VALUE OF BIODIVERSITY

Documenting EU examples where biodiversity loss has led to the loss of ecosystem services

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Final Report

Marianne Kettunen & Patrick ten Brink

With contributions from Jason Anderson, Samuela Bassi, Ingo Bräuer, Indrani Lutchman, Eleanor MacKay, Anil Markandya, Clare Miller, Paulo Nunes, Ana Persic and Matt Rayment

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EXECUTIVE SUMMARY

The objective of this study has been to bring together EU examples where biodiversity loss or the modification/loss of habitats accompanied by biodiversity loss has led to the loss/degradation of ecosystem services, and consequently to economic costs and/or social losses. The information used and analysed in the study has been collected through expert interviews, a literature survey, and a short questionnaire distributed to relevant stakeholders in February 2006.

There are a considerable number of examples of the loss of ecosystem services due to and/or associated with the loss of biodiversity. This study identified 37 relevant examples from 18 EU Member and Accession States. These 37 examples represent a sample of the unknown, but much larger number, of cases where biodiversity loss has led to socioeconomic and financial costs. The final report focuses on a subset of ten of these examples, which are presented as case studies. The report summarises the information and insights gained and discusses the implications of the findings of the study to policy- and decision-making.

The outcomes of this study clearly demonstrate that throughout the EU, a wide range of biodiversity-related services provided by a variety of ecosystems have been lost or degraded. The case studies reveal different levels of biodiversity loss (including loss/degradation of ecosystems and habitats, changes in species population levels and species composition, and decline in the number of species) as well as different underlying causes of the losses.

Table 1e, below summarises information from the 37 examples identified from the survey responses. For these, the most frequently lost/degraded services include food and fresh water (eg marine and fresh water resources), water purification and waste management, water regulation, erosion control and a range of cultural services (eg recreation and tourism).

Table 1e. Examples of the types of ecosystem services lost due to/accompanied by the loss of biodiversity in the EU Member and Accession States. The table summarises the information obtained from the 37 examples identified during the survey. The examples are from 18 Member States.

TYPE OF ECOSYSTEM SERVICE LOST	Examples of the service being lost (no of examples where mentioned)
Provisioning Services	
Food and fibre	YES (19)
Fuel	YES (2)
Biochemicals, natural medicines, and pharmaceuticals	YES (4)
Ornamental resources	YES (1)
Fresh water	YES (13)
Other	-
Regulating services	
Air quality maintenance	YES (1)
Climate regulation (eg temperature and precipitation, carbon storage)	YES (8)
Water regulation (eg flood prevention, timing and magnitude of runoff,	YES (11)

aquifer recharge)	
Erosion control	YES (13)
Water purification and waste management	YES (10)
Regulation of human diseases	YES (2)
Biological control (eg loss of natural predator of pests)	YES (8)
Pollination	YES (6)
Storm protection (damage by hurricanes or large waves)	YES (4)
Fire resistance (change of vegetation cover leading to increased fire susceptibility)	YES (2)
Avalanche protection	YES (2)
Other (loss of indicator species)	Yes (2)
Cultural services	
Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity	YES (22)
Cultural heritage values	YES (9)
Recreation and ecotourism	YES (27)
Other	
Supporting services	
Primary production	YES (9)
Nutrient cycling	YES (7)
Soil formation	YES (4)
Other	-

According to the case studies, habitat alteration and destruction appears to be the most common direct reason behind the loss of biodiversity and related ecosystem services. Additionally, over-extraction of resources, pollution and eutrophication, and changes in ecosystem species composition (eg introduction of invasive alien species) have often contributed to the loss.

Regarding the underlying reasons behind the loss, unsustainable resource management, including overexploitation of aquatic resources and agricultural intensification, combined with sectorally-oriented development initiatives could be distinguished as the principle drivers. In the latter case, a project focused, for example, on increasing the navigability and energy production capacity of a river can lead to extensive destruction of natural habitats, biodiversity and ecosystem services.

All ten case studies provided evidence that the loss of biodiversity and ecosystem services has resulted in socio-economic costs, including financial losses (Table 2). For example, agricultural abandonment and expansion of fire-prone plantation forests has significantly contributed to the increase of wildfires in Portugal. In the last 25 years (1980-2004) fires have burned over around 2.7 million hectares of forest land. Considering only the direct losses associated with primary production, the estimated costs have been about €300 million per year. In the case of the North Sea ecosystem, the state of most commercial fish species has deteriorated during the past decade with some stocks reaching a historical low. The most prominent example of a stock under severe pressure in the North Sea at present is cod whose spawning stock biomass (adults able to reproduce) had declined from a peak of 250,000 tonnes in the early 1970s to less than 40,000 tons in 2001.

Table 2. Estimates of lost value due to the loss of biodiversity-related ecosystem services. The table summarises information from the ten case studies. The losses that have occurred are often indicated by decline in exploited resources or cost/benefits arising from restoration.

CASE STUDY	**ESTIMATES OF LOST VALUE**
Case 1. Decline of European crayfish populations	✓ 40 per cent decline in native crayfish populations in France during the last 6 years; ✓ 95 per cent decline in native crayfish populations in Sweden since ~1900
Case 2. Modification of Danube river ecosystems	✓ Value of restored river fisheries ~US$16 million in the Danube delta; ✓ Value provided by restored habitat in the Danube delta for nitrogen and phosphorous absorption and cycling ~US$112.5 million and ~US$18.2 million respectively per year; ✓ Value of tourism in the Danube delta resulting from restored wetland habitat ~US$16 million per year
Case 3. Modification of Lake Karla ecosystem (Greece)	✓ Loss of entire fish catch in Lake Karla (Greece) of 80kg per hectare; ✓ Restoration of the lake has started at a cost of around €150 million
Case 4. Depletion of the North Sea resources	✓ Cod spawning stock biomass in the North Sea declined from a peak of 250,000 tonnes in the early 1970s to less than 40,000 tons in 2001
Case 5. Destruction of peat bogs in Finland and the UK	✓ Restoration of peat bogs in the Northwest England is expected to help improve drinking water quality and provide benefits between €1.8 and 3.6 million/year
Case 6. Agricultural changes in Portugal	✓ During 1980-2004 fires burned around 2.7 million ha of forest in Portugal; ✓ Costs arising from the loss of primary production due to forest fires ~€300 million per year (2000-2004) ✓ Investments in fire fighting and prevention amounted to €479 million (€17,8/hectare per year) (2000-2004)
Case 7. Eutrophication of the Swedish coast	✓ Estimated overall benefits of increased water quality would amount to €6 – €54 million per year; ✓ Annual costs of removing dead algae are €8119 per km of beach; ✓ Costs of mechanical harvesting of algal mats ~€7145/year
Case 8. Recovery of ospreys in the UK	✓ Osprey tourism is estimated to bring additional expenditure of £3.5 million per year to local economies
Case 9. Reintroduction of beavers in Germany	✓ Increased revenues from tourism in the area of reintroduction can total up to ~€0.55 million per year; ✓ Estimated additional retention of 2800 kgN per annum in the river and of 1900 kgN per annum in the floodplains
Case 10. Unsustainable clam fishing in Italy	✓ ~40 per cent decline in the clam catch between 2000 and 2001 due to decline of stocks

The case studies show that losses are often not directly apparent but become more prominent in the long run, for example, when the trade-offs between ecosystem services take place. Due to the trade-offs the modification of ecosystems to enhance one service can come at a cost to other services. For example, improving provisioning of agricultural goods by increasing the use of artificial fertilisers and pesticides can decrease the fresh water supply and recreation opportunities provided by aquatic ecosystems. Losses may also occur in a different ecosystem and/or socio-economic sector than the benefits making the detection of costs even more difficult. The distribution of costs and benefits is also biased between different stakeholders. Additionally, the benefits are usually obtained on a private level whereas the associated costs are often of a more social or public nature.

To conclude, in several cases the loss of biodiversity and associated services could have been avoided or minimised by considering the full implications of adopted decisions to ecosystem services. It could be argued that such considerations would have improved the sustainability of development initiatives and management practises, contributing to halting the loss of biodiversity in the EU.

ACRONYMS

BEG	Biodiversity Expert Group
CAP	Common Agricultural Policy
CFP	Common Fisheries Policy
COM	Commission Communication
CEC	Communication from the European Commission
DEFRA	Department for the Environment, Food and Rural Affairs
EC	European Community
EEA	European Environmental Agency
EEZ	Exclusive Economic Zone
EU	European Union
EIA	Environmental impact assessment
MEA	Millennium Ecosystem Assessment
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
SEA	Strategic environmental assessment
WGEAB	Working Group on Economic Aspects of Biodiversity (OECD)

1 INTRODUCTION

Escalating human impact on ecosystems is increasingly affecting their capacity to provide services that are critical to human well-being. Such ‘ecosystem services’ include provisioning, regulating, supporting and cultural services (also referred to as ‘nature goods and services’), such as provision of food products, fresh water, genetic information used for biotechnology, crop pollination, maintenance of hydrological cycles, flood and drought mitigation, erosion protection, and air and water purification.

The loss of ecosystem services is often directly or indirectly connected with the loss of biodiversity (ecosystems, species and genetic variation). For example, in the case of provisioning services, the exploitation of biodiversity resources may directly diminish the ecosystem’s capacity to provide the resources in question. In addition, biodiversity plays an integral part in ecosystem processes; hence the loss of biodiversity can ultimately affect the ecosystem’s ability to maintain its regulating and supporting services.

The value of ecosystem services is gaining increasing attention, especially as the costs of mitigating or averting the impacts of lost services are becoming apparent. Also in this context, the role of biodiversity as a fundamental part of ecosystem services is being addressed more often. Several initiatives, such as the Millennium Ecosystem Assessment (MEA 2005), have aimed at demonstrating the economic value of biodiversity and ecosystem services.

Ecosystem services have also become an important consideration within EU biodiversity policy. It is believed that recognising and highlighting the links between biodiversity and ecosystem services will play an important role in convincing stakeholders to avoid biodiversity losses that lead to unacceptable ecosystem services losses and hence help reach the EU goal of halting the loss of biodiversity by 2010.

There are already quite a few examples, both global and European, revealing the multiple values of biodiversity and ecosystem services. However, at the moment, clearly documented examples where biodiversity/habitat loss has taken place and resulted in demonstrated loss/degradation of ecosystem services are scarce. Such examples would particularly help decision-making in situations where the benefits of environmental conservation versus the benefits arising from development are considered.

1.1 Objective and scope of the study

The objective of this study was to bring together EU examples where biodiversity loss or the modification/loss of habitats accompanied by biodiversity loss in the recent past has led to the loss/degradation of ecosystem services, and consequently to economic costs and/or social losses.

This final report presents a set of ten (10) case studies that have been identified, analysed and documented during the study. It summarises the information and insights gained from the case studies and also provides additional information on other relevant EU examples (for other relevant examples please see Annex 11). Finally, the report discusses the implications of the findings of the study for policy- and decision-making.

The focus of this study is on biodiversity-related ecosystem services and, in particular, on services whose existence is, to begin with, closely linked to/dependent on biodiversity. It is, however, acknowledged that ecosystems also provide a range of services that arise from or are mainly related to ecosystem characteristics other than biodiversity (eg navigation, physical natural flood prevention). Such services need not be affected by the loss of biodiversity but often are when biodiversity loss and ecosystem loss are closely linked. It is also recognised that the definition and classification of the ecosystem services adopted in this study (see Chapter 1.2) is not the only existing one, and that alternative definitions and classifications exist.

Additionally, it is acknowledged the explicit links between biodiversity and ecosystem processes, both at theoretical and practical/empirical level, still remain unclear. Aiming to define the actual role that biodiversity plays in ecosystem function and services lies outside the scope of this study. However, the implications of this lack of available information for policy- and decision-making will be discussed.

1.2 Study approach

The definition of ‘ecosystem services’ used in the study and in the final report is that used by the Millennium Ecosystem Assessment (MEA). This definition includes both the goods and services provided by ecosystems. According to the MEA definition, ecosystem services are classified under four main categories: provisioning, regulating, cultural and supporting services (see Chapter 2).

In order to identify examples to form the basis of the study a short questionnaire was developed and distributed to relevant stakeholders in February 2006 (see Annex 12). In brief, the questionnaire requested the respondents to provide one to three European examples relevant to the study. The questionnaire was distributed to relevant organisations, interest groups and individuals. The recipients included the Habitats Committee, Biodiversity Expert Group (BEG), European Habitats Forum, Biodiversity Science Group, Environmental Economics network, members of the study consortium, European Environmental Agency (EEA), Organisation for Economic Co-operation and Development (OECD), and relevant research projects/scientists working with the topic (eg MEA participants).

Based on the information provided, a set of ten case studies was selected to be analysed in more detail in the study. Detailed information on the case studies was collected through literature review and expert interviews. This set of case studies aimed to cover several ecosystem types and services and included examples with different sectoral impacts throughout the EU. One of the most important criteria for selection of the case studies was data availability, particularly regarding the estimates of lost economic value and gained benefits.

The study was conducted in cooperation with several European environmental organisations. The study consortium included the Institute for European Environmental Policy (IEEP – UK and Belgium), BIO Intelligence Service (France), Ecologic (Germany), Fondazione Eni Enrico Mattei - FEEM (Italy), and GHK (the UK). The study was led by IEEP, with compilation of information on the ten case studies divided among the consortium partners. The study was funded by DG Environment of the European Commission.

1.3 Structure of the report

The report includes the following sections:

- Chapter 2 of the report provides a short introduction to ecosystem services.
- Chapter 3 synthesises the information and insights gained from the case studies. It also provides additional information on other relevant EU examples.
- Chapter 4 discusses the findings of the study, particularly in relation to policy- and decision-making.
- Detail of the case studies can be found in Annexes 1–10. Information on the other relevant cases in the EU can be found in Annex 11.
- The questionnaire used to compile background information for the study is included as Annex 12.

2 ECOSYSTEM SERVICES – SHORT INTRODUCTION

2.1 Description

Ecosystem services are the benefits that people obtain from ecosystems. According to the classification used in this study the services can be categorised as follows:

1) provisioning services, such as food, fibre, fuel and water;
2) regulating services, ie benefits obtained from the regulation of ecosystem processes, such as the regulation of climate, floods, disease, wastes, and water quality;
3) cultural services such as recreation, aesthetic enjoyment and tourism; and
4) supporting services, ie services that are necessary for the production of all other ecosystem services, such as soil formation, photosynthesis, and nutrient cycling (see Table 1).

Early references to the concept of ecosystem functions, services and their economic value date back to the mid-1960s and early 1970s. However, the concept of ecosystem services (also referred to as nature's services or ecosystem/nature goods and services) became widely used only in the 1990s (see for example Daily 1997, Costanza et al. 1997, Pimentel and Wilson 1997, Daily et al. 2000). In addition to the classification adopted in this study there are also other variations on the same theme in the literature (see for example de Groot et al. 2002).

Table 1. Classification of ecosystem services

TYPE OF ECOSYSTEM SERVICE LOST *
Provisioning Services
Food and fibre
Fuel
Biochemicals, natural medicines, and pharmaceuticals
Ornamental resources
Fresh water
Other
Regulating services
Air quality maintenance
Climate regulation (eg temperature and precipitation, carbon storage)
Water regulation (eg flood prevention, timing and magnitude of runoff, aquifer recharge)
Erosion control
Water purification and waste management
Regulation of human diseases
Biological control (eg loss of natural predator of pests)
Pollination
Storm protection (damage by hurricanes or large waves)
Fire resistance (change of vegetation cover lead increased fire susceptibility)
Avalanche protection
Other
Cultural services
Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity

Cultural heritage values
Recreation and ecotourism
Other
Supporting services
Primary production
Nutrient cycling
Soil formation
Other

* as according to the MEA

2.2 Trade-offs in using ecosystem services

The use of ecosystem services has a number of difficulties. Modifications of ecosystems to enhance one service (eg provisioning of agricultural goods) generally comes at a cost to other services due to trade-offs. For example, according to the MEA only four of the 24 ecosystem services examined in the assessment, namely crops and livestock provisioning, aquaculture and (in recent decades) carbon sequestration, have become enhanced through anthropogenic influence (MEA 2005). In contrast, 15 other services, such as capture fisheries, timber production, water supply and purification, waste treatment, natural hazard protection, regulation of air quality, climate and erosion, and a wide range of cultural benefits, have become degraded. In addition, the impacts of these trade-offs among stakeholders might vary significantly. For example, enhancing agricultural production through measures such as wetland drainage, artificial fertilisation and irrigation often reduces the benefits arising from the connected aquatic ecosystems.

The benefits arising from ecosystem services have not been traditionally taken into consideration in policy and decision-making (MEA 2005). This has resulted in the current situation where in many areas ecosystem services have been seriously degraded or completely lost.

2.3 Link between biodiversity and ecosystem services

The role of biodiversity in providing ecosystem services is twofold. Firstly, biodiversity is directly used as a source for food, fibre, fuel and other extractable resources. Secondly, biodiversity plays an important role in ecosystem processes providing the regulating, cultural and supporting services. For example, vegetation cover protects the soil from erosion by binding soil particles and minimising the effects of water runoff. Likewise, cultivation of crops is to a large extent dependent on the availability of pollinating insects.

The link between biodiversity and ecosystem processes is manifold. Ecosystem processes are, in particular, influenced by functional diversity within ecosystem (see for example Hooper et al. 2005, MEA 2005). Functional diversity is a measure of how individual species contribute to the working of an ecosystem by, for example, reducing erosion or improving soil fertility through nitrogen fixation. This means that species composition and characteristics, including the effects of dominant and keystone species, and interactions among species (eg competition, facilitation, mutualism, disease, and predation) are often more important than species richness in maintaining ecosystem processes and the related services. Therefore, local or functional extinction, or the reduction of populations of (key) species to the point that they no longer contribute to ecosystem processes, can have dramatic impacts on ecosystem services.

However, the maintenance of ecosystem processes and related services can also depend on the number of species in the ecosystem. For example, having a range of species that respond differently to different environmental perturbations can stabilise the effects of disturbances and variations in abiotic conditions on ecosystem processes (see for example Hooper et al. 2005). For example, species richness is often known to decrease ecosystems' susceptibility to exotic species invasion.

2.4 Valuation of biodiversity and ecosystem services

Biodiversity and ecosystem services have several different types of value, both linked to and independent of human perception (see Turner et al 2004). Use-values are related to direct, indirect or optional use of biodiversity and related services. Additionally, biodiversity and ecosystem services can also have non-use and intrinsic value.

Whereas the value of provisioning services often manifests itself through market prices, the importance of biodiversity as a part of ecosystem processes in producing regulating, cultural and supporting services is not traditionally captured in financial markets. Additionally, many costs associated with changes in biodiversity and the level of related ecosystem services may take some time to become apparent or may be apparent only at some geographical distance from where the change occurred. The changes may also involve thresholds or changes in stability that are difficult to measure. This further hinders the assessment of the real and complete value of an ecosystem and its services.

Private and social values of conserving biodiversity and ecosystem services often differ widely. The private use value of biodiversity and ecosystem services will typically ignore the external benefits of conservation that accrue to society in general. For example, the agricultural sector may benefit from intensive land use practises with any subsequent losses caused by leaching of excess nutrients and pesticides borne by the general public (for example through decreased local water quality and recreation possibilities). Consequently, if private decision-makers are not given the incentive to value the larger social benefits of conservation, their decisions will often result in inadequate conservation.

In general, provisioning services are routinely valued but the economic value of most supporting, cultural, and regulating services is rarely considered, partly due to the difficulties in valuation. Consequently, many decisions continue to be made in the absence of a detailed analysis of the full costs, risks, and benefits resulting from associated changes within ecosystems.

3 SYNTHESIS AND INSIGHTS OF THE STUDY

The survey on the loss of ecosystem services due to/associated with the loss of biodiversity resulted in the identification of a total of 37 relevant examples within the EU. These included examples from 18 EU Member and Accession States: Austria, Belgium, Bulgaria, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Malta, the Netherlands, Poland, Portugal, Romania, Spain, Sweden and the UK.

The examples covered a wide range of ecosystems ranging from different terrestrial systems to fresh water and marine environments. According to respondents, the 37 examples accounted for a vast number of ecosystem services that had been lost or degraded and represented wider losses. The ecosystem services lost due to or associated with biodiversity loss covered all the services categories identified in the MEA. The most commonly mentioned services to be lost included cultural services (eg recreation and ecotourism) provision of food and fibre, fresh water and water regulation and erosion control. The summary of the types of ecosystem services lost are summarised in Table 2.

From the 37 examples obtained 10 examples were selected for more detailed study and documentation:

1. Loss of ecosystem services due to the decline/disappearance of three European native crayfish species from the Atlantic area (France and Ireland), Scandinavia (Sweden), and Circum-alpine regions (Austria).
2. Loss of ecosystem services provided by river basins – case study of the Danube River basin and delta (Germany and Romania).
3. Loss of ecosystem services provided by lakes and their wetlands – case study of former Lake Karla in Greece.
4. Loss of ecosystem services provided by marine ecosystems – case study on the depletion of North Sea provisioning services.
5. Loss of ecosystem services provided by peat bogs in the UK and Finland.
6. Loss of ecosystem services due to changes in agricultural land use – case study on the plantation of monoculture forests in Portugal.
7. Loss of ecosystem services due to eutrophication of coastal marine ecosystems – case study on shallow soft bottom ecosystems around the west coast of Sweden.
8. Value of cultural ecosystem services – case study on the recovery of ospreys in the UK.
9. Restoring ecosystem services by reintroducing a keystone species – case study on the cost and benefits of beaver reintroduction in Germany.
10. Estimating the benefits arising from the conservation of provisioning ecosystem services- case study on valuing alternative clam fishing practices in lagoon of Venice, Italy.

The following Chapter(s) focus on insights from the 10 above-mentioned examples. Some additional information on other relevant EU examples identified in the study will also be provided (see Annex 11).

Table 2. Examples of the types of the ecosystem services lost due to/accompanied by the loss of biodiversity in the EU Member and Accession States. The table summarises the information obtained from the 37 examples from 18 countries during the survey. The types of ecosystem services have been classified according to the MEA system.

TYPE OF ECOSYSTEM SERVICE LOST	**Examples of the service being lost in Member States (number of examples where mentioned)**
Provisioning Services	
Food and fibre	YES (19)
Fuel	YES (2)
Biochemicals, natural medicines, and pharmaceuticals	YES (4)
Ornamental resources	YES (1)
Fresh water	YES (13)
Other	-
Regulating services	
Air quality maintenance	YES (1)
Climate regulation (eg temperature and precipitation, carbon storage)	YES (8)
Water regulation (eg flood prevention, timing and magnitude of runoff, aquifer recharge)	YES (11)
Erosion control	YES (13)
Water purification and waste management	YES (10)
Regulation of human diseases	YES (2)
Biological control (eg loss of natural predator of pests)	YES (8)
Pollination	YES (6)
Storm protection (damage by hurricanes or large waves)	YES (4)
Fire resistance (change of vegetation cover lead increased fire susceptibility)	YES (2)
Avalanche protection	YES (2)
Other (loss of indicator species)	YES (2)
Cultural services	
Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity	YES (22)
Cultural heritage values	YES (9)
Recreation and ecotourism	YES (27)
Other	
Supporting services	
Primary production	YES (9)
Nutrient cycling	YES (7)
Soil formation	YES (4)
Other	-

3.1 Biodiversity and ecosystem services lost

The case studies reveal different levels of biodiversity loss associated with the loss of ecosystem services, including loss/degradation of ecosystems and habitats, changes in species population levels and species composition, and decline in the number of species. A number of case studies demonstrate the negative effects of the loss and degradation of natural ecosystems and habitats on ecosystem services. In this context, examples of both drastic (eg case studies 2 and 3) and gradual changes (eg case studies 4, 5 and 7) exist.

Regarding changes at species level, nearly all of the cases show how reductions in species' population levels can lead to decline in ecosystem services, in particular for provisioning services. The extinction of beavers in Germany and the decline of native crayfish populations throughout Europe also demonstrate the negative impacts caused by the loss of keystone species (functional diversity). Additionally, the case study on the impacts of agricultural changes in Portugal shows how the change of dominant species can alter the processes within ecosystems, ie in Portugal the increased number of eucalyptus and pine monocultures has increased the ecosystems' susceptibility to forest fires. Both the Portuguese case and the case on the decline of crayfish populations demonstrate how the introduction of exotic species and associated changes in species composition can negatively effects the ecosystem processes and services. From the cultural services perspective, the case study of reintroduction of ospreys in the UK shows that the aesthetic characteristics of a species can play an important role in creating ecosystem services. For additional examples on species-level changes affecting ecosystem services in the EU (eg impacts of invasion of alien species and effects of ecosystem species richness) please see Annex 11.

Table 3 summarises the types of ecosystem services lost due to/accompanied by the loss of biodiversity in the ten case studies. In general, the case studies demonstrate the loss or degradation of almost all of the types of ecosystem services identified by the MEA. The most frequently lost/degraded services include food and fresh water (eg marine and fresh water resources), water purification and waste management, nutrient cycling and a range of cultural services (eg recreation and tourism) (see Annex 11 for further examples).

Table 3. Types of ecosystem services lost due to/accompanied by the loss of biodiversity in the 10 case studies documented in the study. The types of ecosystem services have been classified according to the system used in the MEA.

TYPE OF ECOSYSTEM SERVICES LOST		CASE
Provisioning Services		
Food and fibre	• Decline and total loss of fish stocks (freshwater, coastal and marine) • Decline of crayfish stocks • Decline in clam catch • Decline in timber and non-timber products (eg cork, fruit, honey, herbs)	Danube; decline of crayfish; Lake Karla; North Sea; Swedish coastal ecosystem; oak forests in Portugal; Lagoon of Venice
Fuel	• Loss of fuel (wood, peat)	oak forests in Portugal; peat bogs
Biochemicals, natural medicines, and pharmaceuticals	• Loss of aromatic and medicinal plants	oak forest in Portugal
Ornamental resources		
Fresh water	• Decline in purification of catchment's runoff and water in the water body (eg nutrient retention capacity, organic matter and pollution control) • Decline of water retention and purification capacity due to peat bog extraction	Danube; decline of crayfish; beaver reintroduction; Lake Karla; peat bogs; oak forests in Portugal
Other	-	-
Regulating services		
Air quality maintenance	-	-
Climate regulation (eg temperature and precipitation, carbon storage)	• Loss of balancing extremities of the summer and winter climates • Loss of carbon retention and sequestration capacity	Lake Karla; peat bogs; oak forests in Portugal
Water regulation (eg flood prevention, timing and magnitude of runoff, aquifer recharge)	• Declined capacity to regulate peak flows during floods due to loss of natural habitats	Danube; oak forests in Portugal
Erosion control	• Increased erosion of river basin caused by more rapid ground saturation and increased overland flow	Danube; oak forests in Portugal
Water purification and waste management	• Decline in purification of catchment's runoff and water in the water body (eg nitrate retention capacity, pollution control)	Danube; decline of crayfish; beaver reintroduction; Lake Karla; Swedish coastal ecosystem; oak forests in Portugal
Regulation of human diseases	-	-
Biological control (eg loss of natural predator of pests)	-	-

Pollination	-	-
Storm protection (damage by hurricanes or large waves)	-	-
Fire resistance (change of vegetation cover lead to increased fire susceptibility)	• Decreased fire resistance due to increased number of fire-prone species and/or increase in burnable material in forest understorey	Oak forests in Portugal
Avalanche protection	-	-
Other	• Loss of environmental indicator species	Osprey tourism; decline of crayfish
Cultural services		
Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity	• Loss of amenity and aesthetic values • Decreased quality of life • Decrease in properties value (eg due to increase of mass development of insects) • Decrease of educational value • Possible decrease of non-use and passive use values (eg due to the loss of a flag ship species such as osprey)	Danube; Osprey tourism; decline of crayfish; Karla lake; Swedish coastal ecosystem; oak forest in Portugal
Cultural heritage values	• Loss of a key species in terms of provisioning and/or aesthetic value	Osprey tourism; crayfish; Lake Karla; oak forest in Portugal
Recreation and ecotourism	• Loss of tourism and recreation opportunities, both existing and potential (eg water sports, game hunting, hiking, camping, bird watching)	Danube; Osprey tourism; beaver reintroduction; Swedish coastal ecosystem; North Sea; oak forests in Portugal
Other	-	-
Supporting services		
Primary production	• Loss of normal predator-prey dynamics => changes in ecosystem’s trophic levels/food chains, eg primary production	decline of crayfish
Nutrient cycling	• Loss of wetland/river basin nutrient cycling capacity due to loss of wetland habitats (eg denitrification capacity) • Loss of normal predator-prey dynamics => changes in ecosystem’s food chains	Danube; decline of crayfish; beaver reintroduction; Lake Karla; Swedish coastal ecosystem; oak forest in Portugal
Soil formation	• Decreased soil formation capacity due to the increased loss of vegetation cover by forest fires	Oak forest in Portugal
Other	-	-

As generally acknowledged, the case studies also show that the concrete links between the loss of biodiversity and ecosystem services, in particular regulating and supporting services, often remain unclear. Additionally, the evidence available on the real loss of biodiversity and ecosystem services is incomplete since in most cases, including all of the examples documented in this study, no complete assessment of the natural (baseline) status of the ecosystem and its services exists.

The case studies in the Annexes give details on the extent and value of the losses where information was available. Interesting examples include, for example:

Case study 1: In France since 1978, 137 populations of crayfish (*A. pallipes*) declined to 45 populations representing a decrease of 68 per cent of population numbers in 25 years, and a loss of 40 per cent of populations during the last six years. In Sweden, the crayfish population (*A. astacus*) has declined to about five per cent of its pre-1907 level. However, at present the commercial value of native crayfish is about twice the price of introduced exotic crayfish.

Case study 2: The construction of two dams along a section of the Danube between Regensburg and Straubing between 1985 and 1995 has led to the decline of fish species making fishing uneconomic on the impounded stretch of the river. Additionally, the alteration of ecosystem has resulted in mass development of populations of noxious insects to the discomfort of homeowners in the vicinity of the dam. In the Lower Danube (Danube delta), it has been estimated that the transformation of the floodplain and the application of intensive crop production techniques led to a loss in the region of US$500 million per year in the 1980s[1]. The estimated values after restoration include: the value of restored river fisheries ~$16 million; value provided by restored habitat for nitrogen and phosphorous absorption and cycling ~US$112.5 million and ~$18.2 million respectively per annum; and value of tourism resulting from restored wetland habitat ~$16 million per year.

Case study 3: Human intervention in the Lake Karla system began in 1936. The rate of loss substantially increased following the final draining of the lake in 1962, resulting in a complete loss of natural habitats. Following drainage of the lake, the entire fish catch of 80kg/ha has been lost. Reflecting this, restoration has now started at an expected total cost of around €150 million.

Case study 4: In the past ten years, the stock of most roundfish and flatfish species in the North Sea has deteriorated. At present, most of the stocks of commercial fish species in the North Sea are seriously endangered with 30 to 40 per cent of the biomass of these species being caught each year. As a result the state of most commercial fish species has deteriorated with some stocks reaching a historical low. 61 per cent of Europe's demersal fish stocks are outside safe biological limits, together with 22 per cent of pelagic species, 33 per cent of benthic species and 41 per cent of industrial fish stocks such as sandeels. The most prominent example of a stock under severe pressure in the North Sea at present is cod. The spawning stock biomass (adults able to reproduce) had declined from a peak of 250,000 tonnes in the early

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[1] Calculated as costs of floodplain transformation, costs for crop production and monetary losses arising from the loss of ecosystem services

1970s to less than 40,000 tons in 2001 and 70 per cent of young cod die before sexual maturity.

Case study 5: Originally one third of the land area of Finland was covered in peatlands; half of this has been drained for agriculture, converted to forestry or cut for fuel. This amounts to around 5 million hectares lost; peak activity was in the 1970s, when 3000 km^2 were drained per year. In England, it is estimated that there are some 3,800 ha of lowland bogs, about 10 per cent of the original total. In Northwest England, United Utilities and the RSPB anticipate peatland restoration will help improve local drinking water quality in three aspects: microbiology, soil erosion and water colour. While it is difficult to monetise the value of these improvements, the value of the benefits has been estimated at between €1.8 and 3.6 million euros per year, or a total discounted benefit of between €5.5 and 12 million.

Case study 6: Agricultural abandonment and the expansion of fire prone plantation forests has significantly contributed to the increase of wildfires in Portugal. In the last 25 years (1980-2004), fires have burned over around 2.7 million hectares of forest land, an area almost as large as the total territory of Belgium. In the period 2000-2004 the country's surface burnt at a rate of 2.7 per cent/year (1.4 per cent in the 1980's and 1.9 per cent in the 1990's). Considering only the direct losses associated with primary production, the estimated costs have been about €300 million per year. The total investments in fire fighting and prevention amounted to €479 million in this five-year period (€17,8/hectare/year). In 2001 alone, the damage caused by forest fires amounted to about €137 million (eg costs of fire prevention, fire fighting and reforestation, and losses of forest products). During the same year the total economic value of forests in Portugal (total revenues less the cost of forest fires) amounted to ~€1,2 billion.

Case study 7: It has been calculated that the overall benefits of increased water quality[2] in the highly eutrophicated Stockholm archipelago would amount to SEK 60-500 million per year, ie €6–€54 million per year[3]. Replacing the denitrification (degraded due to eutrophication) service of Swedish coastal shallow soft bottom habitats by sewage treatment would cost between SEK 210–SEK 3690 per m^2 per year (€23–€399 per m^2 per year). In terms of provisioning services, the estimated 30-40 per cent reduction in the output of juvenile fish due to the impacts of eutrophication may lead to a corresponding decrease in total catch and total gross income loss to fishermen of between SEK 54 and 72 million per year (€6-8 million per year). As an estimate of the loss of cultural services, the annual cost of removing dead red filamentous algae is SEK 75,000 per km of beach (€8119 per km). The costs of mechanical harvesting of algal mats in the northernmost municipality of the Swedish west coast have been estimated to about SEK 660,000 per year (€7145 per year).

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[2] Calculated as a one-metre improvement in the water transparency during the summer period by using the Secchi disk -method. Suspended sediments and algae decrease the transparency of the water. Therefore transparency is commonly used as an indicator of the water quality.

[3] Calculated using an exchange rate of €1 = 9,23 SEK.

Case study 8: The recolonisation of ospreys (a bird species) in the UK has brought positive impacts for local economies, with ospreys estimated to bring additional expenditure of £3.5 million per year to the areas around nest sites, helping to support local incomes and employment. Additionally, the return of ospreys has resulted in recreational and educational benefits (~290,000 people visiting osprey nest sites/each year).

Case study 9: The reintroduction of beavers in the Spessart Mountains in Hesse, Germany has resulted in increased economic value of the cultural services and services related to recreation and tourism in the region. The average willingness to pay (WTP) aggregated over the number of visitors in the area indicates that the benefits of biodiversity conservation in the Spessart mountains are at least €0.55 million per year. The changes caused by beavers in the ecosystem (dam building) has increased the total river surface by seventeen per cent. As a result, the measure relevant for denitrification, the hydraulic load, has diminished by fifteen per cent. Extrapolated to the whole investigation area a mean additional retention of 2800 kgN/a in the river and of 1900 kgN/year in the floodplains can be estimated.

Case study 10: The introduction of intensive clam fishing technologies in the Lagoon of Venice has had a negative impact on the lagoon ecosystem's resilience. Clam fishing activities have changed the original water movements, and deposit and accumulation of water sediments, therefore negatively affecting the morphology and marine life functions of the Lagoon. The consequence has been a reduction of the clam stock, destruction of nursery areas and feeding grounds of many marine species, including commercial fish stocks. The market data shows a diminishing supply of approximately 40 per cent in the catch between 2000 and 2001 due to a reduction in clam stocks.

3.2 Direct and indirect reasons behind the loss

Habitat alteration and destruction appears to be the most common direct reason behind the loss of biodiversity and related ecosystem services. Additionally, over-extraction of resources (eg case studies 4, 9 and 10), pollution and eutrophication (eg 1, 3, 7 and 8) and changes in ecosystem species composition, for example due to the introduction of exotic species (eg case studies 1 and 6), have often contributed to the loss (see Annex 11 for further examples).

As regards the underlying reasons behind the losses, unsustainable resources management combined with sectorally oriented development initiatives (eg neglecting the trade-offs between different ecosystem services) are the principle drivers behind the destruction and degradation of habitats and ecosystems. The case studies clearly indicate how sectoral orientation and lack of comprehensive, ecosystem based planning has often led to net negative effects both on the ecosystem in question and the neighbouring ecosystems. These negative impacts have become particularly apparent in the long run. For example, increasing the navigability and energy production capacity of Danube River has lead to the loss of other ecosystem services, such as cultural services and provisioning of fish and fresh water. At the Swedish coast the increased use of artificial fertilisers in agricultural ecosystems has lead to the degradation of coastal ecosystems due to eutrophication.

Several case studies also show that in the absence of comprehensive planning and/or management (including consideration of the whole range of ecosystem services) individual decisions, such as fishing effort of an individual fisherman, which by themselves are of little importance may bring negative effects to the ecosystem services when taken together (eg case study 10) . The lack of comprehensive planning is also often one of the underlying reasons behind habitat destruction/fragmentation and related negative effects (eg case study 1).

The case studies indicate that increasing the profits provided by a few ecosystem services at the expense of other services is the most common driver behind loss. The detailed list of drivers for the loss of ecosystem service identified in the case studies includes the following:

1. maximising the profits gained from a few ecosystems provisioning services, such as timber and fish, without considering the impact on other services (eg case studies 4 and 10);
2. enhancing agricultural production through drainage of wetlands and bogs, flooding prevention and irrigation, and increased use of fertilisers and pesticides (nearly all of the cases);
3. enhancing forestry production (eg 2, 5 and 6);
4. increasing energy production (eg 2 and 5);
5. increasing shipping activities and navigability of water bodies (eg 2 and 4);
6. drainage and sewage constructions and effluents (eg 1 and 3);
7. construction of residential developments and other infrastructure (eg 9)

The underlying reasons behind the loss of biodiversity and biodiversity-related ecosystem services are twofold.

1. Firstly, decision making in one sector can fail to address the negative impacts of certain activities on ecosystem services. For example, the case study of Swedish coastal ecosystems shows how the effects of inland agricultural production on coastal fishing were not initially considered in policy making (ie trade-offs between services were neglected).
2. Secondly, sectoral policies can also actively support activities and measures that have a negative impact on ecosystem services. In this context, a number of national and Community policies, including the Common Agricultural and Fisheries Policies (CAP and CFP), have been providing incentives that have been detrimental to several ecosystem services. Even when the appropriate policy and legislative measures are available, a lack of implementation and enforcement can result in continued deterioration of ecosystems and their services (eg the inadequate implementation of the CFP provisions in the EU) (see Annex 11 for further examples).

In addition, the case studies demonstrate how socioeconomic factors can also contribute to the loss of ecosystem services. For example, on several occasions agricultural abandonment has been recognised as a fundamental cause of loss, eg in the case of increased forest fires in Portugal (see Annex 11 for further examples).

The case studies also reflect general changes in the national and EU political atmosphere and awareness during the last decades. Such drastic habitat alterations as carried out in Danube delta and Lake Karla ecosystems could not take place today without first assessing their impacts on the environment. Several other case studies also indicate that no environmental impact assessment (EIA) was conducted in relation to the activities that led to the loss of biodiversity and related services. The negative outcomes documented in the case studies strongly indicate that the application of ex ante assessments would have been beneficial in trying to determine the net effects of development projects and initiatives.

3.3 Loss of economic value

The case studies clearly demonstrate that several ecosystem services have been lost or degraded in the EU and that the loss of individual services has led to economic losses. The value estimates available in the case studies relate most commonly to provisioning services, including the loss of revenue declines in the stocks of aquatic resources (case studies 3, 4, 7 and 10). Additionally, some estimates on the value of regulating services such as water purification (case studies 5, 7 and 9) and cultural services such as tourism and recreation (case studies 7 and 8), are available. Of the ten examples included in the study, the case on the changes in forest ecosystem services in Portugal offers the most complete set of values related to the services of an ecosystem.

In several cases the value estimates arise from the direct costs of restoration of the ecosystem/species (case studies 1, 2, 3, 5 and 6) or benefits gained through the restoration of certain services (8, 9 and 10). These values are often the only ones available because for the majority of ecosystem services no evaluation prior to the loss exists, for example no comprehensive impact assessment has been conducted.

The case studies reflect the recognised problems regarding the valuation of biodiversity and related ecosystem services. Information is often available only for a limited number of services provided by the ecosystem in question. Additionally, information on the associated benefits is also inconsistent and hard to come by (see Chapter 3.4 below). Therefore, even though the case studies provide clear evidence that the loss of individual ecosystem services has led to economic losses it is often impossible to form a complete picture of the real losses and benefits that have occurred.

3.4 Services lost vs. benefits gained

As stated above, the costs resulting from the loss of and/or trade-offs between the ecosystem services can manifest themselves in different ecosystems from where the biodiversity loss occurs. Consequently, these costs may be experienced by different socio-economic sectors and groups of stakeholders than the associated benefits. For example, in the case study on the Swedish coastal ecosystem the costs of agricultural intensification first became apparent in aquatic ecosystems and their associated socio-economic sectors, such as fisheries and tourism. Additionally, the (short-term) benefits resulting from use of ecosystem services are often received on a private level whereas the associated costs are of a more social nature. The latter is revealed for example by the Italian and Portuguese case studies where intensive clam fishing (IT) and increase of plantations of existing timber species (PT) have led/are leading to high social costs (see Annex 11 for further examples).

The case studies also demonstrate that, particularly in a short term, the costs resulting from the loss of ecosystem services are mainly experienced at a local level whereas the benefits can also be received on a wider scale. For example, the benefits of agricultural intensification, improved transportation and increased energy and forest production are experienced also at regional and national levels whereas it takes time for the costs to become apparent (eg case studies 1, 2, 3, 5 and 6).

All of the case studies provide strong evidence that in the long term, the net benefits associated with the loss of ecosystem services are reduced as the negative impacts on other ecosystems and related socio-economic sectors become apparent. Additionally, the case studies also show that due to the trade-offs between different ecosystem services, an intensive use or enhancement of one service often leads to the degradation of other services. Consequently, in the long term the costs often (partly or completely) offset the initial benefits gained. In this context, the case study on the revival of osprey populations in the UK seems to indicate that long-term benefits arising from the conservation and sustainable use of ecosystem services make up both for the conservation costs and compensate for the short-term benefits arising from alternative activities.

The biases described above affect both the valuation and perception of the real costs and benefits of using and maintaining ecosystem services. As the case studies indicate, comprehensive assessments comparing short- and long-term costs and benefits seldom exist. This has often resulted in decisions (management, regional development) that have had negative effects on a range of ecosystem services and resulted in (net) economic losses.

3.5 Reversibility of loss and restoration

For the majority of the case studies the loss of biodiversity and related ecosystem services is fully or partly reversible. However, in most of the cases restoration can only take place if carried out within a certain timeframe after the initial loss occurred.

A number of case studies, eg the reintroduction of beavers, recovery of ospreys and restoration of peat bogs, also provide examples of the successful restoration of ecosystems and their services. The cost benefit analysis on the reintroduction of beavers indicated that the benefits of the restoration are greater than the associated costs.

The case studies also indicated potential barriers related to restoration including, for example, lack of scientific knowledge (eg case study 1) and conflicting interests between the current land use and the original state of the ecosystem (eg case study 3). In some cases the loss of biodiversity and related services is also already considered unlikely to be reversible (case studies 2 and 6). For example, in Portugal restoration is considered to be difficult, or even impossible, in areas situated too far away from the original ecosystems/native vegetation. Additionally, stakeholder support plays an important role in successful restoration. Several case studies show that this support will arise without difficulty when the benefits arising from biodiversity and related ecosystem services are apparent (eg case studies 1, 8 and 3).

4 DISCUSSION AND CONCLUSIONS

4.1 Implications for policy and decision-making

The outcomes of this scoping study clearly demonstrate that throughout the EU, a wide range of biodiversity-related services provided by a variety of ecosystems have been lost or degraded. All of the ten case studies provide evidence that the loss of biodiversity and ecosystem services has resulted in socioeconomic costs, including financial losses. These losses, however, are not always immediately apparent and often become more prominent in the long term. Losses can also manifest themselves in different ecosystems and/or socio-economic sectors than the benefits, making the detection of costs even more difficult. The distribution of costs and benefits is also biased between different stakeholders. Additionally, benefits are usually obtained on a private level whereas costs are often of more social/public nature.

Consequently, it is crucial that decisions affecting ecosystems and their properties are taken on an integrated and cross-sectoral manner. In particular, policy and decision-making processes should include comprehensive considerations on both the short- and long-term effects (eg associated costs and benefits) of available options and/or competing objectives. The trade-offs between ecosystem services and the distribution of costs and benefits between stakeholders (eg the difference between private and social costs) should also be taken into consideration. For example, in cases where short-term private benefits offset social costs, active policy support (eg conservation measures or compensating losses of income) might be needed to secure the long-term viability of ecosystem and its services.

However, due to the difficulties in valuation of ecosystem services (see Chapter 2.4) it is often very difficult, or even impossible, to form a complete picture of the real losses and benefits that might occur. The implications of this uncertainty should also be integrated into policy and decision-making processes, for example through the application of the precautionary approach.

4.2 Implications for regional planning

Regional authorities have a significant role in ensuring that developments in some sectoral areas do not negatively contribute to other sectors, including ecosystem services that are not of direct relevance to them. The insights gained from this study strongly support the application of comprehensive and integrated assessments as a basis for regional land use planning and management (eg project evaluation). In order to estimate the real costs and benefits of a planned activity, the assessments should be able to include both short- and long-term impacts of the activity and capture the distribution of costs and benefits between different stakeholders. Additionally, trade-offs between different ecosystem services, including effects on neighbouring ecosystems, should also be assessed. Where regional authorities develop SWOT (strengths, weaknesses, opportunities, threats) assessments of their region as part of the regional planning process, then the issue of eco-system service losses could usefully be integrated (see ten Brink et al 2006).

Since the comprehensive valuation of ecosystem services is difficult, monitoring the impacts of undertaken activities is also of high importance. In this context, ex post assessments could provide a useful tool to evaluate the outcomes of development initiatives and projects that have been carried out. Additionally, in assessing potential trade-offs between different ecosystem services the concept of ‘critical threshold’ could be applied (see ten Brink et al, 2006). The consideration of critical thresholds within the ecosystem, ie the limits where a small change can lead to non-linear change resulting in critical and often irreversible outcomes could help to clarify whether the benefits in one sector are greater than the losses in another. If it appears that any given decision will lead to the breach of a critical threshold then it is very likely that the losses will be greater than initially expected.

As regards ecosystem services, situations when critical thresholds could be considered include:

- when granting water extraction rights from a river – will the remaining flow be sufficient to maintain habitat for aquatic species and oxygenate downstream waters?
- when considering new road, residential and commercial developments – will these result in habitat fragmentation to the point where remaining habitat patches cannot support certain species? Is this critical at a national/local/global level?
- when setting standards for water and air quality – will lowering standards increase the risk of breaching nutrient thresholds to produce algal blooms and anoxia (lack of oxygen)?

It has already been acknowledged that nature conservation, including the Natura 2000 network, creates several socio-economic benefits (see for example IEEP 2002 and ten Brink et al. 2002). Natura 2000 areas can both provide several ecosystem services (eg cultural values, recreation and tourism) and support the maintenance of services outside the actual areas. In the latter case Natura 2000 areas can, for example, assist in maintaining species diversity and population levels in the region or, in the case of wetlands, contribute to the purification and supply of water. Consequently, integrating Natural 2000 areas into regional and local planning can bring significant benefits by contributing to the supply and maintenance of ecosystem services in the area. The role of Natura 2000 areas in providing ecosystem services will be of high importance in the future as the management of Natural 2000 areas is integrated into the broader context of regional development.

4.3 Role of science and awareness rising

A recent assessment of existing literature indicates that even though valuations of a single service within an ecosystem often exist there is a lack of evaluations of multiple functional uses and ‘before and after’ states of the ecosystem (Turner et al. 2003). This is partly caused by the gaps of knowledge regarding the relationship between biodiversity and ecosystem properties (see below) and lack of information on factors influencing environmental values (including socio-economic factors). However, this type of evaluation would be of high importance in providing support to policy- and decision making.

From the scientific perspective, several aspects regarding the relationship between biodiversity and ecosystem properties still need further clarification. For example, more information is needed on the relationships between different levels of biodiversity (taxonomic and functional) and community structure, and the actual mechanisms of biodiversity effects (Hooper et al. 2005). Additionally, more knowledge regarding certain understudied ecosystems (eg marine systems) and phenomena, such as feedbacks between biodiversity and ecosystem properties, is needed.

The findings of this study strongly support the notion that the loss of biodiversity and related ecosystem services can bring significant socio-economic losses to a variety of sectors and stakeholders. In this respect it seems vital that the stakeholders involved in and affected by the policy and decision-making are aware of the aspects related to ecosystem services (eg possible trade-offs between different services). Given the gaps in knowledge it is also important that decision-makers are conscious of the limitations posed by the lack of available information. This can, if necessary, assist decision-makers to apply methods such as the precautionary approach and critical thresholds. The case studies also indicated that understanding the overall costs and benefits of losing or, alternatively, conserving biodiversity and related ecosystem services often encourage stakeholder support for the maintenance of ecosystem in its normal and functional state.

4.4 Conclusion

To conclude, in several case studies the loss of biodiversity and associated services could have been avoided or minimised by considering the full implications of adopted decisions to ecosystem services. It can be argued that these considerations would have allowed more sustainable development initiatives and management practises to take place, contributing also significantly to halting the loss of biodiversity in the EU. Consequently, the full implications of loss of biodiversity and related ecosystem services should be included as an integral part of future policy and decision-making processes.

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- Case 4: Indrani Lutchman - Loss of ecosystem services provided by marine ecosystems – case study on the depletion of the North Sea provisioning services;
- Case 5: Jason Anderson - Loss of ecosystem services provided by peat bogs in the UK & Finland;
- Case 6: Samuela Bassi - Loss of ecosystem services due to changes in agricultural land use – case study on the plantation of monoculture forests in Portugal;
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- Case 9: Ingo Bräuer - Restoring ecosystem services by reintroducing a keystone species – case study on the cost and benefits of beaver reintroduction in Germany;
- Case 10: Paulo Nunes and Anil Markandya - Estimating the benefits arising from the conservation of provisioning ecosystem services- case study on valuing alternative clam fishing practices in lagoon of Venice, Italy.

Annex 1. Loss of ecosystem services due to the decline/disappearance of three European native crayfish species from the Atlantic area (France and Ireland), Scandinavia (Sweden), and Circum-alpine regions (Austria)

Case study author Ana Persic (BIO Intelligence Service, France),

INTRODUCTION

Crayfish are the largest active freshwater macro-invertebrates in the EU. It has been recognised that crayfish play a key role in the ecology and functioning of freshwater ecosystems. During the last century, however, the loss of native crayfish populations has increased due to anthropogenic pressures, such as poaching, over-fishing, introduction of non-native species, and degradation of water quality due to human activities. Several studies indicate that crayfish species are one of the most imperilled taxonomic groups in freshwaters with over 30 per cent of species being threatened or endangered.

The conservation of components of biological diversity, such as native freshwater crayfish, creates benefits arising from the maintenance of food sources and cultural heritage and from the protection of the aquatic environment and water resources. Therefore, crayfish have both a defined monetary and cultural value in Europe. In Scandinavia, the noble crayfish (*Astacus astacus*) is highly valued both from recreational and economic points of view. Sustainable exploitation is thus a prerequisite for its conservation and social benefits arise in terms of research, education and recreation. In Western Europe, the white-clawed crayfish (*Austropotamobius pallipes*) and the stone crayfish (*Austropotamobius torrentium*) present high cultural and ecological values and are increasingly recognised as flagship species for environmental quality.

This case study summarises the ecosystem effects and socio-economic consequences of the drastic decline of three threatened crayfish species native to the European Union:

- *A .pallipes* decline in the Atlantic area (region Poitou-Charenets in France, and Ireland) where it is considered to be a threatened water quality bioindicator and heritage species;
- *A. astacus* decline in Scandinavia (Sweden), where it has a strong traditional and current fisheries value, and links socioeconomics and conservation;
- *A, torrentium* decline in Circum-alpine countries (Austria) in relation to land-use and habitat deterioration.

All of the background information provided in this case study is derived from the work of the experts of the European thematic network CRAYNET (http://labo.univ-poitiers.fr/craynet/indexcadre.htm) and personal communications with Catherine Souty-Grosset, the CRAYNET coordinator.

BIODIVERSITY LOST

Extent, rate and type of biodiversity lost

In the case of *A. pallipes*, surveys carried out from 1978 to 2003 in Poitou-Charentes (France) demonstrated a significant decline of *A. pallipes* populations in the region and an alarming spread of North-American non-native crayfish species. In France, since 1995, *A. pallipes* populations can still be found in 72 to 73 departments (the country being composed of 95 departments) but entire populations have been lost in 14 departments and there has been a significant decline in population density in 26 departments in 2001. Since 1978, 137 populations of *A. pallipes* declined to 45 populations representing a reduction of 68 per cent of population numbers in 25 years, and a loss of 40 per cent of populations during the last six years. In Ireland, crayfish have also disappeared from several river catchments (eg River Liffey, the Boyne system).

In Sweden, repeated outbreaks of the crayfish plague vectored by infected noble crayfish from Finland have resulted in the reduction of the *A. astacus* population to about five per cent of its pre-1907 population level. The plague was spread further due to introduction of the American crayfish. Due to the negative effects of the non-native species introduction, coupled with the effects of habitat fragmentation, and deterioration of water quality, the populations of *A. astacus* continue to decline. Today, *A. astacus* is considered an endangered species in southern Sweden, and restriction on stockings of the American crayfish have been imposed.

Similarly, habitat deterioration together with the negative effect from the introduction and expansion of non-native crayfish are the predominant threats to *A. torrentium* in Austria, which is now considered both a vulnerable and restricted species. Recently, species protection programmes have been started in several areas of the country but these activities have only been initiated at a small-scale level.

Causes for biodiversity loss

Crayfish populations are under continuous pressure due to:

- pollution: the pollution of freshwaters is an important factor in causing major declines in the populations. Most pollution comes from domestic, agricultural, or industrial wastes, and can be totally toxic; heated effluents may also speed up the process of eutrophication. Rivers are repositories of enormous amounts of human waste, ranging from toxic industrial chemicals and acid rain through agricultural slurries and herbicides to domestic sewage;
- habitat loss: habitat destruction by canalisation, construction of ponds, fragmentation;
- overfishing/overexploitation;
- introduction of alien species: if alien species establish themselves they can alter the ecological community structure radically and lead to the extinction of sensitive native species, or have significant impacts on genetic diversity. Alien species are also responsible for the introduction of diseases such as crayfish plague in Europe.

While these are direct drivers of native crayfish losses in Europe, the indirect drivers are mainly related to unsustainable management and development initiatives that have led to destruction and degradation of habitats. For instance, in Poitou-Charentes, the main reasons of the disappearance of *A. pallipes* populations were: (1) habitat destruction by canalisation; (2) decrease of water quality by use of chemical agricultural products; (3) construction of ponds; (4) introduction of non indigenous crayfish species; and (5) crayfish plague.

In Ireland, canalisation for arterial drainage, decrease in water quality from sewage treatment plant effluents and from agricultural products, and crayfish plague, have been the main reasons behind the loss. On the Liffey river, spasmodic discharge of low-quality effluent from the new large scale sewage treatment plant near Caragh Bridge may have been responsible for the disappearance of crayfish from the entire river below this stretch (50km+). In the future, Dublin's rapid growth is likely to increase the need for further development of waste treatment facilities. Provincial towns are also growing so new roads are being built for commuters to Dublin and these development actions also have direct impact on the environment and the local biodiversity, including crayfish species.

The Importance of various threats to the indigenous crayfish populations of in Europe is shown in Table 1[1].

Table 1. Importance of various threats to the indigenous crayfish populations of in Europe (0 = none; 1 = low; 2 = medium; 3 = high; ? = no information)

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[1] In SOUTY-GROSSET C., HOLDICH D.M., NOËL P.Y., REYNOLDS J.D. & HAFFNER P. (eds) 2006. ‹Atlas of Crayfish in Europe. Muséum national d'Histoire naturelle, Paris, xxx p. (Patrimoines naturels, 64), in press.chapter 2: indigenous crayfish- habitat and threats by Füreder et al.

Ecoregion	**Atlantic Area**		**Scandinavia**	**Circum-alpine region**
	A. pallipes		*A. astacus*	*A.torrentium*
Threat	France	Ireland	Sweden	Austria
Crayfish plague	3	3	3	2/3
Other diseases	?	2	?	?
Non-indigenous species	3	3	3	2/3
Predators	1	1	1	
Exploitation	1	0	1	1
Habitat alterations	2 / 3	1	1	2
Water level reductions	2	2	1	1
Eutrophication	1	1	1 / 2	2
Acidification	1	0	1 / 2	1
Toxicants	3	2-3	1	2/3
Land-use	3	2-3	2	2/3
Fragmentation	3	1	2	3

Additionally, the conservation and management of threatened European crayfish suffers from confused taxonomy. If a species accepted as under threat and protected under national or international legislation is later shown to be a species complex or recommended to be split into a number of sub-species or sibling species, the legal status of its protection becomes unclear. It takes time and resources to get relevant legislation rewritten and passed, and the outcome may be unpredictable. This was particularly the case for *A. pallipes.* Similarly, even though the knowledge of *A. torrentium* had greatly increased in the past few years, until 2000 the status of this species was not well known and the research was developed from 2001.

In the case of *A. astacus* (noble crayfish), in Sweden and Finland there is a high market demand for this crayfish for it is considered as an appreciated delicacy. The old traditions and the role of crayfish in the Scandinavian culture mean that crayfish species have been (over) exploited and have collected a very good price on the market. The introduction of non-native crayfish species (from Finland) for commercial exploitation has caused the introduction of crayfish plaque, a disease that caused severe declines in the native populations in few years. Further introduction of non-native crayfish from California worsened the already bad situation. In addition to these direct drivers of loss, various individual land use planning and development decisions taken together led to both pollution and physical damage of the environment. Such actions thus indirectly impacted the noble crayfish populations.

Fortunately, due to the fact that noble crayfish have commercial importance, a national action plan for their conservation has been put in place but only in 1998. Since August 2003, the Species Protection Act prohibits all import, transportation, and keeping of live non-native freshwater crayfish. New legislation for assessing specially protected areas for the noble crayfish is being prepared by the government.

ECOSYSTEM SERVICES LOST

Since crayfish are considered to be keystone species in freshwater environments as well as cultural and heritage species, declines in native crayfish populations have adverse effects on overall ecosystem function, affecting provisioning, regulating, cultural and supporting services.

Overall ecosystem services degraded by declines in native European crayfish populations may be summarised as follows:

- Provisioning services: food provision through declines in fisheries, astacicultures and loss of traditional recreational fishing, provision of other resources – bait for fishing.
- Regulating and supporting services: loss of crayfish may have an adverse trophic cascade effect on both predators and prey as well as plant development, thus indirectly effecting ecosystem support in terms of water purification, nutriment cycling and primary productivity.
- Cultural services: recreation, ecotourism, education: again, loss of recreational fishing; restriction of opportunities to observe and study natural habitats, native European heritage species.

As well as losses in terms of food resources, the loss of native crayfish species from a food web may have negative impacts on predators - salmonid fishes, otters and water birds. Such losses may have cascading effects on their prey, as well as on aquatic plant development. Since crayfish constitute such an important part of freshwater food webs, the foraging and grazing activities of crayfish species boost primary productivity and are important in nutriment and energy cycling. In their absence, abundant macrophyte growth may occur leading to decrease in available oxygen and thus degrading water quality. Otters (flagship species) and salmonids (bioindicators) are also influenced directly by deteriorating water and river channel quality.

ECONOMIC COSTS, SOCIAL LOSSES AND GAINED BENEFITS

Stakeholders affected by the biodiversity loss

In general, stakeholders affected by native crayfish decline across Europe include water managers, anglers, ecotourists, educators, students, naturalists and the general public.

The stakeholders are highly motivated to protect native species in the face of the threat from non-native species and crayfish plague. They are also very active in informing the public and relevant authorities of the situation. The fact that controlled fishing may not be incompatible with exploitation of native crayfish species, has been already understood by many anglers and naturalists, but has yet to receive wider political or management recognition.

The clearest case may be made for use values of *Astacus* species, whose commercial harvest and associated value-added tourism and heritage features may be important supports to the local economy in northern Europe. For instance the price of 10 cm noble crayfish *A. astacus* in Sweden, Finland, and Norway in 2005 was 40, 45, and 45 €/kg, respectively. *A. astacus* is highly valued, both from a recreational and economic point of view, and sustainable exploitation is a prerequisite for its conservation. Social benefits also follow, in terms of research, education, and recreation.

Scandinavian countries are ahead of other nations with respect to sustainable management options, mainly as a consequence of the wide-scale exploitation of their native crayfish, which is a living tradition in all these countries. Therefore interest and knowledge among the general public, landowners, fishing right owners, crayfish farmers, fishermen, managers and those utilising rivers and lakes for recreation is promoted as a prerequisite for successful conservation of native crayfish species.

Losses vs. benefits gained

There appear to be no long-term benefits gained through loss of native crayfish populations and related ecosystem services. In the short term, practices such as stream canalisation or introduction of non-native species may have appeared economically preferable compared to more sustainable alternatives. However, as illustrated by this study, in the longer term, such practices have hidden costs as are detrimental for the local biodiversity and the ecosystem services it provides to human population. For example, the habitat fragmentation and deterioration in Poitou-Charentes due to stream canalisation has in many ways degraded the ecosystem, and has been the main reason for the decline of *A. pallipes* populations.

With regard to introduced species, it was originally hoped that stocking *P. leniusculus* (introduced from California) into European waters would revive catches of crayfish to their pre-plague levels, particularly in Sweden and Finland. However, this has not proved to be the case. Certainly, the introduction of more resistant and aggressive non-native species was largely exploited for fisheries purposes. For instance, in 2000 it was estimated that 1200 tons of non native crayfish and 200 tons of native *A. astacus* was fished out of Swedish waters explaining the short term gains related to commercial exploitation of non native species.

However, nowadays commercial farms mainly culture native crayfish since they fetch twice the price on the market and there is a demand for native crayfish stocking material for restoration programmes. For instance, in 2000, the farmers got 300-400 SEK per kg for noble crayfish and 100-300 SEK (1.00 SEK = €0.105825) for American signal crayfish. However, catches for both species have declined in recent years. In the native crayfish this has been caused by crayfish plague usually as a result of illegal introductions of non native crayfish. In the non native crayfish, the reasons for the decline remain unknown.

Restoration costs

Experts agree that biodiversity loss could be fully and/or partially reversible if urgently managed. Costs of restoration of specific crayfish populations will depend on the circumstances. In Poitou-Charentes, restoration is now planned, but before that it is necessary to manage the habitats of existing populations in order for these populations to reinforce themselves prior to an attempt to repopulate suitable streams. The costs are mainly related to the purchase of some adjoining plots by certain conservation actors (eg Conservatoire of natural spaces) to secure a sufficient area for restoration. The estimate of buying 140 Ha/year is about €121 000. The cost of an efficient restoration project (during at least 5 years) is estimated to a total of €225 000 per stream. This includes:

- €200 000 euros per stream for the cost of restoration of the habitat and the monitoring of the crayfish populations (ie personnel, land settlement, physical-chemical analysis of the habitats, monitoring of crayfish population parameters).
- €25 000 (€5000/year) for the surveillance and the accurate mapping of the repartition of both native and non native crayfish species.

The choice of streams and existing crayfish populations to receive population reinforcements (6 streams to be selected) or to be chosen as donors (population of the Magot stream, a Natura 2000 site) is currently made in Poitou-Charentes. On the bases of these studies, the end of 2006 will calculate the global cost and a programme, depending of funds, could start from 2007 to 2011.

In Ireland, a modest cost was sufficient to source restocking material over three successive years and to transport this to restock White Lake. Reintroduction to large rivers (Boyne or Liffey) would be a more major task, depending on how many pollution situations would need to be reversed first (eg would the Sewage Treatment plant on the Liffey now be considered 'safe' for crayfish, or would it need to be upgraded to control periodic organic effluents?).

For *A. astacus,* a controlled fishery where the species can be sustained may be an essential tool for conservation. This type of initiative could increase the general awareness and involve more people in the task of protecting the native crayfish species. Therefore, local guidelines for sustainable exploitation should be produced. Other ways of utilising native crayfish, eg farming native crayfish for restocking purposes, is possible. However, the costs of such restoration/reintroduction plans are particularly high.

In Sweden, there are not many cases of restoration/reintroduction and only rough general costs for national programmes dealing with habitat restoration exist. The national programme for liming acidified waters (managed by the national Environmental agency) had a total budget of 20,000,000 in 2004. Of the limed waters, eighteen per cent had noble crayfish as one of the target species meaning that €3,600,000 was spent in improving potential noble crayfish waters during the year 2004. Related to the liming programme, restocking of noble crayfish is done to restore noble crayfish populations lost due to the acidification. In 2004 approximately €30,000 was spent in restocking 7 lakes with noble crayfish. Funds for managing the fishery (managed by the Fisheries Board) were also used for restocking noble crayfish and even though no exact figures are available it is estimated that at least €30,000 of these funds was spent in favour of noble crayfish in the year 2005.

Additionally, in a crayfish restoration project in the water reserve for Stockholm city, the project has a budget of €400,000 for a 4-year period. Finally a crayfish restoration project in River Ljungan in mid Sweden the budget for the whole restoration of a 60 km river stretch is €250,000. For these projects a specific sum is earmarked for pre/post studies and the evaluation and documentation of the project in order to provide information and learn lessons for future restoration initiatives.

In Andalucia, where there are significant problems of invading non-native crayfish species, a large budget has been put in place to restore the key white-clawed crayfish populations. However, within the context of this study no detailed costs of the restoration operations could be obtained.

CONCLUSIONS

The case study shows that the loss of native crayfish species driven by human activities has adverse effects on the goods and services that aquatic ecosystems provide to human well-being. In particular, it demonstrates that native crayfish species are of major ecological, cultural and economic value. The ecosystem services degraded due to the decline of native crayfish populations include provisioning services (food provision through declines in fisheries, astacicultures and loss of traditional recreational fishing); regulating and supporting services (water purification, nutriment cycling and primary productivity); and cultural services (recreation, ecotourism, education). Consequently, with no envisaged long-term benefits of such losses, and with various ecological and socio-economic benefits that may be gained by the protection of these native species, the preservation of native crayfish is of crucial importance.

Legislation is in place in most countries to protect native crayfish species, however in many cases the legislation has not been fully successful in preventing the further destruction of populations of native species. Unsustainable land use practices and development decisions that do not seem not to be directly related to crayfish populations (eg consequences of introduction of non native species, fragmentation of the habitats and the overall decrease in their quality mainly due to pollution) have added up and in the long term they have resulted in unforeseeable detrimental effects on the environment. Consequently, the ability of native crayfish to recover has diminished and the populations continue to decline.

The worst-case scenario predicts that in the future almost all watersheds in Europe suitable for crayfish will become inhabited by non-native crayfish species. In this case all native crayfish species will be considered critically endangered and are likely to survive only in a few protected localities within national parks/restricted areas. Experts argue, however, that it is still possible for some countries to prevent the establishment of non-native crayfish species. It is also emphasised that exploitation and conservation do not exclude each other but sustainable exploitation may be an essential tool for conservation by increasing general awareness and involving more people in protection activities.

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Contacts

CRAYNET 'European Crayfish as keystone species-linking science, management and economics with sustainable environmental quality' http://www.edinburgh.ceh.ac.uk/biota/craynet_page.htm

CRAYNET coordinator: Catherine SOUTY-GROSSET Catherine. Souty@univ-poitiers.fr

Thomas Changeux, Conseil Supérieur de la Pêche thomas.changeux@csp.environnement.gouv.fr

Michel Bramard, Conseil Supérieur de la Pêche, délégation Poitou-Charentes michel.bramard@csp.ecologie.gouv.fr

Dr Ciaran O'Keeffe, National Parks and Wildlife Service
Russell POOLE (Environmental / salmon-friendly improvement of drainage)

J.D. Reynolds Trinity College Dublin (Ireland)
Lennart Edsman (National Board of Fisheries, Institute of Freshwater Research, SE-178 93, Drottningholm,Sweden

Annex 2. Loss of ecosystem services provided by river basins – case study of the Danube River basin and delta (Germany and Romania)

Case study author Eleanor MacKay (Institute for European Environmental Policy – IEEP, London - Brussels)

INTRODUCTION

The river Danube flows for 2,857km from its source in the Black Forest in Germany to its Delta plain at the Black sea in Romania and the Ukraine. It is the only major river to flow west to east in Europe and is second only in length to the Volga. The biodiversity within the river system has provided a range of ecosystem services throughout its course, both directly to the people dependent on the river for their livelihoods but also more widely to the natural environment of the river basin. These services range from the simple provisioning services offered by the river's fish stocks to the more complex relationships of regulatory and cultural services provided by floodplain vegetation and the ecological balance of species.

Two case studies of the Danube have been selected to illustrate the diversity of these services lost through human intervention at different points along the river's course. The first is the impact of dam construction in the upper Danube in Germany, while the second is focused on the lower Danube and its Delta, where considerable efforts in habitat restoration are now being undertaken to regenerate degraded sections of the floodplain. For the purposes of the Danube Case Study, the ecosystem services lost will be discussed separately for the each of these cases.

THE UPPER DANUBE: IMPOUNDED DANUBE BETWEEN REGENSBURG AND STRAUBING, BAVARIA, GERMANY

Biodiversity lost

The construction of two dams along a section of the Danube between Regensburg and Straubing between 1985 and 1995 had a significant impact on the biodiversity of this section of the river. Large areas of floodplain wetland were permanently flooded, resulting in the loss of the wetlands. In addition, a reduction in the biodiversity of the fauna of river system also occurred, both in the number of species and a change in the overall population levels for some species. For example, the population of three fish species are now much lower than would be expected at this section of river and a decline in wetland birds, such as the curlew, and other endangered species has been recorded. In contrast, snail and mussel species have seen a change from a number of species adapted to fast flowing water to an increase in a smaller number of unspecific species types. Another change to the biodiversity has been the increase in mass development of populations of insects, particularly Chironomidae. The biodiversity loss is at least in part not reversible, especially the loss of adapted genetic pools and endangered species where population development is slow, for example the curlew and other limicolas and fish or mollusc species specific to the Danube.

The dam construction and the impounding of the river is the direct cause of these losses of biodiversity. It has the impact of altering the water regime for this section of the river through raising the level of the water, thereby flooding the wetland areas; while within the channel, reducing the speed and turbulence of flow and a loss of the dynamic within the water and groundwater levels. Changing the characteristics of the flow has led to a reduction in the oxygen concentrations within the waterbody, resulting in the change of species present and reducing the turnover of biomass and detritus. The reasons for dam construction was the underlying economic objective of improving this stretch of river for shipping purposes. In addition, the exploitation of the dams for electricity generation through hydropower is also likely to have created support for the scheme. Based on the information gathered for this project, it appears that no comprehensive Environmental Impact Assessment (EIA) was carried out for either dam construction phase and so the negative environmental consequences of construction are unlikely to have been considered or anticipated.

Ecosystem services lost

Three main ecosystem services have been lost as a result of the dam construction; provisioning, regulatory and cultural services. It is also likely that these services are interlinked, with the consequence that deterioration in one has had an impact on the other services.

The provisioning services provided by the Danube at this section are essentially through the fish species that have suffered a decline in population levels since the impoundment of the river. Studies carried out reveal that there is a significant contrast in the population of three indicator species between the last free flowing stretch of river and the impounded stretch between Regensburg and Straubing (Shaller, 2001). Population levels appear to be around a third less in the latter section. This decline has resulted in the loss of the commercial fishery along this stretch of the river, due to a decline in both the abundance and species diversity.

The regulatory services lost are the regulation of water quality within the channel and high flow runoffs from the surrounding catchment. The decline in water quality and self-purification ability of the river has been a result of the reduction in the river dynamics, the flow speed and turbulence and the cycling of water within the river system. This has not only affected the river channel water quality but also the quality of the groundwater in some areas. The decline in quality has been clearly documented from a level II (moderately loaded) to level III (critically loaded) for the river channel and a loss of the use of the groundwater as a drinking water source, although estimates for the cost of an alternative were not available. While much of this water quality and self-purification of the river is not directly linked to biodiversity, the loss of the surrounding wetlands and forest and their water attenuation and to some extent their ability to purify the catchment runoff (through trapping sediment, for example) will have contributed to this reduction in water quality. In addition, the loss of attenuation of water by the wetlands and the change in land use surrounding the dam is likely to have had an impact on the catchment during high flow events. Without these habitats, water is likely to pass through the system more rapidly and cause erosion due to more rapid ground saturation and increased overland flow.

The cultural services lost by the dam construction are twofold. The first is the loss of the wetland habitat and river environment with all of the amenity and aesthetic values provided by both the habitats and their constituent fauna; particularly the bird and fish species (some of which are endangered). The second is a change in state of the balance of species which has resulted in the increase of mass development of insects, particularly the Chironomidae family or midge. Changes to the river dynamics and area of open water will have favoured the expansion in their population during certain periods, without any other form of natural control. These population explosions of the insects have a negative local impact on the human population adjacent to the river resulting in a decrease in their quality of life.

Economic costs, social losses and benefits gained

The impact of the biodiversity loss has been felt to a greater or lesser extent by a wide range of stakeholders along the impounded stretch of the river. The reduction in water quality has had an impact on the wider community and the municipalities, as prior to the dam construction a large investment, both public and private, had been made in improving the quality of the water from level III to level II. The level of public investment alone was in the region of €190 million. As the result of the dam construction was deterioration in quality of the same scale, this provides an indication of the scale economic loss from the deterioration of water quality as a similar amount may need to be spent recapturing the higher quality. While this cannot all be attributed to the ecosystem services provided by biodiversity, as indicated earlier, the quantification of the contribution of biodiversity to this service will make up some fraction of the total. Another related loss to homeowners in the region of the dam is the loss of the use of drinking water through changes to the groundwater regime and the impact of moisture damage to houses also affected by the groundwater change.

The increase in the mass developments of insects has also had a negative impact on homeowners in the vicinity of the dam. Their quality of life has been reduced and more quantifiably, properties have experienced a decrease in value. In addition, this impact has led to the need for mass applications of micro organisms (BTI) to control the problem. This is applied through airborne spraying from helicopters with the reoccurring cost of this likely to be significant.

From the perspective of the fishery, both for professional and private use, it has become uneconomic on the impounded stretch of the river. The reasons for this are due to the decline in stock levels of particular species (suited to fast flowing conditions) and a decline in the overall quality of the fishery.

From the perspective of farmers in the region of the dam, the impact has been mixed. Some benefit has accrued from the intensification of agricultural land, with the conversion from pasture to arable occurring due to changes in the groundwater. This change in the groundwater regime has had negative impacts in other areas however with a decline in the productivity of some land as a result.

The main benefits of the scheme have accrued to the stakeholders wishing to navigate the river and to the generation of electricity from hydropower produced by the dams. The benefits to navigation are thought to be marginal, particularly in relation to the cost of the scheme, as a number of other bottlenecks on the Danube limit the draught of inland waterway vessels downstream. As such the Regensburg to Straubing section has to be viewed in the context of these other stretches, which being Natura-2000 areas require that improvements are done by existing and possible alternative methods. Hydro-electricity generation represents the largest stream of benefits from the scheme over the long term, with €7.25 million and €8.15 million per year generated from each dam respectively (calculated at a value of €0.05 per kilowatt hour).

THE LOWER DANUBE AND ITS DELTA: FLOODPLAIN AND WETLAND DESTRUCTION AND DEGRADATION

Biodiversity lost

Since the turn of the last century, 80 per cent of the Danube's wetlands including many in the lower Danube have been damaged or destroyed. The lower Danube area consists of both floodplain and marshland with a number of endangered habitats and species, including 320 bird species. Much of remaining habitat is now cut off from the natural dynamics of the river and is, therefore, continuing to degrade. The result is that many ecological corridors have been severed; these are critical for the migration and survival of many species.

The cause of this degradation and destruction has largely been for agricultural and navigational purposes. Dykes, drainage systems and irrigation systems have been built along the river and its tributaries to allow the regulation of the fluvial environment enabling floodplain habitats to be converted into arable farmland or monoculture forest plantations. The intensification of agriculture has led to an increase in the application of inputs on the land and as a result, an increase in nutrient loading of the river water. Construction of large hydro engineering projects for navigation such as sea river canals, the iron gate dam and deepening of the riverbed through dredging have had a significant impact on the natural ecosystem.

The underlying reasons why the biodiversity was not preserved are likely to be economic and political. The preservation of biodiversity and ecosystem services in the context of economic development was also not a priority of the former socialist regime of Romania. Collectivisation of agriculture under communism viewed the transformation of wetland into arable land and wood plantation as a more 'productive' use of the land. It is likely that the biodiversity loss is at least in part reversible, where the natural dynamics of the river can be restored and the land use reverted to at least a semi natural state. Continuing pressures from development and pollution input into the river system, however, mean that a restoration to its original state is unlikely.

Ecosystem services lost

Three types of ecosystem services have been lost through the destruction and degradation of the biodiversity of the lower Danube. The first is the provisioning services offered by the delta and river in terms of its fishery. Eutrophication caused by the increase in nutrient loading of the river water upstream has caused a disastrous impact on fish populations in the delta. The fishery represents a significant livelihood for a number of remote rural communities living in the delta, where alternative sources of income are rare.

The wetland and floodplain habitat also represents a significant regulatory service both in terms of the regulation of water levels during high flow events and for water quality. During a flood event, the natural ecosystem of the river margins provides capacity for the attenuation and wider dispersal of large volumes of water thereby regulating the flow in the channel to reduce the size of the peak flow. The removal of these habitats suited to attenuation and storage not only increases the risk of flooding through the removal of the time lag for surface runoff, but also increases the speed and likely reoccurrence of the flood event as flooding may become more likely even at lower flow levels. In terms of water quality, wetlands provide the service of retention and recycling of nutrients such as nitrogen and phosphorous from surface water run off, thereby reducing the nutrient loading of the river channel. The continued degradation of the habitat has the inverse impact of reducing the river's ability to cope with pollution.

The final service offered by the biodiversity is that of a cultural benefit. The wetland and floodplain habitat, an amenity in its own right, is a home to a large number of endangered flora and fauna. This provides aesthetic enjoyment not only for the local population but also the development of tourism, with the associated economic opportunities that this presents. Coupled to this are the intrinsic and existence values of the habitats both in their own right and for the human population. The opportunity for the sustainable development of tourist activities, a potentially significant income where few economic opportunities are present is lost as the habitat degradation and destruction continues.

Economic costs, social losses and benefits gained

As with the case of the upper Danube, the range of stakeholders and the type of cost or benefit received by the impact of the biodiversity loss is wide. For example, the farmers who initiated much of the original degradation of the habitat through creating dykes and irrigation channels have received the initial benefits of improved arable production and plantation agriculture. However, intensive use of the land for monocultures and poor maintenance of irrigation infrastructure has resulted in a longer term degradation of the land, leaving it subject to erosion. Estimates of the value of wetlands creation and restoration in the Lower Danube wetlands system[1] suggest that after restoration and rehabilitation, combined with the use of more traditional and extensive techniques, crops such as maize and vegetables could

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[1] See table in Annex 1 of this case study

provide an economic benefit of $4 and $15 million per year respectively (based on a yield of 40,000 and 50,000 tonnes per annum respectively for an area of 1,500km^2). In the past, it has been estimated that the transformation of the floodplain and the application of intensive crop production techniques made a loss in the region of $500million per year in the 1980s[2] (Vadineau, 2005). This transformation approach stems from the economic focus of the former communist regime, which ultimately led to the severe degradation of the land and the loss of habitat. Since the transition, some privatisation of agriculture has occurred and with some increases in efficiency. A rough estimate of maize yields in Romania is around 4 tonnes per hectare (400 tonnes per km^2) (UNECE, 2001), clearly indicating that the extensification of agricultural production would be likely to reduce yields. However the direct transferability of the maize yield for Romania does not necessarily reflect the yield obtainable on the Danube delta, where land degradation due to the use of previously inappropriate techniques can be assumed to reduce this figure.

The loss of the fishery resource in the delta has strong negative impacts on a small number of stakeholders whose income depends on fishing, particularly where substitutes for economic activity are very limited. The high value of these river fisheries once the habitat is restored, has been estimated[1] at around $16 million (based on a catch of 8,000 tonnes per annum for an area of 1,500km^2).

Benefits from the biodiversity loss are also likely to accrue for the improvement in the navigability of the river channel and the ability to get larger boats to ports higher up the river. This will benefit the industries located upstream, through an improvement to their transport links and those shipping companies providing the haulage. What must be set against this benefit however is the likely ongoing cost of maintaining the dynamic river channel in a navigable state, for example through continuous dredging.

The loss of water quality through eutrophication is likely to impact on the local population increasing requirements for water treatment. High nitrogen and phosphorous levels lead to eutrophication of the water, which is associated with algal blooms posing a threat to both humans and animals. The estimated[1] value provided by restored habitat for nitrogen and phosphorous absorption and cycling is $112.5 million and $18.2 million respectively per annum (based on 22,500 and 1,300 tonnes per year for an area of 1,500km^2). These values are based on the average retention volumes for this type of habitat and the removal costs associated with these chemicals if the service were carried out in a water treatment plant. The amenity value lost to the local community of the decline in biodiversity is also likely to be significant, if very difficult to quantify.

The final group of stakeholders that the loss of biodiversity impacts upon are the tourists to the area and the associated forgone revenue that they can generate for the local community. Clearly tourist activity can also create an adverse impact on the biodiversity itself. However, a more sustainable and sensitive approach to its development could offer the opportunity for a diversification of the local economy and reduce the pressure on the wetland habitat and floodplain. An estimate[1] of the

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[2] Calculated as costs of floodplain transformation, costs for crop production and monetary loss arising from the loss of ecosystem services

economic value of tourism resulting from restored wetland habitat is $16 million per year (based on 200,000 tourists per day for an area of 1,500km^2).

A very approximate rule of thumb estimate for the cost of restoration of the Lower Danube Green Corridor project based on the experience of workers in the field, suggests that for grassroots habitat restoration, the cost is around €20,000 per km^2. Given that the entire size of the project is around 900,000 hectares (ha), based on this cost assumption, an aggregate estimate for the total area would be around €180 million. This figure, of course, is not likely to represent the value of the services lost. Additionally, no estimates on the benefits of this restoration are available.

CONCLUSION

The two case studies on the Danube River illustrate clearly the range of ecosystem services lost through human intervention at differing stages along the river's course. While it is often not easy to quantify the value that these services provide, often their loss is also likely to be associated with some economic cost. These cases demonstrate that often the perceived benefits of schemes such as the dam construction to aid navigation and intensification of cultivation of the delta flood plain may also not fully materialise. It is clear that in both cases, a full assessment of the costs and benefits of the proposal in regard to its impact on biodiversity and ecosystem services more generally, was lacking.

These examples from the Danube are likely to be repeated to a greater or lesser extent on the major river systems across Europe where the pressures for inland navigability are high (the TEN-T networks are of concern from this perspective). The loss of wetland habitat through intensification of agricultural cultivation and increased pollutant loadings such as the case in the delta is also widespread, both in the Mediterranean region and northern Europe.

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Contacts

For the Upper Danube: Dr. Christine Margraf, Bund Naturschutz in Bayern. Email: Christine.margraf@bund-naturschutz.de. Or Georg Kestel, Landscape Architect. Email: G.Kestal@planwerk-landschaft.de.

For the Lower Danube: Dr. Orieta Hulea, Lower Danube Green Corridor Coordinator, WWF. Email: ohulea@wwfdcp.ro

Annex 1. Benefits of wetlands creation/restoration:

Estimates of the values of the impact of the Lower Danube River System reconstruction (1,500 square kilometres) and rehabilitation on the provision of ecosystem service

Resource/service	**Quantity/year**	**Economic value (mil USD)**
Total nitrogen	22.5 Kt	112.5
Total phosphorous	1.3 Kt	18.2
Fish catches	8 Kt	16
Timber	$12X10^4m^3$	1.2
Reed & reed mace biomass	125 Kt	6.2
Crops (mainly maize)	40 Kt	4
Vegetables	50 Kt	15
Animals (cattle, pigs, sheeps)	$20x10^3$	14
Tourist/day	$200x10^3$	16

(data from Vadineanu, 2001- estimations for 1,500 square Km)

These figures are derived from the average quantified rates and yields provided by the particular resource or service. The valuation is based on a number of techniques from the use of the market price for directly traded goods to the use of avoided and replacement costs for services such as nutrient cycling and willingness to pay functions or a combination of methods. From this the average economic value has been derived for each function.

Annex 3. Loss of ecosystem services provided by lakes and their wetlands – case study of former Lake Karla in Greece

Case study author Eleanor MacKay (Institute for European Environmental Policy – IEEP, London - Brussels)

INTRODUCTION

Lakes and wetland areas provide a whole range of vital ecosystem services both on the scale of their own catchments and often over a much wider area. These services can include the provisioning services of food and water, the regulatory services of climate and flood storage, cultural services of recreation and aesthetic enjoyment and the supporting services of nutrient cycling (MEA, 2006). The type and extent of the services is likely to vary depending on the specific characteristics of the Lake system and its interaction with the surrounding environment.

In the Mediterranean basin, it has been estimated that nearly two-thirds of the wetlands area has been lost, with much of this loss occurring in the last 80 years. Changes to agricultural practices, water resources management and the alteration to the traditional use of wetland resources are considered to the primary factors behind this loss. In more recent times, the importance of the assets and the services of wetlands has increasingly been recognised through adoption of initiatives such as the Venice Declaration and Mediterranean Wetlands Strategy (Italian Ministry of Environment, 1996) by the governments of the region and the European Union. However, the prevention of further degradation and loss may prove difficult given that the underlying causes and development pressures are often still present (Zalidis and Gerakis, 1999).

This case study examines the loss of a range of biodiversity and ecosystem services from a formerly internationally important wetland site at Lake Karla in Thessaly, eastern Greece. Human intervention and the gradual loss of the ecosystem began in the catchment in 1936, when extensive flood management works were carried out. The construction of levees and interception ditches were used to reduce the frequency and severity of the flooding of surrounding farmland that was part of the lake's hydrological regime. During the 1950s agricultural practices began to intensify, with groundwater extraction for irrigation and the increased use of inputs to the agricultural land adding to the pressures from the decreased inflow of fresh lake water. Input of untreated industrial effluent from neighbouring cities also began around this time adding to the pollutant loading discharged to the lake. The final drainage of the lake in 1962, resulted in the virtually total loss of the remaining wetland habitat, with much of the former area being turned over to cultivation (Zalidis and Gerakis, 1999).

BIODIVERSITY LOST

Extent, type and rate of the biodiversity loss

The relationship between the loss of the lake system and that of the associated biodiversity is intimately linked. Specifically, two types of losses can be identified; a decline in the faunal species diversity and extent (abundance) of wetland vegetation.

Flora. The loss of the lake water resulted in a significant contraction of the wetland vegetative area. Following the lake drainage, most of the land was converted to agriculture, with the virtual removal of original habitat. The former lake environment was made up of a range of habitat types, owing to the geomorphological features of the catchment and the hydrological regime of the lake. Four lake specific vegetative habitats comprising pelagic, floating vegetation, shallow marshes (including *Juncus sp*. and *Typha sp*.) and emergent vegetation are documented by Zalidis et al. (2005) as being the original lake habitats. The commencement of significant human intervention in the lake system began the process of the contraction and degradation of these habitat types from 1936. The rate of loss substantially increased following the final draining of the lake in 1962, with the result that these habitats have virtually disappeared.

Fauna. Linked both to the decline in the lake waters and the loss of habitat, a significant reduction in the population and species diversity of fish and bird fauna has been identified. Prior to 1936, the lake represented a highly productive commercial fishery, with a large diversity of species. Catches were estimated to have been around 1,000 tonnes per year. Remaining fish species and stocks are significantly depleted (type and number) and are restricted to the drainage ditches, the commercial fishery collapsed following the final drainage of the lake. In terms of bird species, the lake supported more than 143 species, 55 of which were protected by EC Directive 79/409 (Zalidis et al., 2005). The lake also represented a major link for migratory birds between major wetland habitats across the Mediterranean (Zalidis and Gerakis, 1999). The drainage of the lake essentially removed this resource for both the migratory and non-migratory birds, with the result that the abundance and species diversity for both has dramatically reduced.

Causes for biodiversity loss

Two distinct phases of human intervention in the lake system are the direct contributory factors for this loss. In 1936, a phase of flood prevention measures began with the construction of flood control levees on the Pinios river. These works continued until the 1950s, culminating in the construction of interception ditches in the lake's watershed to divert runoff directly to the Pinios river. During the 1950s agricultural intensification and industrialisation of neighbouring cities resulted in an increasing amount of water being used for irrigation and the discharge of untreated effluent into the lake (Zalidis and Gerakis, 1999). The combined result of these actions were a significant reduction in the water inflows to the lake owing to the effective reduction in the catchment area and increasing extraction rates. The net result was a decline in the functions of the system.

The second phase of intervention occurred in 1962, when the decision was taken to completely drain the lake. A 10.5km tunnel was built to the Pagasitikos Gulf to discharge the remaining catchment's waters and the much of the remaining lake bed was given over to agriculture (Zalidis and Gerakis, 1999).

The underlying cause for these interventions relates closely to the frequent flooding of agricultural land and the associated crop damage. The intensification of agriculture and the pressure for raising yields after the war are likely to have been key factors in this. The influence of the wider EU Common Agricultural Policy, subsidising production is also felt to have had a role. The reasons largely attributed to the final drainage of the lake were the continued damage to crops caused by the cyclical flooding of the lake system and the increasing pressures on the government posed by landless farmers.

The loss of the biodiversity was not prevented largely because at the time it was not perceived to be of a high value. Significant social and political pressures for the eradication of malaria and the economic and social pressures associated with the flooding of agricultural land and farmers livelihoods are likely to have received a much higher consideration. Economic and societal 'survival' were the key drivers, and little consideration was given to the environment or biodiversity. The polices of the Common Agricultural Policy providing subsidised production for certain commodities is thought to have also played a role in the intensification of production, particularly that of the heavily water intensive cotton crop.

No environmental impact assessment was carried out prior to the commencement of the flood prevention works or lake drainage in the 1960s. As such, many of the consequences of the interventions were not anticipated, such as the salinisation of the freshwater aquifer.

Reversibility of the loss

The extent to which the biodiversity loss can be reversed is thought to be dependant on the type of remedial action undertaken. A number of habitat restoration studies on the lake have concluded that a fully integrated catchment management approach would be needed (e.g. Zalidis et al., 2005). This is because the causes of the loss are both specific and generic in nature, for example pollution is from both industrial (point) and agricultural (diffuse) sources. Addressing the relationship of the lake with the agricultural system in the area is also likely to prove challenging as the intensification of agricultural practices and land pressures have been identified as a significant cause for the losses, while the natural state of the lake required the seasonal inundation of the surrounding land. It is suggested by Zalidis et al (2005), that current restoration techniques will not normally lead to conditions matching the original ecosystem, functional assessment of the ecosystem can help to identify the type and extent that degraded functions can be restored.

ECOSYSTEM SERVICES LOST

Table 1 below summarises the ecosystem services that were affected by the loss of Lake Karla and the wetland habitat.

Table 1. Ecosystem services affected due to the loss of Lake Karla and the wetland habitat.

Type	Service
Provisioning	Fish
Regulating	Climate, waste/pollution
Cultural	Lifestyle
Supporting	Nutrient cycling

Provisioning – prior to its drainage, the lake had supported a small community of fishermen whose livelihoods were based solely on the lake's fish stocks. Zalidis et al (2005) report that several species were present and harvested from the lake, the two most profitable being the Carp (*Cyprinus carpio (L.)*) and Eel (*Anguilla anguilla (L.)*). They indicate that immediately prior to the drainage, the average annual catch was 80 kilograms per hectare (kg/ha), consisting mainly of Carp. During the period of flood control management works, the combination of the reduction in water inputs and the intensification of the agricultural system resulted in the start of the decline in fish stocks. Zalidis and Gerakis, (1999) suggest that this was probably due to the increased salinity of the water and may have been aggravated further by the continued fishing activities. This would have led to greater stress on the fish stocks and hampered the efforts of the system in finding a new equilibrium. Following the lake drainage, it is reported that only a limited number of fish remain, there is no fishing as they are considered to be unsuitable for human consumption due to the pollutant contamination of the waters (Zalidis and Gerakis, 1999). The result has been the loss of the entire fish catch of 80kg/ha.

Regulating – two types of regulatory services provided by the lake and its wetland habitat have been lost or substantially degraded. The first of these is the regulation of the local climate. The presence of the water body and the associated vegetation regulated the local climatic conditions to remove the extremities of the Mediterranean summer and winter climate. Winters were therefore milder due to wetland surface area and depth and summers cooler owing to the combination of evaporation from the water and transpiration from the vegetation Zalidis and Gerakis, (1999). The loss of the lake and associated wetland habitat has had an adverse effect on the microclimate of the area, it is considered that the microclimatic service is now no longer present in the catchment (Zalidis and Gerakis, (1999).

The second regulating service is that of waste and pollutant regulation. Prior to the 1950s, it is thought that pollutant loads input to the lake were likely to have been very low due to the low intensity of agriculture and industry present in the catchment. It is well established that wetlands and the plant species adapted to this environment habitat have the ability to absorb certain inputs of pollutants and as such the original lake and wetland system is likely to have had capacity for this Zalidis and Gerakis, (1999). The decline in the size of the wetland habitat area and increase in pollutant loadings from agriculture and industry in combination is likely to have reduced the pollutant regulation function of the system. While much of this loss is attributed to the alteration in the lake's hydrology (Zalidis and Gerakis, 1999), the decline in the biodiversity of lake plant species can also be expected to have contributed.

Cultural – the highly productive fishery offered by Lake Karla, combined with the lake's hydrological characteristics led to the evolution of a highly specialised and unique fishing community. To adapt to the differing hydrological regimes of the lake, the fishermen spent nine months of the year in reed huts that they built on the lake (MedWet/Com1, 1998). Following the flood prevention works and loss of the lake inflow, fish stocks declined and with them did the fishing culture. After the drainage of the lake, the remaining fish stock is now considered unsafe for human consumption and as such all fishermen lost their livelihoods and with it the lake's fishing culture disappeared too (Zalidis and Gerakis, 1999).

Supporting – in a similar mechanism to that of the regulating service for waste and pollution, the lake waters and habitat biodiversity provided a supporting service for nutrient cycling. The ability of the wetland habitat to absorb and balance the water nutrient load was degraded as the flood prevention work reduced the water recharge and catchment size of the lake. The intensification of agriculture in the surrounding catchment at the same time also led to an increase in the level of nutrient loading as more artificial inputs were made to the soil. The combined effect was of a decline in the capacity of the lake habitat and increased loading, was further exacerbated by the drainage of the lake to the extent that the nutrient cycling service no longer functions (Zalidis and Gerakis, 1999). Although much of the service is likely to be provided by the water turn over and inflow, the lake habitat plant species also contribute to the provision of this supporting service.

ECONOMIC COSTS, SOCIAL LOSSES AND BENEFITS GAINED

Stakeholders affected by the biodiversity loss

Two clear groups of stakeholder can be identified as being directly affected by the loss of Lake Karla. The fishing community on the lake lost both their means of economic survival and with that the unique closed fishing culture that had developed. The second group of stakeholders are the farmers whose activities in the lake catchment were both dependant upon and contributed to the functioning of the lake ecosystem. Many of the changes that led to the drainage of the lake were a direct consequence of the pressures from agricultural community (i.e. the prevention of flood damage to crops and intensification of agricultural practices through irrigation and inputs). A number of the benefits of the loss of the lake initially accrued to some farmers, although over the longer term these have been lost. The consequences of the lake drainage and wetland loss has over time resulted in a number of negative impacts to the local communities of the lake catchment. As such, the widespread support for habitat restoration (Zalidis et al., 2005) may be interpreted as an indication of the change from an initial favouring of drainage (to remove malarial and flooding risks) to a negative reaction once the full impacts of the drainage were apparent.

Indirectly, the residents of the neighbouring city of Volos were also affected as the construction of the tunnel to drain the lake also acted as a conduit for the transport of pollutants from the cropland and surrounding industries (Zalidis and Gerakis, 1999). Although not directly affected by the loss of the wetland habitat and ecosystem services, they suffered from the negative consequences of the actions taken to drain the lake. Their demonstration against the negative impacts of this resulted in the increased pumping of floodwaters to a piece of municipal land creating an artificial wetland.

Losses vs. benefits

A clear economic loss of the decline in the ecosystem services is that of the commercial fishery supported by the lake. The original fish catch was estimated as around 1,000 tonnes per year, employing in the region of 1,300 fishermen (Perivallon, 1996). The loss of the commercial fishery impacted severely on this group as there were no alternatives and their unique lifestyle was lost (Zalidis and Gerakis, 1999). As indicated previously, the pollution of the remaining water courses means that currently, no fishery is viable.

In terms of the farming community, the economic losses associated with the biodiversity loss were not immediately felt. Much of the justification for the flood intervention works and abstraction of water for irrigation led to agricultural benefits in the short term. Intensification and the reduction in flood damage led to rising yields and income for farms, Zalidis and Gerakis (1999) suggest that these benefits were not however universal and only a few landowners received the economic benefits. Conversely, over time, water shortages and increasing salinity have worsened the agricultural quality of some of the land and frost damage to crops has increased, this is likely to be a consequence of the loss of the climate-moderating effect of the wetland. Agroecosystems have also reportedly lost crop diversity (Zalidis and Gerakis, 1999).

Restoration costs

A partial restoration of just under 4,000 hectares of lake habitat is being funded by the European Regional Development Fund (ERDF) and national contributions. Around 70 per cent of this work has now been undertaken and the approach has been the use of a fully integrated catchment management. The total cost of the restoration is €152,020,000, of which just over €52 million being financed by the Greek government and the remaining €100 million by the ERDF. These restoration costs can be considered to indicate both the real costs (eg loss of fresh water groundwater supplies and natural habitats) and opportunity cost brought forward by lake drainage. At present, the restoration seems to be considered both a good financial investment and valuable in terms restoring the intrinsic value of the ecosystem and its biodiversity.

CONCLUSION

The degradation and final drainage of Lake Karla led to a dramatic reduction in the wetland habitat and the degradation and loss of a number of ecosystem services. The provision of fish and the fishing culture and livelihoods have been lost. The regulation of climate and pollution and support of nutrient cycling within the catchment has also been severely degraded, to the extent that the services no longer function on a scale large enough to provide real benefits. The initial benefits afforded in flood protection and irrigation schemes have in many cases been heavily outweighed by among other things the adverse changes to the hydrological and climatic regime of the area. As a consequence, around 4,000 ha are in the process of being restored on the basis of an integrated catchment management approach.

The case of Lake Karla and the loss of wetland habitat over the past 80 years is a common occurrence in the Mediterranean region due to the growing pressures of agricultural intensification and requirements for water resources. It is thought that over two-thirds of wetland habitats have been lost from the region. Such a drastic alteration of an ecosystem as presented in this case study cannot take place today without first assessing their impacts on the environment and therefore the case study does not fully reflect the causes for the loss of ecosystem services at present. However, the problems and losses resulting from these high-impact development projects are still present and the real costs of the lost services are only now becoming more apparent (eg through the costs of restoration).

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Contacts

Professor George Zalidis. Lab of Applied Soil Science, School of Agriculture, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece. tel +30 2310 998769. fax +30 2310 998738. email zalidis@agro.auth.gr

Annex 4 Loss of ecosystem services provided by marine ecosystems – case study on the depletion of the North Sea provisioning services

Case study author Indrani Lutchman (Institute for European environmental Policy – IEEP, London – Brussels)

INTRODUCTION

The North Sea covers an area of 745,950 km^2 and is a relatively shallow sea with a mean depth of 90 metres. It includes one of the most diverse coastal regions in the world with a variety of habitats including sandbanks and mudflats. It is also one of the most productive areas in the world with a range of plankton, fish, seabirds and benthic communities and is one of the world's most important fishing grounds. Importantly, the North Sea accounts for some 2.5 million metric tonnes of fish and shellfish catches annually and a fishing industry with significant jobs including catching, processing, transportation and shipbuilding. The fish stocks on which these industries are based are not only economically important, but play pivotal roles in the North Sea ecosystem

Overexploitation of North Sea fisheries is now a major threat to biodiversity and ecosystem health. Over the last decade, there has been increasing concern for the impaired status of North Sea fish stocks, as well as the impact of fishing on other parts of the marine ecosystem. The changes observed in the trophic structure are indicative of a trend towards a decreasing resilience of the ecosystem.

This case study summarises the degradation of the North Sea ecosystem services highlighting the major trends in key fish stocks and the socio-economic impacts of these trends. In particular, the case study focuses on the depletion of provisioning ecosystem services for published literature on the over all ecosystem impacts of depleted North Sea fish stocks was not as extensive. However, the case study also describes current trends of other ecosystem components and considers the loss of cultural services (tourism and recreation).

BIODIVERSITY LOST

Extent, type and rate of the biodiversity loss

Plankton: The plankton community in the North Sea, including both phytoplankton and zooplankton, have undergone many changes in the last 40 years. These changes have been linked to climatic and oceanic changes, affected the growing seasons and abundance of these components of the North Sea ecosystem. Long-term trends in both phytoplankton and zooplankton suggest both periods of decline (1979-1980) and periods of recovery (post 1980), including shifts in plankton composition with implications for other components of the North Sea ecosystem (ICES, 2003).

Fish: In the past ten years, the state of the stock for most roundfish and flatfish species in the North Sea has deteriorated. Some of the stocks are at a historical low. This has led to reduction in the number of age groups, with young fish comprising most of the stock populations. Most of the stocks of commercial fish species in the North Sea are in seriously endangered condition with 30 to 40 per cent of the biomass of these species being caught each year. In addition, 70 per cent of young cod, for example, die before sexual maturity. Furthermore, heavy fishing pressure has resulted in 80 per cent mortality in young fish.

Cetaceans: The levels of by-catch (accidental capture in fishing gear) of small cetaceans in the North Sea, particularly harbour porpoises, pose a particular risk to overall populations. It is estimated that the annual by-catch of harbour porpoises in the North Sea is around 7000 (OSPAR, 2000).

Birds: About 2.5 million pairs of seabirds breed around the coasts of the North Sea. In general seabird populations have been increasing on the last 50 years. However, there have been instances where seabird populations have been affected by high levels of fishing. In 2004, seabirds on the North Sea coast of Britain suffered a large-scale breeding failure In Shetland, Orkney and Fair Isle, whereby tens of thousands of seabirds, including skuas, terns and kittiwakes, failed to raise any young. There were strong indications that this breeding failure was linked to a food shortage caused by high levels of fishing for sandeels, the staple diet of these seabirds. In 2004, the waters around the south of Shetland were closed to sandeel fishing altogether, and a reduced 'Total Allowable Catch' (TAC) was introduced to the North Sea. This led to a recovery in most of the bird populations (Lanchbury, 2004).

Benthos: One recent estimate suggests that the beam trawling in the southern and central North Sea reduces total benthic biomass by 39 per cent and benthic production by 15 per cent relative to the unfished state (ICES, 2005). It is also estimated that for every kilogram of North Sea sole caught by beam trawl on the seabed, 14 kilograms of other animals are killed (RCEP, 2004). Another study on the effects of bottom trawling of a heavily fished area in the northeast of England since 1971 provides good evidence of the long-term changes to composition and abundance of macro benthos. It is suggested that the indirect effects on fish diets and benthic predation rate due to changes in community structure by bottom trawling are also affecting the functioning of the benthic ecosystem (OSPAR, 2000).

Causes for biodiversity loss

A range of human activities including agriculture, gas extraction, shipping and tourism, has an impact on biodiversity in the North Sea, directly or indirectly, but most notable are the effects of fishing (EEA, 2003). Over-capacity in fishing fleets combined with damaging fishing techniques, poor management and limited enforcement has resulted in a widespread degradation of species, habitats and food webs. Specifically, the use of destructive gears such as beam trawls inflict significant damage to seabed communities and habitats. Fishing pressure on prey species such as sandeels and pout in the North Sea also threaten wildlife such as seabirds and the recovery of depleted fish stocks indirectly. In addition, the incidental by-catch of non-target fish species, seabird and mammal species has also contributed further biodiversity loss.

Climate change and marine pollution are two other factors causing biodiversity loss in the North Sea. Rising temperatures have coincided with marked changes on the plankton ecosystem with some declines of the main prey species for example, cod. Climate change has been linked to the poor recruitment of cod and the lack of prey species for some seabirds and mammals. Output from the Hadley General Circulation Model estimated the likely effect of climate change on North Sea cod population and it has predicted that even at low level of climate change, there could be absolute collapse by 2050. Some species in the North Sea may well benefit from the warmer temperatures (EEA, 2005).

Since the 1980s there have been attempts to protect the marine environment through a number of European Union (EU) and Member States policies. These include the habitats and birds Directives, the water framework Directive and, more specifically to fisheries, the Common Fisheries Policy (CFP). There are a number of reasons for the continuing decline in fish stocks and marine biodiversity in spite of these fisheries conservation and broader marine environment protection measures.

Europe has taken steps through the CFP to manage fish stocks and aid the recovery of severely depleted fish stocks, most notably cod. However, the high level of employment in fishing in some countries such as Spain, France and Portugal means that there is often a cconflict between the need to preserve the livelihoods of fishing communities dependent on fishing and the recommendations of the scientific advisory bodies on management measures. In the last decade, this has led to political decisions to set higher TACs than those recommended.

In addition, attempts have been made to reduce the overall number of vessels to allow for stock recovery but these have been met with resistance from the fishing industry and have not been effectively implemented or enforced. The result is that successive efforts to reign in fleets have had only modest success in reducing fishing pressure on depleted fish resources and other threatened species, and in reducing by-catches of non target species. The short-term approach to EU fisheries management based on inadequate, sometimes inappropriate technical measures and inefficient control and enforcement mechanisms have all gradually led to deterioration of North Sea fish stocks. (Grieve, 2004). Finally, while the European Commission has proposed and adopted regulations to address by-catch of non-target fish, seabirds, and cetaceans and reduce damage to the seabed and benthic communities, there are concerns that these efforts have been insufficient to halt biodiversity loss in the North Sea.

Reversibility of the loss

Based on experiences in other parts of the world and results from monitoring of closed areas, for example, it is expected that some biodiversity loss is either partly or fully reversible. Fishing rarely makes a species extinct but can greatly affect some species that are significant components of a marine ecosystem. Some fish stocks with a high reproductive rate have successfully recovered from high fishing pressure when reduced, for example, North Sea herring. However, slower growing and less fecund species are much slower at recovery and recent sharp declines in population, biomass and recruitment are unlikely to be reversed quickly. Such species include cod, sharks, skates and rays, and in particular deepwater stocks. Local extinctions can also occur. In the Irish Sea in the 1980s, for example, the common skate, *Raja batis*, was made locally extinct due to overfishing.

ECOSYSTEM SERVICES LOST

In the past ten years, the state of most commercial fish species has deteriorated with some stocks reaching a historical low. ICES reported in 2003, that 61 per cent of Europe’s demersal fish stocks were outside safe biological limits, together with 22 per cent of pelagic species, 33 per cent of benthic species and 41 per cent of industrial fish stocks such as sandeels. Today the situation has not changed significantly.

There have been dramatic declines in the adult population in most commercial species and there are not enough juveniles to enter the system and maintain the population. Stock trends in other fisheries include:

- almost all roundfish stocks have declined and the current harvest is in most cases not sustainable
- several flatfish stocks are harvested at excessively high levels but some are close to sustainable levels
- pelagic species and industrial species (caught for conversion to fishmeal and oil) such as sandeels are in better condition but harvest levels need to be maintained at current levels or reduced to secure sustainability.

The most prominent example of a stock under severe pressure in the North Sea at present is cod. The spawning stock biomass (adults able to reproduce) had declined from a peak of 250,000 tonnes in the early 1970s to less than 40,000 tons in 2001. Despite this decline, fishing pressure continued to increase in the same period. A low spawning stock biomass means that the amount of young fish (recruits) to enter the fishery has been diminished. As the last four recruiting year classes were exceptionally weak, there is little hope of a quick recovery for cod (ICES, 2005).

Other species, which have been fairly common in the North Sea, have disappeared completely or have become very rare. In addition stocks of elasmobranches are at low levels. The spurdog, *Squalus acanthias*, was once the common shark species and is now considered depleted to approximately 5 per cent of its virgin biomass in the whole North East Atlantic. Other species such as porbeagle shark, *Lamna nasus*, have also become rare. Most of these species have disappeared from large parts of the North Sea (ICES, 2002).

Generally, in the North Sea, the biomass of top predators has decreased by two thirds in 50 years. As the bigger predatory fish decline, smaller fish from lower down the food chain have replaced them and slowly the phenomenon of ‘fishing down the food chain’ is taking place. The result is that in the North Sea, plankton eaters have replaced most fish eaters.

According to ICES (2003), the North Sea ecosystem changed notably during the 20th century. Some parts increased in productivity and abundance (certain plankton species) while other parts exhibited long-term reductions (commercial fish stocks). Alongside these long-term changes in productivity, changes have occurred to the composition of some of these communities. For example, there has been a general shift in the benthic community from long-lived to opportunistic species whilst in the fish community there have been increases in abundance of non-commercial species as commercial species have declined. Some of the long-term changes have occurred in parallel but there is need for monitoring to gain a better understanding of the interactions between ecosystem services, in this case fish stocks and biodiversity loss.

Other services affected by biodiversity loss include marine tourism and recreational services that include bird watching, whale watching and sea angling. They are all dependent on a high quality of marine environment and abundant marine life. It is known that these services contribute to the economies of the coastal communities bordering the North Sea, for example, in the Shetland Islands. It is essential that marine resource exploitation does not compromise the sustainability of these services.

ECONOMIC COSTS, SOCIAL LOSSES AND BENEFITS GAINED

For many years it has been the perception that capture fisheries provide a poorer income than many other industries and occupations. One of the reasons is the peripheral geographical location of many fishing enterprises, and the fluctuations in the size of the landings. However, good returns are available in well-managed fisheries or where a limited area of access has been assigned (EEA, 2005). Not all fishing enterprises are equally efficient, but the poor returns available from alternative employment in many fishery-dependent areas, and the generally low investment in peripheral local economies continues to support unprofitable fishing enterprises.

The value of the whole production chain from fishing, aquaculture, processing to marketing is estimated to be approximately 0.28 per cent of the EU gross domestic product, and certainly less than 1 per cent in terms of contribution to the gross national product of Member States (EEA, 2005) However, this does not reflect its highly significant role as a source of employment in areas where there are few alternatives.

The decline in major commercial fish stocks has had a major effect on the fishing industry in the last decade. The value of landings in Great Britain reduced between 1960 and 1999 by around 80 per cent, from £880 million to £196 million (in 1999 prices) (MacGarvin 2001). In Europe, the number of fishermen has been declining in recent years, with the loss of 66,000 jobs in the harvesting sector, a decrease of 22 per cent. There has also been a 14 per cent decline in employment in the processing sector. In Scotland, for example, rising costs and declining catches have cost the Scottish demersal fleet between £19,000 and £90,000 per boat. The value of landings in Great Britian was reduced between 1960 to 1999 by around 80 per cent, from £880 million to £196 million (1999 prices) (MacGarvin 2001). In some areas these trends are threatening the viability of small coastal communities in the absence of suitable alternative employment (EEA, 2005).

CONCLUSION

The North Sea as a region provides a number of important ecosystem services. Fish stocks are particularly important in underpinning the fishing industry, and so supporting employment and economic activities in locally dependent regions of the EU. However, fishing itself is one of the major pressures on the North Sea ecosystem. Fish stocks have declined, and with them biodiversity more broadly and consequently other ecosystem services such as related tourist industries. While the reasons for this decline in the state of the North Sea ecosystems are numerous and complex, the highly politicised nature of EU fisheries policy making under the CFP is key. Short-term political interests have taken precedence over long-term sustainability.

There is general agreement that if the North Sea fish stocks are well managed that there could be a range of potential benefits. Recent estimations are that successful recovery plans to halt the decline of North Sea demersal fish stocks could be worth at least £400 million a year. This is without the added value from fish processing and indirect positive effects such as on tourism and recreational sea fishing activities (Mac Garvin, 2001). Whilst no values have been assigned to the role of a fully functioning North Sea ecosystem if fish stocks were well managed, examples from other parts of the world indicate that there would also be optimum environmental benefits.

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IEEP	www.ieep.org.uk

Annex 5. Loss of ecosystem services provided by peat bogs in the UK & Finland

Case study author Jason Anderson (Institute for European environmental Policy – IEEP, London – Brussels)

INTRODUCTION

Peatlands (used generically here to describe peat bogs, mires, moors, fens, which each have different characteristics) are important ecosystems which cover about 3 per cent of the world's land area, primarily in damp northern climes; in Europe they are found in Scandinavia, the UK, Ireland, northern Germany and Russia. Peatlands are unique habitats, acidic and waterlogged, formed when decaying plant matter subsides in anaerobic conditions and accumulates. A number of species are dependent on the conditions found only in peatlands. The mossy surface vegetation includes plants adapted to the nutrient-poor, including those that catch insects. Butterflies, dragonflies and of course wetland birds and waterfowl are all common.

Peatlands are also both cut for fuel and drained to make way for agriculture, forestry and development. The reasons behind peat land habitat destruction/degradation include:

- Livestock farming: peat is drained to allow heavy grazing, and burned to modify vegetation.
- Forestry is traditionally a major user of peat lands; even where there is little new planting, existing forests affect the species composition of neighbouring bogs, as does the application of fertilisers and pesticides.
- Extraction, for fuel and soil treatments
- Recreation: walking, horseback riding, and all terrain vehicles are damaging the surface of many areas
- Infrastructure: wind farms, telecommunications masts, and hydropower are all planned for peat lands.
- Erosion: particularly in highland areas, much of which may be natural
- Water course liming to combat acidification, but which negatively affects peat.

While peatlands are found in several European countries, this case study looks at two examples: the UK and Finland. In the UK peatlands are in the process of being protected. In addition to providing information on both the loss and present conservation efforts of peat bogs at the national level, the case study presents a peat bog restoration project (by United Utilities and the Royal Society for the Protection of Birds, hereafter the UU/RSPB project) that is underway to reverse damage to an area subject to intensive livestock farming. In the case of Finland the case study considers primarily the climate change implications of peat at the national level, which is abundant and used both as fuel and as land for agriculture and forestry.

BIODIVERSITY LOST

Extent, type and rate of the biodiversity loss

The Finnish word for ‘Finland’ is ‘Suomi,’ which is derived from a word meaning ‘peatland’ or ‘lowlands,’ and the word ‘Finn’ itself refers to the ‘fens’ in which they lived. Peatland is thus integral to the country’s identity. Originally one third of the land area of Finland was covered in peatlands; half of this has been drained for agriculture, converted to forestry or cut for fuel. This amounts to around 5 million hectares lost; peak activity was in the 1970s, when 3000 km^2 were drained per year; currently draining has all but stopped for agriculture and forestry, though 662,000 ha have been earmarked for fuel extraction, of which only 100,000 are actively being used to date. About a quarter of Finland’s native plant species are found in peatlands, and a third of the country’s birds rely on peatlands habitats. 53 species are estimated to be under threat due to drainage and peat extraction.

There are approximately 1.5m ha of upland blanket peat in the UK, of which 215,000 are in England, mostly in the Northwest, as in the case of the UU/RSPB project. Studies from Scotland, where there are over 1m ha of blanket bogs, indicate that nearly 21 per cent was lost between the 1940s and 1980s, primarily to afforestation. It is estimated that in England there are some 3,800 ha of lowland bogs, about 10 per cent of the original total. United Utilities owns 57,800 ha of land in the Northwest. Nearly half of this is in three National Parks, and almost a third is designated as Sites of Special Scientific Interest (SSSIs). A quarter of the land is in poor and worsening condition, a third is stable and almost 40 per cent is in improving condition.

Causes of biodiversity loss

Conversion of peat to forest land has been seen as a valuable economic activity in Finland, and is the primary use of peatland. The converted land increases annual forest stocks by about 15m cubic metres. Nevertheless about 50,000-60,000 ha are used to produce peat for fuel. Around 19.5 TWh came from peat in 1999, of which 45 per cent was for electricity and the rest for heat production. Estimates show that the amount of peatland used for fuel production could rise to 150,000 in the future.

In the case of the area covered by the UU/RSPB project, degradation of the peatland is the result of intensive livestock farming. The 57,800 ha owned by UU is privately held, and the agricultural activities are long standing. Among other things the level of intensive use reflects both common practice and the subsidy ‘headage’ payments, whereby there is incentive to keep more livestock than is sustainable for the land. The traditional practice of over-wintering on moorlands has further degraded the soil, as damage is greatest in wetter conditions. Drainage and seeding grasses on the moors, as well as application of inorganic fertilisers, have further converted the moorlands, as well as decreasing water quality, as oxidised peat makes its way into the public water supply.

Drivers of peatland use and conservation

Although there are clear economic drivers behind the loss of peatland habitats to other uses, there are also countervailing forces lending to their conservation. These include the debate over peat as a renewable fuel, and the recognition of the habitats as needing protection under a range of legislation.

In Finland peat fuel has been viewed as an important indigenous energy resource and as such has received R&D and investment subsidies as well as tax exemptions. Finland views peat as a 'renewable' fuel, and pressed to have it defined as such under the European Directive on Renewable Electricity (COM 2001/77/EC) - this view was not, however, shared by other legislators and peat is excluded, at least meaning there is no extra incentive to increase its use to meet EU targets. However, at national level there continues to be a debate on this issue, with strong arguments in favour of an indigenous fuel that provides rural employment. It is expected that due to the European Emissions Trading Scheme, peat use may drop 30 per cent by 2012; this figure, however, was estimated prior to the recent passage of a tax reduction on peat. Clearly, peatland extraction will continue to compete with preservation as a priority.

In the UK over 500,000 ha of upland habitat that include peatlands are protected through designation as SSSIs or ASSIs. 32 sites are proposed to be Special Areas of Conservation under the EC Habitats Directive, some are designated as Ramsar sites and some are Special Protection Areas under the EC Birds Directive. Nevertheless, significant areas are 'common land,' where rights to cut peat and graze are held in private hands. This is the case in the UU lands, which are in private hands. Nevertheless they have the legal obligation to conserve the land in accordance with government targets for nature conservation. This combination of private landownership wit allowable economic activity on the one hand, and an obligation to conserve on the other, is the justification for undertaking the project to balance the use with conservation.

Reversibility of the biodiversity loss

Peatland restoration is gaining in importance, reflecting growing emphasis on both repairing important habitats, and carbon retention. The success depends on eight factors: 1) area and depth of extraction, 2) type of exploitation (block cutting, drainage, etc.), 3) depth and type of peat remaining, 4) degree of hydrological disturbance, 5) presence of remnant vegetation, 6) nature of former vegetation, 7) nature of surrounding vegetation, and 8) time from abandonment to attempted restoration.

Mire conservation began in Finland in the 1960s as forestry exploitation expanded rapidly. In the 1970s a network of national parks and nature reserves were developed, which covered the main mire habitats. Of the 3.5m ha of pristine mires remaining, a third are protected. About 12,000 ha have been restored in nature reserves.

Having recognised that the small amount of peatlands remaining in England form a unique part of the landscape, intensive efforts are underway to save the rest. In 2002 the Government negotiated to buy the peat harvesting rights from the country's largest peat producer, and a 10-year plan is underway to end peat harvesting. The Fenn's, Whixall and Bettisfield Mosses lowland raised bog on the England-Wales border is thriving after restoration from commercial peat cuttings, proving that the loss of peatlands is reversible. Under a nationwide action plan, nearly 300,000 ha of blanket mire are to be improved and managed by 2010, and a further 225,000 by 2015. At that point 75 per cent of restorable blanket mire will have been restored. The UU project would see conservation management of 100 per cent of the land area, with an increase of 10 per cent in the blanket peat bogs through restoration activity.

ECOSYSTEM SERVICES LOST

Peat ecosystems are wetlands; drying them to provide agricultural land both affects the water resource and chemically alters the peat. Acting as water retention sponges and filters, peatlands protect potable water sources – when they are drained, they both fail to act as filters and add to water quality problems by leaching oxidized peat, causing discoloration.

Living peat also sequesters carbon, as it grows year on year. When it is dried, and also when used in agriculture, not only does it no longer add biomass, it releases greater quantities of carbon dioxide, nitrous oxide and methane. When forested, there is greater carbon sequestration, though more nitrous oxide emitted. Naturally when peat is burned it releases carbon dioxide, further adding to greenhouse gas emissions. Studies indicate that under conditions of increased atmospheric CO_2, peatlands will release more methane; initially they will also sequester more CO_2 through greater growth but this effect appears to be temporary.

The loss of peatlands has a variety of implications. They are unique habitats that support a variety of species specially adapted to them. Draining them also tends to lead to greater fluxes of greenhouse gases, including carbon dioxide, methane and nitrous oxide. It can lead to decreased ground water quality as previously waterlogged peat oxidizes and is flushed into the water supply. Harvesting and burning peat both degrades the habitat and releases CO_2 – growing at a rate of around 1 mm per year, the fuel is non-renewable on relevant time scales. Finally, peatlands themselves are sensitive to rising temperatures and CO_2 concentrations, meaning they are part of a positive feedback loop between draining, harvesting and combustion that releases CO_2, which causes global warming that leads to further drying of peatlands. Even worse, methane trapped in frozen Siberian tundra mires may be released if they melt – a potentially enormous source of greenhouse gases.

About 20 per cent of Finland's greenhouse gas emissions are attributable to peat – through combustion, fugitive energy sector emissions and emissions from disturbed peatlands. The second factor is remarkably high - in the 50,000 to 60,000 ha of peatland producing fuel, which amounts to one per cent of remaining peat land, CO_2 emissions due to loss of natural carbon accumulation, and emissions from stockpiles and ditches, is equivalent to 5 per cent of the emissions from combusting the resulting peat – or some 1.0 Tg CO_2 annually.

In the UU/RSPB case study the link between loss of peatlands and loss of ecosystem services is clear: overgrazing and draining are leading to quality problems in the drinking water supply, which requires expenditure in further processing to correct.

ECONOMIC COSTS, SOCIAL LOSSES AND BENEFITS GAINED

Evidence of the real economic value lost

In Finland, peat fuel is a major issue that dominates the climate change debate. There are strong economic forces allied to the fuel industry, who are supported by rural population centres relying on fuel extraction for employment. Nature protection organisations such as the Finnish Association for Nature Protection are also strong; their work on habitat protection pre-dates the climate change debate, and has considerable traction on the issue of biodiversity preservation. Thus the debate is an active one likely to continue.

Finland has a small population and vast areas of peatlands. Thus while the economic value of peatland converted to agriculture or used as fuel is clear, there are fewer economic activities associated with undisturbed land. However, the link to climate change, where converted peatlands and peat combustion contribute to greenhouse gas emissions, implies economic damage through climate change impacts – a part of which (small globally but significant in the Finnish context) is due to peat.

In Northwest England, there are clearer links between peatland use and economic value. In its restoration project, United Utilities and the RSPB anticipate peatland restoration will help improve local drinking water quality in three aspects: microbiology, soil erosion and water colour. While it is difficult to monetize the value of these improvements, an estimate puts it at between €1.8 and 3.6 million euros per year, or a total discounted benefit between €5.5 and 12 million. This is based on costs incurred for water treatment that are expected to be avoided. The difficulty for the project is placing exact figures on the benefits – as opposed to the known costs and benefits of a new water treatment plant, while costs to change peatland management are known, then exact effect of the restored natural filtration are harder to predict – it is after all a natural system, and one that is dynamic, particularly as it is undergoing restoration. Thus the benefits of the scheme have a wide range of estimation. Of course, these are still the benefits that are easiest to calculate – there will also be improved habitat for species such as the brown hare, red squirrel, juniper, twite, and hen harrier – such improvement is not monetised.

Losses vs. benefits gained

Peat and peatlands have economic value, as land that can be converted to agricultural or forest use, as fuel, and as fertilizer. However, in each case there are alternatives to traditional exploitation that reduce the conflict between preservation and economic activity. There are alternative fuels and fertilizers that can be phased in to replace peat, while more sensitive practices can reduce stress on existing agricultural activities on peatlands.

In the case of northwest England, the UU project will demand certain changes to farming activities, including better waste handling, winter livestock housing, and fencing – but it is also recognized that farming intensity will have to be reduced and a certain amount of land will have to be off limits, meaning that greater diversification in activities is needed to maintain equal incomes. This demands a shift in the whole farm business, requiring planning and funding. There are several benefits the UU project, including improved water colour, reduced cryptosporidium risk, lower long-term costs to water customers, reduced flood risk down stream of improvements and enhanced aquatic, wetland and terrestrial biodiversity

Restoration costs

The UK's action plan to restore 75 per cent of degraded peat mires cost around 20 million euros/year through 2005, and is estimated to cost on the order of €65 million per year for the subsequent 10 years. With a total expenditure of some €680 million to restore 845,000 ha, the cost is around 800 €/ha. Cost information on the UU/RSPB project is available but confidential.

CONCLUSIONS

From the conservation perspective peatlands have the unfortunate distinction of not only being converted to other uses like forestry and agriculture, but of being extracted as fuel. This combination of pressures has devastated large portions of northern Europe's peatland. In their original state peatlands harbour a wide diversity of flora and fauna, being largely wetlands and hence providing a range of interesting habitats. However, in that state they are inhospitable to man and economic activity, so that they tend to be remote areas with little competition for drainage and other exploitation.

The two case studies point out two distinct conservation challenges: on the one hand, overexploitation for livestock in Northwest England is leading not just to a loss of habitat, but to an undesirable outcome in terms of ecosystem services: poor drinking water quality. Adaptation of the land use suffices to balance the use for farming with the preservation of the ecosystem service of water filtration. A certain part of the land is off limits under new land use plans, but the changes are primarily to management and infrastructure, allowing a continuation of agriculture and an improvement in both habitat preservation and the water filtration.

sIn the case of Finland's extraction of peat for fuel, the extractive activity is inherently destructive. From an ecosystem services point of view, not only is there a loss of CO_2 retention due to drainage and extraction, peat combustion itself leads to CO_2 emissions. The mitigating factors are two-fold: first is that post-extraction rehabilitation is possible, and is being done in Finland, and elsewhere. The second is a balance in terms of land area exploited – Finland's peat resources are vast, and the amount of land exploited for fuel is (relatively) limited. However, given that alternatives to peat fuel exist, and CO_2 limitations will become ever tighter, pressure will mount on Finland to reconsider its approach to peat extraction.

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Annex 6. Loss of ecosystem services due to changes in agricultural land use – case study on the plantation of monoculture forests in Portugal

Case study author Samuela Bassi (Institute for European environmental Policy – IEEP, London – Brussels)

INTRODUCTION

Over the past century Portugal has witnessed a strong expansion of its forest cover, which has increased by around 400 per cent. While in the South of the country this has been achieved through the expansion of the '*montado*', an evergreen oak woodland composed predominantly of cork-oak (*Quercus suber*) and holm-oak (*Quercus ilex*), in the North it was the result of forest plantations of pine and, later, eucalyptus forest.

The plantation forests in the North of the country are very different from area's native oak forests[1] and there has been a great deal of discussion on the impacts of this on biodiversity and ecosystem services. Forest plantations, in particular eucalyptus forest, have low species diversity and often replace habitats (both agricultural and natural) with higher original biodiversity. This results in a net loss of biodiversity in the area and brings forward other possible negative effects, eg soil erosion, loss of regulation of the hydrological cycle and excessive nutrient extraction. In addition, forest plantations are more fire prone than the agricultural or native forest habitats that they replace. This increases fire frequency and may delay ecological succession on neighbouring abandoned fields. This change is considered to be one of the underlying causes for the gradual worsening of the fire regime in the country.

This case study summarises how the plantation of forests made up of a monoculture of species has affected biodiversity and biodiversity-related ecosystem services in Portugal. The study also provides general estimates on the value of lost services.

BIODIVERSITY LOST

Extent, type and rate of the biodiversity loss

The loss of forests in Portugal started in the beginning of the Neolithic period due to the conversion of land to agriculture and pastures. As a result the forests became confined to the mountain areas. At the turn of the 19th to the 20th century, a transition from deforestation to reforestation occurred with government organized afforestation. This marked the beginning of a trend that by the end of the 20th century significantly changed the country's landscape. The autochthon tree species in Portugal used to be

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[1] Native forests in the Norther Portugal were composed of three species of deciduous oak (*Quercus pyrenaica, Quercus robur* and *Quercus faginea*)

oaks (including, for example, cork-oak (*Quercus suber*) and holm-oak (*Quercus ilex)*), but the main species used for afforestation was the maritime pine (*Pinus pinaster*), a native species characterised by its pioneer features in ecological succession. The use of eucalyptus (*Eucalyptus globulus*), an introduced species from Australia, began during the 1950s. Due to its fast growth and economic importance (particularly for paper pulp production) the utilisation of eucalyptus rapidly expanded through the private sector. By the 1990s, the afforestation rate with eucalyptus had reached more than 30,000 ha/year (Radich and Alves, 2000).

In 2003, forests in Portugal covered an area of 3.2 million ha (DGF, 2003a) occupying approximately 36 per cent of the land surface. A proportion of 88 per cent of this area was dominated by maritime pine (30 per cent), eucalyptus (21 per cent), cork-oak (22 per cent) and holm-oak (14 per cent)[2] (See Figure 1).

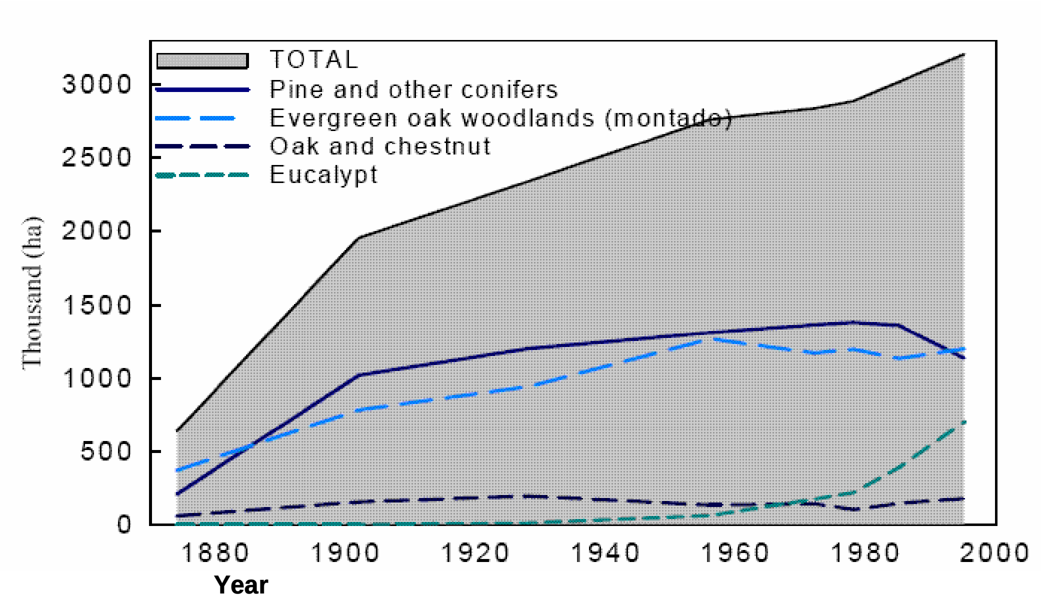

Figure 1. Area of main forest types (by dominating tree species) through time (Radich and Alves, 2000; DGF, 2003a)

The increase in plantations of species such as eucalyptus and pine trees brought a net loss of biodiversity. About 45 per cent of the Portugal species of mammals, birds, amphibians, reptiles and butterflies are associated with the native forests, particularly with deciduous and evergreen oak forests[3]. For example, oak forests are the main habitats of several endangered species (eg the Iberian Lynx). In contrast, eucalyptus plantations support low levels of biodiversity. For instance, only around 13 species of

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[2] http://www.dgrf.min-agricultura.pt/ifn/Tabelas.htm

[3] This estimate is based on the habitat preference of each species (excluding habitats that have only marginal use) as described in the following literature: MacDonald & Barret (1993), Mathias et al. (1999), Barbadillo et al. (1999), Pargana et al. (1996), Almeida et al. (1991), Rufino (1989), Saéz-Royuela (1990), Maravalhas (2003))

bird breed regularly in eucalyptus plantations as compared to 30-35 species recorded in oak forests nearby (Blondel and Aronson, 1999). Furthermore, during the 1980s the decreasing economic viability of wheat cultivation of marginal lands led to either abandonment of agricultural land or eucalyptus afforestation. Given that about 43 per cent of the species occurring in Portugal are associated with agriculture, this change in land use practises contributed notably to the overall loss of biodiversity in the country.

In addition, eucalyptus and pine are more fine–prone species, compared to the fire resistant oaks they substituted. The frequency of forest fires has increased in recent years, causing the loss of thousands of hectares of forests and, accordingly, the degradation of the related biodiversity and ecosystem services.

Causes for biodiversity loss

The expansion of plantation forests has several drivers. Originally plantations were sponsored by the State, functioning as a measure to diminish erosion and to increase wood production. More recently, economic interests (both corporate and small owner) associated with the high profitability of eucalyptus plantations have become the underlying driver behind the extension of plantations.

Agricultural abandonment has also contributed to the expansion of forests. Lack of agricultural workers and low revenues are driving many farmers either to abandon their land or convert their land to more productive forest plantations. The transition from agriculture to forests leads to increased risk of forest fire. It has been noted that the risk of fire is much higher when the transition is due to abandonment than when it is due to an active decision by the farmer to plant a forest. Abandonment also decreases the number of people occupying and tending the landscape and human presence is particularly crucial in the events of fire. In addition, abandonment of crop cultivation has increased the number of farmers involved with extensive animal husbandry. In many interior regions this has lead to the burning of vegetation by shepherds in order to maintain the ecosystem in the early grassland succession stage. It has been recognised that this burning practise has been a major factor in increasing fire ignitions.

Fire intensity has also been further increased by lack of forest management, sometimes hampered by ownership structure. Forest property is divided among a large quantity of smallholders, with no incentive to invest in a high-risk resource without the possibility of benefiting from returns to scale in forest management.

Consequently, wildfires are an increasingly serious problem in Portugal. From 1975 to 2003, the five-year average of burnt area have risen from 40,000 ha/year to 160,000 ha/year (See Figure 2). The year 2003 was particularly dire with fires in an area in excess of 420,000 ha (DGF, 2003b), representing approximately five per cent of the total area of the country. It is estimated that 280,000 ha of the burned area was forest.

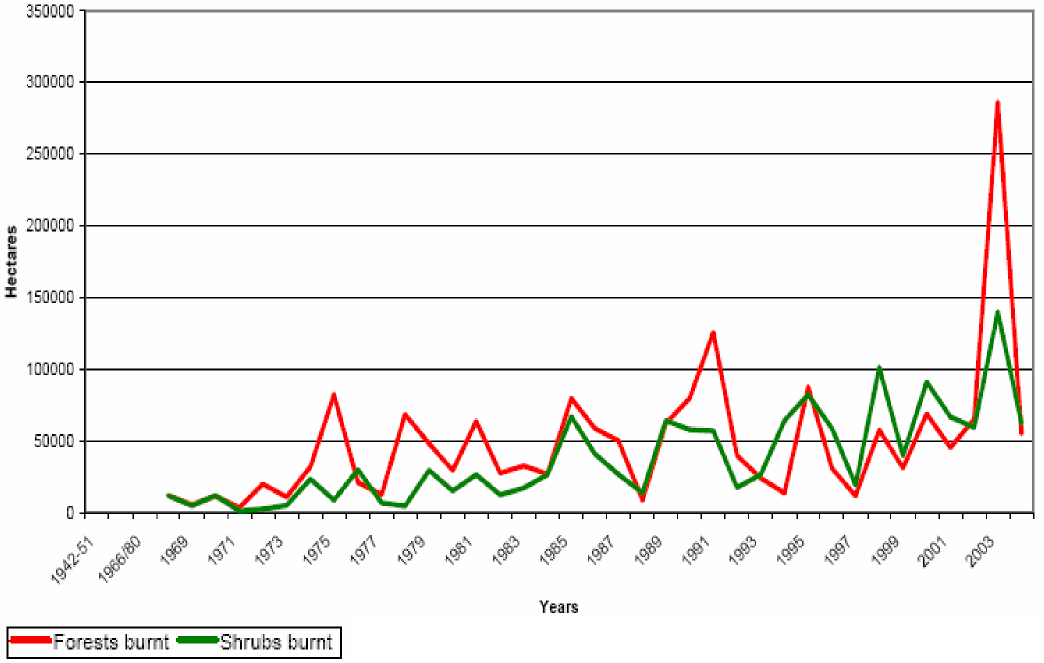


Figure 2. Forest fires in continental Portugal, 1969 – 2004 (Centro de Biologia Ambiental, 2004)

Drivers behind the loss

A mix of public policies and private initiatives that were in place during the past century were the underlying drivers for the afforestation described above. Additionally, a number of socio-economic factors, eg rural depopulation, contributed to the phenomenon.

Socio-economic factors

The ongoing decline in agricultural land area that started in the mid 1950s has not been fully accounted for by an increase in forest coverage. Consequently, scrublands have been increasing on previously farmed areas. These scrublands are often very fire-prone and such fires may quickly spread to neighbouring forests. Additionally, local demand for some inflammable forest sub-products, such as fuelwood, forest litter and shrubs, has decreased contributing to the increased risk of fire. Also, due to the rapid decline in resin tapping since the mid 1980s the presence of resin tappers in pine forests declined. This decreased forest fire vigilance and increased the accumulation of inflammable material in the forests.

Public and private initiatives

Afforestation programmes stimulated by the large amount of uncultivated land suitable for forestry plantations started in Portugal in the beginning of the 20th century. National afforestation plans were mainly based on monospecific plantations of fast growing species for economic exploitation and they were often implemented without taking into consideration the traditional use of the forested lands. As a result, the distribution of maritime pine and eucalyptus trees in Portugal increased sharply. Planting of pines was favoured as pine is a pioneer species suitable for sites that are nutrient poor and non-forested. The spread of eucalyptus was supported both by direct investments (eg pulp and paper companies, non-industrial private forest owners) and national afforestation programmes and incentives.

From 1981 to 1988 a programme financed by the World Bank (WB) provided credit to the public pulp and paper company and to the Forest Services to carry on afforestation with pine and eucalyptus (60,000 ha by the pulp and paper company, almost all with eucalyptus and 71,908 ha by the Forest Services, 8429 of which with eucalyptus). After the WB programme, some incentives for planting eucalyptus remained, however these incentives were drastically reduced at the end of the 1980s. At the time, a vast area of the country was already occupied by eucalyptus (about half of the current area) triggering off the public debate on environmental concerns related to afforestation. The most recent increase in the area covered by eucalyptus is a result of afforestation activities supported by pulp and paper companies and private forest owners.

Three major afforestation programmes were funded by the European Union in the 1980s and 1990s: the Forest Action Programme (PAF: 1987-95), the Forest Development Plan (PDF: 1994-99) and the Regulation (EEC) 2080/92. These programmes gradually reduced (and finally suppressed) the number of measures favouring eucalyptus plantations and new regulations restricting these plantations were established. Under the new afforestation regime, other broadleaved tree species, including the cork oak forests, were supported. This new practise contributed to diversifying the composition of tree species in plantation forests. Additionally, some attempts to promote multiple use forestry were initiated.

The EU funded programmes were expected to reduce the risk of forest fires in the long run. However, the problems related to fires continue to persist, probably due to the negative contribution of other factors, such as depopulation of rural areas. In addition, it has to be noted that in the first phase projects, survival rates for some species (eg cork oak) might have been relatively low. This was, however, most likely to be caused by insufficient research and inadequate dissemination of technical and economical information on the measures supported by the forest programmes (eg species more appropriate for each site to be afforested, methods for conducting afforestation works, etc.). Furthermore, it has been observed that during the course of these programmes there have not been enough complementary efforts to improve the efficiency of the fire prevention and extinction systems needed to protect forests from the risk of burning. A full social cost-benefit analysis on three EU-funded programmes covering the period 1987-1999 is given by Mendes (2004). The main finding is that, from a social point of view, these programmes have been profitable and were worth undertaking, even considering the risk of some of their effects being damaged by forest fires.

In recent years a variety of responses have been taken to address the negative impacts brought forward by the changes in land use practises. These included responses at the European scale (agri-environmental measures in the EU Common Agricultural Policy), national scale (the response of the Portugal government to the 2003 wildfires) and local scale (acquisition of farms by LPN for biodiversity protection). The concerns were also addressed by industry through improved forest management. However, the actual positive impacts of these measures on biodiversity and ecosystem services are often hard to estimate.

Despite the rural exodus in the mid 1960s, protection against the risk of forest fires did not gain a high priority in Portuguese forest policy. The result was that the area of burnt forest during 1987-1999 was almost double the area afforested and reforested with the support of afforestation programmes. Furthermore, some of the area burnt included plantations supported by those programmes. There are many reasons for this lack of political attention. Since the degree of coordination and political strength of public and private stakeholders was weak, public priorities were not well presented on the political decision-making level. Additionally, the intersectoral coordination with other relevant policies was weak (Mendes, 2004a, 2004c). This was despite the fact that, for example, the financial incentives for forestry fell under the competence of the Ministry of Agriculture and managing forest fires depended on the Ministry of Internal Affairs.

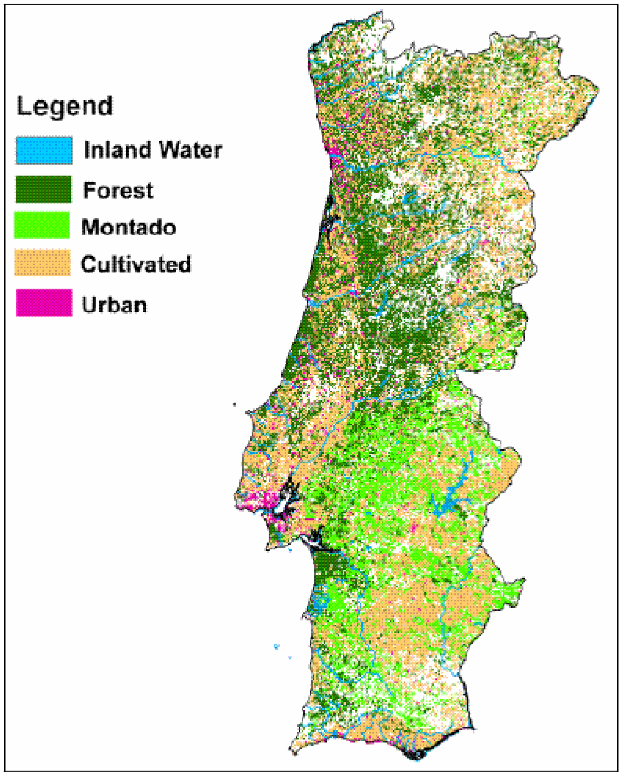
Alternating eucalyptus plantations with other species of native trees can allow managers to retain some of the variety of biodiversity while avoiding the spreading of forest fires. This diversification has recently received more attention but due to the underlying economic interests it has not become a generally adopted practise. The opponents to the diversification claim that cultivation of oaks is less profitable than eucalyptus. However, this argument does not take into consideration the economic loss caused by fires in fire-prone monocultures. Additionally, it is claimed that some soils are mainly suitable for pine. Although true on some occasions, this argument has been also frequently abused.

Reversibility of the loss

A study on the reversibility of biodiversity loss due to forest plantation is currently ongoing (Pereira et al, unpublished data). The study aims to assess what species that are colonising areas of second growth of native oak forest. The research carried on so far has revealed that the process of biodiversity loss may be reversible in areas close to native oak forests where it is easier to allow the formation of natural corridors. The corridors allow native species to move from biodiversity 'rich' areas to nearby plantations where new oak trees are planted.

The restoration of native biodiversity is considered to be difficult, or even impossible, in wide eucalyptus/pine plantations situated far away from oak forests. In these situations, even if monoculture plantations are turned into more diversified forests it will be impossible for native species to reach these isolated areas. In this context it can be noted that *montado*, the native oak forest of the south of Portugal, is still present in large areas of the country allowing the formation of natural corridors to take place (see Figure 3). However, in the north-east, the land cover appears to be only eucalyptus and pine forests and in these areas reversibility could be particularly difficult.

Figure 3. Distribution of mainland systems in the Portugal Assessment (Direcção Geral das Florestas 2003)



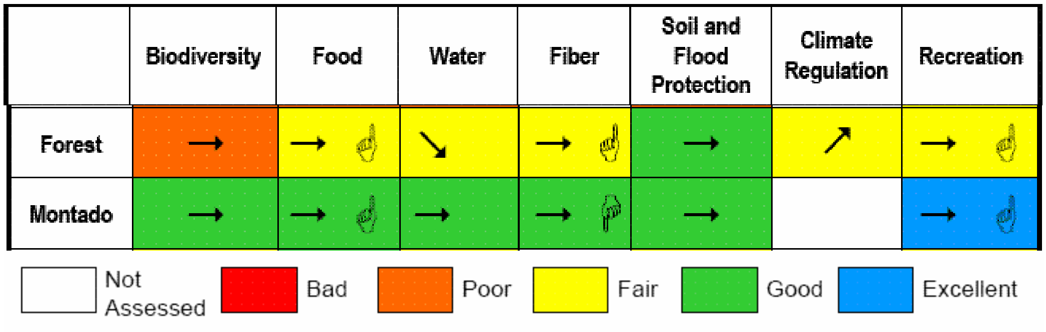
ECOSYSTEM SERVICES LOST

Types of ecosystem services lost

Compared to native oak forest, eucalyptus forest provides a smaller range of ecosystem services (mainly timber provisioning and carbon sequestration). In contrast, native oak forest is a much better provider of services such as soil protection, water provisioning, game, recreation, forest foods and fodder. The types of services lost due to the loss of oak forest may be summarised as follows:

Provisioning services:	fuel (timber provisioning) fresh water food production
Regulation services:	fire resistance water regulation erosion control biological control carbon sequestration
Cultural services:	recreation and ecotourism aesthetic values and sense of identity
Supporting services:	nutrient cycling soil formation

The Portugal Millennium Assessment presents an overview of the state of the main services provided by different ecosystems. In the assessment, native oak forest of South Portugal (*montado*) is considered as a separate category whereas all forests other than *montado* are considered jointly. In the *montado* both the level of biodiversity as well as the level of services appear to be in good condition. In other forests situation appears slightly worse, especially in terms of food, water, fibre and recreation services (See Figure 4)



	Biodiversity	Food	Water	Fiber	Soil and Flood Protection	Climate Regulation	Recreation
Forest	🟧 →	🟨 → ☝	🟨 ↘	🟨 → ☝	🟩 →	🟨 ↗	🟨 → ☝
Montado	🟩 →	🟩 → ☝	🟩 →	🟩 → 👇	🟩 →	⬜	🟦 → ☝

⬜ Not Assessed 🟥 Bad 🟧 Poor 🟨 Fair 🟩 Good 🟦 Excellent

Figure 1: Condition and trend for the services of each Portugal ecosystem (Centro de Biologia Ambiental 2004). Arrows: trend of the condition (or 'stock'); hands: trend of the production (or 'flow') for provisioning services and recreation; question marks: data not available. In some cases services were not assessed because they do not occur or they have a marginal importance.

Reasons behind the loss of ecosystem services

Biodiversity loss and the loss of related reduction in ecosystem services is caused by two distinct, although related, aspects of forest plantation. Firstly, land abandonment or replacing native oaks (including holm- and cork-oaks) by eucalyptus and pine decrease the biological diversity and biodiversity-related services of the ecosystem. Secondly, the frequency and expansion of fire is increased, as pine and eucalyptus are more fire-prone than native species. The services lost in relation to these aspects are summarised below.

Establishment of plantations

- General loss of oak and cork production: It is to be noted that cork is the major non-timber forest product in Portugal, which produces more than 50 per cent of the world's cork. A gradual decrease in cork overall production has been registered since the 1970s (See Table 1).

- Reduced capacity of forests to provide fresh water: Eucalyptus plantations are less effective in retaining fresh water than oak forests.

- Reduced food production: The typical Portuguese silvo-pastoral production (eg chestnut, carob, mushrooms) is mostly associated with forests of holm-oak and cork-oak rather than eucalyptus plantations.

- Decline of services related to agriculture: Agriculture abandonment or substitution with eucalyptus plantations brought a general loss of services related to agriculture, eg provisioning of food, pasture, medicinal plants and water, regulating services for air and water quality and cultural services such as cultural values, recreational services, sense of place and aesthetical values.

- Decreased fire resistance (See below)

Decreased fire resistance

- Carbon sequestration: current knowledge of the role of Portuguese forest in carbon sequestration is limited, but a cautious estimate of Net Biome Productivity assessed that about 1.52 Mt of carbon were sequestrated per year, accounting for seven per cent of carbon emissions in 2000. While carbon sequestration capacity has been improving due to the increase in total forest area, this improvement is hampered by increases in fire frequency and intensity.

- Soil protection and run-off regulation: increased wildfire frequency causes extensive loss of soil cover during rainfall. This also contributes to the deterioration of water quality downstream. If current frequencies of wildfires persist or increase there will be major consequences for the soil cover and for run-off. Physical and chemical soil erosion increase with declining soil thickness, which in turn decreases soil fertility and carbon sequestration. Surface run-off will increase with increasing likelihood of floods.

- Recreation: currently the main recreation activity in forests is hunting, but nature sports and outdoor activities are starting to gain popularity. There are also several campgrounds and spa resorts associated with Portugal forests. The number of recreation visits (excluding hunting) to forest areas is estimated to be about 2 million visiting days per year (Mendes 2004). Fires are likely to decrease the attractiveness of Portuguese forest for tourists.

Table 1. Cork production in ton (Centro de Biologia Ambiental 2004)

Years	Total	Virgin cork	Reproduction cork
Average 43/51	170 666	44 222	126 444
Average 52/60	188 334	57 778	130 556
Average 61/69	221 555	78 444	143 111
Average 70/78	185 966	47 033	138 933
Average 79/87	149 422	33 700	115 722
Average 88/96	170 444	30 000	140 444
Average 97/00	165 500	30 000	135 500

ECONOMIC COSTS, SOCIAL LOSSES AND BENEFITS GAINED

Stakeholders affected by the biodiversity loss

The general public is being affected by the biodiversity loss associated with the expansion of forest plantations. Paradoxically forest owners, although being the main responsible for monoculture afforestation, suffer the most financially from forest fires. Forest property is divided among a large quantity of smallholders. Sometimes forest fires can burn entire land parcels, destroying small owners' main source of income. Although the consequences of fires can be extremely hard for some landowners most of them have no real incentive to invest in forest diversification since on such a small scale the benefits of diversification and related forest management do not easily exceed the associated costs.

Losses vs. benefits gained

In the last 25 year (1980-2004) fires have disrupted about 2.7 million hectares of forest land, an area almost as large as the total territory of Belgium. In the period 2000-2004 the country surface burnt at a rate of 2.7 per cent/year (1.4 per cent in the 1980's and 1.9 per cent in the 1990's). Considering only the direct losses associated with primary production, the estimated costs have been about €300 million per year. The total investments in fire fighting and prevention amounted to €479 millions in this five-year period (€17,8/he/year). In addition, during 2000-2005 forest fires caused 38 deaths and several injuries, destroyed hundreds of human residences and agricultural properties with consequents impacts on public health and safety, economic losses and social stability (eg undermining the citizens' trust in the ability of the country to solve the problem). In 2001, damage cased by forest fires amounted to about €137 million (See Table 2). During the same year the total economic value of forests in Portugal (total revenues - the cost of forest fires) amounted thus to about €1,2 billion.

In recent years, pulp and paper companies have spent more than €3 million per year on **fire prevention** operations (CELPA, 2003). In 2001, the Ministry of Interior spent €8,15 million on fire prevention while €3,12 million was allocated to the co-funding of brigades of fire sappers. Through the EU co-funded programmes of the Ministry of Agriculture €3.08 million was transferred to public and private beneficiaries in the year 2000 to support forest fire prevention (MADRP, 2001b). No data are available for 2001, but it was assumed that same amount was spent as in 2000. These components sum up to a total cost of €17.35 million, which is a lower estimate for the costs of forest fire prevention in 2001 (See Table 2).

The Ministry of the Environment spent around €12.85 million on **fire fighting** in 2001, and pulp and paper companies spent more than €1.5 million. If this is added to the opportunity cost of the time spent in this activity by volunteer fire fighters who have alternative productive occupations (€21.5 millions) it is possible to estimate the total cost of fire prevention for 2001, amounting to €35.85 millions (See Table 2).

Table 2. Cost of negative externalities in the Portuguese forests, 2001 (Mendes, 2004)

NEGATIVE EXTERNALITIES	**Value (000 €)**
Damages caused by forest fires	**136,850**
Costs of fire prevention	17,350
Social costs of fire fighting	35,853
Losses of forest products burnt	38,320
Reforestation costs	45,327
Other forest externalities	No estimate
TOTAL NEGATIVE EXTERNALITIES	**136,850**

In Portugal, in 1999, the forest sector represented 2,43 per cent of the GDP, which makes it one of the top sectors in the economy in terms of value added (See Table 3). Furthermore, the forest sector (considering forestry, forest industries, other forest related industries, forestry and forest industries related services) employs about 228,000 people (Mendes 2004), about 5.13 per cent of total employment in Portugal.

Table 3. Gross value added of the forest sector (at current base prices, in 10^6 euros) (Mendes, 2004). Forest industries include wood and cork processing industries (except furniture), pulp, paper, paperboard, and paper and paperboard products). Sources: a) 1995-99: INE (2003c); b) Gross value added for all sector in 2000 and 2001: INE (2003c); c) Gross value added of forestry in 2000 and 2001: INE (2003b).

		1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Forest Sector	**Forestry**	647	598	562	609	641	781	744
	Forest industries (except furniture)	1 652	1 388	1 490	1 591	1 611		
	(1) Total	2 299	1 986	2 052	2 200	2 252		
(2) All sectors		70 292	74 844	80 791	87 158	92 813	99 798	106 169
(1)/(2)		**3,27 %**	**2,65 %**	**2,54 %**	**2,52 %**	**2,43 %**		

A recent assessment of the value of environmental services suggest that the economic value of ecosystem services from the Portuguese forest (eg both oak and other forests) was at least €1.33 billion in the year 2001 (See Table 4), calculated as the sum of wood (€544 million), non wood forest products and services, recreation and environmental services (NWFP&S) (€622 million), and indirect use values (€164 million).

Most of the value of NWFP&S corresponds to marketable goods, with the internalisation of the corresponding benefits by the forest owners, namely cork, resin, honey, fruits (pine nuts, chestnuts and carob), grazing and acorns for livestock production and some of the hunting. It has to be noted that most of the marketable NWFP&S are related to the native forest ecosystems, rather than to the eucalyptus forests. In addition, NWFP&S (as timber) are all subject to a relatively high risk of destruction by forest fires.

Table 4. Economic value of non-processed forest services and goods in 2001 (Mender 2004)

Outputs	**Physical production**	**Unit value (Eur)**	**Value (000 Eur)**
DIRECT USE VALUES			
WOOD FOREST PRODUCTS	**543,594**		
Timber harvested			**430,604**
Pulpwood Coniferous	2,153,000 m^3	19.54/m^3(pine)	42,070
Broad-leaved	6,684,000 m^3	31.70/m^3 (eucalyptus)	211,883
Saw-logs Coniferous	4,733,000 m^3	33.42/m^3 (pine)	158,177
Broad-leaved	221,000 m^3	41.89/m^3 (oak)	9,258
Other industrial wood	220,000 m^3	41.89/m^3 (oak)	9,216
Fuelwood			**37,273**
Coniferous	286,000 m^3	38.22/m^3(pine)	10,931
Broad-leaved	488,000 m^3	53.98/m^3(*)	26,342
Net growth in standing timber stock			**75,717**
Coniferous	2,060,000 m^3	19.53/m^3	40,232
Broad-leaved	1,794,000 m^3	19.78/m^3	35,485
NON WOOD FOREST GOODS	**584,771**		
Cork harvested			**390,726**
Reproduction cork	128,000 t	2,937/t	375,936
Virgin cork	30,000 t	493 /t	14,790
Resin	15,444 t	200/t	**3,089**
Honey			**7,619**
Origin labelled honey production	172.5 t	3,970/t	684
Other honey production	4,361.5 t	1,590/t	6,935
Fruits collected			**53,310**
Pine nuts	70,000,000 cones	0.20/cone	14,000
Chestnuts	26,118 t	997,6/t	26,055
Carob	31,500 t	272,3/t	8,577
Arbutus berries (Arbutus unedo)	15,130 ha x 200 kg/ha	1,125/t	3,404
Elderberries (Sambucus nicra)	650 t	1,960/t	1,274
Edible wild mushrooms picked up for sale	6,500 t	2,500/t	**16,250**
Plants picked up for sale			**1,400**
Thyme, laurel and other cooking plants	80 t	3,750/t	300
Aromatic and medicinal plants	1,100 t	1,000/t	1,100
Forest goods for intermediate Consumption in animal production			**112,377**
Acorns grazed by pigs in extensive rearing	51,450,000 FU	0.1303/FU	6,704
Grazing resources under forest cover	673,900,000 FU	0.1303/FU	87,809
Grazing resources in scrub land (consumption by goats)	137,100,000 FU	0.1303/FU	17,864
Acorns and other products grazed by other animal species			No estimate
Net growth in the production capacity of non wood forest goods	No estimate, but probably positive		
RECREATIONAL SERVICES	**37,883**		

Outputs	**Physical production**	**Unit value (Eur)**	**Value (000 Eur)**
Hunting	219,005 hunters		21,383
Informal forest recreation	6,000,000 day-visits	2.75/day-visit	16,500
TOTAL DIRECT USE VALUES	**<u>1,166,248</u>**		
INDIRECT USE VALUES			
Carbon storage	1,450,000 tC	20/tC	29,000
Protection of agricultural soil			49,209
Protection of water resources	8,772,520 ha	3.30/ha	28,934
Forest landscape and biodiversity conservation	594,509 ha	95.36/ha	56,695
TOTAL INDIRECT USE VALUES	**<u>163,838</u>**		
TOTAL VALUE (direct and indirect use) 1,330,086			

(*) weighted average of the roadside prices for eucalyptus, chestnut and oak fuelwood.

The main beneficiaries of the forest plantation expansion are the paper industry, the timber industry, and to a smaller degree, individual landowners. Part of the reason why individual landowners benefit from eucalyptus and pine plantation, regardless of biodiversity loss, is because these species have high market values (eg more than €250 million was derived from pine and eucalyptus pulp wood in 2001). Additionally, eucalyptus and pine grow faster than native species, thus their return on the investment is much shorter than the return time of investment in oak forests. Consequently, eucalyptus and pine may be economically more appealing than species like the cork oak that is used mainly for wine bottle stoppers and whose market value is threatened by the increasing use of synthetic stoppers. In addition, some ecosystem services provided by the native forest are not marketed or valued properly and others, especially those related to indirect use, are not valued at all.

Restoration costs

Natural regeneration is generally praised as the best solution to achieve the long-term sustainability of cork oak stands. However, it has been confirmed that there has been a lack of natural tree recruitment over the past decade. This was mainly thought to be caused by overgrazing by livestock that feed on acorns and seedlings (Leiva & Fernández-Alés, 2003). However, it is seems to be more likely that natural regeneration depends on safe microsites, especially shrubs, which are mostly unavailable in the present *dehesa* (Spanish equivalent for *montado*) or *montado* systems, but are present in ungrazed and unmanaged forests (Plieninger et al., 2004).

As an alternative to natural regeneration, plantations are being used extensively to create new cork oak stands, particularly due to the availability of EU subsidies encouraging the afforestation either of shrubland or former agricultural land. This approach has also been used in filling clearing or increasing tree density in sparse stands. The afforestation of large areas has been presented as a way of increasing cork production, raising the land value for farmers and growing, in general, the area for this species. Nevertheless, the results have been disappointing with high tree mortality on the 2-3 years after the plantations leading the landowners to the necessity of further investments in replanting (Louro, 1999). One of the main reasons for this low success is that young cork oak trees regenerate under shade (Alves, 1996). This perquisite condition is, however, absent in an environment where the vegetation cover is removed prior to the establishment of new plantations. Moreover, it is known that besides offering shade the areas underneath tree crowns have enhanced water storage capacity (Joffre & Rambal, 1988) and represent islands of fertility with increased nutrient and organic matter levels (Plieninger et al., 2004). Cork oak plantation may also be hampered by the high susceptibility of young seedlings to *P. cinnamomi* (water mould causing plan infections) (Rodríguez-Molina et al., 2002 in WWF, 2006).

According to DGF (Direcção Geral das Florestas), reforestation through installation of new plantations would cost about €2250/ha. Reforestation can also be done through management of natural regeneration (in the case of pine forests) and improvement of the stands resulting from that. In this case reforestation costs would be lower, ie €1000/ha or less. It was estimated that the cost of restoration of the 45,327 ha of burnt forest recorded in 2001 amounted to €45,327 million (See Table 2). The 2003 forests fire, with its 283,063 ha of forest cover burnt, the restoration costs might be higher than €280 million.

CONCLUSIONS

- The introduction and utilisation of pine and eucalyptus species for reforestation purposes in Portugal was driven by high profitability and production success associated with these species.

- Native oak forests are the most diverse in terms of both biological diversity and diversity of ecosystem services. This diversity has been partially lost with the introduction/application of tree species that in turn host lower species diversity, provide a lower number of ecosystem services and may bring forward negative effects (eg soil erosion, loss of regulation of the hydrological cycle, and excessive nutrient extraction).

- Monocultures in general, and eucalyptus and pine species in particular, are more fire-prone than native forest. The spreading of these afforestation practices, together with agriculture abandonment, has resulted in an increase in frequency of forest fires, which reached their peak in the summer 2003. Forest fires represent a danger for society (in terms of health, economic losses, damages to pubic and private properties etc) and speed up the process leading to the loss of biodiversity and ecosystem services.

- Initially, national and international policies provided incentives for afforestation using eucalyptus and pine. In recent years this has been reversed and planting of a variety of native species has been favoured. However, these measures were not enough to avoid the devastating fires in 2003. Additionally, the loss of biodiversity and biodiversity-related ecosystem services has not ceased.

- The process of biodiversity loss may be reversible in areas close to native oak forests, where it is easier to allow the formation of natural corridors. However, the restoration of native biodiversity is though to be difficult, or even impossible, in isolated eucalyptus/pine plantations.

- The loss of biodiversity results in economic costs. These costs can be estimated in terms of ecosystem services loss (though difficult to estimate) and damages caused by forest fires (ie forest production lost, investment in reforestation, fire fight and prevention) amounting to about €137 millions in 2001. Even though the loss of biodiversity (ie natural oak vegetation) is not the only reason for increased risk and occurrence of fires as socio-economic factors (eg rural abandonment) also play a role in the phenomenon, it is one of the main underlying factors.

- Costs resulting from the loss of biodiversity and ecosystem services due to monocultures are often not properly perceived in economic terms by forest owners. Forest owners tend to focus on timber market values without taking into consideration the economic losses due to the increased fire frequency and reduction of non-timber forest goods and services.

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Contacts

Henrique M. Pereira, Seccao de Hidraulica, Recursos Hidricos e Ambientais, Dept. Eng. Civil e Arquitectura, Istituto Superior Tecnico, 1049–001 Lisbon –Portugal, Tel. +351 218418 343, Email: hpereira@ist.utl.pt

Prof. Mendes, Faculdade de Economia e Gestão (Faculty of Economics and Management), Universidade Católica Portuguesa, Tel +351 226196 294, Email amendes@porto.ucp.pt

Chantal Ménard, Communications Department WWF, Via Po, 25c, 00198 Rome – Italy, Tel. +39 06 844 97 417 / 424, Fax. +39 06 841 38 66, Email: cmenard@wwfmedpo.org

Catherine Roberts, Director's & Programme Assistant - WWF Mediterranean Programme, Via Po 25C, 00198 Rome, Tel +39 06 84497227, Fax +39 06 8413866, Email: croberts@wwfmedpo.org, www.panda.org/mediterranean

Annex 7. Loss of ecosystem services due to eutrophication of coastal marine ecosystems – case study on shallow soft bottom ecosystems at the west coast of Sweden

Case study author Marianne Kettunen (Institute for European Environmental Policy – IEEP, London – Brussels)

INTRODUCTION

Many coastal marine ecosystems in the EU are subject to eutrophication caused by increased supply of nutrients of anthropogenic origin, eg direct point discharges, terrestrial run-off and atmospheric deposition. The increase in available nutrients promotes the primary production in the system augmenting the growth of phytoplankton[1] and macrofauna (eg filamentous algae). This enhanced growth results in the formation of algal blooms (on water surface) and algal mats (at sea bottom) that disturb the ecosystem by limiting sunlight to sea bottom/bottom dwelling organisms and by altering the amount of dissolved oxygen in the water. Additionally, some algae can produce toxic compounds making the algal blooms harmful both to the ecosystem and humans. These changes affect the coastal marine biodiversity and alter the ecosystem structure and functioning in a manner that reduces the ecosystem services provided marine coastal zones.

This case study documents the loss of biodiversity and ecosystem services in the shallow soft bottom ecosystems at Swedish west coast caused by eutropicathion and increased abundance of filamentous algae. Due to their wide distribution and their role in sustaining important ecological functions of the coastal marine zone, the shallow soft bottom systems are considered the key ecosystem in the Sweden archipelago. Therefore, changes occurring in these ecosystems have a significant effect on the services provided by the Swedish coastal marine zones.

BIODIVERSITY LOST

Extent, type and rate of the biodiversity loss

In the Swedish shallow soft bottom ecosystems, loss of biodiversity has been detected at three different trophic levels.

Seagrass meadows: The investigations dating back to 1900 reveal about 75 per cent reduction in the seagrass areal extension in Scandinavia between 1900-1990 (Petersen, 1914). Additionally, over the last two decades a 60 per cent reduction in distribution of *Zostera marina*, the dominant seagrass species in Swedish coastal

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[1] Photosynthetic planktonic micro-organisms, including algae and cyanobacteria

waters, has been observed in the Swedish archipelago (Skagerrak - Kattegat coast) (Baden et al., 2003). Along most sections of the coast both the upper and the lower depth distributions of seagrass have been reduced, resulting in a narrowing of meadows. However, in some areas seagrass meadows have disappeared completely.

Benthic infauna[2]: The studies have shown that the number of species, and the density and biomass of benthic macrofauna is 40-50 per cent lower under mature algal mats than in normal situation (Svensson and Pihl 2001). In particular, the numbers of suspension feeders and surface deposit feeders, which are dependent on good water circulation for feeding and respiration, are reduced (Österling and Pihl 2001).

Fish species: The number of fish species (eg gadoids, labrids, syngnathids) and the density and biomass of fish has been found to be significantly lower in areas where *Z. marina* seagrass is missing (Pihl et al. in press). For example, juvenile cod (*Gadus morhua*) density has been observed to reduce by 96 per cent at sites where *Z. marina* has disappeared. Similarly, four times lower total density and six times lower biomass of gobies has been observed in non-seagrass sites as in comparison to *Z. marina* beds.

Causes for biodiversity loss

Eutrophication is considered the main underlying cause of the loss of biodiversity in Swedish coastal marine systems. It has been estimated that nitrogen loading in the Swedish west coast (Skagerrak and Kattegat regions) has increased about four-fold since 1930 (Rosenberg et al. 1990, Aure et al. 1996, Rosenberg et al. 1996). Additionally, small tidal amplitude makes the Swedish coastal zone and, especially the inner archipelago, sensitive to increased nutrient loading.

The eutrophication of coastal waters is directly linked to the changes in land use practises along the Swedish coast. In particular, the intensification of agriculture and increased application of fertilisers during the last decades have had a significant impact on the phosphorus and nitrogen levels in the coastal waters. In addition, emissions from point sources (urban communities and industry) along the coastline have also contributed to the augmented nutrient discharges to the sea.

On a more general level, the loss of biodiversity and changes in the ecosystem are attributed to the initial lack of knowledge and understanding regarding the effects of increased fertiliser use and eutrophication, and the connections between the land use practises and aquatic ecosystems. Restrictions to the application of fertilisers and proactive measures to prevent the terrestrial discharge are now at place. However, more integrated approaches to plan the development of and land use along the coastal zones have been adopted only quite recently.

Due to eutrophication the growth of phytoplankton and filamentous algae (mainly *Cladophora* and *Enteromorpha*) in the ecosystem has increased leading to frequent phytoplankton blooms and increased occurrence of filamentous algae on shallow soft bottoms (Österling and Pihl 2001). According to the studies, phytoplankton

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[2] Aquatic animals that live in the substrate of a body of water, especially in a soft sea bottom.

production has doubled, from around 100 g-C-m^{-2}-y^{-1} in the 1950s and 1960s, to 200 g-C-m^{-2}- y^{-1} during the period of 1980 to 2000 (Richardsson and Heilman 1995, Lindahl 2003). The average cover of green algal mats in 10 shallow (0-1 m) bays on the Swedish Skagerrak Coast, increased significantly from <3 per cent during the period of 1976 to 1978, to 40 per cent in 1992 to 1994 (Pihl et al. 1995). From 1994 to 1996, the distribution of algal mats was monitored by aerial photography in shallow (0-1 m) soft bottom areas along 200 km of the Swedish Skagerrak Coast, and the average cover of green algal mats ranged from 30 to 50 per cent of the total shallow soft bottom habitat in the archipelago (Pihl et al. 1999).

Eutrophication is considered to result in seagrass loss by decreasing light availability to the leaves through epiphyte leaf fouling. Alternatively, or complementary to the above, overfishing of top-predators might have lead to cascading trophic effects in which epiphytes are released from grazing when small fishes increase and in turn decrease the abundance of herbivores. In addition, altered water exchange due to construction of road banks and leisure boat harbours could have reduced the distribution of seagrass habitats. However, the exact processes causing the degradation of the seagrass habitat at the Swedish coastal zones are not yet known.
Filamentous algae mats on the sea bottom cause the loss of benthic infauna (Osterling & Pihl 2001). Dense algal cover results in low oxygen saturation in the water under the algae due to enhanced bacterial activity and algal respiration. This phenomenon is further emphasised by the reduced water flow and increased sedimentation rate under the mats. Additionally, algae mats form a barrier to settling and prevent new faunal recruitment to the sediment.

The reduced oxygen levels under the algal mats/blooms also affect the survival of fish species. Additionally, the density of algal mats prevents both larval and adult fish immigration. Dense filamentous mats also alter or reduce food resources for fish.

Reversibility of the loss

The reversibility of biodiversity loss and changes in ecosystem processes is dependent on the reversibility of eutrophication. Coastal marine ecosystems of the Swedish west coast have been exposed to gradually increasing discharges of nutrients over several decades, with total input of nitrogen from land and air deposition increasing by 300 per cent since 1940 (Rosenberg et al. 1990). The refilling of the sediment nutrient pool, together with the build-up of algal material, has restrained the shallow soft bottoms into self-regenerating systems[3]. It is possible that such an altered state of nutrient dynamics may, therefore, be resilient to any efforts in reducing external nutrient loading to the system.

It has been estimated that if nutrient concentrations in the Swedish coastal waters were drastically reduced by 50 per cent, the response time of changes in coverage of filamentous algae is in the order of 5 years for a 75 per cent decrease in algae cover (Eilola and Stigebrandt 2002). Modelling with 10-20 per cent nutrient reduction has

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[3] Increased loading of organic material leads to the build-up of the sediment nutrient pool. This further enhances algae growth/production of organic material, refilling the nutrient pool.

resulted in a 35-50 per cent decrease of algae cover after the same time period. It should be noted, however, that none of these estimations result in complete disappearance of algae. It is, therefore, likely that the high nutrient levels of the coastal marine areas are sustained by the ecosystems self-generating nutrient cycling system.

As a conclusion, the effects of eutrophication, including the loss of biodiversity, seem at least partly reversible. However, in addition to reducing the input of nutrients to the coastal marine ecosystems reactive measures, such as mechanical removal of algal mats, might have to be taken to restore the nutrient dynamics within the system.

ECOSYSTEM SERVICES LOST

Provisioning services

Filamentous algae mats alter the quality and function of the soft sediment bottom habitats as nursery and feeding grounds for commercial fishery species (eg flatfish, gadoids, clupeids, and salmonids). In areas where filamentous green algae become dominant, the number of fish species and fish biomass decreases (Pihl et al. 1995). For example, the studies have shown that juvenile cod actively avoid filamentous algae when offered alternative habitats (Borg et al. 1997), and that algal mats negatively affect their foraging success (Isaksson et al. 1994). Juvenile plaice (*Pleuronectes platessa*) mainly feed on benthic infauna (Wennhage and Pihl 2002), a food source that is greatly reduced under algal mats. Further, exudates produced by algae in combination with low oxygen levels increase mortality rates of plaice larvae during settlement (Larson 1997). Additionally, the structural and functional properties of algal mats offer opportunities for some species associated with dense vegetation to expand their distribution, eg. shore crab (*Carcinus maenas*) and sticklebacks (*Gasterosterus aculeatus* and *Pungitus pungitus*). Consequently, provision of ecosystem goods, in terms of the production of fish species of commercial and recreational value, will be significantly reduced as the reproduction of these species decreases and they are replaced by non-commercial fish species and crustaceans.

Regulating and supporting services

The loss of benthic infauna, particularly suspension and surface deposit feeders, decreases the capacity of the benthic system to absorb and transfer organic matter to higher trophic levels (eg fish). Furthermore, by enhancing sediment mineralization and denitrification processes benthic infauna plays an important role in the decomposition of organic matter in the system. The reduced efficiency in cycling and depositing nutrients will lead to an increased net accumulation of organic matter within the ecosystem. This affects the water quality and reinforces the elevated nutrient load in coastal marine systems. In terms of ecosystem services, the loss of benthic infauna diminishes ecosystem’s water purification capacity and its ability to manage organic waste (regulating services). Additionally, decline in benthic infauna further disturbs the nutrient cycling within the system (supporting services).

Cultural services

Social and cultural ecosystem services are affected by algal mats/blooms through reduced aesthetic and recreational attraction. The visual impact of algal mats, the smell of decomposing algae, toxic algal blooms and the physical disturbance on recreational activities such as swimming and fishing, constitute a threat to the Swedish coastal tourist industry. Also, the negative changes in the ecosystem have lead to the loss of cultural values to the inhabitants of the coastal zone (eg loss of amenity and aesthetic values, decreased recreation possibilities).

ECONOMIC COSTS, SOCIAL LOSSES AND BENEFITS GAINED

In general, the economic value of reduced marine eutrophication in Swedish coastal waters and in the Baltic Sea has been estimated in several studies. It has been calculated, for example, that the overall benefits of improved water quality[4] in the Stockholm archipelago would amount to SEK 60-500 million per year, ie €6 – €54 million per year (€1 = 9,23 SEK) (Frykblom et al., 2005). The economic value of the denitrification service could be estimated through the costs of replacing it by conventional sewage treatment. Current denitrification rates have been estimated to be between 0.060 to 1 milli-mol per m^2 per hour (7 to 123 kg per m^2 per year) in shallow sandy soft bottom habitats on the Swedish west coast (Sundbäck and Miles 2000, 2002). In has been reported that the costs of removing nitrogen in conventional Swedish sewage treatment plants are about SEK 30,000 per ton (€3248 per ton) of removed N. New treatment technology may reduce this cost to about SEK 20,000 per ton (€2165 per ton) (Gren et al., 1997). Consequently, replacing the denitrification service of shallow soft bottom habitats by sewage treatment would cost between SEK 210 – SEK 3690 per m^2 per year (€23 – €399 per m^2 per year) (calculated with costs of SEK 30,000 per ton).

In terms of provisioning services (fish), Pihl et al. (2005) studied the effects of algal mats on the recruitment of plaice. Output of juveniles from nursery grounds was reduced by 30-40 per cent during different scenarios of larval supply to the coast. Assuming that this finding is valid also for Danish nursery grounds, this reduction is likely to affect the plaice population and -catches in the whole plaice fishery in the Kattegat and Skagerrak. In the last decade, the total catch in this fishery has been about 9,000 ton per year, which corresponds to a total gross income to fishermen of about SEK 180 million per year (€19 million per year) (Fiskeriverket 2001, ICES 2001). If the 30-40 per cent reduction in the output of juveniles ultimately results in a corresponding decrease in total catch, total gross income to fishermen would be reduced by SEK 54 to 72 million per year (€6 - €8 million per year). It should be noted that the complete economic valuation of the reduction in juvenile output has to take into account several other factors, including changes in fishermen behaviour and costs. However, the figures illustrate the economic importance of shallow soft bottoms as a nursery.

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[4] Calculated as a one-metre improvement in the water transparency during the summer period by using the Secchi disk -method. Suspended sediments and algae decrease the transparency of the water. Therefore transparency is commonly used as an indicator of the water quality.

As an estimate of the loss of cultural services, namely recreation and tourism, camping ground owners in the island of land in the Baltic Sea remove tons of dead red filamentous algae every year in order to keep beaches attractive to tourists. On average, the annual cost of removal work is SEK 75,000 per km of beach (€8119 per km) (Engkvist et al. 2001, Flodqvist and Hasselström 2004). The costs of mechanical harvesting of algal mats in the northernmost municipality of the Swedish west coast have been estimated to about SEK 660,000 per year (€7145 per year) (Harln and Zackrisson 2001).

From the stakeholders' point of view, the costs of the diminished services have been/will be directly affecting the fishermen and fishing industries, tourism related businesses, and inhabitants and visitors of the coastal zone. The benefits relate mainly to the increase in agricultural yields during the last decades profiting directly the agricultural sector and indirectly the overall national income. However, no estimates comparing the benefits of increased agricultural production within the Skagerrak - Kattegat catchment to the lost of coastal marine ecosystem services could be found when compiling this case study. However, it is clear that on the long run the short-term benefits to the agriculture have been to some extent abolished by the negative effects of increased fertiliser use, eg eutrophication.

CONCLUSIONS

The information on the Swedish coastal marine ecosystems indicate that eutrophication of coastal ecosystem has resulted in the loss/decline in biodiversity leading to the loss/reduction of several ecosystem services. The loss/decline of sargrass beds, benthic infauna and juvenile fish due to the increase in filamentous algae has caused or is causing several negative effects to the ecosystem, including declined fish abundance, diminished nutrient cycling and depositing capacity, and reduced aesthetic and recreational attraction. These effects of eutrophication are not unique only to the Swedish west coast but they are also common in many coastal marine ecosystems in the EU.

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Annex 8. Value of cultural ecosystem services – case study on the recovery of ospreys in the UK

Case study author Matt Rayment (GHK, the UK)

INTRODUCTION

The osprey, a fish-eating bird of prey, experienced a sharp decline in the UK and other parts of Europe in the 19th Century, as a result of persecution by humans. The last recorded breeding in the UK was in 1916. The benefits of the restoration of the species to the UK can be taken as an indication of the costs of its earlier loss.

On the species' return to Scotland in the 1950s, the Royal Society for the Protection of Birds (RSPB) introduced a nest protection and public viewing scheme at Loch Garten. Since 1958, more than 2 million people have visited the osprey nest site at Loch Garten. The species has since recolonised England and Wales and there are now nine sites in the UK at which the public can watch ospreys.

The recolonisation of ospreys has brought the following benefits:

- positive impacts on local economies, with ospreys estimated to bring additional expenditure of £3.5 million per year to the areas around nest sites, helping to support local incomes and employment;
- recreational benefits, with an estimated 290,000 people now visiting osprey nest sites in the UK each year;
- educational benefits, with the sites receiving many visits from schools and examples of local school groups contributing to their conservation;
- non-use benefits, including option, existence and bequest values.

The main costs of securing these services relate to the large amount of time, effort and expenditure by conservation organisations, landowners and volunteers in conserving ospreys and promoting their enjoyment and appreciation by visitors to osprey sites.

THE FALL AND RISE OF OSPREYS IN THE UK

The osprey (*Pandion haliaetus*) is a bird of prey, with a wingspan of more than 1.5 metres. It feeds on fish, and is well known for its spectacular plunges into water to catch them. The species is cosmopolitan, with a wide global distribution, and is highly migratory through much of its range (JNCC, 2004).

In Europe, the distribution of Ospreys is largely northern and eastern. Over 90 per cent of the breeding population occurs in Sweden, Finland and Russia, but small numbers also occur in neighbouring countries, and remnant populations are found throughout southern Europe. The total European population has been estimated at 4,732–5,249 pairs, with most birds occurring in Sweden and Finland (Hagemeijer &

Blair 1997). West European ospreys winter in West Africa, and the birds return to Europe each spring to build and refurbish their large stick nests.

Throughout much of its distribution, the Osprey has suffered historical population declines due to persecution by man. In Europe, localised extinctions occurred in the late 1800s and early 1900s (Cramp & Simmons 1980; Hagemeijer & Blair 1997). With protection, recovery in parts of the former breeding range occurred in the early part of the 20th century, but from the 1950s to the 1970s widespread use of persistent organochlorine pesticides lowered reproductive success and slowed the spread of re-colonising birds in many countries (Hagemeijer & Blair 1997; Poole 1989). Widespread restrictions on pesticide use have allowed many populations to begin recovery since the early 1980s, aided in some countries by artificial nest construction (Hagemeijer & Blair 1997).

The osprey was once a familiar site in the skies of England and Scotland. However, during the 1800s the species, along with many other birds of prey, suffered heavily from human persecution and egg collecting, and the last recorded breeding took place in Scotland in 1916. It has since been suggested that ospreys may not have become extinct in Scotland as previously thought, and may have continued to survive in small numbers (JNCC, 2004).

Small numbers of ospreys began to be recorded in Scotland again in the 1950s, and the first confirmed breeding was in 1954. Since then the species has gradually expanded its population and range in Scotland. It recommenced breeding in England in 2001 and Wales in 2004. In 2002, the UK osprey population was estimated at 163 territorial pairs. At least 39 pairs of ospreys breed in sites designated as SPAs (JNCC, 2004).

The potential threat from egg collectors means significant resources still have to be put in place at the newly established sites in England and Wales to ensure the birds are left in peace. The development of controlled public viewing schemes at nine UK sites has helped to reduce disturbance pressure on other sites. These also support a significant tourism industry, so increasing the support for their protection and conservation.

OSPREYS, VISITORS AND ECOSYSTEM SERVICES

The principal ecosystem services provided by ospreys relate to their cultural and aesthetic value, and associated impacts on ecotourism, recreation and education. Ospreys are spectacular birds, and are widely appreciated by people, many of whom will travel significant distances to view the birds.

The RSPB has compiled substantial evidence of the benefits that the recovery of the species has brought to people and local economies. The information provided in this and the following chapters is based in the report by Dickie et al (2006).

Loch Garten

In, 1958 the birds started to breed at the now famous Loch Garten site in Speyside and the RSPB set up 'Operation Osprey', a 24-hour protection watch. The following year, when three chicks hatched successfully at the site, the RSPB took the then bold step of breaking the news to the media and inviting in the public. Some 14,000 people visited the site that spring. The purchase of land at Loch Garten in 1958 specifically for the ospreys was the start of a significant RSPB involvement in Speyside. Ospreys have since nested annually at Loch Garten, and over two million people are believed to have visited the site. Visitors to the Osprey Centre averaged 49,000 per year between 1959 and 1990. Since 1989, osprey numbers have steadily increased in Scotland, and the species has become easier for people to see around Badenoch and Strathspey. Therefore, the uniqueness of the Garten Osprey Centre as a place to see ospreys in the UK has been reduced. This may explain why visitor numbers have fallen, averaging 33,600 per year between 1998/99 and 2000/01 (Shiel et al 2002).

Visitor numbers to the Osprey Centre have fluctuated in recent years, with the presence of chicks in the nest site being the major factor behind years with higher numbers. In 2004, publicity associated with the 50th anniversary of the ospreys returning to Scotland, and the presence of chicks in the nest, resulted in 42,600 visitors. In 2005, chicks were not produced at the Loch Garten nest site, and visitor numbers fell back to 33,000, a similar level to the numbers in recent chick-free years.

Dodd Wood and Whinlatter, the Lake District

Ospreys have been nesting near Bassenthwaite Lake in the Lake District since 2001, the first English breeding since around 1900. In 2003, the Dodd Wood and Whinlatter sites attracted an estimated 100,000 visits during the osprey-breeding season, estimated to involve 70,500 individual visitors. A visitor survey found that 11 per cent of visitors were local people, with the remainder coming from outside the area. 25 per cent of visitors described the ospreys as 'the main reason' for visiting that part of the Lake District, with a further 33 per cent describing them as 'one-of the reasons' for being in the area.

Porthmadog

RSPB set up an osprey watch point at Porthmadog in North-West Wales in 2004. The site attracted 73,000 visits in 2005. An illustration of educational value of the site is that, when the osprey nest was blown down by high winds in 2004, local school children helped to repair it in the hope that the birds would return. The nest repair was successful and the birds returned to breed successfully in 2005.

Rutland Water

The Anglian Water Osprey Project, based at the Leicestershire and Rutland Wildlife Trust's Rutland Water Nature Reserve, has trans-located young Scottish birds to central England and has established breeding ospreys. The site attracted 35,000 visits during 2005, of which 25,000 took place during the osprey season, from April to mid

September. A visitor survey estimated that 40 per cent of visitors were locals, 34 per cent were day-trippers and 26 per cent were holidaymakers staying in the local area. Ospreys were the main reason for visiting the area for 37 per cent of interviewees, and for a further 52 per cent were one of the reasons for visiting the area.

Other sites

Estimated numbers of annual visitors to other osprey sites are as follows:

- Loch of the Lowes, Dunkeld, Scotland – 25,000
- Aberfoyle, Scotland – 34,000
- Tweed Valley, Peebles, Scotland – 10,000
- Wigtown, Dumfries and Galloway, Scotland – 23,000

ECONOMIC IMPACTS, COSTS AND BENEFITS OF OSPREY CONSERVATION

Reports by the RSPB have documented the positive impacts that ospreys have had on local economies, principally by attracting visitors to spend time and money in the vicinity of osprey nest sites.

Economic impacts at Loch Garten

A study by Guffogg in 1996 analysed the economic impacts of the 46,000 visitors to the Loch Garten reserve that year. Guffogg estimated that expenditure attributable to the Osprey Centre and reserve totalled £44.89 per person for holidaymakers and £4.16 per person for day-trippers. He calculated that the visitors to the reserve that year spent a total of £5.8 million in Badenoch & Strathspey, of which £1.7m could be attributable to the reserve itself, supporting an estimated 69 full time equivalent jobs in the local economy (Rayment 1997). There is evidence that the Osprey Centre plays an important role in encouraging people to visit Badenoch & Strathspey, even if only a small proportion of their time in the area is spent on the reserve itself (Shiel et.al. 2002).

Updating these figures to 2000 prices and visitor numbers, Shiel *et al* estimated that the reserve attracted £1.4 million of visitor spending into the Badenoch and Strathspey economy in 2000. Fluctuating visitor numbers have meant that this estimate increased to £1.9 million in 2004 before falling to £1.5 million in 2005 (RSPB, unpublished).

Economic impacts at Dodd Wood and Whinlatter, the Lake District

The 2003 visitor survey estimated that visitors to the sites spent a total of £1.68 million during the day of their visit. By asking visitors the importance of the ospreys (as opposed to other factors) in persuading them to visit the area, the study was able to estimate that £420,000 of this spending could be specifically attributed to the presence of the ospreys (RSPB, unpublished).

Economic impacts at Porthmadog

In 2005, McCraight visited UK osprey-watching sites during research for her dissertation (McCraight, 2005). She carried out a visitor survey at Porthmadog and estimated visitor spending using a similar methodology to that described for Dodd Wood above.

The site attracted 73,000 visits during 2005, resulting in estimated expenditure of £1.2 million in the local economy. Of this, £750,000 of visitor spending was attributable to the presence of the ospreys themselves.

Economic impacts at Rutland Water

McCraight also conducted a visitor survey at the Leicestershire and Rutland Wildlife Trust Reserve at Rutland Water in 2005. From her analysis, local expenditure by visitors to the site was estimated at £678,000 in 2005, of which £154,000 was attributable to the presence of the ospreys.

Total Visitor Expenditures

Using various assumptions to assess visitor expenditures at unsurveyed sites, the RSPB (unpublished) has estimated that osprey watching sites brought additional visitor expenditures of £3.5 million into local economies in the UK in 2005. Of these expenditures, £2.2 million were in Scotland, £0.5 million in England and £0.75 million in Wales.

Recreational Benefits

The only attempt to place a value on the recreational benefits derived from visitors to osprey sites was a study by Harley and Hanley (1989), who used the contingent valuation method to assess the value derived by visitors to Loch Garten. Using a hypothetical entry fee as a payment vehicle, the study estimated a willingness to pay of £1.13 to £1.53 per visitor to visit the site. This is equivalent to some £1.96 to £2.65 in 2005 prices. If this figure were representative of current visits to osprey sites, it would suggest that the 290,000 visitors to osprey sites in 2005 enjoyed an annual consumer surplus to the value of approximately £0.57 to £0.77 million.

Other Benefits

Other benefits resulting from the return of the osprey to the UK include:

- Educational benefits – osprey nest watch sites have hosted many hundreds of school visits, helping to enhance awareness and appreciation of wildlife among school children.
- Non-use and passive use values – like other wildlife species, we would expect ospreys to be valued even by people who do not visit their nest sites. These values

include existence, option and bequest values. No estimates are available of the non-use values associated with osprey conservation.

- Role as an indicator species. To feed, ospreys require clean, unpolluted water that supports healthy fish populations. They are therefore an indicator of the health of the aquatic environment.

Costs of Osprey Conservation

The main cost involved in the recovery of ospreys in the UK has involved expenditures by conservation organisations and others on actions to conserve the species, including the significant efforts involved in preventing damage by egg collectors. As well as conservation organisations, the species has benefited from the actions of many landowners and managers, and volunteers who have guarded and monitored the birds each spring.

Though one of the reasons for the persecution of ospreys in the past was their consumption of fish, and perceived conflicts with fishing interests, it is now widely recognised that the numbers of fish they consume are relatively small and there does not appear to be a significant conflict with fishing interests.

Stakeholders Benefiting

Stakeholders benefiting from osprey related tourism include:

- Visitors: 290,000 visits are made to osprey sites in the UK each year, providing people with opportunities to enjoy and appreciate the birds.
- Businesses: A wide variety of businesses, such as accommodation providers, restaurants, cafes and shops, who provide goods and services to visitors, have benefited from the return of the osprey, initially to the Badenoch and Strathspey area and more recently to the Lake District, Porthmadog and Rutland
- Schools: Osprey sites provide an important educational resource, and receive large numbers of schools visits.
- The General Public: even non-visitors are likely to gain satisfaction from the return of the osprey to the UK, by watching them on television, retaining the option to visit a nest site in future, or by simply being aware of their return.

CONCLUSIONS

The osprey is a charismatic species, which has brought a variety of cultural, recreational and economic benefits to people in the UK following its recolonisation in the 1950s. Conservation efforts have enabled populations of the species to expand, and it can now be watched at a growing number of sites, bringing benefits to increasing numbers of people. These benefits would be lost if the species were allowed to be lost again from the UK, and continuing efforts are needed to protect it, particularly from egg collectors.

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Contacts

Ian Dickie, RSPB, Email: ian.dickie@rspb.org.uk, Telephone: +44 1767 680551

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Annex 9. Restoring ecosystem services by reintroducing a keystone species – case study on the cost and benefits of beaver reintroduction in Germany

Case study author Ingo Bräuer (Ecologic, Germany)

INTRODUCTION

This case study provides an example of the costs and benefits arising from the restoration of ecosystem and its services by the reintroduction of a keystone species, namely by reintroducing the European beaver to the river-floodplain system in Hesse, Germany. The case study investigates the efficiency of expenditures in the field of nature conservation. It deals with the integration of environmental goods in economic decision processes, such as cost benefit analysis (CBA). Ex post CBA can provide an efficient check on conservation policies.

The aim of this work is to show how two economic valuation methods (the Contingent Valuation Method (CVM) and the Replacement Cost Method (RCM)) can be combined to conduct a complete CBA. Evaluated ecosystem goods and services are: conservation of an endangered species and its biosphere, the flood plains and the resulting changes in the landscape, ecosystem functions and biodiversity.

The reintroduction programme investigated in this study is a combination of species and habitat conservation programmes as designed by conservation experts. The programme was launched in 1987/88 by the Naturschutz und Landesforstverwaltung Hessen and is located in the Spessart Mountains in Hesse, Germany. The programme consists of two parts: (i) an introduction and (ii) measures to revitalise flood plains. In the context of this scheme, 18 beavers were released and buffer strips were purchased and managed. Since the introduction, population numbers have been seen to increase constantly and the population is now viable. Due to their success, beaver reintroduction schemes are quite popular in Europe.

BIODIVERSITY LOST

European beavers (*Castor fiber*) occurred once throughout Europe but were exterminated or heavily reduced by over-hunting and, to a lesser extend- habitat destruction, in many countries. At the beginning of this century, only eight relict populations with 1200 beavers in total were left in Europe (Nolet & Rosell 1997).

Beavers are a keystone species of aquatic ecosystems. Through the building of dams, burrows, lodges and canals, beavers significantly modify the structure and dynamics of aquatic ecosystems. This natural disturbance of ecosystems contributes to a higher level of biodiversity both on a species as well on an ecosystem level[1]. This is of

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[1] Moderate levels of disturbances within an ecosystem can lead to greater diversity by generating a patchwork of species populations and successional stages which are more fully able to use the available environmental resources.

interest because the natural habitats of beavers near-natural running waters have become extremely rare in the cultivated landscape, even though this habitat hosts 10 per cent of all German plants as well as a high proportion of animal species. On a more general level, there is a strong link between the preservation of this single species and conservation of the whole ecosystem.

Historically, economic pressures for the over-hunting of beavers arose from the use of pelts and scent glands (castoreum), the latter of which in particular reached extremely high prices. Other, more resent, pressures included the loss of habitats due to the conversion of to arable and building land. While hunting pressure has decreased significantly in recent decades, the economic pressures encouraging the conversion of floodplains still exist.

Programmes for the reintroduction of beavers have been quite successful, and have led to the re-establishment of viable beaver populations in several European countries. Half (53 per cent) of the 87 reintroductions attempted can be considered successful (MacDonald et al. 1995). Failures in beaver reintroduction have mostly been caused by poor habitat quality and a high level of mortality amongst released beavers due to human activities. From the ecosystem point of view, the loss of ecosystem quality that may follow the loss of beavers is only partially reversible, as restoration is often only possible in the narrow boundaries of the actual riverbed. It is often not possible to restore floodplains to their original state.

ECOSYSTEM SERVICES LOST AND REGAINED

In the cost-benefit analysis presented in this study the effects of the reintroduction programme were categorised according to the Millennium Ecosystem Assessment classification (MASR 2005). For each service, the appropriate evaluation method was assigned (Table 1).

Table 1. Ecosystem goods and services affected by the beaver reintroduction, classified according to the Millennium Assessment categories. (MASR 2005)

	Observed Changes[1]	
Direct Consequences	**Cultural Services** • Conservation of an endangered species • Conservation of an endangered ecosystem • Increased biodiversity **Recreation and Tourism (Observation)** • Beaver and succession species • Landscape impression of the river (alteration in the structure of the river bed) • Landscape impression of the floodplain (Succession on buffer strips)	***Contingent Valuation Method***
Indirect Consequences	**Regulating services** • Self purification of the river • [Flood protection (lower running velocity)] • [Flood protection (additional space for retention)] • [Erosion control (riverine vegetation)]	***Replacement Cost Method***
	Provisioning Services (Damage in Cultural Landscape) • Flooding of agricultural land • Damage to forestry • Damage to hydraulic engineering (dykes, drainage channels)	***Market Prices***

[1] Consequences in brackets [ ] have not been quantified.

Effects on biodiversity and cultural services

10 years after the introduction, the following positive effects on biodiversity and habitat diversity could be observed (Harthun 1999). These changes also significantly contributed to recreation and other cultural services provided by the ecosystem.

Within ten years from the date of reintroduction of beavers, the number of dragonfly species (Odonata) rose from three to seventeen and the number of snails and mussels species (Gastropoda and Bivalvia) doubled. Additionally, the mean number of species of caddisflies (Trichoptera) increased from 3.5 to 16.5.

Resulting from the introduction, the habitat-diversity also increased. Dam building by beavers led to the formation of eleven pools and ponds, and two secondary ponds, leading to higher alternation of slow and fast running watercourses. These ponds increased the total river surface by seventeen per cent. In addition, 15,500 m2 of floodplain became flooded.

Effects on regulating services - nitrogen retention

Nitrogen retention occurs in the river as well as in the flooded areas of the floodplains. Beavers have effects on both areas. The effects have to be estimated separately (Figure 1). To quantify the influence of the altered flow velocity on the nitrogen retention within the river, a statistical model from Behrendt & Opitz (2000) was used. For this model the N-retention was derived by comparing the net transport of the river with the theoretically expected loads from the nitrogen emissions inventory. To estimate the denitrification in the flooded areas denitrification rates from literature were used. The recorded rates vary between 30 and 1200 kgN/(ha*year) (see Brauer 2002). For the following calculations a mean denitrification rate of 300 kgN/(ha*year) was assumed. To deal with the high variances of both the statistical model and the nitrification rates for soils, two different variants were calculated (Table 2).

The dam building caused eleven pools and ponds and two secondary ponds. These increased the total river surface by seventeen per cent. The measure relevant for denitrification, the hydraulic load, diminished by fifteen per cent. Extrapolated to the whole investigation area a mean additional retention of 2800 kgN/a in the river and of 1900 kgN/year in the floodplains could be estimated (Table 2). No information on the impact of this increased nitrogen retention capacity to the overall river and its water quality are available, however, since most rivers in Germany suffer from high nutrient loads the reduction can be considered having a positive effect on the overall quality of the ecosystem.

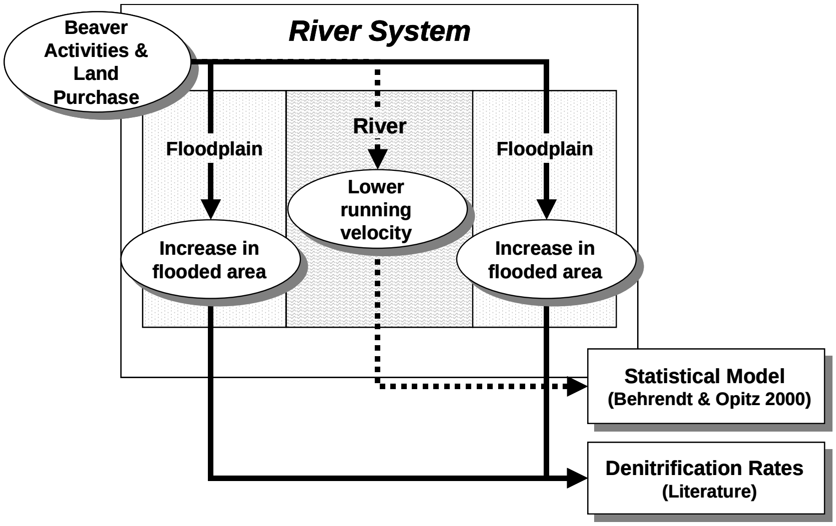

Figure 1. The hydrological model: Influence of beavers on the river system and quantification procedures of nitrogen retention.

Table 2. Additional N-Retention in river and the floodplain. Results of minimum and maximum setting and the mean.

		Mean	**V_{Min}**[1]	**V_{Max}**[1]
River	[kg N/year]	2800	210	3600
Floodplain	[kg N/year]	1900	640	3100
Project duration[2]	[kg N/25years]	115,633	66,354	164,991

[1] Population development is considered during the project duration (1987-2012).

ECONOMIC COSTS, SOCIAL LOSSES AND BENEFITS GAINED

Economic value of the changes in biodiversity

The economic value of the cultural services and services related to recreation and tourism have been assessed by the use of the Contingent Valuation Method. Visitors of the recreation area were questioned about their willingness to pay (WTP) for the conservation programme, in the form of a daily tax for nature. The average WTP ranged from €0.74 to €1.11 per person per day's visit in the Spessart mountains. When the individual WTP is aggregated over the number of visitors, the benefits of biodiversity conservation in the Spessart mountains sum up to at least €0.55 million per year in respect to the assumed project duration.

Economic value of the measured changes in the regulating service 'nutrient retention'

The economic value of the ecosystem service: nitrogen retention, depends on the value that the service is given. This can be calculated by working out what the cost of reducing the same amount of nitrogen through manmade technical solutions would, in theory, be. Two scenarios with different approaches to reaching the required nitrogen reduction in the river were calculated: (i) a prevention strategy using agri-environmental schemes to reduce fertiliser application and (ii) an end-of-the pipe solution where the nitrogen is denitrificated in a sewage plant. The assumed costs of nitrogen retention for agri-environmental schemes are about €2.56 /kgN[2] (Depending on the production system and the intended reduction level, the costs can vary between €1-23 /kgN (see Bräuer 2002)). For nitrogen removal in sewage plants, marginal costs of €7.68 /kgN (15 DM/kgN) are reported in Germany. Depending which reference scenario is chosen, the value of the ecosystem service accounts for (i) €12,000/year (if agri-environmental measures are taken as reference) or (ii) €36,000/year (for sewage

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[2] The original value for the calculations was 5 DM.

plants)[3]. These economic benefits make up 12 per cent (40 per cent, for the sewage plants scenario) of the total annual investment costs of the programme.

Cost-benefit analysis for the reintroduction programme

To keep the cost-benefit analysis as clear as possible, only mean values and one scenario were used. From the different scenarios, the most conservative assumptions were always chosen to guarantee a conservative CBA. Therefore, the presented results are the lower bound of possible outcomes. To offset fixed costs (such as the land purchase) and variable costs and benefits (like management costs and benefits provided by ecosystem services) project duration of 25 years was fixed. All costs and benefits were discounted to the year 2000. The results are presented in Table 3.

In respect to the assumed project duration, the calculated annual benefits derived from cultural and recreational services as well as nitrogen retention had to be extrapolated to cover the complete duration of the project. For this extrapolation, the development of the beaver population was taken into consideration. For an assumed project duration of 25 years the benefits deriving from cultural and recreational services summed up to €17 million. The regulating service was extrapolated to €250,300. The main costs were the land purchase (€1,2 million) and personal costs (€0,6 million). Income effects for local stakeholders caused by damage to the cultural landscape were of minor importance.

Table 3. Cost-Benefit Analysis of the programme.

	Position	**Economic Effects**
Costs	Initiation costs of the programme (land purchase, beavers, etc)	1,244,500 €
	Income effects of local stakeholders (compensation payments)	1,200 €[2]
	Administration and Management (personal costs)	634,000 €
	Sum Costs	***1,879,700 €***
Benefits	Cultural Services, Recreation and Tourism	17,251,700 €
	Regulating service (N-Retention)	250,300 €
	Sum Benefits	***17,502,000 €***
	Total	**15.622.300 €**

The results of the cost-benefit analysis were tested using a sensitivity analysis and judged as robust as far as the efficiency of the project is concerned (Brauer 2002). For example, only ten per cent of the determined willingness to pay is required as having achieved a balanced benefit cost ratio.

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[3] For the year 2000.

CONCLUSIONS

To summarise, the social benefit of the beaver and flood plain conservation clearly exceeds the costs it requires. From an economic point of view, the Hessian Programme for the Reintroduction of Beavers has to be considered as efficient. This efficiency means that within the framework of the programme, public money was spent according to the taxpayers' preferences. Of special interest in this case study is that the estimated benefits of the altered ecosystem service as a by products of a species conservation programme offset a significant part of its overall costs.

The results of this cost-benefit analysis have to be carefully transferred to other regions, as the consequences of a beaver reintroduction depend on the local conditions. Nevertheless the general findings apply to most parts of Europe, since river systems suffer from high nutrient loads and reduced structural diversity and the natural range of beavers covers whole of Europe.

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Contacts

Dr. Ingo Bräuer, Ecologic – Institute for International and European Environmental Policy, Germany, Tel: +49-30-86880-0, Email: braeuer@ecologic.de

Annex 10. Estimating the benefits arising from the conservation of provisioning ecosystem services- case study on valuing alternative clam fishing practices in lagoon of Venice, Italy

Case study authors Paulo Nunes and Anil Markandya (Fondazione Eni Enrico Mattei - FEEM, Italy) l

INTRODUCTION

The level of clam fishing effort in the Lagoon of Venice has strongly increased since 1983, coinciding with the introduction of *Tapes philippinarum*, (the Manila clam). This exotic species originally comes from the Indo-Pacific region and has rapidly adapted to the lagoon environment. It is now responsible for colonising large shallow areas and competing directly in the same ecological niche as the endemic clam species. Furthermore, the relatively high market price of this species, ranging from €4.06 to 7.15 a kilogram, has contributed to its commercial profitability. Because of the open access situation, many operators have taken up this activity. Most of the operators have adopted mechanical equipment, such as the vibrating rake technology, used exclusively for the harvest of this shellfish. Cumulatively, this has led to a significant increase in the clam fishing effort. For example, in 1998, the fishing fleet was composed of about 600 vessels, 84 of which used vibrating rake technology. The vibrating rake is equipped with an electrical cage, shaking and filtering sediment mechanisms with a capacity to harvest 150 to 200 kg of clams per day (Pellizzato et al. 2000).

This case study presents an economic valuation of alternative clam management practices in the Lagoon of Venice. The valuation compares three different management options, including a system based on a complete abandonment of current clam management practices. This manual system permits the maintenance of the highest level (number and quality) of ecosystem services possible in the Lagoon with clam fishing still taking place, however, in the short term it results in the loss of clam catch revenue. In this light, the losses that the stakeholders profiting from current clam provisioning are willing to accept in order to fully or partly abandon the current unsustainable practices can be considered as estimates of the value of part of the ecosystem and its services (focused on clam provision service[1]) in its normal, fully functional state.

BIODIVERSITY LOST

The introduction of the vibrating rake fishing technologies has had a negative impact on the marine ecosystem's resilience. Clam fishing activities have changed the

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[1] There is a wide range of other ecosystem services, but the current case study focuses on that of clam provision.

original water movements, and deposit and accumulation of water sediments, therefore negatively affecting the morphology and marine life functions of the Lagoon. The consequence has been a reduction of the clam stock, destruction of nursery areas and feeding grounds of many marine species, including commercial fish stocks (ICRAM 1994, Pranovi and Giovanardi 1994, Sfriso 2000). In this context, the economic valuation of alternative clam management practices is of central importance. These alternative practices can be compared with the benefits derived from protecting the lagoon from environmental damage.

ECOSYSTEM SERVICES LOST

Manila clams live on seabed and for this reason are very sensitive to water movements and to the deposit and accumulation of water sediments (Orel *et al.* 1997). Since the harvest of this shellfish implies sediment movements, these species characteristics have become exceptionally significant with the introduction of the mechanical and vibrating fishing equipments described above. Since the adoption of these vibrating technologies has brought forward unavoidable negative environmental impacts on the morphology and marine life of the Lagoon they are currently far from being a means for sustainable economical activity. For example, market data shows a diminishing supply of approximately 40 per cent in the catch between 2000 and 2001 due to a reduction in clam stocks (see Granzotto *et al* 2002 for additional details).

The heavy fishing pressure has been followed by increased pollution in the Lagoon due to neighbouring industrial activities, such as the oil refineries located at Marghera. These have also contributed to significant environmental damage to the marine ecosystem, including the destruction of nursery areas and feeding grounds of many marine species, including commercial fishes.

VALUING OPTIONS FOR ALTERNATIVE CLAM FISHING PRACTICES

Biologists, economists and fish management specialists, along with a small group of fishermen, have jointly developed a list of relevant attributes with important linkages to current fishing management practices in the Venice Lagoon. Three main attributes were identified during this group discussion. These attributes refer to (1) the size of the fishing area; (2); the fishing system; and (3) the cost of the annual permit. Furthermore, the discussion provided an indication on the different alternative levels of attributes that affect fisherman's behavior (See Table 1). The attributes (1) and (2), together with the cost of the permits, originally priced in Italian Lira, are interpreted as the various components of any policy package that focuses on the regulation of clam management practices and their environmental damage in the Lagoon. The price of permit, and its range, constitutes a crucial element of the stated choice valuation exercise, since it will allow us to quantify in monetary terms all the involved welfare impacts due to the changes in the fishing systems. Following the well-known steps for a stated choice experiment, the range of permit prices under consideration was the outcome of the analysis of the current market prices for this economic activity as well as from focus group discussions with the fishermen.

Table 1. List of the attributes used in the clam fishing stated choice value application.

1. Fishing area:
    - 3.5 hectares
    - 10 hectares
2. Fishing systems:
    - Traditional: manual rake and fyke-nets
    - Medium intensive (present situation): mechanical rake + fyke-nets
    - Intensive: vibrant rake
3. Price of annual permit (originally stated in the survey in Italian Lira):
    - 258 euro
    - 517 euro
    - 775 euro
    - 4,649 euro
    - 5,165 euro
    - 5,682 euro

Three fishing regimes were considered for analysis. We refer to the 'traditional' system, the 'present situation' system, and the 'vibrating and scraper' system. The traditional system is characterised by operating with small boats and the exclusive use of manual fishing nets. For this reason, it is not associated with significant environmental damage, but it is not very attractive to fishermen as its profitability is low, due to low clam capture rates. The vibrating and scraper system makes intensive use of mechanical suction, vibrating and scraper equipment. This equipment allows fishermen to have very high capture rates (or at the least over the short-term period) and is thus associated with the highest profitability. However, this system is also associated with the highest level of environmental damage to the Lagoon since it is responsible for scraping the lagoon bed, causing significant damage to the marine ecosystem, including the destruction of clam nurseries. The fishery system that is identified as the 'present situation' is characterized by a mix of both regimes, and therefore interpreted as an intermediate system, both from the fishermen's profitability and the environmental damage perspective (see Boatto *et al.* 2002 for a further analysis).

Finally, the size and the location of fishing areas also play an important role on the fishermen choice behaviour. In this context, and bearing in mind the hydro-morphological and scale features of the Lagoon, the research guidelines of past studies were followed. Therefore, an analysis of permits for a fishing area of 3.5 hectares and an area of 10 hectares was considered. The current fishing area is 3.5 ha.

On the basis of the type of clam fishing system, size of the area and cost of the annual permit, a contingent choice questionnaire was developed. The questionnaire is characterized by using the survey so as to describe a set of two alternative fishing management practices and ask respondents to state which one they prefer. In other words, fishermen were directly asked to state their preferences, choosing from the survey the preferred management practice. This valuation method, referred as conjoint valuation, gives sufficient flexibility to set, alter, and combine different levels of each management attributes (See Table 2 for an illustration of a contingent choice question).

Table 2. Example of a stated choice question

Assuming that the following fishing management practices were the only practices available, which one of the two listed below would you consider more attractive for you, if either?		
	Practice A	Practice B
Fishing area (ha)	3.5	3.5
Fishing system	Mechanical rake + fyke-nets	Vibrating rake
Price of annual permit	258 euro	4,649 euro

Primarily, the task was to use the data on the respondent's choices and value the attributes of the fishing management practices to determine fishers' preferences. A following step was to study the degree in which preferences for fishing management practices differed between sectors of the fishing population. In this context, two fishing 'sectors' were defined, corresponding to two types of fishing regimes in the Venice Lagoon. One fishing regime referred to a fishing fleet that is composed of vessels jointly managed by cooperatives. The other referred to a fishing fleet characterised by smaller and individually owned vessels. While the former are currently submitted to a set of cooperative managing rules, the latter are often managed by private individuals, who predominantly fish as a complementary income source to their main economic activity. In addition, some of these individuals are unauthorised or illegal fishermen. Therefore, a key feature was to determine the different preferences of fishermen who operate in collective areas and those who operate in individual areas.

Valuation estimates show that fishermen's willingness to pay for a larger clam fishing area is approximately €568 per year. If one takes into account the interaction between fishing management attributes and the characteristics of the fishers, one can see that the valuation of each management practice differs substantially between the two 'sectors'. The fishermen that operate in the cooperative regime present a higher monetary valuation for an increase in the dimension of the fishing concession, which is now valued at €811 per year, and also a stronger willingness to pay for a change from today's fishing situation towards a fishing practice exclusively based on the vibrating rake system, which is now estimated at between €1,005 and €2,456 per year.

Finally, the adoption of a clam fish management practice in the Venice Lagoon that is exclusively based on the use of manual rakes, which is associated with the lowest damage to the Lagoon ecosystem, will represent a welfare loss of €5,904 per fisherman per year.

The conjoint choice analysis is revealing in terms of the fishermen's perceptions of the sustainability of clam fishing. The most important estimate is the €5,904 they are willing to accept for the first year to move from the present system, which is a mixture of vibrating and manual rakes, to a system based on the manual rake, which would yield currently a net income to them of €26,000 per year rather than €31,904 (Boatto *et al.* 2006). However, in future years this payment of €5,904 will decline as the catch with the present system declines at about 40 per cent per year. Indeed, fishermen would only have to paid for either two or three years depending on the actual decline of the catch under the manual only system[2]. With a 22 per cent per annum drop they would need to receive. with €2509 in year two, and only €460 in year three, after which no subsidy would be required as their catch would be better under the manual only system than under the current approach. Under the 20 per cent drop, only two years compensation are needed, with it being 1911 in year two. The other important estimate is the difference in current values between the mixed system and one based exclusively on vibrating rakes. The latter yields €2,456 a year more at the present time. However, this system is even less sustainable, resulting even faster decline in yields in the future.

Table 3 presents the net present value returns for discount rates of seven and three per cent, which constitute the average interest rates used for private and social investment decisions. The table shows relative yields from the three systems. The following assumptions have been made in deriving these figures:

1. The current system would result in declining yields at a rate of 40 per cent per year.
2. The manual system value is determined so that the individual yearly income is €26,000 (following the economic study on supply chain of the *Tapes philippinarum* clam by Boatto *et al*). In order to capture the sense of the valuation results we consider both a situation where the current system would result in declining yields at a rate of 22 and 20 per cent per year.
3. The 'vibrating-rake only' system has a decline rate of at least 60 per cent a year in catch. The 1998 fleet is about 600 vessels of which 84 used a vibrating rake and this was associated with a decline in catch of 40 per cent per annum. If the whole fleet moved to such rakes the decline would certainly be greater and could easily reach 60 per cent.

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[2] The literature offers two rates of decline of clam fishing value under manual only system – a 20 per cent per annum decline and a 22 per cent per annum decline.

The tables show that with a 22 per cent decline in the catch with a manual only system, the private preference at seven per cent is for the current system, followed by the manual only, followed by the vibrating only. However, with a three per cent discount rate the ordering changes to the manual only being the most preferred. Hence this shows that with a lower discount rate it is possible to have a sustainable solution with private decision-making. Since it is socially in our interest to move to a sustainable solution, it would be desirable for the fishermen to adopt a three per cent discount rate, however, in practice this is unlikely, and therefore the authorities would need to offer an incentive to the private decision makers such that they adopt sustainable fishing practice in this sector.

Furthermore, when the decline in the catch with the manual only rate decreases to 20 per cent, the manual system is the most preferred independently of the discount rate.

This shows how sensitive the choice as to which management practice to adopt is to the impacts from the manual only system. A small change in losses - like that from 22 to 20 per cent - makes a big difference. This suggests that policies that move the manual only system towards improved catches could help direct the market to the more sustainable option.

Table 3. Valuation results.

Year	Current System	Manual	Only Vibrant Rake
1	31904	26000	34360
2	22789	20280	21475
3	16278	15818	13422
4	11627	12338	8389
5	8305	9624	5243
6	5932	7507	3277
7	4237	5855	2048
8	3027	4567	1280
9	2162	3562	800
10	1544	2779	500
11	1103	2167	313
12	788	1690	195
13	563	1319	122
14	402	1028	76
15	287	802	48
NPV@7%	€ 89.481	€ 88.873	€ 77.189
NPV@3%	€ 100.636	€ 102.393	€ 84.792

Year	Current System	Manual	Only Vibrant Rake
1	31904	26000	34360
2	22789	20800	21475
3	16278	16640	13422
4	11627	13312	8389
5	8305	10650	5243
6	5932	8520	3277
7	4237	6816	2048
8	3027	5453	1280
9	2162	4362	800
10	1544	3490	500
11	1103	2792	313
12	788	2233	195
13	563	1787	122
14	402	1429	76
15	287	1143	48
NPV@7%	€ 89.481	€ 95.068	€ 77.189
NPV@3%	€ 100.636	€ 110.491	€ 84.792

Value for decline in clam catch originating from the literature:

Manual only system: declining yield at a rate of 22 per cent per year	Manual only system: declining yield at a rate of 20 per cent per year

CONCLUSIONS

The community sees significant benefits in moving to a system of manual only rakes, in spite of the loss in present earnings. A move towards full use of vibrating rakes only is one that would yield high economic benefits in the very short term (year 1) but would then start to make net losses, given damage to the ecosystem service.

Even the manual only system will face a declining catch (due to fishing and environmental pressures), and the rate of this decline is critical in terms of which fishing option is economically optimal. The choice of options is also sensitive to the discount rate, but less so. There are different ways of looking at the 'accepted losses'. On the one hand the losses can be considered as an estimate of part of the value of the ecosystem and its services (clam provision) in its normal, functional state, while clam fishing still occurs. On the other hand, these values can be seen as relating to stakeholder appreciation of the local economic value of the flow of ecosystem services (clams), where the local authority could see long term economic benefits as larger than those relating to the fisherman and be willing to pay to avoid rapid deterioration of the ecosystem and its services. The authorities' perspective is represented by a lower discount rate (3 per cent) than that of the fishermen (7 per cent private).

Under certain conditions the authorities might wish to compensate fisherman for either two or three years, depending on conditions. If compensation rates were based on ensuring no loss of income to fisherman in each year from a change from current practice to manual only clam fishing, then the following rates would apply:

- two year compensation, where the decline under the manual only system is 20 per cent per annum at €5904 in year €1, 1911 in Year 2.
- three year compensation where the decline is 22 per cent per annum at €5904 in year 1, €2509 in Year 2 and €460 in year 3.

Obviously there are three sets of potential 'benefits' from a move towards more less unsustainable clam fishing:

- ensuring a more sustainable income stream for the fisherman;
- establishing more sustainable economic activity related to clam fishing in the local economic context; and
- broader ecosystem benefits and services (eg other fisheries, amenities, tourism – which have not been valued in this case study).

More data are needed to demonstrate conclusively that such a move would indeed be fully supported, but the fact that a sustainability option has the possibility of being the chosen option in the community is encouraging.

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Contacts:

Michele Pellizzato pellizzato@agriteco.com

CORILA - Consortium for Coordination of Research Activities concerning the Venice Lagoon System, www.corila.it

FEEM - Fondazione Eni Enrico Mattei, www.feem.it

Annex 11 Additional examples on the loss of biodiversity-related ecosystem services in the EU

Loss of biodiversity-related ecosystem services due to the invasion of alien species in the EU

Caulerpa taxifolia is an invasive marine alga that is widely used as a decorative plant in aquaria. A cold-tolerant strain was inadvertently introduced into the **Mediterranean Sea** in wastewater from the Oceanographic Museum at Monaco and as of 2001 the *C. taxifolia* had spread through out the Mediterranean region. *C. taxifolia* forms dense monocultures that prevent the establishment of native seaweeds and exclude almost all marine life. The invasion has resulted in the loss of several ecosystem services, eg tourism, commercial and recreational fishing and recreational activities such as SCUBA diving. Early eradication was not attempted in the Mediterranean, and the infestation is now considered beyond control. *Source: Global Invasive Species Database* http://www.issg.org/database/welcome/

Comb jelly, *Mnemiopsis leidyi,* is indigenous to temperate to subtropical estuaries along the Atlantic coast of North and South America. In the early 1980s, the species was accidentally introduced via the ballast water of ships to the **Black Sea** where it had a catastrophic effect on the entire ecosystem. In the last two decades of the twentieth century, it has invaded the Azov, Marmara, Aegean Seas and recently it was introduced into the Caspian Sea via the ballast water of oil tankers. Due to the *M. leidyi* invasion zooplankton, ichthyoplankton and zooplanktivorous fish stocks in all ecosystems have undergone profound changes. The most recent estimates suggest that due to the invasion the optimal catch commercial anchovy catch in the Black Sea declined by 90 per cent resulting in US $ 16,7 million decline in economic profits per year to the Black Sea fishing nations (primarily Turkey). *Source: Knowler, D. 2005. Reassessing the costs of biological invasion: Mnemiopsis leidyi in the Black sea. Ecological Economics 52: 187– 199.*

In **the Netherlands**, a valuation study has been conducted to evaluate the costs of prevention of harmful exotic algal bloom species along the Dutch coastline (eg construction of a ballast water disposal treatment and implementation of a monitoring program). The valuation study was based on a questionnaire undertaken at Zandvoort, a famous Dutch beach resort. The economic value of the marine protection program included non-market benefits associated with beach recreation, human health and marine ecosystem impacts. The valuation results indicated that the protection program makes sense from an economic perspective as long as its costs are between €225 and 326 million. These values can be considered as an estimate of part of the value of the ecosystem and its services.
Source: Professor Paulo Nunes, Environmental Valuation School for Advanced Studies in Venice Foundation, Venice International University, E-mail: pnunes@unive.it

Loss of biodiversity-related ecosystem services in wetlands and river basins in the EU

In 1965 a 40 km long area of the Daugava River in **Latvia** was affected by the construction of Plavinu hydroelectric power station. The natural environment, now completely lost due to the hydraulic constructions, a unique ecosystem hosting the largest (up to 30 m high) dolomite outcrops with tufa forming springs, canyons and river rapids that provided a habitat for several rare plant and animal species. Due to the alterations several ecosystem services including provisioning of fish and cultural services (local and national identity, aesthetic values, recreation and tourism potential) were lost. The loss of biodiversity and ecosystem services is considered to be irreversible. The main benefits gained were related to the electricity production, however the current supply of Plavinu hydroelectric power station covers only about 1-2 per cent of the national electricity demand. *Contact: Liene Salmina, Latvian Fund for Nature, Email: lsalmina@latnet.lv*.

Dry river valleys in **Malta** have been repeatedly subject to drastic habitat alterations and vegetation removal especially due to building development. The habitat destruction and removal of vegetation has resulted in increased erosion and storm-water flooding problems during the wet season. An increase in artificial impermeable surfaces has also resulted in a greater loss of surface run-off and reduced possibility for any aquifer recharge (almost half of the local supply of water comes from groundwater extraction). It is to be suspected that several changes are irreversible as valleys have been completely built up or covered with tarmac. *Source: A. Nature Trust Malta, www.naturetrustmalta.org.*

Loss of biodiversity-related ecosystem services due to agricultural abandonment

Valley beds in the Ojców and Gorczański national parks in **Poland** are mostly occupied by semi-natural vegetation shaped and maintained by traditional agricultural activities, ie mowing and grazing. These anthropogenic fresh meadows are highly productive and characterised by vast floristic richness. According to a study conducted in 1958-1959 rye grass meadows were characterised as communities with adjusted and rich floristic composition (41-58 species of vascular plants per 100 m^2). Since the late 1980's, repeated studies showed weakening of floristic composition by 27 per cent. At present, 17-35 species are present in those meadows, which is almost 50 per cent of the initial species richness. The changes observed in the meadow ecosystem are caused by changes in land use measures, including increased fertilization and decreased grazing and mowing activities. Indirect reasons behind the change are mainly caused by social transformation and lack of economic profitability in continuing previous land use activities in the area (eg sheep and cow herding). Due to the decline of high diversity-state meadows a number of ecosystem services has been lost. The high-diversity meadows are characterised by high hay production (6 t/ha) with elevated nutrition value where as the nutrition value of current meadows is much smaller. The decrease in the number of flowering species also causes a decline in the food resource for various groups of insects, including pollinators. Furthermore, high diversity-state meadows are very aesthetic and therefore their loss decreases the cultural value of the ecosystem (eg tourist attractiveness). *Contact: Dr inż. Bogdan Wiśniowski, Ojcowski Park Narodowy 32-047 Ojców, tel. +48 12 3891039 and Mr Marek Ruciński, Gorczański National Park, Poręba Wielka, 34-735 Niedźwiedź, tel. +48 18 3317207.*

The livelihoods of the local population in the rural community of Sistelo (Arcos de Valdevez), the National Park of Peneda-Gerês, **Portugal** have traditionally been based on agro-pastoralism and the restrictions imposed by the geography of the mountain (eg steep slopes and extreme climatic conditions) have led to diversified land use practices in the area. Traditionally, agriculture has been carried out on terraces and soil fertilization was assured by animal manure. Animal husbandry was supported mainly by the baldio or common property area. With the aging of the population and the abandonment of agriculture, the landscape is starting to become more homogenised. The agricultural terraces are replaced by the scrubland of early stages of ecological succession. In terms of ecosystem services, there are losses of provisioning services (food provisioning) and of cultural services (the aesthetical beauty of the terraces and the cultural heritage associated with it). The effects of the change on other ecosystem services, such as erosion protection, are not yet clear. For instance, there could be some gains in wood provisioning and in the abundance of wild game. It is also possible than in the long term the general public will benefit from the recovery of the original oak forest which, fire frequency allowing, will in the future cover the terraces. *Source: Pereira, E., Queiroz, C., Pereira, H.M., & Vicente, L. (2005) Ecosystem Services and Human Well-Being: A participatory study in a mountain community in Portugal. Ecology and Society, 14, 14.*

Loss of biodiversity-related ecosystem services due to the intensified agricultural practises in the UK

Agricultural intensification in the UK has caused a loss of biodiversity and the loss of a variety of key ecosystem services. The intensification has been caused by technological and economic changes driving intensification of agriculture and exacerbated by subsidies under the CAP. Biodiversity loss due to the intensification has been substantial (populations of several farmland birds have declined by 50-90 per cent) and it has been accompanied by substantial and well-documented impacts on a variety of ecosystem services, such as water provisioning, air quality maintenance, climate regulation and erosion control. Consequently, additional cost have incurred due to removing pesticides and nitrates from drinking water, dealing with air pollution and climate change impacts, dealing with health crises such as BSE/foot and mouth disease. Biodiversity loss has also led to the loss of cultural services. Agri-environment schemes have shown that the above-described loss is partly reversible, however some species might have become so scarce that declines cannot be reversed. It has been estimated that the annual total external costs of UK agriculture in 1996 were £2343 million (range for 1990-1996: £1149-

3907 million), equivalent to £ 208 per hectare of arable and permanent pasture. Significant costs arise from the following: 1) contamination of drinking water with pesticides (£120 million per year), nitrate (£16 million per year); 2) Cryptosporidium (£23 million per year) and phosphate and soil (£55 million per year); 3) from damage to wildlife, habitats, hedgerows and drystone walls (£125 million per year); 4) from emissions of gases (£1113 million per year); 5) from soil erosion and organic carbon losses (£106 million per year); 6) from food poisoning (£169 million per year); and 7) from BSE (£607 million per year). *Source: Pretty et al. 2002. An Assessment of the Total External Costs of UK Agriculture. Agricultural Systems 65/2: 113-136.*

Loss of pest control due the loss of predatory birds in Malta

Hunting and trapping of birds of prey and similar top predators in Malta has led to negative effects on the island's ecosystems. The hunting has caused an ecological imbalance in the ecosystems resulting in extensive population growth of wild rabbits and rats. Increased numbers of both of these species have in turn reduced possibilities of vegetation regeneration on the island. Additionally, rats seem to be on the increase and are endangering populations of the endemic subspecies *Podarcis filfolensis kieselbachi* (Maltese Wall Lizard). Recently there has also been a widespread incidence of ringing and loss of mature *Ceratonia siliqua* (Carob Trees) possibly attributed to an increase in rodent populations. *Source: A. Nature Trust Malta, www.naturetrustmalta.org.*

Loss of services provided by peat bogs in Müritz national park in Mecklenburg – Vorpommern, Germany

The drainage of peaty basins for agricultural purposes in Müritz National Park in Mecklenburg–Vorpommern, Germany, lead to the degradation of natural habitats originally found in the calcareous, nutrient-poor marshes and along the watercourses impoverished rapidly. Just in the 20 years leading up to the year 2000, 18 per cent of the peat mass was lost to mineralisation, which led to collapsing soil structures and ground levels falling by 20 to 40 cm. The former bog ecosystems collected 1,5000 kg CO2-C/hectare/year. The loss of peat (eg carbon emissions and loss of carbon sequestration) resulted in an output of more than 4,300 kg CO2-C/hectare/year. As the area was converted into intensive agriculture increased use of fertilizer and pesticides followed. The ground-water-level fell down for more then 1,5 meters resulting frequently occurring droughts on an area that used to be a wetland. Additionally, the area is now suffering from eutrophication caused by the increased nutrient, humus and fertilizer input. Because of the unsustainable use of the ecosystem in 20 years (prior to 2000) 89 hectare of fertile soil was lost. It can be concluded that the long-term costs resulting from the degradation and unsustainable use of the ecosystem to a large extent reduced the short-term agricultural benefits. During 1998-2003 a LIFE-nature restoration project was conducted to restore the peat habitats. The overall budget of this restoration project was €531,158,00. *Source: EU-LIFE database*; *Contact: Volker Spicher v.spicher@npa-mueritz.mvnet.de.*

Annex 12 Questionnaire on identifying examples where biodiversity loss has led to the loss of ecosystem services

‘Identifying European examples where biodiversity loss in the recent past has led to the loss of ecosystem services’

Question 1. Please provide 1-3 examples (in your country/other EU countries) where the loss of biodiversity or the modification/loss of habitats accompanied by loss of biodiversity has lead to the loss of ecosystem services so that economic and social services were lost?

For each example please provide:

- Title of the site
- Short description
- Relevant references (literature/data)
- Contact person for more information
- If possible, comment whether the example is unique or common in Europe
- Note whether you think the example is particularly interesting/important to the study

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Example 1

Example 2

Example 3

Answer the questions (questions 2-6) below by providing information for ***every example*** *mentioned above.*

Question 2. Extent, type and rate of biodiversity loss that 1ed to the loss/degradation of ecosystem services? Please note any evidence of the link between biodiversity loss and the loss of ecosystem services. Please note also whether the biodiversity loss is irreversible or fully/partly reversible.

(Please provide information for every example listed in Question 1)

For Example 1

For Example 2

For Example 3

Question 3. Cause of biodiversity loss, including both direct and underlying causes (e.g. overexploitation, habitat destruction, invasion of alien species, economic/social/political reasons etc.)?

(Please provide information for every example listed in Question 1)

For Example 1

For Example 2

For Example 3

Question 4. Stakeholders affected by the biodiversity loss and reduction of ecosystem services?

(Please provide information for every example listed in Question 1)

For Example 1

For Example 2

For Example 3

Question 5. Evidence and scale of the real economic and/or social value lost? Benefits gained in contrast to the biodiversity/ecosystem service lost (both long and short term)? Distribution of the loss and benefits among stakeholder groups?

(Please provide information for every example listed in Question 1)

For Example 1

For Example 2

For Example 3

Question 6. In order to obtain an over all picture of the types of ecosystem services lost/degraded in Europe due to the loss of biodiversity/accompanied by the loss of biodiversity, please

1) Place the examples (1-3) you've described in this questionnaire in the table below;
2) Give your personal opinion/indication on, in general, which of the services mentioned in the table have been lost in your country?

Type of ecosystem service lost[1]	Name of example/s described in this questionnaire (1-3 examples)	Examples of the service being lost in your country YES/NO
Provisioning Services		
Food and fibre		
Fuel		
Biochemicals, natural medicines, and pharmaceuticals		
Ornamental resources		
Fresh water		
Other		
Regulating services		
Air quality maintenance		
Climate regulation (eg temperature and precipitation, carbon storage)		
Water regulation (eg flood prevention, timing and magnitude of runoff, aquifer recharge)		
Erosion control		
Water purification and waste management		
Regulation of human diseases		
Biological control (eg loss of natural predator of pests)		
Pollination		
Storm protection (damage by hurricanes or large waves)		
Fire resistance (change of vegetation cover lead increased fire susceptibility)		

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[1] Classification adopted from the Millennium Ecosystem Assessment (MEA)

Avalanche protection		
Other		
***Cultural services*[2]**		
Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity[3]		
Cultural heritage values		
Recreation and ecotourism		
Other		
Supporting services		
Primary production		
Nutrient cycling		
Soil formation		
Other		

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[2] Can influence values of houses and decisions on where to locate houses/commerce etc.

[3] Important not only for local self-image but also important in ‘branding’ of the region