Working paper N° A/2007

Scoping paper for Streamlining European Biodiversity Indicators for 2010 project (SEBI 2010): costs of invasive alien species in Europe

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November 2007

The European Topic Centre on Biological Diversity (ETC/BD) is a consortium of nine organisations under a Framework Partnership Agreement with the European Environment Agency for the period 2004-2008
AOPK-CR ECNC EFI EEIC ILE-SAS ICRAM JNCC MNHN WETLANDS INTERNATIONAL

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Context:

The Topic Centre has prepared this Working paper in collaboration with the European Environment Agency (EEA) under its 2007 work programmes as a contribution to the EEA's work on indicators.

Citation:

Please cite this report as
McKenzie, E., 2007. Scoping paper for Streamlining European Biodiversity Indicators for 2010 project (SEBI 2010): costs of invasive alien species in Europe. ETC/BD report to the EEA.

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ETC/BD Working paper N° A/2007
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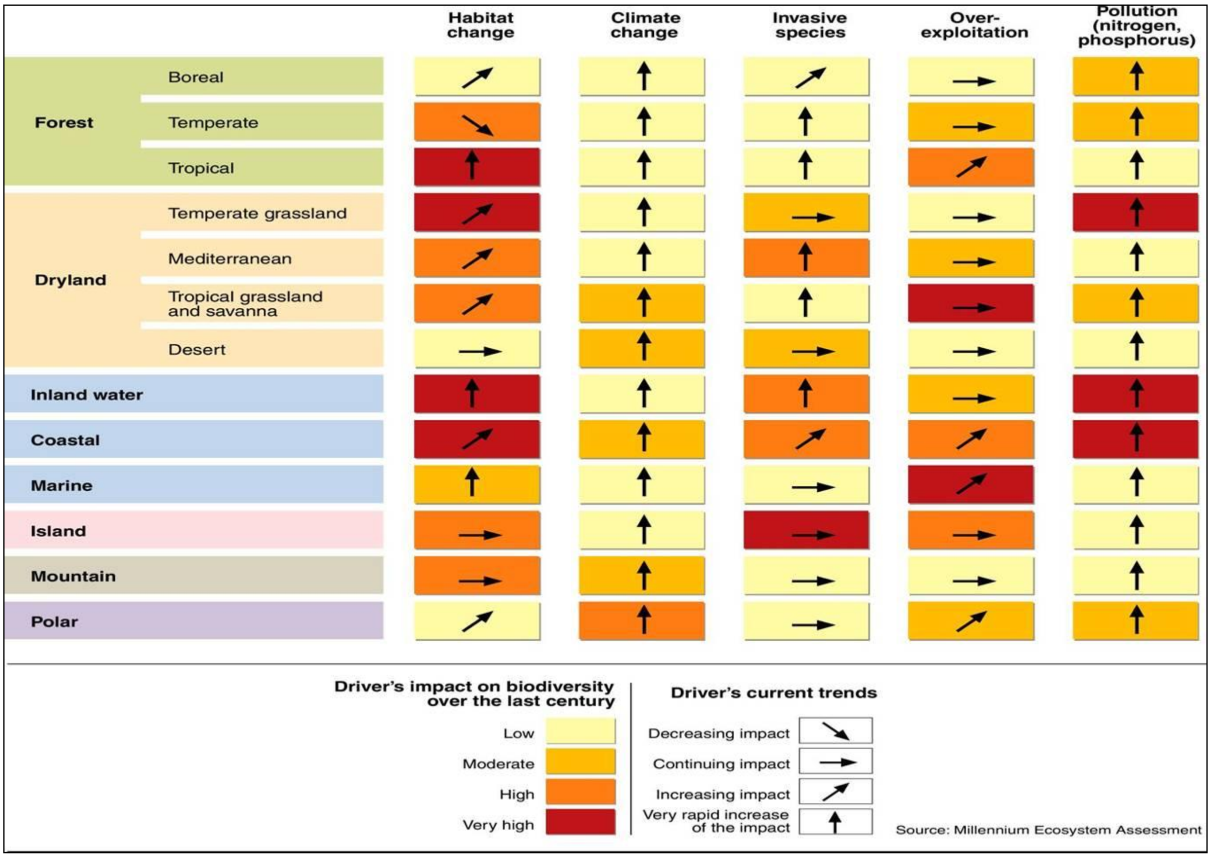
1 Introduction

The Millennium Ecosystem Assessment (2005) identified invasive alien species[1] as one of the five most important direct drivers of biodiversity loss, along with habitat change, climate change, overexploitation and pollution. In recent years, the spread of invasive alien species has increased with the rise in the global movement of people and goods through trade, travel and tourism. Other environmental pressures, such as climate change and habitat degradation, can exacerbate the impact of invasive alien species by creating conditions that allow them to disperse and flourish.

As shown in Figure 1, invasive alien species have already had a very high impact on biodiversity in island ecosystems worldwide and a high impact in coastal, inland water and Mediterranean dry-land ecosystems. The pressure of invasive species on biodiversity is projected to increase even further in forests, tropical grasslands, Mediterranean and savannah dry-lands, inland water systems and coastal ecosystems.

Figure 1: Direct Drivers of Biodiversity Loss



Source: Millennium Ecosystem Assessment (2005)

Awareness is growing about the importance of halting the spread of invasive alien species. There are an increasing array of measures world-wide that control some of the pathways of invasive species, such as quarantine regulations and rules on the disposal of ballast water in shipping. However, we still lack effective implementation of the full range of preventative measures that are needed to address the problem. Several invasive species pathways are not adequately regulated, particularly with regard to introductions into freshwater systems (Millennium Ecosystem Assessment, 2005). Experience has shown that prevention and early intervention are usually more successful and cost-effective strategies than control or eradication of an invasive species once it is established.

[1] The term invasive alien species is applied to any species that does not occur naturally in an area, spreads and becomes established in that area, and damages biodiversity and human interests.

In the Sixth Environment Action Programme of the European Community for 2002-2012, prevention and mitigation of the impacts of invasive alien species were identified as priorities. Within the European Commission's Biodiversity Communication (European Commission, COM (2006) 216 final) invasive alien species are recognised as a key pressure on biodiversity and a priority for action. One of the principal objectives in the first policy area of the Communication ('Biodiversity in the EU') is 'to substantially reduce the impact on EU biodiversity of invasive alien species and alien genotypes'. The Communication proposes that 'a comprehensive EU strategy should be developed for this purpose as well as specific actions including an early warning system'. The Community has still to develop a comprehensive strategy to address the issue of invasive alien species, but work has now begun.

Globally, governments have recognised the problems of invasive alien species through the Convention on Biological Diversity (CBD), which was ratified in 1992. Article 8h of the CBD requires parties to 'prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species'.

Social and economic aspects of invasive species problems have historically received less attention than ecological aspects. The Global Invasive Species Program (GISP) was founded in 1997, in part to explore the human dimensions of invasive species problems more thoroughly. There is particular interest among many working in this field to investigate further the impacts of invasive alien species on human wellbeing, including environmental, social and economic costs and benefits. Invasive species can transform the structure and species composition of ecosystems, thereby driving biodiversity loss. Invasive species can put pressure on native species directly by resource competition, predation and parasitism, or indirectly by changing the way nutrients are cycled. The ecosystem changes caused by invasive species have environmental, economic and social consequences that affect human wellbeing.

2 Aims and Structure of Scoping Paper

Under the Streamlining European Biodiversity Indicators for 2010 project (SEBI 2010), an expert group is preparing a suite of indicators to assess the impacts of invasive alien species on biodiversity in Europe. This scoping paper is part of the Joint Nature Conservation Committee's contribution to this work, undertaken as part of the 2007 Work Programme of the European Topic Centre on Biodiversity. The paper aims to support the development of the SEBI 2010 invasive species cost indicator, by providing a biodiversity economics perspective on the relevant conceptual background, existing literature, methodological issues and future research possibilities. First, the paper provides a conceptual overview, which could be used to develop the methodology for an indicator on the costs of invasive alien species. Second, it outlines some of the findings of existing research into the impacts of invasive alien species globally. Third, the paper highlights the remaining gaps, methodological weaknesses and challenges in the existing literature. Finally, a possible conceptual methodology is proposed for developing an indicator on the costs of invasive species, and the paper explores research activities that could help to take this work forward in Europe.

3 Conceptual Background

This section provides an overview of some ecological and economic frameworks that offer a useful theoretical foundation for considering the impacts of invasive alien species on human wellbeing. It includes a discussion of the Millennium Ecosystem Assessment's categorisation of ecosystem services, the Total Economic Value framework for assessing environmental values, and non-market methods for estimating those values.

3.1 Ecosystem Services

Invasive alien species alter biological diversity, which changes the availability of ecosystem services, which in turn affects human well-being. The effects of invasive alien species on human welfare can be both positive and negative: some impose costs on humans, such as weeds that reduce crop yields; others benefit humans, such as introduced cultivated crop species like corn and rice; some produce a mixture of costs and benefits that affect diverse stakeholders differently. Biological invasions can be introduced intentionally, through human activities such as trade. Often, however, invasive species are introduced to a new environment accidentally, through unintentional human activities or biophysical processes.

Ecosystem services are the benefits that people obtain from ecosystems. Many of these services are affected by invasive alien species. The Millennium Ecosystem Assessment defines a series of categories to assist the identification of ecosystem services:

- **Provisioning services**: The products obtained from ecosystems, including food, fibre, fuel, genetic resources, bio-chemicals, natural medicines, pharmaceuticals, and fresh water;
- **Regulating services:** The benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination, and natural hazard regulation;
- **Cultural services**: The non-material benefits people obtain from ecosystems through spiritual enrichment, reflection, inspiration, education, recreation, eco-tourism, and aesthetic experiences; and,
- **Supporting services**: The services that are necessary for the production of all other ecosystem services, including soil formation, photosynthesis, primary production, nutrient cycling and water cycling.

A few invasive species produce considerable benefits for humans by enhancing provisioning services, such as food crops and livestock breeds. For example, common carp *(Cyprinus carpio)* have been widely introduced in inland water ecosystem around the world. In 2002, over 2.8 million tons of common carp were produced through aquaculture, mostly in developing countries (Ciruna et al, 2004). However, many invasive species adversely affect a range of ecosystem services with severely detrimental impacts on human wellbeing. Some invasive species have increased the risk of natural hazards such as fires, floods and soil erosion. For example, in South Africa invasion of fynbos catchment areas has increased biomass and fuel loads, leading to a greater incidence of fires. Invaded and burnt watersheds experience severe soil erosion, leading to rapid rainwater runoff, and causing flooding, damage to infrastructure and siltation (Van Wilgen et al, 2001). Other invasives reduce crop yields, water supplies, fishery catches, opportunities for recreation, human health, and the aesthetic experiences from interaction with native species and habitats. To take the example of common carp, their introduction has led to the decline and even local disappearance of native fishes in Argentina, Australia, Venezuela, Mexico, Kenya, India and elsewhere (Welcomme, 1988). By feeding in the soft benthic substrates of lakes and rivers, common carp increase siltation and turbidity, decreasing water clarity and harming native flora and fauna (Fuller et al. 1999; Koehn et al. 2000). This has negative implications for water supplies, fishery catches, recreation, health and aesthetic experiences. A comprehensive economic assessment of the impacts of invasive alien species should account for all affected ecosystem services. Most existing studies, however, focus on a small number of provisioning services, such as food crops, timber and fish stocks.

3.2 Total Economic Value

Economic valuation is of interest to policy makers because it breaks down the multidimensional impacts of invasive species on a range of ecosystem services into more easily comparable monetary units. The value of the benefits provided to humans by ecosystem services are conventionally categorised using a Total Economic Value (TEV) framework. This framework divides the value to humans of an environmental good, service or system into direct use, indirect use and non-use values.

- **Direct use values** relate to the direct (extractive and non-extractive) use of an environmental good;
- **Indirect use values** relate to ecosystem functions and services which indirectly provide benefits, such as water storage and flood protection;
- **Non-use values** arise without using an environmental good or service. Non-use values come about from simply knowing that an environmental resource exists or will continue to exist in the future. This value can be split down into an 'option' value (sometimes considered a use value as it can represent the value of an option to 'use' a resource in the future), a 'bequest' value and an 'existence' value.

The Total Economic Value framework has a utilitarian perspective – it only measures values to humans from the environment, and does not account for the 'intrinsic' value of the environment irrespective of human perceptions. Appendix 1 illustrates the Total Economic Value framework in more detail.

A comprehensive economic assessment of the impacts of invasive alien species should incorporate all affected ecosystem services and all elements of the Total Economic Value framework. Most existing studies, however, usually focus on direct use values, and do not take account of all relevant value categories. Turpie and Heydenrych (2000) present one of the few studies that include an assessment of the loss of option and existence values due to the detrimental impacts on native fynbos vegetation of an invasive *Acacia* species in South Africa.

3.3 Economic Valuation Methods

A range of different methods in the environmental economics literature can be used to estimate the utilitarian values of ecosystem services affected by invasive species. The appropriate technique will depend on the application and available data. A common feature of all methods of economic valuation of ecosystem services is that they are founded in the theoretical axioms and principles of welfare economics. Most valuation methods measure the demand for a good or service in monetary terms, as measured by consumers' willingness to pay (WTP) for a particular benefit, or their willingness to accept (WTA) compensation for its loss.

Market-based methods are appropriate for assessing the use values of ecosystem services that are traded in formal markets, such as timber, fisheries and minerals. Such methods need to correct prices to reflect market distortions. For the majority of ecosystem services that are not traded in markets, a range of non-market valuation methodologies are available. Appendix 2 briefly outlines the main economic valuation methods. For full details and further references see Pagiola et al. (2004).

The existing literature on the impacts of invasive alien species has tended to use a small sub-set of these valuation methods, focusing on those that are the least data and resource intensive, but tend to be the most inaccurate. The literature has leant heavily on market-based production cost methods, and non-preference based replacement cost and control cost methods. Data produced with these last two methods have no interpretation based on economic welfare theory in terms of 'willingness to pay'. These methods are also prone to errors; they can lead to both over- and under-estimation and should therefore be used with caution.

3.4 Economic Decision Support Tools

Economic valuation of the impacts of invasive alien species can be channelled into two different types of economic analysis in order to support policy. First, economic values can be used in classical economic analysis, such as cost-benefit analysis or cost-effectiveness analysis, to support decision making over the most appropriate strategy for dealing with invasive alien species. Many existing economic studies are specifically designed to provide information to support decisions on implementation of alternative prevention, mitigation and eradication measures for reducing the impacts of invasive alien species. This type of analysis evaluates invasive species policies by comparing the resulting costs and benefits, including the economic values of invasive species impacts.

The analysis can be undertaken ex-post to evaluate policies that have already been implemented, or ex-ante to assess policies that could be implemented in the future. Ex-ante studies are currently scarce. Those that do exist mostly use ecological-economic models or scenarios to estimate the impacts of hypothetical management regimes.

In the second type of economic analysis, valuation can be used more generally for ‘impact assessment’ studies, which assess the total impacts of invasive species in the status quo situation without any policy measures to address the problem. This type of analysis can raise general awareness of the overall damages (and benefits) of invasive alien species, and may influence decisions over the required scale of future policy action.

4 Existing Research

A number of studies already exist on the impacts of invasive alien species around the world. Most existing studies investigate the partial value of a sub-set of the total ecosystem services affected by a single species in a specific geographical location. The research tends to focus on control costs and economic output losses within the agriculture, fisheries and forestry sectors. These studies suggest that invasive alien species are a serious problem – causing significant environmental and economic damage and necessitating major expenditures on control and mitigation projects. A sample of these studies is summarised in this section. For a more detailed survey, see Born et al. (2005).

4.1 Regional and National Overviews

As part of the SEBI 2010 process, the Expert group on 'Trends in invasive alien species' is developing a list of 'Worst invasive species threatening biodiversity in Europe'[2]. This list defines the most harmful invasive alien species primarily with respect to impacts upon European biodiversity and changing abundance or range. The list also considers negative impacts on human activities, health and/or economic interests. However, data on the economic value of the impacts of invasive alien species were not routinely considered in compiling this list, due to the gaps in and weaknesses of existing information.

On the basis of an initial assessment, Waage et al (2004) suggest that at the European level non-native species introductions have been increasing across a number of taxa in recent decades, and are likely to continue doing so. While acknowledging that the existing evidence base for prediction is poor, they forecast that invasive alien species costs will get worse in the future in the UK.

The Office of Technology Assessment (1993) estimated that 79 invasive alien species had caused approximately US$97 billion in damages in the United States during the period 1906-1991, implying average costs of £1.1 billion per year. Pimentel et al. (2000) estimate the costs of invasive species in the United States to be far higher than this – amounting to approximately US$137 billion per year in terms of damages and control costs. These two examples serve to illustrate the enormous variability of the findings of existing studies.

Pimentel et al. (2001) estimate the annual economic losses of a set of invasive species affecting crops, pastures and forests in six countries – the United States, United Kingdom, Australia, South Africa, India and Brazil – at approximately US$314 billion per year. The cost per capita of these losses was estimated to be approximately US$240 per year. Assuming similar costs worldwide, this implies that damage from invasive species is more than US$1.4 trillion per year, representing nearly 5% of the world economy. In New Zealand, the costs of invasive species are estimated to amount to about 1% of GDP (Bertram, 1999).

[2] Further details available at: http://biodiversity-chm.eea.europa.eu/information/indicator/F1090245995/F1115192484/fol364644/Worst_IAS_documentation_draft_2007-01-08.doc

4.2 Species Case Studies

A range of case studies exist that estimate the impacts of particular invasive species in specific locations in monetary terms in more detail. For example, in certain locations the costs have been estimated of the invasion of the golden apple snail in Asian rice agro-ecosystems *(Pomacea canaliculata)*, which was introduced intentionally into Asia as a high-protein food source. In the Philippines in 1990, the costs associated with rice production losses, control costs and replanting amounted to US$28-45 million (Naylor, 1996). Summaries of relevant case studies have been published by the Convention on Biological Diversity in the context of island and inland water ecosystems (UNEP/CBD/SBSTTA, 2003; Ciruna et al, 2004). It should be noted that some invasive species create benefits for humans. For example, in addition to causing significant costs for people, *Acacia* species in South Africa also generate some benefits, for example by generating employment and income through the provision of material for timber and firewood (Turpie and Heydenrych, 2000). Some introduced species, such as corn, wheat, rice, and cattle, provide a large proportion of the world's food supply (Pimentel et al., 2001). A balanced, comprehensive assessment of the impacts of invasive alien species must incorporate both the costs and the benefits that are incurred.

Some research has demonstrated that invasive species can cause ecosystem instability with dramatic and sudden impacts (although these impacts are rarely, if ever, valued in monetary terms). For example, the Millennium Ecosystem Assessment (2005) notes that the introduction of the invasive, carnivorous ctenophore *Mnemiopsis leidyi* (a jellyfish-like animal) in the Black Sea caused the rapid loss of 26 major fish species and has been implicated (along with other factors) in the continued growth of the oxygen-deprived 'dead' zone.

5 Gaps and Issues

Existing research into the impacts of invasive alien species is limited, and different studies have used very heterogeneous approaches. As noted by Wilgen et al. (2001) and confirmed by Born et al. (2005): *'attempting an objective analysis and summary of studies (on the economics of biological invasions) that have been done is frustrating, as every study has used a different approach, making an accurate assessment of aggregate impacts impossible'* (Wilgen et al. 2001, p154). Information has not been brought together to develop a standard indicator and consistent information on trends in impacts over time is extremely difficult to find. Hence, considerable uncertainty remains about the total impact of invasives.

5.1 Gaps

Most relevant economic studies have been conducted outside Europe – in South Africa, North America, Australia and New Zealand. There are very few studies that examine invasive species issues in developing countries.

Most of the economic studies on the impacts of invasive species that currently exist have serious methodological limitations (Born et al., 2005). Studies often use error-prone valuation methodologies, rough approximations, tenuous assumptions, unreferenced and unpublished data and partial economic frameworks for estimating and scaling up the monetary costs of alien species. Estimates of costs based on market prices often do not account for market distortions, such as those arising from subsidies. Most aggregate estimates are based on summing cost data from a series of specific case studies, which often involve arbitrary economic estimates, scaled up to the national level with simple multipliers. Costs often include both production losses and control costs. It is therefore not clear how much of the costs are due to invasive alien species impacts or ineffective responses to them. Frequently, business data are used inappropriately within the economic analysis (Born et al. 2004).

Critically, almost all existing studies emphasise the impacts of invasive species on the direct use values of provisioning services, such as crop yields in agriculture, catch sizes in fisheries or timber yields in forestry. The direct use value of provisioning services is the easiest category of total economic value to estimate, as it can be done using standard market price based methods, and relatively abundant and reliable data. The indirect and direct use values of regulating services that are affected by invasives, such as pollination, water supply and fire hazards, have been considered in very few studies (Turpie and Heydenreich, 2000; Bertram, 1999). Non-use and option values are rarely discussed and almost never included in modelling. Cultural services affected by invasive species, such as recreation, eco-tourism, and educational and aesthetic experiences, are dealt with rarely. As a result, there are very few studies that estimate all the relevant impacts of invasive species comprehensively or consistently, which makes them difficult to aggregate or compare. The repercussions of impacts on biodiversity tend to be compartmentalised as 'environmental impacts' and are often not assessed in terms of the repercussions for ecosystem services and human wellbeing. Table 1 summarises the value categories covered in a sample of ten studies surveyed by Born et al. (2005).

Table 1: Value Categories Assessed in Sample of 10 Studies

Source	Country Context[3]	Use values			Non-use values
		Direct use value	Indirect use value	Option value	
Bertram, 1999	New Zealand	X	X	X	
Turpie & Heydenreich, 2000	South Africa	X	X	X	X
Wit et al., 2001	South Africa	X	X		
McConnachie et al., 2003	South Africa	X			
Wilgen, 2001	South Africa	X	X		
Reinhardt et al., 2003	**Germany**	X	X		
Cullen and Whitten, 1995	Australia	X			
Tisdell, 1990	Australia	X			
Pimentel et al., 2001	**UK**, Australia, Brazil, India, New Zealand, South Africa, USA	X	X		
Pimentel et al., 2002	USA	X	X		

Source: Born et al. 2004.

Very few of the existing studies explicitly consider ecological uncertainties within the context of invasive species impacts. Some economic studies include sensitivity analyses but these do not explicitly account for the uncertainty of ecological processes (Born et al., 2004).

In summary, it is clear that there are a number of major gaps and methodological weaknesses in the existing literature on the impacts of invasive alien species. In particular, there are few studies that include indirect use and non-use values, include regulating and cultural ecosystem services, or

[3] European countries highlighted in bold.

explicitly model ecological complexities and uncertainties. Furthermore, the existing studies only cover a small number of countries. As a result, a comparison or aggregation of existing information is unlikely to provide robust or meaningful results, and existing studies should be used with caution.

5.2 Methodological issues

Robust estimation of the impacts of invasive species requires an interdisciplinary approach, combining sound ecological and economic modelling. However, there remain a number of major challenges due to the limitations in the ecological and economic foundations for analysis. There are also tremendous hurdles to be faced in scaling up studies from the micro- to the macro-level. These difficulties help to explain why the existing literature is so limited, and should be kept in mind when embarking on future research activities.

First, estimating the total impacts of invasive alien species is difficult because of the limitations in the existing ecological understanding of these phenomena. To begin with, only 1.5 million species of the estimated 10 million species on earth have been identified and described (Raven and Johnson, 1992). Ecological understanding of how invasive species affect other species, ecosystems and ecosystem services is often limited. It can be difficult to determine the geographical boundaries that define a species as 'alien'. It is also often extremely challenging to establish temporal baselines for when invasive species arrived and began to cause damage. It is essential to establish a baseline in order to get a robust indication of the economic costs of invasive species.

Second, the economic methods available to value the impacts of invasive alien species on ecosystem services are only as accurate as the ecological modelling upon which they are based. Even with a sound ecological foundation, valuing ecosystem service changes in monetary terms is a challenging undertaking. Non-market methodologies often require extensive time, funding, data and expertise. Thorough economic valuation may therefore not be compatible with urgent policy needs relating to invasive species.

Third, an assessment of the costs of invasive alien species must be based on a comparison of human welfare 'with' and 'without' invasive species. In order to make these calculations, it is necessary to establish a baseline scenario i.e. the situation that would have occurred without the biological invasion. This involves determining when an invasive species was introduced and began to have adverse effects. This can be extremely difficult, particularly for species that have been in the new environment for a long period, such as the rabbit in Europe.

Fourth, alien species can be introduced from outside the European Union and from one region of Europe to another. For the purposes of establishing an indicator on the costs of invasive alien species for Europe, a decision would need to be made as to whether species spreading between countries within the Union should count as invasive.

Finally, while it is feasible to assess the impacts of invasive species in a defined area over a defined period of time, there are tremendous hurdles to be faced in scaling up studies from the micro- to the macro-level. The extent of the impact of an invasive species depends on site-specific conditions, which makes it difficult to extrapolate findings from individual case studies to other locations. Ecological factors interact in non-linear ways with complex compensating and synergistic effects, making simple summation of impacts of invasives misleading. Widespread, small-scale effects of invasive alien species may be great in total (particularly over long periods of time) but they are very hard to document at sample locations, so there is the potential to underestimate their significance. Furthermore, different valuation methodologies are often used in existing studies, making them hard to compare or aggregate. For all these reasons, it is likely to be extremely difficult to develop a robust macro-level indicator that demonstrates trends in the costs of invasive alien species over time in Europe.

6 Scope of Indicator and Future Research

Within the SEBI 2010 project, an indicator on invasive alien species in Europe has been developed. The specification for this indicator will be published in a European Environment Agency (EEA) Technical Report in the summer of 2007. To complement this indicator, it may be possible to develop supporting information, in an indicator form or otherwise, on the costs of invasive alien species. The indicator could focus on the negative impacts of invasive alien species – the costs of invasions precipitated by both intentional and accidental introductions – while acknowledging that some invasives can produce benefits for humans.

Given the limitations of existing studies, remaining gaps in the research, and methodological issues in this area, there are a number of approaches that could be undertaken to develop on the impacts of invasive alien species in Europe. A number of potential options are discussed below:

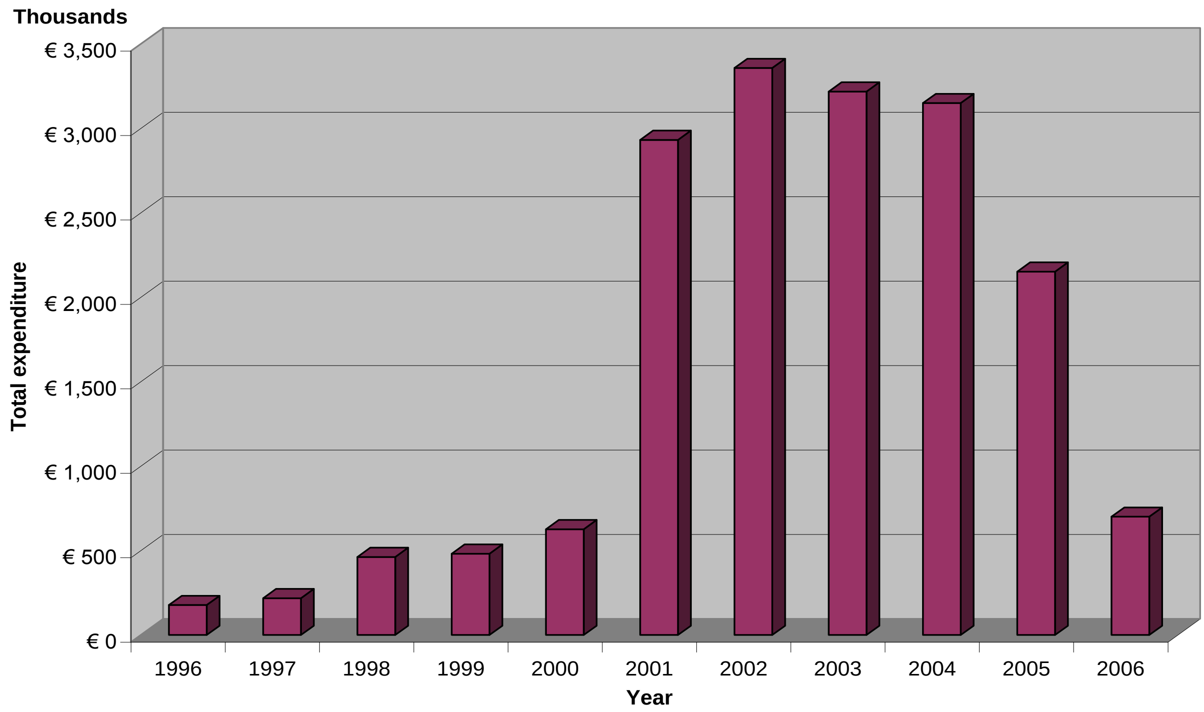
6.1 Control and management costs

LIFE (The Financial Instrument for the Environment) is a European Union financial instrument that was introduced in 1992 for co-financing environmental projects. LIFE co-finances environmental initiatives in the European Union and certain third countries bordering on the Mediterranean and the Baltic Sea, and in those EU candidate countries that have decided to participate. The new LIFE+ regulation is expected to enter into force in 2007, with the general objective to contribute to the implementation, updating and development of Community environmental policy and legislation, including the integration of the environment into other policies, thereby contributing to sustainable development. The regulation does not mention invasive alien species specifically but related projects would be applicable under the LIFE+ component 'Nature and biodiversity', for which at least 50 % of the budgetary resources for LIFE+ dedicated to project action grants is allocated.

The SEBI 2010 Expert Group is already compiling data on the costs of control and management of invasive alien species in Europe, including expenditure on research. European level data is available for funding of EU LIFE-projects addressing invasive alien species in 1992-2002 (EC, 2004, p 24-25). Between 1992 and 2002, the EU LIFE fund supported 715 projects, out of which 109 projects involved management of invasive alien species. Of these projects, 24 dealt almost exclusively with invasive alien species, with a total budget of €23.3 million. An additional 83 projects dealt in part with invasive alien species. It was possible to calculate the budget share directed towards invasive alien species for 44 of these (in total estimated at €4.3 million). It would be possible to update this dataset for the period 2002-2006. Data may also be available on EU research funding for projects addressing invasive alien species beyond the LIFE programme.

In this way, data on control, management and research costs related to invasive alien species could be compiled and aggregated as an overall indicator of total costs. This indicator could be monitored over time and disaggregated to the national level. Additional sub-indicators could provide additional supportive information, such as the proportion of LIFE projects entirely or partially devoted to invasive alien species, broken down across different European funding sources. The aggregated expenditure indicator and sub-indicators could be presented in both tabular and graph form, to show trends over time, across species, sectors and geographic areas. An example of what such an indicator might look like is provided in Figure 2, showing rough estimates of total expenditure on LIFE-funded projects primarily aimed at invasive alien species in 1996-2006.

Figure 2: Expenditure on LIFE funded projects primarily aimed at IAS, 1996-2006[4]



Such information on the costs of control and management of invasive species may be useful for policy purposes. However, at the outset it should be recognised that these figures would only give a partial picture. Many control strategies fail or are ineffective. Therefore, the costs and benefits of such strategies do not necessarily reflect the costs and benefits of invasive alien species. The data would not reflect the environmental costs and therefore would not convey a true picture of the economic value of the impacts of invasive alien species.

6.2 Compile existing studies on broader economic costs

It would be extremely valuable to collate national data on invasive alien species and provide a regional statistical overview for Europe. In the future, all data on invasive alien species could be integrated into the European Nature Information System (EUNIS database[5]), which includes information on species, habitats and their sites present in Europe (European Commission, 2003). No specific information related to invasive alien species is currently available through EUNIS.

A few surveys have been conducted of the existing literature on the impacts of invasive species (Born et al., 2005; Pimentel et al., 2001; Perrings et al., 2000; Richardson et al, 2004), but very few of these are focused on the European context (Di Castri et al., 2003). A literature review could be undertaken to collect, review and analyse all available information on the costs of invasive alien species in Europe. This approach would give an overview of the existing literature in Europe and help to identify remaining gaps. It could help to raise awareness of the problems of invasive species and thereby influence policy[6].

The research could also explore the potential for compiling these figures into a robust and meaningful single indicator. However, the existing literature uses different methodologies for estimating costs,

[4] Note these figures are rough approximations based on a brief analysis of easily available LIFE data. Further analysis is needed to develop a reliable indicator of expenditure.

[5] http://eunis.eea.europa.eu/

[6] According to Waage et al (2004), the US Executive Order of 2000, by which President Clinton established an inter-ministerial Invasive Species Council, was effectively built around Pimentel's broad brush statistics on the costs of invasive alien species.

making it difficult to compile figures into an overall indicator. Instead data could be selected from the studies to be used as part of the indicator and presented in tabular form. A summary table of information from existing studies could be presented, and regularly updated, including facts for each study, such as the country or region, the invasive alien species, circumstances of the invasion, impacts assessed, estimated monetary costs, major assumptions, and caveats of the assessment.

Given the partial coverage of existing studies in terms of geographic area, ecosystem services and values, this part of the indicator would only cover a small proportion of the total impacts of invasive species in Europe and would not comprehensively reflect the full implications for human wellbeing of loss of biodiversity and regulating and cultural ecosystem services.

Table 2 overleaf provides an example of the kind of information that could be collected from case studies by Pimentel et al. (2001) on the costs of invasive species in the UK and Reinhardt et al. (2003) on the costs of invasive species in Germany:

Table 2: Sample of summary information on costs of invasive alien species in Europe

Country	Source	Invasive alien species	Invasion	Impacts	Estimated monetary costs	Assumptions	Caveats
Germany (throughout)	Reinhardt et al (2003)	Ragweed	Intentional for parklands and tourism, and via birdseed.	Annual direct and indirect health costs of allergic reactions.	€ 32.1 million p.a.	Proportion of allergies due to ragweed	Lower-bound estimate. Does not include ecological impacts (unknown) or quality of life impacts. Based on limited data.
UK (throughout)	Pimentel et al (2001)	All alien weeds	Intentional and accidental introductions	Annual loss of crop production	US$ 1. 4 billion p.a.	Proportion of crop losses caused by alien weeds same as proportion of total weeds that are alien.	Simplified assumptions. Only includes direct use value of affected crops.
Germany	Reinhardt et al (2003)	Lesser grain borer and saw-toothed grain beetle	?	Loss of food grain stores. Indirect costs, such as research, and product recalls.	€ 8.7 million p.a.	Proportion of grain loss due to selected species	Simplified assumptions. Only considers grain losses.

6.3 Develop methodology for comprehensive estimation of invasive species impacts

There is a clear need for a robust and consistent methodology for comprehensively estimating the impacts of invasive alien species in monetary terms, including the impacts on the full range of affected ecosystem services. This need has been recognised within the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) of the Convention on Biological Diversity (UNEP/CBD/SBSTTA/10/INF/17). Little work has been done in this area globally and there would be numerous methodological challenges, particularly in valuation of the less tangible ecosystem services affected by invasive species. Research to develop a sound methodology would provide a foundation for future research that could potentially feed into an overall aggregate indicator in the long-term. The methodology would draw attention to the impacts of invasive species on ecosystem services and the repercussions for human wellbeing.

6.4 Develop new case studies in Europe

To develop, test and/or refine a methodology for estimating the impacts of invasive species, a number of case studies could be undertaken in a range of ecosystems and geographical locations in Europe. Case studies would serve to illustrate the impacts of a range of species in Europe and could eventually feed in to an overall indicator showing trends over time.

Any new case studies could be added to the tabular part of the indicator (see Section 6.2) as information became available. If a sufficient number of case studies were undertaken using a consistent, robust methodology, they could be aggregated to form a single indicator of invasive species costs in Europe, but this does not seem possible or likely in the near future.

6.5 Develop broader decision-making tools for invasive species policy

Given the challenges faced in monetary valuation of invasive species impacts, it may be fruitful to focus effort on developing broader decision-making tools that can be used to find solutions to the complex problems of invasive species, without requiring economic valuation of all impacts. Such tools could further develop existing methodologies, such as multi-criteria analysis and risk assessment. On the basis of a survey of economic studies of the impact of invasive alien species, Born et al (2004) recommend focusing future research on multi-criteria analysis. They argue that this type of analysis would be less dependent on scarce quantitative scientific and economic data, allow inclusion of qualitative data relating to less tangible ecosystem values, and deal better with ecological uncertainty.

7 Conclusions

A number of studies already exist that explore the impacts of invasive species around the world. However, these studies tend to be limited in their robustness and scope, and few are based in Europe. In order to develop a meaningful and standardised indicator, a robust, consistent methodology for estimating and integrating the costs of invasive alien species is required. This methodology faces a number of issues, particularly relating to the ecological and economic understanding required for robust valuation of ecosystem services. Given these challenges, careful thought needs to be given about the best approach for developing better information on the impacts of invasive species in Europe. Economic valuation can support policy decisions for dealing with invasive alien species in priority areas. Overall cost indicators will help to make policy makers and the public aware of the seriousness of the problem. The true challenge lies in determining and providing the optimal amount of information on the impacts of invasive alien species, including economic values, necessary for developing decision tools that help to prevent further damage.

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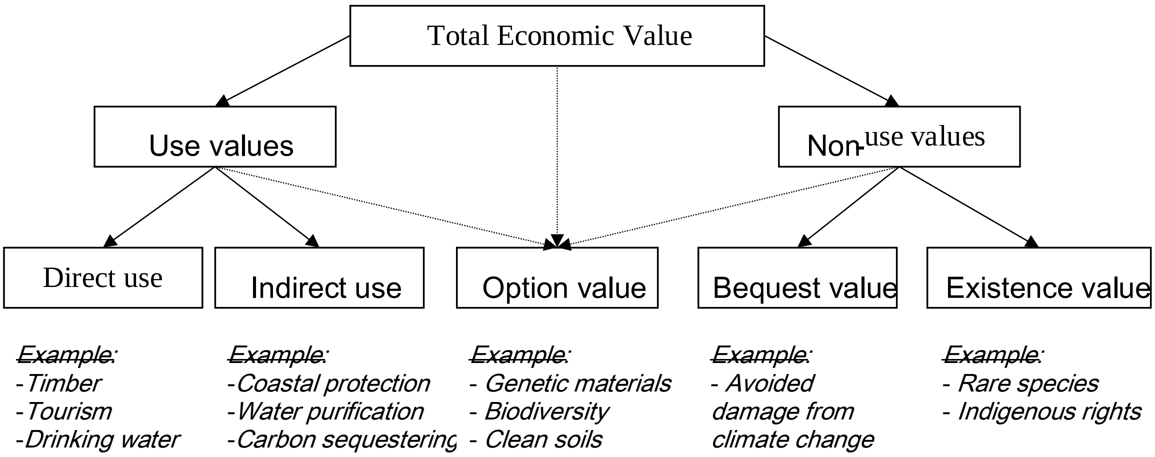
Appendices

Appendix 1: Total Economic Value Framework



Appendix 2: Main economic valuation techniques

Methodology	Approach	Applications	Data	Limitations
Revealed preference methods				
Production function / change in productivity	Trace impact of change in ecosystem services on produced goods	Any impact that affects produced goods	Change in service; impact on production; net value of produced goods	Data on change in service and consequent impact on production scarce
Cost of illness, human capital	Trace impact of change in ecosystem services on morbidity and mortality	Any impact that affects health	Change in service; impact on health; cost of illness or value of life	Dose-response functions linking environmental conditions to health lacking; omits preferences for health; value of life not easy to estimate
Replacement cost	Use cost of replacing lost good or service	Any loss of goods or services	Extent of loss; cost of replacement	Tends to over-estimate actual value
Travel cost	Derive demand curve from data on actual travel costs	Recreation	Survey to collect monetary and time costs of travel; distance	Limited to recreational benefits
Hedonic pricing	Extract effect of environmental factors on price of goods that include those factors	Air quality, scenic beauty, cultural benefits	Prices and characteristics of goods	Data intensive, very sensitive to specification
Stated preference methods				
Contingent valuation	Ask respondents directly their WTP for specified service	Any service	Survey that presents scenario and elicits WTP for specified service	Many potential source of bias in responses; guidelines exist for reliable application
Choice modeling	Ask respondents to choose their preferred option from a set of alternatives with particular attributes	Any service	Survey of respondents	Similar to those of CV; analysis of the data generated is complex
Other methods				
Benefits transfer	Use results obtained in one context in a different context	Any for which suitable comparison studies are available	Valuation exercises at another, similar site	Can be very inaccurate, many factors vary even when contexts seem 'similar'

Source: Adapted from Pagiola et al. 2004