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**Editorial**

# ICAIS continues to spur Global Action Against Aquatic Invasive Species

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The 20th International Conference on Aquatic Invasive Species (ICAIS; http://www.ICAIS.org) was held in Fort Lauderdale, Florida, USA, in October 2017. This event was hosted by the University of Florida's Institute of Food and Agricultural Sciences, with the Invasive Species Centre as Conference Secretariat. During these last two decades, ICAIS has become an important and indispensable forum for scientists working to advance invasion ecology and related management of marine, estuarine and freshwater ecosystems (Lucy and Muckle-Jeffs 2010). The dissemination of these advances through the ICAIS conference—in addition to the publication of these special issues—have influenced governments, scientific and management agencies to direct financial resources towards prevention, control and reducing the spread of invasive species, in order to better protect and conserve biodiversity, natural resources and the health of communities along waterbodies in different regions of the world. The participation of top-level scientists at this forum is key for the dissemination of scientific knowledge, and is a source of new collaborations and inspiration for early-career scientists and decision-makers. The publication of the scientific advances presented during the conference in an open-access peer-reviewed, international journal like *Management of Biological Invasions* is a great opportunity for further evaluating and sharing the work conducted by different researchers. As such, this platform constitutes a reliable source of scientific information that can be used as a reference by different people involved with the environment and invasive aquatic species.

Under the theme of *Global Action Against Aquatic Invasive Species*, the 2017 ICAIS confirmed its global nature with keynote talks on the ecology of non-native species in Europe (Helen Roy, UK), putting knowledge to action in North America (David Lodge, USA), perspectives of aquatic invasive species from a highly urbanized tropical city (Darren Yeo, Singapore), and island biosecurity (Paul Champion, New Zealand).

The present special issue therefore contains papers that were presented at the conference and focused on important and current topics relating to global actions against aquatic invasive species, including risk assessment, prevention, eradication, control, and management. In addition, six research articles from these sessions were published in a special issue of *Aquatic Invasions*, the sister journal of *Management of Biological Invasions* (see David and Janáč 2018; D'Hont et al. 2018; Haubrock et al. 2018; Koopman et al. 2018; Morissette et al. 2018; Pauli et al. 2018; Stepien et al. 2018).

Although they have the benefit of being relatively isolated on the "empty side of the globe", New Zealand has been at the leading edge of the management of invasive plants and animals, utilizing a coordinated and proactive biosecurity approach. Champion (this special issue) details the history and components of this coordinated approach, which includes identifying high-risk species off-shore, managing importation at the border, ongoing surveillance for new introductions, managing internal dispersal pathways, and national eradication programs. The success of invasive species management in New Zealand results in part from geographic isolation and a small national population, but also underscores the importance of having effective legislation and policy that creates a pro-active, science-informed biosecurity governance system.

As Champion (this special issue) describes for New Zealand (and others have previously highlighted, e.g. Hewitt et al. 2004), the most effective management approach may be to prevent the initial introduction of problematic species. To this end, it is important to identify which species have a high probability of being introduced, or of becoming invasive once they are introduced. Building upon this long-standing foundation of informing biosecurity management via research, Wyman-Grothem et al. (this special issue) completed a risk assessment for African longfin eel (*Anguilla mossambica*), a potential import into Michigan, USA for aquaculture purposes, based on the US Fish and Wildlife Service's Freshwater Fish Invasive Species Risk Assessment Model (FISRAM). The risk assessment indicated that the risk of *A. mossambica* becoming invasive in Michigan was relatively low, yet experts consistently rated the risk of transport of the species high and expressed concern about invasiveness of the species in the contiguous USA beyond Michigan as well as the potential for concurrent introduction of the parasitic swimbladder nematode *Anguillicoloides papernai.* This outcome emphasizes the complexity of factors to consider when performing risk assessments for the controlled importation of new species.

Smith et al. (this special issue) assessed the role of the live bait trade as a vector of red swamp crayfish (*Procambarus clarkii*) in Michigan, USA, and showed that the number of retailers selling *P. clarkii* actually increased following a ban on possession of the species. Their work highlights the importance of effective enforcement, but more importantly underscores the critical importance of cooperation between industry, managers, and stakeholders in managing invasive species.

Once a species is introduced in a new location, management and research effort inevitably turns away from prevention towards eradication, control and management of introduced populations. Shannon et al. (this special issue) tested the effectiveness of hot water immersion treatment for preventing the spread of invasive alien species via water-users' clothing and equipment. Based on laboratory testing with two invasive animal species and two invasive plant species, their results suggest that the UK *Check Clean Dry* campaign's recommended treatment of 15 minutes immersion at 45 °C may not result in complete mortality of all species. Instead, they suggest that temperatures above 50 °C may be more effective. Higher temperature treatments can be effective with shorter immersions, and hence higher temperatures may also increase the number of water-users willing to apply the treatment.

Chemical pesticides are the most commonly used control agents for zebra and quagga mussels. However, water temperature, chemical concentration, and exposure duration are all known to influence toxicity, and little research has been published to date on the influence of any of these factors. Luoma et al. (this special issue) tested four different molluscicides at a variety of temperatures and exposure durations. Their results suggest that longer treatments are required in cooler temperatures (≤ 12 °C), but that a variety of toxicant/exposure duration combinations are potentially effective at higher temperatures (≥ 17 °C). Overall, it is quite clear from their results that temperature, treatment duration, and choice of molluscicide all play an important role in the efficacy of treatment. Thus, managers need to be careful in planning their treatments to ensure that eradication is successful.

Because chemical molluscicides are costly and often damaging to native species, Waller and Bartsch (this special issue) tested the use of unpressurized $CO_2$ for management of zebra mussels (*Dreissena polymorpha*) while limiting harm to native fatmucket mussel (*Lampsilis siliquoidea*). With 80–100% mortality of *D. polymorpha* after 96 hours of treatment, their results suggest that $CO_2$ may be an effective method of controlling zebra mussels. Equally important, while $CO_2$ does impact native lampsiline mussels, it appears to have far fewer adverse effects than chemical treatments.

Pucherelli et al. (this special issue) examined the use of medium pressure, hydro-optic ultraviolet (HOD UV) light systems (100 mJ/cm$^2$ target dose) to address biofouling by invasive *Dreissena rostriformis bugensis* (quagga mussel) and *Cordylophora caspia* (colonial hydroid), as well as native freshwater sponges and bacteria in a reservoir along the lower Colorado River. They found that the use of HOD UV light systems in four main turbine cooling water lines and a raw water supply for the onsite water treatment facility at Parker Dam on Lake Havasu, Arizona, USA resulted in significant reduction in total biofouling as measured in dry weight from settlement plates. The Parker Dam facility manager confirmed that biofouling-related maintenance of the coolers (pre HOD UV light installation including yearly cleaning requiring additional staff hours) was reduced by 75% after the first year of HOD UV operation and eliminated in the second and third years after implementation.

Coughlan et al. (this special issue) tested another approach for local control of invasive bivalves: local application of dry ice to kill Asian clam (*Corbicula fluminea*). Under simulated field conditions in the laboratory, dry ice was effective at killing Asian clams in or out of the water, even when clams were covered

in gravel or mud. Although the authors acknowledge that their laboratory results need to be further tested under field conditions, the ready availability of dry ice pellets and straightforward application suggest that this approach may be an effective and environmentally friendly treatment for local control of Asian clam.

In spite of the challenges inherent in finding newly-introduced, low-density populations of invasive species and coordinating an effective response with limited resources, there are eradication success stories. Caffrey et al. (this special issue) describe the successful eradication of chub (*Squalius cephalus*) from the River Inny in Ireland. Reflecting the level of effort required for eradication of even a relatively localized introduction, crews consisting of three electrofishing boats, two tank boats, and a land-based crew worked on the eradication from 2006 to 2013, removing a total of 30 chub from the river. Since no additional chub have been seen or captured since 2010, it appears that this species has been successfully removed from the River Inny and from the island of Ireland.

With limited resources (time and money), invasive species management needs to be precisely targeted for maximum effectiveness. Sea lamprey in the North American Great Lakes are managed via chemical control of the sedentary ammocoete larval stage, which spend 4-6 years burrowed in stream sediments. Targeting of streams to prioritize treatment currently requires surveying of suitable habitat and electrofishing of ammocoetes, which are both costly and time-consuming, and entail risk to survey crews due to water conditions and difficult access. Schloesser et al. (this special issue) developed a semi-quantitative method of assessing sea lamprey densities based on environmental DNA. Environmental DNA sampling could eventually be used to improve targeting of streams for treatment, with particular advantages of ease of sampling and rapid analysis of numerous samples.

New tools for ballast water sampling and analysis also captured attention during the conference and in this special issue with the entry into force of the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* in September 2017. Moser et al. (this special issue) introduce a practical, pocket-sized ballast water sampling device, which, according to the author's testing, returned reliable representative samples of organisms during land-based testing with limited mortality effects. This device can be rapidly connected to a sampling port on the main ballast water pipe, and will likely be useful for collecting samples of organisms in the $\geq 10$ and $< 50$ µm size range, as well as indicator bacteria and pathogens, and water quality parameters.

First et al. (this special issue) describe a framework for validating ballast water compliance monitoring devices (e.g. tools for indicative analysis). Six devices were tested under their framework in a series of concurrent lab and field tests at different coastal locations, along with the microscopy-based vital fluorophore approach (the current standard for quantifying living organisms). An evaluation was then conducted considering device linearity, precision and accuracy. These testing procedures could eventually be applied to actual measurements of ballast water, or could be used to assess variation among different units of a particular monitoring device.

Active engagement by stakeholders is a crucial tool in invasive species management and is facilitated by effective communication. Davis et al. (this special issue) describe the outreach element of a project on invasive alien species management; by using a streamlined communications plan they used two simple metrics—"passive reach" and "interactions"—to measure the extent and the intensity of communications, and to look at the advantages and limitations provided by different media. The study found that broadcast media and social media have the capacity to reach a wide audience, but have a low percentage of interaction. In contrast, workshops and citizen science events tend to reach a much smaller audience, but generate greater levels of engagement. It is appropriate that communication is increasingly a prescribed element of grant-aided funding – scientists need to engage more with the community of practice in order to better manage biological invasions (Caffrey et al. 2015; Lucy et al. 2016).

This special issue of *Management of Biological Invasions* includes papers presenting several advances in the management of aquatic invasive species, which can be referenced by others tackling similar issues in other parts of the world. We acknowledge that there are still many open questions that would benefit from further research, scientific collaboration and open communication and outreach. The prevention, quantitative assessment and management of impacts of biological invasions in aquatic ecosystems remain crucial for the well-being of society in general, and conservation of natural resources in particular. We look forward to additional discussion, debates, collaboration and action against aquatic invasions in the Anthropocene at ICAIS 2019.

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