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Editorial

COVID-19 delays and modifies ICAIS, but the important work goes on

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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

In 2022, the 22nd International Conference on Aquatic Invasive Species returned to Europe as a hybrid event. The conference welcomed representatives from 41 countries, including the largest group of students and early career professionals of any ICAIS conference. The theme of the conference was "Global Climate Change Amplifies Aquatic Invasive Species Impacts." Keynote speakers discussed ongoing invasions and the damaging synergy between climate change and invasions, presented on the value of risk assessment, outreach, and education, highlighted new ways to estimate the economic costs of invasions, and told attendees about some of the work of NGOs in managing invasions. This special issue includes a selection of papers that were presented at the conference, along with a few related papers that were not presented which touch on the risk of specific vectors, improvements in survey techniques to detect new or spreading invaders, and advances in management approaches to control AIS.

Key words: environmental DNA (eDNA), InvaCost, outreach, remote sensing, risk assessment, spatiotemporal modeling, transport vectors

After being delayed due to the global COVID-19 pandemic, the 22nd International Conference on Aquatic Invasive Species (ICAIS) returned to Europe after a 15-year absence in the form of a hybrid event, held from April 18–22, 2022, in Oostende, Belgium. The event was co-hosted by the Netherlands Office for Risk Management and Research (NWA/BuRO) and Belgium's Research Institute for Nature and Forest (INBO), and was supported by Canada's Invasive Species Centre, the ICAIS Secretariat. The first-ever hybrid ICAIS conference, necessitated by the impacts of COVID-19, ultimately made ICAIS 2022 a considerable success. The conference welcomed representatives from more countries than ever before (41) and also had the largest contingent of students and early career professionals of any ICAIS conference. The new ICAIS Diversity Bursary Program also allowed the conference to welcome 11 researchers whose participation was made possible through this funding. This special issue of *Management of Biological Invasions*, an open-access, peer-reviewed, international journal, contains some of the work presented at ICAIS 2022. It continues the 30-

year tradition of ICAIS being a reliable, up to date resource for scientists, policy makers, and management agencies seeking to understand and protect biodiversity and natural resources for a public who rely on aquatic ecosystem services which are increasingly impacted by invasive species worldwide.

Reflecting the connections between two of the major anthropogenic impacts on the global biosphere, the theme of ICAIS 2022 was "Global Climate Change Amplifies Aquatic Invasive Species Impacts". Goals of the conference were to expand knowledge of the latest science and policy, and to inspire cooperation and collaboration between researchers and managers at regional, national, and international levels. Keynote speakers presented on a broad range of topics. Bella Galil showed evidence that the southern Levant is a hotspot for invasions of the Mediterranean via the Suez Canal and that invasions are increasing. Gordon Copp talked about the value of risk analysis to identify potential invaders, to prioritize assessment, and to communicate risks to legislators, managers, and the public. The combined effects of invasive species and climate change on coastal marine ecosystems were the topic of Katja Philippart's keynote, and Melina Kourantidou talked about a new database (InvaCost) that promises to vastly improve our ability to estimate the economic costs of aquatic invasive species. The ongoing repercussions of the Lionfish (*Pterois volitans* [Linnaeus, 1758]/*Pterois miles* [Bennett, 1828]) invasion of the Caribbean and Atlantic were clearly illustrated by Isabelle Côté. Douglas Jensen described ways of making aquatic invasive species (AIS) outreach more effective by making it targeted, specific, and actionable, and Kevin Smith presented on the work of the International Union for the Conservation of Nature (IUCN) and the Species Survival Commission's Invasive Species Specialist Group to address the threat of AIS.

This special issue of *Management of Biological Invasions* includes papers that were presented at the conference, and which focus on detecting, monitoring, mitigating, and preventing the introduction and spread of AIS. Additional research articles from ICAIS 2022 were published in a special issue of *Aquatic Invasions*, the sister journal of *Management of Biological Invasions* (see Verreycken et al. 2023). Both are official journals of INVASIVESNET, the International Association for Open Knowledge on Invasive Alien Species (Lucy et al. 2016).

Two papers in this special issue are focused on the risk of spreading invasive species via specific vectors, alongside survey managers' opinions on how to minimize those risks. The first, by Campbell et al. (2023), followed up interviews of practitioners of life release (Campbell et al. 2021) by surveying members of regional panels on aquatic nuisance species to identify best practices for Buddhist life release in the United States. Life release, where animals are freed from captivity into the environment to live out their lives in nature, is a demonstrated invasion pathway globally (Magellan 2019). Suggested best practices include releasing recovered

wildlife in collaboration with wildlife rehabilitation centers or partnering with wild bait harvesters to release bait into the waterbody from which it was harvested (Campbell et al. 2023). Couch et al. (2023) also examined the risk of a specific vector of spreading invasive species. In this case, the vector examined is the fieldwork undertaken by wildlife and natural resource institutions and their partners. Couch et al. (2023) identify significant challenges to designing and implementing policies and guidelines to prevent the spread of invasive species via this vector, including resistance due to costs, and implementation challenges due to institutional and program complexity. Assessment is also likely to be challenging, although assessment could also improve implementation of and adherence to policies (Couch et al. 2023). The authors describe a conceptual framework for evaluating policies, and then illustrate application of this framework using a new policy implemented by the Pacific Region of the U.S. Fish and Wildlife service as a case study (Couch et al. 2023).

Although there will naturally always be a place for field sampling to assess the spread and distribution of invasive species, as illustrated by O'Shaughnessy et al. (2023), techniques such as remote sensing, spatiotemporal modeling, and eDNA sampling continue to rise in popularity because they allow more efficient use of scarce field time and human resources. O'Shaughnessy et al. (2023) use a targeted rapid assessment survey (RAS) approach focused on 22 marinas across the Republic of Ireland. Marinas aid the spread of invasive species by functioning as reservoirs, with species brought in from larger harbors via recreational boats and subsequently spreading into natural areas (Clarke Murray et al. 2011; Thomas et al. 2011; Afonso et al. 2020). The authors recorded 25 non-native species, including 19 invertebrates and six macroalgae, of which four species were new to the Republic of Ireland (O'Shaughnessy et al. 2023). Spread of non-native species via recreational vessels is supported by the results, but aquaculture activities are associated with the sites with the largest number of non-native species outside the Dublin area (O'Shaughnessy et al. 2023). This is consistent with research that has previously shown that aquaculture facilitates the spread of non-native species (Naylor et al. 2001).

Three papers in this issue use quite different techniques to lessen the burden of fieldwork on researchers tracking the spread, abundance, and distribution of non-indigenous species. Kvifte (2023) utilizes nature photography websites to note the establishment and spread of *Clogmia albipunctata* (Williston, 1893), a moth fly that breeds in drains and kitchen sinks, in Sweden and Denmark. While the threat posed by *C. albipunctata* to native diversity is unclear, the project clearly illustrates how researchers can leverage the ubiquity of mobile phone cameras, photography websites, and apps such as iNaturalist to greatly expand their reach into the environment. Follow-up surveys could thus be much more targeted to specific areas or to address particular research questions. Miranda et al.

(2023) also seek to improve the focus and efficiency of surveillance and management programs for invasive species. In this case, the approach is to use spatiotemporal modeling to assess the distribution, relative abundance, and aggregation of bigheaded carp (Silver Carp, *Hypophthalmichthys molitrix* [Valenciennes, 1844], and Bighead Carp, *H. nobilis* [Richardson, 1845]) in the Cumberland River and the Tennessee River, USA. Their results indicate significant temporal and spatial variation in distribution and aggregation, where fish are intensely aggregated in channels in spring and scatter widely during summer and fall (Miranda et al. 2023). These results could be useful in developing monitoring or harvesting programs to manage and mitigate damage by these two highly invasive species (Miranda et al. 2023). Finally, Ghiani et al. (2023) demonstrated how satellite imagery can be used to map and monitor invasive alien macrophytes quickly and efficiently, in time steps as short as five days (limited by image releases by the European Space Agency, in this case). By combining remote sensing data with GIS and modeling tools, this monitoring method could also be expanded to inform prevention, action planning, and prioritizing interventions (Ghiani et al. 2023). We are in a time of amazing technological growth, and Ghiani et al. (2023), Kvifte (2023), and Miranda et al. (2023) illustrate some of the opportunities to leverage that technology in the fight against AIS.

Two papers advocate making field sampling itself more efficient by utilizing environmental DNA (eDNA) techniques. Everts et al. (2023) combined eDNA-based analyses using quantitative droplet digital PCR and habitat assessments to determine the current distribution of American bullfrog (*Lithobates catesbeianus* [Shaw, 1802]) in Flanders, Belgium. Their results showed a fragmented distribution pattern, suggesting multiple anthropogenic introductions, and demonstrated that bullfrogs were highly selective in choosing breeding sites, potentially offering managers a way of targeting interventions at key locations (Everts et al. 2023). Bommerlund et al. (2023) similarly used qPCR analysis of eDNA samples to detect two invasive amphipods, *Crangonyx pseudogracilis* (Bousfield, 1958) and *C. floridanus* (Bousfield, 1963). These species present multiple challenges for detection and management: they are cryptic and difficult to detect, they are taxonomically difficult to distinguish, and their exact distributions are relatively unknown (Bommerlund et al. 2023). Environmental DNA offers possible solutions to all these difficulties. The authors developed eDNA assays for both species, and then analyzed samples from sites known to host the species (Ireland) as well as unknown sites (Belgium, Netherlands, France, Norway). They successfully detected both species in sites where they are known to be established and showed that the other locations were negative (Bommerlund et al. 2023). Both Bommerlund et al. (2023) and

Everts et al. (2023) demonstrated that eDNA is an efficient and powerful tool for assessing the distribution, spread, and even aspects of the ecology of AIS.

Effective control of AIS is likely to be multifaceted, with environmental conditions limiting the spread and persistence of species, direct interventions by management organizations controlling populations, and protective techniques used in particular areas or industries to minimize harm caused by AIS. Three papers in this special issue touch on these aspects of AIS management. Gantz et al. (2023) describe the relationship between temperature and dissolved oxygen and zebra mussel (*Dreissena polymorpha* [Pallas, 1771]) veliger density and adult survivorship in San Justo Reservoir in central California, USA. This information adds to our knowledge of the environmental conditions tolerated by this highly invasive species, and can inform the timing of management actions such as water drawdowns to control them (Gantz et al. 2023). Direct control of AIS has often involved application of pesticides, and the control of Sea Lamprey (*Petromyzon marinus* [Linnaeus, 1758]) populations in the Great Lakes using TFM (4-nitro-3-(trifluoromethyl)-phenol) represents a relative success story for this approach. However, changes in the inert ingredients of TFM that reduced its stability led to the development of a new formulation to improve thermal stability and effectiveness (Luoma et al. 2023). The authors tested this new formulation in the laboratory and in the field, and demonstrated that it has superior characteristics that are likely to restore its effectiveness. Additional field treatment applications will allow researchers to further refine application parameters (Luoma et al. 2023). Occasionally, the most effective approach to controlling AIS may be to control the harm caused, rather than attempting to control the population more broadly. Madzivanzira et al. (2023) describe the socioeconomic harm caused by Australian redclaw crayfish (*Cherax quadricarinatus* [Von Martens, 1868]) scavenging and damaging fishes caught in gillnets in the Zambezi Basin. In this case, the authors describe an effective method of controlling damage to catches by placing baited traps along gillnets, thereby misdirecting crayfish into the traps and away from the fisheries catch (Madzivanzira et al. 2023). This approach represents a pragmatic approach to control a significant socioeconomic issue caused by an invasive crayfish, which has the advantage of being relatively inexpensive and easy to deploy globally (Madzivanzira et al. 2023).

Pragmatism in terms of limited resources and a multifaceted approach are likely to be the best possible path forward to aquatic invasive species issues globally. This special issue of *Management of Biological Invasions* includes diverse papers and describes important advances in preventing spread of, managing, and suppressing aquatic invasive species. For managers, scientists, and stakeholders, these advances are a useful resource to help them address similar issues in their local area. However, aquatic invasive species will continue to be a major challenge impacting biodiversity,

natural resource conservation, and society. There are many research questions still to answer, and collaboration, research, and communication continue to be vital tools in advancing the field of the management of biological invasions. As a community of practice, we look forward to learning about, discussing, and debating those new findings, and developing new partnerships and collaborations at future ICAIS conferences.

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