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Viewpoint

Tackling invasive alien species in Europe II: threats and opportunities until 2020

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Editor's note:

This is one of five papers prepared by participants of the conference "Freshwater Invasives – Networking for Strategy II". Held in Zagreb, Croatia from the 11th – 14th July 2016, the conference was organized by the University of Zagreb, Faculty of Agriculture, European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) and the Croatian Biological Society (HBD). The primary objective of the conference was to share new information and provide a forum where international scientists, policy makers and stakeholders could encourage the development of the management and policy in the increasingly important area of biological invasions.

Abstract

Invasive alien species (IAS) are a significant and growing problem worldwide. In Europe, some aspects of IAS have been addressed through existing legal instruments, but these are far from sufficient to tackle the problem comprehensively. The FINS II Conference considered the relevance of Top 20 IAS issues (Top 10 threats and opportunities) for Europe determined at the 1st Freshwater Invasiveness – Networking for Strategy (FINS I) conference held in Ireland in 2013. Using a similar format of sequential group voting, threats from FINS I (lack of funding, of awareness and education; poor communication) and several new threats (lack of lead agencies, of standardized management and of common approach; insufficient monitoring and management on private property) were identified by 80 academics, applied scientists, policy makers and stakeholders from 14 EU and three non-EU countries (including 10 invited speakers) during four workshop break-out sessions (legislation remit in both EU/non-EU countries; best management and biosecurity practice for control; data management and early warning; pathways of introductions and citizen science). Identified opportunities include improved cooperation and communication, education and leadership to enhance public awareness and stakeholder participation, systems establishment for early detection, rapid response, monitoring and management of IAS using standardised methods of data collection, storage and usage. The sets of threats and opportunities identified underline the importance of international cooperation on IAS issues in communication, education and funding as priorities, as well as in standardization of legislation, control methods and best practise of research.

Key words: non-native species, legislation, policy, environmental management, sequential rank voting, scoring system

Introduction

Biological invasions, with the threats they pose to aquatic biodiversity, represent particularly difficult challenges to society in general and to decision makers in particular (e.g. Vitousek et al. 1997; Dudgeon et al. 2006; Ricciardi et al. 2017). Across Europe, there is a wide range of policies, legislation and management approaches (including citizen awareness initiatives) to deal with non-native species (NNS), and in particular invasive alien species (IAS). However, in several European countries, legislation and management for IAS are either entirely missing (e.g. Slovenia) or lack regulatory structures (e.g. Croatia) to make them effective (Povž and Šumer 2005; Piria et al. 2016). Also, there has been a general lack of coordination on how to approach IAS management both within and between European Member States (MSs) (see Copp et al. 2005a; Ojaveer et al. 2014). All of these shortcomings impinge upon the increased risk of NNS introductions and consequent dispersal, which can eventually lead to significant adverse impacts on native biodiversity, local and national economies, ecosystem services and human health (Scalera et al. 2012).

To some extent, EU legislation to deal with NNS has already been enacted. This includes plant health (European Council Directive 29/2000), animal diseases (Regulation EC 882/2004), wildlife trade (Council Regulation EC 338/97), and the use of NNS or locally-absent species in aquaculture (Regulation EC 708/2007). More recently, to address the urgent need for a coordinated European response to IAS (European Union 2014), the EU enacted Regulation 1143/2014 on the "Prevention and management of the introduction and spread of invasive alien species" (henceforth, EC Regulation on IAS) – the first large piece of European legislation on NNS since the aforementioned Council Regulation EC 708/2007. Prior to enactment on 1 January 2015, when the EC Regulation on IAS came into force, an international conference on Freshwater Invasives Networking for Strategy (henceforth FINS I) was convened in Ireland in 2013 to identify key issues relating to IAS and propose measures to help develop the EC Regulation on IAS. This meeting, which brought together experts from a range of disciplines and responsibilities, focused on four pillar themes, namely biosecurity, economics, management and risk assessment, from which a list of the Top20 IAS issues was produced (Caffrey et al. 2014).

To develop and update the outcomes of FINS I, FINS II was convened in Croatia in July 2016 to identify changes and ongoing needs in IAS management subsequent to the introduction of the new regulation in its pre-implementation phase. The present article reports on the outcomes of FINS II consensus workshops, which undertook to: 1) assess whether the Top 20 IAS issues, threats and recommendations determined at FINS I (Caffrey et al. 2014) were still relevant; and 2) identify the Top 10 threats and opportunities that will need to be addressed in the implementation phase of the new EC Regulation on IAS. Notably, the distinction between IAS and NNS (the former representing about 10% of the latter: e.g. Williamson and Brown 1986; Gozlan 2008) will be maintained throughout to emphasise that not all introduced species are invasive, and that some species may not be invasive when first introduced but become invasive after a "lag phase" (e.g. Crooks and Soulé 1999; Copp et al. 2005a).

Methods

The FINS II workshop, held from 11–14 July 2016 and organised jointly by the University of Zagreb and the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC), brought together 80 delegates, including academics, applied scientists, policy makers and stakeholders from 17 countries (i.e. Croatia: 47 participants; Ireland: 4; Poland: 4; UK: 4; France: 3; Italy: 3; Belgium: 2; Czech Republic: 2; Finland: 2; Germany: 2; Austria: 1; Bosnia and Herzegovina: 1; Greece: 1; Netherlands: 1; Serbia: 1; Slovenia: 1; Turkey: 1). Of these, only five were also delegates at FINS I. On Day 1, a plenary meeting composed of the FINS I delegates, session leaders, co-leaders and rapporteurs established the workshop protocols. The Top 20 IAS priority issues, threats and recommendations identified at FINS I (Caffrey et al. 2014) were then designated to provide the baseline scope for four parallel workshop sessions to be held on Day 3, whereas Day 2 was designated for invited speakers' presentations. Parallel sessions were set up to address four main "themes": 1) legislation remit in both EU and non-EU countries; 2) best management and biosecurity practice for control; 3) data management and early warning; and 4) pathways of introductions and citizen science. On Day 3, each workshop group was allocated five of the 20 IAS issues (op. cit.), and group members were asked to determine whether or not those five issues remain relevant since enactment in 2015 of the EC Regulation on IAS. Group members were also asked to identify new key threats as well as opportunities (as a new element) to be addressed up to 2020, by discussing each issue in the context of the corresponding workshop session theme.

Each workshop session was coordinated by two moderators and recorded by a "rapporteur" (indicated in parentheses), respectively: Theme 1) M. Piria and P. Simonović (J.M. Caffrey); Theme 2) E. Sarat and G.H. Copp (D. Jelić); Theme 3) Q. Groom and M. Weinlander (F.E. Lucy); and Theme 4) E. Tricarico and A. Duplić (T. Tomljanović). All four workshop activities were overseen by J.T.A. Dick and H.E. Roy. The first two parallel theme sessions were held in the morning and the other two in the afternoon (all sessions lasted three hours). The participants individually chose one theme for the morning and one for the afternoon, with all information relevant to the discussions and voting protocol provided at the beginning of each session, when each of the five issues selected for a theme was projected on a screen and discussed initially by each group. Following discussions, workshop participants identified five to eight threats and opportunities during each session. Two assessment sheets were provided for this purpose, namely one for the threats and one for the opportunities (totalling 25–40 threats and 35–40 opportunities). These sheets were collated, then each delegate was asked to allocate a score of 1–5 to each of the listed threats and opportunities identified for each of the five IAS related issues. Notably, the ranking and scoring scheme followed Sutherland et al. (2009) and Caffrey et al. (2014). Votes were then counted by the workshop coordinators to generate two lists per workshop group, namely one for the threats and one for the opportunities.

On Day 4, workshop coordinators and rapporteurs identified commonalities between the lists of threats and opportunities generated by the four workshop sessions – in some cases merging very closely aligned threats and opportunities and produced condensed lists of six to seven threats and opportunities as follows (see also Appendix 1): Session 1) Legislation remit in both EU and non-EU countries (five threats and six opportunities); Session 2) Best management and biosecurity practice for control (seven threats and six opportunities); Session 3) Data management and early warning (seven threats and seven opportunities); and Session 4) Pathways of introductions and citizen science (seven threats and seven opportunities). This resulted in a combined list of 26 threats and 26 opportunities in total. A further round of consolidation merged closely-aligned threats and opportunities from all four sessions' lists to produce a final list of 16 threats and 11 opportunities for FINS II. The results were then presented in a final plenary workshop session during which 33 delegates were asked to score the remaining threats and opportunities (as before, as per Sutherland et al. 2009 and Caffrey et al. 2014), which by rank order resulted in a list of 10 priority threats and 10 priority opportunities (Table 1).

Results and discussion

At FINS II, all IAS issues identified at FINS I (op. cit.) were considered to have on-going relevant for implementation of the Regulation on IAS, resulting in a new list of Top 10 IAS threats and Top 10 opportunities (Table 1). Amongst the identified threats, several were similar to those identified at FINS I (Caffrey et al. 2014): Lack of funding and resources, Lack of awareness and education, Conflict of interests, and Poor communication. As regards opportunities, two (i.e. Cooperation and communication, Funding and related economic issues) were scored with the same number of votes, hence resulting in the same rank number (Table 1). Opportunities are logically linked to threats and refer to improvements of communication and cooperation between

Table 1. Top 10 IAS threats and Top 10 opportunities determined at the FINS II conference (*denotes new derived threats).

Threats			Opportunities		
Voting scores	Rank	Description	Voting scores	Rank	Description
72	1	Lack of funding and resources	57	1	Cooperation and communication
37	2	Lack of responsible lead agencies*	57	1	Funding and related economic issues
35	3	Lack of awareness and education	47	3	Education and outreach
21	4	Lack of standardisation in data management*	37	4	Increased interdisciplinarity in IAS analysis and management
20	5	Lack of common approaches to biosecurity*	33	5	Sharing of data and expertise
19	6	Conflicts of interest	32	6	Common practices
17	7	Insufficient monitoring of IAS*	24	7	Competent authorities
16	8	Poor communication	15	8	Use of legislation to enforce compliance
15	9	Private property*	12	9	Enhanced cross-legislation monitoring and management of IAS
14	10	Difficulties in the implementation of legislation in bordering non-EU countries*	7	10	Increased assessment of relevant natural capital, including ecosystem services

various institutions and stakeholders, funding resources, education, data analysis and management. In addition, emphasis was placed on the need to share common practices (i.e. risk analysis, standards, monitoring and management), to designate competent authorities, and to harmonise legislative frameworks amongst countries.

Unchanged threats

Lack of funding and resources (rank 1)

Resource availability was one of the weak links identified in the legislative framework of the EC Regulation on IAS. This is because no specific financing mechanisms or strategies have yet been set up – this was highlighted as a key gap by the EU MSs during discussions that led to approval of the text (Genovesi et al. 2015). In the past two years, the EC has put out two calls for assistance with NNS financing, but slow administrative mechanisms in the responsible authorities of certain countries are likely to be impeding further progress. Also, this action is intended for EU MSs only, and not for non-EU countries. The EU financial instrument for the LIFE Environment programme is the most frequently used instrument for setting up IAS action programmes. This is because IAS can harm European native species and ecosystems, which are therefore considered within the LIFE Nature and Biodiversity call (Scalera 2010). However, these projects are highly competitive, and they are only partly funded (up to 75%) by the EU. As proposal preparation requires considerable effort, this is likely to discourage applications from managers of nature reserves/areas and institutions. Moreover, LIFE projects mainly finance IAS control/eradication of already established IAS, and only recently started financing early detection and rapid eradication actions, as well as information campaigns to increase public awareness, e.g. LIFE AlterIAS http://www.alterias.be/en/ (27 April 2017) and LIFE ASAP http://www.lifeasap.eu/en/ (27 April 2017). The creation of an EU funding mechanism for IAS emergencies therefore remains a priority, and long-term core funding, rather than short-term projects, will be crucial for tackling IAS related threats.

Lack of awareness and education (rank 3)

Awareness and education are critical for future management of NNS because ignorance of NNS related impacts contributes to their introduction and spread (Cambray 2003; Copp et al. 2005a, 2005b; Verbrugge et al. 2014). Different perceptions exist regarding the introduction and eradication of NNS at all stakeholder levels, and these are influenced by ecological, socio-cultural and economic factors (García-Llorente et al. 2008; Verbrugge et al. 2013; Bonanno 2016). The lack of formal education about NNS and consequent low awareness of their overall impact on biodiversity and economy may be having serious implications for decision making, such as commensurability (e.g. the impacts in natural ecosystems may be valued as more important than those in other ecosystems), context dependency (e.g. the impacts of alien species inside or outside the region of interest may be valued differently) or personal decision biases that can lead to conflicts in NNS valuation and management (Essl et al. 2017). The level of public support for control and eradication programmes varies greatly (i.e. depending on people and countries) – this is highest amongst those familiar with control and eradication projects (e.g.

Bremner and Park 2007). Awareness campaigns in some countries have so far been promoted by governmental agencies, e.g. the "Check, Clean, Dry" initiative in New Zealand (http://www.biosecurity.govt.nz/cleaning: 27 April 2017) and in the UK (http://www.nonnativespecies.org/checkcleandry/: 27 April 2017) and the "carpathons" in Australia (Gilligan et al. 2005). Nevertheless, public awareness and education about NNS isssues still require considerable improvement in most EU countries. For example, a NNS survey conducted in Italy by the National Institute for Environmental Protection and Research (ISPRA) revealed a scarcity of knowledge about NNS amongst responsible authorities and associations involved in biodiversity conservation. This contrasted universities, protected areas and provinces, which are most active against IAS (Alonzi et al. 2009). In the UK, Anderson et al. (2014) demonstrated the benefits of conducting a biosecurity campaign, with respondents who had heard of the "Check, Clean, Dry" campaign being more likely to undertake biosecurity measures than those who had not. However, public engagement in targeted campaigns is still required to reach the widest possible audience and to emphasise the importance of biosecurity for ensuring effective management of IAS over the long term (Gozlan et al. 2013). Overall, increased knowledge amongst the general public of NNS issues and their effects on economy and native species that can come from education and public awareness campaigns will encourage political action, which is vital to improve policy and management practices on IAS (Genovesi et al. 2015). This is especially true in countries that have only recently prioritised (e.g. Croatia, Slovenia) or begun to prioritise (e.g. Serbia) IAS issues (P. Simonović, pers. comm.). Raising awareness and education, which have been foreseen in the EC Regulation on IAS (Article 22), are therefore a key action for governments and action groups (Wittenberg and Cock 2001).

Conflicts of interest and Poor communication (ranks 6 and 8, respectively)

Several communication problems and conflicts of interests were highlighted at FINS I (Caffrey et al. 2014), including communication between government departments, environmental agencies, stakeholder groups and the public. One of the consequences of inadequate and unclear communication is that research output, which focuses heavily on bioinvasion impacts, does not reflect the real priorities of scientists or decision-makers, who regard research on IAS prevention as being critically important (N'Guyen et al. 2015). Furthermore, information on management techniques is scarce. The lack of knowledge sharing in many countries limits managers, who cannot easily acquire the knowledge and training needed for setting up prevention, control and eradication programmes, thereby impeding further development and adoption of effective techniques. Poor communication on control techniques has even contributed to the prevailing pessimism about the potential to manage IAS successfully (Simberloff 2009). To this end, increased collaboration between researchers, decision makers and other stakeholders is needed to negotiate conflicts of interest, set priorities, align research and management with policy, share information and expertise, as well as to educate and involve the public. For this reason, the development and adoption of innovative communication methods, particularly using new technologies, should be prioritised. An example of this is the use of mobile phone applications to record observations, thus enhancing the potential for early detection, rapid response and dissemination of information.

New identified threats

Lack of responsible lead agencies (rank 2)

In most European MSs, IAS management and responsibilities are generally split across various national agencies and government departments (Caffrey et al. 2014). However, it is important that a single lead authority, with a clear statutory responsibility for IAS, is established in each MS. This responsible agency should be appropriately resourced and dedicated solely to IAS related issues. Such a responsible agency should develop a coherent and coordinated national approach to IAS and facilitate communication and collaboration with government departments, scientific and environmental institutions, NGOs, stakeholders and public within that MS.

Lack of standardisation in data management (rank 4)

At the local, regional and global scales, data availability on NNS occurrence is progressively improving as a result of the increasing number of online databases. However, the current major difficulty relates to database interoperability and standardisation (Graham et al. 2008), as databases often vary considerably in how they treat NNS status, survey effort and comprehensiveness (Hulme and Weser 2011). The implications of different standards are as yet poorly recognised, but to ensure comprehensive assessments, data and information systems need to be scientifically validated and compatible with each other. Examples are the European Alien Species Information Network (EASIN http://easin.jrc.ec.

europa.eu: 27 April 2017), which aims to merge data from several regional and national databases at the European scale (Katsanevakis et al. 2012), and the Biodiversity Information Standards Organization (TDWG: http://www.tdwg.org/: 27 April 2017), which aims to provide global standards for data exchange.

Lack of common approaches to biosecurity (rank 5)

Despite recommendations, the unified strategic approach to biosecurity (e.g. border controls, protocols to prevent spread, trade regulations) suggested by Caffrey et al. 2014 is still lacking. To comply with the new EC Regulation on IAS, national competent authorities (i.e. groups of experts) responsible for biosecurity need to be established in each MS. The Convention on Biological Diversity (CBD), the EC regulations on the use of NNS in aquaculture and on IAS, consistent with other recent national and international legislation on NNS place greatest emphasis on prevention of introduction and spread. This is clearly more cost-effective and less environmentally damaging than either reactive eradication or long-term control and containment (e.g. Britton et al. 2011). The most effective and least expensive measure to reduce new introductions and to slow or preferably completely stop the spread of IAS is the promotion and implementation of good biosecurity practice. Too often, biosecurity is presented as a rigid list of actions to be conducted without consideration of the expected outcomes (Caffrey et al. 2014). Whereas, to be fully effective, the widest possible audience (from government level to individuals) must be reached so that IAS related issues can be understood and proposed solutions entertained, including the encouragement to implement appropriate biosecurity measures, e.g. sanitary and phytosanitary measures (Caffrey et al. 2014). Yet, there is a clear lack of cooperation, coordination, consistency and cohesion with regard to biosecurity, both within (e.g. Copp et al. 2005a) and between MSs (Caffrey et al. 2014). This has led to the development of divergent approaches to biosecurity best practice within the EU, with some MSs paying relatively little attention to this important preventative measure. For this to change, collaborative international research needs to be implemented. For example, biosecurity initiatives for stakeholders and water user groups have been implemented in both Ireland (http://www.fisheriesireland.ie: 27 April 2017) and the UK (http://www.nonnativespecies.org/checkcleandry/: 27 April 2017). These include protocols that have been agreed with, as well as implemented and promoted by, the respective stakeholder groups (e.g. anglers, cruise operators, paddle sport enthusiasts, scuba divers). A range of easy-to-use and effective biosecurity products (e.g. disinfectant solutions) has also been developed in Ireland for use by water users (http://www.fisheriesireland.ie). The adoption of clear and coherent procedures as well as reliable products at the international level is therefore expected to increase biosecurity effectiveness, with a consequent reduction in the introduction and spread of IAS both within and between European countries.

Insufficient monitoring of IAS (rank 7)

A milestone innovation in the new EC Regulation on IAS is the obligation placed on MSs to assess the key introduction pathways of IAS listed as being of EU concern and to develop action plans to prevent new unwanted arrivals. Entry prevention requires a strengthening of controls on both intentional and accidental movements of organisms (Genovesi et al. 2015). An effective early-warning system has not yet been established or clearly defined, although a EU notification system tool has been launched (https://easin-notsys.jrc.ec.europa.eu/notsys/: 27 April 2017). In this regard, permanent monitoring of IAS could be a key approach. However, IAS monitoring programmes need to be implemented in most European countries (Copp et al. 2005a; Ojaveer et al. 2014), particularly non-EU countries such as Serbia (P. Simonović, pers. comm.) or Bosnia and Herzegovina (A. Adrović, pers. comm.). Indeed, certain EU countries, such as Austria (M. Weinlander, pers. comm) or Slovenia (M. Povž, pers. comm.), which are EU MSs since 1995 and 2004, respectively, do not have a permanent and functional IAS monitoring system. In addition to having different legislation, monitoring and management approaches, the level of monitoring may also vary between MSs due to funding and other constraints. Differences are even more pronounced at the borders between MSs and non-EU countries. Further, the problem related to methods of standardisation for monitoring becomes evident when comparing data from various European countries. This is especially relevant for those countries that share water basins and corridors. Moreover, access to monitoring data can be difficult, particularly if these are available in non-English languages or come from local projects. Finally, an additional potential problem with non-EU countries can be the lack of technical skills or expertise in monitoring implementation. For the above reasons, monitoring of IAS must be harmonised in terms of methods, effort, timeframes, language, terminology, accessibility and data exchange across both EU and non-EU countries, and especially between neighbouring countries.

Private property (rank 9)

Limited access to, and possible interventions on, private property is another potential threat, as is the inability to harmonise various regulations associated with complex legal issues. This obviously hampers IAS management in some areas. To this end, a legal basis is needed to permit authorities to enter private property for NNS management interventions. However, access to private property alone is not sufficient to enable effective management due to possible different attitudes to NNS. Thus, raising awareness amongst landowners may help in establishing a relationship with managers, thereby allowing them action to intervene with techniques commensurate with NNS threats throughout the year and over a sufficiently long period of time to achieve the desired results (Britton et al. 2011). By way of example, in the Sologne pond area in France, environmental managers leading the American bullfrog *Lithobates catesbeianus* (Shaw, 1802) eradication programme have had to face recurring problems of access to private property, and this has compromised the effectiveness of management actions (i.e. pond draining and set-up of trap barriers: Sarat et al. 2015a, 2015b). Although awareness and communication actions were undertaken and access to private properties improved over time, managers were confronted with strong opposition from land owners to the proposed management actions. This included refusal to drain ponds or cut vegetation along the banks but also demands to stop actions during the hunting season for waterfowl. Overall, limited access to private property is just one aspect of a more complex issue related to communication and implementation of management techniques. A possible means to minimise these problems is to establish agreements with owners about land management. In the above example, in exchange for the retrofitting of drainage systems and pond maintenance, managers of the American bullfrog eradication programme would gain full management rights on the target site for one or two years. This system of agreements, which is a form of compensation agreed upon beforehand, is a means of dialogue engagement that should improve relations between managers and owners. It clearly empowers both parties by defining the lines of responsability and by ensuring transparency in the interventions carried out, while creating more support and raising awareness at the same time. This was made possible under the European LIFE funding that will be implemented by 2017. Despite the necessity for a legal approach, awareness and communication with all stakeholders remain the best guarantees for effective management interventions.

Difficulties in the implementation of legislation in bordering non-EU countries (rank 10)

Issues associated with IAS are cross-border and cannot be disentangled exclusively at the intra-EU level, whereby MSs along EU borders may be at potentially greater risk of new bioinvasions relative to their non-EU neighbours (EC 2008). A common ground in the implementation of legislation between the EU and its neighbouring countries is therefore urgently needed. Under the EC regulation on the use of NNS in aquaculture, and the regulation on IAS, MSs are obliged to foster cooperation with third countries (Article 22). However, several steps need to be taken in this direction, beginning with identification of the main limitations in the implementation of common legislation between EU and non-EU countries. Firstly, NNS and biodiversity are generally of low priority in the political agendas of many countries, and this hampers the implementation of EC directives and/or regulations. Secondly, non-EU bordering countries are not obliged to enforce EU laws concerning NNS, and this could leave open invasion corridors, such as canals, transboundary water courses and lakes (Hulme 2015). Also, cross-border management of IAS between EU and non-EU countries is poorly funded and fragmented in nature (e.g. Interreg projects), which limits the extent or impedes the existence of NNS monitoring projects for early warning and rapid response system at a pan-European level. Finally, the lack of coordination of scientific effort on IAS between EU and non-EU countries (e.g. in the absence of common IAS lists and databases) represents a major drawback in the implementation of cross-border legislative action. As an additional sign of concern, all of the above issues might be further exacerbated by the recent swaying of some non-EU countries towards "isolationist" regimes.

Opportunities

Cooperation and communication (rank 1)

Many bordering countries, particularly those in the Balkan Peninsula, share the same or a related language, whereas in countries with different languages, the level of bi- or multi-lingualism can be high, particularly in border areas. To enhance communication and cooperation regarding NNS issues, networks and databases such as CABI-ISC, EASIN, ESENIAS, DAISIE, GISIN, GISID-ISSG, NAISN and NOBANIS (see Box 1) have proven useful, but further opportunities exist. An increase in the number of such networks might improve cooperation and communication locally, but decrease it

Box 1. List of abbreviations.

ABT – Aichi Biodiversity Targets
CABI-ISC – Centre for Agriculture and Biosciences International-Invasive Species Compendium
CBD – Convention on Biological Diversity
DAISIE – Delivering Alien Invasive Species Inventories for Europe
EASIN – European Alien Species Information Network
EC – European Council
EIFAAC – European Inland Fisheries and Aquaculture Advisory Commission
ESENIAS – East and South European Network for Invasive Alien Species
EU – European Union
FINS – Freshwater Invasives – Networking for Strategy
GBIF – Global Biodiversity Information Facility
GISID-ISSG – Global Invasive Species Database-Invasive Species Specialist Group
GISIN – Global Invasive Species Information Network
IAS – Invasive Alien Species
IAS issues – Top 20 IAS priority issues, threats and recommendations (Caffrey et al. 2014)
INVASIVESNET – The International Association for Open Knowledge on Invasive Species (network of networks on IAS)
ISPRA – Italian Institute for Environmental Protection and Research
IUCN – International Union for Conservation of Nature
MS – Member State (plural = MSs)
NAISN - North American Invasive Species Network
NBSAP – National Biodiversity Strategies and Action Plan
NGO – Non Governmental Organization
NOBANIS – European Network on Invasive Alien Species
NNS – Non-native Species
UK – United Kingdom

globally. Therefore, it is recommended that financial resources be made available to establish an international coordination centre to facilitate effective communication and cooperation among EU and non-EU countries and the relevant stakeholders. This centre could be established as part of a recognised international organisation. For example, the INVASIVESNET network has been proposed as the overall coordinating body to facilitate knowledge exchange and encourage improved management of IAS and their impacts (Lucy et al. 2016). The establishment of a coordination centre, which was foreseen under the EC Regulation on IAS, has already taken place by way of EC contract (http://ec.europa.eu/environment/nature/invasivealien/: 27 April 2017) (see Box 2).

Funding and related economic issues (rank 1)

Biological invasions can result in both intended and unintended costs on society with their risk depending on human behaviour (e.g. Perrings 2001; Ricciardi et al. 2017). As mentioned earlier, prevention and rapid response to new invasions are the most cost-effective means to avoid or mitigate the economic damage caused by IAS. As such, the creation of a EU-based emergency funding mechanism remains an important priority. Economic sustainability is always a hard challenge and can be exacerbated by economic downturns sometimes leading to the closure or suspension of global and regional initiatives on IAS (Lucy et al. 2016). However, the new EC Regulation on IAS provides, for the first time, the necessary enforcement power to tackle IAS as well as the basis for the establishment of a permanent fund by which to implement the Regulations. This would no doubt be directly linked to the designation of a competent authority, including NNS experts devoted to the implementation of the Regulation on IAS. A similar type of structure is also required under EC Regulation 708/2007 on the use of alien or locally-absent species in aquaculture (EC 2007), even though it remains unclear whether or not MSs have actually created or nominated "competent authorities" in response to Regulation 708/2007. Regardless, a common competent authority could oversee the implementation of these two new regulations, given their common objectives to manage NNS and mitigate their potential adverse impacts. Funds should be allocated following assessment and prioritisation of management actions. Through this funding system, IAS-related issues could be monitored continuously, hence overcoming the constraints with time and financial availability typical of LIFE, bilateral or regional Interreg projects. The European structural funds represent an opportunity at the strategic level for MSs to fund development and improvement of national

Box 2. National and local school educational non-native/invasive species websites.

Website of the ALTERIAS Life project – http://www.alterias.be/en/
Governmental awareness campaign in New Zealand – http://www.biosecurity.govt.nz/cleaning
The Convention on Biological Diversity website – http://www.cbd.int/idb/
The European Alien Species Information Network (EASIN) website – http://easin.jrc.ec.europa.eu
EASIN Notification System (Notsys) tool – https://easin-notsys.jrc.ec.europa.eu/notsys
Website of the European Commission – http://ec.europa.eu/environment/nature/invasivealien/
Inland Fisheries Institute in Ireland awareness campaign – http://www.fisheriesireland.ie
An international open data infrastructure website -The Global Biodiversity Information Facility – http://www.gbif.org
Website of the Alien Species Awareness Program project – http://www.lifeasap.eu/en/
National geographic educational website – http://nationalgeographic.org/activity/introduction-invasive-species/
AquaInvaders project website – http://naturelocator.org/aquainvaders.html
Governmental awareness campaign in UK – http://www.nonnativespecies.org/checkcleandry/
GB non-native species secretariat website – http://www.nonnativespecies.org/index.cfm?pageid=530
The National Ocean Service education program in US – http://oceanservice.noaa.gov/education/stories/lionfish/teachers.html
Educational video "10 things to know about alien invasives" –
https://player.vimeo.com/external/208516902.hd.mp4?s=34f3b9c3a57d8385ea568516177ffb8bc9475233&profile_id=174&download=1
RINSE (Reducing the Impacts of Non-native Species in Europe) project website – http://www.rinse-europe.eu/smartphone-apps
Biodiversity Information Standards – http://www.tdwg.org/
Center for Invasive Species Management in Montana, USA http://www.weedcenter.org/education/k-12.html
World fish migration website – http://www.worldfishmigrationday.com/

mechanisms for monitoring, management and public awareness. However, sustained funding of early detection and rapid response is still not present in many MSs and should therefore be secured.

Education and outreach (rank 3)

The current decline in (or lack of) environmental sciences programmes, and especially invasion biology and native biodiversity, at primary and secondary school levels, and even within some university curricula, is likely to have future adverse consequences in terms of NNS awareness amongst scientists and the general pubic. It is therefore recommended that the aforementioned trend be reversed, with particular emphasis on biological invasions. Topics should cover NNS identification, distribution and environmental biology as well as the risks associated with NNS introductions, establishment, dispersal and impacts on native species and eco-systems. Training in these disciplines at an early age will increase awareness, which will aide in the prevention of new introductions and wider NNS dispersal. The range of educational activities related to NNS issues could involve summer schools, workshops activities and master classes for local school groups as well as participation in local "citizen and science" initiatives (e.g. Crowl et al. 2008; Delaney et al. 2008; Dickinson et al. 2010). The involvement of educators from nature protection areas and NGOs is helpful in expanding the public's knowledge of biological invasions. Teaching and learning techniques would include study through play (http://www.nonnativespecies.org/index.cfm?pageid=530: 27 April 2017), with the addition of educational information about NNS on the internet from national and local school websites, mobile applications (e.g. http://naturelocator.org/aquainvaders.html: 27 April 2017; http://www.rinse-europe.eu/smartphone-apps: 27 April 2017) as well as TV shows (e.g. https://player.vimeo.com/external/208516902.hd.mp4?s=34f3b9c3a57d8385ea568516177ffb8bc9475233&profile_id=174&download=1: 27 May 2017). Expanding the public's knowledge can be achieved in several ways including stakeholder meetings and workshops (e.g. International Day for Biological Diversity http://www.cbd.int/idb/: 27 April 2017; World Fish Migration Day http://www.worldfishmigrationday.com/: 27 April 2017), printed media such as magazine and newspaper articles (including the angling press), and popular science books on NNS. In the case of aquatic ecosystems, educational signs/panels, pamphlets or brochures on display at public-access points (e.g. angling and boating venues), as well as at the meeting venues of fisher and inland aquaculture unions, can help improve NNS awareness amongst union members and employees alike. Opportunities may also arise to host joint workshops (such as between angling societies) aimed to raise awareness amongst local fishers about IAS and their impacts on aquatic resources and biological diversity. This would ensure that this global issue is brought to the local level for action.

Increased interdisciplinarity in IAS analysis and management (rank 4)

In order to understand better the threats IAS pose to natural capital and ecosystem services, collaborative interdisciplinary research is required. Economic meta-analysis and modelling can inform interdisciplinary research on the linkages between IAS and changes in ecosystem function (Balvanera et al. 2014; Walsh et al. 2016). Moreover, the assessment of impacts on human and wildlife health caused by IAS is a new prominent area of study, requiring in depth research and a collaboration with experts in human and animal health (Mazza et al. 2014; Roy et al. 2016). Better data acquisition and management protocols are needed to support more accurate empirical assessments of the damage caused by IAS and the related costs for control. This will facilitate efficient implementation of NNS legislation through cost-benefit analyses of the feasibility of management options and for cost-efficient prioritisation of management actions (Olson 2006). Economic meta-analysis offers the opportunity to strengthen collaboration between economists and invasive species scientists, and it can be useful for implementing prevention, control and management strategies of NNS. Finally, to address the issue of increasing public awareness on IAS more effectively, and thus boost the prevention phase, a stronger link between social scientists and experts in communication should be established to improve education and dissemination strategies.

Sharing of data and expertise (rank 5)

The sharing of digital data represents an opportunity to enhance productivity and innovation in NNS related research and management. Scientists have always shared data and expertise amongst colleagues and collaborators, but the Internet has further enhanced the sharing and partnership of resources. This increased communication opportunity has led to the creation of aggregated datasets that would have been otherwise impossible to obtain (e.g. Warren et al. 2013). However, the nature of data sharing has also changed. Scientists are now publishing research data openly to support the evidence base and transparency of research, but also to maintain the longevity and usefulness of the data themselves. Similarly, online international cooperation is improving the sharing of best practices between countries. One of the key drivers behind the accessibility of open data repositories in the case of biodiversity data is led by the Global Biodiversity Information Facility http://www.gbif.org/ (27 April 2017). The provision of open source tools for publishing and accessing global datasets is driving many changes in the way data are managed by institutions and will transform the way through which observational biodiversity research is conducted.

Common practices (rank 6)

Discrepancies amongst countries in their approach to NNS issues could be overcome by adopting common practices, for example in the process of risk analysis and horizon scanning to identify potential new IAS (Kolar and Lodge 2002; Sutherland et al. 2008; Gozlan et al. 2010; Roy et al. 2015; Gallardo et al. 2016). The list of invasive alien species of EU concern was created as a result of Regulation 2016/1141 (EC 2016) and was drawn up by the Scientific Forum and the Committee on Invasive Alien Species. This list needs to be kept up-to-date and a first update is under preparation. Common practices would also allow the drafting of national black lists (or white lists, Simberloff 2007) of existing and potential IAS following the same procedures, including prioritisation of interventions. The advantages of having common approaches to the establishment of NNS prioritisation lists would greatly simplify comparisons between countries.

Competent authorities and enhanced cross-legislation monitoring and management of IAS (ranks 7 and 9, respectively).

In compliance with the EC Regulation on IAS, the opportunity exists to establish in each MS a national competent authority responsible for biosecurity and IAS-related issues as well as a central EU body to provide disaster-relief-type funding for priority rapid responses. Opportunities to improve and develop the monitoring and management of IAS could be achieved through cross-border cooperation. This may foster communication and allow development of education and training programmes, thereby raising public awareness of IAS related issues. Policy makers at the local level are also more inclined to cooperate when a language is being shared, and in countries where this occurs cross-border programmes may have a higher likelihood of success. Rivers often form the borders between countries, and joint projects on border rivers, such as the Danube and Rhine, can act as models for future monitoring and management of each country's water course. Joint projects serve as venues for knowledge sharing and for the creation of teams from each country working together to focus on specific characteristics of shared waters, including the identification of species thought to be of potential threat (e.g. the Joint Danube Survey: http://www.icpdr.org/main/activities-projects/joint-danube-survey). Since successful monitoring

is hindered by a lack of trained taxonomists (Stokes et al. 2006), working groups that focus on shared waters could ensure more efficient identification of IAS, including the improved ability to identify those IAS likely to have greatest impact on the native biota. Local-based focus groups provide an opportunity to include other stakeholders in the process, such as non-governmental organizations (NGOs) and local fishing societies, which results in better trained amateurs and a higher overall level of awareness. In addition, the role of the academic community should not be neglected. In fact, cross-border cooperation between universities raises the profile of projects, the emphasis of academia on fundamental science to underpin management practices can make projects more attractive to funding bodies. Pooling of scientific resources between countries will therefore foster new and innovative approaches to the overall management of rivers in any region.

Use of legislation to enforce compliance (rank 8)

Legislation is a key element in the approach to IAS but by itself it is insufficient (Caffrey et al. 2014). Biodiversity strategies and action plans promoted by the CBD have been prepared by several EU countries and provide an opportunity for the implementation of IAS management at both the international and national scale (CBD 2016). Obligations for CBD and the Aichi Biodiversity Targets (ABT) include EU and neighbouring non-EU countries. The ABT are part of the Strategic Plan for Biodiversity 2011–2020. This overarching framework, which aims to protect biodiversity and enhance its benefits for people, was approved by governments in 2010 and has since been recognised by the United Nations as setting the global framework for action on biodiversity. However, additional actions are required to allow targets to be met by 2020, and these include Strategic Goal B Target 9, which is to "Reduce the direct pressures on biodiversity and promote sustainable use". However, some of the national targets and/or commitments contained in the National Biodiversity Strategies and Action Plans (NBSAP) set lower standards compared to the ABT, or do not address all of its elements (including Target 9). In Europe, the following countries have addressed most elements of Target 9: Belgium, Czech Republic, Denmark, France, FYR Macedonia, Greece, Ireland, Norway, Slovakia, Slovenia, Sweden, Switzerland and the United Kingdom (CBD 2016). Future development of a comprehensive national policy framework on NNS, particularly for candidate countries to the EU, should be harmonised or integrated with existing frameworks implemented in Europe.

Increased assessment of relevant natural capital, including ecosystem services (rank 10)

IAS can adversely alter the hydrology, biogeochemical cycling and biotic composition of invaded ecosystems, which in turn can modulate the effects of other stressors (Strayer 2010). Despite growing recognition of the harm caused by IAS, biological invasions remain a largely unquantified threat in terms of their impact on natural capital and ecosystem services (Walsh et al. 2016).

Recent research suggests that impacts of IAS are likely to remain high in forthcoming decades (Early et al. 2016). Therefore, the definition and quantification of IAS impacts on natural capital and ecosystem services is essential to develop appropriate policies and effective management responses (Cook et al. 2007). In general, the links between IAS, other stressors and the provision of ecosystem services remain poorly studied (Pejchar and Mooney 2009; Strayer 2010; Balvanera et al. 2014; Walsh et al. 2016), and, as stated above, require interdisciplinary research. The impacts of IAS on ecosystem services need to be defined in terms useful to managers and policy makers if an effective ecosystem-scale decision and policy framework is to be developed (Balvanera et al. 2014; Walsh et al. 2016). Indeed, there is a need for a move beyond idealised experimental conditions to realistic, *in situ* management scenarios involving a complete assessment of the supply and delivery of services to stakeholders (Balvanera et al. 2014).

Concluding remarks

The implementation of new regulations on IAS throughout the EU is just one step towards successful NNS management. Research communities and societies in general have a long way to go to tackle this problem. In the near future, cooperation and communication, education and leadership need to be prioritized by EU authorities, national governments and non-governmental organizations in order to establish, support and implement the system for quick detection, eradication, monitoring and management of IAS efficiently and effectively. While doing so, divergent perceptions of IAS in society, including denialism (Ricciardi et al. 2017), need to be taken in to account and significant resources and efforts allocated to raising awareness among the general public, specific stakeholder groups and local governmental agencies. In addition, standardisation of methods for data collection and usage, and best practices will significantly improve the efficiency and speed of concerted efforts against IAS, as would insightful legislation aimed at reducing barriers for

action implementation. Above all, the problem of IAS is global, and therefore international cooperation is of paramount importance to the effective management of IAS.

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Supplementary material

The following supplementary material is available for this article:

Appendix 1. Final lists of threats and opportunities obtained at each of the four sessions in the first round.

This material is available as part of online article from:
http://www.reabic.net/journals/mbi/2017/Supplements/MBI_2017_Piria_etal_Appendix_1.xlsx