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Editorial

International Conference on Aquatic Invasive Species – ICAIS returned to Europe after 15 years

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Editors' Note: This study was contributed in relation to the 22nd International Conference on Aquatic Invasive Species held in Ostend, Belgium, April 18–22, 2022 (https://icais.org). This conference has provided a venue for the exchange of information on various aspects of aquatic invasive species since its inception in 1990. The conference continues to provide an opportunity for dialog between academia, industry and environmental regulators.

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Abstract

The 22nd International Conference on Aquatic Invasive Species (ICAIS) was held as a hybrid event in Oostende, Belgium from 18–22 April 2022. The conference addressed the theme of "Global Climate Change Amplifies Aquatic Invasive Species Impacts" and aimed to expand knowledge on the latest science and policy, inspire cooperation and collaboration on research and management projects at a global scale. Seven renowned international scientists provided keynote presentations on perspectives of climate change within their respective areas of expertise. This special issue of Aquatic Invasions presents nine academic papers addressing a range of aquatic invasive species issues including predation, life history dynamics, ecosystem impacts, and physiological tolerances. The papers highlight the need for regional, national, and international cooperation, collaboration on research and management projects, and targeted, specific, and actionable outreach to combat the growing threat posed by aquatic invasive species.

Key words: Non-native aquatic species, freshwater, marine, estuarine environments, climate change, research on AIS

Although the long-awaited return of the International Conference on Aquatic Invasive Species (ICAIS) to Europe was further delayed as result of the global COVID-19 pandemic, ICAIS arrived to European shores after a 15-year absence. Hosted by the Research Institute for Nature and Forest (INBO – Belgium) and the Office for Risk Assessment and Research (BuRO/NVWA – The Netherlands), the 22nd ICAIS conference was held in Oostende, Belgium between 18–22 April 2022, with the aid of Canada's Invasive Species Center, the ICAIS Secretariat. For the first time in its 30-year history, ICAIS was organised as a hybrid event due to the challenges presented by the COVID-19 pandemic. The hybrid component allowed for both on-site and virtual participation. The conference attracted over 400 attendees from 41 countries, including many students and early-career researchers.

For the past 30 years, ICAIS has been the most comprehensive international forum to discuss and address new and emerging issues related to aquatic invasive species (AIS) in freshwater, marine and estuarine environments. The conference provides a platform for presentation of research to advance our shared understanding and progress global action to limit the introduction, spread and persistence of AIS worldwide. The theme of ICAIS 2022 was "Global Climate Change Amplifies Aquatic Invasive Species Impacts", demonstrating the interconnectedness of global invasive species issues with that of the major threat posed by climate change. In doing so, the conference sought to expand knowledge on the latest science and policy, and inspire regional, national and international cooperation, along with collaboration on research and management projects at a global scale. Special sessions at ICAIS 2022 were devoted to the management of AIS, research at the interface of climate change, as well as the interplays among aquatic invasive species and diseases, with a LIFE RIPARIAS workshop also being hosted by ICAIS. The post-conference tour provided participants with the opportunity to see a large variety of marine and freshwater invasive species in their invaded habitat in both The Netherlands and Belgium.

Seven renowned international scientists from different disciplines provided keynote presentations on perspectives of climate change within their respective areas of expertise. According to Bella Galil, the southern Levant is a frequent entry point for Mediterranean invasions through the Suez Canal, and the number of invasions is on the rise. Meanwhile, Gordon Copp highlighted the importance of conducting risk analysis to identify potential invaders and communicate the risks to lawmakers, managers, and the public. Katja Philippart gave a keynote lecture about how invasive species and climate change can negatively impact coastal marine ecosystems, and Melina Kourantidou spoke about an exciting new tool, InvaCost, that can help better estimate the economic effects of aquatic invasive species. Isabelle Côté used the lionfish invasion in the Caribbean and Atlantic as a case study to illustrate the ongoing repercussions of invasive species. Douglas Jensen suggested ways to improve outreach about aquatic invasive species by making it targeted, specific, and actionable, while Kevin Smith discussed the efforts of the International Union for the Conservation of Nature (IUCN) and the Species Survival Commission's Invasive Species Specialist Group to combat invasive species threats.

This Special Issue of "Aquatic Invasions" offers nine academic papers, and while five of these papers documenting AIS research were presented at the 22nd ICAIS conference, four additional papers are included in this issue intrinsically linked to matters discussed during the conference. The papers of this Special Issue consider a variety of different issues associated with AIS across a wide range of species; from amphipods and crabs, to fish, mussels, prawns and snails. Papers regarding management of AIS presented at the conference can be found in a special issue in the journal "Management of Biological Invasions" (see Johansson 2023). Both journals are open-access and peer-reviewed and are official journals of INVASIVESNET, the International Association for Open Knowledge on Invasive Alien Species (Lucy et al. 2016).

In laboratory experiments, Spilmont and Seuront (2023) investigated the interaction between the invasive alien North American amphipod *Ptilohyale littoralis* and the invasive alien Asian shore crab, *Hemigrapsus sanguineus*. Their study provides evidence of predator-prey interactions between these two introduced crustaceans, which co-occur on rocky shores along the French coast of the eastern English Channel. While *H. sanguineus* can efficiently predate *P. littoralis*, a prey preference was not apparent when crabs were offered a choice between the alien amphipod and a native blue mussel, *Mytilus edulis*. This research suggests the invasive crab will opportunistically select prey, and the presence of the invasive amphipod will

not elevate predatory pressure on populations of *M. edulis* which have a critical influence on the composition of natural benthic intertidal communities that rely on the bivalves engineering abilities. In turn, it is clear that *H. sanguineus* will not avoid consumption of the introduced amphipod prey, and unlike potentially naive native predators, the invasive crab may help limit the spread of *P. littoralis*.

In their research article, through stomach analyses complemented by DNA metabarcoding, Wallin Kihlberg et al. (2023) demonstrated the impacts of predation by an invasive fish, the round goby *Neogobius melanostomus*, on native biota between two geographically distinct populations residing within the Baltic Sea. Previously, diet studies have been based on visual prey identification only, and this has likely over-emphasized the importance of hard-shelled, invertebrate prey like dresseinid mussels. With the application of additional DNA metabarcoding, Wallin Kihlberg et al. demonstrate an approach which is less biased towards hard body structures and thus can be used for determination of highly degraded prey. Their study confirmed the generalist diet of the round goby but demonstrated also that its diet composition varied between areas and years. Visual stomach content analysis indicated blue mussel to be the main prey in the southern Baltic, whereas DNA meta barcoding reveals that hydrobiid gastropods were the major component of round goby diets in the North Baltic Sea. Additionally, metabarcoding revealed that several fish species - as egg or larval stages - were also part of the round goby diet, such as sticklebacks, herring, and cod (Gasterosteidae, *Clupea harengus*, and *Gadus morhua*). These data clearly suggest that *N. melanostomus* is part of a complex and poorly understood food web within the Baltic Sea, consisting of trophic predation links that may underpin a complex feedback mechanism whereby the round goby is simultaneously a competitor, prey, and even a predator of other predatory - and commercially important - fish species.

A long-time invader in Europe and more recently in North America is the Chinese mitten crab *Eriocheir sinensis*, but despite its long invasion history not much is known about its mechanisms of geographic expansion and fluctuations in abundance over the years. In their paper, Ewers et al. (2023) reveal at least two different mechanisms by which abundance and distribution of *E. sinensis* are co-regulated. At a regional scale, newly established populations appear to considerably increase in abundance before successful geographical expansion of the crab's range occurs. Beyond this, the suitability of receiving environments rather than an increased number of dispersal opportunities appears to govern the successful establishment and persistence of *E. sinensis*. In particular, through the assessment of a case-study population residing within the Elbe river (Germany) it seems that improved riverine water quality and rising sea surface temperatures promote increased abundance and regions with similar environmental profile could be at risk of invasion by *E. sinensis*.

Another AIS that has raised concern on both sides of the Atlantic Ocean is the quagga mussel *Dreissena rostriformis bugensis*. Ten years after its initial introduction, Trunfio et al. (2023) assessed the three populations residing in the Moselle river (France) and found that zebra mussel, *Dreissena polymorpha*, is still the most abundant invasive species (i.e. 2/3 of dreissenid individuals), but the quagga mussel represents on average 60% of the dreissenid biomass In turn, the quagga population observed is composed of five different length cohorts with large, overlapping size ranges, which suggests year round breeding. Growth of the quagga shell length was at least 1.4 times greater than zebra mussels and growth did not cease during winter months. In addition, small individuals (4 to 14 mm) were lacking from the quagga mussels samples, which may be attributed to selective predation by invasive round gobies, *N. melanostomus*. Although the assessed Moselle populations were mostly genetically homogeneous and similar to those found elsewhere in Europe,

the presence of multiple haplotypes are indicative of several successive introduction waves, a process that may continue in the future. Nonetheless, the rate of veliger production, winter growth and, potentially, predation by gobies, appear to be the main determinants of quagga mussel life history dynamics in the Moselle river.

When the survival of a species is already imperilled, the introduction of invasive species can bring about further declines and even local extinction. Through an assessment of historical and contemporary distribution records for fish species of the genus *Carassius* from 1875–2021, Fedorčák et al. (2023) show that invasive gibel carp *Carassius gibelio* have gradually become eudominant in a wide spectrum of habitats and biotopes across Slovakia and surrounding watersheds of the Middle Danube basin since the 1960s. This has coincided with the dramatic decrease of the native crucian carp, *Carassius carassius*, and it appears that the native is now very close to localised extinction within the study area. In addition, to the invasive characteristics of the gibel carp, anthropogenic factors such as aquaculture and uncontrolled stocking have contributed to the rapid spread of this species, especially in artificial biotopes.

Bushuiev et al. (2023) investigated the presence and distribution of the East Asian river prawn *Macrobrachium nipponense* in Ukraine across four river basins and two lagoons. Their study reveals that *M. nipponense* has become widespread in the lower reaches of both the Danube and Dniester river basins, their interfluves and in water bodies to the east of the Dniester river. The dramatic population increases in the Danube and Dniester river seems to be the result of successful local adaption and favourable environmental conditions. In the freshwater reaches of the Danube and Dniester, these invasive prawns demonstrate high growth rates and attain greater maximum body length than those recorded in the native range. In turn, alien *M. nipponense* residing in small shallow brackish-water reservoirs of the region show significantly lower growth rates, yet female prawns mature at a much smaller size, indicative of an adaptive strategy, which may support the establishment and persistence of this species. Interestingly, Bushuiev et al. (2023) also considered the worthwhileness of an organised, ecosystem-friendly commercial fishery of *M. nipponense* in the Danube river. They concluded that further research to support increased selectivity of fishing gears, as well as devise optimal licensing requirements and adequate positioning of fisheries within the river basins is needed to ensure the promotion of regional conservation goals.

In their paper, Dickey et al. (2023) assessed the south-east Asian predatory gastropod, *Anentome helena*, which is commonly traded around the world despite its uncertain taxonomic status, as the *A.* "*helena*" species complex is known to comprise at least four cryptic species. Dickey et al. performed functional response experiments using the pulmonate snail *Physella acuta* as prey to assess the impact of this non-native predatory *A. helena*. They found maximum feeding rate to be significantly reduced at a lower temperature (18 °C) which could be due to decreased metabolic activity compared to what is considered the 'optimal' temperature (22 °C). While Dickey et al. concluded that *A. helena* presently exert limited impacts in the short-term, there is a concern that increased temperature for freshwater systems due to climate change and thermal pollution will likely underpin the establishment, persistence and ecological impact of *A. helena* in European freshwater systems as a consequence of deliberate or accidental releases of this species.

For many invasive alien species, the mechanisms that underpin their success as invaders are frequently assumed rather than proven, and an improved understanding of physiological tolerances could assist with management efforts. In their study, Jaishanker et al. (2023) considered the freshwater Japanese mystery snail (*Heterogen japonica*) which was originally introduced to the United States in the early 1900s. While *H. japonica* has since established populations throughout the

North American continent, little is known about its physiological tolerances. Jaishanker et al. consider salinity and temperature gradients as possible limiting factors of its spread. A fully factorial design was used to assess the tolerance of juveniles to differing environmental conditions, with consideration of interactions between salinity (0.2 and 2 PSU) and temperature (25 °C, 34 °C and 38 °C). While almost all juveniles (99.5%) survived at 25 °C, all juveniles at 38 °C died by the end of the 14-day monitoring period (i.e., 100% mortality), irrespective of salinity. However, the onset of mortality at 2 PSU would suggest that there may be scope for expansion through estuarian systems, whereby short exposure periods of < 4-days may not result in 100% mortality.

Invasive alien species can dramatically alter food webs, yet in many ways our understanding and ability to predict changes to food web interactions remains limited. Rosa et al. (2023) investigated the influence of non-native aquatic invertebrate species on food web structures within two reservoirs located in the Grande River (Brazil). This was achieved through analysis of the digestive tracts of 874 fish, which was combined with an assessment of the composition and density of both native and non-native potential invertebrate prey available in sediment from the two reservoirs. Results indicate that most of the energy flow, between benthonic invertebrates (prey) and the fish community (predators), primarily occurred through non-native prey species at one study site, especially *Limnoperna fortunei* and *Macrobrachium amazonicum*. Consequently, the second study site demonstrated a more even division between non-native and native prey species. While species loss simulations indicated that the networks did not differ substantially between random losses and losses between groups, the loss of prey species would decrease the probability of occurrence of highly connected species. Nonetheless, results indicate that the presence of non-native prey especially *M. amazonicum*, may influence the interaction network structure, leading to community dependence on non-native species to ensure robustness to environmental disturbances.

The 22nd ICAIS conference and the collection of papers presented in this Special Issue of "Aquatic Invasions" covered a broad range of studies across a plethora of alien species while tackling various issues associated with interplays among AIS and climate change, including predation, life history dynamics, ecosystem impacts, and physiological tolerances. This Special Issue highlights the need for regional, national, and international cooperation, collaboration on research and management projects, and targeted, specific, and actionable outreach to combat the growing threat posed by AIS in tandem with climatic change.

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