Meanwhile, the study of Figueiredo et al. (2018) reminds us that the invader-mediated food web disruption need not to be realized through local extirpation or drastic abundance reduction of a food web component but also through subtle behavioral mechanisms. In two complementary studies from Central Europe, Cerwenka et al. (2018) document round goby *Neogobius melanostomus* (Pallas, 1814) invasion success in the upper Danube, while Jakubčínová et al. (2018) predict that further spread of the goby in the region will likely remain restricted to large rivers only. There was also significant coverage of molluscs in this special issue, which is testament to their invasive potential across the globe. Using a mesocosm experimental approach, Działowski et al. (2018) showed that the zebra mussel, *Dreissena polymorpha* Pallas, 1771 was the primary driver of plankton abundance, even in the presence of multiple

external stressors. Despite the invasiveness of the zebra mussel in North America, increasing numbers of surveys in various rivers and lakes in Central and Eastern Europe have shown that the species is currently being displaced by the closely related quagga mussel, *Dreissena rostriformis bugensis* (Andrusov, 1897). This led Metz et al. (2018) to investigate potential factors that may be driving *D. r. bugensis*' competitive advantage over *D. polymorpha*. The researchers found that *D. r. bugensis* had higher growth rates than *D. polymorpha* in European waters and as a consequence, may be able to reach sexual maturity earlier. Such an advantage would be crucial when competing with other sessile organisms for space and food. The results from this study are also supported by D'Hont et al. (2018) who carried out a field study using settling plates to investigate salinity tolerance and growth rates of the two invasive mussels. The work by D'Hont and colleagues was presented at this year's ICAIS and is also presented as part of this special issue. A single paper that focused on invasive amphipods is also presented here as a non-conference paper. In that study MacNeil and Campbell (2018) utilized an impressive data set on the distribution of a *Gammarus* amphipod that spanned more than half a century of sampling. Their study provided valuable insights into long term range expansion of an introduced species but also cautions against premature predictions of future distribution of invasive species.

Among the aquatic invaders covered at the ICAIS, Ponto-Caspian species have been the subject of special attention in past decades. The trend has continued in this special issue of *Aquatic Invasions*, where the majority of model species are of Ponto-Caspian origin. The apparent success of these invaders is often attributed to their ability to adapt to changing salinities. This led Pauli and Briski (2018) to search for *in situ* evidence of their euryhalinity and for evidence of a possible salinity niche shift during the invasion process. To this end, they conducted a literature search to compare the salinity ranges of 55 Ponto-Caspian species in their native and introduced region. The results confirmed that the majority of these species occupy a wide range of salinities. Furthermore, having demonstrated that the vast majority of Ponto-Caspian invaders occur in freshwater habitats in their native range, the study shed some light on recent numerous invasions of freshwater and brackish areas by these species. These researchers also showed how disjunct our knowledge is on the ecology of these invaders especially with regards to native records. This is an important point because it highlights one of the main problems of invasion biology, namely data deficiency.

The North American channel catfish *Ictalurus punctatus* Rafinesque, 1818 in Europe can serve as an example for the general lack of data on biological invasions. While the species has been introduced into more than 20 European countries, data on its realized or potential impact on native fish assemblages in Europe are very limited. Haubrock et al. (2018) have filled some of this knowledge gap by conducting the first dietary study of this American fish within the European continent. They documented channel catfish feeding opportunistically, with an apparent ontogenetic dietary niche shift. The study also indirectly suggested the rise of a novel trophic system in the study area (the Arno River, Italy), with non-native species largely prevailing in channel catfish diet.

The data deficiency is particularly apparent in the evaluation of an invader's impact on the recipient ecosystem. For many non-native species, we lack such data completely and for most others we have to make judgements based only on a few documented cases (Vilà et al. 2010; Pyšek et al. 2012). One reason for this unfortunate status is that impact studies are typically time-demanding and require observations prior to the invasion itself. In this special issue, Morissette et al. (2018) reported the first study to assess the impact of the round goby on native fish assemblages in the St. Lawrence River. Using a long-term dataset, the authors demonstrated both negative and positive effects of round goby on native fishes. The goby probably out-competes benthic darters (Etheostomatidae), the abundance of which significantly decreased after the goby became established. In contrast, two small-bodied species, brook silverside, *Labidesthes sicculus* (Cope, 1865), and emerald shiner *Notropis atherinoides* Rafinesque, 1818, increased in abundance. Likely factors are the lack of direct competition with gobies, combined with release from predation pressure as gobies are preyed on by resident piscivores. Native food webs are therefore an additional factor that can influence the varying impacts of round-goby invasions (van Kessel et al. 2016; Janáč et al. 2018). This is part of a growing body of literature which emphasizes the importance of the specific interactions between invaders and native species in assessing the true impacts of biological invasions.

Long-term data collection is indeed beneficial for studies of invasion patterns. For Stepien et al. (2018), sampling of genetic material over a time-span of almost 30 years allowed the researchers to follow the genetic trajectories of European ruffe, *Gymnocephalus cernua* (Linnaeus, 1758) as they invaded the Great Lakes in North America and Lake Bassenthwaite in northern England. Interestingly, the trajectories were

similar for both of these distant and independent invasions. In both invasions, the comparison with native ruffe populations indicated a founder effect, likely caused by relatively low initial propagule pressure. A further decrease in allelic richness over time was then apparent, followed by recovery which suggests possible arrival of new propagules. This study was able to document the temporal complexity of the invasion process through real-time tracking of species range-expansion.

This special issue of *Aquatic Invasions* also has a strong focus on dreissenid mussels which is not surprising considering that ICAIS was originally set up in 1995 to focus exclusively on zebra mussel research (Lucy and Panov 2014). Included in this issue are two complementary papers that explored natural and anthropogenic drivers of abundance and diversity in dreissenids (D'Hont et al. 2018; Koopman et al. 2018). D'Hont et al. (2018) combined both short-term and long-term field experiments to show that despite a higher salinity tolerance and earlier settling times for *Dreissena polymorpha*, *Dreissena rostriformis bugensis* dominated over the former on settling plates. The suggested reason was that *D. r. bugensis* had comparably lower winter mortalities and faster growth rates than *D. polymorpha*, which likely conferred a competitive advantage. Meanwhile, Koopman et al. (2018) assessed the effect of ship-induced flow velocity on native and invasive molluscs. The authors found that the invasive *D. polymorpha* had the highest tolerance to such anthropogenic disturbances and bivalves in general were more tolerant than gastropods. Shipping activities are thus likely to shift the molluscan species pool to individuals that are sessile and flow-resistant. Both of these studies were conducted across various riverine systems in Europe.

Research on other invasive molluscs was also presented at the conference, including a potential eradication method for the Asian clam, *Corbicula fluminea* (Muller, 1774) which has spread throughout the waterways of North America and certain regions of Europe (Coughlan et al. 2018); assessing the dispersal patterns of the apple snail, *Pomacea maculata* Perry, 1810 in the Florida everglades (Posch et al. 2013); and teasing apart the global phylogeographic patterns of the marine bivalve, *Mytilus galloprovincialis* Lamarck, 1819 using archived DNA sequence data (Pickett and David 2018). There were also numerous presentations dedicated to Asian carp research, which included monitoring surveys and behavioral studies along with genetics and range expansion research. Other presentations included an assessment of round goby invasions in Europe (Janáč et al. 2017), the possibility of ballast water as a vector for the introduction of the notorious

lionfish, (MacIsaac et al. 2016) and the dispersal of bullseye snakehead, *Channa marulius* (Hamilton, 1822) in Florida waters (Benson et al. 2018).

There continues to be an increase in the number of papers evaluating the efficacy of environmental DNA (eDNA), in monitoring for aquatic invasive species: four abstracts implementing eDNA in early detection were presented at this conference. While eDNA is a promising tool for biomonitoring, it is still in its infancy and its exclusive use in targeting non-indigenous species has revealed novel ways to deal with issues such as detection sensitivity (false positives) and proper primer pair selection for troublesome barcode markers (Ficetola et al. 2016 and references therein).

Public engagement and citizen science have been a staple of ICAIS from as far back as 2003. At the 2017 meeting, there were oral presentations on several engagement initiatives including the redesign of a volunteer AIS monitoring program in Wisconsin, USA which sought to increase the number of citizen scientists involved in a detection program in that region. Meanwhile, in the Netherlands, an interesting multi-media tool, LINVEXO, has been developed as a teaching aid to help students learn about invasive species, their impacts and how certain actions can help constrain their spread (<https://itzit.com/visual-education/>).

A new session that was introduced in this meeting (“Information Management”) focused on the management and application of large databases in detecting AIS along with subsequent risk assessment. Every subfield of the ecological sciences (including invasion biology) are undergoing the aptly termed “Big Data revolution”, where large amounts of data are being generated at a breathtaking pace (Soranno and Schimel 2014). To make sense of such data, analytical tools for processing and analysis are needed. One such tool at the University of Georgia’s Centre of Invasive Species and Ecosystem Health has been developed to track real time AIS detection carried out by trained researchers and citizen scientists. The data is then aggregated and funneled to the appropriate experts for verification. The ideal end-product of this workflow is rapid response by local environmental authorities where in-state procedures can be enacted quickly.

In conclusion, this year’s ICAIS was yet another successful conference bringing together leading scholars across industry and academia to tackle perhaps the most important ecological problem of our time aside from climate change. Despite the continuing success of these meetings, the next few years are likely to be challenging times for our field considering the challenges that invasion biology is

currently facing at multiple levels. Limited funding due to budgetary constraints is a serious and continuing problem. While certain regions like southern Africa has been successful in advancing invasive species research through the establishment of special “centres of excellence”, governmental funding across North America, Europe, South America and elsewhere has either been eliminated, cut or has fallen each fiscal year. An even bigger threat and one which can severely impede the implementation of policies for dealing with aquatic invasive species is the rise of invasive species denialism (see Ricciardi and Ryan 2018 and Sagoff 2018). It is therefore imperative that meetings like the ICAIS continue to expand and diversify its audience and participant pool to ensure the future sustainability of the discipline.

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