Common market, shared problems: time for a coordinated response to biological invasions in Europe?

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Summary

Not only are the total numbers of alien species established in Europe increasing but, for many taxa, the rate at which they have become successfully introduced is higher now than at any time in the past. For Europe to address biological invasions at a continental scale there must be an end to the fragmented legislative and regulatory requirements addressing invasive species and the piecemeal approaches to tackling invasive species across Europe that fail to coordinate pre- and post-border actions. More than ever before, a single European coordinating centre with a specific remit to manage biological invasions is needed. At the same time, the knowledge base resulting from the recently completed EU projects DAISIE and ALARM provides an excellent foundation for concerted management action. A new agency, the European Centre for Invasive Species Management (ECISM), should be developed with a mission to identify, assess and communicate current and emerging threats to the economy and environment posed by invasive species. ECISM would integrate all invasion related activities across Europe and target six key areas: scientific advice; coordinating surveillance; identification of emerging invasion threats; initiating responses; supporting training; and communicating to the public and stakeholders. Expertise addressing biological invasions is heterogeneously distributed across Europe resulting in variable efficiencies in national monitoring and surveillance. As a result Europe's borders can be easily penetrated by alien species.. Furthermore, relative to understanding of the ecology, distribution and taxonomy of alien species in Europe, expertise in management and mitigation of impacts is the preserve of little more than 10% of invasion scientists. ECISM would bring together expertise from across Europe to address problems across nations. The disparate nature of expertise in Europe also means that as assessing the risks of alien species has become increasingly complex specialist expertise and access to appropriate databases is required and could best be delivered by a dedicated body that would ensure consistent and rapid delivery of appropriate risk assessments. Though invasive species can impose considerable impacts on economy and ecosystems, only 2% of Europeans feel that invasions are a significant threat to biodiversity. ECISM would build public awareness of the problem of invasions, involve the public in finding alternatives and solution, build long-term partnerships with concerned sectors and users, and encourage voluntary approaches and best practices where feasible.

Key words: biological invasions, early warning, economy, Europe, impact, management, monitoring, policy, rapid response, surveillance

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1. Introduction

Europe is undoubtedly a major source of many of the world's worst invasive alien weeds, pests and diseases that, following introduction to new regions, have resulted in significant economic and environmental impacts across the globe. However, the perspective of Europe as the source rather than recipient of invasive species is in urgent need of revision in the light of new data. The results of the first continent-wide assessment of the scale and impact of biological invasions, from the Mediterranean Sea to the Arctic tundra, reveal that Europe's borders have been breached by 11,000 alien species (DAISIE 2009). Over half of all alien species recorded in Europe are terrestrial plants (Lambdon et al. 2008), aquatic and terrestrial invertebrates account for a further third of species, while only around 6 % are vertebrates. Compared to previous estimates of alien species in Europe, the new data identify over five times as many alien bird species, a threefold increase in alien mammal species and twice as many alien plants (Hulme 2007). Not only are the total numbers of alien species established in Europe increasing but, for many taxa, the rate at which they have become successfully introduced is higher now than at any time in the past (Hulme et al. 2009a). Alien species may impact on the populations of specific native species through hybridisation, by facilitating the spread of pathogens or parasites, via grazing or predation or via competition for resources. For Europe to address biological invasions at a continental scale there must be an end to the fragmented legislative and regulatory requirements addressing invasive species, an end to uncoordinated activities led by the different Directorates General of the European Union that do not appear to appreciate the cross-cutting nature of biological invasions, an end of the piecemeal approaches to tackling invasive species across Europe that fail to coordinate pre– and post-border actions and of course an end of underfunding of taxonomy, management efforts and basic research on invasive species. More than ever before, a single European coordinating centre with a specific remit to manage biological invasions is needed (Hulme et al. 2009a). A new agency, the European Centre for Invasive Species Management (ECISM), should be developed, perhaps along the lines of the European Centre for Disease Prevention and Control (ECDC), with a mission to identify, assess and communicate current and emerging threats to the economy and environment posed by invasive species. ECISM would integrate all invasion related activities across Europe and target six key areas: scientific advice; coordinating surveillance; identification of emerging invasion threats; initiating responses; supporting training; and communicating to the public and stakeholders.

2. Scientific advice and research direction

The study of biological invasions is still a young research field with rather fragmented knowledge: we do not have sufficient information on those characters which make a species invasive. This makes plausible prognoses extremely difficult, especially since biological invasions often show stochastic characteristics, influenced by a variety of events and driven by different factors. Today, we still have limited information on the spreading capabilities of species, their pathways into invaded habitats, and on the invasibility of ecosystems. Economic and environmental impact data are only available in 11% and 13% of all alien species, respectively (Vilà et al. 2009) and this makes prioritisation among several alien species

very difficult, if not impossible. Given the size of its economy, broad science base and long-established research institutions it is indeed worrying that current knowledge of impacts in Europe lags behind many parts of the world (Fig. 1). As in many parts of the world, current understanding of invasions in Europe reflects a biased taxonomic picture (Pyšek et al. 2008).

Besides research at the species level we need more experimental investigations at the ecosystem level to understand how invasive species alter ecosystem processes and services. The world is actually changing very fast and we would like to understand the interdependence of invasive species, global climate, land use changes and changes in biogeochemistry caused by trends in economic development and society (Nentwig 2007). In this regard, ECISM would establish a reputation for scientific excellence and leadership and be a major resource for scientific information and advice on biological invasions for the Commission, the Parliament, the Member States and their citizens. The type of research required includes studies to increase ecological understanding as well as projects that will develop and implement technical solutions. This includes technologies to prevent invasive organisms from being transported via containers or by other introduction vectors, in or on other organisms, in wood or soil etc. Once an invasive organism has established, any countermeasure is much more costly than prevention, thus, control costs represent a good investment, able to prevent future environmental and economic damage. Also the methods which are presently applied may demand further improvements in efficacy, ease of application and costs. Of special concern is waterborne transport: its economic importance will continue to increase and the number of alien species spread by ships is expected to rise concurrently (Hulme 2009). For aquatic organisms, the most prominent invasion vectors are ballast water and hull fouling of ships, important pathways include the waterway networks in Europe or maritime canals (Hulme et al. 2008). Furthermore, biological invasions require an interdisciplinary perspective that brings together natural sciences with social and economic perspectives. Perceptions of invasive species range from positive economic views from stakeholders who trade or use alien species recreationally to complete opposition to any species not native to a region. Building consensus across such a spectrum of views will require the application of interdisciplinary techniques such as cost-benefit analyses, willingness-to-pay, cost-effective and multi-criteria approaches. Scientific, social and technical solutions to minimize the spread of aliens are urgently needed and could be achieved by ECISM through:

1. Being a catalyst of biological invasions research in both natural and socio-economic sciences.
2. Promoting, initiating and coordinating scientific studies.
3. Producing guidance, risk assessments, scientific advice.
4. Involving stakeholders and policy-makers in setting priorities

This will involve improving research on biological invasions in the EU. ECISM would identify gaps in scientific knowledge and work with EU funders to steer research calls, as well as evaluate proposals. The European Union has supported a variety of research initiatives that address different aspects of biological invasions (Table 1). Yet these projects are funded by quite different mechanisms and schemes which often have their own research priorities and rarely communicate with or are aware of other similar areas of research. For example, under the 6th Framework Programme, projects were supported through (i) the Mobil-

Table 1: Selected examples of research relevant to biological invasions funded through the European Commission since 2000.

Title of the project	Acronym	Funding Scheme[a]
Biological control of weeds in Europe	–	1
Biological control of pest insects and mites with special reference to Entomophthorales	–	1
Bio-control symbioses (Symbiotic complexes for biological control of pests)	–	1
Algal introductions to European shores	ALIENS	2
Exotic plant invasions: deleterious effects on Mediterranean island ecosystems	EPIDEMIE	2
Giant hogweed (*Heracleum mantegazzianum*) a pernicious invasive weed: developing a sustainable strategy for alien invasive plant management in Europe	GIANT ALIEN	2
New ecological pest management of pernicious scale insects in Mediterranean forest and groves	PHOCUS	3
Assessing the risk and understanding the processes of invasion by non-native fish species within and between river catchments	ALIENFISHMIGRATIONS	4
Biological invasions: patterns and processes. An integrative approach with the bullfrog *Rana catesbeiana* in Canada & Europe	INTEGRINVA	4
Does neutral genetic diversity predict evolutionary potential?	GENETIC DIVERSITY	4
Effects of global warming and alien species invasions on high diverse communities of NW Mediterranean Sea	GORGCHANGE	4
Exotic bees and introduced plants: the role of pollinator limitation in the establishment and spread of alien weed species	POLLIM	4
A multidisciplinary approach to host-shifting and invasive potential by gyrodactylid parasites	GYROSCOPE	4
Invasion success of crustacean zooplankton: adaptive mechanisms vs. broad physiological tolerance	EVOLEXOTIC	4
Parasite transmission in an introduced species: implications of population structure and heterogeneous landscapes	MADRAT	4
Phylogeography and genetic diversity of the red squirrel, *Sciurus vulgaris* in Europe, in relation to the range expansion of the American grey squirrel, *Sciurus carolinensis*	GLIRES	4
Population dynamics of invasive forest seed insects	POPFIME	4
The dependency of major ecological shifts on life-history responses to environmental influences	ECOSHIFT	4
Control of an invasive predator for conservation: spatial density dependent dispersal in American mink	DISPERSE	4
Bee research and virology in Europe: identifying the research needs for protecting European agriculture and ecosystems against viral diseases	BRAVE	5
Environmental impacts of invasive alien species in aquaculture	IMPASSE	5
European Network on emerging diseases and threats through invasive alien species in forest ecosystems	FORTHREATS	5
Permanent network to strengthen expertise on infectious diseases of aquaculture species and scientific advice to EU policy	PANDA	5
Risk analysis for *Phytophthora ramorum*, a newly recognised pathogen threat to Europe and the cause of sudden oak death in the USA	RAPRA	5
Risk assessment of new and emerging systemic iridoviral diseases for European fish and aquatic ecosystems	RANA	5
Registration of biological control agents	REBECA	5
Dramatically reducing spreading of invasive, non-native exotic species into new ecosystems through an efficient and high volume capacity ballast water cleaning system	OCEANSAVER	6

Table 1: Continued.

Title of the project	Acronym	Funding Scheme
Delivering alien invasive species inventories for Europe	DAISIE	7
Sustainable ballast water management plant	BAWAPLA	7
Marine ecosystem evolution in a changing environment	MEECE	8
Enhancements of pest risk analysis techniques	PRATIQUE	9
Invasive predator control: response of American mink to eradication in relation to farm distribution	MINKCONTROL	10
Island selection and lizard ecology	ISLE	10
Modelling of non-native fish species responses to climate change	ALIENFISH&CLIM CHANGE	10
Biological control of broomrapes	BIOBROOM	10
Testing monitoring systems for risk assessment of harmful introductions by ships to European waters	HIBS	11
Ecological consequences of a comb jelly invasion for the Mediterranean areas (Black-Azov Seas)	–	12
Evaluating the effect of an invasive species on local mullet communities in the Mediterranean; a parasite community approach	–	12
A conservation strategy for *Anaecypris hispanica*	–	13
Active preservation of the natural reserve Valli del Mincio	–	13
Conservation of priority species in Mediterranean marshes (*Aphanius iberus*, *Valencia hispanica*, *Botaurus stellaris*, *Larus audouinii*)	–	13
Environmental regeneration and protection of a green way	–	13
Restoration of alluvial woods and oak woods along the Ticino River	–	13
Restoration of Atlantic oakwoods	–	13
Restoration of riparian ecosystem in the natural reserve of Galachos, Spain	–	13
Study and conservation of the Açores Natural Patrimony	–	13
Wilderness area Dürrenstein – Niederösterreich (Lower Austria)	–	13
Sustainable control of the horse chestnut leafminer, *Cameraria ohridella* (Lepidoptera, Gracillariidae), a new invasive pest of *Aesculus hippocastanum* in Europe	CONTROCAM	13
Threat to European maize production by invasive quarantine pest, western corn rootworm (*Diabrotica virgifera virgifera*): a new sustainable crop management approach.	DIABROTICA	13

[a] Programme codes: 1. European Cooperation in the field of Scientific and Technical Research (COST) does not itself fund research, but supports networking activities such as meetings, conferences, short-term scientific exchanges and outreach activities. 2. Energy, environment and sustainable development (EESD) one of four thematic research programmes funded under Framework 5 (1998–2002); 3. Fifth Framework Programme Specific research programme in the field of Agriculture and Fisheries (FAIR) includes research agro-industry, food technologies, forestry, aquaculture and rural development); 4. Sixth Framework Programme's (FP6) "Mobility" action that targets programmes that support the trans-national mobility of experienced researchers at different stages of their careers by broadening or deepening their individual competence; 5. Sixth Framework Programme's "Policy support and anticipating scientific and technological needs" activity; 6. Sixth Framework Programme action for small and medium-sized enterprises (SMEs) wishing to pursue horizontal research activities; 7. Sixth Framework Programme "Sustainable Development, Global Change and Ecosystems" action that supports research to implement a sustainable development model in the short and in the long term, integrating its social, economic and environmental dimensions; 8. Seventh Framework Programme (FP7) "Environment (including climate change)" action; 9. Seventh Framework Programme (FP7) in "Food, agriculture and fisheries, and biotechnology" action; 10. Seventh Framework Programme (FP7) "Strengthening, quantitatively and qualitatively, the human potential in R&D in Europe" action; 11. Programme international cooperation (INCO) with third countries (not EU member States); 12. Programme international cooperation with scientists from the independent states of the former Soviet Union (INTAS); 13. Financial instrument supporting environmental and nature conservation projects throughout the EU (LIFE).

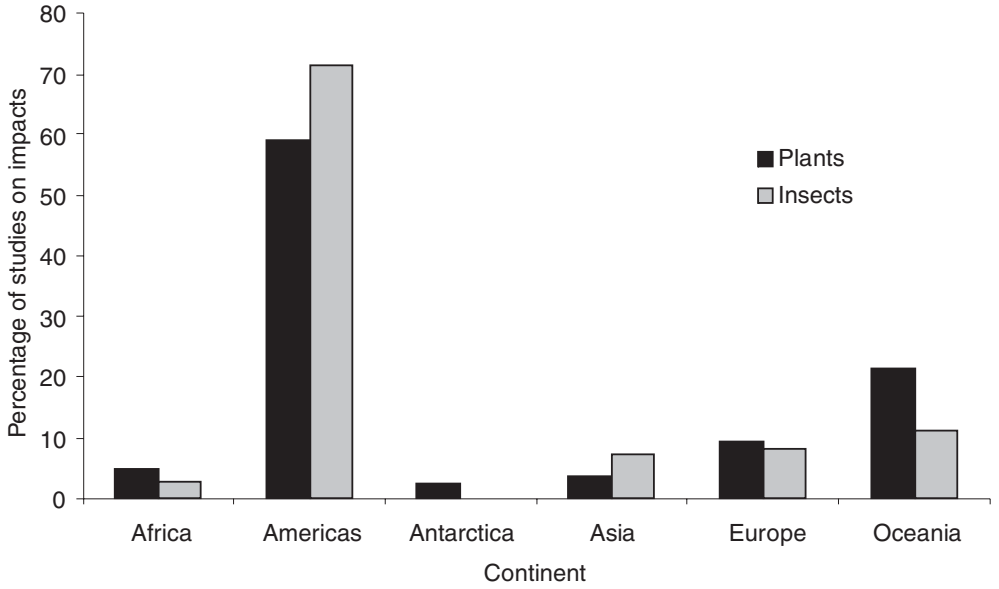

Figure 1: An estimate of the current level of knowledge regarding alien species impacts across continents for insects (data from Kenis et al. 2008) and plants (data from Levine et al. 2003).

ity Programme that funded Marie Curie Fellowships that aimed to promote trans-national mobility for training purposes; (ii) the Policy Support Programme designed to underpin the formulation and implementation of Community policies; (iii) the SME Programme that supported horizontal research activities involving small and medium-sized enterprises by providing scientific contributions to policies that are targeted precisely on needs; (iv) and the Sustainable Development Programme that aimed to strengthen the scientific and technological capacities Europe to be able to implement a sustainable development model in the short and in the long term. However, even within the Sustainable Development Programme, projects addressing the marine and terrestrial environments were coordinated separately. Thus, the existing approach results in a fragmented science base and a disparate research community and as a result there is often duplication of activities that represents an ineffective use of the limited research funds available. There is a need for a overseeing body that can bring together these different research teams either on a permanent basis or specifically designed for each Framework Programme, much like the concerted actions in the 4th Framework Programme (Hulme et al. 2000) or Integrated Projects in the 6th Framework Programme (Settele et al. 2005). ECISM would provide oversight and coordination of future EU funded research on biological invasions, ensure consistent data archiving, access and sharing, and connect researchers to ensure previous research informs future science. In this way, ECISM would build links between scientists, their research programmes and datasets by maintaining an interactive directory of experts and running cross-cutting scientific symposia.

3. Surveillance and early warning

Some impacts of invasions could have been reduced if European states had uniformly

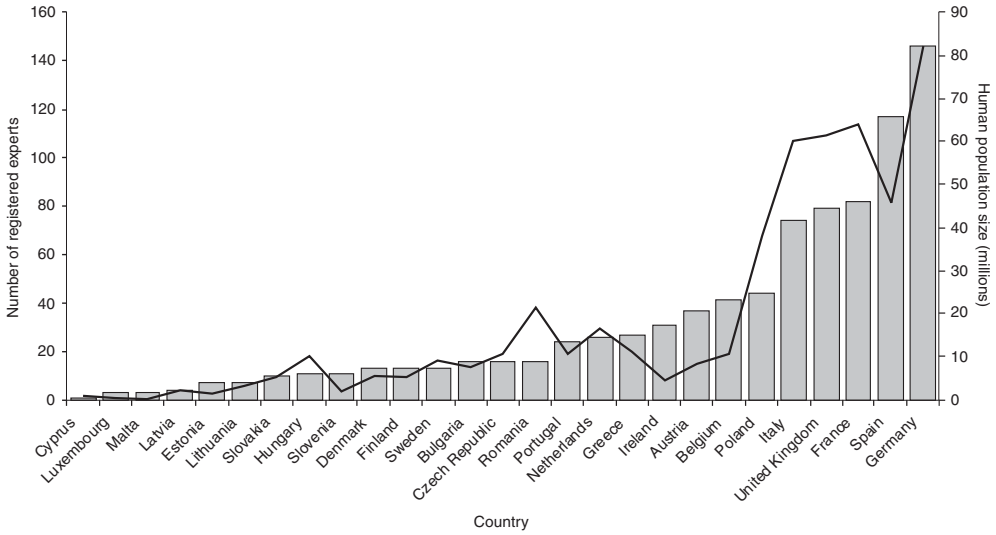

Figure 2: Number of experts registered in the DAISIE Expertise Registry for the countries of the European Union (bars; data from www.europe-aliens.org, accessed on 20 May 2009) in relation to their human population size (line; data from http://epp.eurostat.ec.europa.eu).

applied relevant codes of practice and taken rapid action to eradicate introduced species following their detection, e.g. grey squirrel *Sciurus carolinensis* invasion in Italy, caulerpa *Caulerpa taxifolia* invasion in France, zebra mussel *Dreissena polymorpha* in the Baltic. Similarly, several biological invasions now threatening Europe might have been prevented by a higher level of awareness of invasive alien issues and a stronger commitment to address them (e.g. introduction of the comb jelly *Mnemiopsis leidyi* into the Aegean). An early warning system and the surveillance of key entry areas, based on warning lists of most dangerous alien species, and immediate removal of newly detected invaders is the best strategy for management. This implies that expertise for the identification of relevant taxa is available, the responsible authorities established contingency plans for the eradication of specific taxa, and suitable methods are on-hand. Unfortunately, expertise addressing biological invasions is heterogeneously distributed across Europe (Fig. 2) and thus relying on national monitoring and surveillance alone to protect Europe's borders will not be effective at preventing further introductions. Again, this makes a strong case for pan-European coordination of such activities. Eradication of an alien species is always better than its control or management because the latter implies the persistence of the alien, and cannot prevent future environmental and economic impacts. ECISM would be responsible for the surveillance of invasive alien species in the EU and maintain the databases for such surveillance. It would:

1. Develop integrated data collection systems covering all member states, maintain the databases for surveillance and establish EU-wide standard case reporting.

2. Coordinate and ensure the integrated operation of the dedicated surveillance networks and support strengthening of national surveillance systems.

3. Monitor trends of invasive species across Europe in order to provide a ratio-

nale for actions in member states and disseminate the results to stakeholders for timely actions at EU and country levels.

This system would facilitate access to and exchange of information concerning invasive species, including data on distribution and abundance of invasive species, their life histories and the economic, environmental, and human health impacts they might cause. A relevant step towards a comprehensive database of alien and invasive species in Europe and of experts has been achieved within the DAISIE project (www.europe-aliens.org, DAISIE 2009). Now, this database needs further maintenance and development to an early warning system, that can link through to interception data and receive regular updates on new naturalizations and occurrences of alien species across Europe.

4. Horizon scanning and risk assessment

Major challenges for the development of an integrated invasive species risk assessment scheme in the EU include the absence of data required to make accurate analyses of the risks throughout the region and the lack of guidance on appropriate protocols (Andreu & Vilà 2009). Risk assessment processes have insufficiently exploited important new scientific and technological developments, and the risk assessment procedures are complex, discouraging take-up among all EU member states (Baker et al. 2009). Many factors need to be considered to determine whether particular pathways can introduce pests; a particular pest can enter, establish and cause impacts in an area; and what measures would be appropriate to reduce the risk to an acceptable level. Recently, following a request from the European Commission, the EFSA Scientific Panel on Plant Heath was asked to deliver a scientific opinion on two pest risk analyses made by the European and Mediterranean Plant Protection Organization (EPPO) on invasive alien plants (American skunk cabbage *Lysichiton americanus* and floating pennywort *Hydrocotyle ranunculoides*). The Panel was in particular asked (i) whether these species could be considered as harmful for the endangered area of the European Community and thus potentially eligible for addition to the list of harmful organisms in the plant health Directive 2000/29/EC, and (ii) whether the identified management options were appropriate through an evaluation of their efficacy, feasibility and impact. In delivering this opinion the Panel conducted a detailed review of the EPPO pest risk analysis, using the internationally accepted standard for pest risk analysis for quarantine pests ISPM No 11 (FAO 2004). The Panel concluded from the available information that both species were invasive, but damage was documented only for a limited area of the European Union, hence there was insufficient evidence that either species should be listed as a quarantine pest (EFSA 2007a, b). EFSA recommended further work, including monitoring and surveillance, was needed to address the areas of uncertainty identified in the EPPO document, in order to identify the areas of the European Community at risk and enable management options to be considered. Further risk assessments submitted by Lithuania and Poland to have ragweed *Ambrosia artemisiifolia* listed as a quarantine pest also failed to be approved due to incomplete information (EFSA 2007c, d).

It appears standard information required for species risk assessments in the future will have to include: (i) the effect of abiotic factors on the establishment, development, reproduction, survival and dispersal of the species in both the native and

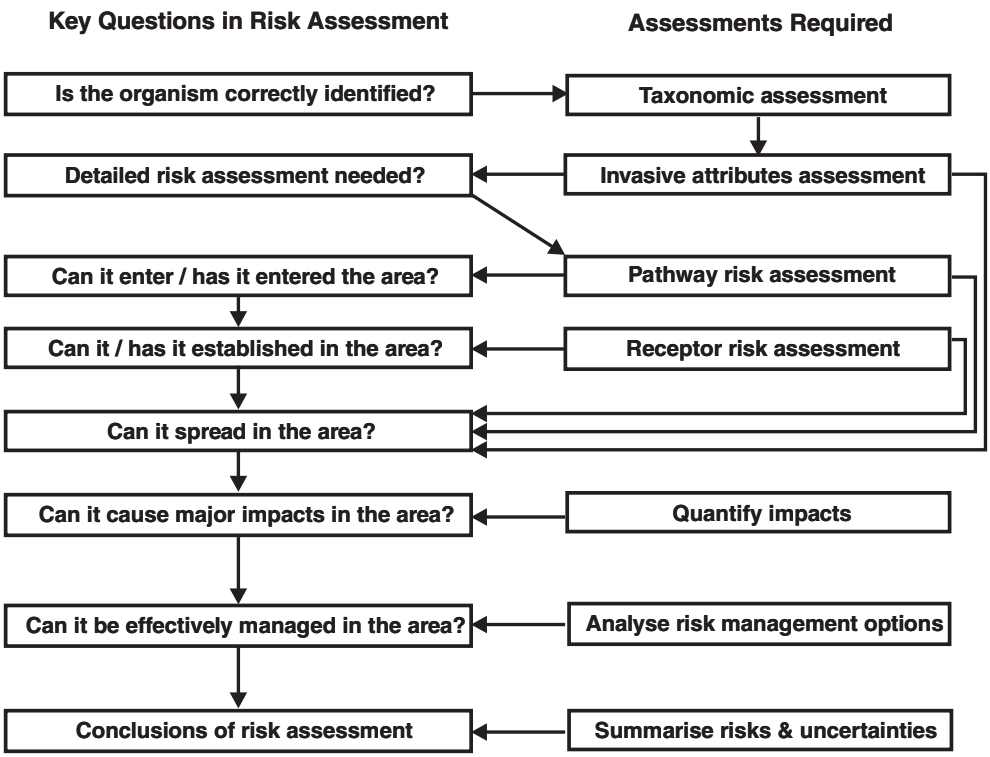

Figure 3: Key questions and assessments required to address the risk of invasion of a newly recorded alien species (modified after Baker et al. 2008).

introduced range; (ii) the population dynamics of the species in areas where it is present but not invasive; (iii) the volume of trade in the species as entering and moving within Europe, including further analysis of the pathways of entry; and (iv) the nature and occurrence of areas within Europe where conditions result in invasiveness of the species, supported by the use of modelling and geographic information system (GIS) tools. As a result, future risk assessments of alien species will undoubtedly become more complex as the tools are refined (Fig. 3). The key issues that need to be addressed in risk assessment require specialist expertise and access to appropriate databases. If future risk assessments require this level of detail, a dedicated body charged with undertaking such research would ensure consistent and rapid delivering of appropriate risk assessments. In cooperation with the member states, ECISM would establish procedures for systematically collecting, collating and analysing data across the globe with a view to identify emerging invasion threats which could affect the economy, environment and health of the Community. Activities would include:

1. Preventing the intentional introduction and spread of invasive species, including the identification of emerging pathways.

2. Minimizing the risk of introductions via unintentional pathways.

3. Managing a science-based process to evaluate risks associated with introduction and spread of invasive species and a coordinated and systematic risk-based process to identify, monitor, and interdict pathways that may be involved in the introduction of invasive species.

ECISM would forward to the European Parliament, the Council and the Commission an annual evaluation of the current and emerging threats from invasive species in the Community. ECISM would assess the potential economic and environmental impacts, capture and communicate uncertainty, map future endangered areas, summarize risk, link pathway analysis to the construction of systems approaches to prevent pest entry and create a decision support system for the management of pest outbreaks.

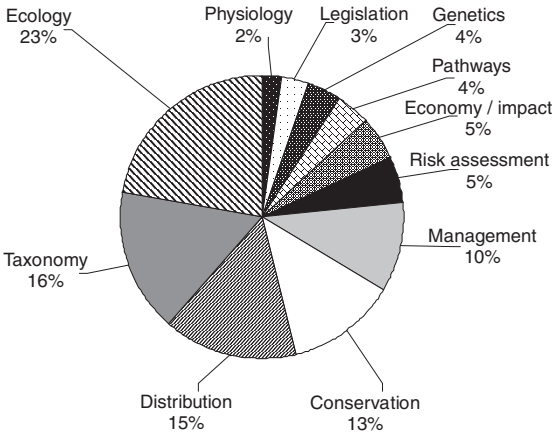

Figure 4: Relative expertise in the European Union across different aspects of biological invasions. Data from 872 experts taken form the DAISIE Expertise Registry (www.europe-aliens.org, accessed on 20 May 2009).

5. Rapid and continuing response

Once early detection occurs, resources need to be mobilized to eradicate the IAS incursion. In the case of the invasive marine alga *Caulerpa taxifolia* field containment and eradication treatments were implemented only 17 days after discovery in the coastal waters of California in 2000 (Anderson 2005). In contrast, the species was discovered in the Mediterranean Sea in 1984, warnings were first sounded in 1989 and over the next decade it had colonized more than 100 km^2 of benthos (Meinesz 1999). These two contrasting scenarios illustrate the importance of prior experience, rapid confirmation of species identity and risk, as well as a consensus among stakeholders to follow a particular management strategy. Furthermore, an effective response system requires: (i) a sound scientific basis upon which to plan actions, (ii) the tools and protocols with which to respond and (iii) the capacity as well as resources to achieve its goals (Hulme 2006). In Europe, much more effort has to be made to control invasive species. Unfortunately, relative to understanding of the ecology, distribution and taxonomy of alien species in Europe, expertise in management is the preserve of around 10% of invasion scientists and the interest of research community community confirms this pattern (Fig. 4) A recent assessment of the perceptions of environmental managers in Spain revealed that they felt current management measures were insufficient to control alien plants due to limited economic resources, lack of public awareness and support, and an absence of coordination among different public administrations (Andreu et al. 2009). Managers also expressed concern about the fact that much scientific research is concerned with the ecology of alien plants rather than with specific cost-efficient strategies to manage alien species, a view also borne out by the emphasis of much of the scientific literature on biological invasions (Hulme 2003). Experience shows that it is possible to successfully eradicate alien species if careful planning, sufficient financial support and adequate

political and social assistance are provided. In contrast, there are numerous cases of invasive species which were not removed because of limited awareness by decision-makers, gaps in the legal framework or authorization process, ignorance, or due to public opposition. ECISM would be the EU reference point to support the investigation and control of continuing and emerging invasion problems, including:

1. Appropriate and timely reaction in case of invasion threats.
2. Coordinated approach in outbreak investigation and control between affected countries.
3. Rapid mobilization of European experts in response to requests for assistance from countries.
4. Efficient communication between all stakeholders during response activities.

ECISM would aim to ensure the rapid mobilization of "outbreak assistance" teams, diagnostic capacity, and the immediate availability of the necessary material for priority eradications. For longer term management, guidelines and standard operating procedures would ensure that biological invasions are managed in an effective and coordinated manner.

6. Training and capacity building

Maintaining a relatively low exposure to pests and diseases is essential to the economic viability and environmental health in Europe. To maintain this level we must ensure the effective exclusion, eradication and management of invasive species. These goals can only be achieved if a sufficient number of people equipped with appropriate knowledge and skills in the management of invasive species are available in Europe. However, the availability of expertise varies widely across Europe (Fig. 2) and only 16% of experts are taxonomists (Fig. 4). Taxonomy is a particular problem in invasion ecology since often resident taxonomists are faced with identifying organisms from different parts of the world often belonging to taxa differing from native species they are familiar with (DAISIE 2009). In general the taxonomic expertise is highly biased. For example, 7% of all species known so far are fungi and the DAISIE Expertise Registry counts only 3% of experts on fungi in Europe, about 1% (or less) of all organisms are Protozoa or algae yet the number of experts is between 2 and 4% while 16% of species are plants but they can count on a quarter of all experts. For invertebrates: molluscs account for 4% of all animal species (10% of all experts for animals), annelids 1% of animal species (5% of experts), and crustaceans 3% of animal species (12% of experts). Of greater concern is that while 77% of all animal species known so far in the world are insects, the registry identifies only 27% of all experts for this group in Europe. In contrast, vertebrates in total account for only 4% of all animal species but comprise 32% of all animal experts in Europe. Thus in terms of skills and training, Europe suffers from a scarcity of experts on insect invasions. Taxonomists are increasingly needed to address the threats of biological invasions and for this to occur there needs to be the training opportunities as well as the employment prospects for these skills (Wheeler et al. 2004). Presently in Europe, the education opportunities are limited to a small number of courses that build on generic provision in agricultural or environmental sciences, with minor specialization in specific areas of invasions. While suitable for undergraduate training, these courses do not deliver the targeted training required by professionals working in this area. Therefore, current educational opportunities on offer in Europe may not adequately address current industry needs. The development of capacities in the EU to respond to biological invasion threats de-

pends on the availability of training resources. ECISM would support and coordinate training programmes in order that the member states and the Commission have sufficient numbers of trained specialists, particularly in species identification, surveillance techniques, risk assessment, species distribution modelling, forecasting and population dynamics, and management techniques. Activities would include:

1. Assessment of training provision across Europe relevant to management of invasions.

2. Provision of short-courses targeted at professional development in key skill areas.

3. The development of a network of training partners and sharing of training materials.

4. Coordination and recognition of professional qualifications in invasive species management.

ECISM would develop training curricula, promote use of a common language among European invasive species researchers, and produce field manuals for the management of alien species.

7. Public awareness and stakeholder consultation

Our society usually is not aware of its dependence on nature and neglects the threat of biological invasions, thus specific education programmes or public awareness campaigns are necessary. This education from school level onwards should cover the whole of society but especially particular sectors such as landowners, hunters, fishermen, foresters, gardeners, landscape architects, scientists, people involved in aquaculture and pet trade, and non-governmental organizations, especially animal rights organizations. ECISM would ensure that the public and any interested parties are rapidly given objective, reliable and easily accessible information with regard to the results of its work, act in close collaboration with the member states and the Commission to promote the nec-

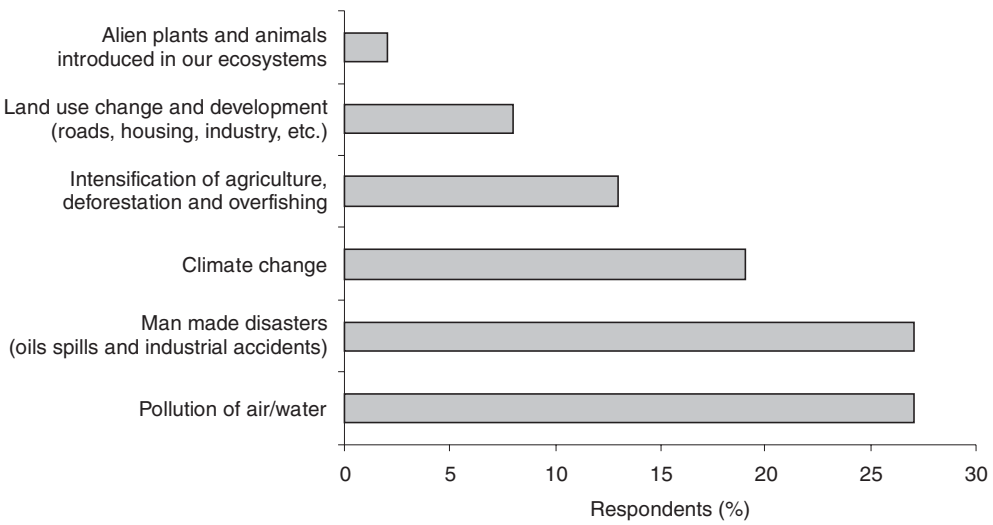

Figure 5: Perceptions of the major threats to biodiversity held by European citizens. Data from Gallup Organisation (2007).

essary coherence in the risk communication process on invasion threats as well as with regard to public information campaigns. Recently, the Gallup Organisation polled Europeans regarding their perception of the major threat to biodiversity (Gallup Organisation 2007). Only 2% of respondents thought that the introduction of plants and animals into European ecosystems was the main reason for biodiversity loss, an order of magnitude fewer than for pollution, man-made disasters or overexploitation (Fig. 5). ECISM activities would therefore include:

1. Efficiently communicate the output of the ECISM to professional audiences.
2. Communicating key invasion messages to the media and to the European public.
3. Support the development of member states communication capacities.

A key activity would be the hosting of open access e-journals with short rapid communications and longer surveillance and research articles on invasive species including recent records, spatio-temporal trends, inventories and management methods. Lessons can certainly be learnt from the success and effectiveness of recent e-journals such as Aquatic Invasions (Panov & Gollasch 2006) and alerting systems such as the EPPO Reporting Service. Public awareness has to be increased in two important areas. First, the precautionary principle implies that future species introductions should be avoided wherever possible and aliens should be eradicated as soon as they are detected; and second, the polluter-pays principle applies economic costs of the damage caused by an alien species to be refunded by the responsible party. In contrast to the widespread laissez-faire policy, this visualizes the connection between alien species and damage to ecosystem structure and function, goods and services, and their market valuation. Market-based instruments have to address invasion externalities and should offer incentives to avoid risks, e.g. licence fees (more risky products would be more expensive), insurance bonds or other cost-sharing instruments. Many exotic birds and fish, released or escaped from captivity into the wild where they cause problems, may serve as an example. It is quite clear that such a change in perception remains a major challenge, even among scientists (Hulme et al. 2009b). ECISM would build public awareness of the problem of invasions, involve the public in finding alternatives and solution, build long-term partnerships with concerned sectors and users, and encourage voluntary approaches and best practices where feasible.

8. The way forward

To date, the Europe's response to the problems of alien species has been driven by commitments to international agreements such as the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) and the Convention on Biological Diversity (CBD). Yet these commitments have not always been supported by action. Under the CBD, EU Member States rate implementation of Article 8h "to prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species" as a significantly lower priority than nations outside Europe (Hulme 2007) and only two EU states (France and Spain) have ratified the International Convention for the Control and Management of Ships' Ballast Water and Sediments. This difference between policy awareness and implementation has led average annual rates of alien species establishment in Europe to progressively increase since 1900 for many taxa (Hulme et al. 2009a). Yet the "cumulative number of alien species in Europe since 1900" is a

headline indicator to measure EU progress towards the CBD target to achieve a significant reduction of the current rate of biodiversity loss by 2010 (EEA 2007). Clearly the EU will need to be far more pro-active in the management of alien invasions to ever meet such a target. As a consequence, the European Commission has put forward to the European Council and Parliament a proposal for an EU strategy on invasive species (EC 2008). The strategy emphasizes prevention as the most cost-effective way forward and presents three policy options that move beyond the business as usual scenario: maximize the use of existing legal instruments; adapt existing legislation through specific amendments, or establish a comprehensive, dedicated legal framework to address biological invasions. Within the third option, the proposal states "The last option is to develop a new legal framework for tackling invasive species with independent procedures for assessment and intervention. A dedicated agency could also be set up to deal with technical aspects. Mandatory monitoring and reporting procedures and rapid response mechanisms could also be established". Elsewhere we have addressed some of the challenges facing the first two options of the proposed strategy and make a case for the third option (Hulme et al. 2009a). However, the establishment of ECISM does not necessarily need to go hand-in-hand with a stronger and more elaborate regulatory framework. ECISM would largely reinforce and harmonize international, national and regional initiatives on the issue of biological invasions within the existing European framework.

It is not essential that ECISM has the role of an executive agency. Many of the activities proposed for ECISM do not require a change to existing legislation: scientific advice; coordinating surveillance; identification of emerging invasion threats; supporting training; and communicating to the public and stakeholders. Only in initiating responses would new legislation be required to enable the authority of ECISM to coordinate and undertake action in specific European states. The ECISM vision is not one of a regulatory body, policing legislation across Europe but a facilitative body aiming to bring European expertise and knowledge together for the first time. Regulatory roles could be incorporated into the ECISM mandate but would be less effective if this was at the cost of the many other activities proposed in this paper. Thus ECISM can exist whatever final model is proposed for a future European Strategy on Invasive Species. This allows flexibility in that different levels of legislative action may exist in different Member States in Europe and ECISM would need to work within these different frameworks. Indeed, potentially ECISM should exist before any new legislation is put into place so that the centre could assist in the consultation and development of this legislation.

Understandably, there will always be resistance to the establishment of a new agency with fears that bureaucracy will increase without necessarily advancing the area. Further more, a range of sectors may feel threatened if a new agency impinges on their current areas of responsibility or could divert funds away from their own organizations. But the key question is whether the current approach in Europe is sufficient and if not, is there a better alternative to establishing a single pan-European coordinating agency? The foregoing has highlighted key areas that fall between existing organizations that will not be adequately addressed through the piecemeal, uncoordinated approach currently undertaken in Europe. Several organizations already have partial responsibility for biological invasions in Europe e.g. EPPO,

EFSA, European Environment Agency, DG Environment as well as a host of national organizations. However, they have not integrated their activities and there is a risk of duplication and ineffective action within such a dispersed set of organizations. ECISM would be the only way to ensure a coordinated approach across Europe in six key areas: scientific advice; coordinating surveillance; identification of emerging invasion threats; initiating responses; supporting training; and communicating to the public and stakeholders. These roles are far broader than those that exist for European Topic Centres (ETC) whose role is to arrive at efficient structures of European data systems to deliver policy relevant data to the European Environment Agency. The role of the ETC is primarily one of information harmonization, quality control, exchange and collation through EEA member countries and key international organizations for the subsequent delivery in the form of reports and databases. Aspects of biological invasions would certainly cut across a number of existing ETC especially those on Biological Diversity (e.g. indicators); Land Use and Spatial Information (e.g. monitoring networks); Water (e.g. water quality) and Air and Climate Change (e.g. response of aliens to climate change). However, at present no ETC adequately addresses biological invasions. The cross-cutting nature of biological invasions suggests that while ECISM would contribute to the European environment information and observation network (EIONET) its remit could not be subsumed in any existing ETC. Furthermore, while the European Environment Agency is a key stakeholder, biological invasions are the responsibility of many parties in Europe and ECISM would have a wider reporting remit since it would address issues such as transport, trade, agriculture, fisheries, health, etc. It is therefore likely that the ETC model, based as it is on rather nebulous consortia of organizations (rather than a single physical centre) and with overall governance managed by the EEA, would not adequately address the threats of biological invasions across all sectors.

The proposed ECISM activities would incur costs but these activities parallel those of European Centre for Disease Prevention and Control and this agency currently runs on an annual budget of less than €30 million. This is ten times more than the cost of running a single European Topic Centre (<€3 million per year) but in the case of biological invasion, such a sum is less than 0.5% of the annual cost of alien impacts to the European economy (Hulme et al. 2009a). The costs of running and delivering across these activities for biological invasions have not been calculated but are likely to be less than €30 million especially if activities currently undertaken by other European bodies are brought under the ECISM remit, thus avoiding duplication and maximizing the critical mass in one centre on this important topic. The benefits gained by coordinated action across Europe will far outweigh these running costs.

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