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Aquatic invasive alien species – top issues for their management Outcomes from the IFI/EIFAAC conference "Freshwater Invasives – Networking for Strategy" (FINS)

Galway, Ireland, 9–11 April 2013

European Inland Fisheries and Aquaculture Advisory Commission

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS DOCUMENT

This publication presents the structure, the particulars, the methods for identifying and prioritizing the invasive alien species issues, the information derived from the invited presentations and the posters, as well as the outcomes of the conference "Freshwater Invasives – Networking for Strategy (FINS)" of Inland Fisheries Ireland (IFI) and the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) held in Galway, Ireland, 9–11 April 2013. It was drafted by J.M. Caffrey (IFI), in cooperation with J.T.A. Dick (Queen's University Belfast), C. Gallagher (IFI) and F. Lucy (Institute of Technology Sligo), and finalized for publication in a joint effort by J.M. Caffrey and G. Marmulla (FAO). The information provided and the views and opinions expressed in this information product are those of the authors and the conference participants and do not necessarily reflect the views of FAO. The results of the conference were initially published in the open-access journal *Management of Biological Invasions* in April 2014. However, as FAO felt that the issue of IAS and the results of the Galway conference, of which the FAO Regional Fishery Body EIFAAC was the co-organizer, are very important, this publication was produced with the aim of widely disseminating information on the IAS issue and the conference results, within and beyond Europe, to the broadest relevant audience. The summaries of the posters presented at the conference (Chapter 3), the biographies of invited speakers (Appendix 7), the list of the Top 20 IAS issues, and that of the reserve issues, developed at the conference (Appendixes 8 and 9) are reproduced as submitted.

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ABSTRACT

In November 2014, the European Union (Member Organization) (EU) published a new Regulation to address invasive alien species (IAS) and protect biodiversity. This Regulation entered into force across the EU in January 2015. Its aim is to "prevent the introduction of, control or eradicate alien species which threaten ecosystems, habitats or species". In an effort to provide focus to the Regulation prior to its publishing and to identify the major issues relating to IAS in Europe (28 countries of the EU and other European countries), the views of invasive species experts from around the world were sought. These were consolidated at an international conference (Freshwater Invasives – Networking for Strategy [FINS]) that was held in Ireland in April 2013. A major outcome from this meeting of experts was the production of the "Top 20" IAS issues that relate primarily to freshwater habitats but are also directly relevant to marine and terrestrial ecosystems. This list will support policy-makers throughout the EU as preparations are made to implement this important piece of legislation. A further outcome from the conference was the formation of an expert IAS advisory group to support EIFAAC in its work on invasive species.

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Abbreviations and acronyms

BT	benefit transfer
CABI	Commonwealth Agricultural Bureaux International
CAISIE	Control of Aquatic Invasive Species and Restoration of Natural Communities in Ireland
CAPRA	Computer Aided Pest Risk Analysis
CBA	cost-benefit analysis
CBD	Convention on Biological Diversity
CEA	cost-effectiveness analysis
CHARISMA	Cultural Heritage Advanced Research Infrastructures
CIRB	Controlling Priority Non-native Invasive Riparian Plants and Restoring Native Biodiversity
COST	Cooperation in Science and Technology
CPUE	catch per unit effort
DAISIE	Delivering Alien Invasive Species Inventories for Europe
DEFRA	Department of Environment, Fisheries and Rural Affairs
EC	European Commission
eDNA	environmental DNA
EFSA	European Food Safety Authority
EIFAAC	European Inland Fisheries and Aquaculture Advisory Commission
EPPO	European and Mediterranean Plant Protection Organization
EU	European Union (Member Organization)
EUPHRESCO	European and Mediterranean Plant Protection Organisation
FINS	Freshwater Invasives – Networking for Strategy
GB	Great Britain
GB NNSS	GB Non-native Species Secretariat
IADA	Irish Angling Development Alliance
IAS	invasive alien species
IBWT	inter-basin water transfer
IFI	Inland Fisheries Ireland
IMPASSE	Environmental Impacts of Aquatic Species in Aquaculture
IPPC	International Plant Protection Convention
IUCN	International Union for Conservation of Nature
LAG	local action group
MS	member State (of the European Union [Member Organization])
NGO	non-governmental organization
OIE	World Organisation for Animal Health
PRATIQUE	Enhancements of Pest Risk Analysis Techniques
(q)PRC	(quantitative) polymerase chain reaction
R&D	research and development
SAC	special area of conservation
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures
SSSI	site of special scientific interest
USA	United States of America
WFD	Water Framework Directive
WTO	World Trade Organization

EXECUTIVE SUMMARY

Globally, invasive alien species (IAS) are considered to be one of the major threats to native biodiversity, with the International Union for Conservation of Nature (IUCN) citing their impacts as "immense, insidious, and usually irreversible". They threaten the ecological stability of infested habitats, and native species therein, as those are highly sensitive to the adaptive and pervasive traits of the non-native species. It is estimated that 11 percent of the about 12 000 alien species in the 28 countries of the European Union (Member Organization) (EU) and other European countries (Europe) are invasive, causing significant environmental, economic and social damage; and it is reasonable to expect that the rate of biological invasions into Europe will increase in the coming years.

In an effort to regularize the response to this threat across all member States (MS) of the EU, a draft Regulation on "the prevention and management of the introduction and spread of invasive alien species" was published in September 2013. This proposed legislation aims to prevent, minimize and mitigate the adverse impacts of IAS on biodiversity and ecosystem services, as well as limiting social and economic damage. In order to determine the most urgent and pressing IAS issues in Europe, an international conference on Freshwater Invasives – Networking for Strategy (FINS) was convened in Ireland in April 2013. A horizon-scanning and issue-prioritization approach was used to elucidate the "Top 20" IAS issues in Europe. These issues do not focus solely on freshwater habitats and taxa but relate also to marine and terrestrial situations. The management advice identified to address the Top 20 IAS issues represents a tool for IAS management and will also support policy-makers throughout the EU as they prepare to implement new European IAS legislation.

This document describes each of the Top 20 IAS issues determined during the conference. It explains the nature of the threat posed and whether it occurs at a local, national or international level. It also presents advice relating to how the issues can be best managed or resolved.

A further objective of the conference was to form a Europe-wide expert advisory group to support a major European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) project on IAS. The composition of this advisory group is presented in this publication. The conference also brought together key organizations from MS within the EU that will work together as a network to highlight the key issues raised and work towards bringing about their resolution.

1. INTRODUCTION

A multiplicity of pathways and vectors currently exist to facilitate and indeed hasten the intrusion, introduction and spread of potentially invasive non-native species throughout the globe. Although not all non-native species intrusions and introductions result in harmful or damaging outcomes, current evidence indicates that the increasing scale of invasive non-native species occurrences necessitates serious scrutiny and, moreover, a coordinated international response.

In the 28 countries of the European Union (Member Organization) (EU) and other European countries (Europe), the approach to invasive alien species (IAS) intrusions, introductions and spread has been fragmented and uncoordinated (European Commission, 2013). As a consequence, the rate of IAS intrusions, introductions and spread has increased significantly in most European (EU and non-EU) countries in recent decades (O'Flynn, Kelly and Lysaght, 2014). The increased occurrence of IAS has resulted in significant adverse impacts on native biodiversity, ecosystem services, local and national economies and human health in many affected countries and localities. In an effort to raise the understanding concerning harmful IAS and to regularize the response to this ever-increasing threat across all EU member States (MS), the EU published a draft Regulation on "Prevention and management of the introduction and spread of invasive alien species"[1] in September 2013.

The draft Regulation aims to establish a framework for action to prevent, minimize and mitigate the adverse impacts of IAS on biodiversity and ecosystem services, as well as limiting social and economic damage. This will be achieved through measures to ensure coordinated action, focusing resources on priority species and on increasing preventative measures, in accordance with the approach taken under the Convention on Biological Diversity (CBD) and with the EU's Plant and Animal Health Directives (2000/29/EC [European Union, 2000a] and 2006/88/EC [European Union, 2006]). The proposal centres on a list of "IAS of Union concern" that will be drawn up within the MS using appropriate risk assessment methods and expert scientific evidence. Selected species will be banned from the EU, meaning it will not be possible to import, buy, use, release or sell them. In order to achieve this, it is anticipated that the draft Regulation will insist that MS put in place control systems to: (i) prevent IAS being introduced into their territories, including enhanced border biosecurity measures and restrictions on live imports of certain plants and animals; (ii) ensure early detection and rapid eradication of identified IAS that are inadvertently introduced; and (iii) control species on the EU list that are already present in an MS.

In order to determine the key issues relating to IAS that significantly affect the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) members (33 countries and the EU), and to identify measures, including the development of the proposed EU Regulation on IAS, as well as organizations and experts that would be in a position to advise in relation to these issues, an international conference was organized in Ireland in April 2013. The IFI/EIFAAC Freshwater Invasives – Networking for Strategy (FINS) conference brought together experts representing divergent disciplines, including scientists, academics, politicians, policy-makers, economists, managers, practitioners and key stakeholder representatives. This conference targeted four pillar themes: biosecurity, economics, management and risk assessment, and policy. The hosts for this conference were Inland Fisheries Ireland (IFI) and EIFAAC. Its Scientific and Organizing Committee included experts from throughout Europe (see Appendix 1). While the primary focus of the conference was on freshwater species, the discussions and recommendations are applicable also to terrestrial and marine species.

[1] Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species.
(http://ec.europa.eu/environment/nature/invasivealien/index_en.htm)

The three-day conference was organized with a set of clear objectives to:

- provide a forum where international scientists, policy-makers, managers, key stakeholder groups and others could discuss prioritized issues relating to IAS, with a view to informing policy development and management in EIFAAC countries;
- inform debate in relation to the focus and direction of the proposed EU Regulation on IAS;
- publish a scientific paper detailing the Top 20 IAS issues relating to IAS in Europe;
- make issue-based recommendations that will inform policy-makers in relation to IAS, both within individual MS and throughout the EU;
- form a Europe-wide expert advisory group to support the EIFAAC project on the "Aquatic Invasive Species in Europe" (see Appendix 2) and related issues concerning IAS;
- identify those responsible or that might adopt a level of responsibility in individual MS;
- bring together key organizations from the MS within the EU that will work together as a network to address the key issues raised and work towards bringing about their resolution.

The purpose of this publication is to present management advice based on the pertinent outcomes from the FINS conference to the Management Committee of EIFAAC and, through this Committee, to the members of EIFAAC, including the EU. The advice is also directly relevant to policy-makers and legislators involved in the implementation of the EU Regulation on IAS. The advice will further help in the timely completion of an EIFAAC project "Aquatic Invasive Species in Europe" (Appendix 2).

This EIFAAC Occasional Paper draws heavily from a scientific paper published in the open access journal *Management of Biological Invasions* (http://dx.doi.org/10.3391/mbi.2014.5.1.01) in April 2014 and describes the workings of the FINS conference and the major outcome from this event – the Top 20 IAS issues for Europe (Appendix 3). It provides recommendations on how best to resolve or mitigate many of the threats posed by the Top 20 IAS issues.

2. CONFERENCE STRUCTURE, PARTICULARS AND METHODS FOR IDENTIFYING AND PRIORITIZING THE IAS ISSUES

The identification of priority IAS issues for discussion at the conference was central to the success of the event. In order to determine those IAS issues deemed to be most critical and impactful in countries across Europe, broad-scale consultations with appropriate international experts and organizations were held in advance of the conference.

Several months before the three-day FINS conference (9–11 April 2013) in Galway, Ireland, potential delegates and international experts were invited to submit a list of priority issues relating to freshwater invasive species, as determined by themselves, their organizations and/or their policy-makers. These issues would form the basis for the invited presentations on Day 1 and the workshop sessions on Days 2 and 3 of the conference.

Conference delegates were requested to use a scoring scheme devised by the Conference Organizing Committee to rate and rank each of the issues they submitted. The scoring scheme (scores from 1 to 10) was apportioned as follows: urgency of the issue (most urgent = 10); risk (ecological, economic or other) if the issue is not addressed (highest risk = 10); and feasibility of addressing the issue (most feasible = 10). Contributors were also requested to comment on: (i) the specificity of potential strategies to address the issue; and (ii) barriers that might prevent progression of the issue. They were also asked to provide examples of best practice. An illustration of the types of submissions received is presented in Appendix 4. All submissions were collated, and the wide-ranging issues raised were combined into four broad pillars for the themed presentations and workshops: (i) biosecurity, (ii) economics, (iii) management and risk assessment, and (iv) policy. Further distillation of the priority issue inputs, utilizing scores and comments, provided between 8 and

11 issues, posed as statements, under each pillar (see Appendix 5). These provided the initial focus for the workshop sessions and were distributed to invited delegates weeks prior to the staging of the conference.

The structure of the conference was geared to maximize focused and informed discussion on the four pillar themes. Twelve invited speakers (see below) with acknowledged expertise in each of these four fields addressed the more than 160 delegates (Appendix 6) on Day 1 of the conference. A keynote and two invited experts had been selected as speakers to address each of the four pillar themes. The speakers were requested to consider the IAS issues raised by the potential delegates prior to the conference and to use their presentations to inform the debate that would follow in the workshop sessions.

The biosecurity theme was led by Mr Phil Hulme (Professor of Plant Biosecurity, Bio-Protection Research Centre, New Zealand), supported by Mr Joe Caffrey (Senior Research Officer, IFI, Dublin, Ireland) and Ms Birgit Oidtmann (Veterinary Epidemiologist, Centre of Environment Fisheries Aquaculture Science, the United Kingdom of Great Britain and Northern Ireland).

The economics theme was led by Ms Frances Williams (Economist, Centre for Agricultural Bioscience International, Kenya) and supported by Mr Jarle Steinkjer (Senior Advisor, Directorate for Nature Management, Trondheim, Norway) and Mr Stephen Hynes (Senior Lecturer, Socio-Economic Marine Research Unit, National University of Ireland, Galway, Ireland).

The management and risk assessment theme was led by Mr Hugh MacIsaac (Professor and DFO/CAISN Invasive Species Chair, University of Windsor, Canada) and supported by Mr Anthony Ricciardi (Professor of Biology, Redpath Museum, McGill University, Montreal, Canada) and Ms Toril Loennechen Moen (Senior Adviser, Norwegian Biodiversity Information Centre, Trondheim, Norway).

The policy theme was led by Mr Niall Moore (Head of GB Non-native Species Secretariat, York, the United Kingdom of Great Britain and Northern Ireland) and supported by Ms Helen Roy (Senior Scientist, Centre for Ecology and Hydrology, Oxford, the United Kingdom of Great Britain and Northern Ireland) and Mr Olaf Weyl (Principal Scientist, South African Institute for Aquatic Biodiversity, South Africa).

Brief biographies of the invited speakers are presented in Appendix 7, as they highlight the depth and breadth of experience of the experts invited to lead the conference.

Days 2 and 3 were devoted to workshop sessions that aimed to elucidate the Top 20 IAS issues in Europe and to formulate recommendations or management advice that aimed to mitigate or resolve these issues.

To complement the information expected from the invited speakers, potential delegates were invited to submit abstracts of posters that would be displayed and discussed during the conference. As with the presentations and workshop sessions, these poster submissions focused on the four pillar themes. The posters were displayed at the conference venue for the duration of the conference, and formal poster sessions, where authors were available to discuss their results, were convened on the evenings of Days 1 and 2.

The approach taken to deliver the Top 20 IAS issues broadly followed the horizon-scanning and prioritization methodology of Sutherland *et al*. (2008), where invited policy-makers and academics use a structured and formal scheme of scoring to achieve consensus. A formal scheme of scoring to achieve the prioritization was adopted in this process. At the FINS conference invited delegates attended presentations on the four pillar themes given by IAS experts, and subsequently participated in two days of focused workshop sessions. As with the Sutherland *et al*. (2008) model, a formal scoring scheme was adopted to rank the issues, with iterations of the process allowing the

merging of related issues and reduction of the length of the list. The benefits of this approach include: the ability to identify issues that are core to solutions or are not yet dealt with by legislation/policy; the bringing together of a wide range of stakeholders to inform decision-making; reducing time lags between problem identification and solutions; and influencing policy/funding decisions through pressure brought to bear by consensus of critical actions that are required. For example, rapid response and contingency funding for IAS threats continue to be highlighted as critical by scientists but are more difficult to sell to politicians. The problem of IAS had not, until the conference, been subject to horizon-scanning or prioritization methodologies, although each of a series of such exercises published for conservation, biodiversity, agriculture and food security identified IAS as priority issues (Sutherland *et al*., 2008, 2009, 2010, 2011, 2012a, 2012b, 2013, 2014; Pretty *et al*., 2010; Ingram *et al*., 2013).

On Day 2 of the conference, four workshop sessions were organized to address the four pillar themes. Two parallel workshop sessions were convened, with the morning sessions addressing "biosecurity" and "management and risk assessment", and the afternoon sessions addressing "economics" and "policy". Each of the workshop sessions was attended by 45–60 delegates. Each workshop session started with a 15-minute presentation by the coordinator (the keynote speaker for that theme on Day 1), where the rules and timelines were issued. A rapporteur was assigned to record proceedings. Each delegate was given a sheet with the main issues for discussion and ranking at that session ("biosecurity" and "economics" each had 8 issues while "policy" and "management and risk assessment" each had 11 issues to address – see Appendix 5). These had been issued to the delegates in advance of the conference for deliberation.

At this time an opportunity to add to the list of issues was given to the delegates if, in their opinion, something significant had been omitted. In the following two hours, each of the issues was presented to and discussed by the group. Roughly equal time was allocated to each issue. At the end of the workshop session, each delegate was given five votes. It was not necessary for the delegate to use all five votes, but no more than one vote per delegate per issue was permitted. The vote was confidential. Votes were counted by the coordinator and rapporteur, and the issues were ranked based on the number of votes allocated to each. Before the workshop session ended, the post-vote ranked order of issues was presented to and discussed by the delegates.

On the evening following the four workshop sessions, the coordinators, rapporteurs and the Organizing Committee discussed the outcomes from each of the workshop sessions and prepared a ranked list of issues for presentation to the synthesis workshop session on Day 3. A review of the top 5 ranked issues to emerge from each of the themed workshop sessions revealed 11 stand-alone issues, with the remaining 9 issues demonstrating a distinct commonality, even though they derived from different workshop themes. Following an introduction to the synthesis workshop session on Day 3, where the aims, methods and goals were presented to the plenary, the commonality of issues was discussed. A collective decision was made to merge these nine issues into four discrete issues. Five issues that had not been ranked in the first five from each of the four themed workshop sessions could now be promoted to the Top 20. These were selected in the following manner: the next three issues, those ranked 6 to 8, from each of the four themed workshops were presented to the delegates and voted on as before. This produced the five issues, in rank order, that were now included in the Top 20. The Top 20 IAS issues are presented in a table in Appendix 8. The seven remaining issues provided six stand-alone reserve issues that were not included in the Top 20. These are presented in Appendix 9.

Delegates were assigned specific issues from the Top 20, as appropriate to their expertise, and requested to expand on the subject to clarify why it had emerged as a priority issue and how it might be resolved, and to comment on the feasibility of achieving effective implementation of any suggested resolution. The results from these deliberations constituted the essence of a scientific paper published rapidly in the open access journal *Management of Biological Invasions* (Caffrey *et al*., 2014; see Appendix 3).

During the conference, delegates with specific expertise relating to different aspects of IAS were requested to join an advisory team that would provide management advice to EIFAAC and particularly the EIFAAC Aquatic Invasive Species Project, as required. As a result, a strong advisory team, with representatives from throughout Europe, was formed.

3. INFORMATION DERIVED FROM THE INVITED PRESENTATIONS AND POSTERS AS BASIS FOR DEVELOPING THE TOP 20 IAS ISSUES LIST

3.1. Invited presentations

The summaries for the twelve invited presentations, under the four pillar themes, given on Day 1 of the FINS Conference are presented below.

3.1.1. Biosecurity

The topic "**Biosecurity: where invasive species and regulatory policies collide**" was presented by Mr Phil Hulme. Biosecurity is a strategic and integrated approach that encompasses the policy and regulatory frameworks that analyse and manage risks to plant and animal life as well as health, including associated environmental risk. It covers all activities aimed at managing the introduction of alien species to a particular region and mitigating their impacts should they become invasive. This includes the regulation of intentional (including illegal) and unintentional introductions and also the management of invasive alien weeds, pests and pathogens by central and local government, industry and other stakeholders. Biosecurity activities occur in different steps that start offshore or pre-border in order to reduce the risks posed by pests originating from other countries, then continue at a nation's borders to stop pests, pathogens and weeds from entering a particular region, and finally are implemented within a region or post-border to locate and eradicate or manage risk organisms that have crossed the border and established in the region. Biosecurity management is a major challenge that requires knowledge and analysis of the diverse and complex risks along this continuum to identify, prioritize and apply measures in a coherent manner to progressively reduce the risks. To illustrate this challenge, both the range of economic and environmental impacts posed by alien species, as well as the diversity of pathways with which these species are introduced into a new region, are reviewed. Against this background of increasing biological invasions, the effectiveness of current regulatory tools is appraised and forms the basis for recommendations as to where improvements in the management of biosecurity threats should be made. Effective biosecurity is limited by problems in obtaining an objective measure of the hazards posed by alien species, challenges of predicting complex hierarchical and non-linear systems, difficulties in quantifying uncertainty and variability, as well as cognitive biases in expert judgement. Other approaches include scenario planning that seeks qualitative inputs regarding hypothetical events to facilitate long-range planning using multiple alternatives, each explicit in its treatment of uncertainty. This represents a change from prevention towards adaptive management where the difficulty in prediction is acknowledged and investment targets early detection, mitigation and management.

The topic "**Biosecurity initiatives to empower stakeholders in the fight against aquatic invasive species**" was presented by Mr Joe Caffrey. Worldwide, the introduction of non-native species that become invasive is one of the major causes of species extinctions in freshwater habitats. These invasive species can also pose serious economic and social problems in affected countries. It is important, therefore, that rigorous and informed mechanisms to stop the introduction and spread of these harmful species, and to mitigate their adverse impacts, be developed and adopted. Effective biosecurity to achieve the above requires the availability of appropriate legislation and enforcement mechanisms, coordinated surveillance, monitoring and rapid reaction capabilities, tried and tested control/management procedures, and a public that is educated in relation to the threats posed by invasive species.

In Ireland, considerable effort has recently been focused on developing comprehensive education and awareness programmes for the public and for key stakeholder groups. The aim is to impart useful and accessible information relating to the range of freshwater invasive species that are present in Ireland, and those that could be introduced, and the risks that they pose to the environment and to the economy. Information is also provided on the proper identification of aquatic and riparian invasive species and how to competently report sightings. This information is provided through various media, including a recently produced interactive app for use on smartphones. The importance of cleaning and disinfection for a wide range of water users has also been highlighted. Protocols and procedures for proper cleaning and disinfection of technical field survey equipment, angling tackle, boats, scuba diving gear and other materials used in freshwaters have been developed and demonstrated to stakeholders and interested parties. New and innovative biosecurity initiatives aimed at making the disinfection process easier and more cost-effective have been developed and will be described. Capacity building among stakeholder groups is the primary focus of this effort, with the ultimate goal of empowering these water users to operate and implement these biosecurity initiatives. It is anticipated that appropriate legislation to support the above biosecurity measures will be enacted in Ireland in the near future.

The topic "**International and national and biosecurity strategies in aquatic animal health**" was presented by Ms Birgit Oidtmann. With a growing global human population and an increasing demand for food protein, aquatic animal protein has become an increasingly important resource. In several geographic areas, wild stocks have been severely overfished, increasing the demands on aquaculture. In response, aquaculture production has dramatically risen in the last 30 years. Movement of live aquatic animals, within and between countries, for aquaculture and the ornamental trade, are important routes of disease spread. In recent decades, many aquatic animal diseases have emerged to have a substantial economic impact on aquaculture, sometimes with ecological consequences. Effective biosecurity strategies provide protection to both farmed and wild aquatic animal populations by minimizing the risk of introducing pathogens and minimizing the consequences if pathogens are introduced.

The term biosecurity has been variously defined on numerous occasions depending on the context in which it is used (e.g. bioterrorism, agriculture). However, in general, biosecurity involves practices, procedures and policies that are used to prevent the introduction and spread of pathogens and invasive species. Biosecurity strategies can be applied at the farm, regional, country, supranational and international level. At the international level, the main reference organization for the development of measures relating to international trade in animals and animal products is the World Organisation for Animal Health (OIE); an overview of the OIE standards is provided. Members of the OIE commit themselves to apply the standards provided by OIE, usually through national legislation and policy. In some parts of the world, supranational economic and political unions have developed, which apply common policies and legal frameworks. One example of such a supranational community is the EU. The legal instrument that provides the biosecurity framework for aquatic animal health for the EU is Council Directive 2006/88/EC (on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals). The Directive is used to illustrate how the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) and OIE standards have been translated into legislation. At the national level, the role of the competent authority and instruments to prevent the introduction of exotic diseases and limit the impact of endemic diseases are described and discussed; import risk assessments and awareness of international developments play an important role in informing biosecurity strategies. Biosecurity at the farm level is assisted by the development of biosecurity plans. Owing to the close connection between farmed and wild aquatic animal populations, there is a risk of pathogen exchange between the two. Introduction of exotic pathogens may have significant consequences for both wild and farmed populations.

3.1.2. Economics

The topic "**The economic costs of invasive alien species to the Great Britain (GB) economy**" was presented by Ms Frances Williams. The impact of IAS can be manifold, ranging from loss of crops, damaged buildings, and additional production costs to the loss of livelihoods and ecosystem services. A number of estimates of the economic impact of IAS on various countries exist, but the detail in many of these estimates is lacking and the impact on different sectors of the economy is largely unknown. The study estimated the annual cost of IAS to the economy of Great Britain (England, Scotland and Wales) and provided assessments of the economic cost of IAS to twelve sectors. Case studies were also used to demonstrate the costs of control at different stages of invasion. The economic benefits of IAS were excluded, and the majority of costs are "direct use" costs[2], not other non-use or non-market costs[3]. Costs were based on a detailed questionnaire followed up by detailed one-to-one interviews with individual experts and representatives of key organizations, and combined with a thorough review of the scientific and grey literature and the Internet, which provided more than 500 relevant references. The data were used to estimate the costs, partially based on calculations for individual species, which was anonymously reviewed by selected experts from each of the sectors.

The total annual cost of IAS to the GB economy was estimated at GBP 1.7 billion (equivalent to about USD 2.6 billion[4]). A meta-analysis of previous studies of the economic impact of IAS on the economy of various countries revealed that, on average, direct costs constitute only 1.75 percent of estimates of IAS costs. Therefore, the estimated GBP 69 million (equivalent to about USD 105 million[4]) worth of costs caused by freshwater invasive species to the GB economy annually could be as high as GBP 3.9 billion (equivalent to about USD 6 billion[4]), though no work has been carried out to confirm or challenge this estimation. Challenges included lack of IAS-specific data, reluctance of people to share data, and a lack of awareness of what species are invasive. This lack of data meant that extrapolations and assumptions had to be made, based on the ecology and biology of the species. Lack of time meant modelling methods could not be used. More work is needed, with the purpose of the study guiding the methods used. Accurate modelling takes time and should be used when more precise data are needed. Estimates may be quicker and appropriate for a more general audience. If indirect and non-use costs are to be included, a considerable amount of field research will be needed as these data do not exist. However, assessments of economic costs are one starting point in changing people's attitudes to IAS and the damage they cause.

The topic "**Some economic aspects of the introduced Atlantic salmon parasite *Gyrodactylus salaris* in Norway**" was presented by Mr Jarle Steinkjer. The invasive salmon parasite *Gyrodactylus salaris* is among the worst threats to Atlantic salmon (*Salmo salar)* today. It is a small (0.5 mm) ectoparasitic monogenean that is found on the fins and skin of Atlantic salmon in its freshwater phase. In Norway, *G. salaris* has caused epidemics that have devastated stocks of Atlantic salmon in 48 rivers. The density of salmon parr in infected rivers has been reduced by an average of 86 percent, and the catches of salmon are reduced on average by 87 percent. The occurrence of *G. salaris* in Norwegian salmon rivers causes a yearly economic loss in the range of EUR 34–40 million (equivalent to about USD 44.5–52 million[5]). This loss is primarily due to the lost salmon fishing in infected rivers and loss of sea fishing in the adjacent sea areas. The most visible factor is the loss of local economic ripple effects of salmon fishing in the rivers. It is worth noting that the economic loss mainly affects communities around the infected watercourses. In addition, the Norwegian Government has spent about EUR 9 million (equivalent to about USD 11.8 million[5]) per

[2] Direct costs include reduction in extraction of ecosystem resources such as: food production or increase in production costs; reduction in visitor numbers to a park; and biodiversity maintenance costs.
[3] Non-use / non-market costs include: value placed on existence of a species or natural environment now and in the future; reductions in ecosystem services functions; and reduction in potential future use of an ecosystem.
[4] Based on the GBP/USD exchange rate of about 1.53 at the time of the conference, i.e. in April 2013
[5] Based on the Euro/USD exchange rate of about 1.31 at the time of the conference, i.e. in April 2013

year on measures to limit the damage caused by the parasite. The most important measures are: surveillance; preventing the spread of the parasite; eradication of the parasite from infected rivers; and conservation and restoration of fish populations that are directly affected by the parasite or indirectly as a result of the actions implemented for the parasite eradication. In the 35 years of *G. salaris* being present in Norway, expenditure on the problem has reached EUR 90 million (equivalent to about USD 118 million[5]). If the loss of income on salmon fishing and loss of local economic ripple effects in the same period are included, a rough estimate suggests that Norway has experienced a total economic loss of EUR 430–538 million (equivalent to about USD 563-705 million[5]) as a consequence of the introduction of *G. salaris* in 1975.

The topic "**The economics of aquatic invasive species**" was presented by Mr Stephen Hynes. Invasive species are generally introduced into an ecosystem as the intended or unintended consequence of economic activity. While there are many studies available examining the costs and benefits of programmes for the control of particular weeds, pests and pathogens, there are in comparison very few studies examining the economics of biological invasions. This is all the more surprising given that these invasive species can impose significant costs on society. Apart from assessing the costs, economics also has a role to play in terms of the control of invasive species. Effective control of invasions depends on using the right economic instruments. As the risks of invasions into an ecosystem tend to be low but the potential costs high, the costs tend not to be reflected in market prices. Moreover, the control of potential invasive species is a public good where there will be a tendency of underprovision by the market. The purpose of addressing this issue is to present an overview of the potential economic impacts of invasive species in Irish waters and to discuss the economic instruments that could be used in the prevention, eradication and control of such species.

3.1.3. Management and risk assessment

This topic "**Pathways for introduction of alien invasive species exclusive of international shipping: a Canadian experience**" was presented by Mr Hugh MacIsaac. International shipping has dominated concern regarding the introduction of IAS to aquatic ecosystems globally, as both ballast water and hull fouling are potent pathways for the introduction of new species. In the Great Lakes, ballast water release from mainly European-source ships has accounted for at least 55 percent of known established IAS introductions. Recently, however, this pathway has diminished in importance and attention has turned to other pathways, including domestic "Laker" vessels that typically operate exclusively within the Great Lakes, but on occasion some of these vessels travel to ports on the St. Lawrence River where they may load freshwater or brackish water for subsequent discharge in the Great Lakes. Surveys indicate that the ports of Montreal, Sorel, Tracy and Trois Rivieres are most likely to contribute new species to the Great Lakes through domestic ballast transfers. In addition to these vessels, attention is also focused on the trade of live organisms, particularly the pond, aquarium, and live food trades. Two alien plants – water lettuce and water hyacinth – were documented in the lower Great Lakes on a recurring basis. Possible hypotheses to account for these observations include successful overwinter survival, death of parental plants after successful production of viable seeds, and/or reintroduction on an annual basis. *In situ* experiments indicate that neither of these species can tolerate current winter conditions, and no evidence of seed production in water lettuce has been found. However, water hyacinth will produce seeds, and experiments have revealed successful germination of scarified seeds incubated at 28 °C. Human introduction of these plants has also been confirmed at two locations in the lower Great Lakes. Live importation of alien fishes remains problematic in Ontario despite implementation of laws to the contrary. Four interceptions of live Asian carp species were made in Ontario in 2012, and eDNA records suggest possible occurrence of the fishes at some locations in the Great Lakes. Elsewhere, British Columbia has conducted an eradication campaign for a single northern snakehead fish, and implemented legislation prohibiting release of these fishes into provincial waters. The province is also working with agencies in the west of the United States of America to prevent the introduction of live zebra and quagga mussels on boats trailered from infested areas in the southwest of the country. Clearly, the issue of IAS introductions has not gone away,

rather the problem continues to evolve as species ranges and knowledge of pathways change. As ballast water regulations affect the global shipping community, this important vector should dramatically decline in importance, leaving hull fouling and live trade or organisms as potentially dominant vectors of IAS introduction.

The topic "**Forecasting the impacts of introduced species: a major challenge for risk assessment**" was presented by Mr Anthony Ricciardi. Non-native species are being introduced to lakes and rivers at increasing rates worldwide. The impacts of the vast majority of these invasions have not been studied. Most of these species are thought to have only minor ecological effects, whereas others are known to have substantially altered water quality, contaminant cycling, food webs, and native biodiversity. Managers lack risk assessment methods to prioritize invasion threats because very few general models, or even "rules of thumb", exist to predict the impacts of aquatic invasions. A major challenge to prediction is the variation generated by the influence of site-specific physical and biological factors that affect the invader's local abundance and performance. In particular, interactions with other introduced species can produce synergistic effects that are extremely difficult to predict. Nevertheless, analyses of data from invasions worldwide have revealed patterns of impact that may prove useful to risk assessment. Invaders that have strong impacts typically have the following characteristics: (i) they have high reproductive rates; (ii) they are introduced into regions where no ecologically similar organisms exist; (iii) they are either predators or suspension feeders, with high rates of resource consumption; and (iv) they have a history of impacts in other regions. Other caveats have emerged: the "tens rule" (that only about 10 percent of established species become harmful ecologically or economically) may severely underestimate the true proportion of species that threaten fisheries, and there appears to be no relationship between the impact of an introduced species and its ability to spread.

The topic "**A new generation risk assessment of alien species**" was presented by Ms Toril Loennechen Moen. In June 2012, a report entitled "Alien species in Norway – including the Norwegian Black List 2012" was published. The report includes a new generation of ecological risk assessments of the 1 180 known alien species that are reproducing in Norway. In total, there are 2 320 known alien species in Norway, but 1 140 of these are not reproducing – or are considered not to have the opportunity to reproduce in Norway within 50 years. The risk assessments are conducted using a newly developed method, which is based on quantitative rather than qualitative criteria. The method estimates the species' probability to establish and disperse (that is, the invasion potential of the species) and its effect on the indigenous species and nature. The set of criteria may be used on all species groups and is independent of geographical region. The set of criteria consists of nine elements, where three determine the invasion potential and six determine the ecological effect. All criteria are used for all species, and from this the species are placed in one out of five categories: severe impact, high impact, potentially high impact, low impact or no known impact. The two categories that indicate highest risk – severe and high – constitute the 2012 Norwegian Black List. A selected number of potential invaders ("door knockers") are also risk-assessed using the same method. There is a strong need for an international set of criteria for risk assessment of alien species, and the Norwegian Biodiversity Information Centre hopes that the method developed there may be of assistance in this regard. In addition, there is a need for more focus on lack of knowledge regarding alien species in Norway.

3.1.4. Policy

The topic "**Developing invasive non-native species policy: coordination, prioritization and delivery**" was presented by Mr Niall Moore. There is a growing awareness among scientists, politicians and the general public that invasive non-native (alien) species (IAS) are a serious and increasing threat to the environment and economy. However, the policy in this area is still underdeveloped in many countries. While the overall principles are generally agreed, the development and implementation of appropriate national policies often pose a significant challenge. As an issue that cuts across many areas of government policy, the response to IAS usually involves numerous

government departments and agencies and other bodies, as well as different levels of government. There are also highly variable governance structures in different countries, with some very centralized while others have considerable devolution of policy and delivery. Also key to developing and delivering IAS policy is the engagement of players outside government such as non-governmental organization (NGOs), trade, industry and the research community. Faced with this complex policy and delivery environment, a key issue therefore is that of how to achieve optimum coordination of response. In this era of shrinking government budgets, it is important to know how to best prioritize the use of scarce resources, foster and spread good practice and learn lessons from other more developed policy areas, such as plant and animal health.

The topic "**Linking invasive alien species information across Europe**" was presented by Ms Helen Roy. The EU has committed to tackling IAS through Target 5 of the EU Biodiversity Strategy to 2020, which is in line with Target 9, Decision X/2 of the Conference of the Parties (United Nations). An information system is a prerequisite to meet strategy through effective early warning and rapid response for prevention and control of IAS. Initiatives to collate information on IAS have resulted in the development of many databases differing in their geographic, taxonomic and ecological coverage. There are a number of constraints that might limit the effective use of existing databases: data obsolescence, lack of interoperability, and uncertainties for long-term sustainability of the various tools. Here, recent relevant activities in relation to the collation and dissemination of IAS information were discussed with particular reference to two systems – the GB Non-Native Species Information Portal, and Delivering Alien Invasive Species Inventories for Europe (DAISIE) – and coordination through a forthcoming COST Action (Trans Domain TD109). The COST Action will facilitate enhanced knowledge gathering and sharing through a network of experts, providing support to a European IAS information system that will enable effective and informed decision-making in relation to IAS. An overarching priority will be to identify the needs and formats for alien species information by different user groups, and specifically for implementation of EU 2020 Biodiversity Strategy. Correspondingly, early warning tools and rapid response protocols will be developed.

Last but not least, the topic "**Managing alien fish invasions in South Africa**" was presented by Mr Olaf Weyl. South Africa has a long history of alien fish introductions. Alien fish such as common carp, brown trout and largemouth bass were introduced because native fish faunas contained few species with potential for fisheries development. Coupled with introductions for biocontrol, aquaculture and the pet trade, alien fishes now outnumber natives in many river systems, and South Africa is considered a global fish invasion hotspot. Although government-mediated stocking programmes ceased in the late 1980s, alien fishes continue to increase their distributional ranges through illegal private stocking, escape from aquaculture and via interbasin water transfers. Alien fish introductions are considered one of the main threats to aquatic biodiversity because they have an impact on native biota through predation, habitat alteration, disease transfer and hybridization. As is the case for other invasive biota, the control and management of alien fishes is included in the National Environmental Management: Biodiversity Act. Implementation measures include import and movement controls and, more recently, alien fish eradication in conservation priority areas. However, management actions are complicated because many alien fish are important components in recreational and subsistence fisheries that contribute towards regional economies and food security. As a result, management of these conflict species often meets with considerable resistance, particularly from angling organizations. Here, an overview of fish introductions and their associated impacts in South Africa was provided and both existing and evolving national policies and legislation for the management of alien fishes were described. The implementation strategies used by provincial conservation authorities were discussed with regard to the available human capacity and the sometimes innovative approaches used to prioritize and manage fish invasions at local levels.

3.2. Summaries of posters presented at the conference

As the contents of the posters were also used to identify and consolidate the Top 20 invasive species issues, the poster summaries are presented here below together with the authorship of the posters. The authors' affiliations are given in the footnotes.

"**Biosecurity measures to reduce the secondary spread of the invasive freshwater Asian clam, *Corbicula fluminea***" by J.H. Barbour[6], S. McMenamin[6], J.T.A. Dick[6], M.E. Alexander[6] and J. Caffrey[7]

This the presented study aimed to test the efficacy of biosecurity methods for cleansing gear, such as fishing nets, to reduce secondary spread of Asian clams. Three experiments were undertaken on clams of different size cohorts, which were immersed in different concentrations of Virkon Aquatic®, salt water or household bleach, for different lengths of time. After treatment the clams were returned to freshwater and monitored. The percentage of dead clams was assessed 24 hours post-treatment and analysed with respect to treatment type, immersion time and clam size. Virkon at 2 percent induced significantly higher mortality than Virkon at 1 percent (82.91 percent and 66.66 percent mortality, respectively) and mortality increased significantly with immersion time, but there was no significant difference in mortality between clam sizes. Higher bleach concentration significantly increased clam mortality, with 0.5 percent and 10 percent bleach solutions inducing an average mortality of 14.44 percent and 56.66 percent, respectively. There was no significant effect of immersion time. Saltwater induced higher mortality than controls, but average mortality was only 11.11 percent after 24 hours. There was no significant effect of immersion time or clam size. A fourth experiment was carried out using Virkon Aquatic® to discern long-term effects (240 hours) and with the inclusion of a drying time. Again, 2 percent Virkon induced significantly higher mortality than 1 percent (56.39 percent and 38.89 percent, respectively); however, drying time and immersion time showed no effects on mortality. Virkon emerges as an effective biosecurity measure, but its use requires further research to attain 100 percent clam mortality.

"**Using an integrated modelling approach to assess the potential spread of the 'Killer shrimp' *Dikerogammarus villosus* in Flanders (Belgium)**" by P. Boets[8], K. Lock[8] and P.L.M. Goethals[8]

A new and powerful tool to perform risk assessment of invasive species lies within the use of modelling techniques. Because of the complexity of biological invasions, an integrated and interdisciplinary approach is required to support the risk assessment and understanding of the processes involved. In this study, a coupled modelling approach was used in order to assess the future potential risk of dispersal in Flanders (Belgium) by *Dikerogammarus villosus*, a highly invasive species, under changing environmental conditions. First, a habitat suitability model was constructed based on a regression tree model, to determine the preferred chemical water quality conditions. Secondly, this habitat suitability model was combined with a chemical water quality model, because it was expected that the suitable habitat would increase with improving water quality. Finally, migration speed based on a network analysis was taken into account, to model the spatio-temporal spread of *D. villosus* in Flanders. According to the model simulations, the species is primarily present in large rivers and canals with good chemical water quality. With improving water quality due to a decrease in chemical oxygen demand and orthophosphate concentration, the species will be able to colonise new habitats rapidly. Based on its calculated average migration speed of 5 km per year, it is expected that within 15 years the species will be able to colonise all main watercourses in Flanders, where the water quality is sufficient and the habitat is suitable. A validation based on the observed presence shows that the model accurately predicts areas with a high suitability for *D. villosus*. This coupled modelling approach is useful as a practical method to perform risk assessment for areas that are vulnerable to invasions. Increasing mechanistic understanding of the biology, ecology and dispersal of invasive species can support effective prevention and control measures.

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[8] Laboratory of Environmental Toxicology and Aquatic Ecology, Ghent University, Ghent, Belgium

"**Implementation of practical biosecurity measures in Ireland by the Irish Angling Development Alliance (I.A.D.A.)**" by R. Caplice[9] and P. Walsh[9]

I.A.D.A. believes that the threat posed by aquatic invasive species is the most serious facing Ireland's natural fisheries and, consequently, the control of invasive species is a top priority. During the past two years the I.A.D.A., in close collaboration with Inland Fisheries Ireland, has proactively introduced a national 'NO DIP NO DRAW' scheme, nationwide biosecurity awareness events and angler managed disinfection facilities, all of which were outlined in the poster.

"**Invasive alien aquatic plants in freshwater lakes and ponds in Aquitaine (South-West France): colonization dynamics and management**" by A. Dutartre[10] and V. Bertrin[10]

In the Southwest of France, between the Gironde and Adour estuaries, over twenty lakes and freshwater ponds are lined up along 200 km of Atlantic coast. They represent a great heritage value related to their ecological diversity and human uses. Among various aquatic plant communities, some species, such as *Isoetes boryana*, *Lobelia dortmanna* and *Littorella uniflora*, are protected. Since about 40 years, these water bodies are colonized by invasive alien plants, such as amphibious (*Ludwigia* sp, *Myriophyllum aquaticum*) or submerged (*Lagarosiphon major*, *Egeria densa*) taxa. These species are able to spread quickly in interconnected water bodies, and slowly from a watershed to another. *Egeria densa* is the most recently introduced species. It currently replaces *L. major* in several lakes. The nuisances due to these important plant beds on boating, fishing and summer tourism drove the managers of water bodies to perform control management. Harvest interventions have been regularly performed for the past 20 years on a pond overgrown by *L. major*. Mechanical interventions have also been conducted since the early 90s on the shoreline of various water bodies colonized by *Ludwigia* sp and *M. aquaticum*. The hand pulling of these two species is regularly done on several small ponds. In 2011, *L. major* was harvested on large areas of two lakes, as well as *E. densa* in a newly colonized lake.

"Potential solutions for the control of riparian and aquatic invasive weeds in Europe: a review on the progress of classical biological control programmes in the UK" by D.H. Djeddour[11], K. Jones[11], K.M. Pollard[11], M.K. Seier[11], R.A. Tanner[11], S. Varia[11], S.V. Wood[11] and R.H. Shaw[11]

The European Water Framework Directive requires as its most important objective "Good Ecological Status" to be achieved for all water bodies by 2015. The control of non-native species invading riparian and aquatic ecosystems and severely impacting on biodiversity, as well as increasing potential flood risk and bank erosion, thereby also falls under this EU legislation. Conventional mechanical and chemical control methods are both costly and labour intensive, and often inadequate to manage invasive plant population on a catchment, national or cross-border scale. Furthermore, with Europe also striving to reduce overall pesticide use, chemical herbicides registered for application in sensitive riparian and aquatic systems have and will become more restricted. Therefore, it is suggested that the most viable option to control non-native invasive plant species is classical biological control. This management strategy exploits the fact that most invasive plant species arrive in their new environments without the suite of natural enemies which contributes to the control of their populations in their native ranges. Classical biological control aims to redress this imbalance by reuniting those plant species with their co-evolved arthropods and pathogens which have shown to be highly host specific and suitable during extensive safety testing conducted under quarantine conditions following strict international protocols. In order to fulfil its obligations under the Water Framework Directive, the UK is leading the research into this long-term and sustainable

[9] Irish Angling Development Alliance (I.A.D.A.) – a national alliance of angling clubs and angling stakeholders, formed to address all issues affecting angling.

[10] REBX, Irstea, Cestas, France

[11] CABI-UK, Egham, United Kingdom of Great Britain and Northern Ireland.

solution for invasive and riparian non-native plant species which are also common in many other European countries. Currently, the UK government Department of Environment, Food and Rural Affairs (DEFRA) is funding research into the potential for classical biological control of four target weeds: *Crassula helmsii*, *Hydrocotyle ranunculoides*, *Impatiens glandulifera* and *Fallopia japonica*.

"**Signal crayfish get help to spread – Illegal introductions, crayfish plague outbreaks and the distance to Lake Vättern**" by L. Edsman[12] and P. Bohman[12]

There are two species of freshwater crayfish in Sweden, the endemic and critically endangered Noble crayfish (*Astacus astacus*) and the introduced Signal crayfish (*Pacifastacus leniusculus*). Data on crayfish are stored in the Swedish Crayfish Database, which we used to explore two phenomenon's concerning illegal introductions. Illegal introductions of the crayfish-plague-carrying Signal crayfish is regarded the main threat to the Noble crayfish. Localities of crayfish plague outbreaks were matched with localities of illegal introductions north of the River Dalälven, the northern border for legal introductions. During 2007, 439 lakes and rivers with Noble crayfish were declared plague-struck by the regional authorities. During 2007, 24 illegal introductions of Signal crayfish were discovered. In all cases of crayfish plague, apart from the northernmost one, the outbreaks of plague were connected to an illegal introduction of Signal crayfish. 98 percent of the plague incidents were north of River Dalälven. The distances from Lake Vättern to sites of illegal introductions in middle Sweden were investigated. Lake Vättern is the second largest lake in Sweden with a strong Signal crayfish population. It is the only lake, out of 4000 in Sweden, that has been open (since 1999) for public fishing. 96 sites of Signal crayfish occurrences without permit were found from 1999 to 2005. With increasing distances from Lake Vättern, occurrences decreased. This indicates that the fishery in the lake has served as a main source of stocking material for illegal introductions in middle Sweden.

The role of Signal crayfish as a vector for crayfish plague and consequently their fatal effects on Noble crayfish is beginning to be recognized. There is, however, a general belief that the Signal crayfish has been a great success giving an improved fishery, resulting in economic benefits. On the contrary, the net effect of the introduction of Signal crayfish into Sweden has recently been estimated to cost €5.3 per person per year.

"**eDNA and Irish Sea Lamprey**" by M. Gustavson[13] and J. Carlsson[13]

Environmental DNA (eDNA) can be collected non-invasively from water or substrate samples without directly interacting with the focal species. The procedure relies on collecting species DNA directly from their environmental habitats to detect presence and quantify the amount of target DNA by using a quantitative PCR instrument. By selecting species-specific DNA probes, the researcher is able to monitor presence and relative increases/decreases in biomass over time and among habitats. Environmental DNA is currently used by the US Department of Natural Resources to monitor the spread of the invasive Silver Carp, already well-established in the Mississippi River Basin and threatening the Great Lakes. Also, Danish researchers are using eDNA for biodiversity assessments. There are many applications of this new research tool; each requires customization of sampling and analysis protocol to the study's focal species. Once calibrated the process becomes redundant and can be used, without further modification, in routine sampling programs. The current proposal is a pilot project aimed at developing an effective, sensitive sample and monitoring program utilizing eDNA to detect the presence/absence and relative abundance of the Irish Sea Lamprey in Mulkear River**.** The project will test the efficacy of eDNA for detection and quantification of Irish Sea Lamprey re-establishment throughout the Mulkear River drainage region following removal of river

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weir barriers. The projects results are expected to show the applicability of eDNA for Irish Sea Lamprey management in Ireland and utilized as a technique for management, conservation and mitigation of other threatened or invasive aquatic species in Ireland.

"**Biosecurity: corporate responsibility and working practices**" by R. Harrison[14]

Ecus Ltd has been involved in a wide range of projects for monitoring and control of invasive non-native aquatic species. In addition, during routine ecological surveys, staff of Ecus Ltd encountered a whole host of different invasive non-native species and pathogens and, as ecologists working on multiple sites across the UK, they have the potential to be a vector of spread for these species and pathogens. This has lead them to think about their responsibility for biosecurity and how their working practices could potentially cause the spread of these species into other areas and what they can do to minimize the risk of spreading invasive non-native species and pathogens. Ecus now has a Biosecurity Policy and a Biosecurity Work Instruction which all staff within the company are aware of and incorporate into projects. These working practices for biosecurity are reviewed on a site-by-site basis and where specific risks are identified, strategies to minimize contamination between sites are put in place.

The poster introduced the biosecurity working practices adopted by Ecus Ltd and looks at several case studies to show how biosecurity practices need to be addressed on a site by site basis to prevent the spread of invasive non-native species and pathogens. Such case studies include treatment of New Zealand pigmyweed (*Crassula helmsii*) on Sites of Special Scientific Interest (SSSI) sites, monitoring for the presence of the killer shrimp (*Dikerogammarus villosus*) on 18 SSSI sites across the UK and prevention of crayfish plague during translocation of white-clawed crayfish (*Austropotamobius pallipes*).

"**Invasive species management coordination in the Loire catchment area**" by S. Hudin[15] and E. Sarat[16]

Invasive species are recognized to disturb ecosystems in their functioning at different levels. They also have impacts on the uses of the areas where they occur, these social needs often being the main reason for their initial treatment, at least in France. The search for effective techniques to eradicate them has led to the multiplication of management initiatives, some of which were redundant within the Loire basin. Managing these invasive species has also raised the need for exchanges, experimentation and data collection. A working group on the aquatic invasive plants was started in 2002, when the Loire-Bretagne water agency initiated exchanges between the structures involved in their management in the Loire catchment area, such as river syndicates, collectivities and scientific experts, and more. These helped gather information on the species, to list the ones causing the main problems. This list in 2004 contained seven species. In 2008, the updated list counted more than 60 taxa.

The working group has now regular meetings, edits a newsletter four times a year, disposes of a documentary base accessible *via* the web, and has edited common tools. The support of the group by the Loire nature program has triggered the creation of regional groups, following the pattern of the first region at the estuary, which was the initial inspiration for the basin group. Now most of the Loire catchment area is covered by territories of action for these groups. Now that the exchanges are structured and the results well received, the same pattern for invasive animals is now emerging in the territorial groups. A first step was to list the invasive vertebrates in the basin and to assess their level of risk. Then a document summarizing the information on these species was edited in 2012.

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[16] Office National de la Chasse et de la Faune Sauvage, Orléans, France

"**Non-chemical removal of Himalayan balsam *Impatiens glandulifera* in a special area of conservation**" by F. Igoe[17], K. Murphy[17], T. Collins[17], N. Riordan[17] and E. Linehan[17]

Inland Regional Development (IRD) Duhallow, a community development organization, is leading a €1.9 m. EU LIFE+ project, in partnership with Inland Fisheries Ireland, to enhance the status of the upper portion of the River Blackwater Special Area of Conservation, South West Ireland. One of 27 key project actions is to remove the invasive plant Himalayan balsam *Impatiens glandulifera* from a major tributary of the River Blackwater Special Area of Conservation (SAC) using non-chemical means only. The effectiveness of the eradication programme is being assessed by walk over monitoring, the use of fixed quadrats to estimate plant densities, native vegetation recovery. An experimental site is also in place for stakeholder demonstration purposes. Results are promising to date, with dramatic reductions in treated areas just one year after treatment. The total length of channel, roadside verge etc. treated in 2012 was in excess of 24 km, making it the largest *H. balsam* eradication programme in Ireland. It was demonstrated that large-scale non-chemical removal of Himalayan balsam along river banks is a viable and environmentally friendly option, where adequate resources are available coupled with strategic planning. The operation must include local stakeholders to ensure that long-term objectives are realised and that further re-infestation does not occur.

"**Invasion genetics of bighead and round goby in European freshwaters**" by I. Kalchhauser[18], P. Mutzner[18] and P. Burkhardt-Holm[18]

Currently, Switzerland is experiencing an invasion of bighead goby *Ponticola kessleri* and round goby *Neogobius melanostomus*. These bottom-dwelling fish are native to the Caspian and Black Seas and have been extraordinarily successful at colonizing European and American freshwaters and coasts. Both species are naturally sessile and do not display migratory behaviour. Their spread is thus supposedly facilitated by cargo vessel traffic. However, measures, protocols or regulations to minimize the transfer of species by freshwater cargo vessel traffic plainly do not exist. This can be attributed to a lack of sound evidence for the role of cargo vessel traffic in the displacement of freshwater fish species. Microsatellite amplification protocols for bighead goby and round goby have been established. Using a subset of 10 microsatellites, it was shown that the recently established and spatially close (2 km) populations at the harbour Kleinhüningen and the watergate Birsfelden are genetically distinct. This indicates that they were introduced from separate sources and argues against natural dispersal by upstream migration. It is now aim to identify the source populations and to correlate genetic data on population kinship with cargo vessel traffic parameters, for example the number of port calls linking the populations. Other research aims to establish monitoring procedures tailored to the species' characteristics to identify their position in the food web in order to pinpoint suitable predators, to develop custom-made spawning traps for egg removal, and to identify the exact modalities of ship-mediated introductions.

"**The recovery of aquatic life after the control of an invasive weed *Lagarosiphon major***" by E. Keenan[19], M. Millane[20], H. Moran[20], J.M. Caffrey[20], and J.-R. Baars[19]

The invasion of the aquatic weed *Lagarosiphon major* has led to substantial changes in the macrophyte community of littoral habitats. The tall canopy-forming morphology of this rooted non-native plant has displaced a mixture of low-growing charophytes and changed the associated benthic invertebrate communities. Benthic barriers using jute matting have led to the successful control of *L. major*, and this study assessed how the native plant and invertebrate communities recovered over time once jute was applied. Typically the charophyte (native keystone vegetation) oospores in the

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sediments germinated and grew through the loose weave of the biodegradable benthic barrier. A space-for-time substitution was used to assess the recovery of benthic invertebrates at sites that had been controlled between 2 and 39 months prior to sample collection. Trial plots were established and compared to un-impacted macrophyte stands to assess how recovery took place. The pattern of oospores within the sediments was assessed in 5 cm sections in a 20 cm sediment core, and germination trials determined the potential for charophyte recovery. The results show that the invertebrate communities were significantly affected by the control application. Initially, a thin layer of sediment on the jute was colonized by chironomids and some molluscs, increasing the abundance per unit area. As charophytes established (until full cover) a heterogenous habitat was created supporting a greater number of invertebrate species and overall abundance. After about 20 months the benthic community was indistinguishable from un-impacted charophyte stands. Charophyte oospores were generally abundant under charophyte beds as 850 000 oospores/m^2 were recorded in the top 5 cm sediment layer, and similarly high numbers occurred at lower depths. Weed beds of *L. major* significantly reduced the number of oospores in the first 5 cm of the sediment. Reductions of 99 percent under *L. major* and 98 percent under *E. canadensis* were recoded relative to charophyte stands, although oospores at all depths (0–20 cm) were still viable. The implications for plant and invertebrate recovery and considerations for future management are presented.

"**A review of the status of the common carp *Cyprinus carpio* (L.) in Ireland - A naturalised species or an invasive threat?**" by R. Macklin[21], S. Harrison[21] and D.V. Chapman[21]

Although present in Ireland since the early 17th century, the common carp, *Cyprinus carpio*, is not native to Ireland and could pose a future invasive threat. The potential invasive threat was quantified, using the Fish Invasive Scoring Kit (FISK), and by reviewing the range expansion of carp in Ireland since 1950. The FISK score of carp was calculated to be 33, indicating the species is highly invasive in Ireland and is in agreement with studies carried out in the UK Distribution maps were constructed from records in published literature, from consultations with angling bodies and with Inland Fisheries Ireland, facilitating a review of the temporal changes in the range and distribution of carp from 1950 to the present day. There has been a significant increase in the range of carp, by an order of 297 percent in the national 10 km grid square network during this period. The characteristic pattern of extinction and invasion of carp in Irish water bodies indicates clearly that carp have not spread by natural dispersal, but rather as a result of human-mediated introductions. While carp can be considered a naturalised species, successful recruitment remains sporadic in Irish waters, indicating that natural recruitment is not a critical agent driving their expansion. However, future climatic warming and the increasing popularity of carp as an angling species may facilitate further expansion in the species' range. Given that carp are capable of disrupting aquatic habitats because of their benthivorous feeding habits and longevity, a species-specific management plan should be developed to regulate stocking practices.

"**Targeting the aquatic invasive weed *Lagarosiphon major* using biological control**" by R. Mangan[22], W. Earle[22], J.M. Caffrey[23] and J.-R. Baars[22]

The rooted submerged African oxygen weed *Lagarosiphon major* (Hydrocharitaceae) is native to southern Africa where it is host to numerous phytophagous insects that regulate the plants' growth. This study assessed the prospects of reuniting the insects with *L. major* in the introduced range as classical biological control agents. A number of natural enemies were discovered in the native range of the plant and several of these were imported into quarantine for further study in Ireland. Those causing the most damage to the vegetative parts of the plant were selected, and included several species new to science. These included a leaf-mining fly *Hydrellia lagarosiphon*

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(Ephydridae), a shoot mining midge *Polypedilum* (*Pentapedilum*) n. sp. near *reei* (Chironomidae) and two leaf shredding nymphulid moths. To assess their suitability as biocontrol agents, laboratory trials were conducted to determine their life history, insect-plant interactions, damage to plant growth and the degree to which native plants were accepted as alternative hosts. The feeding activity of all the agents had a significant impact on the growth rate of plants and reduced the viability of shoot fragments. Temperature base models predict that *H. lagarosiphon* is likely to complete at least three generations a year in Ireland, and the mining midge has a rate of increase of 1.1 and a population doubling time of 7.2 days. Host range tests to date indicate that the fly has the narrowest host range of the candidates assessed and is unlikely to attack native species. Further multi-generation trials are required to determine the potential of some Potamogetonaceae to support the shoot-mining midge in order to complete its host range testing. Both nymphulid moth species were found to feed on a wide range of native species and are rejected as biological control agents. Provided evidence-based risk assessments are made using modern host screening techniques, classical biological control offers the only self-sustaining and environmentally sensitive control technique. Considered an effective control option in other parts of the world biological control of some of our other non-native weeds should be explored.

"**French Working Group: Biological Invasions in Aquatic Environment (WG BIAE)**" by E. Mazaubert[24], A. Dutartre[24] and N. Poulet[25]

The presence of invasive species often comes along with negative impacts on the environment and on human activities and health. That can also have significant economic consequences. For these reasons, a French Working Group "Biological Invasions in Aquatic Environments" was instituted in 2009. Co-ordinated by the French National Agency for Water and Aquatic Environments (ONEMA) and the National Research Institute of Science and Technology for Environment and Agriculture (IRSTEA), this group gathers researchers, institutions and managers involved in different aspects of invasive species management. The main objectives of the WG BIAW are to generate a set of guidelines for the management of biological invasions in aquatic environments and develop operational tools of species management intended for managers and policy makers. Since 2012, a French website presents the WG BIAE and describes the ongoing studies: http://www.gt-ibma.eu/. This website also presents the activities carried out by different groups working on biological invasions collaborating with the WG BIAE and events (meetings, conferences, training) in connection with this topic. Still under construction, this website will offer, ultimately, a bibliographic database and a list of websites of interest. In addition, a balance sheet of available knowledge on existing management interventions on IAS in aquatic environments in France should take form as a guide of "good practices". Providing a clear basis for reflection and a reasoned approach for managers to aid the implementation of management actions, this guide should take into account the specificities of each situation, including the characteristics of the site itself, alien species being managed or whose management is desired, and human needs expressed. Its realization is planned in two parts: the first will include general information and in the second, a collection of management actions should be detailed as precisely as possible.

"**Zebra mussel control using Zequanox® in an Irish waterway**" by S. Meehan[26], F. Lucy[26] and B. Gruber[27]

Due to the invasion of Zebra mussels in European and North American waters there is currently a need for an environmentally friendly mussel control method to replace chlorine and other control products currently utilised. Marrone Bio Innovations (MBI), an American company that

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develops natural pesticides, is commercialising a natural product, Zequanox®, comprised of dead *Pseudomonas fluorescens* CL 145A, which effectively controls Zebra mussels. This study focused on controlling Zebra mussels at the Grand Canal, Tullamore harbour, Ireland. The objectives were to: demonstrate an effective method of Zebra mussel control in inland waterways using Zequanox®; trial a method which could be used for Zebra mussel fouled navigational structures; reduce the spread between waterways; and evaluate water quality to demonstrate the "no negative impact" and to monitor product dispersion. A trial authorisation was issued from the Department of Agriculture's biopesticide unit. Permission was granted by statutory bodies including Waterways Ireland and Inland Fisheries Ireland, following an ecological survey of the site. Non-target trials were carried out on other aquatic species, as agreed with National Parks and Wildlife Service. A curtain made of scaffband was placed into the canal, sealing off an 8 m x 0.5 m section on either side of the canal wall to be treated with Zequanox®. After the 8 hour treatment period the curtain was kept in place for a total of 24 hours, to allow for natural degradation of the product. Water quality was monitored before, during and after treatment. Juvenile Zebra mussel survival after treatment and mortality of seeded adult mussels and naturally settled Zebra mussels was monitored. These results provide important insights into Zebra mussel control methods and potential future use of Zequanox® to control Zebra mussel populations whilst conserving and maintaining the ecology of Ireland's waterways.

" **"West is Best?" – The potential influence of riverine water hardness on the invasiveness of the Chinese mitten Crab (*Eriocheir sinensis* H. Milne-Edwards 1853)**" by E.H. Morgan[28], R.E. Stephens[28], J. Albrecht[28], G. Torres[28], L. Giménez[28] and L. Le Vay[28]

The Chinese mitten crab (*Eriocheir sinensis*) is listed on the IUCN's "100 of the World's Worst Invasive Species" list. Its burrowing activities can compromise the structural rigidity of embankments and flood defence systems, with potentially severe implications. Recent molecular analyses confirm that admixture between UK and continental European populations continues to occur, most likely due to the high shipping traffic within the region. However, despite a rapid increase in density and geographic range since the 1990s, no sightings of *E. sinensis* have been documented within rivers towards the west of the UK. To help elucidate whether or not this observed distributional pattern is at all driven by the chemical environment of our rivers, the current study aimed to empirically test the survival, growth and moult frequency of *E. sinensis* when exposed to various degrees of water hardness under laboratory conditions. Following collection from the River Thames (Hammersmith, London), juvenile crabs were transferred to one of three water hardness treatments (n=30 each), namely soft, medium and hard water (<20, 160-180 and >320 mg $CaCO_3$ L-1 respectively), mimicking an anthropogenically-mediated transfer from a known source population. Whilst crabs were capable of surviving in all three treatments for at least 5 months, the rate of survival of *E. sinensis* was significantly lower within the soft water treatment (Log-Rank: $\chi^2 = 10.95$, $p = 0.004$). Whilst not enough moults were observed to make any quantifiable comparisons of crab growth, the overall rate of moulting is thought to have been delayed by several days in soft water crabs. Following moulting, soft water crabs often took longer to harden and occasionally lost limbs, nearly always breaking at the merus of the pereopod. Many also died during the moulting process. Whilst Chinese mitten crabs were tolerant to relatively high ammonia across all treatments, pH was shown to decline more rapidly in soft water, likely due to the decrease in the buffering capacity of this treatment and perhaps a subsequent stress-related increase in their respiration rate (and thus CO_2 output). Whilst our findings suggest water hardness as a potential barrier to *E. sinensis* invasions, covariates of soft water rivers of the western end of the UK must also be investigated, including flow rate, flooding potential and habitat suitability. Quantitative monitoring of larval supply into UK estuaries must also be made a priority.

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"**Distribution, condition and abundance of non-native Ponto-Caspian gobies from the tributaries of the Danube in Croatia**" by M. Piria[29], I. Jakovlić[29], N. Šprem[29], T. Tomljanović[29], D. Matulić[29] and T. Treer[29]

During the last decades several species of Ponto-Caspian gobies (Pisces, Gobiidae) have expanded upstream from their native distributions and invaded most of Europe, albeit their reported distributions vary greatly. Three invasive Ponto-Caspian species have so far been reported in Croatia: bighead goby *Ponticola kessleri*, monkey goby *Neogobius fluviatilis* (Pallas, 1814) and round goby *Neogobius melanostomus* (Pallas, 1814). Their distribution, abundance and condition from the River Sava were analysed over a three-year period (2010-2012). Distribution and condition of monkey goby in tributaries of the River Sava (Kupa, Kupčina, Korana and Ilova) were also presented. CPUE values (number of fish per 100 m shoreline) were calculated and compared between the sites. A total of 246 specimens of monkey goby, 141 specimens of round goby and 21 specimens of bighead goby were analysed. In terms of distribution, monkey goby was found along the entire longitudinal profile of the River Sava and all studied tributaries. Round goby is still spreading upstream in the River Sava (ca. 80 km in one year) and the high CPUE at some selected sites were recorded (84 individuals per 100 m shoreline). Bighead goby occurred only in lower part of the River Sava. Condition factor varied between 0.74–1.06 for monkey goby, 1.18–1.21 for round goby and 0.96–1.26 for bighead goby. Values of *b* parameter of length weight relationship indicate good body condition in the Rivers Sava (monkey goby b=2.884–3.229; round goby b=3.290–3.312; bighead goby b=3.343), Kupa (monkey goby b=3.249) and Ilova (monkey goby b=3.291) and poorer body condition in the rivers Kupčina and Korana (monkey goby b=2.490–2.549). The presented results indicate that all three investigated species are well adjusted to their new habitat and that further range expansions are highly likely.

"**Biosecurity in the water environment; effective management or forlorn hope?**" by T. Renals[30]

The Invasive Non-Native Species Framework Strategy for Great Britain provides a national policy framework for invasive species management. No single organization has been identified as having responsibility for invasive species management in Great Britain (GB). Instead, responsibility is shared across a wide variety of government and non-government bodies, relevant sector groups and volunteer groups. The Environment Agency has responsibilities for environmental regulation, flood risk management and enhancing biodiversity in England and Wales. It tends to take leadership for coordinating action against aquatic invasive non-native species, particularly if their impact is a perceived threat to Good Ecological Status as described within the Water Framework Directive. Biosecurity affects the way work is done, how assets are regulated and the way assets are managed. Staff is reviewing the activities they do and try to minimize the risk of spreading invasive non-native species and the diseases they may vector. They have identified their high risk activities and performed a survey of the 2 300 staff engaged in those activities. This has provided them with an important insight for their training and behavioural change programmes. The biosecurity programme has been stimulated by the continuing arrival of Ponto-Caspian invertebrates into GB. Since 2010, *Dikerogammarus villosus* and *D. haemobaphes* have been recorded in GB. *Dikerogammarus haemobaphes* has been found to be distributed across England. Their management response has been to attempt to contain these species by risk-assessing the potential pathways of spread and encouraging appropriate biosecurity. A government-led publicity campaign 'check-clean-dry' has encouraged anglers and boat-users to inspect, clean and dry their equipment between uses. Although the campaign was instigated by the arrival of *D. villosus*, the campaign covers a broad spectrum of plants animals and the diseases they may vector.

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"**Invertebrate invasive species (neozoa) as fish diet in Lake Constance**" by R. Roesch[31], F. Bonell[31] and C. Becke[31]

Lake Constance is shared by Germany, Austria and Switzerland. It underwent intensive re-oligotrophication in recent years with a Phosphorus concentration of only 5.9 mg/m³ in 2012 (www.IGKB.org). The lake was invaded by several invasive invertebrate neozoa (www.neozoen-bodensee.de). *Dikerogammarus villosus* has been detected for the first time in 2003 and *Limnomysis benedeni* in 2006. Both species spread over the whole lake within a few years. In 2011, both species have been preyed upon especially by up to 50 percent of sampled perch (*Perca fluviatilis*) and ruffe (*Gymnocephalus cernuus*), with *L. benedeni* as diet mainly in spring and autumn and *D. villosus* mainly during summer. Cyprinids and whitefish (*Coregonus lavaretus*) preyed upon the invasive species to a much lesser extent. The degree of stomach fullness of those perch that preyed on invasive species was significantly higher than the degree of stomach fullness of those specimens without invasive species in their stomach. In 2012, in shore areas, *D. villosus* was the main prey of all age classes of burbot (*Lota lota*). Despite high densities in the lake *L. benedeni* was of minor importance in the diet. To the contrary, in deeper areas burbot had been exclusively piscivorous.

Depending on the sampling site, up to 100 percent of 0+ perch had ingested *L. benedeni*. In general, *L. benedeni* and *D. villosus* have been accepted by perch, ruffe and borbot as (main) diet items. Preliminary data suggests that final length of 0+ perch is higher than in the years before invasive species had been detected. However, only long-term trends will show if the new diet organisms will affect fish growth and commercial fisheries yield.

"**Changing management principles disrupted natural fish fauna in Norwegian lakes**" by O.T. Sandlund[32], T. Hesthagen[32] and Å. Brabrand[32]

The management goals regarding inland fish in Norway has gone through periods of changing goals, from maximized harvestable biomass (1860s-1950s), through improved recreational fisheries (1950s–present) to conservation of native aquatic biodiversity (1970s–present). These changing policies have left a permanent mark on the occurrence and distribution of inland fishes. In southern Norway, the coregonids, European whitefish (*Coregonus lavaretus*) and vendace (*C. albula*), were originally restricted to low-lying lakes and slow flowing rivers. Since the adoption of artificial hatching of fish eggs in the 1860s, local interests were encouraged by national authorities to stock coregonids into new lakes. The aim was to create harvestable fish stocks. This was highly successful for whitefish, with the total number of whitefish lakes increasing from 110 to 540. In some local mountain areas it appears that up to 70 percent of introductions resulted in established populations. Work with vendace was much less successful, probably due to inadequate hatchery technology for the smaller eggs of this species. This policy continued until the 1950s, changing the face of Norwegian lake fish fauna. The major impact of whitefish on the native fish fauna in lakes has been in particular a substantial reduction or even local extinction of Arctic charr. The impacts on ecosystems included a dramatic change in zooplankton size and composition, increased chlorophyll and total phosphorus contents, and decreased Secchi depth.

"**Inundative Classical Biological Control–A new concept for an old problem**" by C. Pratt[33] and D. Shaw[33]

Classical biological control is a new concept to many in the European Union. "Inundative classical biological control" has, however, been carried out in the United Kingdom (UK) for around

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five years against the highly invasive water fern, *Azolla filiculoides*, with great success. The weevil, *Stenopelmus rufinasus*, arrived in the UK as a stowaway on *A. filiculoides* in the 1920s and has persisted in the wild ever since. Its specificity for only *Azolla* species and its long-term residence, without negative environmental impacts, have allowed the redistribution of *S. rufinasus* without licencing restrictions. The Commonwealth Agricultural Bureaux International (CABI) has been using this weevil against *Azolla* with remarkable results, clearing the surfaces of small private ponds to large canals and lakes of *Azolla*. The weevil's success is also its downfall, as unlike many biocontrol organisms, *S. rufinasus* is prone to removing all traces of its only food source, leaving it with no option but to disperse or starve. The *Azolla* control programme at CABI blurs the line between commercial and non-commercial biocontrol production and raises the expectations of biocontrol to a high level, one that most biocontrol agents would not be expected to reach. Nonetheless, *S. rufinasus* is known to be present in many European countries and it would seem that the use of an "ordinarily resident" weed biocontrol agent whose safety is proven in the field, will be the easiest introduction to countries wary of classical biocontrol *per se*. Thus, the Azolla weevil is being used as a demonstration trial in the multi-country InterReg 2-Seas RINSE programme (Reducing the Impact of Non-native Species in Europe) and should raise awareness of this excellent alternative approach to weed management, especially for those affecting Water Framework Directive goals.

"**Methods and networking strategy of invasive vertebrates species management on the Loire river catchment area**" by E. Sarat[34] and S. Hudin[35]

On the Loire river catchment, invasive plant management is now coordinated. However, management and knowledge of invasive fauna remained uneven and a clear overview of invasive fauna management was necessary. The presence in the Loire basin of invasive vertebrate fauna was assessed and priority management actions were determined at the basin scale, using the ISEIA method (Invasive Species Environmental Impact Assessment). At the same time management experiments were assembled and tools were created to meet the needs of managers. Information and common tools (species factsheets, management experiments, bibliographic database legislation syntheses) were summarized in a document entitled "Vertebrate invasive species on the Loire river catchment: knowledge and management techniques". The next step will be to determine strategies and surveillance networks in each regional group, in order to enhance management priorities, stop the emerging species and encourage information transfer among managers, NGOs and policy makers.

"**An examination of the potential vectors and pathways of spread of *Corbicula fluminea* in Ireland**" by R. Sheehan[36], F. Lucy[36] and J.M. Caffrey[37]

The highly invasive Asian clam *Corbicula fluminea* was first reported from the island of Ireland in 2010 in the River Barrow. *Corbicula fluminea* has subsequently spread to the Rivers Nore and Shannon. Within the Shannon River, *C. fluminea* is now present throughout much of its length, with two established populations, one in the northern section and another 100 km downstream. An experiment was devised to identify the vectors of spread for *C. fluminea* in the northern section of the Shannon river basin. In an attempt to prevent or slow the pace of spread of the invasion it was deemed important to identify invasion pathways, with a focus on the specific conditions in Ireland. The vectors most likely to spread *C. fluminea* within the study site are accidental movement by anglers, recreational boaters and waterfowl. A hub of lakes, radiating out from the Shannon River, at the town of Carrick-on-Shannon, was chosen for the experiment. This sampling area was selected for a number of reasons, namely the proximity of a population of *C. fluminea* in the main river stem, the number of lakes in the area that are subject to angling pressure and as a location of interconnecting Irish

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navigable waterways. The study was designed to detect various vectors and pathways of spread. Sampling sites were selected on the basis of angling activity, boater movement, and a navigable connection to the Shannon River. Control sites were selected on the basis of remoteness, lack of boating or angling activity. The poster provided an overview of this research in 2012 and also the current known state of the *C. fluminea* invasion on the Island of Ireland.

"**Decision support systems for control of alien invasive macrophytes (DeCLAIM)**" by J. van Valkenburg[38] and J. Newman[39]

The aim of this European and Mediterranean Plant Protection Organization (EUPHRESCO) funded project was to generate a prototype decision support system for optimal control measures for four representatives of the most problematic growth forms of non-native invasive aquatic weeds: Myriophyllids and Stratiotids s.l. (i.e. *Hydrocotyle ranunculoides, Cabomba caroliniana, Myriophyllum aquaticum, Ludwigia grandiflora*). Based on limited habitat characteristics at recorded United Kingdom and the Netherlands localities of the species, areas have provisionally been predicted as potentially at risk of invasion. Based on published sources and field experiments on *Hydrocotyle* and *Cabomba* life-cycles of the target species have been analysed so as to predict 'vulnerable' stages to enhance efficacy of control measures. Modelling of growth strategies of the four species using the Cultural Heritage Advanced Research Infrastructures (CHARISMA) model showed dominance in relatively rapid timescales and exclusion of competing species. This resulted in a working document with an overview of current control options and some new concepts for optimal prevention and control of the selected aquatic weed species. To promote practical use of the information by surveyors in the field there are illustrated fact sheets on the management of the target species. As an outcome of the project, the following documents are freely available on the Q-bank (interactive image-driven identification of non-native aquatic plants) website:

- Background information for *Cabomba caroliniana*, *Hydrocotyle ranunculoides*, *Ludwigia grandiflora* and *Myriophyllum aquaticum*;
- One page field recognition cards for *Cabomba caroliniana*, *Hydrocotyle ranunculoides*, *Ludwigia grandiflora* and *Myriophyllum aquaticum* both for the United Kingdom (in English) and for the Netherlands (in Dutch);
- A risk assessment field sheet, to report new sightings in the field;
- A guide for *Cabomba caroliniana*, *Hydrocotyle ranunculoides*, *Ludwigia grandiflora* and *Myriophyllum aquaticum* describing for each species the biology, ecology, morphology, life
- cycle, management weak points, management restrictions and techniques (both for the United Kingdom and the Netherlands);
- Bibliography for *Cabomba caroliniana*.

"**Interactive image-driven identification of non-native aquatic plants**" by J. van Valkenburg[40], R. Pot[41], E. Boer[42] and L. Duistermaat[42]

Information on non-native plants has been compiled to facilitate their identification. Focus was on species that pose a (potential) threat to the biodiversity of the ecozone comprising northern Germany, The Netherlands, Belgium and northwest France. Some species that might be found as contaminant in commercial exports originating from the Netherlands are also included. This information is now available at http://www.q-bank.eu/plants. Image driven, interactive identification keys are added to the information system. The keys can be used for various growth stages in a range

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of 'habitats': seed identification of contaminants in birdfeed, weeds in bonsai plants, seedling identification, invasive terrestrial plants and invasive aquatic plants. Image driven identification helps to avoid misunderstandings in terminology. The interactive, multiple entry system serves identification in the absence of certain characters, which is often the cause of failure in dichotomous keys. The keys are linked to the species information in the database, including datasheets, distribution maps, specimen information etc. The use of the interactive keys can be demonstrated at the symposium and participants are invited for a test ride.

"**The danger of inter-basin water transfer schemes in driving alien fish establishment**" by J. Woodford[43,44], C. Hui[45] and O.L.F. Weyl[43,44]

Inter-basin water transfer (IBWT) schemes carry water from one river catchment to another to supplement water supply for human consumption. It has long been recognized that these engineering projects enable the transfer of organisms by breaking the biogeographic barriers between catchments. However, the ability of IBWTs to facilitate freshwater invasions has not been fully contextualised due to a lack of quantitative studies on the rate at which organisms are transferred. In South Africa, an irrigation scheme consisting of multiple ponds fed by water from an IBWT scheme provided an opportunity to assess how propagule pressure derived from the water transfer network affected the success and rate of fish species establishment in the ponds. When establishment success of ten fish species was compared across 30 ponds, and linked to the number of propagules entering the irrigation network over time, establishing species received significantly more propagules than non-establishing species. There was also a significant correlation between the rate of establishment in the ponds and propagule pressure across the species. Furthermore, even fish that lacked the life-history strategies to establish populations within lentic environments were found in some ponds, demonstrating the ability of IBWT schemes to enable range expansion of fishes regardless of a species' initial invasiveness. The study highlights the need to consider the effect of transferring propagules of organisms between catchments when designing IBWT schemes, as they are likely to eventually result in a total homogenisation of fish communities between the donor and receiving catchments.

3.3. Summary of the key information presented

The 12 oral presentations, in combination with the 27 poster presentations and summaries, introduced a broad range of cross-cutting invasive species issues relating to biosecurity, economics, management and risk assessment, and policy. The provision of this information to conference delegates in turn stimulated the discussion at the workshop sessions on Days 2 and 3 of the conference. The authors of the oral and poster presentations participated fully in the workshop sessions and contributed significantly to the development of the Top 20 IAS issues and the management recommendations that were ultimately achieved. Round-table discussions on existing and developing management procedures within MS and the developing EU regulations were discussed within the context of each workshop session. The development of management advice was discussed frankly both in terms of bottom-up and top-down approaches; this was facilitated by the presence of a broad spectrum of practitioners, field scientists, academics, policy-makers and managers.

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4. KEY OUTCOMES FROM THE FINS CONFERENCE

4.1. Top 20 IAS issues and management recommendations

One of the principle goals of the conference was to provide a forum of experts that would help prioritize issues relating to IAS in Europe in order to better inform policy development in EIFAAC countries and to inform debate regarding the proposed EU Regulation on IAS. Detailed debate and discussion on Days 2 and 3 of the conference helped generate a list of the Top 20 issues relating to IAS in Europe. The four pillar themes from which the Top 20 IAS issues were developed are depicted in Figure 1. A summary description of each of the Top 20 IAS issues determined during the workshop sessions and using information derived from the invited presentations and posters is presented below.

Figure 1
A diagrammatic representation of how the four pillars of the FINS themed workshop sessions combined to produce the Top 20 IAS issues in Europe in 2013

The table in Appendix 4 describes the individual issue, assesses the nature of the threat and whether it is of local, national or international importance, and offers recommendations as to how best the issue can be dealt with or resolved. The Top 20 IAS issues that follow do not appear in any order of priority but broadly follow the three-stage hierarchical framework recommended by the Convention on Biological Diversity, i.e. prevention; early detection and eradication; and long-term management, containment and control.

4.1.1. Biosecurity awareness

Biosecurity covers all activities aimed at managing or preventing the introduction of new species to a particular region and mitigating their impacts. This includes the regulation of intentional (including illegal) and unintentional introductions and also the management of weeds and animal pests by central and local government, industry and other stakeholders (Wittenberg and Cock, 2001). Routine application of biosecurity at appropriate levels would minimize new introductions, spread and impacts. However, application needs to be consistent across the biosecurity continuum including pre-border (importers), border (customs and plant/animal health inspectors) and post-border (e.g. public, trade).

Politicians, officials, businesses and individuals can all contribute to prevention through their awareness and their actions. The increasing concern of governments with potential, rather than proven, harm has seen a welcomed shift in policy focus from the remediation of damage to the prediction of risk. The SPS Agreement is one of the more prominent examples of this trend in that it prescribes scientific risk assessment as a basis for measures dealing with risks to human, animal and plant life or health (WTO, 1995). As a consequence, the task is often seen as a government responsibility, usually delegated to one or more departments. Legislation is often clouded in jargon

and detail and is challenging to communicate to industry or the public. Officials can become embroiled in procedures and not look at the intent of legislation or the likelihood of compliance. Penalties for contravention are often highlighted while the benefits of compliance are sometimes less readily identifiable (Secretariat of the Convention on Biological Diversity, 2001). Where ignorance about the various implications of a biosecurity threat exists, this in itself should not be used as a reason for postponing or failing to take appropriate eradication, containment and control measures where serious or irreversible environmental damage may occur. Too often, biosecurity is regarded as a rigid list of actions, i.e. a process to be followed without thought of the intended outcome. Therefore, it is important that efforts to raise awareness that contribute to biosecurity be made at all levels, from governments to actions by individuals. A broad range of stakeholder input should be sought, not only with regard to policy changes but also in terms of reviewing the effectiveness of interventions and legislation (Wittenberg and Cock, 2001). Practitioners may be able to suggest simple, efficient and cost-effective solutions that may not emerge from elsewhere. To be fully effective, as wide as possible an audience should be facilitated to understand the issue, buy in to the proposed solutions and be encouraged to implement appropriate measures in their own businesses or lifestyles. Punitive sanctions will be required in some instances, and reinforcing-required behaviours will need to be incorporated into strategies. Awareness raising needs to be a fundamental action between government departments and within government agencies, trade groups and the public (Wittenberg and Cock, 2001). Enhanced "earned recognition" would facilitate this, particularly if an accreditation scheme for both training and compliance could be part of the mix. Attention to these biosecurity issues is urgent, as costs increase disproportionately after invasions and secondary spread (Leung *et al*., 2002; Kettunen *et al*., 2008).

4.1.2. Coherent EU legislation for effective biosecurity

Legislation is a key element of the approach to IAS. To date, the EU has legislated in some areas of IAS, e.g. plant health (2000/29/EC [European Union, 2000a]) and animal health (2006/88/EC [European Union, 2006]), Wildlife Trade Regulation (Council Regulation [EC] No. 338/97 [European Union, 1997]) and the Aquaculture Regulation (Council Regulation [EC] No. 104/2000 [European Union, 2000b]). This still leaves the majority of IAS outside any coherent EU regime and only covered by peripherally relevant legislative instruments, such as the Birds and Habitats Directives (Genovesi and Shine, 2004). The benefits of having a coherent regime (as per the proposed EU Regulation on IAS) are clear and include an agreed framework for risk assessments, border checks and requirements for rapid action, as well as more emphasis on identifying pathways (Kettunen *et al*., 2008; Shine *et al*. 2009).

Many IAS occur in aquatic habitats where the Water Framework Directive (WFD) has a major role in monitoring, assessment, regulation and management. While the text of the WFD does not explicitly mention alien species, guidance from the European Commission (EC) makes it clear that such species constitute a "pressure" on waterbodies and thus lie within the scope of the WFD (Guidance Document, 2003). One of the main objectives of the WFD is to achieve at least "good ecological status" in rivers, lakes, and transitional and coastal waters by 2015, and the presence of IAS known to have severe impacts on species and habitats poses a threat to achieving this objective. Throughout the whole of the EU, however, there is no consistent view on the best way of using the WFD to tackle the problems of IAS in aquatic ecosystems.

The lack of a unified EU strategic approach applies not merely to those species that are covered under the WFD but more generally to IAS (European Commission, 2013). This has led the 27 MS to develop diverging approaches that are likely to continue as awareness of the importance of the issue grows (Shine *et al*., 2009). The legislative framework across the MS within the EU is already complicated, with some restricting the import of many species and others banning the sale, keeping, trade, etc. of IAS (Shine *et al*., 2009). In general, the legislation is not underpinned by comprehensive risk assessments and is, thus, potentially open to challenge under the rules of the

World Trade Organization. The need for more coherence is clear, therefore, and the most suitable level for this is the European Union.

Legislation by itself is not sufficient. Enforcement of the provisions of legislation is also necessary in order to ensure that all MS comply. Once an IAS becomes established in one MS, it is more difficult to prevent it from spreading within the single-market area (Kettunen *et al*., 2008; Shine *et al*., 2009). This may well require MS to take action against species that are not priorities for them ("solidarity action") but which may become significant for their neighbours. The lack of finance, expertise and appropriate funding mechanisms in some countries are further confounding factors that may hinder progress in carrying out risk assessments or instigating control measures (Shine *et al*., 2009). Lack of capacity is likely to be a particular problem for smaller MS, but even larger MS may not have the resources to implement the provisions of any EU directive or regulation (e.g. proposal for a European regulation on the prevention and management of the introduction and spread of IAS [European Commission, 2013]).

4.1.3. International biosecurity best practice

Although some individual countries are acknowledged to implement effective biosecurity measures (e.g. New Zealand), there is a clear requirement to improve related strategies for cooperation, coordination, consistency and cohesion between countries (European Commission, 2013). Utilizing proven procedures on an international level could greatly increase biosecurity effectiveness and consequent reduction of spread between and within countries (Wittenberg and Cock, 2001; European Commission, 2013). This is especially true in Europe where the effectiveness of a continent-wide approach will depend on the weakest link in individual national biosecurity strategies (Shine *et al*., 2009).

The geographical contrast between implementing biosecurity on islands versus measures for intercontinental countries provides challenges for a common approach (European Commission, 2013). Many differences in biosecurity protocols exist owing to variation in international policy, legislation and resourcing of enforcement (Shine *et al*., 2009; Pyšek and Richardson, 2010). In addition, related legislation for transport and trade of food and other live goods may interfere with the development of common biosecurity measures. Moreover, different national strategies towards identifying problem species could mean neighbouring countries may not share the same priority species and may act as sources of future introductions (Secretariat of the Convention on Biological Diversity, 2001). States need to be aware of the biosecurity strategies in neighbouring countries as well as trading partners (Dahlstrom, Hewitt and Campbell, 2011). In Europe, a forum for organizations with responsibilities for biosecurity should be established where best practices can be shared.

4.1.4. Regulatory framework to prevent introduction of IAS

Despite the recognition that IAS is an increasing problem, there are currently still substantial gaps in international trade rules to prevent their spread. The Sanitary and Phytosanitary (SPS) Measures Agreement (WTO, 1995) is the highest-level international agreement setting out basic rules on food safety and animal and plant health standards that may have a direct or indirect impact on international trade. The purpose of the SPS Agreement is to ensure that countries do not use SPS measures to erect protectionist trade barriers. However, there is currently no standard-setting body with a mandate to develop SPS-recognized standards to prevent the spread of IAS.

In addition to the gaps in international trade rules, there is also a significant lack of international standards to address animals that are IAS but are not pests of plants. A report by an ad hoc technical expert group on gaps and inconsistencies in the international regulatory framework in relation to IAS suggested the following options to deal with this gap: (i) expansion of the mandate of the World Organization for Animal Health (OIE) beyond a limited number of animal diseases; (ii) development of a new instrument or binding requirements under an existing agreement or

agreements, such as the CBD or other appropriate frameworks; and (iii) development of non-binding guidance (CBD, 2005).

In 2006, the CBD requested consultation with relevant international bodies and instruments to address the lack of international standards covering IAS, in particular animals that are not pests of plants, under the International Plant Protection Convention (IPPC). Since 2006, some progress has been made. However, there is currently still no standard-setting body with a mandate to develop SPS-recognized standards to prevent the spread of IAS.

The experience with trade rules aimed at the prevention of transboundary spread of animal diseases has demonstrated that the spread of animal pathogens still occurs despite a comprehensive regulatory framework. This includes diseases listed by the OIE (and therefore specifically controlled), but also new and emerging diseases. A particular challenge is how to deal with disease threats that have not yet been recognized. Members of the WTO may use more stringent trade measures over and above those provided through WTO-recognized standard setting bodies if they can be scientifically demonstrated as necessary to protect human, animal or plant life or health.

In the context of IAS, a comprehensive regulatory framework is missing. Therefore, it is likely that most measures to mitigate the introduction of IAS will require the conducting of targeted risk assessments. The costs of import risk assessments are substantial and, for this reason, there are very few examples where such risk assessments have been produced. In the early phase of a new or emerging disease, insufficient data are available to underpin a risk assessment, leading to an exposure of the importing country to an unknown risk. Similar principles would apply for IAS.

It is clear that a competent body specifically charged with responsibility for developing a framework for standards to prevent the spread of IAS is needed within each MS. Suggestions as to how this may be realized were provided in the CBD expert ad hoc group report from 2005 (CBD, 2005). Moreover, the SPS rules need to be revisited. As the substantial damage caused by IAS is very difficult to predict, greater emphasis needs to be placed on prevention. Once an IAS has become established, it is virtually impossible to eradicate, and the costs for control lie with the importing country. A shift towards prevention may have an impact on free trade but would be justified by a reduction in the cost burden for control on MS.

4.1.5. Dedicated and appropriate resources for IAS

Resources to tackle IAS appropriately include suitably experienced staff and finances for equipment, specialist contracted staff, educational materials and research. The need for dedicated resources extends not only to tackling long-established threats but also to ensure that countries are equipped to respond to and prevent newly detected invasions (Shine *et al*., 2009). While the public profile of IAS throughout Europe has risen substantially in recent years, this has not been met with any significant increase in dedicated resources. In Ireland, legislation relating to IAS provides a framework to regulate for their introduction and intentional further spread but does not place a legislative requirement to allow for powers of access to government officials, or agents working on their behalf, to undertake control. Nor does it always provide the legislative powers to enforce landowners to undertake control of IAS on their land (European Communities [Birds and Natural Habitats] Regulations, 2011). Historically, efforts to tackle IAS have been on an ad hoc basis, with little or no coordination. In recent years, however, there has been a significant move towards working at catchment level using funds provided by government grant aid and European funding, in addition to the creation of local partnership projects (e.g. LIFE+ CAISIE project – http://www.caisie.ie; Interreg

IVA[46] CIRB [Controlling Priority Non-native Invasive Riparian Plants and Restoring Native Biodiversity] www.qub.ac.uk/research-centres/cirb/).

At a European level, legislation surrounding plant and animal health leads the way in providing effective and efficient mechanisms to detect and respond to new threats (European Commission, 2013). These legislative frameworks are resourced to respond to new threats in an effective, planned and timely manner, with political and public support in place to back up a response action. Their efficacy is apparent with reference to the internationally high-profile cases that include the foot-and-mouth disease outbreak in the United Kingdom of Great Britain and Northern Ireland in 2001 and the recent detection of ash dieback (Chalara) in that country in 2012. However, the legislation that regulates IAS at European level is often fragmented and, within MS, does not task a single government department or state agency with responsibility for IAS (European Commission, 2013). It is recommended that, at a central European level, a contingency fund should be established from which MS can request emergency funds to respond to new threats that meet agreed criteria. The EC is currently developing a dedicated Regulation to tackle the threat of IAS, and this provides an opportunity to ensure that dedicated and appropriate resources are committed at the European and national levels (European Commission, 2013). In turn, political, industry and public support to tackle the challenges posed by IAS will be required. This should be regarded as an urgent priority. However, it is likely that no moves will be undertaken until the full scope of the pending EC Regulation is known, as this will undoubtedly direct any national action.

4.1.6. New technologies for early detection

Governments worldwide have focused efforts on prevention of IAS (e.g. Environment Canada, 2004; Veitch *et al*., 2007; European Commission, 2013). However, prevention does not always work and IAS may spread inadvertently – for example, via ballast water or as hitchhikers with stocked species (Carlton and Geller, 1993; Ruiz *et al*., 2000) – or be introduced intentionally through unauthorized releases (Gertzen, Familiar and Leung, 2008)**.** Available evidence, mainly from terrestrial situations, indicates that the success of intervention efforts is inversely related to the size of the population acted upon (Grevstad, 1999; Leung *et al*., 2002). Therefore, detecting IAS incursions at the earliest possible time, when populations are small, provides the best opportunities for rapid response. However, the ability to detect IAS is poorly developed and often based on serendipitous finds, e.g. *Caulerpa taxifolia* (Vahl) Agardh in San Diego Bay (Anderson, 2005); bloody-red shrimp *Hemimysis anomala* Sars in the Great Lakes (Pothoven *et al*., 2007), and, usually, managers learn of new invasions at late stages, prohibiting the use of rapid response.

However, new technologies are available and may assist with early detection. Molecular methods based on detecting DNA in water (environmental DNA or eDNA) or using DNA in organisms may greatly enhance surveillance programs (Jerde *et al*., 2011; Dejean *et al*., 2012; Zhan *et al*., 2013). Recent examples include detection of American bullfrogs, *Lithobates catesbeianus* Shaw, in France (Dejean *et al*., 2012) and Asian carp in the Great Lakes (Jerde *et al*., 2011). A second approach (next-generation sequencing; 454 pyrosequencing) does not survey for specific species but instead uses a traditional sample, e.g. plankton. This is processed to obtain DNA from all of the species present. The DNA sample is amplified, sequenced and cross-referenced against online data bases, e.g. BOLD, Genbank (Zhan *et al*., 2013). Optical methods may also present opportunities for early detection of IAS, whereby a library of images of key IAS is built using imaging from every possible orientation. Samples with possible IAS are then screened through a system that uses laser images to detect species in a processed stream, e.g. plankton sample. However, the system is dependent on accumulation of library images of relevant species.

[46] IVA = fourth A phase (IV = Roman numerals).

Key impediments are reluctance to readily accept new technologies and their associated costs, but the latter are declining, e.g. eDNA costs have declined tenfold in recent years. Early adoption of such new technologies is recommended. The benefits associated with the new technologies should be widely disseminated, with assistance provided for those who might adopt them in the future and, if possible, reduce costs by sharing of equipment or personnel. Because some of the equipment is beyond the domain of regional governments, national or EU centres could be established that provide equipment and skilled personnel. Existing centres for food pathogen detection and identification might provide an appropriate model. In the short term, samples can be sent to universities or corporate labs for processing. However, skilled bioinformatics expertise is still required in order to process the resultant data. Advanced early detection capabilities provide better opportunities to answer questions regarding whether rapid response should be undertaken, and how to do it.

4.1.7. Early warning mechanisms

Early detection and appropriate rapid response is acknowledged as a vital component in invasive species management (Genovesi and Shine, 2004). The circulation of information through a formalized early warning system, such as alerts or notifications, has been identified as a key driver of this process (Genovesi *et al*., 2010; European Commission, 2013). Species alerts that are processed and communicated through a formalized early warning mechanism can significantly raise the profile of the targeted species with practitioners, resource users and the general public. The availability of a formalized early warning mechanism, as proposed in the new EU Regulation on IAS, can also result in: (i) targeted surveillance of pathway introduction "hotspots" and habitats vulnerable to its invasion; (ii) submission (and expert verification) of first and additional sightings of the alert species; (iii) reporting of the verified sightings to the competent authorities for further assessment of risk and rapid response; and (iv) the implementation of biosecurity measures to prevent further introductions or spread. Species alerts should be communicated internationally to inform horizon scanning and risk assessment for other MS.

Ideally, MS should have completed detailed risk assessments of potential non-native species introductions to determine which species would warrant a species alert. Factors to consider before issuing an alert include: (i) when to issue the alert – is this pre- or post-border entry or when a single individual or established population is detected?; (ii) is the early warning system coordinated by a centralized body or multiple competent authorities? If it is the latter, there is a need for clear consistent messages; and (iii) who is the alert sent to? Is it to the relevant authorities or should it also include relevant stakeholders and the public?

Resources are vital to support surveillance and monitoring of pathway introduction hotspots and habitats vulnerable to invasion. This may include development of identification materials, training in best surveillance methods and promotion of biosecurity measures. Consideration should be given to managing expectations following the issuing of the species alerts. Cognizant of these potential obstacles, it will be important for individual MS to undertake risk assessments that will inform horizon scanning and early warning, develop a formalized early warning strategy with clear lines of communication and responsibility, develop an expert registry to support species diagnosis and report verification, and provide resources for supporting early detection awareness, species identification, surveillance and biosecurity measures.

4.1.8. Rapid risk assessment methods to prioritize future invasion events

Policy-makers and practitioners in conservation and IAS management often make decisions based on insufficient evidence and are limited by existing knowledge gaps. Science is often not involved sufficiently early in the policy process. The diffuse distribution, variable quality and lack of harmonization of information on IAS limit the ability of managers to combat invasions (Ricciardi *et al*., 2000). Invasion events are often unexpected but many could be predicted. In this respect, global collaboration is essential in order to manage IAS. The establishment of a list in which species that

pose the most significant threats are identified, prioritized and consequently prohibited for import and sale in Europe has been proposed to improve the existing legislation (European Commission, 2013). The development of effective and rapid risk assessment methods supported by research-based knowledge could enhance the prioritization of future invasion events. Current risk classifications show a high dissimilarity between countries. According to Verbrugge *et al*. (2012), this may be due to differences in: (i) national assessment protocols; (ii) species–environment matches in various biogeographic regions; and (iii) data availability and expert judgement.

It is not easy to quantify the ecological and economic impact of IAS. There are many knowledge gaps that prevent effective risk assessment. There is often a lack of knowledge on the mechanisms underlying impacts of introduced species. Predicting and quantifying the impacts of IAS has proved to be difficult and challenging. Current research often does not provide quantitative information that is required to assess the impact of IAS on ecosystem structure and functioning. In addition, there is considerable inconsistency on whether certain IAS have a positive or negative impact and on how environmental conditions, species interactions and other stressors can reinforce or alter these impacts. Moreover, there is insufficient time and resources to perform risk assessments for all possible IAS. In most cases, risk assessment is performed for those species with a history of invasion in other countries. However, a significant proportion of IAS in Europe are native elsewhere in Europe. Risk assessment and the use of a "black list" may, therefore, need a regional or national focus. Although the need for a European early warning system has been acknowledged (Genovesi *et al*., 2010), legal standards for alien species are still lacking.

There is a need for: (i) a European standardization of risk assessment protocols; (ii) a global information system (database) on risk assessment; and (iii) an understanding and prioritization of knowledge gaps, as foreseen in the new EU IAS Regulation. Performing a detailed risk assessment for all species would be very costly, time-consuming and unnecessary (Genovesi *et al*., 2010). IAS should be prioritized through a preliminary rapid risk assessment (based on expert opinion and consensus) to highlight IAS that require a detailed risk assessment.

4.1.9. Standardized pan-European risk assessment to underpin EU IAS blacklist

Restricting the influx of emerging IAS is essential in order to prevent further damage to biodiversity in the EU, to its economy and to the health of its membership (European Commission, 2013). The availability of so-called blacklists and alert lists (as foreseen by the new EU IAS Regulation), representing non-native species that will pose a significant risk if they gain entry to the EU, can provide a good starting point to stop the introduction of IAS (European Commission, 2013). However, these lists have to be underpinned by cost-efficient, robust and transparent risk assessments (Wittenberg and Cock, 2001; Verbrugge *et al*., 2012). Cost-efficiency is needed to make it feasible to tackle the assessment procedure with appropriate resources. Robustness is needed to guarantee the quality of the result of any assessment, and transparency is required to convince the authorities and other interested parties of its objectivity. Any assessment should be performed in a two-step approach that includes: (i) screening of a large number of potential invasive species with a prioritization tool (horizon scanning); and (ii) elaboration of detailed pest risk assessments that will be able to justify trade restriction for a shortlist of priority species (e.g. Kelly, O'Flynn and Maguire, 2013). These species include those that are characterized by a strong capacity to rapidly spread and cause serious damage to native species or ecosystems, and have a high probability of entering into Europe through international pathways.

Any EU IAS blacklist or alert list that is not underpinned by a standardized risk assessment process will face difficulties in being adopted and in complying with the WTO SPS Agreement, when trade restriction is involved (WTO, 1995; Dahlstrom, Hewitt and Campbell, 2011).

It will be important to have a list of species whose entry into the EU is prohibited. However, it will be equally important that all of the species on this list are risk assessed (European Commission,

2013). It will be necessary to establish expert panels throughout the EU and farther afield that are familiar with the species on the list and with risk assessment methodologies. These panels should include invasive-species scientists, regulators and policy-makers, economists and relevant stakeholders. It may also be necessary to obtain pan-European agreement on a standardized risk assessment method that will be applicable to all species and countries involved. Work performed within the framework of the European and Mediterranean Plant Protection Organization (EPPO) and the PRATIQUE and IMPASSE projects is a good starting point to address adequately the issues of IAS prioritization and risk assessment.

4.1.10. Knowledge gaps in risk assessment

A large number of case studies demonstrate that aquatic invasions can reduce native biodiversity and alter water quality, contaminant cycling, food webs and fishery yields (Ricciardi and MacIsaac, 2011). Unfortunately, managers lack appropriate risk assessment methods to prioritize invasion threats because few general models or "rules of thumb" exist on which to predict the occurrence and impacts of IAS. Thus, risk assessment is limited by knowledge gaps and uncertainty.

The importance of knowledge gaps and confidence limits is clear in the background requirements of the risk assessment but no provision has been made in the actual risk assessment to undertake critical research and development (R&D) for gap filling. Levels of confidence in risk assessments are usually allocated low, medium or high, depending on the opinion of the risk assessor on the answer to the standard risk assessment questions. While some electronic systems exist (e.g. CAPRA http://capra.eppo.org) that analyse confidence limits, there appears to be little quantitative assessment of these limits.

While funding for comprehensive risk assessments is generally inadequate, the scientific challenges to prediction are also extensive. For example, impacts of the same species may vary over time and space owing to localized habitat differences (Ricciardi, 2003; Strayer *et al*., 2006). Moreover, invaders can interact with one another (Ricciardi, 2001) and with other stressors (Didham *et al*., 2007) to produce unpredictable effects. Such events are expected to become more frequent as introduced species accumulate in aquatic systems, decreasing predictive power in highly invaded systems (e.g. Ricciardi, 2001).

Furthermore, the invasiveness of a species cannot be used as an indicator of its potential damage, as there appears to be no relationship between the ecological impact of an introduced species and its ability to spread (Ricciardi and Cohen, 2007). Highly successful invaders do not necessarily cause the greatest local impacts, whereas poor colonizers can be highly disruptive where they are established. Thus, risk assessments are limited by the quality of information available for both colonization and ecological impact. Similarly, impact data are often scarce, even for species that are deemed to be major invasion threats (Kulhanek, Ricciardi and Leung, 2011). This is a major impediment to risk assessment.

The R&D needed to complete the basic risk assessment or to increase the confidence level in the recommendation of the risk assessment has to be targeted. Confidence limits should be based on (at least) semi-quantitative systems (e.g. using the number of published studies related to questions answered). In addition, actively managed databases with sufficient quantitative data on all IAS are needed in order to make impact information readily accessible to scientists and managers.

4.1.11. The importance of economic analysis in risk assessment

Risk assessments allow decision-makers to determine the priority species that warrant intensive prevention, control and/or other management efforts. Economic considerations should form part of these assessments so that species that are more likely to cause an economic problem, for example by disruption of ecosystem services or reduction in recreational benefits to the general

public, can be given a higher priority. While multiple species can make their way into an ecosystem, not every species poses the same level of risk or cost. Recognizing that time and money are limited means that allocating resources to priority areas requires an understanding of the economic risks associated with various species. Attempts to incorporate economic analysis into risk assessment should examine the risk level at which the priority species are to be examined and evaluated for their potential harm. The economic resources allocated to prevention, control and various management strategies should reflect the relative risks associated with different species, with priority given to the most harmful species. Economic meta-analysis could be used, based on other species with similar attributes in similar ecosystems, as new data for species-specific risk assessment are unlikely to be easily or quickly compiled.

A serious limitation is the lack of data that are readily available for use in economic analyses of the potential costs of new IAS introductions. Meta-analysis is still viewed with suspicion by some, relating to the tendency of research to be narrowly case-focused. Given that time and money are scarce, broadening the metrics towards creating data for a meta-analysis is likely to represent a low priority. Another limitation is the low level of communication between invasive species scientists and economists, with the two groups working in parallel rather than collaboratively. This lack of collaboration can also reduce the effectiveness of management options and allocation of resources.

Risk assessment studies should be conducted so that standard summary statistics and data are compiled in a consistent manner to allow cross-comparison. For early stage invasions, an economic risk assessment could be conducted using meta-analysis to provide an early indication of economic damage. This would also foster collaboration between economists and invasive-species scientists. Education regarding the capabilities of meta-analysis should be more widely disseminated.

4.1.12. Rapid response – a vital tool in IAS management

Prevention is preferable and less costly than the management of IAS. However, where prevention is not possible, early detection and rapid response are the next most cost-effective lines of approach. Effective early detection and rapid reaction increase the likelihood that a response will be effective, while also preventing the further spread and the ecological and economic damage caused by IAS (Genovesi 2005).

Rapid response is most effective where timely action can bring about eradication or significant containment of the targeted IAS. Rapid response programmes need to be initiated quickly and implemented thoroughly if successful eradication is to be achieved. Wotton and Hewitt (2004) identify three main components of an effective rapid response system: (i) processes and plans to guide response actions; (ii) tools with which to respond; and (iii) the capability and resources to carry out the response.

Rapid-response protocols and procedures have been developed in many countries throughout the EU. Most agree that within individual MS a lead agency or coordinating body, with the authority and resources to act, is required to steer the process. This lead agency will oversee the implementation of the rapid response within that MS while also facilitating communication with government departments, environmental agencies, stakeholder groups and the public. Talking, planning and consensus-making should be conducted before the introduction of the IAS. Once an introduction occurs, a system needs to be in place that allows for rapid decision-making, allocation of resources, and immediate deployment.

In a number of European countries, rapid-response protocols have not been developed or, if processes are in place, are inadequately resourced and seldom activated (Genovesi *et al*., 2010). Rapid-response protocols should ensure and facilitate the availability of trained personnel, equipment, licences/permits and other resources to contain and potentially eradicate newly detected IAS.

Each MS should establish a lead or responsible agency with the capacity and authority to deliver an agreed rapid-response protocol. This agency should receive input from government departments, environmental agencies, industry/academic and other stakeholder or volunteer groups in order to develop effective rapid-response protocols. Each of these groups should have a designated point of contact responsible for coordinating activities and conveying information to the lead agency.

To save time and resources, it may be prudent to seek preapprovals for any authorizations, licences or consents that may be needed in order to legally undertake action. In addition, advocacy and education at all levels within each country will be required in order to develop the political and societal will to commit sufficient funds for rapid-response emergencies.

4.1.13. Emergency powers to manage IAS

The benefits (both economic and ecological) from eradication of a known IAS early in the invasion stage, or in a pre-release stage, are obvious. The cost–benefit ratio of removal of small numbers of IAS is probably in the order of 100 000s to 1 over time. For example, the cost to control *Ludwigia grandiflora* in the United Kingdom of Great Britain and Northern Ireland in 2010 was about GBP 75 000 (equivalent to about USD 115 000[47]), whereas if the species were left uncontrolled for 5–10 years, the cost is estimated to rise to about GBP 80 million (equivalent to about USD 122 million) (Williams *et al*., 2010). *Ludwigia* is not an expensive species to control, but with submerged macrophyte species, fish species and invasive mollusc species, the costs are considerably higher, resulting in cost–benefit ratios of early intervention in the order of 10 000 to 1 (Williams *et al*., 2010). The lack of herbicides for use in aquatic situations has resulted in excessive costs for treatment of many submerged macrophyte and algal species. The requirements for monitoring and assessment prior to control have often resulted in population explosions of IAS that are now difficult to control or manage effectively (e.g. *Lagarosiphon major* in Lough Corrib, Ireland [Caffrey *et al*., 2011] and *Hydrocotyle ranunculoides* in the United Kingdom of Great Britain and Northern Ireland [Duenas and Newman 2010]). It is important that effective management tools are made available to IAS managers to limit spread or eradicate IAS where possible.

The primary obstacles to rapid action are restrictions on the use of tools by the EU (e.g. European Communities [Plant Protection Products] Regulations 2012, European Food Safety Authority [EFSA], WFD, etc.). The intention of primary water legislation has been to improve water quality, but it has precluded the use of many effective management tools (e.g. aquatic herbicides for use on submerged weeds). There are many conflicting pieces of legislation that countries are required to comply with. The WFD requires all watercourses to be of at least good ecological status by 2015. However, the presence of IAS can stop a waterbody achieving this. Other legal obligations prevent the control or management of IAS and so, inevitably, many waters in most EU countries could fail to achieve good ecological status because of confused legislation. The organizations capable and willing to undertake IAS control exist in most countries, but they are hampered by legislation designed for other purposes. It is hoped that the enactment of the new EU Regulation on IAS (European Commission, 2013) will assist the management of nuisance IAS by simplifying national approaches to the control of such species.

A potential solution to supranational obstacles would be to implement national legislation requiring control or active management of IAS by the most effective method, and providing derogations from EU and current national legislation implemented as a consequence of EU membership.

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[47] See note 4

4.1.14. Novel control In IAS management

Most current IAS control strategies rely on traditional technologies including removal by hand, net or machine, chemical application of pesticides or biocides, electricity, and structural barriers. These are all fairly low-tech, and there is a need to embrace innovative control techniques to maximize control efficacy and minimize economic and environmental management costs. Some tried and tested techniques, such as weed biocontrol, are considered innovative in Europe and are underutilized despite their routine use elsewhere in the world (Sheppard *et al*., 2006). In most European countries, where the use of chemicals is extremely limited by legislation, physical removal of aquatic weeds is common practice (Caffrey *et al*., 2011). In fisheries management, there are primarily only two chemical tools applied the piscicide rotenone and copper-based molluscicides. Traditionally, fish are controlled and managed primarily by netting and electrical applications. For invasive mussel control, physical removal is conducted by divers or using heavy industrial equipment. Such operations can incur high labour and infrastructure costs. Very little biocontrol technology has been developed for fisheries other than using triploidy in some fish.

Examples of innovation and highly effective IAS control methods in current use include: the use of specific biological control agents from the country of origin of the targeted IAS; the use of non-chemical approaches to macrophytes, such as light exclusion using biodegradable jute matting (Caffrey *et al*., 2010) and inert dyes (McNabb, 2003) and electromagnetism; alarm pheromones as management tools for invasive amphibians (Hagman and Shine, 2009); encapsulated particles that contain poisons to target specific filter-feeding bivalves (Costa, Aldridge and Moggridge, 2011; Calazans *et al*., 2013); selective naturally derived biocides for zebra mussel control (Meehan *et al*., 2013); sound/pressure waves to deter or eradicate invasive fish (Gross *et al*., 2013); and electrical fields as barriers or deterrents to IAS (Rahel, 2013), and electric fields to control crustaceans, molluscs and amphibians; as well as integrated management using novel combinations of herbicide and pathogen to target invasive alien weeds (Weaver and Lyn, 2007; Weaver *et al*., 2007).

Perhaps the single-most important future challenge to developing novel control methods and implementing them on a broad scale is the lack of funding for primary research. Commonly, control/management of IAS is viewed as a public-good activity and, consequently, funding is limited as there is little return for a would-be investor. In addition, legislation and policy may unintentionally impede the development and use of novel approaches. It is vitally important to fully research and implement novel techniques, including biocontrol, as their availability will restrict the use of inappropriate and occasionally dangerous control techniques. Adequately funded, sustained research is required, including technology transfer from primary research to commercialization by the business sector. All potential interventions should be clearly described and available for land managers (whether private or government) to act upon based on both economic and environmental criteria.

4.1.15. Knowledge transfer to improve IAS management

Knowledge transfer between those engaged in research, policy and management is of the utmost importance if successful IAS management initiatives are to be implemented. These initiatives need to inform society's perception of IAS and take into account the demands of stakeholders from all sectors. They also need to utilize carefully the resources that are available. Owing to the magnitude of the IAS problem in the EU, it is important to encourage cooperation and knowledge transfer between scientists of various disciplines (e.g. ecology, economy, geography, geology, climatology) (Eisworth and Johnson, 2002; Hibbard and Janetos, 2013) as well as management practitioners and policy-makers (Wainger and Mazzotta, 2011). It is also important that the flow of knowledge goes in both directions, with managers and policy-makers informing researchers, and vice versa. Each field of expertise has its own strengths, approaches and knowledge concerning IAS, but each also has its own limitations. Collaboration, cooperation and knowledge transfer help to achieve a synergistic approach, which should improve the level of success achievable in IAS management.

4.1.16. Outreach to foster improved IAS management

Usually, IAS spread as the unintended consequence of people's activities, whether through leisure, work or disposing of waste (Perrings *et al*., 2005). Unless policy recognizes that most IAS are introduced and spread by ignorance, and address this issue with targeted programmes that will result in behavioural change, the environment will continue to be affected by repeated invasions.

The CBD recognizes prevention as the most cost-effective element of IAS management. Prevention may involve recognizing and managing pathways of invasion or changing public behaviour to prevent IAS from entering the wild. A key factor in influencing behavioural change is ensuring that all sectors of the population are aware of the issue, feel engaged and are encouraged to contribute actively to solving the problem.

The public are generally receptive to awareness campaigns and are often keen to engage in IAS control programmes, once they understand the associated impacts. In the last 15 years, public engagement with IAS in the United Kingdom of Great Britain and Northern Ireland has given rise to more than 80 local action groups (LAGs). These LAGs vary in their composition and remit. Groups often begin with control of an invasive species, and then progress onto awareness raising and making contributions towards national eradication campaigns. This has included the delivery of national biosecurity awareness campaigns. In addition to providing a means for the public to contribute actively to invasive species management, they also provide a forum for relevant public bodies, NGOs and landowners to share resources and coordinate their work.

The provision of appropriate funding is the greatest impediment to delivering local action. It is also important that there be coherence and consistency in the terminology and message being delivered through IAS awareness campaigns. The promotion of biosecurity for the prevention and spread of IAS remains a key challenge, particularly with industry.

European funding to assist with public engagement, awareness raising and local action should be made available through LIFE+, Horizon 2020, INTERREG or other funding streams. To date, corporate sponsorship has been an underutilized area of funding. Opportunities for cooperation between LAGs across Europe should be encouraged and facilitated. Similarly, cooperation between LAGs and industry should be encouraged and supported by government. It is vital that industry and the commercial sector become more engaged in implementing preventive biosecurity measures.

4.1.17. Effective communication to raise awareness of IAS

It is essential to maintain and enhance the profile of IAS with the public, policy-makers and other stakeholders to achieve appropriate surveillance, early warning and rapid response. Recent publications that downplay the importance of IAS as environmental pressures have undermined the profile of invasive species (Richardson and Ricciardi, 2013). Effective communication of clear messages is essential to raise awareness of the real threat posed by IAS. Such communication should be centred on species, habitats and invasion biology. There are excellent examples of successful awareness raising campaigns such as "Check, Clean, Dry" and "Be Plant Wise" (e.g. www.nonnativespecies.org), but it is important to reiterate key messages regularly to ensure appropriate and effective responses. However, all this relies on appropriate information delivered in a non-technical and accessible format. There is a possibility that people become complacent with respect to IAS and, therefore, it is critical to maintain interest through continued effort. Raising awareness successfully relies on a multitude of traditional and innovative approaches from printed materials, press releases and public events to social media and other web-based applications, but resources are required for publication and dissemination of materials. It is also critical that relevant information can be displayed in appropriate locations, for example at points of entry to a country such as ports and airports. Therefore, there should be an explicit requirement for raising of IAS awareness

to be embedded within legislation, highlighting the economic benefits of early warning and rapid response.

The development and adoption of innovative communication methods using new technologies should be prioritized. Regular sharing of good practice through web-based resources and webinars is essential. However, it is important to adapt resources to recognize cultural differences between countries. There will be cases where an approach designed for a local issue will be more effective than a national campaign. Establishment of local networks (including LAGs), such as those coordinated by the Great Britain Non-native Species Secretariat (GB NNSS), could provide an effective method for dissemination of key messages. In addition, targeted campaigns designed for specific groups, such as anglers or recreational boat users, could be more effective than generic campaigns for all. The recent guide commissioned by the UK Environmental Observation Framework "Guide to Citizen Science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK" provides a framework for public-facing campaigns (Tweddle *et al*., 2012). The EU LIFE+ CAISIE project document "Guidelines on Effective Stakeholder Engagement Programmes for Invasive Species Management" also provides specific and targeted guidance for stakeholders on this issue (Inland Fisheries Ireland, 2013). Rapid and effective implementation of strategies will be essential to underpin all priority issues in relation to IAS. Measures of success can be difficult to determine for communication campaigns, but priority should be given to evaluation. It is important to review and adapt communication mechanisms on a regular basis to maximize efficacy.

4.1.18. Non-market valuation in IAS economic assessment

Freshwater ecosystems provide many valuable services to society (Carpenter, Stanley and Vander Zanden, 2011). While the value of some of these services (e.g. water for domestic use, wild fish and aquaculture for direct consumption) is easier to quantify as they tend to be traded in established markets, the value of many other services is rarely captured. These non-market values include carbon sequestration, waste assimilation, habitat conservation and recreation opportunities provision. Without incorporating the value of these services into the decision-making process, their loss owing to the occurrence of an IAS may be ignored or underestimated, resulting in a net loss to society.

Economic costs of IAS are usually associated with: (i) production loss; (ii) preventing introductions; (iii) monitoring existing populations; and (iv) conducting control or eradication schemes. The total cost tends to ignore the loss of non-market ecosystem services that may result. When monetary values are assigned to the loss of non-market ecosystem services, the estimate of the total costs increases significantly (Williams *et al*., 2010). Many of the impacts resulting from the loss of non-market service can be valued through an approximation known as "willingness to pay" for changes in the provision of the service. Methods developed to estimate the value of these services range from revealed preference (based on consumer actions) to survey-based stated preference methods (Hanley, Barbier and Barbier, 2009).

The main limitations to including non-market values in an economic assessment of freshwater IAS are the difficulty of generating estimates of these non-use values and disagreements over the best quantitative methods. There are further difficulties in predicting the nature and magnitude of impacts. Moreover, lack of uniformity in methodologies can make it difficult to compare the cost of invaders across catchments or regions.

It will be important that economic analysis investigates the value, in monetary terms, of the loss in non-market goods and services rather than just report the financial price of production loss and invasive management. Policy-makers need to be educated about the existence of associated non-use costs. Adopting standard valuation methodologies across impact studies related to the same IAS would also greatly improve the usability and comparability of non-market valuation exercises in

making policy decisions. A database of non-market estimates related to waterbodies should also be compiled. Benefit transfer (BT) can be used where the values of an ecosystem service from another already completed study site can be applied to the policy site of interest.

4.1.19. Cost analysis in IAS management

Costs associated with IAS management need to be justifiable, as they are commonly significant. To justify these costs two economic approaches can be taken. Cost–benefit analysis (CBA) will determine the value of benefits over costs, while cost-effectiveness analysis (CEA) will quantify and compare the cost of different management options. Benefits that should be included in a CBA include values associated with the existence and production of native species, ecosystem services provided by the affected species, and employment opportunities created by them. Costs should include loss of benefits caused by the IAS, as well as expenditure on their control and eradication. Other costs include reduced recreational activity opportunities, increased pest damage and decreased productivity. Utilizing CBA or CEA enables managers to justify their spending on IAS management by demonstrating that the most effective control methods are being used, or that there is an economic benefit to justify the costs.

The main limitations to including CBA and CEA in IAS management planning are cost and associated resources. The CBA and CEA processes have considerable data requirements, with detailed information needed on the costs of an action as well as the economic benefits that will be accrued. Limited data exist regarding the benefits associated with IAS removal (e.g. management costs saved) and, although environmental valuation techniques can place a monetary value on the benefits, the associated data collection can be time-consuming and expensive. The time required to conduct a reliable CBA is an issue where a rapid response is needed, especially in the case of a new IAS threat. Species prioritization will be required as it is unlikely that sufficient resources will exist to carry out a CBA or CEA for all IAS. A CEA is less costly because only direct costs of each management option are included.

As cost is the main constraint to carrying out CBAs and CEAs, appropriate funding needs to be included in annual budgets of MS. However, this will only happen when budget-makers understand both the related importance and need for these in the IAS management decision-making process.

4.1.20. Single responsible agency – the answer to national IAS management

New EU legislation on IAS should provide controls to limit the spread of listed invasive species from nations trading into the EU, while also offering a mechanism to control the spread of these species between MS. In order to manage IAS in the EU effectively, it is critical that MS with shared borders collaborate and communicate fully, and share common expertise, information and responsibility relating to IAS. Island MS are well positioned to control the import of invasive species at their borders, but they need to share IAS lists and alerts with other MS and even countries outside the EU.

In order to develop a coherent and coordinated national approach to IAS, it is necessary to identify clear lines of responsibility that will support coordination between national agencies and government departments. Moreover, a robust approach to IAS management will require expertise and support from diverse interests, including specialists, stakeholders, government departments, regulators and administrations. It is considered that a single and appropriately resourced group or agency with a clear national responsibility for IAS is required to facilitate the coordination required to spearhead this national approach.

The management of IAS at MS and EU levels is uncoordinated, with responsibilities split between different MS and among various national agencies and government departments. Moreover,

some governments do not fully recognize the threats posed by IAS and have not considered the business case for investment in prevention. The MS need to work proactively to implement the new EU IAS Regulation effectively. In addition, the EU should support MS in controlling the spread of listed IAS from trading blocks outside the EU. A single agency with a clear national responsibility for IAS is required within each MS. In addition, a coordinated approach to the control and spread of IAS to island States, which have a unique control advantage, is required.

4.2. Synthesis of key management recommendations

While the Top 20 issues described above represent stand-alone threats posed by IAS to biodiversity, environment, ecosystem function, the economy and even human health, a number of significant cross-cutting themes are apparent. These are important when considering the management recommendations and advice offered in the publication, and they are discussed below under four main headers: knowledge exchange requirements, resource issues, developing common strategies and the regulatory framework.

The conference demonstrated that networking among a range of scientists, academics, politicians, policy-makers, economists, managers, practitioners and key stakeholder representatives provided a thorough analysis and identification of the Top 20 IAS issues in Europe. Moreover, developing and maintaining these international networks can be used to develop practical and consistent IAS management advice throughout Europe, using the new Regulation as a core instrument. These networks could then be utilized to produce key performance indicators to determine the effectiveness of IAS management. This should be a dynamic and iterative process in line with the typical unpredictability of IAS spread and resulting invasion impacts.

4.2.1. Knowledge exchange requirements

Each of the four pillars, i.e. biosecurity, economics, management and risk assessment, and policy, highlighted the need for consolidation of knowledge. In fact, more than 50 percent (11 out of 20) of the issues concerned knowledge requirements. This varied from diverse education and training needs required for biosecurity and risk assessment, to the development of communication networks for early warning systems. There is an identified requirement for increased awareness of IAS among both the public and the legislature. Outreach programmes for the public are needed in order to minimize accidental introductions of IAS. Knowledge exchange between scientists, practitioners and policy-makers should be encouraged to foster channels of communication in order to improve understanding of individual roles and develop a coordinated approach to IAS management. There is also a need to disseminate information on the advantages of new technologies. Policy-makers also require education on the existence of non-market costs and, in order to evaluate these costs, biologists need to effectively network with socio-economists to develop combined analyses. If a coordinated international best practice for biosecurity and risk assessment is to be developed, there needs to be a consistent and informed approach. This requires knowledge sharing and networking among international experts. A similar approach could address knowledge gaps in risk assessment methods. Knowledge requirements identified in the Top 20 issues can be broadly categorized under two headings, i.e. training and networking, each of which have associated resource issues.

4.2.2. Resource issues

Resource issues were identified on both the national and international levels of scale. The FINS delegates explicitly stated that a centralized funding source was needed at EU level to remediate the current lack of funding, specialist staff and appropriate equipment needed for IAS management. Outreach programmes also require EU financial resourcing for public engagement, awareness raising and the establishment of LAGs. Funding is also required for the R&D of novel control methods (e.g. biocontrol). In order to leverage funding, effective cost analysis and non-market evaluations need to become part of IAS management. Evidence of the total pecuniary and societal costs of invasions

allows for better decision-making in IAS management. Financial resourcing is also needed to target the R&D needed to increase the confidence levels in risk assessment methods. It is clear that funding is required for all of the Top 20 issues. However, investment in networking (that informs management), outreach (that mitigates accidental spread), new technologies (for control) and cost analysis (that informs priorities for management decisions) will reduce the economic and ecological long-term costs of invasions.

4.2.3. Developing common strategies

Common strategies were also a cross-cutting theme for all the four distinct pillars. In particular, there is no consistency of approach or coordination to biosecurity between EU member states and other countries. This is unacceptable as biosecurity activities start offshore or pre-border in order to reduce the risks of invasion. The workshop recommended the sharing of best practice in Europe and further afield via established fora (e.g. New Zealand Bio-Protection Research Centre; South Africa Centre for Invasion Biology; Australian Department of Agriculture, Food and Fisheries; GB NNSS). These could also be used to develop standards to prevent the introduction of IAS and to provide an international system for early warning mechanisms. A lead organization is required at the national level within each MS in order to coordinate rapid response. Expert panels are required in order to develop and conduct risk assessments. The responsibility for IAS management is often fragmented at the national level. This can blur the clear lines of responsibility between national and government agencies. Highly variable governance structures within different countries make the development of a common approach problematic. These issues appear to indicate that only a single responsible agency, with representation from the MS, will be able to provide a mechanism to achieve effective national IAS management within the EU.

4.2.4. Regulatory framework

The EU could legislate for a common approach to prevent and manage the introduction and spread of IAS in its territory. Currently, the majority of IAS are only covered by peripherally relevant legislation (e.g. the Habitats Directive and the WFD). In 2013, the European Commission published a proposal for a Regulation on IAS. The proposal aims to establish a framework for action to prevent, minimize and mitigate the adverse impacts of IAS on biodiversity and ecosystem services. The outcomes from the FINS workshops fully support the need for such European legislation on IAS and highlight the issues that need to be addressed by this legislation. The narrative that accompanies each of the issues in this paper should serve to assist and guide the policy-makers and legislature in the implementation of this important and urgently needed Regulation.

4.3. EIFAAC advisory group on IAS

Another important outcome from the conference was the establishment of an international advisory group of invasive-species experts. During the conference, a number of delegates were invited to join this advisory group, the aim of which is to assist and support the existing EIFAAC panel of invasive species experts in achieving the broad objectives of the EIFAAC project on the "Aquatic Invasive Species in Europe" (see Appendix 2) while also assisting with other more broad-based issues relating to IAS. Foremost among these goals was to inform the development of the proposed EU Regulation on IAS and to promote and support its implementation, particularly from an EIFAAC perspective, when it becomes law in January 2015. The following experts now comprise the EIFAAC Advisory Group on IAS:

- Colin Bean, Senior Science and Policy Adviser, Scottish National Heritage, the United Kingdom of Great Britain and Northern Ireland
- Jaimie Dick, Professor of Invasion Ecology, School of Biological Sciences, MBC, Queen's University Belfast, Belfast, the United Kingdom of Great Britain and Northern Ireland
- Daniel Hefti, Federal Office for the Environment, Species Management, Berne, Switzerland

- Stephanie Hudin, Chief Scientist, Conservatoires d'espaces naturels, Orleans, France
- Frances Lucy, Director of Centre for Environmental Research Innovation and Sustainability, IT Sligo, Ireland
- Vincent Medoc, Institute of Ecology and Environmental Sciences, University Pierre et Marie Curie, Paris, France
- Marina Piria, Senior Lecturer, Faculty of Agriculture, Department of Fisheries, Zagreb, Croatia
- Teppo Vehanen, Finnish Game and Fisheries Research Institute, Finland
- Hugo Verreycken, Senior Scientist, Research Institute for Nature and Forest (INBO), Groenendaal, Belgium.

5. THE WAY FORWARD

Invasive alien species (IAS) continue to represent a significant threat to global biodiversity, ecosystem services and the economy. Cognizant of this and in light of the fact that a new EU IAS Regulation was pending, world invasive-species experts were gathered at a conference in Ireland to review the status of aquatic IAS in Europe and to determine the issues relating to these damaging species that were deemed the most important or critical. As a result of these deliberations, a list of issues, here referred to as the Top 20 IAS issues, was agreed as described in the chapters above. Not only were the principle threats posed by IAS identified, but also management recommendations in respect of each of the Top 20 issues were identified.

To ensure that the best use is made of the outcomes from this international conference, it is important that they are widely disseminated, within and beyond Europe, to the broadest relevant audience. Hence, in addition to their inclusion in the open-access journal *Management of Biological Invasions* (http://dx.doi.org/10.3391/mbi.2014.5.1.01) in April 2014, the results are also published in this EIFAAC Occasional Paper. Furthermore, the results from the conference have been discussed at a number of international IAS meetings.

Central to many of the recommendations made to address the Top 20 IAS issues is the need for a unified or shared approach to IAS across all MS in Europe. This relates to training, biosecurity awareness, best practice for control and management, early warning and risk assessment methods, policy development and funding. Ongoing cooperation, communication and knowledge exchange between MS are imperative in order to ensure that a coherent and coordinated approach is taken to the threats posed by IAS. Within MS, open lines of communication need to be maintained between academics, scientists, practitioners and policy-makers if they are is to understand their individual roles and to work in a unified manner to manage IAS.

Conference delegates were at one in demanding that a centralized funding source, at EU level, be provided to counteract the lack of funding, specialist expertise and appropriate equipment available in most MS. Without adequate resources, individual MS will not be in a position to address imminent IAS issues. Centralized investment now will reduce the economic and ecological long-term costs of invasions. It is imperative that this message be brought to the attention of the EU.

The conference clearly identified the fact that there is no consistency of approach or coordination to biosecurity between EU MS and other countries. To address this, Europe should become acquainted with and implement best biosecurity practice as operated in countries such as New Zealand, Australia and South Africa. Here, infringement of biosecurity regulations is not tolerated and, as a consequence, the rate of IAS introduction to these countries is minimized.

A further consensus that emerged from the conference was the need for a single responsible agency at EU level, with representatives from each MS, to coordinate activities relating to IAS control

and management. Failure to establish such a central agency will result in an uncoordinated and fragmented approach to these damaging species.

Now that the Council of the European Union has adopted the "Regulation on the prevention and management of the introduction and spread of invasive alien species (PE-CONS 70/14)" it is important that the Top 20 IAS issues elucidated during the FINS conference be brought to the attention of the EU legislature. Many of the threats identified by the conference are similarly noted in the Regulations, and the recommendations issued here will be of significant value to those charged with implementing the Regulations. It will be important to ensure that all relevant documentation relating to the Top 20 IAS issues and recommendations to address these are made available to those officers in the EU charged with implementing the Regulations.

Experts at the FINS Conference identified issues that are relevant to all IAS, whether freshwater, marine or terrestrial, and across broad taxonomic and trophic groups. The outcomes from the conference should be used to educate IAS managers, stakeholders, policy-makers and the public at large. In addition, IAS managers in MS throughout Europe should be actively encouraged to incorporate the recommendations into their ongoing development and operation programmes.

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Appendix 1

FINS organizing committee

Chairman

Joe Caffrey, Inland Fisheries Ireland, Dublin, Ireland

Members

Jaimie Dick, Queen's University Belfast, Belfast, United Kingdom of Great Britain and Northern Ireland

Cathal Gallagher, Inland Fisheries Ireland, Dublin, Ireland

* Francesca Gherardi, University of Florence, Rome, Italy

Frances Lucy, Institute of Technology, Sligo, Ireland

Cathy Maguire, European Environment Agency

Niall Moore, GB-Non-Native Species Secretariat, United Kingdom of Great Britain and Northern Ireland

Maria Piria, University of Zagreb, Zagreb, Croatia

Odd Sandlund, Norwegian Institute for Nature Research, Norway

* Francesca Gherardi sadly passed away in January 2013. May she rest in peace.

Appendix 2

EIFAAC Project on Aquatic Invasive Species in Europe

In January 2012, a project proposal entitled 'Management/Threat of Aquatic Invasive Species in Europe' was submitted to EIFAAC by Joe Caffrey (Inland Fisheries Ireland) for consideration. The project was agreed by both the Technical and Scientific and the Management Committees and commenced in early 2013. It was agreed that Joe Caffrey would chair the EIFAAC project team that would be responsible for project delivery.

The objectives as set out in the agreed project proposal were:

1: To convene a conference of aquatic invasive species managers, scientists and policy-makers from EIFAAC countries and from farther afield to drive the objectives below, by Q2 2013.

2: To inform the development of the pending EU Invasive Species Strategy (which may result in the development of a European Directive), by Q2 2013. The conference proceedings will detail the outcomes from detailed workshop sessions and will aim to directly influence the draft Strategy. In addition, an oral presentation of the outcomes from the conference and workshops will be offered to the authors of this document.

3: To develop a coordinated approach to forecasting (using best Risk Analysis practice) aquatic invasive species invasions, by Q4 2015.

4: To produce an effective deterrent to the advance of aquatic invasive species. This will involve harmonizing alert, rapid reaction, control and management, and mitigation programmes that currently exist in member countries, by Q4 2015.

5: To develop and coordinate international biosecurity protocols and approaches within Europe, by Q4 2015.

Appendix 3

Published scientific paper from the FINS Conference in 2013 – reference and abstract

Management of Biological Invasions (2014) Volume 5, Issue 1: 1–20
http://dx.doi.org/10.3391/mbi.2014.5.1.01
Open Access
Tackling Invasive Alien Species in Europe: the Top 20 Issues
Joe M. Caffrey *et al.*

Abstract

Globally, Invasive Alien Species (IAS) are considered to be one of the major threats to native biodiversity, with the World Conservation Union (IUCN) citing their impacts as 'immense, insidious, and usually irreversible'. It is estimated that 11 percent of the *c*. 12 000 alien species in Europe are invasive, causing environmental, economic and social damage; and it is reasonable to expect that the rate of biological invasions into Europe will increase in the coming years. In order to assess the current position regarding IAS in Europe and to determine the issues that were deemed to be most important or critical regarding these damaging species, the international Freshwater Invasives - Networking for Strategy (FINS) conference was convened in Ireland in April 2013. Delegates from throughout Europe and invited speakers from around the world were brought together for the conference. These comprised academics, applied scientists, policy-makers, politicians, practitioners and representative stakeholder groups. A horizon scanning and issue prioritization approach was used by in excess of 100 expert delegates in a workshop setting to elucidate the Top 20 IAS issues in Europe. These issues do not focus solely on freshwater habitats and taxa but relate also to marine and terrestrial situations. The Top 20 issues that resulted represent a tool for IAS management and should also be used to support policy-makers as they prepare European IAS legislation.

Appendix 4

Example of priority issues submission by delegates prior to conference

Name (1)	Topic (2)	Issue (3)	Description (4)	Urgency (5)	Risk (6)	Feasibility (7)	Specific/ Broad (8)	Barrier (9)	Best Practice/ Solution (10)
Joe Caffrey	BIO	Chemical elimination	Legislative barriers to quick response	10	10	5	8	EU Legislation	Disinfection using solution
Jaimie Dick	BIO	Small scale water vectors	Problems with transportation of water etc in small craft in Europe	7	8	5	8	Finances, enforce-ment	Ballast Water Regulations N. America
Jaimie Dick	BIO	Ports/customs	Failure to detect invasives	10	10	3	8	Finances	NZ, Australian customs
Jaimie Dick	BIO	Pet, aquarium trade	Release of pets/aquaria contents	6	7	5	6	Legislation	
Niall Moore	BIO	Pathway assessment prioritization and management	Similar to Jamie's one at 11 but a bit broader.	8	9	5	10	No standardized accepted methodo-logy	
Frances Lucy	BIO	Internet trade	Failure to block imports	10	10	3	7	Legislation	Education/ outreach
Frances Lucy	BIO	Spread by agencies/LA	Poor work practice	7	7	8	8	Enforce-ment	Disinfection/ Education
Frances Lucy	BIO	Ignorance of the facts	No awareness of biosecurity issue	10	7	7	10		Education/ outreach
Hugh MacIsaac	BIO	Wood dunnage	Policies enforced?	10	9	9	8	Enforce-ment	
Hugh MacIsaac	BIO	Hull fouling	Poorly studies in most countries	10	10	7	8	Research	Australia RA for ships
Hugh MacIsaac	BIO	Climate change	Tropical species in temp areas, temp ones in arctic?	9	8	7	7	Research	
Frances Williams	BIO	Public awareness	Lack of awareness of IAS, therefore unwitting spread by public (including commercially) into a country	7	8	9	8		NZ, Australian customs

Notes:

1 Delegate's/proposer's name (or ANON)

3 Brief title of issue e.g. biosecurity legislation

4 Describe issue in 20 words or less

5 How urgent is the issue: Score: 1–10 (most urgent=10)

6 Risk if issue not addressed: Score 1–10 (highest risk=10) (risks can be ecological, economic etc.)

7 How feasible is it to address the issue; can it be done quickly: Score 1–10 (highest feasibility=10)

8 In developing a strategy to address the issue, how specific (e.g. to one species), or broad (e.g. spans taxonomic groups) would this be: Score 1-10 (broadest=10)

9 Barriers - what is preventing or might stop progression of the issue?

10 Are there examples of best practice? Comments on solution/best practice

Appendix 5

List of questions regarding pillar themes issued to delegates

Biosecurity	
1	How can we make biosecurity relevant to stakeholders and the wider public?
2	'Carrot or stick' approach - do we need to implement appropriate legislation?
3	What alerts and early warning mechanisms should be made available to facilitate the rapid communication of and rapid reaction to AIS threats?
4	What rapid reaction mechanisms should be made available to facilitate the timely response to AIS threats?
5	Should provision be made in EU legislation for a 'nuclear' option (e.g. *Gyrodactylus* in Norway)?
6	How do we establish co-operation, co-ordination, consistency and cohesion in respect of biosecurity between countries?
7	How to best co-ordinate between agencies on a common approach to AIS biosecurity (e.g. customs / border controls)?
8	How should we use the results from cost benefit analyses for biosecurity measures to drive policy?

Management & Risk Assessment	
1	Risk assessment: should we consider abandoning it and is it fit for purpose?
2	How can we go about developing a standardized methodology for risk management across Europe?
3	How can early detection monitoring systems ensure adequate and timely action ('rapid response')?
4	What is required to create efficient early warning and rapid response capabilities?
5	How to develop mechanisms to increase international knowledge sharing / networking to improve risk assessment and management?
6	How do we justify securing derogations from the EU for the use of herbicides and other chemicals (e.g. rotenone) to respond to specific AIS threats?
7	Should there be greater resources given to biocontrol research to develop effective AIS control methods?
8	Should more funding be given to research for AIS management and to identify and prioritize future invasion threats?
9	How can public awareness be effectively used as a management tool to inform behaviour?
10	How can climate change predictions inform invasive species management?
11	How can we improve networking and technology transfer for the management of AIS?

Policy	
1	Is there a requirement for a dedicated EU legislative instrument on invasive species?
2	How do we raise the profile of invasive species at a national and international political level?
3	Should there be a single agency responsible for IS in Europe and who will fund this?
4	How can we standardize national AIS legislation across Europe?
5	How do we standardize approaches to AIS among public stakeholders within countries?
6	Can the EU Animal Health and Plant Health Directives provide a template to inform the development of AIS legislation?
7	How does policy development impact on stakeholders e.g. angling, boating, aquarium and horticultural trade?
8	Is there a requirement to develop national and non-European AIS black lists - how would these be communicated?
9	Global free trade - how to overcome the barriers and limitations to implementing effective invasive species policies?
10	How can we incorporate IS components into other relevant national and international legislation?
11	How do we 'future proof' policy so that any action required can be quickly taken?

Economics	
1	Cost benefit analyses - is it always worth taking action?
2	How to manage commercially valuable invasive species - what assessment tools can be developed?
3	Should economic considerations be part of invasive species risk management?
4	Should the stakeholder be involved in economic assessment and risk management (e.g. angling, tourism, aquarium and horticulture trade)?
5	How do we assess the true direct and indirect financial cost of invasive species? Do we include every possible element?
6	How to internationally standardize a robust and accepted economic assessment methodology?
7	How can we best identify international funding mechanisms for AIS?
8	How can we best identify potential collaborators to develop international AIS proposals for drawdown of international funding?

Appendix 6

List of participants

Surname	Name	Organization	Country
Ankettell	Tom	IRD Duhallow LIFE+	Ireland
Bacchereti	Simona	Association Europeene pour l'Information sur le Development Local	Belgium
Baars	Jan-Robert	University College Dublin	Ireland
Barbour	Jennifer	Queens University Belfast	United Kingdom
Becker	Colin	Inland Waterways Association of Ireland	Ireland
Boets	Pieter	Ghent University	Belgium
Boon	Philip	Scottish Natural Heritage	United Kingdom
Brazier	Bill	University College Cork	Ireland
Butler	Martin	Inland Fisheries Ireland	Ireland
Byron	Michael	Inland Fisheries Ireland	Ireland
Caffrey	Joe	Inland Fisheries Ireland	Ireland
Callanan	Kevin	Dublin City Council	Ireland
Caplice	Richard	IADA	Ireland
Carlsson	Jens	University College Dublin	Ireland
Casey	Donal	Donegal County Council	Ireland
Chapman	Deborah	University College Cork	Ireland
Collins	Rob	The Rivers Trust	United Kingdom
Clancy	Frances	Geomara	Ireland
Collins	Theresa	IRD Duhallow LIFE+	Ireland
Conneely	John	Inland Fisheries Ireland	Ireland
Connor	Lynda	Inland Fisheries Ireland	Ireland
Cowen	Jonathan	Inland Fisheries Ireland	Ireland
Crudden	John	Angling Council of Ireland	Ireland
Cullagh	Alan	Inland Fisheries Ireland	Ireland
Cusack	Eamon	Institute of Fisheries Management	Ireland
Davenport	Keith	Ornamental Aquatic Trade Association	United Kingdom
Deegan	Bryan	Inland Fisheries Ireland	Ireland
Dick	Jaimie	Queen's University Belfast	United Kingdom
Dillon	Kieran	Revenue Commissioners	Ireland
Doherty	Dennis	Electricity Supply Board	Ireland
Donovan	Tom	INVAS Biosecurity	Ireland
Dooley	Richard	Office of Public Works	Ireland
Earle	William	University College Dublin	Ireland
Early	John	Northern Ireland Environment Agency	United Kingdom
Edsman	Lennart	Swedish University of Agricultural Sciences	Sweden
Ellershaw	Megan	Natural England	United Kingdom
Flynn	John	Inland Fisheries Ireland	Ireland
Follis	Emily	Queens University Belfast	United Kingdom
Freeman	Nuala	Sustainable Water Network (SWAN)	Ireland
Gallagher	Cathal	Inland Fisheries Ireland	Ireland

Gallagher	Tara	Inland Fisheries Ireland	Ireland
Gallagher	Paul	Inland Fisheries Ireland	Ireland
Gavin	Liam	Inland Fisheries Ireland	Ireland
Gebben	David	Queens University Belfast	United Kingdom
Greene	Frank	Inland Fisheries Ireland	Ireland
Greer	Christie	Queens University Belfast	United Kingdom
Gross	Jackson	Smith-Root, Inc.	United States of America
Gustavson	Michael	UCD	Ireland
Hanlon	Paula	Galway County Council	Ireland
Harrison	Rob	ECUS Ltd.	United Kingdom
Harty	Feidhlim	Wetlands Systems	Ireland
Hefti	Daniel	Swiss Federal Office for the Environment	Switzerland
Heinimaa	Petri	Finnish Game & Fisheries Research Institute	Finland
Horrill	Chris	River & Fisheries Trusts of Scotland	United Kingdom
Hudin	Stephanie	Natural areas Conservancies Federation	France
Hulme	Philip	Lincoln University	New Zealand
Hyland	Alison	An Taisce	Ireland
Hynes	Stephen	National University of Galway	Ireland
Jebb	Matthew	National Botanic Gardens	Ireland
Joyce	Rosina	Galway County Council	Ireland
Kalchhauser	Irene	University of Basel	Switzerland
Kane	John	DCAL	United Kingdom
Keatinge	Rory	Geomara	Ireland
Keenan	Elaine	University College Dublin	Ireland
Kelly	Owen	Inland Fisheries Ireland	Ireland
Kelly	Peter	Inland Fisheries Ireland	Ireland
Kelly	Myles	Inland Fisheries Ireland	Ireland
Kelly	Matthew	Geomara	Ireland
Lenihan	Patrick	Mulkear LIFE / Tralee IT	Ireland
Kerins	Catherine	Inland Fisheries Ireland	Ireland
Loennechen	Toril	National Biodiversity Information Centre	Norway
Llanazares	Adela	Madrid	Spain
Lindholm	Markus	Norwegian Institute for Water Research	Norway
Lucy	Frances	Institute Of Technology, Sligo	Ireland
Macklin	Ross	University College Cork	Ireland
MacIsaac	Hugh	University of Windsor	Canada
Malley	Marcus	Craigavon Borough Council	United Kingdom
Mangan	Rosie	UCD	Ireland
Matthews	Milton	Inland Fisheries Ireland	Ireland
Mazaubert	Emilie	National Research Institute of Science & Technology for Environment & Agriculture	France
McCloone	Paul	Inland Fisheries Ireland	Ireland
McEnroe	Martin	Angling Council of Ireland	Ireland
McCole	Con	Carra Mask Corrib Water Protection Group	Ireland
McGavigan	Catherine	Queens University Belfast	United Kingdom

McMullan	Cornelius	Inland Fisheries Ireland	Ireland
Meehan	Sara	Institute of Technology Sligo	Ireland
Millane	Mick	Inland Fisheries Ireland	Ireland
Monaghan	Philip	Galway Mayo Iinstitute of Technology	Ireland
Moore	Niall	GB-Non Native Species Secretariat	United Kingdom
Moran	Helen	Inland Fisheries Ireland	Ireland
Murphy	Paul	EirEco Environmental Consultants	Ireland
Murphy	Kieran	IRD Duhallow LIFE+	Ireland
Murray	Liam	Inland Fisheries Ireland	Ireland
Naughton	Oisin	Inland Fisheries Ireland	Ireland
Newman	Jonathan	Centre for Ecology and Hydrology	United Kingdom
NiChionna	Maire	Galway County Council	Ireland
O'Beirn	Francis	Marine Institute	Ireland
O'Briain	Rossa	Inland Fisheries Ireland	Ireland
O'Conchuir	Ruari	Inland Fisheries Ireland	Ireland
O'Donoghue	Frank	Inland Fisheries Ireland	Ireland
O'Farrell	Martin	Smith-Root Europe Ltd.	Ireland
O'Flynn	Colette	National Biodiversity Data Centre	Ireland
Oidtmann	Birgit	CEFAS	United Kingdom
O'Keeffe	Ciaran	National Parks & Wildlife	Ireland
O'Neill	Ken	Inland Fisheries Ireland	Ireland
O'Reilly	Teresa	West Regional Authority	Ireland
O'Reilly	Sinead	University of Glasgow	United Kingdom
Paolacci	Simona	University College Cork	Ireland
Pattison	Zarah	University of Stirling	United Kingdom
Pender	Clinton	VAKI	Iceland
Persson	Gunnar	Centre for Veterinary Contract Research & Commercial Services Ltd.	Norway
Piria	Marina	University of Zagreb	Croatia
Reid	Adam	DCAL	United Kingdom
Renals	Trevor	Environment Agency	United Kingdom
Ricciardi	Anthony	McGill University, Montreal	Canada
Ring	Tim	IRD Duhallow LIFE+	Ireland
Roesch	Roland	Fisheries Research Station Baden-Wuerttemberg	Germany
Roy	Helen	Centre for Ecology & Hydrology	United Kingdom
Ruane	Cathal	Office of Public Works	Ireland
Russell	Nigel	Waterways Ireland	United Kingdom
Sandlund	Odd	Norwegian Institute for Water Research	Norway
Sarat	Emmanuelle	French National Game & Wildlife Service	France
Shannon	Adam	TSGE LLP	United Kingdom
Shaw	Richard	CABI	United Kingdom
Sheehan	Rory	Institute Of Technology Sligo	Ireland
Smyth	Noeleen	National Botanic Gardens	Ireland

Steinkjer	Jarle	Directorate for Nature Management	Norway
Sutton-Croft	Michael	RINSE (Reducing the Impact of Non-Native Species in Europe)	United Kingdom
Tanner	Robert	CABI	United Kingdom
Thor Asgeirsson	Magnus	Riverwatcher	Iceland
Trodd	Wayne	Environmental Protection Agency	Ireland
Turley	Maurice	Queens University Belfast	United Kingdom
van Valkenburg	Johan	NVWA / National Reference Centre	The Netherlands
Vehanen	Teppo	Finnish Game & Fisheries Research Institute	Finland
Walsh	Daniel	Galway Mayo Institute of Technology	Ireland
Walsh	Peter	Ireland Angling Development Alliance	Ireland
Walsh	Jim	Inland Fisheries Ireland	Ireland
Ward	Bryan	Inland Fisheries Ireland	Ireland
Weyl	Olaf	South African Institute for Aquatic Biodiversity	South Africa
Wilkie	Neil	Astrale LIFE	Ireland
Wightman	Glen	Inland Fisheries Ireland	Ireland
Williams	Frances	CABI	Kenya
Woodford	Daragh	South African Institute for Aquatic Biodiversity	South Africa

Appendix 7

Biographies of invited speakers

Phil Hulme

Since 2007, Mr Philip Hulme is a professor and holds the inaugural Chair in Plant Biosecurity at Lincoln University, a unique position established by Lincoln University and the New Zealand Ministry of Primary Industries, which aims to bridge the gap between academic research and policy implementation in this strategically important field. In this capacity, he leads the World-Leading Biosecurity Theme at the Bio-Protection Research Centre, New Zealand. Prior to taking up his current position he was the Head of Ecosystem Dynamics at the NERC Centre for Ecology & Hydrology in the UK where he coordinated major European programmes on biological invasions including DAISIE (Delivering Alien Invasive Species Inventories for Europe) and within ALARM (Assessing Large Scale Risk to Biodiversity using Tested Methods). His primary research focus is in quantifying, predicting and managing the risks arising from biological invasions. As a leading invasion biologist, has long argued for better communication between scientists and practitioners, and helped identify key disparities between the needs of managers and research priorities while developing tools to better inform invasive species management, risk assessment and policy response. More recently, as an editor of the *Journal of Applied Ecology*, he launched Practitioners' Perspectives a new feature to give voice to stakeholders in mainstream ecology journals.

Joe Caffrey

Mr Joe Caffrey is a Senior Research Officer with Inland Fisheries Ireland (IFI), a statutory body whose primary function is the protection and conservation of the inland fisheries resource. He was awarded his Doctorate in Aquatic Botany from University College Dublin, Ireland, in 1990. He has been employed with IFI and its predecessor organizations since 1976. His principal research interests over this time period have focused on the biology, ecology and management of aquatic macrophytes and non-salmonid freshwater fish species in natural and artificial aquatic habitats. In more recent years his research has brought him into contact with freshwater invasive species and he is currently heading up the Invasive Species Section within IFI. This work involves researching the biology and ecology of freshwater invasive species (whether macrophyte, macroinvertebrate or fish) that are present or are likely to be introduced to Ireland and developing new and innovative methods to control or manage them. He offers advice to the Government in relation to his primary research responsibilities and provides support in the development of national policy and legislation in these areas.

Birgit Oidtmann

Ms Birgit Oidtmann works in the Epidemiology and Risk team at the Centre for Environment, Fisheries and Aquaculture Science (Cefas), an agency of the Department of the Environment, Food and Rural Affairs (Defra). Birgit studied veterinary medicine at the University of Munich (Germany) and was awarded the Dr Vet Med there in 1994. Her area of work ranges from import risk analysis, development of models for risk ranking fish farms, development of surveillance schemes over leading experimental research work to advice to support Defra aquatic animal health policy. Currently, she leads a Defra funded research project on risks associated with commodities imported for human consumption and an European Food Safety Authority (EFSA) funded project on risk categorization of fish farms She worked on an OIE *ad hoc* group on risks associated with aquatic animal commodities and a number of EFSA working groups. She is a guest lecturer and the Royal Veterinary Collage, London. She have been involved in the development of a number of EFSA working groups, e.g. Assessment of the health risks of feeding of ruminants with fishmeal in relation to the risk of TSE (2007); 2. Aquatic species susceptible to diseases listed in Directive 2006/88/EC (2008); Scientific Opinion on Epizootic Ulcerative syndrome (2011).

Frances Williams
Ms Frances Williams has worked for CABI, a not-for-profit international organization that improves people's lives by providing information and applying scientific expertise to solve problems in agriculture and the environment, for 3 years. She has a Masters in Environmental Economics and Management from the University of York and has a range of experience in assessing direct and indirect economic costs, cost effectiveness and cost benefit analyses, including the economic costs of invasive alien species in a variety of geographic, climatic and ecological contexts. She has also carried out analyses of farmers' livelihood coping strategies in response to changed community resource management, including analysis of sources of farming inputs and adaptive response mechanisms in relation to household income size. Her work has involved use of published literature, grey literature and technical, farmer and household interviews, gathering, analysing and evaluating both quantitative and qualitative data.

Jarle Steinkjer
Mr Jarle Steinkjer is a Senior Adviser at the Directorate for Nature Management (DN), an advisory and executive governmental agency that works to preserve and enhance biodiversity and provide for outdoor recreation. He was a graduate freshwater biologist from the Norwegian University of Science and Technology in 1984. He has been employed at DN since 1985. Over this time period he has been working with the management of Atlantic salmon and freshwater fish. He has since 1988 been in charge for the action plan for combating the introduced salmon parasite *Gyrodactylus salaris.* In more recent years his is also working with freshwater invasive fish species. These efforts include measures to prevent the spread of alien species, and combatting introductions where this is considered necessary to prevent damage to the natural biological diversity.

Stephen Hynes
Mr Stephen Hynes is a lecturer in the Disciple of Economics in the National University of Ireland, Galway, Ireland with responsibility for the program of research within the Socio-Economic Marine Research Unit (SEMRU). He has a strong background in applied marine and environmental/natural resource economic research and extensive work experience in econometric modelling. Stephen received his PhD in Environmental Economics from Stirling University, Scotland. He has previously worked as an environmental economist in the Rural Economy Research Centre, Teagasc and as a lecturer in Economics in the Department of Economics, NUI Galway. Stephen's main research interest is in the economics of the natural resource exploitation and his work has been published by a number of the top ranked journals in the fields of marine, agriculture, environmental and natural resource economics.

Hugh MacIsaac
Mr Hugh MacIsaac is a professor at the Great Lakes Institute for Environmental Research at the University of Windsor, who studies pathways and vectors of species introduction. Hugh has worked on alien invasive species for 23 years and currently directs the Canadian Aquatic Invasive Species Network, a consortium of 31 professors from across Canada. His current interests include ship and non-ship pathways of AIS introduction, and use of molecular tools for early detection programs in ports and harbours

Anthony Ricciardi
Mr Anthony Ricciardi is a professor of biology at the Redpath Museum, McGill University (Montreal), where he holds a Quebec Strategic Professorship and teaches courses on invertebrate biology, environmental science, and the ecology of invasive species. He received his Ph.D. from McGill in 1997 and did postdoctoral work at Laval University (as an NSERC Fellow) and Dalhousie University (as a Killam Fellow) prior to joining the McGill Faculty of Science in 2001. Currently, he is the Associate Director of Research for the McGill School of Environment. For the past 20 years, his research has aimed to develop a predictive understanding of the ecological impacts of aquatic invasions. He serves on the editorial boards of the journal *Biological Invasions* and the journal *Diversity and Distributions*. He is also a member of the scientific committee of the Canadian Aquatic Invasive Species Network.

Toril Loennechen Moen

Ms Toril Loennechen Moen is an adviser at the Norwegian Biodiversity Information Centre (NBIC) in Trondheim, Norway. NBIC is an official national source for information on biodiversity in Norway and the Centre's major role is to provide society with updated and easily accessible information on ecosystems, species and genes (populations). Moen has been employed at NBIC since 1999 as the project manager of the work on names, nomenclature and taxonomy. She is also deeply involved in the work on risk assessments of alien species which has led to the publication "Alien species in Norway – with the Norwegian black list 2012" published in June 2012. The risk assessments have been done on all reproducing species from all multicellular species groups found in Norway, using a brand new semi-quantitative method developed mainly by the Centre of Conservation Biology at the Norwegian University of Science and Technology (NTNU). For her Ph.D.-studies which was conducted at the Norwegian University of Science and Technology (NTNU), Moen researched the dispersal of selected alien marine worms (Polychaeta; Serpulidae) spreading around the world on ship hulls and in ballast water.

Niall Moore

Mr Niall Moore is the head of the Non-native Species Secretariat for Great Britain (GB), which he has led since the Secretariat was established in 2006. The role of the Secretariat is to help co-ordinate action across government and its agencies in GB, including establishing and running a risk analysis mechanism for invasive non-native (alien) species, overseeing public awareness campaigns and much interaction with non-government stakeholders. Niall was also one of the main drafters of the GB Invasive Non-native Species Strategy. Niall has a PhD in Zoology (from University College Dublin) on the behavioural ecology of fallow deer and subsequently worked as a vertebrate ecologist specializing in deer, bats, raptors and invasive species before taking up his job at the Secretariat. He is currently on a three-month secondment to the European Commission in Brussels helping with the development of a dedicated legislative instrument on Invasive Non-native Species.

Helen Roy

In 1997, Ms Helen Roy completed her PhD on the ecology of ladybirds, *Pandora neoaphidis* (fungal insect pathogen) and other aphid natural enemies at Rothamsted Research (linked with Nottingham University) and took up a position as lecturer in the Department of Life Sciences at Anglia Ruskin University. Helen combined research with teaching for 10 years before taking up a position (research scientist) with the Biological Records Centre (Centre for Ecology & Hydrology) where she is responsible for zoological data and research and works extensively with national zoological schemes and societies. Her research focuses on the effects of environmental change on insect populations and communities. She is particularly interested in the dynamics of invasive non-native species and their effects on native biodiversity. She coordinates the UK Ladybird Survey and is using the large-scale and long-term coccinellidae datasets (distribution and abundance) to understand and predict the effects of the arrival of the non-native harlequin ladybird (*Harmonia axyridis*) on native species. This work was selected for the 2009 Royal Society Summer Science Exhibition and the Moscow Science Festival in 2010. Helen has been invited to exhibit her research on ladybirds at the BBC Gardener's World Exhibition in June 2011. Helen is working on a project to produce a comprehensive information portal on non-native species in Great Britain. She also leads a European study group within the International Organisation for Biological Control (IOBC) on the Risks and benefits of Exotic Biological Control Agents which uses the harlequin ladybird as a model species. Recently she was excited to hear that a proposal she has led for a COST Action on IAS has been approved and will commence in 2013. Helen continues with her research interests first initiated in her PhD on the ecology and dynamics of insect host-parasite interactions and has recently led an editorial team to produce a journal special edition (*Ecology of Fungal Entomopathgens* – Springer) which reflects her work in this field. She has also recently published another journal special issue (*Invasive alien arthropod predators and parasitoids: an ecological approach*), an activity through the IOBC WG that she leads. The ecology of ladybirds is a subject that appeals to the public and throughout her career Helen has taken every opportunity to communicate her research to a wider audience. This has included natural history talks, school visits, bioblitz, popular science articles, podcasts and a significant number of interviews with the media.

The arrival of the non-native harlequin ladybird in 2004 captured the imagination of the media and there has been sustained media interest in research on this species over the last six years. Helen has a passion for communicating science to a wide audience and engaging people through citizen science. She has just published a review "Understanding Citizen Science and Environmental Monitoring" on behalf of the UK Environmental Observation Framework.

Olaf Weyl

Mr Olaf Weyl's current research focus at SAIAB is geared towards providing information with which to better manage Africa's aquatic biodiversity. To this end he has worked on freshwater ecosystems in several African countries including Mozambique, Malawi, Namibia, Botswana, Zambia and South Africa. Current interests are fisheries, native fish conservation and alien fish invasions. As a result his research is multidisciplinary and includes not only research on natural systems and processes but also research on understanding how humans alter and benefit from aquatic systems. Recent invasive fish related projects include assessing the impacts of recreational angling species such as carp and bass on native fish and invertebrate communities; parasitological and ecological research on eels; monitoring the recovery of stream ecosystems after alien fish removal using piscicides; impacts of hybridization resulting from fish introductions; managing fish invasions in protected areas and assessing the role that alien fishes play in subsistence and recreational fisheries in South Africa. He also provides policy support with regard to inland fisheries and legislation on alien fish management. Mr Weyl is active in the development of decision-making tools used by provincial nature conservation departments to assess invasion risks through fish introductions. He is on the editorial board member of African Zoology, African Journal of Aquatic Science and Journal of Fish Biology and provides expert advice for several organizations including the Endangered Wildlife Trust and the World Wildlife Fund.

Appendix 8

Top 20 IAS issues developed at the FINS Conference in 2013

Issue	Threat	Local National International	Recommendations
Biosecurity awareness	Lack of prevention will facilitate ready introduction of IAS	L/N/I	Raise biosecurity awareness from government level to individuals
Coherent EU legislation for effective biosecurity	Majority of IAS are only covered by peripherally relevant legislation (e.g. WFD and Habitats Directives)	I	EU must legislate for a unified EU strategic approach to biosecurity
International biosecurity best practice	There is no consistency of approach or coordination between MS and others	I	Share best practices in Europe and farther afield through established forum
Regulatory framework to prevent introduction of IAS	Substantial gap in international trade rules to prevent spread of IAS	I	An organization responsible for developing standards to prevent the introduction of IAS is needed
Dedicated and appropriate resources for IAS	Current lack of funding, specialist staff and appropriate equipment	N/I	Centralized funding source at EU level is needed
New technologies for early detection	Ability to detect IAS at early stage of infestation is poorly developed	N/I	Disseminate advantages of new technologies and share equipment and specialist personnel across MS
Early warning mechanisms	No formal national or international system of warning in most MS	I	Communicate and process early warning/ species alert information using agreed mechanisms
Rapid risk assessment methods to prioritize future invasion events	Risk assessment methods can be slow and cumbersome	N/I	Develop a preliminary rapid risk assessment to highlight priority IAS
Standardize pan-European risk assessment to underpin EU IAS black list	Risk assessment methods are not standardized across EU	I	Establish expert panels across EU to develop and conduct risk assessments
Knowledge gaps in risk assessment	Few general models or rules of thumb exist to steer risk assessments	I	Target the R&D needed to increase the confidence levels in risk assessment methods
The importance of economic analysis in risk assessment	Not all IAS pose the same risk or cost; most costly need to be prioritized	N	Increase the level of communication between IAS scientists and economists
Rapid response - a vital tool in IAS management	Many countries have not yet developed rapid response protocol	N/I	A lead agency to coordinate rapid response is required in each MS

Issue	Threat	Local National International	Recommendations
Emergency powers to manage IAS	Once an IAS becomes established it is virtually impossible to eradicate	N	Provide derogations from EU and national legislation that restricts speedy IAS control
Novel control in IAS management	Traditional control methods can be relatively ineffective and costly	N/I	Provide funding for research and development of novel control methods e.g. biocontrol
Knowledge transfer to improve IAS management	Currently, there is a lack of communication between scientists, practitioners and policy-makers	N/I	Encourage cooperation and knowledge exchange between scientists, practitioners and policy-makers
Outreach to foster improved IAS management	Most IAS are spread inadvertently due to ignorance	N	Provide European funding for public engagement, awareness raising and establishment of local action groups
Effective communication to raise awareness of IAS	Awareness of problems associated with IAS among public and others is lacking	N	There is a requirement for IAS awareness raising in EU legislation
Non-market valuation in IAS economic assessment	Non-market values (e.g. recreation) are rarely considered	N	Educate policy-makers about existence of non-market costs and ensure their inclusion in IAS management evaluations
Cost analysis in IAS management	Commonly, cost analysis for IAS management does not include loss of benefits caused	N	Costs associated with IAS management must include both cost benefit and cost effectiveness analysis
Single responsible agency - the answer to national IAS management	Responsibility for IAS management nationally is often fragmented	N	Clear lines of responsibility between national agencies and government departments are needed at a national level

Appendix 9

Reserve issues not included in Top 20

- Optimize coherent use of infrastructure and enforcement from other appropriate legislation (e.g. Animal Health Directive, Plant Health Directive)
- Ensure integration and accessibility of available information on IAS
- Assess cost effectiveness and sustainability of an intervention or policy
- Carry out primary economic assessments to be used as case study examples
- Encourage use of standard economic assessment methodologies throughout all MS
- Identify/clarify those responsible in risk management (e.g. Government, industry, landowners)

In November 2014, the European Union (Member Organization) (EU) published a new Regulation to address invasive alien species (IAS) and protect biodiversity. This Regulation entered into force across the EU in January 2015. Its aim is to "prevent the introduction of, control or eradicate alien species which threaten ecosystems, habitats or species". In an effort to provide focus to the Regulation prior to its publishing and to identify the major issues relating to IAS in Europe (28 countries of the EU and other European countries), the views of invasive species experts from around the world were sought. These were consolidated at an international conference (Freshwater Invasives – Networking for Strategy [FINS]) that was held in Ireland in April 2013. A major outcome from this meeting of experts was the production of the "Top 20" IAS issues that relate primarily to freshwater habitats but are also directly relevant to marine and terrestrial ecosystems. This list will support policy-makers throughout the EU as preparations are made to implement this important piece of legislation. A further outcome from the conference was the formation of an expert IAS advisory group to support EIFAAC in its work on invasive species.

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