The Economic and Social Aspects of Biodiversity

Benefits and Costs of Biodiversity in Ireland







Comhshaol, Oidhreacht agus Rialtas Áitiúil
Environment, Heritage and Local Government

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Biodiversity Forum

Executive Summary

The Social and Economic Benefits of Biodiversity

This report has been commissioned by the Biodiversity Unit of the Department of the Environment, Heritage and Local Government to identify the nature and scale of benefits that we, as a society, derive from biodiversity. It is important that public goods, including those supplied by nature, are reflected in decision making. It is also important to ensure that the benefits of policies which protect biodiversity are at least commensurate with the costs of such policies. While the scope of this report is far from comprehensive and can only aspire here to a preliminary assessment, it is clear that the benefits of biodiversity far exceed the costs of current levels of biodiversity protection.

Biodiversity is commonly understood to include the number, variety and variability of organisms living on Earth. We have become accustomed to having decisions of protecting nature, or allowing economic development, being presented as an either/or choice. However, as our knowledge of ecology has developed, so too has our realisation that human beings have a dependence on ecological systems. Gradually, this realisation is filtering through to policy makers, particularly now that climate change looks likely to exacerbate the challenges facing both biodiversity and economic development. Consequently, 'biodiversity protection' appears largely to be replacing references to conservation. This reflects not just a tendency to adopt the latest fashionable terminology, but is based on a significant difference in the interpretation of the two terms. As environmentalist and broadcaster Dick Warner recently observed,[1] 'biodiversity' implies that we protect species, not for their sake, but for our own.

Human activity has always had an impact on biodiversity, but in recent centuries this impact has intensified to a position where we are in danger of undermining the primary functions of natural systems and to an extent that could ultimately threaten our own future. Losses of biodiversity have resulted from the destruction of natural habitats, over-exploitation of resources, pollution and changes in the composition of ecosystems due, for example, to the accidental or deliberate introduction of non-native species.

Loss of biodiversity is our loss. The incentive to protect biodiversity does not simply arise from a benevolence towards the natural world. Rather, a high level of biodiversity also ensures that we are supplied with the 'ecosystem services' that are essential to the sustainability of our standard of living and to our survival. This report details a range of critical ecosystem services on which we depend in various economic and social sectors. In agriculture, these include the maintenance of soil structure and the supply of nutrients, pollination and pest control. For water supply, it includes the filtering and purification of rivers and lakes, including the decomposition of our own pollutants and waste. In the marine sector, there is the obvious direct benefit of a fish catch, but this harvest itself depends on food chains and habitats provided by a robust functioning level of biodiversity.

1 'Wings' Spring 2007, Birdwatch Ireland

Crucially, our own health depends on biodiversity, for example as a source of pharmaceutical raw materials, but also in terms of the quality of the food that we eat, opportunities for physical exercise and resistance to disease. The benefits extend to our well-being and quality of life. Not only are we attracted to scenic landscapes that are largely the product of biodiversity, but most of us also value environments and wildlife in their own right, often irrespective of whether we have ever visited or seen them - or, indeed, expect to.

We can mislead ourselves by believing that our agriculture or fisheries can get by without biodiversity. For the past fifty years or more our farming has been sustained by high levels of fertilizers and pesticides, our timber and pulp is provided by plantation forests supplied with a similar intensive diet of inputs, and our wild fisheries can be substituted by aquaculture. Similarly, we have developed a large number of synthetic drugs with which to fight most diseases and we know - or rather before MRSA, thought we knew - how to kill pathogens to ensure high standards of hygiene.

However, very few if any of these activities can be undertaken without some input from natural biodiversity. Furthermore, their long-term sustainability is being compromised by the depletion of ecosystem services or cumulative pollution. Even now, we are peddling harder to stay put as we are forced to replace ecosystem services that we once took for granted. No longer can farmers be sure that their crops will be reliably fertilized by bees. Nor can we still assume that our domestic sewerage will be recycled into the natural environment without accumulating in groundwater or watercourses. In such circumstances, the last news we need to hear is that climate change could yet further undermine the natural systems on which we still depend.

Valuing Biodiversity

Putting a value on biodiversity is no easy task. In recent times, economists have developed techniques to place a monetary value on many aspects of the environment, sometimes to the consternation of ecologists. Nevertheless, everybody would agree that there are some things which are too fundamental or too complex to value in a meaningful way. Ultimately, our survival depends on a functioning biodiversity. Even though we may have habitually taken ecosystem services for granted, they are of potentially infinite value to human society.

For practical purposes, what matters is knowing the approximate marginal value of key ecosystem services at the present time. That is, the value of biodiversity in terms of the incremental benefits or goods to which it contributes. Even in this respect, valuation is a challenging exercise in that we need some understanding of the proportion of these benefits or goods for which ecosystem services are responsible.

A marginal value allows us to begin to determine how much we should be spending on biodiversity protection. If we have an angle on the benefits, then we can assess how far these benefits exceed the amounts that are currently being spent on relevant policies, or vice-versa. Naturally, we also need to know how effective those policies are. Typically, such policies benefit not only biodiversity, but have other purposes such as providing for recreation or protection of the landscape.

The report presents an assessment of the benefits of selected ecosystem services in the principal social and economic sectors. Although only a preliminary estimate is proffered, the current marginal value of ecosystems services in Ireland in terms of their contribution to productive output and human utility is estimated at over €2.6 billion per annum. This is, however, an estimate that rests on only a few key examples and which necessarily omits other significant services such as the waste assimilation by aquatic biodiversity and benefits to human health.

Agriculture

Despite the prevalence of artificial fertilisers and pesticides, agriculture would be impossible without essential ecosystem services. Biodiversity is essential in the breakdown and recycling of nutrients within the soil. A huge variety of innumerable creatures perform this service, of which we use the example of earthworms as a keystone species. Biodiversity is also essential to the pollination on which a wide range of crops, including forage plants, depend. It is also vital to pest control, without which productivity losses would be far greater. Each of these services is threatened to one extent or another by excessive use of artificial inputs, pollution, non-native alien species, removal of semi-natural habitat or the use of heavy machinery.

Where biodiversity is diminished by inappropriate farming methods, so the need for expenditure on artificial inputs is increased and the prospect for sustainable agriculture recedes. One indication of the value of biodiversity could be provided by the increasing amounts that would need to be spent on these inputs to substitute for ecosystem services together with the external costs of pollution or damage to health that arises from excessive use of fertilizers or pesticides.

Alternatively, the value of biodiversity can be represented by the potential value of output from sustainable systems in which the use of artificial inputs is moderated. Even for Ireland's largely grassland based farming, this value is substantial. This report places a tentative value on the services of the soil biota to nutrient assimilation and recycling of €1 billion per year. Greater reliance on pollination, for example for the more extensive production of clover-based forage or the production of oilseed for biofuels, could raise the value of this ecosystem service to €220 million per year or even €500 million per year. The value of baseline pest control is worth at least €20 million per year before savings on pesticides of perhaps a further €2 million. Estimates of the public utility benefits of the current external benefits of sustainable farming, for example landscape and wildlife habitats, have been put at €150 million per year, but would surely rise significantly if these benefits applied to all farms and were accompanied by improved water quality or health benefits.

Forestry

Commercial forestry depends similarly on nutrient recycling and pest control. Some forests also retain a value for hunting or a collection of wild food (e.g. fungi). In addition, many forests, natural or commercial, are important for human utility, as amenities for recreation and habitats for wildlife. As in agriculture, these forest ecosystem services are threatened by the same mix of intensification of production, pollution and alien species, the latter including some serious pests. At present, the level of ecosystem services is valued at €55 million per year, but this has the potential to rise to €80 million per year if more environmentally sensitive forestry is practiced, or more should the area of broad-leaf trees be expanded.

Fisheries

The ocean, as well as rivers and lakes, provides a provisioning ecosystem service in terms of a fish catch. Fish are harvested directly, but this catch itself depends on a functioning ecosystem that supplies nutrients, prey species, habitats and a desirable water quality. Over-fishing, pollution, destruction of habitat and alien species are amongst the many threats to marine biodiversity.

The present quayside value of the fish catch is €180 million per year, but could be worth twice this amount if fish populations were to be managed sustainably. Aquaculture and the seaweed industry are worth over €50 million and also depend heavily on ecosystem services. The value of assimilation of waste emptied by our rivers or sewerage outflows cannot be estimated, but is certainly substantial. Bizarrely, despite the obvious benefits of marine biodiversity, we are still unable to shake off a policy of subsidising the over-exploitation of fisheries. Although we spent a pittance on the protection of marine biodiversity, lack of political realism and willpower remain the principal constraints.

Water

Within the aquatic environment, biodiversity performs a significant service both in terms of recycling nutrients and ensuring desirable water quality for agricultural use, fisheries and human consumption. Likewise, this same biodiversity assimilates human or animal waste and industrial pollutants. Many aquatic habitats are important for these services, for flood mitigation, recreation or amenity. Our dependence on water quality means that any degradation through excessive pollution is amongst the first adverse human environmental impacts of which we are likely to become aware.

A distinction must be drawn between the huge external cost of water pollution and the value of the ecosystem service. The latter is of value for assimilating excess nutrients from diffuse pollution, but can be overwhelmed. Without full consideration of this service, the value of biodiversity is estimated at up to €385 million per year. The true value would diminish if we managed agricultural and residential pollution better, but rise if fish populations recover or water-based recreational expenditure were to increase.

Human welfare

A very important contribution is made by biodiversity to human welfare. This occurs directly through our appreciation of nature, be this through nature watching or eco-tourism, or simply through the complementary association between environments that are attractive and rich in biodiversity . Biodiversity also has an obvious role in angling and water sports.

Nobody has yet brought together the marginal utility value of all ecosystem services as they contribute to natural environments in Ireland that are used for passive enjoyment or for recreation. Irish inland waters and the coast represent particular omissions. However, from those studies that have been conducted, the utility value (including environmentally-sensitive agriculture as noted above, but excluding health) can be estimated as being at least €330 million per year. Recent work by the Heritage Council suggests an incremental value for policies to enhance the natural environment of €65 million per year.

Health

The connection between biodiversity and health is only beginning to be understood. Clearly, a functioning ecosystem contributes to a supply of nutritious food and water of a quality essential to human health. In addition, it ensures that many diseases, and their vectors, do not get out of hand. Although this may be best understood through reference to many tropical diseases, the importance of these regulatory services in temperate climates is beginning to be understood through instances where natural systems have been disrupted by human interference, bird flu being a probable example. Biodiversity has also been important to the isolation of many important drugs.

Good health has a utility benefit that probably exceeds that of any other sector. The potential health expenditure savings due to high environmental quality are equally sizeable. Although the routes through which biodiversity contributes positively to health are too indirect or multi-dimensional to quantify in this report, they are certainly huge and deserving of more attention.

Policy costs

Policy costs are estimated in the region of €370 million per year. However, only a proportion of these are truly incurred on protecting biodiversity despite the Convention on Biological Diversity to which Ireland is a signatory. Even within the Parks and Wildlife Service only a proportion of spending, i.e. around €35 million per year, is spent directly on biodiversity or habitat protection.

A significant amount of spending is also undertaken by the Environmental Protection Agency (EPA), but while this indirectly benefits biodiversity, its principal aim is to reduce pollution toxicity and to protect environmental quality in conformance with EU Directives.

The Rural Environmental Protection Scheme (REPS) could be identified as a policy that directly benefits biodiversity by protecting species and habitats found on agricultural land. The policy cost is around €280 million per year, although only a portion of this is relevant to biodiversity as REPS supplies other objectives, including aesthetic benefits, food quality and animal welfare. A significant benefit of REPS is as a social transfer to more marginal farmers that coincides with rural development objectives.

Other policies are difficult to identify. Expenditure is incurred by the National Roads Authority (NRA) on measures to protect biodiversity along new roads, but this expenditure has not been estimated by the agency. A new Forest Environmental Protection Scheme (FEPS) has recently been launched by the Forest Service, but initial expectations of expenditure are modest. Although the cost of biodiversity requirements for new plantings are borne by private forestry companies in terms of lost timber production, these costs are recouped in the form of forestry grants.

Net benefits

We are increasingly conscious of the damage that human activities are doing to the environment. Environmental policy is typically evaluated in terms of its success in reducing these adverse impacts. However, we are less accustomed to thinking of what the environment does for us. Even though only a few examples of biodiversity benefits have been estimated - and then only very approximately given the scope of this report and our limited understanding of ecosystem services - it is clear that the benefits far exceed the costs of policies to protect biodiversity.

Amongst the most urgent of the threats we face is that of a total collapse of fish stocks. Hitherto, we have responded to declining fish stocks by attempting to place quotas on those species at risk. Everybody now agrees that, for a variety of reasons, these policies have not been very successful. It is only recently that the relationship between commercial fish stocks and the underlying ecosystem has been demonstrated.

In other areas, there have been recent positive trends in environmental policy. Some formerly polluted rivers are becoming cleaner, natural forests are no longer being felled, agricultural policy is no longer paying farmers to drain wetlands or rip up hedgerows, and previously native species, such as the golden eagle, have been reintroduced. The damage that is continuing to affect natural systems is now more subtle and elusive, for example the accumulation of toxins, nutrification of watercourses and soils, or the gradual attrition of natural habitat. Subtle or not, future generations will face a huge bill in terms of public health, water purity and, ultimately for environmental rehabilitation, if we continue to abuse biodiversity.

The report finds that there are substantial net social and economic benefits from biodiversity when compared with the policy costs. Nevertheless, direct expenditure on the protection of biodiversity is not always necessary. Environmental impact assessment and integrated land use planning can do much to minimise threats to biodiversity. Awareness and political decisiveness are critical too. By designing policies that do not reward people for damaging the environment, and by enforcing these with environmental standards, biodiversity protection need not cost the earth.

Introductions

1. BIODIVERSITY: ECONOMIC AND SOCIAL ASPECTS

1.1 THE IMPORTANCE OF BIODIVERSITY

Biodiversity is a fundamental characteristic of life on Earth and encompasses the "whole range of variation in living organisms" (Wilson, 1993). It can be defined in terms of genetic variation, species variation or ecosystem variation. Throughout the EU much biodiversity has been lost in recent decades. For many years in Ireland, biodiversity remained relatively protected by the low economic growth. However, as the economy has raced ahead in the past ten years, so biodiversity is being threatened by built development and changes in land use management. Like all countries, there is also the pervasive risk that climate change will further multiply the problems associated with loss of biodiversity.

Reviewing the state of biodiversity in the EU, Kettunen and ten Brink (2006) identify habitat change and destruction as being the most direct reasons for biodiversity loss. Other significant factors include over-exploitation of resources, pollution and changes in ecosystem composition due to colonisation by non-native plant and animal species.

Biodiversity is not of value for purely esoteric reasons. It is of value to all of us for the ecosystem services that a healthy biodiversity provides. Kettunen and ten Brink categorise these as the provisioning, regulating, supporting and cultural services that underpin our supplies of food, clean water and renewable resources, and which maintain hydrological cycles and, ultimately, our climate. An early reaction to the loss of biodiversity was the recognition that this was eroding our quality of life, an observation that was articulated so well by Rachel Carson in 1962, in her famous book, Silent Spring. However, as the continued loss of biodiversity is threatening to undermine the ecosystem services on which we depend, so the direct economic consequences of this loss are becoming increasingly apparent.

Science has revealed much of the importance of biodiversity, but an economic and social assessment is needed to communicate the fact that biodiversity loss also has an economic and social impact. Considerable costs will be faced in the protection or replacement of ecosystem services, so policy decisions are required if these costs are to be avoided. These decisions need to be guided by both an understanding of the value of biodiversity to current economic and social systems, and an appreciation of what the costs of inaction could be.

Such a valuation does not imply that nature is all good. From a human perspective, many species have a negative impact on our utility, namely agricultural pests or bacterial disease. Taking a wider perspective, however, these pests and diseases are kept in check by a functioning ecosystem. Indeed, many species which may be better known as pests also play a critical positive part in this functioning of the ecosystem through interdependencies and evolutionary adaptation.
Neither does it necessarily follow that high levels of biodiversity are better than low levels. The

presence of particular key species or functionality (what we call a "healthy" ecosystem) may be more important than the absolute numbers of species. Generally, though, it is the case that a high level of biodiversity is likely to coincide with overall stability. The more species there are in an ecosystem, the more likely it is that species will be ecologically similar or able to provide the same functions as others in the event of exogenous change to the ecosystem (van Rensburg & Mill, 2006, Vitousek & Hooper, 1993). This stability provides an insurance against sudden change. This concept of insurance is little different from people's own reliance on various income earning skills or their possession of a broad portfolio of investments (Tilman et al., 1995).

1.2 THE NATURE OF BIODIVERSITY

Biodiversity is a public good. That is, it is unpriced by normal market processes. As such, it is subject to 'market failure' in that there are no prices through which to indicate its scarcity. This, in turn, presents issues in relation to the neglect or misuse of natural systems.

To understand the value of biodiversity, it is first necessary to examine and categorise the multiple benefits it provides. Many of these can be quantified in economic terms. They include:

- The underpinning of the provision of ecosystem services, ensuring the productivity of agriculture, forestry, fisheries, water purification and climate moderation;

- Contributing to quality of life by providing utility to people directly through their appreciation of nature or landscapes and through their enjoyment of a type of recreation that depends on a functioning ecosystem, e.g. angling, water sports, hunting.

- Providing economic returns directly in relation to recreation and tourism, including nature tourism.

- Contributing to human health through the recycling of nutrients and decomposition of pollutants (including those that could find their way into potable water supplies), or through benefits to health due to the physical exercise of recreation undertaken in open spaces.

Table 1.1 Classification of Ecosystem Services (based on Kettunen & ten Brink, 2006)

TYPE OF ECOSYSTEM SERVICE
Provisioning
Food and fibre Fuel (e.g. wood, bio-oils) Biochemicals and pharmaceuticals Fresh water
Regulating
Air quality Climate regulation Water regulation (flood prevention, waste assimilation, evapotranspiration) Erosion control (ground protection) Water purification and waste management Regulation of human diseases Pest control Pollination
Cultural services
Social relations, aesthetic values, sensual, spiritual Recreation and tourism
Supporting services
Primary production Nutrient cycling Soil formation

While biodiversity is a public good, it commonly has the characteristic of an open access resource such that many of the benefits are realised as private benefits, whereas the associated costs are shared social or public costs. For example, clean water may be needed by a factory, but that same factory's pollution reduces the quality of water for people and other factories downstream. However, it does not necessarily follow that human activity is inevitably bad for biodiversity. In some cases, biodiversity can be enhanced by human activity. Extensive farming provides a diversity of practices and associated landscapes that, in turn, favour biodiversity (Tscharntke et al., 2005). Indeed, there is concern that the virtual abandonment of some farming areas has reduced biodiversity (Rensburg & Mill, 2006).

However, the net situation that we currently face is one in which biodiversity is being degraded. Where the costs and benefits are not shared equally by the same individuals, as is typical where goods have both private and public attributes, there is the prospect that one decision-maker will trade-off biodiversity loss in return for benefits, for example, higher short-run productivity, without considering the full extent of the future costs or the costs for others. Incomplete information, together with the geographical separation of beneficiaries and losers, raises the possibility of adverse outcomes due to market failure. These impacts are often barely perceptible to begin with as they are gradual or cumulative. The full costs may only be realised after long periods of time or by future generations.

1.3 VALUATION OF BIODIVERSITY

In 1995, a team of ecologists and economists estimated the value of biodiversity to the global economy as being in the region of $US33 trillion annually (Costanza et al, 1995). However, not only does this figure, by its authors' admission, represent a minimal estimate of the value, but knowing that the human race ultimately depends on a functioning ecosystem does not help much with the choice of policies to protect it. Better, therefore, to focus on the value of an additional unit of biodiversity, or the cost of the loss of a unit of biodiversity. The value of the marginal product of biodiversity demonstrates the contribution of the ecosystem to the incremental production of goods, services and human welfare at any one point of time. This information places policy-makers in a better position to judge what trade-offs are necessary between the costs and benefits of policies needed to protect biodiversity (Dickie, 2006).

As things stand, there are many decisions that have biodiversity impacts, but which do not consider the full costs, including those that affect the wider public. Many of these social and economic benefits and costs, be they public or private, can potentially be quantified. Where biodiversity contributes to primary production, its value can be demonstrated in terms of the price of final products such as food or raw materials. Contributions to human utility are also an economic benefit that can be quantified using methods such as stated or revealed preference to demonstrate monetary estimates of these values. Such valuation ensures that impacts to social welfare are treated equally with other financial considerations.

Stated or Revealed Preference Methods

Stated preference relies on survey approaches through which people provide estimates of their willingness-to-pay (or willingness-to-accept) for the protection of biodiversity where this can be shown to contribute directly or indirectly to their quality of life. Instances would be the association with outdoor recreation, or other indirect uses or even non-uses such as a pure appreciation of wildlife or biodiversity. Revealed preference achieves the same objective where this utility can be demonstrated through associated market mechanisms. Examples here would be where property prices capture proximity to an attractive natural landscape, or the costs of travel to a recreational area with high biodiversity.

Production Function Approach

In the production function approach, biodiversity forms an input to an economic process. This requires some detective work to attribute that proportion of the value of product which is contributed by ecosystem services. For instance, although a single type of crop or tree might have value as food or timber, its growth depends on a variety of ecosystem services performed by various species. Similarly, ecosystem services will enhance forage production on a farm and this will contribute to the weight gain of grazing animals and a higher final price.

Cost-based Approaches

Cost-based approaches do not provide estimates of utility, but rather provide a demonstration of the value of biodiversity through a surrogate product. For example:

- 'Replacement cost' examines the amount that would need to be spent to replace the ecosystem services that are provided by biodiversity. Examples could include hand pollination or the use of fertilizers or pesticides.

- 'Damage avoided' looks at the cost of adverse outcomes which could arise in the absence of a functioning ecosystem. This approach could be used to quantify the external costs of activities which ignore or damage biodiversity of which the health impacts of pesticides would be one example.

- 'Preventive expenditure' is related to the above in that it calculates how much would need to be spent to avoid such costs. One example that follows on from the above would be the additional water purification needed to remove pesticide residue.

Methods adopted

In this report, the production function method is used most regularly, albeit rather crudely given the range of ecosystem services which must be considered here. Ideally, it would be necessary to attribute that component of value which is contributed by biodiversity. It is also necessary to avoid double-counting or over-estimating the costs that are truly attributable to biodiversity. For example, the above examples of the replacement cost posed by the purchase costs of pesticides can be added to the social costs of their potentially adverse health impacts as an instance of the cost of lost ecosystem services. However, the costs cannot simply be added to that of the preventative expenditure which must be made on water purification that might remove toxic pesticide residue.

Valuation, of any kind, is not straightforward. Production function or cost-based methods are challenged by the limited scientific understanding of ecosystem functions, including in areas that are highly important to primary production such as soils and the oceans. Imperfect information also applies to the use of stated preference tools based on surveys in that most people have a very limited understanding of biodiversity even where they do value its outcomes. In this case, it could be better to establish people's willingness-to-pay for the protection of particular key species or landscapes, and then to use these values as a demonstration of the value of the biodiversity on which these species or landscapes depend.

Economic valuation can also never be more that partial. Although we can artificially raise short-term productivity or substitute for some loss of biodiversity, productive activities, such as agriculture, are ultimately dependent on biodiversity. The value of biodiversity is therefore essentially equivalent to the total value of the output from agriculture, forestry or fisheries. For a benefit-cost approach to have meaning, it is more practical to focus on marginal values as described above. It is also practical and illustrative to refer to a handful of species which have been identified as being critical to economic activity. To demonstrate the importance of protecting biodiversity, it may also be persuasive to choose those species which are endangered. Indeed, this threat to individual species may have arisen because their value has hitherto not been appreciated or accounted for in economic terms.

Where a limited number of example species are used, it is important to remember that these species, in turn, do not exist in isolation but depend on a functioning ecosystem. Bees, for example, do not survive just by pollinating agricultural crops. Rather, they depend on a range of wild plants which, themselves, occupy particular habitat niches or depend on other insects, birds or mammals for their reproduction and dispersion. It is this classic beautiful complexity of nature which can never be quantified entirely.

1.4 STRUCTURE OF THE REPORT

The report is structured as follows. Following this introduction, a synopsis is given of international and European policy on biodiversity. The chapter discusses the political background and motivations for biodiversity protection and the extent to which these policy initiatives are being applied in Ireland.

The following chapters examine the role of biodiversity and of ecosystem systems in our key economic and social sectors, namely:

- agriculture
- forestry
- fisheries
- water quality
- roads and infrastructure
- health
- social welfare and quality of life

The sub-chapters are broadly organised into sections that examine:

- the relationship between the sector and biodiversity
- relevant species and their function
- ecosystem services
- economic and social values
- threats to biodiversity, and
- costs of protection.

The structure is not exactly repeated for each topic as the relationship between biodiversity and activity within each sector inevitably varies, including the role played by ecosystem services.

A summary of the benefits of biodiversity is then provided, together with a broad comparison of the costs in terms of both current and possible policy and the economic implications of failing to protect biodiversity. For the reasons discussed above, this chapter cannot aspire to be a cost-benefit analysis. Rather, it discusses what measures have been introduced by individual government departments to protect biodiversity. It examines the extent to which government departments are conscious of the social value of biodiversity, or whether this consciousness is simply a response to international agreements and European Directives.

This core section of the report is followed by a short chapter on the impact of climate change. Climate change is likely to have a serious impact on biodiversity. Between 30%-50% of species have been identified to be at risk from the changes in climate predicted for this century (CEC, 2007). Furthermore, our capacity to adapt to climate change and to deal with its implications will be strengthened by the presence of a healthy level of biodiversity.

Finally, we bring this information together in a concluding chapter that also contains recommendations for government action on biodiversity.

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2. AN OVERVIEW OF POLICY AND LEGISLATION

2.1 INTRODUCTION – THE GLOBAL CONTEXT

The range of individual policies and policy drivers connected to biodiversity in Ireland is extensive, while their history, relationships, implementation and enforcement issues are complex. The majority of these instruments are directly relevant and of great significance to social and economic concerns on this island, but a full discussion of these aspects would form a large volume of text on its own. Rather than discuss each of these in detail, this section provides a general overview of the over-riding international and national policy context within which biodiversity conservation must be considered. It gives specific consideration to policy drivers of relevance to the Irish economy and society, and highlights some major linkages with current socio-economic issues in Ireland.

2.1.1 Development of modern biodiversity policies

Today's policy framework for environmental protection dates back to the beginnings of the green movement in the mid-1960s. Politically, modern nature conservation policies in Ireland and elsewhere have roots in a number of international summits and treaties of the early 1970s (e.g. the 1972 United Nations Conference on the Human Environment). In the 1980s, the establishment of the UN World Commission on Environment and Development focused global political attention on the connection between environmental quality and economic growth. The concept of Sustainable Development is now firmly fixed into almost all national and international objectives relating to economic and social progress. The phrase itself has, perhaps, been somewhat over used in recent years and it is frequently applied to discussions outside of the socio-economic-environmental context. In the framework of the current report, the definition stated in the 1987 report of the World Commission ("Our Common Future"), is worth repeating:

> "Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs".

The World Commission's report stressed an urgent need to achieve this form of sustainability in human development and economic activity. This led to the United Nations Conference on Environment and Development (UNCED, popularly known as the Rio Earth Summit) held in 1992 in Rio de Janeiro. The parties to the Earth Summit recognised that the natural environment (the biosphere) provides both the supporting framework and the raw materials for human life and development, and that a healthy natural environment is absolutely essential to the success of human economic and social development, and to our overall health and well being. At the Earth Summit, the world's governments recognized the need to redirect international and national plans and policies to ensure that all economic decisions fully took into account environmental impacts. The UN Convention on Biological Diversity (CBD), which was opened for ratification at the Earth Summit, is the main international instrument governing the conservation of nature and biological resources, and is one of a number of international conventions concerned with the sustainable use and conservation of the natural world.

The CBD has been ratified by 190 parties (189 countries and the European Union). Ireland ratified the CBD in 1996. The CBD covers key aspects of biodiversity conservation and management, including natural resource management, and the social, cultural and economic values of biodiversity, recognising that the "conservation and sustainable use of biological diversity is of critical importance for meeting the food, health and other needs of the growing world population". Biodiversity provides a range of essential goods and services to human societies, which cannot be provided artificially, or for which the costs associated with the development of alternatives is prohibitive. Examples of these "ecosystem services" are provided in Table 2.1 below.

Table 2.1 Ecosystem Goods and Services provided by Biodiversity

Supporting services • Primary production • Nutrient cycling • Soil formation • Decomposition / recovery	Provisioning services • Food • Fresh water • Wood and fibre • Therapeutic compounds
Regulating services • Climate regulation • Disease regulation • Water purification • Flood mitigation	Cultural services • Aesthetic • Spiritual • Educational • Recreational

The three main objectives of the CBD are:

- The conservation of biological diversity
- The sustainable use of its components; and
- The equitable sharing of the benefits arising out of the utilisation of genetic resources.

The main implementing and review body of the CBD is the Conference of Parties (COP), which consists of representatives from each of the ratifying parties, and which meets approximately once every two years. At each COP meeting, based on a review of new biodiversity research and current progress and implementation of the CBD, additional objectives and targets (collectively adopted as "Decisions") are set, to which parties are bound.

The Convention defines biological diversity as:

"The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

In essence, this definition recognises three interdependent levels – ecosystem diversity, species diversity, and genetic diversity within species. In the wider context of the Convention and related COP decisions, another level should be recognized – the landscape level, constituting the broader biophysical environment and biogeographical patterns which biodiversity has helped to create, and of which biodiversity forms an integral part. The implications of this definition for Ireland will be discussed in more detail in following sections.

A key provision of the CBD is the preparation of national biodiversity strategies or plans, and the integration of biodiversity into all relevant sectors. This recognises that any activity which involves or results in the consumption of natural resources, the production of waste, changes in population movements or demographics, or the removal or fragmentation of natural habitats or other change in land use patterns, can have an effect on biological diversity. This, in turn, will have further direct or indirect effects on human well-being. Article 6 of the Convention requires each Contracting Party to:

> "develop national strategies, plans or programmes for the consideration and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes, which shall reflect, inter alia, the measures set out in this convention relevant to the Contracting Party concerned"

and also to:

> "integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies."

Under the strategic plan of implementation of the CBD[1], ratifying states have agreed to significantly reduce the rate of loss of biological diversity by the year 2010. This was further endorsed by international governments at the UN World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa, in the same year (often referred to as "Rio +10"). A major outcome of Rio +10 was a broadening and strengthening of the concept of sustainable development, to more completely account for the relationships between economic growth, environmental quality, livelihoods, and natural resource management. This is now the over-riding policy goal relating to the use, management and conservation of natural resources worldwide. The implementation phase of the CBD, working towards the 2010 target, comprises actions under specific thematic areas, based on key ecosystem types and issues which are recognised to have greatest significance to environmental health, economic and social welfare, and to international development. These include agriculture, forests, wetlands, marine and coastal areas, islands, and inland waters.

[1] Arising from Decision VI/26 taken at the 6th COP meeting, in 2002.

Under the CBD, Contracting Parties have also agreed to adopt an "ecosystem approach" to biodiversity conservation, and to adapt this approach for policies which may affect biodiversity in relevant sectors. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It recognizes that human societies, with their cultural diversity, are an integral component of many ecosystems, and, when applied in a wider political context, it attempts to encompass the essential structure, processes, functions and interactions between humans and our natural environment.

2.1.2 Biodiversity and international development

Fully sustainable development requires that economic, social, public health, environmental and development concerns are addressed simultaneously and holistically. This will ensure that benefits can be maximised across sectors, and that the implementation of policies in any one area does not negatively affect progress in other areas. It is unfortunate that, in the years since the UNCED, the concept of sustainability has frequently been considered as just an environmental concern. This has generally led to shortfalls in the development and implementation of "sustainable development" policies worldwide. The United Nations has reported that since the 1972 UN Conference on the Human Environment, most environmental trends have worsened. Clearly, ensuring that development is truly sustainable is a major challenge that requires a high degree of inter-disciplinary and cross-sectoral co-operation and understanding. Over the past five years, experience and research in environment, social and economic areas have highlighted the dependency of human development and well-being on biodiversity and ecosystem services, leading to a growing focus on biodiversity loss as a significant threat to international development, economic security and human well-being.

In the year 2000, the UN Millennium Declaration on the fundamental challenges facing the international community in the 21st Century was adopted by the General Assembly and signed by the Heads of State from 152 nations. In 2001, the Secretary General set out a 'roadmap' of Millennium Development Goals (MDGs) for achieving the aims of the Declaration – reducing poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women by 2015. Over the following five years, experience in implementing the goals lead to a growing consensus that the Millennium Goal relating to environmental sustainability is the keystone upon which the success of other goals depend. Biodiversity conservation is a critical aspect of sustainable development, and its importance to human well-being has been emphasised by the reports of the Millennium Ecosystem Assessment (MA), a UN global project which assessed the consequences of ecosystem change for human well-being, and which identified the scientific basis for action needed to enhance the conservation and sustainable use of those ecosystems. The main findings of the MA included the following:

- Over the past 50 years, human impacts on ecosystems have resulted in a substantial and largely irreversible loss in the diversity of life on Earth.

- Although some of the changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, with negative impacts for some people. These effects include the emergence and spread of disease organisms, reduced livelihood security, loss of food resources, and the exacerbation of poverty. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems.

- The degradation of ecosystem services is a barrier to achieving the Millennium Development Goals, and could grow significantly worse during the first half of this century.

- The challenge of reversing the degradation of ecosystems, while meeting increasing demands for their services, will involve significant changes in policies, institutions, and practices that are not currently under way.

In his statement to the world's first global stakeholders' meeting on the importance of biodiversity to human health and well-being (COHAB 2005, the first International Conference on Health and Biodiversity, which took place in Galway in August 2005), the former UN Secretary General Kofi Annan, said:

> "If we fail to use and conserve biodiversity in a sustainable manner, the result will be increasingly degraded environments, and a world plagued by new and more rampant illnesses, deepening poverty, and the perpetuation of patterns of inequitable and unsustainable growth. Unfortunately, our actions run the risk of taking humanity down this path… human activities are fundamentally changing the planet, perhaps irreversibly… Over the last fifty years, pollution, climate change, degradation of habitats and overexploitation of natural resources, led to more rapid losses of biological diversity than at any other time in human history. Such losses put the livelihoods and health of current and future generations in jeopardy."

In response to the reports of the MA and other international consultations, the UN has incorporated the 2010 biodiversity target as a target within the MDGs, essential to their success and to future global economic development and security.

Some other relevant multi-lateral instruments which Ireland has ratified or is a party to are listed below:

- The International Treaty on Plant Protection (1997)
- The UN Framework Convention on Climate Change (opened at Rio in 1992), and the Kyoto Protocol.

- The Ramsar Convention on Wetlands of International Importance (opened at Ramsar, Iran, in 1979)
- Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) (in effect since 1975)
- The UN Convention on the Conservation of Migratory Species and Wild Animals (Bonn, 1994)
- Convention concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972)

2.2 THE EUROPEAN CONTEXT

2.2.1 EU Legislation on biodiversity

Legislation on biodiversity and nature protection at European Union level dates back to the Directive on the conservation of wild birds (the Birds Directive), which was adopted in 1979. Although several environmental directives of relevance to biodiversity have been implemented since then, the Birds Directive, and the 1992 Directive on the conservation of natural habitats and of species of wild flora and fauna (the Habitats Directive) are the most directly relevant in the context of this discussion.

The Birds Directive aims to provide far-reaching protection for all of Europe's wild birds, and identifies 194 species and sub-species as particularly threatened and in need of special conservation measures. EU Member States are under a general obligation to preserve, maintain or re-establish sufficient habitats and ecosystems to support the conservation of all bird species covered by the Directive. In addition, for certain species that are of conservation concern, of European importance or are important migratory species, Member States must designate protected sites known as Special Protection Areas (SPAs). The decision on the selection of sites for SPA designation may take account of economic and social considerations, but the decision must be based primarily on conservation needs.

The Habitats Directive is much broader in scope than the Birds Directive, extending the coverage to a much wider range of rare, threatened or endemic species, including around 450 animals and 500 plants throughout Europe. Its aim is to restore, or maintain, natural habitats and species of wild flora and fauna of "European Community interest" to a favourable conservation status. Some 200 rare and characteristic habitat types are also targeted for conservation in their own right. The Habitats Directive established the 'Natura 2000' network of sites of highest nature value. This consists of Special Areas of Conservation (SAC) designated by Member States, and incorporates the SPAs designated under the Birds Directive. Over 20,000 sites have been included in the network so far (throughout the EU25), covering almost a fifth of Europe's land and water (equivalent to the size of Spain and Italy put together). As part of Natura 2000, the selected areas benefit from increased protection. In principle, Member States must take all the necessary measures to guarantee their conservation and avoid their deterioration.

Under both the Birds and Habitats Directives, two pillars of legislation are identified – the first pillar dealing with protection of habitats (through which Natura 2000 sites are designated) and the second dealing with protection of species listed in the Annexes to the Directives (e.g. through protection of their habitats, nests, eggs and breeding places, and through the control of capture, killing, harvesting, hunting and trade). Under the legislation, the integrity and conservation status of Natura 2000 sites, and the system of protection for the listed species, must not be negatively impacted by development or other activity, except where there are "imperative reasons of overriding public interest, including those of a social and economic nature".

In EU legislation, the concept of habitats and species of "Community interest" is largely based on conservation criteria – for example, sites which hold high proportions of national or international populations of a given bird or mammal, or which are important for the national or EU-wide conservation of an endangered species, etc. However, under current EU policy, in light of the findings of the MA and following the implementation of many recent EU environmental directives, the concept of Community interest potentially has a wider frame of reference than nature conservation concerns alone. For example, sites may have Community importance not only because of the component flora or fauna, but because of the importance or value of the ecosystem services which they provide. It is likely that future legislation on environmental protection may recognise the relevance of these sites to wider social and economic issues.

Considerations of impacts on biodiversity arising from plans and programmes, including physical development and policy goals, are regulated by two other important EU Directives which should be mentioned here – the Directive on the assessment of impact of certain private and public projects on the environment (the Environmental Impact Assessment, or EIA, Directive) and the Directive on the assessment of the effects of certain plans and programmes on the environment (the Strategic Environmental Assessment, or SEA, Directive).

The EIA Directive applies to impact assessment of certain projects involving physical development, consumption of raw materials and production of wastes, or land use change. This includes, for example, construction, manufacturing, exploration, energy generation and waste management projects. EIA is an important tool for ensuring that the end results of a project have minimal negative impacts on the environment, including biodiversity, or that such impacts can at least be identified, and where possible remedied or remediated.

The EIA Directive is focused on individual projects. Experience throughout the EU has shown that the wider policy framework itself represents a significant barrier to sustainable development, by tacitly allowing specific types of projects in potentially unsuitable circumstances or locations. EIA, when implemented with the Habitats and Birds Directives, should ensure that many impacts on biodiversity are prevented and that development is sustainable. However, the problems associated with subtle, unforeseen, long term, cumulative or additive impacts are often not adequately accounted for by EIA, due to uncertainty, lack of scientific knowledge, or gaps in other relevant policy structures. The implementation of the SEA Directive aims to overcome these issues, by ensuring that certain programmes and plans – including Regional Development Plans, infrastructure programmes and certain other supporting policies – are appropriately assessed for their potential environmental impacts, prior to their implementation. This is a potentially significant development towards the conservation and sustainable use of biodiversity throughout the EU, and has implications for the decision making process across all sectors of government.

Some other EU legal instruments are relevant to the aims of conservation and sustainable use of biodiversity:

- The Environmental Liability Directive, which implements the "polluter pays" principle and covers damage to natural habitats protected under the 1992 Habitats and 1979 Bird Directives.
- The Water Framework Directive, which has established an EU framework for the protection of all water bodies in the EU in order to prevent and reduce pollution, promote sustainable water use, protect the aquatic environment, improve the status of aquatic ecosystems and mitigate the effects of floods and droughts.
- The Aarhus Convention, which provides for access to environmental information and public participation and access to justice in environmental matters.
- The seven environmental thematic strategies adopted by the European Commission, on the marine environment, soil, the sustainable use of pesticides, air pollution, the urban environment, the sustainable use and management of natural resources, and waste prevention and recycling. They take a long-term (20-25 years) holistic and ecosystem-based approach to these issues, which cut across several policy areas.

2.2.2 Development of the EU's policy framework for biodiversity

The EC Biodiversity Conservation Strategy (ECBS), adopted in 1998, was developed to meet the EC's obligations as a Party to the CBD. The ECBS provides a comprehensive response to the many requirements of the CBD, and aims to anticipate, prevent and tackle the causes of significant reduction or loss of biodiversity at the source. This will help both to reverse present trends in biodiversity reduction or losses and to place species and ecosystems, including agro-ecosystems, at a satisfactory conservation status.

At the Gothenburg Summit in 2001, EU countries recognised that biodiversity loss is continuing at alarming rates with potentially severe consequences for livelihood security and sustainable economic growth throughout the EU and worldwide. The first EU Sustainable Development Strategy (SDS) was adopted at Gothenburg, and special attention was given to the issue of biodiversity conservation. In recognition of the importance of biodiversity to human well-being and economic development throughout the EU, Member States agreed to work towards halting biodiversity loss, (rather than merely to "reduce the rate of loss" as stated in the CBD strategy) by the year 2010 – a significant and ambitious aim which requires intense collaboration within and across all sectors of government and civil society. In order to implement this aim, four Biodiversity Action Plans (BAPs) have been adopted at EU level, outlining in detail what actions are required, and highlighting the need for a cross-sectoral approach. The four areas targeted are agriculture, fisheries, economic and development cooperation, and conservation of natural resources.

During the Irish Presidency of the EU in 2004, the Irish Government convened an international conference in Malahide, Co. Dublin, entitled "Biodiversity and the EU: Sustaining Life, Sustaining Livelihoods". This Conference was the key event in a critical policy review process, which was widely endorsed by Member States and civil society organisations. Discussions focussed on EU action towards meeting the 2010 target, and the Conference prepared a 'Message from Malahide' detailing priority objectives, targets, indicators of success and implementation arrangements.

Following these developments, biodiversity objectives have been further integrated in a wide range of other sectoral policies. This includes the Lisbon partnership for growth and jobs, reinforcing the message that biodiversity must be considered in economic and social development policies made by central government or at decentralised level. Recent reform of the Common Agricultural Policy (CAP) aims to help mitigate the damaging trends of intensification and the abandonment of high-nature-value farmland and forests. Considerable progress has also been made in integrating biodiversity concerns in the Common Fisheries Policy (CFP), which was reformed in 2002. The previous short-term (annual) decision-making approach of the CFP is replaced by multi-annual recovery plans for those fish stocks that are in danger of collapsing and multi-annual management plans for healthy stocks. The new CFP aims to adjust the size of the EU's fishing fleet according to fish stocks and to promote environment-friendly fishing methods.

In 2006, in response to the Message from Malahide and the results of the Millennium Ecosystem Assessment, the European Commission produced a Communication on "Halting the loss of biodiversity by 2010 – and beyond; sustaining ecosystem services for human well-being". The Communication reviews progress in implementation of the EU Biodiversity Strategy and Action Plans and proposes an Action Plan to 2010 and beyond. For the first time, this Action Plan addresses both the EU institutions and Member States, specifying the roles of both levels of governance in relation to each action. It provides a comprehensive plan of priority actions towards specific, time-bound targets, requiring enhanced consideration of biodiversity in planning and development activities across all sectors.

2.3 THE IRISH CONTEXT

2.3.1 Legislation

A number of Legislative Instruments with relevance to biodiversity have been implemented in Ireland. As most of these have roots in the corresponding EU Directives as discussed above, very little additional detail is required here, except to note that some Irish legislation goes further than the requirements of EU law, or provides structures which allow for the greater integration of environmental concerns into non-environment policy areas. Three aspects of note are: the Wildlife Act 1976 (as amended by 2000 Act)", which provides for the designation and protection of Natural Heritage Areas to protect habitats and species of national significance; the EPA Act (as amended by the Protection of the Environment Act, 2003), which allows for independent assessment and licensing of certain industrial activities which may impact on the environment; and the various Planning and Development regulations, which require appropriate assessments of potential impacts on biodiversity and the wider environment, arising from various development and economic activities.

2.3.2 The National Biodiversity Plan

As discussed above, each party to the CBD, including Ireland, has agreed to prepare a National Biodiversity Strategy and Action Plan to implement the CBD within their own national boundaries. The Irish National Biodiversity Plan (NBP) was published by the Government in 2002, with a mid-term review published by the Minister for the Environment Mr Dick Roche T.D. in November 2005. A revised NBP is planned for the period 2008 - 2011.

The plan pays special attention to the need for the integration of the conservation and sustainable use of biological diversity into all relevant sectors: "The full and effective integration of biodiversity concerns into the development and implementation of other policies, legislation, and programmes is of crucial importance if the conservation and sustainable use of biodiversity is to be achieved."

Amongst other actions, the NBP requires specific actions in the key areas of agriculture, forestry, wetlands and inland waters, and marine and coastal areas, and also calls for the development of "sectoral biodiversity action plans" to ensure that the conservation and sustainable management of biodiversity is actively pursued by each government department and agency. A set of guidelines on production of these plans has been published by the NPWS, and an Interdepartmental Biodiversity Steering Group comprising representatives from all Government Departments has been put in place.

2.3.3 The National Development Plan and the National Spatial Strategy

Ireland's first National Development Plan and Community Support Framework (2000 – 2006) set the national agenda for social and economic growth and regional development, based on four key objectives:

- to continue sustainable national economic and employment growth
- to strengthen and improve Ireland's international competitiveness
- to foster balanced Regional Development
- to promote Social Inclusion.

The Irish Government and the European Commission identified four priority considerations to be factored into the NDP: poverty, equal opportunities, the environment, and rural development. These cross-cutting or horizontal principles supported all Programmes in the Plan, which oversaw significant investment in social improvements, infrastructure developments and scientific and technological research.

The second NDP, for the period 2007 to 2013, was launched in January 2007. This plan outlines a programme for the investment of €184 billion to support environmentally sustainable economic and social growth over the next seven years, including an allocation of €25 billion in "programmes that will directly and positively impact on environmental sustainability". The NDP recognises that "Ireland's biodiversity, which includes our ecosystems, provides environmental services vital to human welfare. These environmental services include the provision of food, fresh water, clean air and nutrient recycling, all of which are essential to human life. Furthermore, our natural environment is valuable and worthy of protection in its own right."

Table 2.2 below highlights some of the principle themes of the NDP 2007 - 2013 for which biodiversity provides important services.

Table 2.2 Biodiversity in principal themes of NDP

Individual aspects of the NDP	Relevance of Biodiversity
Economic and Social Infrastructure	Biodiversity provides basic resources and natural capital required to maintain and increase economic and social development, and presents a range of opportunities for technological innovation and job creation, supporting recreation, social cohesion and protecting and enhancing human and animal health.
Education, Training and Skills Development	Biodiversity supports job security and growth in food production, sport, tourism, construction, healthcare, manufacturing and the arts.
Enterprise, Science and Innovation	Biodiversity both supports and provides the resource base for food production and other manufacturing industries, tourism, and scientific and technological innovation.
Social Infrastructure and Social Inclusion	Biodiversity and conservation can play an important role in urban regeneration, community development, social cohesion and integration, poverty mitigation and job creation, and even crime prevention.
All-island Cooperation	Biodiversity in Ireland must be viewed and managed as an all-island resource, particularly due to cross-border linkages created by both natural and man-made infrastructure and development policies.
Development of the Rural Economy	Biodiversity is essential to rural economies, sustaining agriculture, forestry, fisheries, tourism and a range of other indigenous industries.

The National Spatial Strategy for the period 2002 – 2020 is designed as a framework to assist Ireland to achieve "a better balance of social, economic, physical development and population growth between the regions". The NSS contains a large focus on the need for sustainable development, and, importantly, recognises that sustainable development is more than just an environmental concept. In addressing the spatial and regional issues for its implementation, the NSS recognises the fundamental importance of Ireland's natural resource base to the economy and to future national development. Furthermore, it explicitly recognises that biodiversity has intrinsic economic and social value, whether through its importance for recreation or tourism, or its relevance to agriculture, forestry, fisheries and other indigenous industries.

Under both the NDP and the NSS, ensuring that continued national economic and social development (in the short, medium and long term) is not jeopardised by negative impacts on Ireland's biodiversity, requires a high level of cross-sectoral understanding and partnership. The

Strategic Environmental Assessment process under EU and Irish legislation represents a useful instrument in this regard, although a strong framework for identifying, monitoring and targeting the critical ecosystem services which support development within each sector is still required. The ecosystem approach, when applied to economic and social considerations, can help to set out the basis of this framework. Although the second NDP has not been subjected to a Strategic Environmental Assessment, many of the programmes and policies that follow from it will be subject to the SEA process under EU and Irish law. This is of particular relevance to Development Plans and Settlement Strategies at the local, county and regional level. In line with the EU Sustainable Development Strategy, the Lisbon Agenda and the EU Biodiversity Action Plan, the conservation of biodiversity must be given high priority as an integral aspect of the successful planning and implementation of the Plan.

REFERENCES

United Nations Commission on Environment and Development (the Brundtland Commission) and the Rio Earth Summit – the Brundtland Commission Report entitled "Our Common Future" is available at http://ringofpeace.org/environment/brundtland.html

The report of the 1992 Rio Earth Summit (UNCED) is available at:
http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm

The United Nations Convention on Biological Diversity (CBD) – the text of the CBD and information on COP decisions can be found at www.cbd.int

The report of the first International Conference on Health and Biodiversity (COHAB 2005) is published by the CBD Secretariat on their website at:
https://www.cbd.int/doc/programmes/areas/agro/agro-cohab-rpt-smry-en.doc

Millennium Ecosystem Assessment – the background and reports of the Millennium Ecosystem Assessment can be found at www.maweb.org

The U.N. Millennium Declaration is available at
http://www.un.org/millennium/declaration/ares552e.htm, and information on the Millennium Development Goals can be found at http://www.un.org/millenniumgoals/ and at
http://www.undp.org/mdg/

European Policy and Legislation on Biodiversity and Nature Conservation – the EUROPA website of the European Union provides a portal for information on all aspects of EU biodiversity policy and legislation, including full text downloads of EU and European Commission decisions and directives, convention texts etc. Go to:
http://ec.europa.eu/environment/nature/home.htm or ec.europa.eu/environment/index_en.htm

Information on Irish Legislation on the Environment and Nature Conservation can be found on the website of the Department of the Environment, Heritage and Local Government at http://www.environ.ie/, and on the website of Ireland's National Parks and Wildlife Service at http://www.npws.ie/WildlifePlanningtheLaw/.

The National Biodiversity Plan is available at http://www.npws.ie/Biodiversity/Ireland/

Ireland's National Development Plan – details of the NDP, including the text of the NDP for 2007 to 2013 and a review of the previous NDP (2000 – 2006) can be found at www.ndp.ie

Ireland's National Spatial Strategy – the text of the NSS can be found at
www.irishspatialstrategy.ie.

(All of the above website URLs are correct as of June 2007.)

3. ECOSYSTEM SERVICES IN AGRICULTURE

3.1 THE RELATIONSHIP BETWEEN AGRICULTURE AND BIODIVERSITY

Through agriculture we have learnt to harness ecosystem services to our own interests by increasing the level and reliability of the production of food crops necessary to our survival. As technology has progressed, we have also achieved a degree of independence from natural systems such that high levels of biodiversity are not required for high levels of production. We can selectively encourage those plant or animal species that are of value to us. We can also substitute for the ecosystem services of others through the application of inorganic fertilizers or the use of pesticides. Indeed, it could be argued that it is largely because our agricultural systems are artificial that we need artificial inputs. For instance, agriculture monocultures (single product) supply pest species with a single food crop, providing the opportunity for potential population explosions of pests in the absence of pesticides. By comparison, a natural system has a diversity of habitats and species that ensures that these same pests are regulated within natural norms and balances.

If there were no natural systems of any kind it would nevertheless be impossible to produce food. In principle, therefore, the value of biodiversity could be represented as the total value of all food production. However, it is easier to understand the marginal value of biodiversity in the sense of the contribution of various ecosystem services to additional agricultural output.

Technology has permitted big advances in agricultural productivity, but it has its limitations. Technology has diminishing returns and there are limits to our capacity to select and substitute. We cannot, for example, supply all the nutrient demands of crops through fertilizers alone. Neither can we hope to control all potential agricultural pests. Applying more and more inputs undermines future sustainability and leads to external costs for others.

(1) Sustainability

It is beginning to be appreciated that intensive agriculture cannot be sustained in the long-run without consideration being given to the need to ensure the continuance of ecosystem services. For example, while pesticide formulations have, indeed, improved over the years to better target pest species, they are unlikely to ever achieve 100% success. Even if they do, they are likely to be depriving other beneficial species of a food source or some other productive interaction. They can also leave behind residues that interfere with the functions of yet other species, many of which are likely to be beneficial to agriculture and often in ways that are, as yet, little understood. As an example, monoculture crop systems reduce the variety of food sources for bees, while pesticides do an equivalent amount of damage to bee populations, as do herbicides by reducing other out-of-season food sources. Yet bees are important to the pollination of some crops grown under monoculture systems such as oilseed rape.

By diminishing biodiversity, intensive agriculture is removing the foundations on which it depends and is placing itself at risk of future catastrophe. The rather biblical scenario is one where the population of a pest species gets out of control due to the reduction in the population of its natural enemies. Equally, the same would be true of less visible pathogens, some of which could threaten the future of domesticated animals or particular crops that have been selectively bred for high productivity and which have often lost much of their natural disease resistance.

Particular uncertainty relates to exogenous factors, the most pressing of which is climate change and the fear that a diminished biodiversity will fail to respond quickly enough with the result that some ecosystem services could be undermined. Crops could be deprived of essential ecosystem services even where the crops themselves have been selected for a modified climate. The risk may be small, but the implications are unknown, though potentially huge. We may not be able to quantify the insurance value of having a high level of biodiversity (Costanza et al. 2000), but a cautious approach represented by the "precautionary principle" would suggest that we ignore biodiversity at our peril.

(2) External costs

Secondly, loss of biodiversity due to agriculture leads to externalities, or external costs, for others. Application of fertilizers or pesticides is inevitably imprecise and certain amounts will always find their way into surface or ground water. Pesticides pose a particular threat to human health as their very toxicity can lead to problems such as increased rates of birth defects, infant mortality, cancers or other diseases. Fertilizers lead to the eutrophication of water bodies by providing nutrients to algae which then reduce oxygen levels to the point where rivers and lakes become unsightly or devoid of aquatic life. The chapters on Water and Human Welfare, discuss the value of healthy river/lake systems to society for the purposes of drinking water and recreation or the indirect value represented by people's appreciation of the wildlife wetlands support. Consequently, there are very real and significant economic and social benefits associated with the avoidance of human health problems, recreation and tourism.

In principle, these external costs could be internalised by ensuring that farmers are charged or fined for pollution. However, diffuse pollution is difficult to identify and difficult to control. Government has therefore opted for the alternative of providing incentives to farmers to reduce pollution. Within the Common Agricultural Policy (CAP) these incentives have been provided in the form of agri-environmental policies, represented in Ireland by the Rural Environmental Protection Scheme. REPS was originally designed to reduce the negative externalities of agriculture, but the scheme has evolved over time to recognize the value of biodiversity within farming and of the need to adapt existing measures to protect biodiversity. These benefits are being realised through lower intensity farming or farming in which semi-natural systems are preserved. Such systems can often provide for higher levels of biodiversity than purely wild systems.

It would be a fallacy to presume that REPS does not have a useful income transfer function as well as an environmental function. Neither is the scheme entirely directed at protecting biodiversity. However, to an extent, the amount spent on REPS, at upwards of €280 million per year, does provide an indication of the minimum value that society places on both good environmental management and biodiversity.

3.1.1 Valuing Biodiversity within Agriculture

The value of biodiversity is at a maximum where an agricultural system is designed to be sustainable. Where the system is more intensive, this value may appear to be less, but future output will depend on some restoration of biodiversity. A closed-system organic farm in which no inputs are imported would represent the ultimate example of a sustainable system. The problem is that output is lower on organic farms and the price premia of organic produce does not generally compensate for lower yields in terms of higher revenue. Relative produce prices are still determined by supply and demand of all food products as much as by production costs.

Intensive agriculture is capable of producing a higher output. Although ecosystem services have distinct value, it is worth remembering that high intensity systems with low biodiversity dependence are commonly being selected by farmers the world over. Many farmers have clearly decided that the opportunity cost of protecting biodiversity, for example by setting aside areas of natural vegetation, is less than the economic benefits of a more intensive system (Ghazoul, 2007). Aside from some fundamental processes, the associated value of biodiversity therefore appears to be low.

This situation may arise because of a lack of awareness of the benefits of ecosystem services. It can also arise because biodiversity is a public good that often requires protection at community level, whereas agricultural output is a private benefit. Scientific opinion is that intensive agriculture is not sustainable in the long-term (Ryan, 1999), but farmers are not always in the position of being able to consider the environmental damage or the costs to future generations.

As an alternative, a broadly sustainable, but non-organic system would have a stronger relationship with biodiversity. A two-tier intensive/extensive agricultural sector is now the rural development prospect for Ireland and much of the EU (Binfield et al, Agri-Vision 2015). The extensive scenario has employment and social benefits and is likely to be represented mainly by smaller farms that are partly dependent on rural development payments. These payments reflect policy support for a scenario that favours farming systems which benefit the environment, rather than a system that ensures that high-output farming systems conform to environmental criteria. The former farms will not be able to match the high yields of the more intensive sector, although they are often capable of producing higher quality food. Before taking into account the social costs and benefits, ecosystem services may appear to be more valuable on these extensive farms than they would be for those with a greater dependence on artificial inputs.

A sustainable, high biodiversity system may not produce the gross quantity of output of an intensive farm. However, the value of biodiversity is best represented by its capacity to support a sustainable farming system with its associated environmental and social benefits.

A broadly sustainable agriculture of the kind envisaged under Rural Development Policy may still depend on external inputs and produce some waste, but to a lesser extent than the intensive alternative. These wastes should be of a quantity that could be assimilated by the environment. Where nitrates or phosphates accumulate due to ecosystem services having been diminished or overwhelmed, the cost of "clean-up" or of "damage avoided" provides a measure of the benefits of a functioning biodiversity.

Consequently, the value of biodiversity within a broadly sustainable agricultural system is represented by both the value of the crop and the benefit of damage avoided.

Amongst the problems which may arise when the ecosystem is damaged, is eutrophication. Eutrophication of surface waters due to phosphates and, to a lesser extent nitrates, is amongst the principal problems facing the Irish environment. A reduction in human welfare arises from eutrophication due to phosphates. Human health risks also arise where excess nitrates are not removed from drinking water. This is rarely done in Ireland despite elevated levels in parts of the South and South-East (GSI 2000).

In the UK, the benefits of dealing with all sorts of diffuse pollution to water have been estimated to be worth £250 million per year (Environment Agency, 2002). A measure of the value of a functioning biodiversity is the avoidance of the external costs from this pollution. A whole-farm sustainable system that is more dependent on biodiversity provides a more continuous supply of nitrogen to plants and pasture with far less wastage than fertilizers. Indeed, leaching of these nitrates is typically 25-50% less on more sustainably managed or organic farms.

As the welfare element is considered elsewhere in this study, it is worth addressing the costs of physical removal of pollutants. For example, the annual cost of nitrate removal in the UK has been estimated at between £24 and £38 million (Redman, 1996, Cobb et al. 1999. Defra, 2004). Adjusting these estimates for the number of households in Ireland and the size the arable sector suggests that at least €2 million per year should be spent to avoid additional external costs. In fact, the Department of Agriculture is spending €39 million per year on the Nitrate Directive via the Farm Waste Management Scheme and those elements of REPS directed at nutrient management. There will be private costs too for some farmers, most especially pig and poultry producers who must comply with IPC licensing.

3.1.2 Ecosystem Services

It is neither practicable nor entirely possible to deduce the relevance of all biological diversity in agricultural systems. This is because there are few studies in this area and global knowledge on the topic is very sparse. Most studies have focused on the adverse impact that agriculture is having on biodiversity, rather than the positive impact of biodiversity to agriculture. To illustrate the value of biodiversity, we can focus three principal ecosystem services, namely:

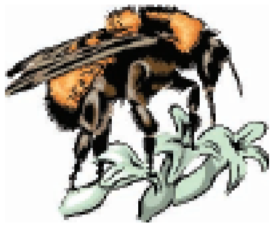
1. Pollination
2. Soil nutrient recycling,
3. Pest predation and parasitism.

In recent years, ecological thinking has edged away from the concept of "keystone species" responsible for such ecosystem services. Instead, there has been a recognition of the functional inter-relationships that exist between all species together with renewed attention to the issue of whether 'high biodiversity = stability', therefore providing the insurance required for sustainability. This, in turn, has led to increased interest in the concept of "redundancy", i.e. where the same ecosystem services can be provided by more than one species (Bolger, 2000). Within this hypothesis, it is accepted that the extent to which a species is redundant may depend on environmental circumstances at any one time.

Nevertheless, there is some evidence to suggest that those species that are most important, and which exhibit low redundancy, are the same species that could be lost first to environmental change (Larsen et al. 2005). The concept of keystone species therefore still has some validity and is, at least, of illustrative value.

3.2 POLLINATION

3.2.1 RELEVANT SPECIES AND FUNCTION



Amongst the most well-known services performed by a healthy biodiversity is pollination. Of pollinators, bees are the keystone species. As nectar is collected for both the colony and for the benefit of the individual bee, bees make more flower visits than any other insect. In Britain, honey bees (Apis mellifera) are presumed to be responsible for 80% of pollination, but bumble bees (Bombus terrestres) are the more efficient pollinators from a human perspective. Bumble bees are more active in our cool, wet climate. They are also the more willing to fly further from field boundaries into larger fields (Santorum & Breen, 2004). Their longer tongue length means they are able to pollinate a wider range of plants. While there are 13 true bee species in Ireland, the population of bumble bees, in particular, has unfortunately declined in recent decades. In parts of Britain and other European countries, this decline is now regarded as being quite serious.

3.2.2 RELEVANT SPECIES AND FUNCTION

Agricultural crops

Bees have an important, and often critical, role in the pollination of many horticultural and fruit crops. Ireland's agriculture also benefits from this pollination service, although our climate does mean that a lower proportion of agricultural output is represented by these crops than in most other European countries.

While Ireland may not be a big producer of fruit or horticultural crops, it does have a dependence on one crop whose association with pollination could easily be overlooked. Clover is very dependent on bees for pollination. Clover is a forage crop that fixes nitrogen from the air and so contributes both to animal weight and growth (Nolan & Grennan, 1998). Furthermore, clover is a substitute for nitrogen fertilizers on extensive and organic pastures. It could yet attain renewed importance given EU controls on artificial nitrogen fertilisers and expected trends towards extensification. Seeding depends on bees at a quantity of up to 15 colonies per hectare. Both honey and bumble bees can fertilize the agriculturally important white clover, but the latter's readiness to travel longer distances makes them the more useful pollinator in larger fields. For red clover, the length of the flower means that only bumble bees can "trip" the flower.

Of other crops, Ireland may not be a big producer of fruit, but some pollinated crops are nevertheless locally important, including tomatoes, strawberries and smaller quantities of apples and berry crops such as blackcurrant. Organic production of each of these crops is becoming more common. Apples have a high dependence on pollination by bees and between 0.6 and 5 colonies per hectare are required. Blackcurrants are also highly dependent on both honey and bumble bees.

In the case of strawberries, pollination is of most value to increasing seed number. Bee pollination also contributes to improved quality and fruit size.

Bee pollination is less important for tomatoes as pollination is achieved by wind, aided by the physical shaking of the flowers. Bees do, however, improve the efficiency of this process by vibrating the flower. Bee pollination is also of only modest importance to oilseed rape. However, it is reported to improve the timeliness and evenness of crop maturity (Williams et al, 1987). Furthermore, oilseed rape could yet become a very important crop in the future for biofuel.

Domesticated bees

Of course, given past trends towards agricultural intensification, it is no surprise to find that bees too have been domesticated for the purpose of pollination. The services of wild bees have in many cases been replaced by the provision of hives. In fact, this is a long established practice in orchards and the mutually beneficial relationship between beekeepers and farmers has been the subject of key economics papers (Coase, 1965). Due to natural population fluctuations, together with the decline in numbers of wild bees, this service has now become artificially available in glasshouses and polytunnels. Beginning with honey bees in the eighties, domestication of the more useful bumble bee has now become common. Bumble bees are less manageable than honey bees, although the latter are notoriously unreliable in tunnels, often choosing to escape once vents are opened.

Wild plants and gardens

Despite some domestication, wild bees will continue to be essential to the success of clover and of other crops grown on larger fields. Furthermore, as well as agricultural crops, bees are of obvious value to many wild plants. As can be expected, many of these plants provide food or habitat for other species, including those that are valuable, in some way or another, to ourselves. Some of these wild plants could be considered weeds by farmers but, in fact, provide nectar for the bees outside of those times when their services are required by commercial crops.

Naturally, bees also have an important role in gardens, including those where vegetables and fruit are grown. In turn, this makes bees essential to the output of the valuable garden centre trade.

3.2.3 ECONOMIC AND SOCIAL VALUES

International estimates

In the US, Robinson et al. (1989) have estimated that 31% of the value of US agricultural production is dependent on bees. This contribution is conservatively valued at over €9 billion per annum. Morse and Calderone (2000) are less cautious and estimate pollination to be worth up to €14.6 billion. Similarly, an estimate for Canada has been placed at C$1.2 billion per annum (Winston et al, 1984).

In the EU the contribution of wild bees has been estimated at €5 billion per annum, and €4.25 billion for domesticated bees (Corbett et al, 1991).[2] For the UK, Carreck and Williams (1998) apply a weighting system for different crops. Using this method, they estimate a value of £172 million for outdoor crops and £30 million for those under cover. On the same basis, they estimate the average value of each honey bee colony to be £12.

The Economic and Social Value to Ireland

Bees provide a service to production that can be estimated directly in economic terms. An approximate estimate of the current pollination benefit of bees in Ireland would be €85 million per annum. This figure would represent a reduction on previous years given the increasing use of polytunnels and domesticated bees for much fruit and tomato production, in part because of the declining bee population. Domestication of bees has become far more widespread since the early nineties and provides something of a guarantee against natural fluctuations in bee populations despite the greater efficiency with which wild bees fertilise plants. As tunnels provide effective climate control, only rather small areas of outdoor strawberry production remain.

Table 3.1: Direct benefits of pollination
(Applying the pollination weightings used by Carreck and Williams, 1998)

	Weighting	Area (ha.)	Value	Value of pollination
Clover (weight gain direct & indirect)	0.5	10% area 20% wt gain 5-8% sheep	€1,479mn (cattle) €1,323mn (milk, etc.) €190mn (sheep)	€29mn.
Oilseed rape	0.1	3,400	€5mn.	€1mn
Peas, beans	0.1	3,400	€50mn.	€5mn.
Apples	0.9	631	€2.6mn.	€2.3mn.
Strawberry	0.1	150 (450 indoor)	€4mn.	€0.4mn.
Blackcurrant	0.9	200	€0.1mn.	€0.09mn.
Other soft fruit	0.1 – 0.9	225	€28mn.	€14mn.
Total value				€53mn

Gross values before subsidies. 2005 values (CSO).

[2] Original estimates were in ECUS. All figures would need to be adjusted upwards for inflation.

There is no specific information on the marginal value of bees. However, it would not be unreasonable to attribute a portion of the additional input cost represented by the provision of domesticated colonies to the decline in the wild bee population as an indication of the benefit of this ecosystem service. Moreover, the relative value of wild bees is increasing as the population declines and farm systems change. Demand for biofuels is expected to bring about a doubling of the area of oilseed rape across the EU (Doyle, 2007). Bees are also important to the cross-pollination of an increasing production of hybrid crops, including fruits.

Furthermore, the role of bees in the pollination of clover may mean that this ecosystem service becomes yet more important given that clover is a natural substitute for polluting nitrogen fertilizer. Were clover to play a greater role beef and dairy production given trends to more rigorous environmental criteria including nitrate management, the biodiversity contribution of pollination could be worth far more in the future. Currently, grassland farmers account for two thirds of the €250 million spent annually by Irish farmers on nitrogen fertiliser (CSO, 2006). In the UK the external costs of excess nitrogen application, in terms of human health and acidification, have been estimated at between £0.5 and £1 billion per year (Hartridge and Pearce, 2001).

In that bees are also important for parks and gardens, they also perform an important economic role in helping to support Ireland's 380 garden centres and an amenity/plant industry that is worth around €300 million of which the farmgate value of nursery stock is €50 million. Gardens have a very important social role too, of course, and one that certainly has economic, social and health benefits. The bees contribution is, though, of more value to vegetables than for blooms.

Of ultimately more importance, is the equivalent economic and social benefits that are associated with countryside recreation. Bees ensure the survival of many wild plant species and are vital as food or habitat for Irish wildlife as well as being a fundamental element of the familiar rural landscape that is valued by so many people. The size of this public good is unknown, but is obviously considerable. According to Corbet et al. (1991), 27% of the 321 bee-pollinated wild plant species are endangered.

3.2.4 THREATS

Pollination is an ecosystem service that is under threat from the falling bee population. As well as falling absolute numbers, there has been a decline in the diversity of species recorded on farms. Bumble bees, in particular, have declined significantly. Already, in Britain, field beans often have to be pollinated by hand because of the shortage of bees. In Ireland, crops grown under cover are already dependent on domesticated bees. Orchard owners are taking pro-active steps to ensure pollination given both the decline in wild bees and falling interest in beekeeping.

The exact reasons for the decline in many bee species are unknown, although the usual suspects present themselves. Insecticides and herbicides are certainly two culprits. So too has been a viral disease that has been slowly spreading northwards across the country. More insidious, perhaps, is the trend to monoculture using uniform seeding supported by fertilizers and large field size. These practices have reduced the variety and continuity of the bees' food sources. Bees are noticeably less common and diverse on intensive farms (Santorum & Breen, 2004).

Ultimately, a healthy wild bee population is essential to the renewal of the domesticated population. In the United States, honeybee populations have declined from around 3.4 million colonies in 1989 to 2.5 million in 2004 (USDA 2006). In 2006, beekeepers witnessed a massive and sudden decline in domesticated populations known as "colony collapse disorder". Although the problem affected between one quarter and a half of beekeepers, the cause of the problem remains unknown (Reilly, 2007).

3.2.5 COST OF PROTECTION

REPS contains a field boundary measure and another to protect field margins and streams from chemicals. Growing recognition of the biodiversity benefits of field margins, and the direct contribution that this habitat can make to on-farm productivity, means that REPS is being redesigned to better support biodiversity explicitly. Much, however, depends on implementation as attempts at ensuring a good mix of hedgerow plant species can be undermined by careless crop spraying and nutrient management (Feehan, 2002).

Measures that protect hedgerows and leave field margins uncultivated may not be sufficient on their own, but they will help to combat the decline in the bee population. Banaszak (1997) recommends that 25% of farm area should be preserved as semi-natural habitat to ensure bees' survival.

3.3 SOIL MICRO-ORGANISMS, INVERTEBRATES AND FUNGI

3.3.1 RELEVANT SPECIES AND FUNCTION

The soil biota is the most species rich component of the terrestrial ecosystem (Bolger et al, 2000). One gram of soil alone contains several thousand species of bacteria and other micro-organisms (Torsvik et al, 1994). Macrofauna such as earthworms physically break up the litter from vegetation such as dead grass and leaves, while also releasing some nitrogen to plants and benefiting soil structure. Mycorrhizal fungi, microbes and smaller invertebrates then take over and are responsible for final decomposition and the essential supply of nitrogen. This organic life ensures that the soil is the second biggest store of carbon after the oceans.

Rather little is known about the smaller species and microbes, for instance springtails (Collembola), mites and nematodes, on which very little research has been conducted in Ireland. Likewise, little is known about the complex positive and negative inter-relations that prevail between species, the vulnerability of these relationships, or levels of redundancy (i.e. where various species perform the same functions).

3.3.2 ECOSYSTEM SERVICES TO AGRICULTURE

Soil biodiversity is critical to agriculture. Without the ecosystem services provided by the soil micro-organisms, farming would not be possible. The absolute value of biodiversity could therefore be quantified as the value of all agricultural output as a minimum. It is true that intensive agriculture can do without the services of some organisms by replacing their contribution to nutrient recycling with a supply of inorganic fertilizers (just as domesticated bees can partially replace wild bees). However, doing so at sustained high levels ultimately risks undermining other ecosystem services that cannot be substituted. It also contributes to water pollution in that inorganic fertilizers remain in the soil only for short periods before being flushed out by rain. Only a maximum of 50% of soil nitrogen can ever be derived from artificial inputs (Robertson & Swinton, 2005).

Amongst soil fauna, the contribution of earthworms is perhaps the most familiar and understood. Earthworms are most at home in broad-leaf woodland, in mixed farms and on pasture. The last of these can support between 10-15 species and as many as 390 individuals (per square metre). Despite all this activity, the direct contribution of earthworms to nitrogen provision could be less than 1%. However, earthworms are essential to the initial process of litter removal and its fragmentation for use by other soil organisms. Their burrowing and cast formation is also of great value to maintaining a good soil structure which allows water infiltration and aeration.

Ploughing drastically reduces the population of earthworms, particularly where the land is given over to monoculture (Schmidt et al, 2001). However, where the use of mechanical methods is minimized, earthworm numbers can actually be higher on more intensive than on low input fields, at least where subject to field rotations and possibly due to the higher harvesting waste that is left behind (Bailey et al., 1999; Cole et al., 2006). Only in the case of intensive monoculture systems is there unanimous agreement that agriculture can have an adverse impact on the soil biota. Earthworm populations can also help rehabilitate previous tillage land where this has been left fallow and can even be purchased for this purpose (Schrader & Larick, 2003). Where earthworms are absent, organic acids in the soil can increase leading to increased soil acidification.

Relating the ecosystem service of earthworms with agricultural productivity is an unreliable approach given that earthworms are but one part of the web of inter-related ecosystem services. To begin with, different earthworm species provide varying functions at different soil depths. Another factor is that the various ecosystem services which are performed varies depending on the agricultural activity. For example, earthworms have been observed to lead to a significant uptake of nitrogen in wheat systems not subjected to ploughing, but make an indistinct contribution where wheat is grown with nitrogen-fixing clover (Schmidt, 1999). Indeed, the relative contribution of earthworm and clover is difficult to pin down precisely, although earthworms do benefit clover by aiding germination and increasing the availability of phosphates.

The results of experiments performed in field plots often vary. However, New Zealand or the Dutch polders provide large-scale laboratories in that earthworms were formerly absent. In New Zealand, Stockdale (1966) found dry matter production increased by 19% in two years after introduction of A. catiginosa. Long-term improvements were of the order of 25-30% in New Zealand (Lacy, 1977) or 10% on the Dutch polders (Hoogerkamp et al, 1982).

Where earthworms have diminished, dramatic reductions in soil porosity have been identified with consequent lower water infiltration (Lee, 1985). Westeringh (1972) observed a significant build up of un-decomposed surface matter on Dutch farms where the earthworms and other soil fauna were no longer present.

3.3.3 ECONOMIC AND SOCIAL VALUES

Soil biodiversity was far and away the highest biodiversity value estimated by Costanza et al. (1997) at over $17 billion. Estimating the contribution of one species is near impossible given that the contribution of each single species is complementary to that of others. For earthworms, the relationship with dry matter growth is itself subject to many factors. Nevertheless, this keystone species has a clear value in both releasing nutrients to the ecosystem and in removing dead matter that would otherwise choke new growth or harbour disease and pests.

Bailey at el. (1999) examined the value of earthworms through the relative costs and productivity returns of two arable systems, one based on ploughing and seeding, the other on direct drilling which relies on earthworms for aeration and mineralisation. Comparing the relative populations of earthworms, they arrive at a value of between £0.08 and £0.48 per kilo of earthworms. At a minimum earthworm biomass of 125kg/ha., this would be equivalent to between £10 and £60 per hectare per year.

Losey and Vaughan (2006) focus on a particular obscure, but nevertheless valuable function, namely dung burial. While this might seem a little peripheral, it is worth noting that each cow can produce over nine tonnes of waste per year. It is also worth bearing in mind that, in Australia, dung beetles needed to be imported at an early stage in the country's settlement so to deal with the accumulation of sheep and cow manure that would otherwise have taken many more months to disappear from the landscape while meanwhile providing a micro-habitat for parasites. In Ireland, this service is performed by both earthworms and beetles. Losey and Vaughan estimate the value of their work in the US to be €380million per annum based on the value of beef cattle alone. Dung beetles also assimilate most of the nitrogen from the dung (2%) which would also be lost to the atmosphere.

Another route to identifying the value of soil biota is through its more efficient and continuous supply of nutrients to plants. Artificial nitrates are quickly leached into the subsoil and external environmental costs follow in terms of the pollution of watercourses. As noted above, this cost can be estimated in terms of the cost of nitrate removal from drinking water and from the external cost of eutrophication of waters that are valued for angling or amenity. Bailey et al. (1999) estimated that the more intensively farmed fields in their survey experienced excess leakage approximately twice that of the low input system.

Economic and Social Values in Ireland

If the approach of Bailey et al. were to be transferred to Ireland, the benefits would amount to £18 million per year if the same conditions apply. However, the overwhelming majority of agriculture in Ireland involves animals. Nitrogen recycling is still critical to grass production, but nitrogen losses are less as Ireland's more permanent ground cover reduces erosion and leaching. Phosphates from slurry applications are the greater problem.

The Losey and Vaughan study of cow pats is of relevance as earthworms are important to their disposal in Ireland. In a similar European context, Holter (1982) found that an average population of earthworms in Denmark was responsible for the disposal of at least one third of the mass of cow pats. However, high grass growth and trends to reduced stocking density mean that the fouling of pasture is a less serious problem here than in some other countries.

For Ireland, it is perhaps easier to consider the contribution that earthworms make to the overall production of vegetative dry matter (forage). Average baseline conditions in Ireland support over one livestock unit (roughly one adult dairy or beef cow) per hectare. The soil fertility that makes this possible could, in principle be replaced through artificial inputs. However, continuous artificial nitrogen input would reduce the transformation properties of the soil (Fromm, 2001). Furthermore, the soil biota has the virtue of providing a constant stream of nitrogen. If results from New Zealand or the Netherlands apply to Ireland, then earthworms contribute to up to 25% more forage production than would be achieved in their absence at this baseline. Hence, the presence of earthworms could be said to contribute up to €723 million per year in terms of the value of livestock production.[3] Adding a comparable contribution to tillage and horticultural crops (value €1.3bn) - noting especially the important services that earthworms provide to soil structure - could raise this value to over €1 billion. The figure would still be modest in relation to the value of the whole soil biota.

In practice, some artificial nitrogen fertilizer is used even in low intensity cattle farming. Rather than considering the soil biota's capacity to replace nitrogen fertilizers, it may be more pertinent to consider its capacity to quickly recycle nitrogen from slurry whose inefficiency as a fertilizer means it is prone to pollute watercourses. Indeed, an active soil biota has the potential to replace slurry in association with a grazing system that employs clover. Clover is both forage and fixes nitrogen from the air. It is difficult to manage, but could be more widely adopted by farmers in response to new

[3] Irish beef, dairy and sheep output (2005) was respectively valued at €1,417mn, €1,335mn and €192million. Exports (less live imports and milk products) totalled €2,573mn.

nitrate regulations that now limit the application. Nearly 40% of dairy farms with intensities less than 2 livestock units are affected by the nitrate regulations. More widespread adoption of clover could replace a small portion of the 300,000 tones of artificial fertilizer which is applied each year at a cost of €270 million (McQuinn et al, 2005). However, a potentially greater benefit could follow from any replacement of slurry which, as a waste product, costs nothing, but imposes a far higher cost on the environment.

3.3.4 THREATS

Many useful species are clearly reduced in numbers by intensive agriculture, particularly tillage on large fields where pesticides and herbicides are used. The low level of recovery in earthworm populations following intensive tillage has alarmed some researchers (Curry et al, 2002). On the other hand, there are species, e.g. M. minuscule, which do appear to thrive on cultivated land (Schmidt & Curry 2001).

Earthworm populations have been threatened by the importation of exotic species, notably the New Zealand flatworm (*Arthurdendyus triangulatus*) which predates on earthworms. However, the evidence to date is that flatworm populations have largely been confined to gardens and have struggled to sustain high populations away from this favourable habitat. Ultimately, flatworms cannot survive without their prey. However, they are an additional unwanted source of instability to an ecology that is already threatened by disruptions due to climate change and chemical residues.

Tunnel warfare

Earthworms in Ireland are under attack from deadly alien Australisian flatworms whose choice of attack is to inject poisonous enzymes into their prey before eating them alive. Such a vicious end is hardly deserving of a creature which has a justified reputation of the gentle good guy of the soil community. However, it seems that once transplanted to new surroundings, earthworms can very quickly become the destructive boyz-in the hood. While, at home, the common earthworm *Lumbricus terrestris* is content to labour away at turning over the nutrients from leaf and other vegetable litter, this enthusiasm has run wild in North America where earthworms were not previously to be found. In the maple forests of the eastern United States, the familiar flowers and other flora of the forest floor depended on a thick layer of leaf litter or "duff". Unfortunately, where European earthworms have established themselves, the forest floor has been reduced to bare earth. As though this is not bad enough, *terrestris* may soon have a new territorial battle in its new home in the form of a yet more voracious competitor belonging to the Asian genus *Amynthas*, once better known to anglers as good fishing bait, it harbours aggressive territorial ambitions.

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The concept of redundancy comes into its own in relation to the soil biota given the great number of species present. Some ecologists favour a more profound impact for macrofauna such as earthworms (Cole et al., 2006). Another observation is that redundancy is less prevalent in soils with low biodiversity (Bardgett, 2002; Cole et al., 2006). Beare et al. (1995) accept that there is a high level of redundancy within single functions, but that a suite of species is necessary to ensure that these functions are continued under changing environmental conditions, within multiple micro-habitats and at various depths (Griffiths et al., 2000; de Ruiter et al., 2002). Climate change could cause major disruptions to these species assemblages and inter-dependencies which could undermine familiar ecosystem services while also permitting the release of soil carbon into the atmosphere with compounding consequences for temperatures. Soils are the largest reservoir of carbon after the oceans.

3.3.5 COST OF PROTECTION

No specific measures have been introduced to protect the soil biota despite its fundamental importance to agriculture. Certainly, REPS measures play a part by promoting better nutrient management and by reducing the incentive to apply chemicals. Nitrate regulations could also lead to farmers playing greater attention to the natural supply of nutrients through the soil biota. In the UK, increasing attention is also being given to soil erosion, especially given the prospect of climate change induced drought and flash flooding. Conservation tillage in which use of ploughing is minimised is reported to reduce erosion losses by 90% (CIW, 2006). It would also help to protect earthworms and other invertebrates which, in turn, play an important role in naturally supporting soil structure and improving water infiltration.

3.4 PEST CONTROL

3.4.1 RELEVANT SPECIES AND FUNCTION

A healthy level of biodiversity ensures that insect and animal pests are more likely to be controlled by their natural enemies. More intensive farming in which pesticides and other chemicals are used removes the food source of many natural enemies while herbicides and removal of field boundaries reduce their habitat. Insecticides keep pest populations low, but do so at the risk of environmental pollution and with the possibility of destabilizing the system such that pests could experience a sudden increase in population in the absence of predators. Indeed, pest species may become resistant to some insecticides in the long run.

Insectivorous birds provide an important service in terms of pest control. So too do predators such as ground-dwelling spiders and carabid beetles, flying species such as gall midges (Cecidomyiidae), hoverflies (Syrphidae) and ladybirds (Coccinellidae). In addition, there are thousands of parasitoid species such as wasps which infest host species with their eggs.

3.4.2 ECOSYSTEM SERVICES TO AGRICULTURE

In Ireland, fungus presents the greatest risk to agricultural production. Therefore, indiscriminate use of fungicides, followed by herbicides, are the main problems for biodiversity. Losses to insects are less than in some other countries, but are not insignificant. For example, aphids are a major problem and also a common prey or host for other insects. Schmidt et al (2003) found that aphid populations were 70% higher in the absence of flying predators and parasitoids. They were 172% higher when both these and ground-dwelling predators were removed. Pasasitoids appear to be most effective. Indeed, most pests are not controlled by pesticides, but by their natural enemies. Providing artificial habitats, such as "beetle banks" of dead wood, can be highly effective in controlling these farm pests (MacLeod et al., 2004; Thomas et al., 2000).

Predators and parasitoids are of most benefit to horticulture and cereal farming. As these crops represent a lower proportion of Ireland's agriculture than in many other European countries, the overall relevance of predators and parasitoids is less. Even so, aphids and other pests can cause serious losses for arable farmers by their feeding on roots, shoots or pollen, or through the spread of fungal and viral disease.

3.4.3 ECONOMIC AND SOCIAL VALUES

International studies

The economic benefits of predator and parasitoid populations obviously depend on the level of aphid infestation and the type of crop. Schmidt et al's experiment was performed on winter wheat for which a threshold level of economic damage has been estimated by Giller et al (1995) at five aphids per shoot.

Few other studies have quantified these benefits. In the US, Losey and Vaughan (2006) estimate crop losses due to insects to account for 15% of the value of production. They further estimate that 65% of any additional loss is being avoided through the use of pesticides or predatory natural enemies. By assuming that 39% of this loss is due to native pest species, they arrive at an estimate of the benefit of natural pest suppression to be €4.5 billion per annum.

Integrated pest management (IPM) can be used to manipulate predator populations in order to control pests without resorting to pesticides. In one such system for a celery crop in the US, Reitz et al. (1999) report the use of 25% less pesticide and lower pest management costs. Studies in the UK have shown that IPM systems can reduce costs with little if any reduction in output. At present, in eastern England, around £100 per hectare is spent by arable farmers on agro-chemicals other than fertilizer (Defra, 2000).[4] In the UK, Hartridge and Pearce (2001) have estimated the costs of physical removal of pesticides from drinking water to be £125 million per year, with the additional costs of food and water monitoring, as well as farmer sick days to be £10.8 million per year.

[4] Pesticide is often taken to include both herbicide and insecticide. In this section, the term is taken as being equivalent to insecticide.

As well as the potential monetary savings on pesticide use, there are also significant benefits to human health from IPM as such chemicals have been implicated in various diseases and birth defects. There is also the avoidance of further losses of biodiversity. Pesticides have been implicated in the decline of species such as grey partridge and corn bunting. In the US, health and biodiversity costs have been estimated as being twice those of the actual expenditure on pesticides (Pimental et al. 1992). Most European studies have produced more conservative estimates of external costs, although, for Germany, these have still been placed at US$148 million per year, or 20% of pesticide expenditure (Waibal & Fleisher, 2004).

Economic and social values in Ireland

Aside from the Losey and Vaughan estimate, the capacity of predatory or parasitoid species to reduce significant outbreaks of pests does not appear to have been demonstrated in economic terms. Some evidence of relevance for Ireland is available from the use of IPM or similar systems in North-West Europe. Bailey et al. (1999) report on the use of integrated agricultural production (IAP) in a farm in Scotland where reduced levels of pesticides were used in a system of managed input reductions. They find that the integrated system provides higher returns (31%) than a conventional agricultural system. Output is lower, but so too are variable costs, mainly due to the lower use of chemical inputs. Bailey et al. report that 20% less pesticide was used on the IAP farm.

Around 2,800 tonnes of chemicals were used by Irish farmers per annum in 1994 (Taylor & O'Halloran, 1999), a figure that is since likely to have increased based on UK trends and the larger area of oilseed rape. In Ireland, annual cereal pesticide sales are €600,000, but additional amounts are spent in horticulture and in gardening, bringing the total figure to over €3.3 million. Pyrethroids are the most commonly used insecticide. A 25% reduction in pesticide usage due to improved protection and recognition of the role of natural enemies in pest management could therefore account for benefits of half a million euro in saved expenditure and the public benefit of avoided external costs to health. However, a greater benefit is realized in terms of damage avoided through the existing level of predation.

3.4.4 THREATS

Inevitably, intensive agriculture reduces populations of predatory and parasitoid species, particularly where pesticides are used. Possibly the scale with which agro-chemicals are used may be more critical than their actual toxicity (Purvis & Bannon, 1992). By relying on large fields, monoculture also has the detrimental affect on predatory species by removing the hedgerows and other on which they depend. Specialized parasitoids often have smaller ranges than their hosts, and are therefore vulnerable to any fragmentation of habitat or loss of habitat diversity which reduces the variety of food sources and the potential to disperse (Zabel & Tscharntke, 1998; Tscharntke, 2005). Carabid beetles are an exception that can recover from insecticide attacks due to their capacity to disperse.

Supplies of pollen are often an alternative food source for many parasitoid species which may depend on only a single pest host. Other species, such as spiders and predatory beetles, are influenced by the landscape mix at a larger spatial scale (Symondson et al, 2002).

3.4.5 COST OF PROTECTION, CURRENT MEASURES AND FUTURE STRATEGY

The capacity of particular species to recover from environmental shocks varies. Important means to preserve key species include maintaining a network of field boundaries and a continuation of diverse food supply through mixed or intercropping or crop residue. Unadulterated field margins appear to be especially important. Although these can also provide a habitat for pest species (van Emden, 1965), the evidence is that predatory species benefit proportionately. In a review of various studies, Bianchi et al. (2006) report that predatory species were 74% higher, and pest species 45% lower in varied landscapes.

3.5 IMPLICATIONS OF BIODIVERSITY LOSS IN AGRICULTURE

3.5.1 BIODIVERSITY CHANGE

The rural landscape is changing over time. In the more productive areas, this change was quite dramatic in the early years of membership of the European Common Agricultural Policy. The more distinct changes have arisen from changes in farming practice, with implications for natural vegetation and habitats. As natural habitats have become more fragmented, the populations of widely seeding species and their associated host species are vulnerable. Numbers of bees and other beneficial insects have declined dramatically largely because of the lower diversity of farming systems and loss of habitat, for instance hedgerows. In turn, natural plant species which depend on animals and insects for seed dispersal or pollination are themselves in danger of extinction. Formerly common farmland bird species have either disappeared or been forced into more marginal habitats. Many of these species, including corncrake (Crex crex), corn bunting (Miliaria calandra), yellowhammer (Emberiza citrinella) and grey partridge (Perdix perdix) are associated with mixed farming systems. As Irish farming has become more specialized, there is a lower variety of food sources to support these species, particularly as grassland systems have become more dominant.

3.5.2 IMPLICATIONS FOR AGRICULTURE

The loss of biodiversity on Irish farms has been well-documented (for example, Jones et al. 2003). Biodiversity loss has implications for our own social and economic well-being, and for agricultural productivity. If plant diversity is being reduced over time, then the consequences of this extend beyond the habitat of wildlife alone. Tilman et al. (2005) refer to numerous studies that have demonstrated that lower plant diversity leads to less primary productivity, less carbon storage and greater leaching of nitrates.

Farming systems high in biodiversity can have a productivity that matches, or even exceeds, that of systems supported with high inputs. A linear relationship between grassland plant species richness and plant productivity can be demonstrated, at least initially (Finn et al, 2000, Gross et al, 2000). This productivity, in terms of forage production, in turn contributes to weight gain by herbivores. The gain may be less than that which can be achieved through deliberate intervention to improve sward diversity, for example through the seeding of productive grasses or clovers, but is achieved without polluting inputs and with the benefit of sustainability and high biodiversity. In Britain, Bullock et al (2001) have reported increases in hay yields of 60%. Although the costs of the seed exceeded the value of the production gain in the first years, these higher yields continue for subsequent years. Furthermore, part of the higher long-term yield also derives from an associated portfolio effect. That is, the diversity of vegetation is less vulnerable to changes in external conditions such as exceptionally wet or dry years (Tilman, 1996).

Agriculturalists understand that a diverse covering of vegetation provides herbivores with naturally diverse and nutritious grazing. Many farmers too recognize the benefits of both vegetation and crop diversity. They are aware that combined sheep/cattle grazing systems can be more productive than ones based on simple species. Sheep reduce the amount of clover but increase the amount of Poa trivialis, whereas cattle tend to increase the relative amount of clover to grass (Conway et al, 1972, van Rensburg, 2006). Unfortunately, artificial support policies have tended to favour specialization. Research by De Falco and Perrings (2005) confirms the benefits of diversity in terms of both revenue and risk aversion in cereal production. High levels of stocking, supported through the application of inputs and additional food supplements, will impact on the more palatable species, leaving behind less palatable and nutritious grasses such as nardus or mollinea in the case of upland grazing (Hulme et al. 1999). Early appearing grass species that are important for spring nutrition are also suppressed by heavy grazing (Silva, 1987). Even after 30 years, fields that have previously been fertilized with phosphates (15-30kg/ha), have been found to still be dominated by single species such as L. perenne with only low levels of nutritious Agrostis tenuis and Poa trivialis (Culleton et al, 2001).

3.5.3 POLICY OPTIONS

Policy is now changing. Significant changes have been foisted on the CAP in response to budgetary constraints and pressures to achieve consensus on world trade. REPS has encouraged more environmentally friendly farming and is incorporating new measures that are more pro-active. Even aside from REPS, all farmers are now being supported through area-based payments rather on output. This reduces the incentive to over-production and leaves open more options for enlightened policy support.

There is, however, no evidence, as yet, that agri-environmental measures such as REPS, are having any significant impact on biodiversity (Feehan et al, 2002), an observation that appears to be mirrored elsewhere in Europe (Kleijn, et al, 2001). Part of the problem is that agri-environmental schemes only operate at farm level whereas biodiversity really requires policies that operate at the wider landscape level. At this level, Haines-Young et al. (2003), in a major UK study of all farm types, find positive trends towards more extensive (lower input) farming in the uplands, an overall lessening of the conversion of semi-natural habitats, and an increase in woodland cover. At the same time, though, they report a decline in the quality of these habitats and a widespread loss of biodiversity on lowland farms. Similar trends have probably been occurring in Ireland.

Looking ahead, there is still the risk that smaller Irish farms will disappear and those that remain will be yet more homogeneous and dominated by grass. Marginal farming areas could be farmed very extensively or virtually abandoned (Binfield, et al. 2003). Such trends could further reduce biodiversity.

The positive factor is that Irish farmers have shown themselves to be responsive to policy incentives. Just as in the past, policy led to a loss of low-intensity mixed farming, so it can be re-tuned to support more sustainable farming and better agri-environmental policies that could deliver on biodiversity. One option is a landscape led approach, rather than a conservation led approach, that maintains biodiversity in complex landscapes containing areas of natural and semi-natural habitat that compensates for more intensive activity elsewhere (Tscharntke et al., 2005).

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4. BIODIVERSITY AND FORESTRY

4.1 THE RELATIONSHIP BETWEEN FORESTRY AND BIODIVERSITY

Forests provide a range of ecosystem services including the direct benefits of forest products and amenity, and the indirect benefits of carbon sequestration and the retention and filtering of water. In countries with large areas of forest, both temperate and tropical, these benefits have been argued to far exceed those from timber or conversion to agriculture (NFPA, 2006).

The situation for Ireland is rather different in that forest represents such a small proportion of the land area. While the area under forestry has increased from just over 1% to 9.8% of the land area (Fahy & Foley, 2004), almost all this increase has been represented by commercial forestry based on exotic conifers. As trees grow quickly in Ireland's climate, the wood is fibrous and so is used mostly for pulp and board. This leads to a tendency for short-rotations whereas longer rotations would be more ideal for biodiversity.

The Forest Service has set a national target of increasing forest coverage by 20,000 hectares per year to 2035. Conifers will constitute the greater proportion of this planting, but the Native Woodland Scheme and elements of the Woodland Improvement Sub-Measure now encourage the planting of native broadleafs too. This is a positive move in that broad-leaf woodland contains a high diversity of plant and animal species that cannot readily adapt to commercial forestry. Furthermore, the inclusion of objectives for broad-leaf woodland is especially important for biodiversity in that surviving examples of old woodland sites are rare. In 2002, such forests represented only 6.3% of Coillte's estate.

The benefits of native broad-leaf woodland arise from the mix of tree, shrub and ground-cover plants, the varying age profile of the trees, and the presence of natural clearings represented by alternative micro-habitats. The rich biodiversity is demonstrated by an abundance of invertebrates which survive on dead or decaying wood or hole-nesting birds. The scarcity of such woodland in Ireland means that many of these species are now absent or rare, although the mixture of pasture, conifers and scattering of broad-leafs does mean that Ireland has an estimated 40% of the European population of badgers (Hayden, 1995).

Plantation forestry typically contains many of the same limited range of non-native species (Carey, 2003). Trees are usually grown as a densely-planted monoculture. Alternative planting regimes which are more supportive of biodiversity are likely to be less economic. They can be supported through appropriate grants, although potentially an enhanced market exists for hardwoods, e.g. for house construction or flooring, and this could yet encourage more broad-leaf planting. Short-lived biomass plantations, although typically another monoculture, could also have some biodiversity benefits where not clear-felled or planted on ecologically valuable land.

(I) Sustainability and External Costs

Much of Ireland's plantation forest has been planted on poor quality grazing land in uplands. By adding diversity into a largely grassland landscape, plantation forestry can provide some ecological benefits in its early years before canopy closure. Young plantations support good populations of songbirds, small mammals and associated predators such as hen harriers and merlin (Hickie, 1990, Good et al, 1991). Alternatively, if allowed to fully mature, trees can provide for large invertebrate populations, hole-nesting birds and for other species feeding off dead-wood.

Unfortunately, much of the planting prior to the mid-1990s occurred on old demesnes and marginal land, sometimes replacing previous areas of broad-leaf. Where this has occurred, the benefits have often been out-weighed by the destruction of valuable semi-natural or peatland habitats. If planted on poorly buffered soils, conifer plantations can contribute to the aluminium toxicity and the acidification of water-courses leading to a loss of aquatic biodiversity and external costs for anglers due to reduced fish populations. In addition, a sizeable external cost arises from the aesthetic impact of blocks of densely packed conifers which have been planted with little consideration for the surrounding landscape, a familiar site in many upland areas.

Despite these shortcomings, Clinch (1999) reported that the public have a generally positive view of the Government's afforestation targets even though these marginally failed to pass a cost-benefit test using Department of Finance criteria. He noted that there is some potential to realise external benefits in terms of carbon sequestration, but that the biodiversity benefits of proposed expansion may be limited. On the assumption that planting would occur on poor grazing land, Clinch believed that this would involve the replacement of one low diversity system with another.

The Forest Service has acted to ensure that all forestry is now subject to Sustainable Forest Management. Planting guidelines now take ecological and landscape factors into consideration. This has involved retention of areas of broad-leaf and of ecologically valuable glades of open space. Eligibility for grant aid also requires that planting occurs on yield class 14 or above which effectively excludes marginal land and peatland.

4.2 RELEVANT SPECIES AND FUNCTIONS

The threat of deforestation of tropical forests has meant that they have been the subject of much research activity which has demonstrated their benefits in terms of climate, water retention, erosion prevention, pollination and pharmaceutical products. However, ecosystem services within temperate European forestry have received rather less attention, particularly for plantation forests.

In terms of the positive contribution of biodiversity to tree growth or quality, much of the same ecosystem services provided by biodiversity in agriculture also apply to commercial forestry. For example, the natural recycling of organic matter and mineralization of nitrogen is as relevant to forestry as agriculture and sufficient to avoid the need to apply artificial fertilizer. However, phosphates are regularly applied in the early years.

Forest managers are more conscious of biodiversity from the perspective of meeting government policy requirements which, themselves, stem from a perception that biodiversity has social value. Wood is no longer the sole output of forestry, particularly for a semi-state organization such as Coillte. Increasingly, forest managers are being required to take account of biodiversity and sustainability to meet government environmental criteria or to qualify for product certification. The absence of an obvious feedback in terms of ecosystem services, means that foresters have less incentive than farmers to respect biodiversity as a route to qualifying for government environmental payments at least economic cost. Nevertheless, managing for biodiversity does not necessarily imply significant net costs in that a more diverse age or species stand can provide some direct benefits as described below.

From the perspective of the Forest Service, biodiversity objectives do help to justify support to the sector in the context of increasing the nation's forest cover. Hence, indicators have been developed by the COFORD BIOFOREST project (http://bioforest.ucc.ie) as a means of demonstrating biodiversity outputs. These include structural indicators of biodiversity (e.g. area, connectivity, dead wood), compositional indicators (species numbers and diversity) and functional indicators (frequency or intensity of natural or human activities).

The principal social benefit of forest biodiversity in Ireland has been realised through recreation. As biodiversity and landscape variety are contributory factors to recreation activity, native woodlands would provide the highest benefits. Nevertheless, a good number of forest estates, although dominated by conifers, are popular destinations for tourism due to their open access and aesthetic value.

The hen harrier

Coillte have been active in the establishment of Biodiversity Action Plans for various threatened species. One of these is the hen harrier, a striking pale grey Bird of prey which breeds in scattered upland areas of Ireland. The hen harrier population has a love-hate relationship with forestry. On the one hand, it favours young conifer forest as nesting habitat, but it also needs undisturbed moorland for hunting. While its numbers had been increasing into the seventies, it has since declined due to the maturity of much forest and the loss of other areas to land reclamation. Persecution has also played a part, while the impact of windfarms is, as yet, unclear.

Agreement has recently been reached between the National Parks and Wildlife Service and the Forest Service to coordinate forestry plantings in Special Protection Areas so as to provide the ideal habitat mix by protecting existing blanket bog and ensuring a continual forest age stand.

4.3 ECOSYSTEM SERVICES

Soil fauna

The soil biota performs important ecosystem services in terms of nutrient recycling and nitrogen mineralisation. Some organisms form partnerships with tree roots to extract nutrients, others are important for breaking down organic matter. Just as earthworms remove dead vegetation from surface soil layers, they also perform the same function with leaf litter. Earthworm populations are highest in broad-leaf forest where they can contribute to the removal of the annual leaf fall within months. Comparing deciduous plots with and without earthworms in North America, Groffman et al. (2006) report removal of 28% of carbon in the top 12 cm of the forest surface. The pine needles of a typical commercial forest are less digestible and tend to accumulate for longer, trapping nitrogen. Therefore, while regular recycling of nutrients may be less important than for crops, there is a dependence on a rather narrow range of species that can digest this litter. Without this service, the forest surface would soon be smothered by material which would, in turn, provide a habitat for pests and pathogens. Retention of biodiversity also helps in the disposal of post-harvest litter and chipped debris. However, this benefit does not appear to have been quantified.

Pest management

Irish forests are relatively healthy compared with much of the rest of Europe. The principal problems are caused by fungal root rot (fomes and honey fungus) with some additional damage being caused by green spruce aphid and pine weevil as well as grey squirrel and deer. The spread of the pine weevil (Hylobius abietis) has been encouraged by the quantity of stumps left behind following clear cutting (Battles, 2007).

Purser et al (2006) remark on Ireland's vulnerability to alien pest species such as the great spruce bark beetle, particularly in the context of climate change which could present more favourable conditions for these pests. An indicator of the potential damage is provided from Britain where a North American beetle was responsible for the virtual removal of elms from the countryside during the seventies.

Nevertheless, there is little information on the role of biodiversity in keeping pest species in check (Watt, 1992). A predator wasp, Bracon hylobii, helps to keep down numbers of weevils, but not enough to stop Coillte artificially introducing parasitic nematodes or using insecticides. It is generally agreed that monocultures would be more susceptible to pests (Lugo, 1997). There is some evidence from abroad that mixed species forests do have a lower incidence of pests, e.g. spruce budworm in North America (Stiell & Berry, 1985; Hartley, 2006).

4.4 ECONOMIC AND SOCIAL VALUES

Around 2.5 million cubic metres of timber is produced in Ireland each year which, once processed, has a gross value added of €395 million. Typical rotations last for 40-50 years and, given that more than half the forest estate is less than 25 years old, this implies that production will increase in the future. In terms of jobs, the sector employs, directly or indirectly, 16,000 people.

As the soil biota is not under imminent threat of extinction and the benefits of pest control are unproven, the case for valuing the direct biodiversity benefits to forestry production is weak. Insecticide use during tree establishment costs over €100 per hectare and may need to be repeated for up to four years in some circumstances, including an absence of natural predators.

The stronger argument for protecting biodiversity rests on the social benefits. Various international estimates have been provided over the years of the non-market benefits of forestry, principally recreation, but also biodiversity and carbon sequestration. Forestry, as a topic, is regularly visited by environmental economic studies. In Ireland, the CAMAR study indicated an average willingness-to-pay per visit of between €1.02 and €2.73 (2003 values) (ni Dhubhain et al, 1994). A more recent report (Coillte/Irish Sports Council, 2005) put this value at €5.42, equivalent to €97 million per annum, but with up to an additional €268 million being spent on food and accommodation associated with visits. Both figures are based on forest use rather than biodiversity specifically. Clinch (1999) included non-use values in his estimate of €21.27 million per annum, noting also that this is a net figure allowing for people who dislike forestry. More recently, Bacon and Associates (2004) estimate that the current non-market benefits of forestry (recreation, carbon storage and biodiversity) are worth €88.4 million per annum, but that the poor treatment of biodiversity within the existing estate means that its contribution amounts to only €5.6 million per annum over that of the alternative land use (assumed to be REPS). On the basis of an assumption that 13% of the afforested area is set aside for biodiversity, Bacon and Associates calculate the proposed 20,000 hectare expansion would enhance this value by €1.6 million per year (a discounted NPV of €23m). This figure is small, however, in comparison an estimated value of carbon sequestration at €45 million per year.

It has to be acknowledged that these figures are modest due to the small size and composition of the forest estate. Whereas recreation is the main social benefit in Ireland, forests are a more prevalent feature of the landscape of continental Europe where they contribute more distinct benefits in terms of tourism and hunting. In the UK, the annual value of forestry recreation alone has been estimated at £392 million (Willis et al, 2003). However, the UK has 2.66 million hectares of forest (732,000ha broad-leaf + 256,000ha for amenity).[5] By comparison, Ireland has 700,000 hectares of forest, most of which is coniferous plantation with inevitably lower recreational and biodiversity benefits than broad-leaf forests, particularly native old-growth forests. The Irish population has little experience of mature deciduous forests as so few examples exist. Probably these benefits would be greater with an enlightened policy of expansion that encompasses amenity and biodiversity. As it is, Coillte have shown renewed interest in the amenity value of forestry in recent years.

4.5 THREATS

Most commercial forestry plantations have hitherto been comprised of Sitka spruce or lodgepole pine with the result, not only of a monoculture, but a monoculture of an exotic species. Biodiversity is typically low, particularly where plantations are large and of a single age class. The planting of single blocks of 200 hectares were not uncommon in the past.

Furthermore, as noted above, these forests were often planted on the most marginal agricultural land which, by virtue of its inherently low productivity, had frequently been little impacted upon by human activity and still characterised by high biodiversity.

A continuation of such trends would threaten biodiversity. Fortunately, the afforestation of blanket bogs has now virtually ceased due to the low yield class and absence of state grants for planting in such locations, but planting is continuing on marginal land that can be of biodiversity and landscape value. Government criteria for the Afforestation Grant Scheme now require the retention of 15% of the afforested area for biodiversity. Ten per cent of this area is recommended for broad-leaf trees. Other areas have been left as peatland or heath (O'Sullivan, 2004). Open spaces are recommended by ecologists for bats, birds and herb species. Clear felling is also being discouraged so as to permit the development of a more unevenly aged stand.

5 http://www.chm.org.uk/library/ecosys/forest/

Coillte is continuing with an ecological inventory and making improvements to forest structure, including the preservation of dead wood, so as to encourage biodiversity. Biodiversity Action Plans have been initiated in relation to pearl mussels (threatened by acidification and sedimentation), lesser horseshoe bats, hen harriers and raised bogs. Supported by EU LIFE funding, the company is involved in several projects to restore mature woodlands and bogs, including projects that are examining alternative forest management for peatlands in the West.

4.6 COSTS OF PROTECTION, CURRENT STRATEGIES AND FUTURE POLICY

Ecologists are realising the benefits of mimicking natural woodland environments (Hartley, 2002, Bengtsson, 2000). Hartley (2002) speculates on the potential economic benefits of using woodland as shelter belts or of realisation of higher timber values by allowing trees to age. Coillte agrees that older trees, including spruce, have a financial value as seed sources both for in-situ regeneration and for restocking and sale. However, while the benefits of sustainable management are imprecise, the costs are more tangible to forest managers. The setting aside of 15% of the forest area involves a direct cost. Although, many such areas will have relatively low productivity, others will involve an opportunity cost of lost timber production particularly where the land used for the preservation of old deciduous growth is located at riverside locations where soils are most fertile. Allowing selected trees to age also involved an opportunity cost, noting the timber value of older trees and the fact that most trees in Ireland have hitherto been grown for fibre. Selective felling, as an alternative to clearfell, also has a direct cost.

Compensation for these opportunity cost of forestry, included the productive land set-aside, is received in the form of afforestation grants and premia payments. The former vary from €3,414 per hectare for unenclosed conifers to €7,604 per hectare for enclosed beech. Clearly, there are economic and strategic objectives behind these grants as well as biodiversity objectives. Almost €94 million was spent on grants and premia in 2006 with around a further €1.5 million being on predominantly broad-leaf schemes (Government of Ireland, 2007). All plantings have to conform to biodiversity principles, but biodiversity benefits are maximised where broad-leafs are planted. Payments directed at broad-leaf plantings (in excess of rates for conifers) amounted to around €12 million. While accepting that other plantings are subject to biodiversity objectives, these broad-leafs are also supported for their non-biodiversity amenity and landscape benefits. Therefore, €12 million could be taken to be a reasonable estimate of the policy cost of biodiversity.

In addition, foresters experience private costs and benefits from conforming to biodiversity principles. Sustainable forest management, as attested by FSC certification, has been accepted as a necessary objective by Coillte. Unfortunately, no studies have been undertaken by Coillte, or apparently anybody else, to calculate the costs involved. Bacon and Associates (2004) apply a zero value to broadleafs. Where these constitute 15% of the planted area, the final opportunity cost of lost forestry income can be assumed to be up to €2,400 per hectare (or a present value of €342 over the forest cycle) assuming the set-aside area would otherwise be good for commercial forestry.

However, from another perspective, Irish forestry has been capitalising on sustainable management through FSC certification. Potentially, broad-leaf trees could have a premium timber value if they are well cultivated. Furthermore, Coillte has realised a payback in that accredited soft or hardwood products are more marketable. For government contracts and exports to the UK and Germany, certification is increasingly being demanded by the major timber merchants in response to policy. Certification also confers PR benefits and competitive advantages for the company's board products in relation to plywood imports from Brazil and the Far East.

Despite the positive policies that Coillte has adopted for biodiversity, almost no new areas are being planted aside from replanting. It is assumed that much of the expansion in the area of forestry will come from private plantings, mostly by farmers. Although forestry payments are conditional on the basic biodiversity requirements described above, there is no public access to most of these plantings and no arrangements for biodiversity management. The Forestry Service has now begun to fill this gap through a new Forestry Environmental Protection Scheme (FEPS) for REPS farmers. The pilot scheme has a target of 2,700 hectares on which growers can receive premia top-ups of €200 per hectare (first 40ha) thereafter for five years in addition to the normal grants available under the Afforestation Scheme.

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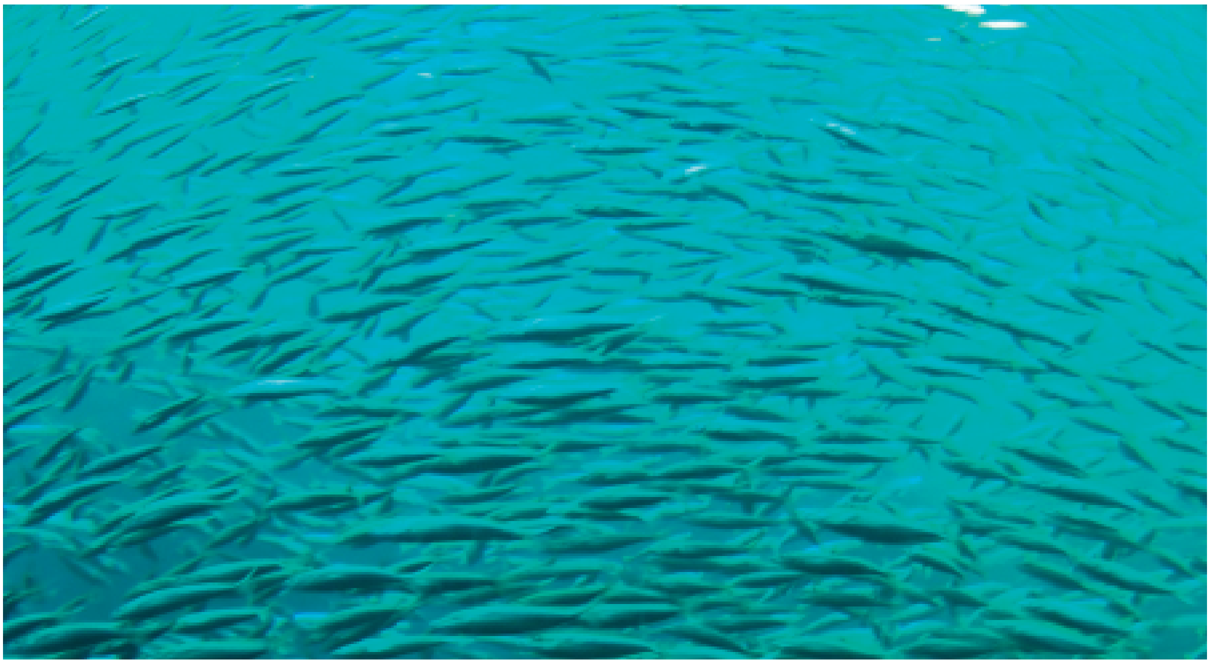
5. BIODIVERSITY, MARINE FISHERIES & AQUACULTURE



5.1 THE RELATIONSHIP BETWEEN FISHERIES AND BIODIVERSITY

Globally, the oceans provide the primary source of food for over 3.5 billion people (UNEP 2004). Seafood delivers more dietary protein than cattle, sheep or poultry (FAOSTAT Data 2005) and a wide variety of vitamins and minerals including vitamins A and D, phosphorus, magnesium, and selenium. Research shows that omega-3 fatty acids, found abundantly in seafood, have important health benefits, such as improved infant brain development and protection against heart disease and stroke (Stone 1996, Krauss 2000, Kris-Etherton 2002).

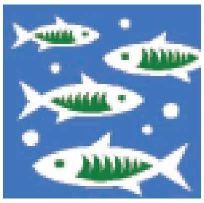
Capture fisheries in coastal waters alone contribute $34 billion to gross world product annually. However, the financial value alone belies the importance of the sector for employment and livelihoods. Ninety per cent of the world's fishermen and women operate at the local community level, and bring in over fifty percent of the global fish catch (UNEP 2004). The small-scale fisheries sector directly employs about 40 million people. If support staff, supporting industries and dependents of these workers are added to this figure, then small to medium fishing enterprises support the livelihoods of more than 200 million people worldwide (FAO SOFIA 2004, McGoodwin 2001).

Inshore coastal zones cover only 8% of the Earth, but the services they provide are responsible for approximately 43% of the estimated total value of ecosystem services (Millennium Ecosystem Assessment, 2005). Being the most productive part of the ocean, the coastal boundary ecosystem contains 90% of marine fishing grounds. Furthermore, as nearly 40% of the human population lives within 100 km of the coast, marine ecosystems also provide an essential service in assimilating and detoxificating pollution from coastal cities and rivers.

Biodiversity drives the productivity within the marine ecosystem. Benefits derive from both genetic diversity and diversity of diet. However, it is only recently that the direct contribution of biodiversity has been realised, most recently from the results of the largest international marine biodiversity study to date headed by Dalhousie University in Canada (Worm et al. 2006). Examining fishing grounds from around the world, the authors found that a 78-80% increase in primary and secondary productivity, and a 20-36% enhancement of resource use efficiency, occurs under high biodiversity systems when compared with low diversity systems. Furthermore, higher diversity systems were also quicker to recover from fish depletion or other catastrophes.

Based on an analysis of commercial fish catches between 1950 and 2003 in various fishing grounds worldwide, Worm et al find that the populations of 29% of commercial fish species have now collapsed, i.e. to be below 10% of their former levels. The trend appears to be accelerating. Cumulative yields have fallen by 13% (10.6 million tonnes) since 1994 despite the increased efficiency of fishing effort. The rates of depletion have been greater in those waters that are low in biodiversity. Even more worrying is that capacity for recovery is greatly undermined by this loss of biodiversity, a contributory factor to which is fishermens' own ability to switch easily to other more easily caught species. Worm et al. conclude that, on current trends, global collapse of fisheries is likely by the middle of the century. Climate change, combined with changes in oceanic currents, could accelerate the trend in that low levels of biodiversity will be unable to provide the necessary resilience to ecological change. Despite this gloomy prediction, the authors accept that recovery is still possible if radical measures are taken. In principle, this is possible. At the Johannesburg World Summit on Sustainable Development in 2002, the EU and other international states committed themselves to harvesting at no more than maximum sustainable yield by 2015.

5.2 RELEVANT SPECIES AND FUNCTION



Clearly a direct relationship exists between marine biodiversity in that, unlike any other sector described in this report, fish are caught and consumed by large numbers of people. Comparable activities such as hunting, berry picking or mushroom collection are insignificant in comparison. These catches are the outcome of much greater underpinning primary and secondary productivity, as well as the essential contribution of biodiversity to nutrient cycling and population stability.

Biodiversity increases the efficiency with which resources are distributed, including the channelling of biological productivity up the food chain towards economically important species. However, the complexity of inter-dependencies between species is only beginning to be understood as the discussion of Ireland's coral reefs (below) demonstrates. It is only now, at a time when the world's fishery resource is under such threat, that the vulnerability of the marine ecosystem is being revealed. The sustainability of the resource depends on the survival of relatively undisturbed fisheries and on nursery habitats such as oyster beds and wetlands, as well as the filtering and detoxification services provided by filter feeders and vegetation. The destabilising of these systems is blocking productivity at lower levels leading to population explosions of simple species such as jellyfish and the regular occurrence of algal blooms while commercial species nearer the top of the food chain appear to have embarked on an inexorable decline.

Marine Fisheries

Ireland's Marine Fishing Industry is an important and valuable source of economic activity both nationally and, particularly, to the coastal communities where it is based. Approximately 1,415 vessels are registered as part of the Irish fishing fleet, grouped into four segments that broadly reflect their normal fishing patterns or the gear used (BIM, 2005). The fish catching sector alone provides at least 6,000 direct jobs while an additional 10,000 jobs onshore are dependent on catches from Irish vessels.

Although Irish landings have fallen in response to declining fish populations, the fall has not been as considerable as might be expected from the preceding description of the status of stocks. Indeed, in 2004 (the latest year for which figures are available), total catches amounted to 309,332 tonnes, which compares with a total catch of 288,924 tonnes in 1994. The years selected for comparison are important as the catch represents a modest fall if comparison is made with a year such as 1998. Landings reached their height in this year at a time when both policy makers and industry had already been aware of the threat of over-fishing for over ten years.

Of more significance has been the change in the composition of landings and of the structure of the industry. Many vessels have responded to quotas by transferring to non-quota or newly commercial species, particularly of pelagic (open water) fish. Notably, this has included blue whiting, a fairly unpalatable fish which is mainly used for fish meal and whose catch in 2004 totalled 61,470 tonnes. The species was not even separately identified in the 1994 statistics, but the rise in catch has been such that new controls are now being recommended. By comparison, catches of herring, a species whose former abundance supported thousands of jobs around the coast, have fallen to 33,178 tonnes from 51,006 tonnes in 1994.

The Common Fisheries Policy has attempted to restrict the landings of species whose populations have fallen below "safe biological limits" through a mixture of total allowable catch (TAC) for various species, fishing effort restrictions (e.g. days-at-sea), technical conservation mechanisms (i.e. gear restrictions), and closures of spawning areas. These measures have been supported by naval patrols and enforcement by locally based or on-vessel fisheries officers. The CFP was reformed in 2002 in response to widespread acceptance of the failure of European fisheries policy due to a combination of factors, including poor enforcement, inadequate research, the setting of catch limits whatever scientific advice existed, and the undermining of TACs by illegal practice and the discard of small fish or disallowed species.

The Reform has involved greater industry consultation, more socio-economic analysis and the replacement of extreme changes in TAC by graduated annual changes up to 15% that are more acceptable to fishermen. Nevertheless, formidable problems of enforcement and political conviction remain. The multi-state access permitted to off-shore fisheries makes monitoring and enforcement especially challenging. Ireland, for instance, is responsible for the vast North-Western Regional Advisory Committee (RAC) area extending from the North of Scotland south into the Celtic Sea. Added to the practical challenges, is the process of continual negotiation over national fishing rights fought out largely by Member State politicians in response to domestic economic considerations of the fishing sector. It is only recently that the politicians in the Council of Member States have begun to concede to the increasing weight of scientific evidence put forward by the Commission that demonstrates the critical condition of many fish stocks .

Figure 5.1a Irish fish landings (home ports)

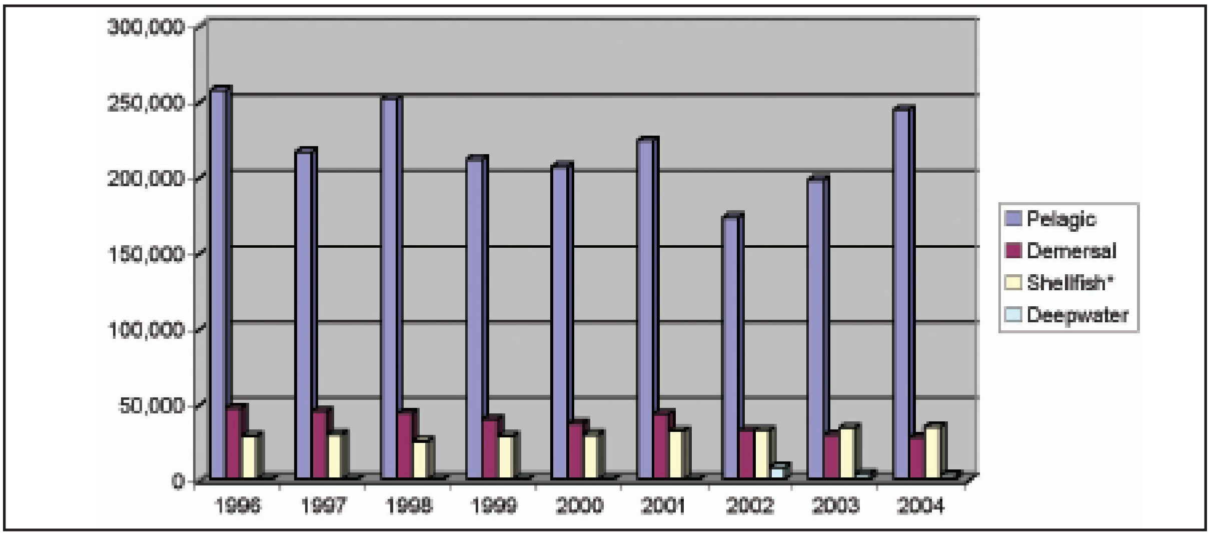
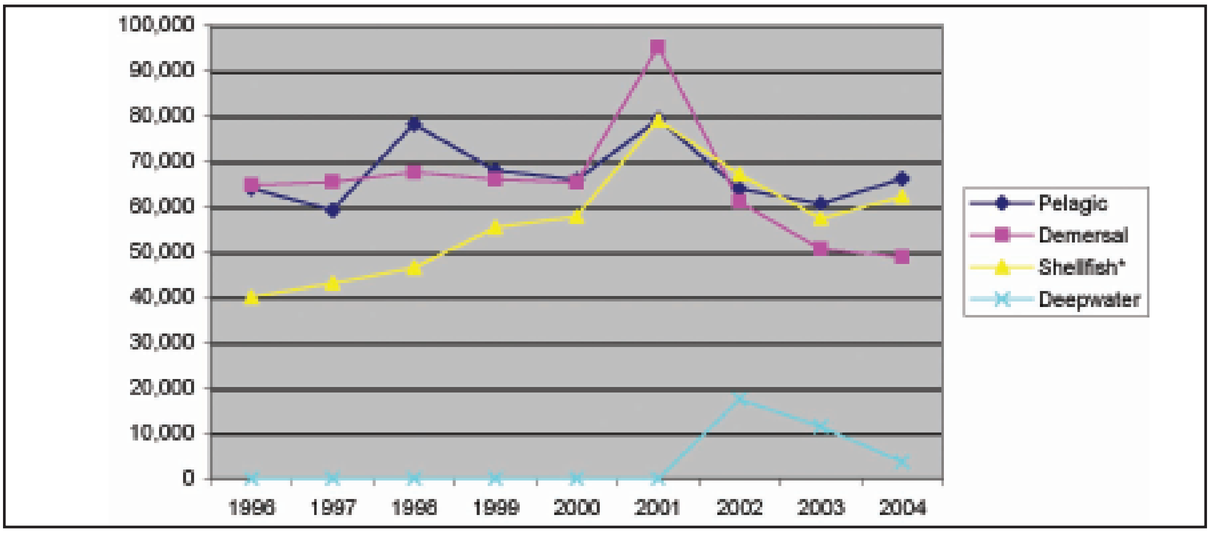


Figure 5.1b Value of fish landings (home ports)

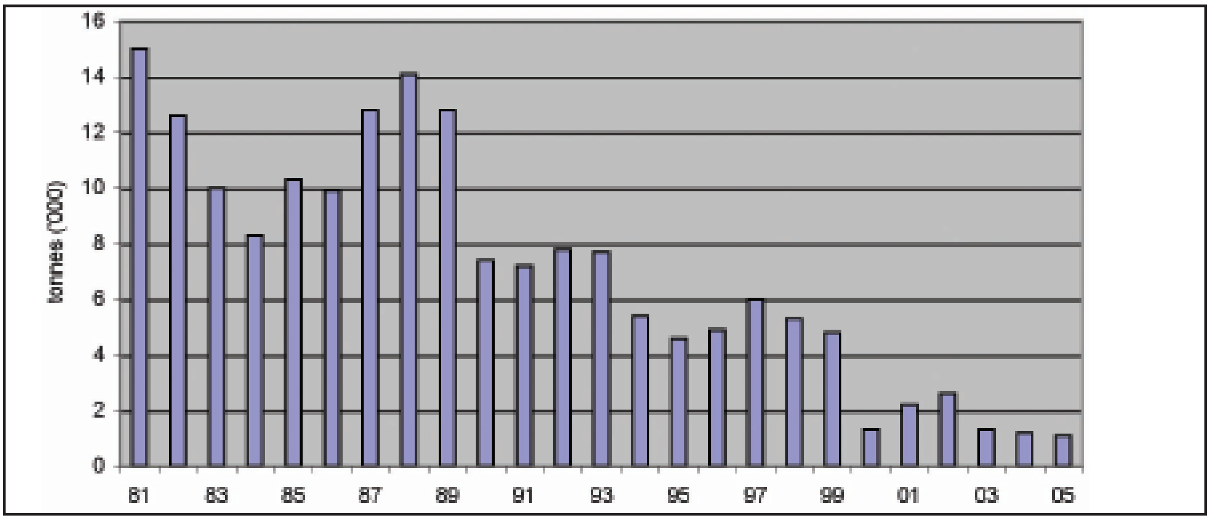


* Source: CSO. Farmed shellfish not included

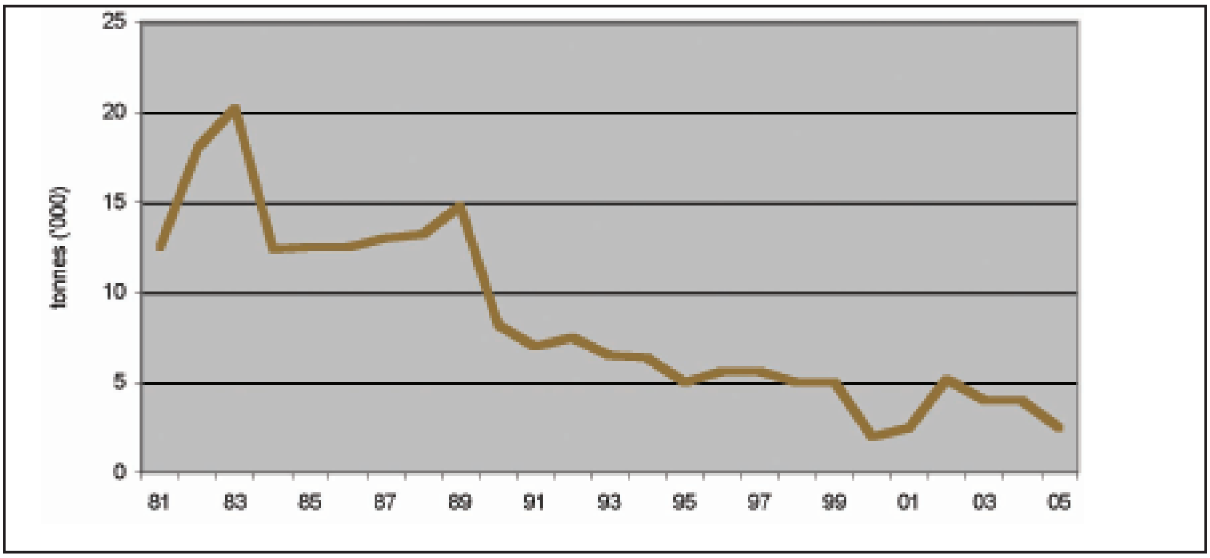
By comparison, the catch of familiar demersal species, often termed white fish, has decreased significantly in response to cuts in quota. In 2004, landings of cod were just 1,246 tonnes compared with 4,984 tonnes in 1994 and 8,001 tonnes in 1996. Catches of haddock and whiting have also fallen significantly. The spawning population of cod in the Irish Sea is now believed to be one fifth of what it was in the early seventies. Of wild shellfish, catches of blue mussel have also declined considerably. However, the overall shellfish catch is up slightly on ten years earlier due to significant investment in Dublin Bay prawns. The total prawn catch has increased to 6,790 tonnes in 2004 from 2,970 tonnes in 1994.

Figure 5.2 Irish Sea Cod: Landings and Spawning Biomass 1981-2005.

(a) landings



(b) spawning biomass



source: Marine Institute

Fisheries and the National Spatial Strategy

Ireland's National Spatial Strategy recognises the value of coastal and inland fisheries to the country's economic development, and their significant potential for providing sustainable alternative sources of employment in rural areas. The strategy states that the economic revitalisation of many parts of the west of Ireland has been driven by a diversification in the regional economy that has been largely supported by the exploitation of natural resources (food production, tourism and related ventures).

The NSS determines that the managed utilisation of these resources can facilitate further diversification in rural economies and revitalise other areas along the western seaboard. It recognizes that this enterprise potential cannot proceed without "high environmental quality". In other words, the flow of ecosystem services such as primary production, regulation of water and soil quality, cultural and recreational values, and provision of food resources and other commodities, is insufficient in some areas to enable a significant rejuvenation of the local economy. For fisheries, the NSS identifies a need for effective catchment management and planning, "embracing all key factors and with effective integration of inland fisheries and land use planning". In coastal areas, it calls for holistic approaches and cross-sectoral co-operation within the framework of Integrated Coastal Zone Management systems that recognise the importance of the coastal environment to the stability of marine fisheries and the sustainability of associated economic activities.

By comparison the inshore fishery has not been subject to any traditional resource management. The fishery is very much open access, is fully exploited and, as a result, has experienced severe declines in the local populations of several shellfish species such as cockle and scallop. Potentially the fishery could benefit by virtue of falling entirely within Irish jurisdiction. Although they have been long coming, reforms are being made. For example, stock assessments are now being undertaken by BIM for the principal commercial species. In addition, around 755 inshore vessels have recently been added to the fleet register, a significant advance on a situation where previously the capacity had been unknown. Nevertheless, there have been persistent problems with the pollution of shellfish waters (Irish Times, 2007a).

BIM hopes that the sector can be encouraged to accept new management requirements currently being drafted with the support of Species Advisory Groups within the Shellfish Management Framework. The Review Group hopes that a dedicated strategy will be led by the DCMNR in this regard. Indeed, locally, new requirements are inevitable as a consequence of the forthcoming implementation of marine SACs intended to protect fish and shellfish species, but also marine flora and birdlife. As such designations provide the future pro-active intervention of non-fisheries interest, notably through DG Environment, the hope is that the sector will be encouraged to first take the opportunity for self-regulation.

Aquaculture

Aquaculture is an activity that dates back at least 4,000 years (Rabanal 1988). However, it has only been of significance in terms of global food production in the past 50 years (Millennium Ecosystem Assessment 2005). In many regions, aquaculture could help to reduce the pressures on stocks of wild fish while meeting consumer demand (Millennium Ecosystem Assessment 2005). Nevertheless, while the industry expanded substantially in the 1990s, recent output has since shown little or no growth throughout the EU (EC 2007).

Aquaculture has, to some degree, provided alternative employment in areas that once employed people in in-shore fishing. However, it is still dependent on the quality of the supporting ecosystems and its sustainability is ultimately tied to that of wild capture fisheries. The productivity of the marine environment, its capacity to assimilate pollutants and to regulate natural patterns and cycles of disease, is highly dependent on biodiversity and associated ecosystem services (e.g. NRC. 1995, 1999; Humbert 2003; Worm & Duffy 2003; Covich et al 2004; Levy 2004, Millennium Ecosystem Assessment 2005). Aquaculture cannot be sustained in polluted, degraded, low-biodiversity environments, and a reduction in the health and stability of ecosystems within the wider aquatic environment can undermine the quality and viability of aquaculture output. Therefore, it is in the best interests of the sector to ensure that any environmental impacts are minimised (BIM. 2003, Davenport et al 2003). From the perspective of biodiversity, it is also important to note that, in general, the diversity of species supply from aquaculture is well below that of capture fisheries (Millennium Ecosystem Assessment 2005).

Nevertheless, aquaculture is a valuable source of employment, with particular potential in disadvantaged areas, or areas which were once supported by active fishing industries (FAO, 1999; MacAlister Elliot & Partners, 1999). It also makes a cultural contribution in Ireland through a supporting influence on the Irish language in certain Gaeltacht communities (White & Costello 1999). The value of aquaculture output has grown from €37.2 million (26,500 tonnes) in 1990 to around €124.6 million (57,422 tonnes) in 2006. In 2006, the sector employed over 2,000 people on a full and part time basis. (see Browne et al 2007).

The dependence of aquaculture on healthy ecosystems, and the potential impacts that it can have on biodiversity, present challenges for the industry. The risks that aquaculture can present to marine or freshwater ecosystems have been well documented. As noted above, aquaculture appropriates a range of services provided by the supporting ecosystem (e.g. Bunting 2001; Beveridge, Phillips & Macintosh 1997). It also interacts with this ecosystem through physical, biological and chemical impacts (e.g Davenport et al 2003, Millennium ecosystem Assessment 2005). In addition to localised direct impacts, there is increasing concern that the wider management and development activities of the sector can also have other wider-ranging impacts. For example, capture fisheries supply fish-meal to much of the aquaculture in northwest Europe. This is reported to have had negative impacts on certain wild fish stocks, and upon the stability of ecosystems which support wild bird colonies and other species (RSPB, 2004; RCEP 2004, Roycroft et al 2007).

In 1989/1990, wild stocks of sea trout collapsed in Ireland's Mid-Western Region (Poole and Whelan 1996, Gargan et al 2002, 2007). The Connemara district rod catch, which had represented a large part of the Mid-Western regional fishery, fell from an annual average of 9,570 sea trout between 1974 and 1988, to just 240 in 1990. This collapse has had significant impacts on angling tourism and related economic activities in the region. Serious declines of wild salmon and sea trout have also occurred in salmon farming areas on the west coast of Scotland in the early 1990's (Walker 1994). Studies by the Central Fisheries Board (Gargan et al, 2002, 2007) and others have determined that sea lice from marine salmon farms were a major contributory factor in the sea trout stock collapses.

In summary, it is agreed that aquaculture activities can have negative impacts where coastal zone management is inadequate and where ecosystems are already under stress (Ackefors & Enell 1990; Gowen et al. 1990; Braaten 1991; Black 2001; European Commission 2002; Scottish Executive 2002; Davenport et al, 2003; BIM 2003; RCEP 2004). In order to support the long term viability of the sector, Bord Iascaigh Mara (BIM) initiated the Coordinated Local Aquaculture Management Systems (CLAMS) in 1998 to coordinate development of the industry guided by Single Bay Management Plans that take into account competing interests and environmental criteria.

Table 5.1 Aquaculture impacts

Physical impacts:	Chemical impacts	Biological impacts
• Reduction in the area of natural habitat • Creation of non-natural physical features – cages, pontoons, berthing etc • Land reclamation for associated buildings or infrastructure • Alteration of local hydrographic profiles; • Changes in sediment character; • Increased suspended solid levels	• Changes in oxygen content in the water column • Input of waste organic compounds to sediments and within the water column • Input of nutrients to sediments and within the water column • Input of antibiotics, anti-infectives, anti-foulants, parasiticides etc to sediments and within the water column	• Changes in ecological community structure and function • Addition or removal of food resources from the water column and alteration of energy flows • Reduction in biomass and diversity of primary producers, zooplankton and decomposers • Changes in pathogen ecology with disease impacts on existing wild communities • Escape or release of non-native and invasive alien species or GMOs • Secondary or non-target impacts of anti-predator controls • Increased selection pressures for anti-microbial resistance in pathogenic microbes.

Sources: Davenport et al 2003. See also Beveridge et al 1997, Garrett et al 1997, Bunting 2001, Millennium Ecosystem Assessment 2005.

Irish coral reefs

Reefs, formed by the skeletons of countless generations of corals, are some of the most biologically diverse habitats on the planet. As well as providing shelter for corals themselves, the reef system supports a huge diversity of other organisms. It has been estimated that over 4,000 species of fish inhabit the world's coral reefs (Spalding et al, 2001). Primary production in shallow water reefs is high due to the symbiotic partnerships between corals and photosynthetic algae, and the degree of nutrient cycling that occurs between corals, algae, and other organisms. Reefs, such as the Great Barrier Reef and those in the Red Sea, are major tourist attractions as well as a fisheries resource. Much of the economic value of coral reefs - estimated at nearly $30 billion per year - is generated from nature-based tourism, including scuba diving and snorkelling (Millennium Ecosystem Assessment, 2005).

Coral reefs are not confined to warmer climates. They also occur in deeper cold waters, up to depths of 3,000 meters, often in areas where there is no significant primary production, and where they may be supported by nutrients and organic compounds re-suspended from the seabed or brought down from highly productive surface waters by ocean currents (Thiem et al, 2006). A large cold-water reef system, located approximately 200km off Ireland's west coast, has only recently been explored in detail. These reefs are formed mainly by the coral Lophelia pertusa which forms the most structurally complex physical habitat for species in the deep sea. Lophelia reefs can have a species diversity as high as reefs in shallow tropical waters. Over 860 species of animals have been recorded on such reefs in the north-east Atlantic. Reefs can grow to 35 metres in height, be hundreds of metres wide, and reach 13 km long.

The value of Lophelia reefs to fisheries has not been determined. It is likely to be significant for some commercially important species, and probably performs an important role in sustaining a productive food chain in deep sea environments, e.g. through nutrient cycling, by providing a habitat for suspension feeders, and by providing nursery and rest areas for species which in turn support larger predators. Over 1,300 species of invertebrates and fish have been found in Ireland's Lophelia reefs, including commercially important cod and redfish.

Reefs are endangered by the dragging of heavy fishing gear along the sea bed. In 2006, the Irish Government announced plans to conserve these reefs by nominating four sites in Irish waters as Marine Protection Areas, and by preventing harmful fishing practice in three others in international waters.

Seaweeds

Ireland has a diverse seaweed industry which has developed in the past 30 years. Certain species of seaweed have always been harvested on Irish coasts as a food resource and have been a traded good for thousands of years. Carrageen or Irish moss (Chondrus spp) and dillisk (Palmaria spp) have long been part of the culture of many communities on the west coast and can still be found on the shelves in many Irish supermarkets. Recognising the potential of this natural resource, the government launched the Irish Seaweed Forum in 1999 to collate the opinions of a range of stakeholders. The Forum's report on the sustainability of the Irish seaweed industry determined that natural seaweed resources in Ireland are under-utilised and that potential high-value industrial applications has yet to be fully realised.

The most economically important seaweeds in Irish waters include two types of maerl; maerl is a collective term for several species of calcified red seaweed which grow as unattached nodules on the seabed, often forming extensive beds. Maerl is slow-growing, but over long periods its dead calcareous skeleton can accumulate into deep deposits overlain by a thin layer of pink, living surface. Maerl beds are an important habitat for a wide variety of marine animals and plants which live amongst or are attached to its branches, or which burrow in the coarse gravel of dead maerl beneath the top living layer.

The Irish seaweed industry is broadly based, with the product being supplied to agriculture/ horticulture, cosmetics, thalassotheraphy, the biopharma sector (functional foods, pharmaceuticals and nutraceuticals) and for human consumption. At present, about 32,000 tonnes of wet weed is harvested in Ireland. There is considerable interest in expanding the potential product range and especially in adding value to extracted components for a wide range of uses (Marine Institute, 2006).

The introduction of mechanical harvesting of seaweed was identified as a key area in the development of the domestic seaweed industry. Kelp is the largest and most structurally complex brown algae and often forms dense standing stocks or "kelp forests". They are exploited world-wide and are of major economic importance to the hydrocolloid industry as a source for alginates (used in a wide variety of products from soups, jellies and ice cream to antiacids, burn treatments, cosmetics and fire proofing). They also are of high ecological significance. Kelp are complex three-dimensional structures providing habitat, food and shelter for various species and are characterized by high productivity and a diversity of associated flora and fauna. They also form important reproduction and nursery grounds for fish.

Kelps are the most prominent constituents of lower intertidal and subtidal Atlantic rocky shores. Studies recently conducted by the Irish Seaweed Centre have provided information on kelp growth, biomass, biodiversity of kelp beds and the impact of experimental harvesting. Based on these data, total natural kelp resources (L. digitata plus L. hyperborea) are estimated to be 81,641 tonnes in Galway Bay and about 3,000,000 tonnes for the entire coastline of Ireland. The value of these beds to the fisheries sector has yet to be determined.

5.3 THREATS TO FISHERIES AND ASSOCIATED RESOURCES

Between 1995 and 2005, 85 million tonnes of fish were taken from world marine fisheries, of which about 60 million tonnes was used directly for human food. The projected world food demand for fish in the year 2020 was about 130 million tonnes. The increase in the world's population between 1970 and 2000 has resulted in a massive increase in demand for seafood, encouraged especially by economic growth in Asia where fish consumption has doubled in the last three decades. Ireland is not immune from these international developments given that some high value species such as abalone are exported to the Far East, while processed fish products are imported from as far away as New Zealand.

Given predicted declines in productivity, it is not possible for wild fish to continue to meet this demand (Delgado 2003). The European Commission has estimated that 81% of the Community's commercial fish species are being fished unsustainably (Marine Institute 2007). Another study reports that over-fishing has led to the loss of about 90% of the global ocean's large predatory fish (Myers & Worm 2003). The Millennium Ecosystem Assessment (MA) has determined that "harvest pressure has exceeded the maximum sustainable yield in one quarter of all of the world's wild fisheries and is likely to exceed sustainable levels in most other wild fisheries in the near future. In every ocean in the world, one or more important target species stocks have been classed as "collapsed", over exploited, or exploited to their maximum sustainable levels. Freshwater fisheries have been similarly impacted. Approximately 20% of the world's 10,000 freshwater fish species have been listed as threatened, endangered, or extinct in the last few decades.

A feature common to all major world fisheries is, not only the decline in overall catches, but a decline in the average trophic level of the species landed (Pinnegar et al, 2003). That is, the higher-value predator species at the top of the food chain are being replaced with smaller and lower value species. The size of most species caught is also declining.

Estimates based on current rates of diversity loss indicate that there will be no viable fish or invertebrate species (molluscs, cephalopods, crustaceans, etc.) available to fisheries by 2050 (Earthwatch Institute, 2006). However, the trends in species loss are still reversible. While the demand for fish is increasing, fish farming could relieve the pressure on wild fisheries, but only if sustainable practices are adopted.

Long-term plans aimed at restoring fish stocks to a safe level are having a painful impact on fishing communities. The European Union is implementing a major restructuring of the EU fishing fleet in order to tackle the decline in fish stocks. Essentially, this has involved large scale decommissioning of sea fleets, including the Irish fleet. The pressures are exacerbated by increasingly sophisticated catching and changes in the composition of fish caught.

State aid has been available to support the sector during this restructuring process under the Financial Instrument for Fisheries Guidance (FIFG). A Commission Action Plan to counter the social, economic and regional consequences of the restructuring of the EU fishing industry was adopted in 2002. The latest reform of the Common Fisheries Policy extended the scope for the permanent decommissioning and temporary removal of vessels as well as compensation, early retirement, and diversification. However, there is too much reliance on fisheries protection enforced by locally based fisheries officials or national navies. The multi-national nature of the fleets makes it even more difficult to apply legal penalties, especially in that courts may be more accustomed to dealing with criminal acts than fisheries issues. Much faith is being placed in the future real-time monitoring of vessels to ensure that these do not stray into protected areas.

A further potential threat is presented by climate change. Already, it is being reported that cod and other cold water species are moving north in response to small changes in sea temperatures. There are also concerns that cliff based seabird colonies – one of the more dramatic wildlife sites in Ireland and Britain – will be rendered empty and silent by declines in small fish species which provide their major food source.

Harmful Algal Blooms (HABs)

Since 1950, nutrient loading from pollution has emerged as one of the most important drivers of ecosystem change in freshwater and coastal ecosystems (Millennium Ecosystem Assessment 2005). This pollution has caused acidification, has depleted oxygen levels in freshwater and estuarine environments through eutrophication.

Pollution can cause hypoxic "dead zones" in coastal areas, but its effects also extend hundreds of kilometres out to sea. An indicator of this pollution, reactive (biologically available) nitrogen, has increased by 80% from 1860 to 1990. Human activity supplies more reactive nitrogen than is produced by all natural pathways combined and projections suggest that levels may increase by a further two thirds by 2050.

Along coasts around the world, outbreaks of pathogens and harmful algal blooms (HABs) are becoming increasingly common (Knap 2002). These regular population explosions are believed to arise from elevated nutrients in coastal waters, removal of filter feeders such as oysters, and transport of contaminated ballast water between major ports worldwide. Sometimes referred to as red or brown tides, the resulting biotoxins are harmful to humans and animals. Filter feeders such as oysters and clams accumulate these biotoxins in their tissues and they can concentrate further as they move up the food chain. When eaten, symptoms include nausea, respiratory problems, memory loss and even death. A recent study has determined that the global economic losses associated with HABs over the 30 years has reached $1 billion (Anderson et al. 2000).

5.4 ECONOMIC AND SOCIAL VALUES

Although the Irish catch has fallen slightly in the last five years, the value of the catch has remained steady at around €180 million. An approximate 5% fall in the value of landings since 1998 represents a very minimal level of the cost of loss of biodiversity in that the fall is mainly a consequence of reduced quota. Overall, values have been maintained due to the sale of higher value species to premium markets. BIM has been instrumental in encouraging higher value processing. In addition, the value of externally traded fish and fish products has also increased to €391 million. One consequence of these developments is that Irish landings in foreign ports now total over 120,000 tonnes compared with only around one quarter of this amount in 1994.

Trends to landings abroad have not been in the interests of Irish fishing communities. They have to be seen in the context of the remarkable decline of ports such as Castletownbere, Rathmullen, Arklow and Carlingford and the relative concentration of pelagic landing in Killybegs. Moreover, the forces of supply and demand in response to declines in the European catch do not appear to have had an impact on prices at the quayside. In part, this has occurred because of the impact of fixed quotas. Another factor is that owners of many smaller vessels have been reticent to respond with better marketing or simple processing given the tightness of margins and the uncertain policy future.

From a biodiversity perspective, the cuts in the catches of familiar demersal species such as cod and haddock are too little too late. The capacity of the population to recover has been questioned by many scientists. For instance, the Marine Institute has observed that 75% of Ireland's stocks are now outside of safe biological limits (2006). Policy has reacted only hesitantly to the scientific advice. Illegal catches and misreporting have undermined conservation strategies directly, but also indirectly by depriving scientists of accurate data for the modelling of fish populations. Discards of smaller fish or less desirable fish are a significant problem in terms of age structure and biodiversity (Trenkel & Rochet, 2003). In some Irish and Scottish trawl fisheries, discards account for an incredible 70-90% of the catch (EC, 2007). In the same category, the continuing by-catch of whales and dolphins is of much ecological concern.

State-funded modernization of the demersal sector, combined with the privately resourced expansion of the pelagic fleet, has occurred without any corresponding increase in quota. The observed result has been a situation where "too many vessels are chasing too few fish". An especially worrying trend in recent years has been the diversion of fishing effort to non-quota species, although quotas frequently follow the resulting over-fishing. For example, in the late 1990s, some vessels switched to deep water species living below 400m, notably orange roughy. Most of these species are unfamiliar to consumers and so end up as fishmeal. Most of them also reproduce extremely slowly (see box). New controls have now been applied, but these may be having a corresponding adverse impact as vessels switch back to traditional species whose populations are already under pressure.

The inshore fishing fleet has suffered considerable decline, but has been making something of a recovery in recent years. Problems have arisen due to the netting of fish near shore which has affected the population of available fish in that many spawning grounds are located near the coast. The smallest boats do not possess the harvesting technology that is available to larger ocean-going vessels. However, in contrast to some whitefish species, prices have improved, allowing shellfish, crab and shrimp boats to weather the storm.

5.5 COSTS OF PROTECTION

The Orange Roughy (Hoplostethus atlanticus)

Like many deep-sea species, the orange roughy, has been targeted by fishing industries worldwide, typically in response to quota cut-backs for traditional species. Formerly called "slime head" by US fishermen and invariably discarded, the orange roughy (now "Emperor Fish" in France) is, in contrast to many deep-sea species, palatable and not an especially peculiar or ugly-looking fish. However, like many deep-sea species, the roughy breeds extremely slowly, not maturing until it is 25 years old. Indeed, it is thought that the species can survive for as much as 150 years which, according to Krista Baker of the Memorial University in the US, would be "like eating a fish that was born when Lincoln was president". As the species has a tendency to shoal around elevated areas of the sea bed, it is easily caught by trawlers using modern sonar devices. Consequently, its population quickly plummets in response to any increased attention it receives from the fishing industry. Bad enough as this is, the dragging of fishing gear along the sea bed has been implicated in the destruction of corals of the west of Ireland. In fact, "ghost fishing" by abandoned gear is believed to be a continuing threat. As noted above, these habitats are now understood to be highly important to marine biodiversity, including the survival of many commercial species.

industry within two or three ports. In essence, this is the root of the problem. Many fishermen face falling margins and fishing communities continue to feel frustrated by the impact of quotas. At the same time, the owners of a reduced number of highly efficient vessels have continued to catch similar amounts of fish with the encouragement of influential industry groups and, sometimes, with the support of state investment. This state of affairs makes it difficult for any group to argue for further controls.

Over the past eight or nine years, nearly €60 million has been spent by the State or EU on investment in the restructuring of the whitefish fleet. The objective of this investment has been to increase efficiency and improve safety. Only a minor element of the funding can be attributed to concerns of reduced fish populations and, thereby to biodiversity. Similarly, considerable state investment has been made in the aquaculture sector. While the substitution for wild stocks has only been a minor incentive for this investment, it is to be hoped that growth in the sector will ultimately relieve the pressure on wild populations (as it has done, to some extent, for salmon and shellfish). For now, farm production of species such as hake, halibut and cod is still in its infancy.

The European Common Fisheries Policy has accepted the need for sharp cuts in quota in response to scientific advice. These projected cuts still fall short of those demanded by best scientific advice, but there does appear to be a gathering acceptance of the need for action to avoid a collapse of stocks. The need for action is acknowledged by policy makers and the industry in Ireland. For instance, the Seafood Industry Strategy Review Group (2006) has repeated the call for new sustainable fishing practices. A combination of whitefish fleet decommissioning and a restructuring of the pelagic fleet are recommended, although the Board has been mindful to argue that this should be industry-led. To date, state investment has been made available for the modernization of pelagic vessels and for the decommissioning of larger whitefish vessels. Many of the former are increasingly landing in foreign ports where there have been some instances of misreporting. Decommissioning of whitefish boats has targeted larger vessels over 18 metres, but not the medium sized boats that are believed to have a continuing impact on whitefish stocks. Consequently, the Review Group has recommended a new round of decommissioning for the whitefish fleet together with better enforcement, improvements to fishing gear and temporary closures of some fishing grounds. The Group also recommends that vessels use improved gear so as to minimise the problems of by-catch and damage to reefs by fishing gear.

The Review Group's report bases much of its recommendations on those contained in the White report on decommissioning (White, 2005). This study makes the case for the immediate decommissioning of one quarter of the whitefish fleet at a cost of €45 million, or an increase over planning spending for 2007 of €36 million. This time, the principal rationale is stock protection. Although the proposed incentives are generous, the total is a modest sum compared with the total annual value of the industry at nearly €400 million. As potentially the industry could have a value well in excess of this amount, there is a large positive net present value from decommissioning.

The more uncertain factor is whether this benefit will be eroded by better harvesting technology, illegal catches or, indeed, by indecisive EU politicians. Better long-term stock management is beginning to pay dividends as demonstrated by a recovery in the Northern hake population. Fishing effort is also reported to have fallen in the principal fishing grounds, for example by 35% in the Irish Sea since 2000 (CEC 2007). Nevertheless, the Commission accepts that a high risk situation is emerging due to the continued over-exploitation of stocks. A future Ecosystem Approach to the management of the marine environment has been recommended by the European Commission (EC, 2002). Such an approach is now being pursued to manage fisheries in a manner that takes into account maximum sustainable yield and the impact on other components of the marine ecosystem, including the effects of by-catch. The problem is the Ecosystem Approach is highly data intensive. This presents a particular difficulty where reduced fishing effort also provides less data for resource modelling. However, a precautionary approach is already being promoted in the absence of firm scientific data.

Instead, BIM hopes that improved management of fishing effort backed by new technology will provide a more immediate dividend. This could include real-time location and identification of fishing vessels to ensure that closed areas or quotas are not being compromised. New gear to reduce the substantial amount of discards is also being developed. Currently, these Technical Conservation Measures are being enforced through command and control mechanism. BIM would like to see more pro-active incentives to encourage uptake. Such a move appears overdue given unwelcome trends to the use of smaller net mesh sizes in response to the falling size of fish caught. Over time, it is hoped that improved monitoring and data will transform fishermen's attitudes from ones of exploitation cultured under open access regimes, to an acceptance of the importance of conservation and stock management. One route to this end would be the replacement of extreme changes in Total Allowable Catches by more graduated annual changes decided upon though the direct interaction of fishermen with scientists and policy makers. Such changes require more sophisticated management, more data on fish stocks, and also the political will to follow up on scientific advice.

The Atlantic Dawn

In 2000, the privately financed €70 million Atlantic Dawn became both Ireland's, and the world's, largest 'supertrawler'. At 14,000 tonnes, it dwarfed all other vessels in the fleet. Capable of catching 300 tonnes of fish per day, the ship would have caused Ireland to far exceed its pelagic capacity ceiling. Consequently, the vessel needed to obtain one of a limited number of licenses that the EU has negotiated to fish for stocks of sardinella, mackerel and horse mackerel off the coast of West Africa. The risk that failure to obtain such a license could have a knock-on impact on the parent business in Donegal, led to intensive lobbying by the government on behalf of the owner, the late Kevin McHugh, a self-made man from Achill. The Atlantic Dawn was ultimately successful in obtaining a license. Its catch is landed in Morocco and the Canary Islands where it is believed to employ 500 people. The vessel has run into occasional problems with the Mauritanian government over alleged infringements of its license. In 2007 it was sold to the Dutch firm Katwijkse Shipping.

Sources: Sunday Business Post 22/6/03, 19/02/2006. RTE 5/3/2007 Irish Times (b) 24/2/2007

Integrated Coastal Zone Management

Aside from over-fishing, Ireland's marine and coastal biodiversity faces many pressures, including pollution, oil and mineral exploration, recreation, marina development and general over-development. In the 1990s the European Commission implemented a Demonstration Project on Integrated Coastal Zone Management (Cummins et al. 2004). A draft policy on ICZM (Brady, Shipman & Martin, 1997) was prepared at the time. However, despite widespread enthusiasm for ICZM, policy continues to be characterised by a sectoral approach. There is no official policy of ICZM and there continues to be poor coordination between bodies responsible for the marine (Heritage Council, 2006). Of policies to date, CLAMS represents one of the better examples of an integrated approach that includes environmental objectives. However, it is evidently a sectoral policy that prioritises the interests of aquaculture.

The absence of an overall policy of coastal zone management leads to frequent conflict, not least because of the lack of public participation and the absence of coordination. The costs of ICZM have not been estimated, but are likely to be modest in comparison with the costs of dispute resolution or environmental degradation. Ireland is currently at risk of being fined by the European Court for its persistent failure to eliminate pollution from shellfish waters (Irish Times, 2007a).

Strategic Environmental Assessment has been recommended for major offshore developments such as windfarms, tidal barrages and extractive developments (Heritage Council, 2006). The controversy over the proposed Shell oil pipeline in Mayo demonstrates the financial implications of planning which fails to take into account wider environmental and social factors. The dispute would not have been avoided by ICZM and has little to do with biodiversity, but it does underscore the need for an agency to manage Ireland's coastal zone. Any such agency should have the organizational and financial means to ensure that coastal activity and development occurs in a manner that is environmentally, socially and economically sustainable. Without this integrated management, the protection of the marine and coastal environment, including its biodiversity, will continue to be at risk.

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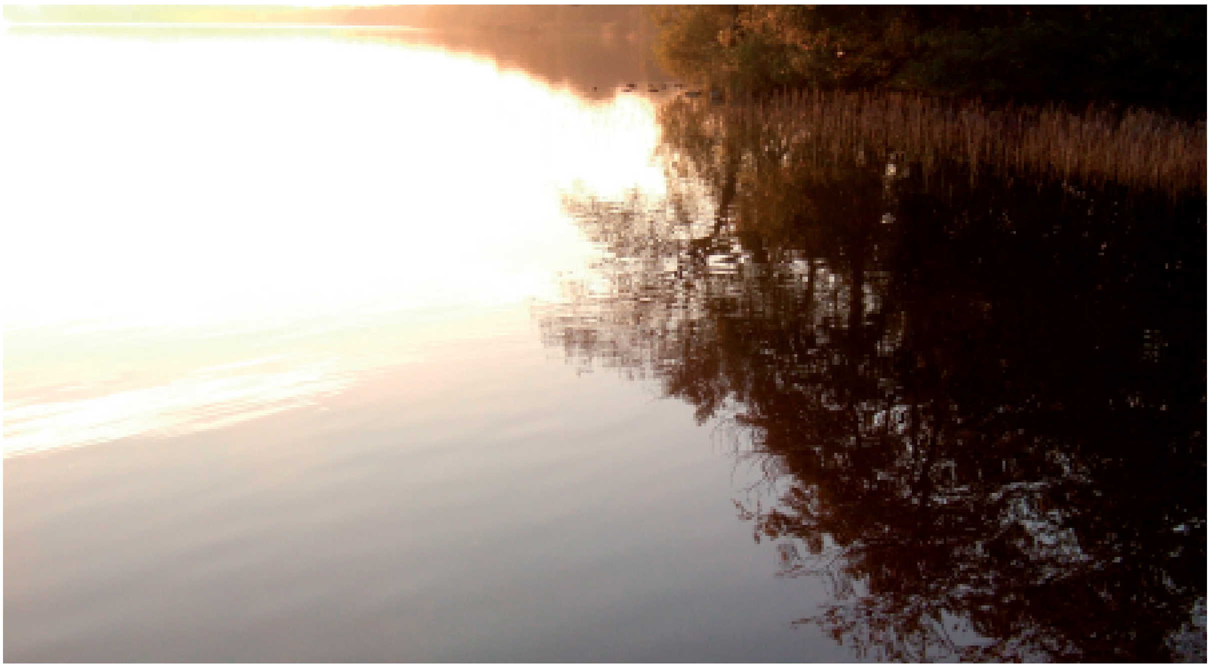
6. BIODIVERSITY AND WATER



6.1 THE RELATIONSHIP BETWEEN FISHERIES AND BIODIVERSITY

Rivers, lakes and wetlands provide us with a variety of economic benefits that include a contribution to the regulation of the water cycle, nutrient cycling and sediment capture, fertilisation of flood plains, transport, drinking water, water for agriculture and industry, waste assimilation, fishing and recreation. Even a dirty river can provide for transport. However, a high level of biodiversity provides a crucial regulating service by ensuring the good standard of water quality on which all other economic benefits depend to one degree or another. This allows water to be used for drinking, has an indirect provisioning value in terms of fish production and cultural services in terms of recreation and amenity.

The ability of water to accept pollutants is itself an economic benefit, albeit one with social costs and one that operates most successfully where a functioning ecosystem survives to break down these pollutants. However, clean water has a more fundamental value. Much water is used for drinking and for domestic, agricultural or industrial purposes. For these services, a high level of source water quality is obviously desirable. Where this is not available, water can, of course, be purified, albeit at rising expense depending on the level of purification required. High quality water is most essential for the harvesting of fish. Here there is a strong relationship between water quality and fish catch. Angling, as a purely recreational activity, is relevant here too, as was, until just recently, commercial wild salmon harvesting. Indeed, all water-based recreation depends, to one extent or another, on the availability of high quality water.

(1) Sustainability and External Costs

Consciously, or unconsciously, countries seeking rapid economic development often get by with greatly diminished water quality. China is one current example. However, doing so involves social costs. Ultimately, there is a strong relationship between water quality and quality of life. The free access nature of water means that it provides a ready means for the disposal of pollutants. Doing so, can mean that costs are passed downstream to other activities that need to abstract water and to any business or individual whose health or livelihood depends on clean water. Typically, the external cost to others exceeds the private benefits to the polluter, most certainly over time. However, policing pollution is difficult, particularly where the polluters are responsible for many jobs or have political influence. Industrial polluters are, though, easy to identify. Once the economic case is accepted, end-of-pipe treatment typically provides an initial solution. Management is more difficult where the pollution is diffuse as is the case with much pollution from agriculture or scattered rural residential development.

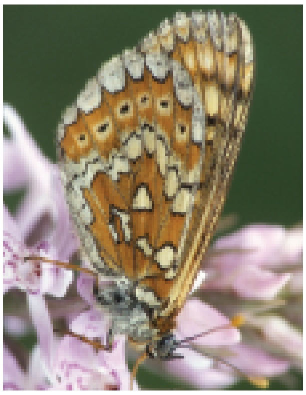
Once pollution management is effective, it is possible to clean up rivers and lakes. Rivers such as the Thames or Liffey are substantially cleaner than they were in the past. However, restoration takes time and can involve considerable cost. Keystone species of a formerly complex aquatic ecosystem may have been lost. Lakes also act as depositories of pollutants. Even though the latest EPA data indicates some slight improvement in lake quality over the past five years, many important aquatic species and fish might never recover their former populations.

UN Living Planet Index

The Living Planet Index, created by the World Wide Fund for Nature and the UNEP-World Conservation Monitoring Centre, provides a measure of the trends in more than 3,000 populations of 1,145 vertebrate species around the world. The 2004 freshwater species population index took into account trend data for 269 temperate and 54 tropical freshwater species populations, 93 of which were fish, 67 amphibians, 16 reptiles, 136 birds, and 11 mammals. The index showed that freshwater populations have declined consistently and at a faster rate than the other species groups assessed, with an average decline of 50% between 1970 and 2000. Over the same period, marine fauna decreased by 30%. Overall, the trend is one of continuing decline in each ecosystem over the 30-year period.

Much of this decline has been the result of human impact, including the diversion of freshwater from estuaries (e.g. by river and lake abstraction schemes), which affects the delivery of water and sediment to nursery areas and floodplains. Furthermore, the intensification of agriculture and the release of poorly treated or untreated wastewater, has resulted in a substantial increase in nutrients entering the aquatic environment.

6.2 RELEVANT SPECIES AND FUNCTION



Good water quality is a two-way process. Numerous species are involved in cleaning water. These can be classified according to feeding groups and include vegetation shredders such as water lice and crayfish (Gammanus sp.), collectors/filterers such as blackfly and mayfly, larvae grazers such as snails and beetles, and bottom feeding detritivores (Cummins & Klug, 1979, Ostroumov, 2002). A good deal of interaction occurs between these species. For example, symbiotic relationships may exist between bivalves and fish, while crayfish and insect larvae also form a food source for fish. Otters and birds are next in the food chain.

Pollution from phosphates and nitrates has the effect of raising the nutrient load in rivers and lakes. This encourages an increase in algae which is an important food source for the aquatic grazers or zooplankton whose numbers increase in response. By controlling the algae, these species perform an ecosystem service which is especially important for rivers at risk of falling into the slightly and moderately polluted EPA categories 3 and 4. However, once this eutrophication rises above a certain threshold, algal growth proliferates choking off the oxygen supply to other species.

As many species have evolved under circumstances of low nutrient status, even low levels of pollution can quickly have a destabilising impact. The mayfly is one familiar example of a species that depends on high quality water and is of obvious importance to the diet of many fish. At the other end of the scale in terms of longevity is the freshwater pearl mussel which can survive for 100 years and which lives only in clean turbulent waters. Due to the vulnerability of young pearl mussels to pollution, the species has declined by over 80% in the last ten years. Much of the remaining population is believed to comprise adults born before Independence!

Other forms of pollution also have an impact, for example heavy metals from industrial pollution. Metals such as aluminium can also be released from soils by acidification due to poorly sited commercial forestry. High sediment loads are damaging too. Sedimentation from farming, arterial drainage or construction can raise temperatures and physically overwhelm filter feeders and fish populations. Thresholds can quickly be reached beyond which some plant species are no longer effective against heavy metals or at which filter feeders can no longer absorb finer particulates.

6.3 ECOSYSTEM SERVICES

Purification

The principal ecosystem service is the regulating one of water purification, benefiting both water abstraction and the assimilation of pollutants. Water from surface sources is highly dependent on natural aquatic systems for its preliminary purification. By comparison, groundwater is especially vulnerable to surface pollution, and its quality is greatly influenced on the frontline by soil micro-organisms. In contrast to much of Europe where much water is derived from ground sources, only one quarter of Ireland's water comes from groundwater sources.

The aquatic ecosystem is capable of mopping up nitrates and phosphates, but has evolved in conditions where nutrients were scarce and is vulnerable to being overwhelmed by excessive quantities. Once this occurs, artificial water treatment is required for human needs, the cost of which increases as the level of pollution rises. By 2022, it is anticipated that 85% of Ireland's rivers could require protection through treatment of effluent as their assimilative capacity will be at risk of being exceeded (DEHLG, 2005). It is perhaps ironic that much effluent treatment can be achieved through the artificial creation of wetland ecosystems. Increasing interest in reedbed systems for the treatment of waste is being shown by local authorities, industrial firms and some rural households. Such systems even seem to be able to control bacterial pollution from e-coli, a common problem with rural water supplies due to livestock pollution and domestic sewerage. Riverside vegetation is promoted within the Rural Environmental Protection Scheme (REPS), partly to trap farm pollutants.

Fish catch

The aquatic ecosystem provides a provisioning service in terms of the economic and recreational value of fish species. As a result of its separation from mainland Europe at the end of the last ice-age, Ireland could not be reached by true freshwater species. As a result, the species diversity of native freshwater fish in Ireland is relatively low in comparison with the UK and the rest of Europe (Quigley & Flannery, 1996). Fully half of our total freshwater fish, including familiar species such as pike (Esox lucius) and roach (Rutilus rutilus), have been introduced and dispersed by humans (Went 1950; Moriarty & Fitzmaurice 2000). Nevertheless, Fitzsimons and Igoe (2004) contend that Ireland has some of the finest fish faunas in Western Europe as many freshwater fish communities have remained unchanged since the Ice Age. Ferguson (2004) highlights the large and unique genetic diversity of the native brown trout and pollan. Several Irish inland waters, such as Lough Corrib, Lough Mask, and Lough Melvin, are world famous as brown trout angling destinations, attracting a substantial amount of angling tourism.

Not all fish demand the highest quality water, but higher value species such as salmon typically do due to their insectivorous diet and migratory reliance on the chemistry of specific rivers. Fish and eels were important food and income sources in the past, but the number of locations where these species can now be harvested is very few. The wild freshwater catch has now largely been substituted by fish farms, although these farms themselves depend on good quality water (see Fisheries). In 2004, commercial production of trout from such farms was valued at around €600,000.

In the case of salmon, legislation has now just been passed, amidst much opposition, to close the wild commercial fishery in response to the declining catch. While various factors have had a role in the salmon's decline, poor water quality has certainly been one factor. At around 139,000 fish, the catch had fallen to just 64% that of just four year's earlier and is only a fraction of that caught in the past. Although, as a result, wild salmon attract a premium price, the value of the commercial share had fallen to just €4 million per year (Indecon, 2003). The decision to close the commercial fishery was partly due to recognition that the recreational value of an individual salmon is worth up to €1,000 compared to between €25-60 for a netted wild salmon. The total value of the recreational fishery has been estimated at between €11.5 million and €15 million.[6]

Wetlands

A further ecosystem service is produced by wetlands. In Ireland, peatlands are a distinctive wetland feature of the cultural landscape. Although of no use to groundwater recharge, peatlands act as a sponge, absorbing water at times of high rainfall and so acting as a buffer against flooding. Surface mosses are highly efficient at absorbing water and are of horticultural value for precisely this reason. As such, peatlands and their vegetation regulate the flow of water with consequent economic and social benefits. Given that raised and blanket bogs are dependent on the collection of nutrients from the air and from precipitation, they also possess a highly specialised biodiversity.

Peatlands are also of major benefit in offsetting global warming. Although they do release methane, a potent greenhouse gas, they also act as carbon store, without which huge quantities of CO_2 would be released into the atmosphere. Releases of this nature, due to the deforestation of tropical peatlands in Indonesia, are thought to have contributed up to 40% of global greenhouse gas (GHG) emissions in 1997 and 2002 (Page et al, 2002), but are not currently included in national calculations in relation to the UN Convention on Climate Change. In Ireland, carbon emissions are occurring directly due to the burning of peat as fuel, but also indirectly as bogs dry out in response to the drainage undertaken to facilitate peat harvesting. While conversion to agriculture has virtually ceased in response to agricultural policy reform, the drying out is continuing due to current harvesting and past drainage. This is leading to a corresponding release of carbon and methane. A healthy surface flora is representative of a stable bog, but also minimises its desiccation. Potentially, drains can be blocked and bogs re-wetted to permit the establishment of a peatland ecosystem.

6.4 ECONOMIC AND SOCIAL VALUES

Water is both a public good and a private good. The economics of water use includes a sizeable element of external costs in that pollution by agriculture, industry and the domestic sector presents a social cost to downstream users. Furthermore physical abstraction by these sectors reduces the ecosystem's capacity to maintain clean water, particularly during periods of low flow. Agriculture is in the position of being the biggest user and polluter of water sources.

Polluted water presents a significant health risk. The greatest threat is presented by heavy metals from industry, mining or natural sources. The ecosystem is unable to mitigate this pollution which

6 The €11.5m. figure was estimated by Indecon, of which €6.5m.is due to visiting anglers. In his submission to the Oireachtas Ctte, consultant, Michael Nealon believed that the value of the latter is at least €10m.

can be exacerbated by acidification. Fortunately, pollution by heavy metals is rather rare in Ireland. Rivers and lakes in Ireland are relatively clean compared with some other European countries. Nevertheless, the recent cryptosporidium outbreak in Galway demonstrates the result of complacency in not providing adequate control of pollution or of water purification. Twenty-nine percent of rivers are classed as being slightly or moderately polluted (EPA 2005) mostly due to non-point source pollution from agriculture, particularly of phosphates and nitrates. Nitrate is the greater threat to health and considerable amounts are being spent to reduce nitrate pollution under the Nitrates Directive, for instance through €39 million of investment under the Farm Waste Management Scheme as well as through REPS. The health risk from nitrates is confined largely to groundwater sources, although only around 2.6% of sources are reported to have elevated levels (EPA, 2002). Biodiversity has a positive impact by recycling the nitrates before water filters down to groundwater.

An indication of the external cost of pollution is available from the net amounts that local authorities anticipate having to invest in water quality management in excess of cost recovery. Expenditure has increased by €40 million per year since 1999. Indeed, the current NDP proposes expenditure of €4.75 billion between 2007 and 2013. Under the previous NDP, a total of €3.7 billion was ear-marked for water and waste water treatment. Of this, around €500 million was spent on capital investment in the Rural Water Programme. Under the Rural Water Programme, most expenditure has been on water supply rather than sewerage (in principle, development levies recover the cost of sewerage for new housing schemes). In 2006, €120 million was spent on the supply of rural drinking water, while sewerage accounted for only €10m. Of expenditure on public schemes, the situation is reversed with only around one fifth being spent on supply. Prior to the previous NDP and launch of the Water Services Investment Programme, much rural treatment was grossly inadequate. However, at least as much has needed to be spent on distribution as on a new treatment plant.

In terms of the ecosystem services, spending on drinking water purification is relevant in that much of this treatment is necessary because ecosystem services have been overwhelmed. The annual cost of nitrate removal in the UK has been estimated at between £24 million and £38 million per year (Redman, 1996, Cobb et al, 1999). No such removal occurs in Ireland, but a sizeable 36% of rural Group Water Schemes are contaminated by e-coli (EPA, 2005). Treatment costs are low at about 1-2 cent per 1000 litres, or roughly 15% of total operating costs (WRRC 2001). In Ireland, operating costs have been estimated at €0.5/m3 (DKN et al. 2004). Some treatment will always be necessary even where the ecosystem is healthy. However, increasing levels of pollution (corresponding with ecosystem damage) imply a rising marginal cost as simple chlorination is replaced successively by sand filtration, active carbon or ozone treatment. On top of this cost, is the substantial amount that must be spent on new plant. As with waste water treatment, considerable recent investment has had to be made in water supplies to close this long-standing infrastructure deficit.

Alternatively, it is possible to examine the amounts that are likely to be spent under the Water Framework Directive (WFD) to ensure that most rivers achieve the required Good Ecological Status by 2015. These amounts include the above expenditure on waste water treatment plus river basin management. As well as being a cost, these substantial sums can also be regarded as reflecting the value that the public are presumed to place on clean water, i.e. purity that can be maintained by the ecosystem itself. No estimates of the additional amounts that will need to be spent under the WFD on catchment management are yet available aside from the modest amounts (€16 million per annum) being spent on pilot schemes. An illustration of the ultimate costs can be taken from the USA where New York State has recently purchased an up-stream watershed area for $1.5 billion having found that catchment management is more cost-effective than the $3-8 billion that would need to be spent on waste water treatment (Ramsar Bureau, 2006).

A functioning ecosystem supports recreation and amenity. Whereas drinking water passes through a treatment plant, recreation requires a clean water environment to which the main threats are eutrophication and acidification. A recent report by the Marine Institute (2003) estimates that water-related recreation accounted for 45% of domestic tourist expenditure, comprising boating (€17m), freshwater angling (€33m) and other fresh water-based leisure (around €20m). Based on Marine Institute figures for 1999, the approximate annual spend by overseas tourists in these activities today would add a further €65 million, although this may be an under-estimate. A portion of this expenditure becomes capitalised in a realised value of recreational assets. For example, fishing rights along the Rivers Errif or Moy are valued at between €4-8,000 per salmon, equivalent to €500,000 per kilometre of riverbank. Such high values represent a scarcity rent which would not be realised if other rivers were rehabilitated, but which does give an indication of the economic case for protecting water quality. Indeed, the Marine Institute report indicates a willingness of many people to engage in more water-based recreation should better facilities be provided in the future.

Table 8.1 in the chapter on Human Welfare provides an indication of the benefits to recreation of improving environmental water quality based on transfer valuations from UK studies. Further information on angling benefits is provided in the Annex to this chapter. The social benefits are substantial. Large numbers of people participate in these activities. For example, around 190,000 nationals (29,000 taking an overnight trip) are involved in water-based activities. A further 97,000 overseas visitors are also involved in angling (Marine Institute, 1996, 2003). The social value is not confined to these water recreation interest groups, but is multiplied substantially by the very large numbers of people who benefit from countryside recreation and amenity. Studies consistently show the attractiveness of water and the importance that people attach to rivers, lakes and canals as valued heritage (Campbell et al, 2006; Heritage Council, 2007). These values are presented in the chapter on Human Welfare.

Table 6.1: Categorisation of benefits

Rivers and groundwater	Reservoirs, lakes and broads	Coastal waters and estuaries
Informal recreation. Angling. Commercial fisheries. In-stream recreation Heritage, archaeology and landscape. Amenity. Abstractions. Biodiversity and non-use.	Recreation. Heritage, archaeology and landscape. Amenity. Biodiversity and non-use.	Informal recreation. Coastal bathing. Water sports. Recreational fishing. Shellfisheries. Biodiversity and non-use.

Source: Guidance Part 1, Table 2.1. Environmental Agency for England and Wales (2004)

6.5 THREATS

Aquatic ecosystems are under constant threat. As well as the most sensitive species such as the pearl mussel, salmon populations have collapsed in many rivers and crayfish have been eliminated from the Liffey and Boyne by sewerage (Persic, 2006). Pressures on water for both abstraction and waste assimilation have increased in line with economic growth. Although the latest figures record only a slight reduction in quality, the EPA admits that inadequate funding of effluent treatment presents a potential crisis Much investment has already been made in municipal sewerage treatment, but rapid rural development is being permitted without the assurance of future waste water treatment. Scattered housing development in the countryside is subject to high sewerage standards in principle, but there is the serious risk that maintenance of these systems will be inadequate. Agricultural pollution could decline due to new policy incentives for improved nutrient management, but elevated levels of phosphate could persist in soils and the ecosystem for many decades. There is a precarious future for many water species and especially for those such as the pearl mussel, lamprey or arctic char, which depend on the highest quality water.

Non-native species represent a further threat to the functioning of the ecosystem. For instance, Lagorasiphon is presenting a serious threat to angling given its capacity to choke off sunlight. Salmon fisheries in Lough Corrib and elsewhere are currently under significant threat from the proliferation of this exotic weed. Elsewhere, rivers and lakes are threatened by an explosion in numbers of zebra mussel, another alien species. The full impact of the mussel's dramatic population growth is still unknown. Certainly, it can interfere with abstraction and boating. While it can, at first, have a positive impact on water quality, it does so by cleaning lakes of the very nutrients on which other organisms survive. In Lake Michigan, numbers of zebra mussel are so great that their rotting remains eliminate oxygen leading to a proliferation of toxic species that tolerate low-oxygen environments.

The Pollan – a true Irish fish

The pollan (*Coregonus autumnalis*) is the only member of the whitefish family found in Ireland, and is found nowhere else in Europe. The species is limited in its current distribution to four large lakes, Lough Neagh and Lower Lough Erne in Ulster, and Lough Ree and Lough Derg, on the Shannon. Pollan were once present and probably abundant in other Irish lakes. The Irish pollan is now known to be distinct from the other European coregonids. It is highly endangered in Ireland, having been reduced by ecosystem degradation due to pollution, habitat loss, invasive species, climate change and commercial fishing (Foy et al., 2003, Harrod et al., 2002, Maitland & Campbell, 1993, and Rosell, 1994).

Lough Neagh has the only remaining abundant population of pollan and still supports a small scale commercial fishery. Although there are no firm data on trends in abundance, catches are known to be much reduced from former levels. The Shannon lakes' populations of pollan are down to 5% to 9% of former levels, or just 1% in terms of former biomass. Lough Derg once supported a commercial pollan fishery of local cultural and economic significance, with catches of pollan amounting to "hundreds per night" during the 1960s. However, the population has declined drastically. Gill-net surveys in the late 1990s captured no pollan in Lough Derg and only 15 specimens in a survey of Lough Ree (Griffiths et al., 1997). Recent annual catches number 3 or 4 specimens per year (Rosell et al, 2004). The Lower Lough Erne population of pollan is severely reduced, a major decline having occurred sometime between 1960 and 1990. The pollan is now listed on Annex V of the EU Habitats Directive (92/43/EEC) and in the Irish Red Data Book as Endangered. An all-Ireland Species Action Plan for the pollan has been prepared (2005). A failure to reverse the decline in this species would not only signal the loss of a unique aspect of Ireland's natural heritage, but also the loss of an economically and culturally valuable natural resource.

6.6 COST OF PROTECTION

Below a certain threshold, the restoration of particular rivers or wetlands can sometimes be achieved through consensus amongst former polluters. However, where ecosystem damage has already occurred, the use of biomanipulation to restore ecosystems can cost far more than ex-ante protection.[7] For example, the restoration of water quality in the Florida Everglades is put at $685 million. In Ireland, specific projects have been undertaken as three year pilots for the WFD. These include the Three Rivers Project in Leinster (€8.3m) and the Lough Derg and Lough Ree Catchment Monitoring and Management Project (€3m), together with its successor for the Shannon (€8.5m) (www.wfd.ie). These amounts are a fraction of what is ultimately likely to be spent enforcing the WFD. Indeed, €47 million was allocated to the WFD in the Water Services

[7] Pers comm. M. McGarrigle of the EPA regarding experience of ecosystem restoration in the Norfolk Broads.

Investment Programme between 2005-07. The risk of further cryptosporidium outbreaks like that recently experienced by Galway City could yet lead to more pro-active catchment management particularly in relation to diffuse pollution from agriculture and domestic septic tanks. The investment can be seen as the value that society places on a functioning aquatic ecosystem and the services it provides. As of yet, no statements are available on the cost of implementation (Heritage Council, 2006).

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7. BIODIVERSITY, ROADS AND INFRASTRUCTURE

7.1 THE RELATIONSHIP BETWEEN ROADS, INFRASTRUCTURE AND BIODIVERSITY

Inevitably, the construction of roads and physical infrastructure such as power lines or pipelines has an adverse impact on biodiversity as green field sites are normally involved and wildlife habitat is destroyed in the process. However, where environmental impact assessment is undertaken there is an opportunity to identify important habitats and to either protect these or to mitigate the impacts of new development. In particular, spare parcels of land provide opportunities for habitat creation even where this comprises nothing more than reversion to a natural regeneration of scrub in an intensively farmed landscape. Furthermore, the linear verges and habitats alongside new roads often possess a wealth of biodiversity due to the lack of human disturbance or use of herbicides. Some species are unconcerned by noise and have even used this to their advantage, notably the kestrel which is commonly seen hunting above motorway verges.

The principal adverse impact arises from fragmentation of habitat. Fragmentation has been a feature of more intensive farming and is certainly an outcome of much built development such as housing. Invariably, new roads present a significant risk of habitat fragmentation. As habitats become smaller and less continuous their functional integrity is reduced and their reduced size increases the prospect of their being over-looked when it comes to future development. As such, habitat fragmentation affects all species, although it is obviously a greater problem for mammals. As well as the inevitable physical danger posed by roads, breeding populations can also be reduced to below sustainable levels. The reduced opportunity for migration also inevitably increases the vulnerability of species to climate change. Fires caused by cigarettes or broken glass discarded by passing motorists may worsen this risk as summers become drier and hotter.

On the other hand, roads can provide new linear habitats. Motorway verges are often planted with trees, typically now native trees, and an absence of subsequent intervention or infrequent mowing can provide a quality habitat. It's a habitat that does not suit all species given the proximity of traffic and regular interception by junctions or overbridges, although some species such as the aforementioned kestrel can benefit from the vegetation growth and background noise. The linear habitat also compensates, albeit partially, for the fragmentation of previous habitats. Although, this has, in some instances, benefited the spread of invasive non-native species.

Pollution can be a problem. Run-off from the road surface can deposit pollutants such as petrochemicals into adjacent watercourses. Local authorities may also be less than cautious in their application of herbicides. Major new roads normally include sites for holding ponds to retain such run-off, but pollution is a problem on many existing roads.

A further problem is that the improved accessibility typically encourages new built development which can lead to the loss of adjacent habitats. Although such potential cumulative impacts should be identified by the environmental impact assessment, subsequent local planning decisions may pay inadequate attention to minor habitats.

7.2 RELEVANT SPECIES AND ECOSYSTEM SERVICES

Although it may sound bizarre to talk about ecosystem services in the case of roads, there are some indirect benefits from mitigation. For example, roadside trees capture polluting dust particles and also mitigate noise levels. These benefits can be over-stated, but appear to be highest for the first line or two of trees and diminish rapidly beyond these. In addition, as noted above, holding ponds containing reedbeds and their associated species perform the value of removing pollutants before they can find their way into the wider environment. There are ecological benefits from these services, but the principal benefits are in terms of human health and well-being.

Aside, from the benefits there are particular species which are at risk from roads. These include:

- Badgers. Badgers are a protected species under the Wildlife Acts 1976 & 2000 and sets cannot be disturbed. The NRA therefore aim to identify sets prior to construction. In cases, where a set is in the direct line of a road, efforts may be made to temporary relocate the population to a new location. More typical, though, is for underpasses to be provided together with badger proof fencing along the road. These mitigation measures are, of course, far from perfect, especially as badgers may be drawn to roadside habitats to forage. Furthermore, older roads will not possess such mitigation even though they are likely to be carrying far more traffic than at the time they were first surfaced. Dead badgers are a frequent siting along roadsides.

- Otters. These mammals are widespread in Ireland, although they usually exhibit a low density population. As such, they are susceptible to habitat fragmentation. The width of major roads is a deterrent to otters using underpasses, but new roads now tend to channel minor streams under roads using a slightly meandering course with an accompanying raised platform.

- Bats. Detailed guidelines exist to minimise the danger to bats from tree-felling, timing of works, damage to roosts, building demolition, bridge restructuring or lighting following road opening. In this respect, bats are typically better protected with major road schemes than with built developments or renovations where the need for protection is often ignored by developers. However, there are still problems where roosts or territories go unidentified.

- Deer. As two of Ireland's three species of deer are non-native and present a nuisance for forestry, mitigation measures are typically restricted to the erection of deer proof fencing to avoid collisions. Speed restrictions may be imposed where deer are present. Native red deer live in the remoter areas of Ireland, but mitigation measures such as underpasses are used in other European countries.

7.3 ENVIRONMENTAL IMPACT ASSESSMENT

All large public infrastructure developments are subject to environmental impact assessment under the EC Directive 85/337/EEC. So too are larger private developments which have implications for land use, public well-being, and air or water quality. Specialists are contracted to identify and assess potential impacts as they affect human beings, flora, fauna, soils, water, air, climate, landscape, material assets and cultural heritage. On the basis of these investigations, mitigation measures or alternative development options are proposed.

Where roads are concerned, the National Roads Authority issues guidelines on impact assessment. It also has a dedicated Environmental Section. For specific projects, assessment usually commences with a constraints study of the likely impacts of alternative route options. This is followed by a more detailed Route Selection Report at which stage a limited amount of fieldwork is typically undertaken. Finally, once a preferred route has been selected, an environmental impact study is commissioned. Assessment is usually along a route corridor within which some degree of re-alignment is possible in the event that significant impacts are identified. However, this does not preclude a re-routing of a section of road in the event that serious impacts are predicted. At present, the use of cost benefit analysis in road development is limited to an assessment of journey time savings and accident costs and takes no account of full economic costs over time, including biodiversity (Ozdemiroglu & Bullock, 2001). The limited scope of CBA is arguably a factor which contributes to the NRA's preference for new routings over the more extensive renovation of existing routes. New routes have high time savings, low accident rates and low impacts on existing material assets, but possibly greater impacts on biodiversity and landscape which are not quantified in the same manner.

EIA does not explicitly consider biodiversity. Rather, assessments are made of flora and fauna and these record, species presence and vulnerability, as well as their dependence on habitats and external inputs such as aquifers and water supply. Seasonality can be a problem given the timing of site investigations. Indirect or secondary impacts are also relevant. It has been argued that by proposing a cutting for the Kildare Bypass with its possible implications for the aquifer recharge to Pollardstown Fen National Nature Reserve, Kildare County Council gave greater weight to equine and landscape concerns than potential ecological impacts.[8] Whatever the truth of the matter, the issue delayed the bypass by three years. An impermeable membrane was eventually provided at an additional cost of €5 million. The ultimate cost of the bypass had risen to €160 million from initial estimates of €70 million.

The EIA process is comprehensive, but is subject to some weaknesses in implementation. A common complaint concerns objectivity in that consultants are appointed by a client who is typically the developer or a public agency charged with infrastructure development. This is not necessarily as serious as it sounds in that EIA is directed at removing the causes of adverse impacts prior to development consent. Furthermore, consultants have a professional reputation to maintain and would be aware that their findings are open to scrutiny within a possible oral hearing. Lack of objectivity is possibly a greater prospect with smaller private projects where an appeal to An Bord Pleanala or an oral hearing is not expected. However, ecology is likely to be less of a casualty than the supposed "soft" social sciences.

One further weakness of EIA is its limited scope. Although some attention is given to interactions between different impacts, EIA makes no allowance for a quantification of non-market or external costs as they affect human beings. A further characteristic of the limited scope of EIA is its restriction to a single project. The assessment is required to consider cumulative impacts, but these can be rather tenuous. Road construction commonly presents a cumulative impact in that built development may follow in its wake. Although the road builder is required to adopt mitigation measures proposed by the specialist, it is difficult for the Environmental Impact Statement to address cumulative impacts which are long-term or uncertain. Furthermore, whereas the road builder must adopt the mitigation measures included in the EIS, subsequent new developments are not so constrained. The developer or planner may ignore this advice or simply be unaware of it.

8 Newsletter of the Irish Waterways Association of Ireland (2004).

Strategic Environmental Assessment should compensate for the project-based limitation of EIA. SEA is directed at policy rather than projects and, specifically, the sustainability of policies. It aims to focus on key environmental constraints rather than to collect the more comprehensive data of an EIA. To date, SEA in Ireland has only been required of local authorities in the preparation of development plans. More often than not this process has extended only to an elaboration on the environmental proofing of intended policies. This is unfortunate as SEA is the ideal means through which to examine the wider implications of development as they affect topics such as biodiversity. For roads, the main adverse impact on biodiversity arises from habitat fragmentation. However, the implications of this impact are impossible to examine at the level of an individual project using EIA. The assessment of climate impacts is similarly compromised.

7.4 COST OF PROTECTION

While the NRA has detailed guidelines on the measures that should be taken to avoid ecological impacts, there have been no assessments of the cost of these measures. Inevitably, costs vary enormously between schemes depending on the nature of the landscape. In addition, it is very difficult to isolate these costs as, under Design and Build Schemes, the road builder frequently provides a lump sum estimate of the amount spent on all environmental works, including visual and noise mitigation and earthworks. The NRA are currently looking into the costs of environmental mitigation. In the immediate term, the best that can be done is to use the NRA's guide prices for road features of relevance to biodiversity and apply these to a typical 10km of dual carriageway. For this length of road an ecological impact assessment might cost €20,000 while mitigation measures to protect habitats and water quality could cost €45,000.[9] The figure excludes the costs of stockproof fencing, earthworks, planting and the costs of road diversions around ecological features. Given the length of new road constructed each year, this suggests a total annual cost of at least €35 million.

[9] Assuming two badger underpasses @ €4500, 50 bat boxes @ €210, 20 sediment trap @ €540 and 2 retention interceptors @ €7500.

References:

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8. BIODIVERSITY AND HUMAN WELFARE

8.1 THE RELATIONSHIP BETWEEN HUMAN WELL-BEING AND BIODIVERSITY: 'TOTAL ECONOMIC VALUE'

Biodiversity provides a wide variety of benefits in terms of human welfare. In the other chapters of this report dealing with productive sectors, the benefit of biodiversity has arisen mainly from ecosystem services. Within a categorisation of Total Economic Value, these benefits can be included under the category of 'use value', be this 'direct' as in the harvesting of fish populations, or 'indirect' as in the array of aquatic ecosystems that support fish populations. The benefits apply to economic systems and enhance both incomes and people's well-being.

In addition, there is a direct benefit where human activity responds and benefits from biodiversity as, for instance, with recreational angling, bird-watching, dolphin watching or similar activities. These benefits are realised by individuals and become part of their preference structure and decision making. In other respects, the benefit of biodiversity is indirect as, for example, where people visit attractive landscapes which are themselves partly a product of biodiversity. Indirect values also derive from such activities as the watching of nature television programmes, reading of relevant books or articles, or from journey amenity. The relationship between biodiversity and human health as discussed in chapter 4.7 provides a further instance of an indirect value.

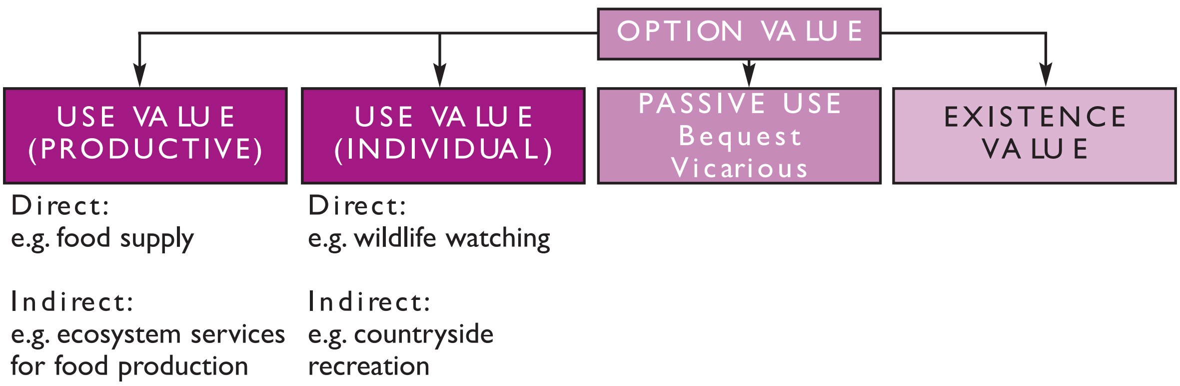
'Passive use values' include the positive utility one may feel from bequeathing a healthy biodiversity to future generations, or from vicarious values, i.e. valuing the benefits enjoyed by others.

Unambiguous non-use or 'existence values' occur where people are not engaging in activities such as angling, bird-watching or countryside visits, but nevertheless benefit from knowing that there are healthy fish populations, that birds and their habitats are protected, or that Ireland has an attractive countryside.

It is the indirectness of many biodiversity benefits that make its value difficult to quantify. Much of this arises from what Costanza (1997) calls an "infrastructure" value in which biodiversity supports other activities. Fromm (2000) argues that this input is ignored by the above categorization of Total Economic Value because this considers only outputs and is unconscious of the complementary relationships that exist between species. Society, he argues, is largely ignorant of the inter-related functional benefits of biodiversity which together contribute a vital security value. This security value contributes to activities from which there is an individual benefit, such as recreation, and to productive benefits such as food supply. These benefits are dependent on the ecosystem services provided by a complex web of biodiversity. Without an understanding of these relationships there is a risk of unpredictable, possibly irreversible welfare losses.

In fact, these values can also be included under a Total Economic Value taxonomy. For instance, Fromm's "security value" is analogous to option value, an accepted component of passive use values which applies where there may be a benefit in protecting biodiversity for potential future use. However, Fromm does make the point that we know so little about biodiversity that its true indirect or option value likely far exceeds those benefits that we can identify. These benefits may not be singularly confined to identifiable species. The chapter on agriculture noted that ecologists are moving away from discussion of keystone species to a consideration of the uniqueness (or not) of the functions of each species, including investigation into the substitution of functions between species or species redundancy. This is still an area of which we only have the vaguest of understanding. The huge degree of ignorance of ecosystem services means that protecting biodiversity has an insurance value, and particularly so in the face of climate change. This insurance value underpins the need to include safe-minimum standards or a precautionary principle in cost-benefit analysis.

Figure 8.1: Total Economic Value



8.2 VALUING BIODIVERSITY

Biodiversity contributes directly and indirectly to our diet and to our health, but also to our quality of life. As these are amongst the key responsibilities that government has for its subjects, so biodiversity is deserving of protection. Its importance is acknowledged by National, European and International policy. However, the benefits of biodiversity are little understood or often intangible and so tend not to be priced by the market. Without a price signal to indicate importance or scarcity, biodiversity is under-valued and public and political awareness may be low. Failure to recognize the benefits, together with individual variations and inequities in use values, means that social or economic activities can impact adversely on biodiversity. When this occurs, costs, i.e. external costs, are passed onto others. Sometimes these activities can even be encouraged by policy, such as through ill-considered taxation and subsidy schemes. The Common Agricultural Policy is commonly used as an example. Past manifestations of the CAP strove to increase agricultural productivity without consideration of the consequences for biodiversity or the wider public good.

As an un-marketed public good, it is necessary to attribute a value for biodiversity based on an estimation of the contribution to human welfare or utility. One method is to take the price of a marketed good that is associated with biodiversity, for instance agricultural production, fish catch, clean water or land values. The other method seeks this information indirectly by observing people's behaviour (e.g. travel and spend), or directly by asking people to quantify the value they place on biodiversity through expressions of willingness-to-pay to protect it.

Costanza et al. (1998) attempted to place an approximate value on biodiversity at a global level. Curtis (2004) also attempts a comprehensive approach, but focuses on the local level (a World Heritage Area in Queensland) using a combination of land values and an expert group interpretation of the value of ecological services. However, valuing biodiversity in its entirety is an impossible task. A fundamental criticism is that economic value estimations should ideally be of incremental or marginal changes in the quantity of a resource. Inevitably, the value at any one time depends on this change in relation to the total stock of a resource.

One yardstick by which to measure the welfare value is in terms of people's income and their respective willingness to pay (or be compensated) for changes in a valued resource. Contingent valuation methods (CVM) are employed to derive estimates of people's willingness-to-pay. Discrete choice experiments (DCE) achieve a similar goal, but with greater reliability in relation to changes in the attributes of a resource (for example, 'number of species' would be one of the many attributes of biodiversity).

Economic valuation methods are anthropocentric. They seek only to value those components for which there is an interaction with human welfare. Nunes and van den Bergh (2001) review a number of papers relevant to this topic, but find that few examine biodiversity specifically. Most address aspects of biological resources and are of tenuous relevance to biodiversity (Pearce, 1999). Some surveys have sought to value individual species. Often these have limited themselves to so-called charismatic species, for example, whales (Loomis and Larson, 1994). Typically these species are familiar occupants at the top of the food chain, although they may nevertheless be representative of a healthy biodiversity. Other studies have estimated the value of particular habitats (e.g. Stevens et al., 1997). Some of these studies have looked at locations described as "biodiversity reserves" or have included estimates of ecotourism value and expenditure (e.g. Norton & Southey, 1995). Values tend to be higher if there are associated recreational pursuits. The value placed on recreational sites may also increase as more pristine sites, especially those characterised by high biodiversity, become more scarce. Nevertheless, any valuation must ensure that estimation is not subject to substitution effects whereby survey respondents may fail to take into account other alternative locations or species.

Most valuation methods relate to a specific programme or policy that aims to protect the species or habitat. This avoids confusion with the intrinsic value of a site or species in that survey respondents understand that such policies necessarily involve an economic cost.

Christie et al. (2006) refer to a recent UK study in which only 26% of people admitted to having heard of the term "biodiversity". [10] They acknowledge that it is difficult to ask general questions of the public about biodiversity and easier to ask people to value rare or endangered species than to ask about ecosystem services. To test this argument, they asked people to value various components of biodiversity in relation to agri-environmental schemes, namely familiar species, rare/unfamiliar species, habitat, and ecosystem services. Their results bore out the researchers' doubts as to public comprehension of biodiversity, finding that while people valued biodiversity, they were content to leave it to the experts as to how this was best achieved. In addition, they found that the public place a higher value on policies that ensure the survival of biodiversity (rather than slowing its loss) and on the protection of ecosystem services of benefit to mankind (rather than those of benefit to all species).

8.3 WELFARE VALUES FOR BIODIVERSITY PROTECTION, LAND USE, WATER AND HEALTH

8.3.1 Land use

Natural heritage

Wilderness locations high in biodiversity are popular subjects for environmental economists. Invariably such locations attract high expressions of willingness-to-pay largely by virtue of their uniqueness. Visitors may be willing to pay a large

[10] DEFRA (2002) Survey of Public Attitudes to Quality of Life and the Environment – 2001, DEFRA, London.

amount to experience such locations, but value estimates typically include a large measure of passive or existence value too.

Wilderness is rare in Ireland. Remote areas of the west coast are one example, as could be Connemara or mountainous areas such as Kerry, Mayo, Wicklow or the Mournes. However, it is the Burren that is most regularly referred to when it comes to biodiversity. In fact, all these locations are dominated by semi-natural habitat associated with various farming systems. Ireland's bogs also possess a combination of wilderness and high biodiversity.

A recent national survey for the Heritage Council (Keith Simpson & Associates et al. 2007) found that the Irish public placed a slightly higher value on natural heritage compared with cultural heritage. Their willingness-to-pay for additional measures to protect both forms of heritage averaged €46.83 per person per year. This is equivalent to €90 million per year once aggregated across the adult Irish population.

Agriculture

Chapter 4.1 discussed the value of ecosystem services to agriculture. Two outputs of both agriculture and its associated ecosystem services are farmland habitats and landscapes. As farming is practiced over 90% of Ireland, today's wildlife is that which has readily adapted to this land use. The biodiversity includes common and less common species. It also includes the interaction of biodiversity with farming activities, geology and topography, with the result being some familiar cultural landscapes.

The most relevant Irish study to date on the welfare benefits of Irish farming is that undertaken on the Rural Environmental Protection Scheme (REPS) by O'leary et al. (2005) and Campbell et al (2006a) on behalf of Teagasc and the Department of Agriculture and Food in Northern Ireland. REPS compensates farmers for farming in an environmentally friendly manner that protects valuable features of the landscape. These features include farm buildings and stone walls, but also other features that correspond to a healthy biodiversity, namely wildlife habitat, rivers and lakes, hedgerows, pasture and upland pasture. REPS includes a basic premium to cover environmental sensitive farming, but also optional supplementary measures designed to encourage more pro-active conservation. The latest round of REPS funding has extended these proactive measures to include additional supplementary measures for wildflower meadows and corncrakes.

Campbell et al. did not set out to report an average willingness-to-pay for REPS, but rather to examine the distribution of individual willingness-to-pay, finding that, for 41% of respondents, this amount exceeded the average annual per capita cost of the scheme of €63. The researchers used a choice experiment method to determine willingness-to-pay for specific landscape elements, finding that rivers and lakes were easily valued most. They believe that this preference for rivers and lakes results from a logical perception that water quality is indicative of the overall state of the rural environment.

Table 8.1 Willingness-to-pay for agri-environmental features (per person pa)

	Wildlife habitat		Rivers and lakes		Hedgerows		Pasture	
	"some"	"a lot"	"some"	"a lot"	"some"	"a lot"	"some"	"a lot"
Mean WTP	€117	€201	€278	€456	€81	€166	€178	€203
Median WTP	€114	€196	€277	€471	€80	€167	€203	€176

Note: figures after exclusion of lexicographic (fixed) preferences. Source: Campbell et al. (2006b)

Similar studies have been conducted in other countries. In the UK, studies have been undertaken of Environmentally Sensitive Areas (ESAs) in England (Willis et al., 1993) and Scotland (Hanley et al., 1998). However, these studies were specific to a single geographically bounded ESA whereas over one quarter of Irish farms are in REPS with the proportion being far higher in many western counties.

Allowing for the level of scheme participation and the prevalence of various landscape features, Campbell et al. estimate aggregate benefits for 2003 of at least €150 million per annum. Although less than the current annual spend of €280 million (approx €195 in 2003), the study was unable to address all the benefits of REPS. Other benefits include specific biodiversity welfare benefits that are not immediately associated with landscape or a single wildlife habitat measure. There is also the benefit of ecosystem services, of which (noting the remarks by Fromm), survey recipients would be largely unaware. In addition, there are social benefits to the smaller landholdings that dominate REPS participant numbers. Here too there is a relationship with biodiversity in that these smaller farms are typically more dependent on ecosystem services than larger, more intensive farms that make greater use of artificial inputs.

Naturally, benefits to human welfare derive from the quality of the wider farmed countryside aside from that which benefits from REPS payments. There is no figure to indicate the benefit of this countryside asset. It would, though, be substantial. In terms of use benefits alone, surveys suggest that almost 40% of the population undertake six or more walks in the countryside each year (Bullock, 2004).

Forestry

Forestry has more often been addressed by environmental economic studies. Some of the main schools of environmental economics are in the US, Canada and Scandinavia where large areas of forest abound. However, another rationale for the interest in quantifying forestry's welfare benefit is that foresters have difficulty demonstrating rural social benefits that are comparable to agriculture and instead seek to justify state supports on the basis of non-market benefits. While chapter 4.2

did demonstrate that forests make a modest positive contribution to biodiversity, these benefits would be less visible to the Irish public than for farmland given the dominance of commercial softwood forestry and the relatively small area that is planted. Nevertheless, as many forests are open to recreation, the benefits have a higher use value component than does private farmland.

The Forestry chapter listed estimates of the non-market benefits of forestry. These include the studies by CAMAR (ni Dhubhain et al., 1994) and Coillte/Irish Sports Council (2005) which focused largely on recreation benefits and local expenditure. The study by Clinch (1999) gave greater attention to non-use values by which he arrived at an estimated benefit stream of €21 million per annum.

Bacon and Associates (2004) provide the most recent estimate of non-market benefits at €88 million per annum, including carbon sequestration. However, they note that some past forestry practices have probably reduced welfare due to negative landscape and water quality impacts. Bacon and Associates refer to a UK study by Garrod and Willis (1997) in which the public indicated a willingness-to-pay of up to 56.4 pence per household for each additional 1% unit of new forestry grown to a "desired biodiversity standard". Taking the average benefit respective to the type of planting now being encouraged by the Forest Service, Bacon and Associates arrive at a respective value of 42.5 cent per household for Ireland. On this basis, the biodiversity value of the proposed national forestry expansion programme would be €1.6 million per year. However, the existing forestry estate was not planted to the same biodiversity guidelines and, despite its larger area, biodiversity could only be valued at €5.6 million per year more than the next likely alternative land use of agriculture under REPS.

8.3.2 Water

Given its importance to human consumption and recreation as well as biodiversity, it can be expected that clean water makes a highly valuable contribution to human welfare. As discussed in Chapter 4.4, this purity depends to a large extent on a functioning biodiversity. The report Economic Evaluation of Water Supply and Waste Water Projects produced by DKN, Aquavarra and the ESRI (2004) for the Department of the Environment undertook a thorough review of various benefit estimation studies that could be relevant to Ireland. Drawing on the review of twelve studies from Southeast England by Green and Tunstall (1991), as referenced in the Environment Agency (England & Wales) report Benefits Assessment Guidance for Water Quality and Water Resources Schemes (2003), DKN et al. arrive at the following table of the value of water quality changes based on informal water-based recreation.

Table 8.2: Benefits of changes in the quality of water used for informal recreation

Quality change from	To	Transfer value (2001 UK prices)	Value (2007 euro)
Q2 or Q 1 Not capable of supporting water birds	Q3 Good enough for water birds	£0.65 per visit, by day tripper or holiday maker	92 cent
Q2 (top) or Q3 Good enough for water birds	Q3 (top) or Q3-4 Good enough to support fish	£0.13 ditto	18 cent
Q3-4 Good coarse fishery	Q3-4 (top) or Q4 Able to support trout	£0.09 ditto	12 cent

Source: Environment Agency Guidance, Part 2 Table 2.9, from Green and Tunstall (1991)

The above categories of water quality are roughly equivalent to the categories A, B, C and D as published by the EPA as below:

Q Value	Pollution status	Quality Class
Q5 Q4-5 Q4	Unpolluted	Class A
Q3-4	Slightly polluted	Class B
Q3 Q2-3	Moderately polluted	Class C
Q2 Q1-2 Q1	Seriously polluted	Class D

Source: DKN Economic Consultants, Aquavarra, ESRI (2004)

We have added euro values at 2007 prices to Table 8.3. However, this is only as a rough guide. Accurate transfer of foreign valuations to Ireland (value transfer) is awkward in that it requires assumptions about Irish preferences for water quality and reliable data on the numbers of people involved in water-based recreation. On the one hand, public access to rivers is more limited in Ireland than in England. On the other, there are many more lakes (approx. 6,000). The Marine Institute estimates that 190,000 people undertake active water-based recreation each year. However, the numbers visiting lakes for more casual purposes, such as for walks, is certainly many times this number. For each of these users, wildlife sightings and other evidence of high biodiversity would be one of the attractions.

Hynes and Hanley (2006) provide one of the few Irish studies on water-based recreation, in this case for whitewater kayaking. They report an average consumer surplus gain of up to €14.50 per visit from a 25% improvement in water quality, but note that the estimate varies widely depending on the analytical method used.

Values for active water-based recreation are inevitably high due to direct association between the activity and the resource. Angling, in particular, has a dependence on biodiversity given its reliance on an aquatic food web. The study by DKN et al. provides the following data for angling benefits, again referring to data in the Environment Agency Guidance, itself based on UK studies by Green and Willis (1996) and the Foundation for Water Research (1996).

Table 8.3: Benefits from Improvements in a Coarse and Trout Fishery, per Angling Trip

Quality of Fishery to be Created	Willingness to Pay per person per trip	Marginal value of improvement in quality (2001 prices)	Value (euro 2007)
'Poor' (coarse = Q1, Q2 or Q3, assumed average fish biomass <600g/100m2) (trout = average density > <0.8 fish per 100m2)	£4.30 (coarse) £9.81 (trout)	No fishery to Poor = £4.30 (coarse) Coarse fishery to Poor = £1.94 (trout)	
'Moderate' (coarse = Q2, Q3, Q3-4 or Q4 biomass 600-2000g/100m2) (trout = 0.8-2 fish per 100m2)	£4.53 (coarse) £11.43 (trout)	Poor fishery to Moderate fishery. Coarse = £0.23 Trout = £1.62	
'Good' (coarse = Q3, Q3-4 or > Q4 biomass >2000g/100m2) (trout = >2 fish per 100m2)	£6.87 (coarse) £17.91 (trout)	Moderate fishery to Good fishery = £2.34 (coarse) £6.48 (trout)	

Source: Guidance Part 2 Table 3.14. Green and Willis (1996) in FWR (1996)

Unfortunately, there have been few Irish angling studies to date despite the close relationship between environmental quality and catch. However, Curtis (2002) has undertaken a survey of domestic salmon anglers by which he estimated consumer surplus benefits of between €62 and €185 in excess of travel costs, implying a total willingness-to-pay of €247 per trip. Salmon angling is a premium activity in Ireland. Relevant willingness-to-pay values quoted in the Environment Agency Guidance are only €28.20 per trip, in this case for significant improvements to existing salmon fisheries rather than for the consumer surplus per visit. DKN add that such improvements in water quality would provide additional benefits through new angling activity and estimate that existing anglers will extend their trip by 1.5 days on average in response.

Passive use benefits are more difficult to define. High values have been reported for well-known wetland locations of high biodiversity value. For example, a willingness-to-pay of £77 million per year was reported to protect the Norfolk Broads from saline flooding (Bateman & Langford, 1997). For more familiar locations, some of the benefits of water quality are capitalised in the value of adjacent properties. For example, lake or riverside properties in Leitrim and Roscommon typically attract premia of 25% (pers comm.), although these prices rely more on aesthetic benefits than biodiversity per se. The aforementioned REPS study by Campbell et al. (2006) does demonstrate a high willingness-to-pay for policies that protect water quality at a national level.

The Environment Agency's Guidance also provides evidence of passive use values. Table 8.4 lists those that have particular relevance to biodiversity and, potentially, to drinking water. A study by Georgiou et al. (2005) indicates the value of changes in levels of [any one of] ammonia, dissolved oxygen (DO) and biological oxygen demand (BOD), all of which are important to biodiversity. Equivalent EPA categories are again provided by DKN et al. (2004). Similar figures have been constructed by Willis and Garrod (1996).

Table 8.4: Passive use values from improvements in water quality

Change from	To	Value per km of Improved River
Water quality of total ammonia (mg N/litre), dissolved oxygen (% saturation) or BOD (mg/l) equivalent to Q1	Small improvement – to Q2	£0.06 to £0.16 per km per household per year
	Improvement – to Q3	£0.09 to £0.31 per km per household per year
	Improvement – to Q3-4	£0.14 to £0.50 per km per household per year
	Large improvement - to Q4 or higher	£0.17 to £0.60 per km per household per year

Source: Georgiou et al (2005)

The proportion of river channel falling into the EPA quality categories A, B, C and D is respectively 70%, 17%, 12% and 1% (EPA, 2004). Given the total number of households (1.3 million), and with figures indexed to 2006, the mid-point of above figures would suggest current values of €174 per kilometre for an improvement to Class B in the rather small proportion of rivers of inferior C and D standard, and €91 per kilometre for an improvement to Class A of all other rivers. Once again, this figure is a crude transfer estimate in that Irish preferences for water quality would vary from those of people in the English Midlands surveyed by Georgiou et al. Ireland also has a low population relative to its total river length of 20,500km and a higher proportion of unpolluted rivers than the UK.

8.4 THREATS

Just as biodiversity is threatened by adverse agricultural or forestry changes or water quality impacts, so too is human welfare to the extent that this depends on biodiversity. For some activities, such as angling or birdwatching, the impact is direct. For others, the benefits are indirect in that the principal benefits are realised as physical recreation, enjoyment of landscape or consumption of quality food and drinking water. In the anthropological terms through which the natural environment is valued by economics, the value of biodiversity in any one location depends on the degree to which that biodiversity can be substituted by high biodiversity in other locations. It also depends on the relative proportion of active users and passive users and the size of the population catchment. Values are likely to be higher the more unique the environment or species. Consequently, the Serengeti, the Amazon or the Great Barrier Reef would be valued on a global scale and existence values dominate use values. Values are also likely to be higher the greater the likelihood of irreversible change or catastrophic loss.

Ireland's peatlands may not match the drama of the Serengeti, but they do represent examples of rare ecosystems. Some peatlands are protected largely through funding from the Dutch public whose own peatlands are now virtually extinct. This relationship is repeated for all natural environments. It is a fundamental rule of economics that, as a resource becomes more scarce, so its value will increase. In addition, average incomes are rising and recreation, including countryside and water-based recreation, is income elastic with demand increasing over time. It is to be hoped that this rising participation will also lead to greater awareness of biodiversity loss with the result that a greater value is placed on its protection.

8.5 COST OF PROTECTION

National policies that aim to protect biodiversity are likely to attract public approval and be valued in economic terms. The relationship between a quality environment and quality of life is tacitly realised by policy makers in terms of actions to protect the rural environment, to maximise forest amenity and to sustain a functioning aquatic ecosystems. In some cases, biodiversity is an external benefit or complementary objective to other political priorities such as maintaining a rural population, offsetting global warming or ensuring clean water supplies. In any event, the overall objective should be to maximise the public benefits.

Policies such as REPS are expensive. Hence, the interest of policy makers in commissioning studies that help to demonstrate the resulting public benefits. The budget for REPS is more than the €150 million estimated by Campbell et al., and has now risen to €280 million. However, there are additional biodiversity and social benefits that were not considered by the survey and which certainly exceed the difference. For each €100 of forest income, the state makes transfers of €123 to the sector (Bacon and Associates, 2004). The biodiversity benefits of much of this forestry are modest, but here again there are complementary benefits such as security of timber supply, employment, rural development and carbon sequestration.

The requirements of the Water Framework Directive have been most onerous in terms of public expenditure. However, much of this expenditure, particularly in waste water treatment, has been in response to past underinvestment in essential environmental infrastructure. €1.5 billion was spent on waste water treatment under the last National Development Plan (2002-06). Around €4.3 billion is intended for all water infrastructure expenditure under the new NDP, very little of which will now be provided through the EU Structural Fund. Although much of this money will be invested in end-of-pipe wastewater treatment, River Basin Management Districts have been established with the objective to ensure at least "good water status" for ground and surface waters and associated ecosystems by 2015. This will necessitate improved protection at catchment level, particularly protection of surface waters and aquifers and controls on diffuse pollution.

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9. BIODIVERSITY AND PUBLIC HEALTH

9.1 THE RELATIONSHIP BETWEEN HEALTH AND BIODIVERSITY

Biodiversity, through the provision of ecosystem goods and services, provides the basis for all life on earth. From a human perspective, this includes the support base for economic activity, for social welfare and for health. Changes in biological diversity or species assemblages - for example as a result of species loss, the introduction of alien/invasive species, habitat loss or fragmentation, pollution or nutrient depletion - can significantly affect key ecosystem processes and inter-species (or inter-community) relationships. As discussed elsewhere in this report, this can have a wide range of direct or indirect consequences for human society and economic systems. Not least of these, are the potential effects on plant, animal or human health (see, for example, Corvalan 2005, Hales and Corvalan 2006; McMichael 2001, 2005, 2006; Chivian 2002, 2002a).

Biodiversity in all its forms has direct relevance to human well-being and quality of life. The connections are often intricate and, in many cases, poorly understood. However, many specific cause-effect examples, affecting both modern and ancient civilizations, have been well documented in. A full analysis of the relevance of biological diversity to the health, well-being and security of Irish people is outside the scope of the current report. Indeed, at the time of writing, no specific research or assessment of the links between biodiversity and health (physical, mental, spiritual, social or even economic) in Ireland has been carried out. This chapter aims to provide a general overview of the key issues, drawing on examples of international studies that are of relevance to Ireland.

While many ecosystem services can be given an economic value, it is worth reiterating that, for many sectors of society, the value of biodiversity and ecosystems exists, not so much in terms of economic gains, but rather in terms of losses avoided or moderated by the existence of a healthy natural environment. While the benefits of ecosystem services to food production can be readily understood, their value as life-supporting services protecting population health is more difficult to comprehend. The following key points provide as a general framework for the discussion on the following pages:

- In Ireland, as in the rest of the world, people's health ultimately depends on the health of ecosystems. Since the functioning of these ecosystems and the sustainability of the goods and services they provide are dependent on biodiversity, then biodiversity represents the foundation for human health. Stated more simply: without a natural environment that is healthy and capable of supporting a diversity of life, no human population can exist.

- Today, in local environments where the integrity of ecosystems has been compromised, e.g. in urban areas or areas of intensive agriculture, healthy populations can only exist if they are supported by healthy or productive ecosystems elsewhere. Our society draws on services and resources produced by ecosystems in other areas where the natural resource base has not been significantly eroded. Fisheries are a prime example.

- As Ireland's natural environment is transformed and the integrity of our native ecosystems is damaged, we become more dependent upon the biodiversity resource of other countries. Developed countries are becoming increasingly dependent on the biodiversity of a global ecosystem. Unfortunately the health of the environment in the developing countries is increasingly threatened by numerous factors that governments may be ill-equipped to manage, for example market forces, population growth or unsustainable development practices. This gives concern for global ecological instability, with very real consequences for the global economy and the well-being of people everywhere.

- Our own ecological footprint (the physical and geographical impact of human activities on the natural world) expands beyond our national boundaries to those regions that supply us with the ecosystem goods and services which we require, but which we cannot provide for ourselves. As our economy grows and our population expands, so does our demand for material goods extending our ecological footprint with implications, not only for our own resource supply and livelihood security, but for that of other countries too.

- In particular, some of what are arguably the most important services provided by biodiversity - provision of fresh water and clean air, the regulation of the climate, the production of healthy food, and the regulation of pests and diseases - are under threat on a global level, adding to the urgency of protection of biodiversity at home.

(See also Soskolne and Bertollini, 2002).

In August 2005, the First International Conference on Health and Biodiversity convened in Galway, Ireland. The conference was attended by 150 people from over 60 countries, was the first time that such a diverse group of people had come together to address the importance of biodiversity to human health and well-being. The report of the COHAB 2005 conference (see CBD 2006) has been widely endorsed by the EU, UN agencies and other international bodies, a symbol of the growing recognition across all disciplines that the conservation of biodiversity is essential to the protection of human interests, and that collaboration and partnership across normal institutional, cultural and conceptual barriers is required to tackle the issue. This awareness has been greatly increased following the publication of the reports from the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005).

As a result of this and other important initiatives which have been initiated worldwide in the past five years, there is an increasing understanding amongst policy makers that the continued and accelerating pace of global biodiversity loss threatens the stability, security and health of human populations. This was further highlighted and strengthened by the reports of the Millennium Ecosystem Assessment and recent discussions of the UN General Assembly, recent EU communications, and decisions of the G8 group of nations.

9.2 HUMAN HEALTH AND WELL-BEING AS A FUNCTION OF ECOSYSTEM HEALTH

Some general examples of the links between biodiversity and human health and well-being are outlined in Table 1 below.

Table 9.1: Indicative examples of the importance of biodiversity in Ireland to human health and well-being.

Importance of biodiversity and healthy ecosystems:	Examples:
Biodiversity supports indigenous food production with widespread benefits for dietary health and livelihood sustainability.	Ecosystem health and stability is required to support agriculture, horticulture, aquaculture and mariculture, together with the communities which they sustain. Maintaining agricultural biodiversity supports good dietary health through fresher food and lesser dependence on chemical inputs.
Biodiversity is important for the regulation and control of infectious diseases.	Disruption of ecosystems or wildlife populations can affect disease ecology and result in spread of diseases to / between wildlife, livestock or man. Examples include avian influenza, bovine tuberculosis, demodectic mange, toxoplasmosis, Hantavirus pulmonary syndrome, lyme disease, leptospirosis and salmonellosis.
Biodiversity and natural habitats mitigate against floods, droughts and other natural disasters.	There is compelling evidence that loss of local wetland habitats led to more severe impacts of the Asian tsunami in several areas in 2004 and of hurricane Katrina in the USA in 2005. In Ireland, habitats in which biodiversity is an integral part, such as sand dunes, estuaries, callows and wetland woods act as buffers to floods and severe weather events.
Biodiversity supplies vital natural products and therapeutic compounds, with medicinal, economic and cultural value.	Many species provide culturally important medicines and raw materials, particularly for indigenous peoples or isolated communities. Many modern drugs that are derived from wild species include pain killers. Even in Ireland, there are still species with potential therapeutic values that have yet to be investigated.
Species, habitats and landscapes have social, cultural and spiritual importance.	Ecosystem change and landscape degradation can result in a disconnection of populations from their environment, with negative implications for physical and mental well-being, particularly in urbanised and industrialised areas. This has been linked to the prevalence of 'diseases of affluence', although the actual incidence of conditions such as diabetes, obesity or cardio-pulmonary illness is often highest amongst lower income households.

The following sections outline just a few of the key relationships between biodiversity and health, with illustrative examples and case studies.

Note: except where otherwise specifically stated, the term "health" is used in general terms in this chapter to represent physical and mental health, livelihood security, societal security and overall well-being. Plant and animal health are also dealt with under some headings, particularly where these factors have a direct bearing on human health or well-being.

9.3 BIODIVERSITY, FOOD QUALITY AND DIETARY HEALTH

Food production depends on both managed diversity (crops, livestock and certain other species) and unmanaged diversity (including pollinators, biological control agents and the inter-relationships between species of woodlands, field margins, hedgerows and soils, etc.). The importance of diversity in crop and animal breeding programmes has been recognised for centuries. Diversity provides the basis for modern breeding systems which are important for enhancing traits such as resistance to pests and disease. Maintenance of diversity also increases yield stability and improves the resilience of crop species to environmental perturbations such as drought or flooding (Frison 2005, Halwart 2006, Qualset 2005, Gari 2004, Burlingame and Toledo 2006).

Nevertheless, while global food production per capita has increased over the past 20 years, there are still over 850 million people on earth facing food shortage or famine. Agricultural biodiversity is of critical importance to producers in poor countries where stability of supply and the minimisation of risk is of far greater importance than maximising yields and productivity.

In Ireland, agriculture supports the livelihoods of almost one million people, including people involved directly and indirectly in farm management and production and related services. Despite this importance, Ireland's agricultural biodiversity is a largely unexplored resource. The stability of the food supplies may not currently be at risk in Ireland, but food production systems are based almost entirely on monoculture or intensive techniques which have a range of negative impacts on the natural environment, affecting both managed and unmanaged biodiversity. The loss of plant diversity that accompanies larger fields and monocultures often results in more regular pest attacks. Pesticides are used in response with further impacts on biodiversity and possible risks for human health. Alternatively, genetically modified crops are being developed with inherent resistance to diseases, but with, as yet, unproven implications for the environment and human health. In contrast, more diversified and less intensive agro-ecosystems retain natural pest control by supporting a greater number and diversity of predators and parasites that attack herbivorous pest species.

Research has shown that food production systems that conserve and encourage unmanaged diversity often support higher yields and crops that are naturally more resistant to climatic extremes and diseases. Enhancing this diversity, particularly in the development of indigenous breeds, can have significant benefits for local economies and rural livelihoods. The main stumbling blocks to the promotion of these systems have been inertia favouring easily replicable low-cost uniform systems and the greater management demands at farm level. The risks of relying on intensive systems, low in biodiversity, may yet be revealed as climate change impacts on weather stability, pest and weed populations and the flow of ecosystem services. Enhancing wild biodiversity and the managed diversity of food cropping systems can not only provide real economic and social benefits in the short term, but may also help us to adapt and protect crop and livestock health in the longer term.

Diversity in food production can have other positive impacts on society. International research has shown that diverse diets, based not merely on nutritional diversity, but supported by species diversity, are associated with lower risks of illness, greater longevity and reduced mortality. In other words, a diet that includes a high diversity of food types, supported by agricultural systems that increase managed diversity without excessive use of artificial inputs such as pesticides, is of significant direct benefit to human health.

The spectre of famine in Ireland may have receded into our history, but many people are still affected by a more widespread "hidden hunger" of vitamin, mineral and micronutrient deficiencies. These deficiencies are associated with a range of health problems affecting over two billion people worldwide. Many low-income households in Ireland endure poor quality diets, high in saturated fats and low in nutritional value. However, an equally important factor is the promotion of a limited range of high sugar/water, poor quality products due to the structure of mass-production food industry. The impacts of low dietary nutrition in children include poor concentration in school, restricted intellectual development, diabetes, cardiovascular disorders and lower resistance to infection (McWhirter 2002, Friel & Conlon 2004, Save the Children 2007). These illnesses are also becoming increasingly prevalent amongst people in higher income brackets, where long working and commuting hours and poor work-life balance, give rise to "diseases of affluence" such as obesity (Kiely 2001).

Although social factors are involved, including income or time poverty, there is still an obligation on us to ensure that fundamental food supplies and inputs are wholesome and unadulterated. Research from elsewhere in Europe has shown that diverse diets, incorporating a diversity of food species, are associated with lower risks of illness, greater longevity and reduced mortality. Recognising this, the EU and the Conference of Parties of the UN Convention on Biological Diversity have called on all governments to ensure that "the genetic and species diversity of agricultural produce is preserved and improved, and that the importance of dietary diversity based on various crop and livestock varieties is explained and promoted to consumers". There is an increasing demand in Ireland for locally grown and organic produce, and this has seen a growing interest in country markets in many Irish towns. There are currently over 115 farmers' markets in Ireland (www.irelandmarkets.com). Many would argue that the future of many small farms depends on their conversion to a biodiverse and locally-focussed agricultural industry, producing high-quality, affordable and widely available produce in a manner which benefits biodiversity and the health of the wider community.

9.4 BIODIVERSITY AND INFECTIOUS DISEASES

Naturally occurring microbes – including bacteria, viruses, fungi and protozoa – comprise a significant portion of wild biodiversity worldwide. These organisms are responsible for supporting and regulating a range of key ecosystem functions and, hence, provide the foundation for a wide range of ecosystem services for example, bacteria and fungi are vital to waste decomposition and nutrient cycling, driving primary productivity and affecting climatic patterns on a massive scale. Disease-causing microbes (pathogens) and parasites play an equally important role in ecosystem functioning and productivity. They are not all pleasant, but nevertheless play an essential part in natural selection, maintaining the health of ecosystems and populations of wild flora and fauna. Cycles of infection, disease, morbidity and mortality have played a significant role in the evolution of life and have also driven the evolution of human societies and cultures (McMichael 2001, 2004, Fowler 2005).

The Problem with Microbes

We really know nothing about microbes. With 1.8 million animal or insect species identified, biologists get understandably excited whenever a new species is discovered. In fact, they need look little further than their own back garden. The average teaspoon of soil or water contains millions of micro-organisms, many of which have never been identified. The problem is that these microbes are so small and so similar.

Metagenomics is a new technique that pools all species in a sample and which sequences each by piecing together short fragments of DNA rather like a jigsaw. From such techniques, we are learning that as much as 90% of all microbial biodiversity may arise from species that are actually rather rare. We know almost nothing about these species' functions, although we have learnt that one relatively rare bacterium could be responsible for all the fixing of nitrogen from the atmosphere. Indeed, such techniques are allowing us to find microbes in even the most unlikely of places including oxygen-less environments, deep ocean trenches and even mine-water with the acidity of battery acid.

Source: New Scientist (Nicolls, H.) 17/3/2007

Biologically rich ecosystems consist of numerous organisms that interact with each other in complex ways. An outcome of these interactions is an equilibrium between and within species, which helps to regulate the prevalence of diseases. Infectious diseases are a product of the pathogen, vector, host and environment. Intact ecosystems control the populations of pests and diseases, minimising the risk of destructive outbreaks. Many micro-organisms circulate naturally within a wild "host" population without causing any illness or symptoms of disease. An example is the multitude of bacteria and viruses found within the human digestive tract, and the other flora which occur on our skin. Other examples include certain avian influenza viruses which have no effect on the host bird species, wild immuno-deficiency viruses which are benign in their hosts, and lyme disease parasites which can circulate innocuously in rodent, deer and lizard populations.

While often having positive role on the regulation of wild species, the risk of disease arises when these micro-organisms come into contact with a species outside of the natural ecology of that organism. Ecosystem disturbance, for example, through pollution, habitat loss or fragmentation, species extinction, or the introduction of invasive species, can lead to changes in disease ecology with potentially disastrous effects for wildlife, domestic animals, crops, or man. This has been most clearly demonstrated in diseases that are caused by organisms that spend part of their life-cycle outside of their definitive host (see for example Patz et al 2000, Cifuentes and Rodriguez 2005, Plummer 2005, Kahn et al 2006, Gould et al 2006, Estrada-Pena and Venzal 2006, Cumming and Guégan 2006). Important examples of parasitic diseases in Ireland that are affected by environmental conditions include leptospirosis, varroasis, fascioliasis and cryptosporidiosis.

Zoonotic diseases (zoonoses) – those spread from animals to humans - are of particular social and economic importance. Recent epidemics of zoonotic diseases such as HIV/AIDS (originating in wild primates in Africa), SARS (from civets in Asia) and highly pathogenic avian influenza (HPAI strain H5N1 spread by migratory birds) illustrate the importance of animal reservoirs as sources of emerging infectious diseases. By virtue of their genetic, physiological, and behavioural similarities with humans, primates are thought to be likely sources of pathogens that can pose a significant threat to human populations. The HIV pandemic is a forceful example of this threat. The Millennium Ecosystem Assessment (MA) Health Synthesis notes that bushmeat is believed to have led to the first transmission of HIV to humans. SARS may have entered the human population via wild species before crossing to animals raised domestically and consumed as food in China (Bell et al 2004).

This is not to deny the role of animal populations as potential reservoirs of emerging infectious diseases, but to demonstrate the implications that disruption to ecosystems can have through unprecedented animal-human contact. Modification of landscapes and other impacts on ecosystems can lead to shifts in species interactions, population movements and demographics, in turn facilitating an increase in pests or the spread of disease organisms. There is growing evidence from around the world that disturbance of habitats and ecosystem services can lead to outbreaks of new types of communicable diseases in wildlife, livestock, crops and people. Modern intensive methods of meat and poultry production facilitate the rapid spread and amplification of disease as these systems are intensive and rear animals with low disease resistance. The Millennium Ecosystem Assessment has emphasised that alteration of ecosystems can lead to changes in the relationship between populations of vectors and potential hosts, and thus to new patterns of disease spread which are often unforeseen. The individual and societal costs are potentially catastrophic. (See also Graczyk et al 2000, McMichael 2001, Patz et al. 2004, Marcogliese 2004, Norris 2004, Baumgartner 2004, Brownstein 2005, Hampton 2005, COHAB 2005, Steele, Oviedo & McCauley 2006).

In Europe and the US, other diseases which have long been recognized in wild animals are of increasing importance as diseases of humans and of agriculture. Examples include several viral, bacterial and parasitic diseases spread from wild birds and mammals which are coming into increasing contact with people due to habitat disturbance and urbanisation. Genetic diversity is increasingly recognised as an important factor in the ability of wild populations to withstand stresses such as diseases. Indeed, this is true for man too. Recent research is indicating that a large proportion of the European population possesses genetic characteristics derived from the Great Plague which may yet have evolutionary benefits against future pandemics (Galvani & Slatkin, 2003).

Worldwide, the incidence of zoonotic diseases is expected to increase in coming decades since the opportunities for pathogenic organisms to jump across the species barrier have multiplied. Reasons include rapid urbanization, population growth and movement, the clearing of new agricultural land, the growing trade in meat, milk and other animal products, greater world trade, travel and tourism, and the rate of biodiversity loss and ecosystem change (Karesh & Cook 2005, Karesh et al. 2006, Swift et al. 2007, Pearl 2004, Kimball et al. 2004). Another important factor is global warming, which allows certain species, in particular insects, to colonize new regions where they could yet propagate new pathogens.

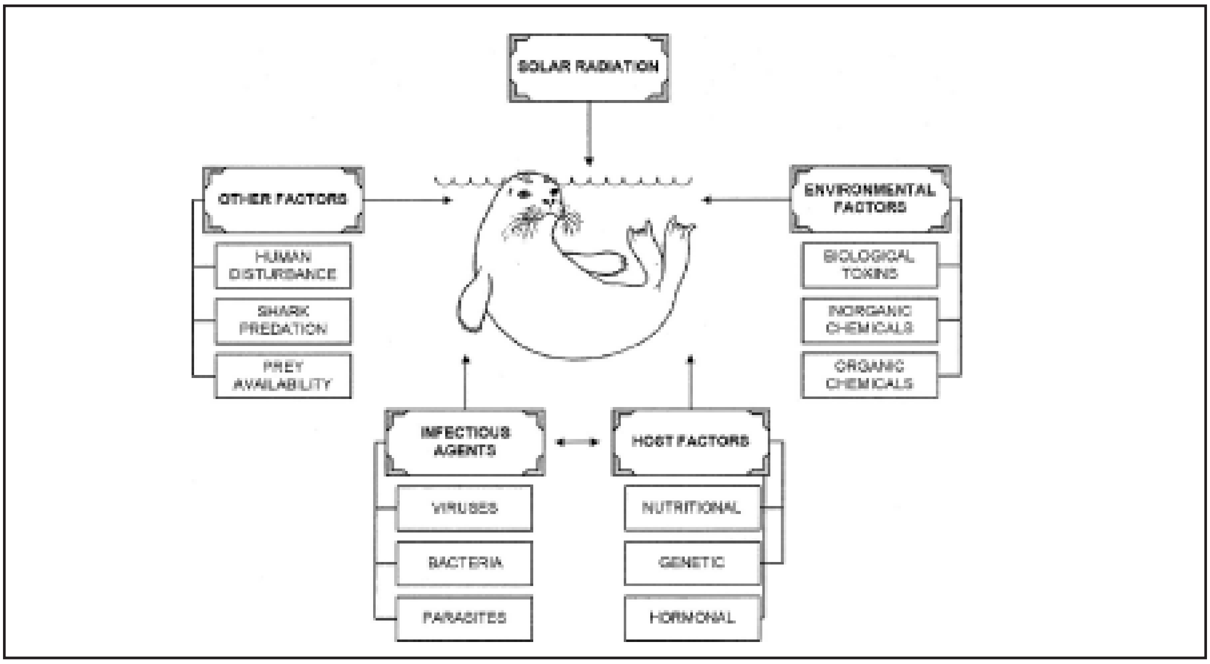
In Ireland, diseases such as tuberculosis, leptospirosis, toxoplasmosis, cryptosporidiosis, brucellosis and salmonellosis have known links with wildlife. There is also the risk that previously unknown diseases, or diseases which are recognised in wildlife but have not been identified as important threats to people, could cross the species barrier to the human population. Examples include the Sin Nombre virus in the USA (from wild mice), new crytosporidium strains (from wild deer) in Europe, Anaplasma parasites (from wild rodents), mange, toxoplasmosis and echinococcus throughout Europe (from foxes); and the worldwide emergence of new calcivirus strains (from marine mammals). (See Brown 2001, Ong et al. 2002, Deplazes et al. 2004, Rabinowitz & Zimra 2004, Schweiger et al. 2007.)

Wildlife sentinels of ecological health.

The past five years have seen a growing interest in the field of conservation medicine, a discipline at the crossroads of public health, environmental science and veterinary medicine. Conservation medicine examines the complex relationships between nature, ecosystems and human health, recognising that human, plant and animal health are influenced by ecological sustainability and the interactions between people and the ecosphere (Aguirre et al. 2002). The discipline has been mainstreamed into the global environmental and health sectors. Indeed, the basic concepts of conservation medicine, i.e. that humans depend upon a healthy environment and that our actions impact on ecosystems with implications for our own society, are the basis of much EU environmental legislation.

One of the areas of this field that is of increasing importance and of particular relevance to developed countries is the use of wild animals as sentinels of ecological health (Aguirre and Tabor 2004). By observing the health and disease status of wildlife populations, particularly larger animals, scientists can often gain a greater appreciation of environmental conditions at ecosystem level. In this way, the target species can act as the canary in the mineshaft, providing an early warning of environmental health problems. Marine wildlife, in particular, has been of great interest in this regard. For reasons of public safety and food quality, research into the exposure of many food species to pollution has been ongoing for years. In this regard, assessments of the health of mammals and other species near the top of the food chain are of greater interest (Hatcher & Hatcher 2004, Bond et al. 2004, Burger & Gochfeld 2004). In Ireland, some analysis has been recently conducted on blood and tissue samples from dolphins in Irish coastal waters to determine exposure to PCBs and organochlorines (Smith et al, 2000, Berrow et al. 2002), while other assessments have looked at the expression of genetic abnormalities in cetaceans (for example, Berrow & O'Brien 2006). A wider programme of wildlife health monitoring, examining the state of health of selected marine species, is warranted, particularly when Ireland's coastal waters are so important to wildlife and human populations alike.

Figure 9.1. The concept of sentinel species (courtesy of International EcoHealth Association)



9.5 RELEVANT DISEASES

A few case studies of globally important human and animal diseases relevant to Ireland are given below.

9.5.1 Hanta viruses

An important example of zoonotic diseases is that of the Hantaviruses, a group of viral pathogens spread by rodents throughout the world. The organisms are spread to people through contact with rats and mice or their excreta, and are specific to geographic areas and rodent species. Infection with the virus in rodents is benign, with no illness or symptoms displayed by infected animals. Infection in people can however be extremely serious, often presenting as a mild flu but potentially developing into a severe disease of the blood and circulatory system involving the heart, lungs or kidneys, known as Haemorrhagic Fever with Renal Syndrome (HFRS).

People are often at greatest risk in areas with high rodent population densities, or where rats and mice frequent areas of human habitation. In Ireland, this would include rural areas where rodent numbers are typically high around agricultural lands, and urban areas, around accumulations of litter, public parks, areas near landfills etc. Evidence of human Hantavirus infection has been found in blood samples taken from wild rodents and hospital patients in Northern Ireland since the 1990s (e.g. McKenna et al, 1994, McCaughey et al, 1996). As we become more urbanised, and as we impact on ecosystem integrity through physical development and habitat disturbance, there may be an increased risk of Hantavirus disease within the Irish population.

A common response to dealing with outbreaks of rodent-borne disease is to increase the use of rodenticides. Unfortunately, indiscriminate use of poisons can have severe impacts on non-target animals including species that naturally prey on rats and mice such as cats, badgers, martens, owls and other raptors, impacting upon a natural and important control mechanism for rodent populations (e.g. Kittlein 1997, Singleton, 1999, Duckett & Karuppiah 1990, Brakes 2005). Furthermore, there is an increasing problem of rodenticide resistance among rats and mice in Europe (e.g. Russell 2003, Pelz & Klemann 2004).

9.5.2 HIV / AIDS

The emergence of the Human Immunodeficiency Virus (HIV) and the associated Acquired Immune Deficiency Syndrome (AIDS) in the late 1970s alerted the scientific community to the risk of unknown and severe pandemic diseases arising in the human population from unexpected sources, in this case from human-wildlife interactions.

Recent research suggests that cross-species transmission of Simian Immunodeficiency Viruses (SIV) from primates to humans probably occurred as a result of butchering practices associated with the bushmeat trade. Subsequent human-to-human transmission eventually resulted in the spread of HIV in human populations facilitated by changes in population movements and by human impacts on the environment. International travel ensured its worldwide spread.

In Ireland, HIV has infected 4,251 people (to 2006), resulting in 895 AIDS cases and over 400 deaths, since 1994 (NDSC, 2006). This is relatively low in European terms. However, the rate of spread has increased in recent years and now stands at over 300 cases reported or diagnosed per year sine 2001. Globally, the World Bank has estimated that the economic impact of HIV Aids has reached over $1.6 Billion (€1.2 billion). No information is available on the economic costs of HIV management and control in Ireland. However, in the UK, the costs are estimated at £16,000 (€23,000) per patient per year. The UK government has estimated that every infection of HIV prevented saves between £500,000 and £1 million (€735,000-€1,470,000) in direct and indirect costs. Other recurring and unavoidable costs include public education and awareness programmes, vaccine and other medical research, screening of transfusion products and transplant organs, etc.

9.5.3 Avian Influenza

The influenza viruses are a group of pathogens of man, animals and a wide variety of avian species. Avian influenza may be transmitted from one species to another, either directly from birds to people or other species, or through an intermediate host, such as pigs or cats (Lamb & Krug, 1996). This creates a genetic 'melting pot' in which viruses can swap their genes and acquire each other's properties, thus generating new viruses that would pose a further threat to human health.
The recent spread of highly pathogenic H5N1 avian influenza through Asia into Africa and Europe has involved at least 53 countries (including 23 in Europe), and resulted in huge impacts on the poultry industry across at least 12 countries (WHO 2007). Hundreds of millions of domestic fowl

have died or been killed during the outbreak.The total economic losses is estimated at in excess of US$10 billion, with other unquantified economic and psychological impacts on farm workers and people in associated industries whose livelihoods have been affected. The World Bank has predicted that the continuing spread of the virus could significantly affect global economic growth. At present (May 2007), the H5N1 virus does not have the capability of spread from person to person. However, the genetic material of the virus could evolve gradually into more virulent strains or, alternatively, could combine its genetic material with that from other influenza viruses that already infect humans (referred to as "genetic reassortment"). The more frequently humans come in contact with infected birds; the more likely this is to happen.

It has long been recognised that wild birds can introduce low pathogenic influenza virus (LPAI) into domestic poultry. Depending on the nature of the poultry population and the animal husbandry techniques used, strains of LPAI have the potential to become highly pathogenic (HPAI) within poultry flocks, resulting in severe outbreaks and mortality amongst farm birds (Lamb & Krug, 1996). On occasion, these massive outbreaks can spill-over into wild bird populations or to other animals. For example, the H5N1 HPAI virus has infected domestic and wild cats, pigs and horses, as well as humans. In Sweden and Germany, mink and pine marten respectively have been infected with HPAI after feeding on infected birds (ECDC/Eurosurveillance, 2006). Until recently, it was considered that wild birds could not act as a source for long range transmission of HPAI strains due to their lethality – commonly referred to as the "dead birds don't fly" premise.Trade in poultry and wild animals and international travel were therefore considered to be the most likely risk factors. However, analysis of the recent international spread of the H5N1 virus has led to a change in this model of HPAI epidemiology (EC, 2006). The large spill-over of H5N1 into wild bird populations, together with the persistence of infection within local areas (suggesting the emergence of local wild reservoirs for the virus), the rapid spread of the disease along bird migration routes, and the apparent absence of coinciding trade outbreaks, indicates that at least some wild bird species are capable of carrying and spreading the disease across long distances to domestic flocks.

While it is considered that all bird species are capable of being infected with H5N1, the species considered most likely to be implicated in long-range spread are migratory species of waterfowl, including geese, swans and ducks. The international wild bird trade is also recognised as a major risk factor for the global spread of H5N1, as evidenced by the first case in the UK in 2005, which occurred in an infected Suriname parrot which died in a quarantine station. The wild bird trade and transboundary movements of poultry flocks are now strictly monitored and subject to intensive infection control and quarantine procedures, though illegal trade activities worldwide still represent a high degree of risk. Migratory movements of wild birds cannot, however, be controlled.

For Ireland, where we are currently HPAI-free, the most likely potential entry route of the H5N1 virus is through wild bird migration. Compared to most other EU countries, Ireland is a relatively small country with disproportionately high numbers of wintering waterbirds (EC, 2006). H5N1 has spread to parts of Southeast Asia, the Urals, Kazakhstan and Siberia from where some waterbird species migrate to EU countries. From here, the continent-wide dispersal of the virus through migration and vagrant bird movements would be possible. An assessment of migratory waterbirds conducted for the European Commission in 2006 identified the main risk species and their migration routes. Of the 17 highest risk species identified, 13 occur in Ireland, with large numbers of many of these species coexisting in wetland areas upon their arrival after migration.

Once the link between wild bird migrations and the spread of H5N1 was made, there were calls worldwide from agricultural communities, and from some government agencies, for the mass culling of wild birds and draining of wetlands in which they congregate, in order to prevent the spread of the disease and to protect poultry flocks and livelihoods. However, any such impact on wild bird populations may actually increase the risk of global spread, as well as increasing the risk of a more virulent strain of the virus evolving (BirdLife 2007, FAO 2007).

Maintaining genetic biodiversity within wild bird populations is likely to be an important factor in the limitation of spread of avian influenza viruses. Genetic diversity provides the basis for resistance to environmental stresses and diseases within any given animal or plant population. As the culling of wild birds would reduce genetic diversity, this could conceivably impact on the development of resistance to HPAI strains and actually facilitate the development of more virulent forms of the virus. Furthermore, it is known that disturbance of habitats such as wetlands can affect migration routes and patterns, potentially leading to the spread of the virus into areas not normally at risk, or the possibility of reassortment through mixing of species or flocks that would not otherwise naturally come into contact (Karesh 2005, Corvalan et al. 2005, Kapan 2006). The World Health Organisation (WHO) and Food and Agricultural Organisation (FAO) of the United Nations, and the International Organisation on Animal Health (OIE) have urged national governments to prohibit the culling of wild birds for precisely this reason.

Protection of wider biodiversity and ecosystem health may play an important role in preventing the spread of HPAI by maintaining the resilience of non-avian animals to the disease. Other environmental stresses (including pollution, habitat disturbance, or impacts on food species), which impact on the biodiversity and ecosystems that support wildfowl populations, can affect wildfowl behaviour and the distribution and movement of bird populations. Therefore, the protection of biodiversity in the wider natural environment, including wetland areas and associated habitats, is considered an important aspect of regulating and limiting the spread of H5N1 (Rapport 2006).

Avian Influenza monitoring in Ireland

The last recorded outbreak of HPAI in Ireland was in 1983, when a H5N8 HPAI strain infected two commercial turkey flocks, one commercial duck flock and one broiler flock. In the subsequent period to 2006, LPAI outbreaks (associated with several distinct strains) occurred in eleven years. Surveys in wild birds only commenced in Ireland in 2003 as part of an annual EU-wide survey, so the possible links between domestic and wild flock outbreaks in previous years is unknown. Although LPAI has been isolated from wild birds in Ireland in each year from 2003 to 2006, there have been no concurrent outbreaks in domestic flocks. The absence of AI in Irish domestic flocks since 1998 may be attributable to improved animal husbandry practices in line with revised EU and WHO guidance and standards. However, as shown by the current global spread of H5N1, the risks of spread via migratory birds are significant, and there are many factors at play including travel, trade, agricultural practices and environmental conditions. A number of rare bird species in Ireland including corncrake, lapwing, godwits, snipe and curlew, could be threatened by an outbreak of H5N1 HPAI in this country. It is therefore imperative that a holistic and trans-disciplinary approach to preventing novel HPAI outbreaks is taken, and that the health, agricultural, and environmental sectors collaborate to devise a strategy that recognises the importance of protecting ecosystem integrity and wildlife health.

sources: NDSC, FAO, CBD and WHO.

9.5.4 Bovine Tuberculosis (TB)

As an example of an economically significant disease associated with wildlife, bovine TB is of particular relevance and importance to Ireland. The role of wild badgers in the spread of TB to cattle has been researched extensively. It has long been acknowledged that badgers probably do spread the bacterium to cattle when they feed or commute through pasture. About 20-25% of badgers in Ireland may be infected with TB, and it is suspected that between 10% and 20% of outbreaks in cattle are due to cross-infection from badgers (Hayden 2000). Wild deer have also been identified as a potential source of cross-infection, with other species such as foxes and stoats, potentially playing a role in the spread of the disease.

In the UK, following publication of the Krebs report on bovine TB, a major programme of culling and localised eradication of badger populations was implemented. The trial was abruptly called off after only two years when it became clear that the incidence of TB in cattle actually rose. Subsequent studies clearly indicated that in at least some areas, the greater incidence arose from the displacement of 'carrier' animals from setts and the redistribution of badgers through the countryside. Furthermore, research has shown that, at least in certain regions, the route of TB has been from farm animals to badgers, contrary to what was previously thought. This was demonstrated during the foot and mouth epidemic in 2001, when the nationwide suspension of cattle TB controls actually led to an increased incidence of TB in badgers. It is possible that the development and intensification of cattle farming across the countryside has created the conditions under which bovine TB became endemic within the badger population, facilitating further spread of the disease to cattle. (Woodroffe et al, 2006)

Although the status of the badger as a common animal in Ireland is not under any immediate threat, the UK experience suggests that there is a very real risk that localised disturbance of badger territory, fragmentation of habitats, and the resulting displacement of local badger populations (all of which can result from human activity), could result in an increase in the occurrence of TB in cattle. There has been extensive research into badger biology and TB in Ireland, but no assessment has been carried out to date on how the current rate or future patterns of landscape change in Ireland might impact on the health of livestock or wider ecosystems. Such research is urgently required, and long overdue as the pace of infrastructure development increases.

9.5.5 Other diseases

A number of other disease organisms which occur in Ireland have been associated with outbreaks in other countries that have been exacerbated by human impacts on biodiversity, some with significant economic and public health implications.

For example, there is also some evidence, albeit largely anecdotal, that changes in fox populations and their distribution may be leading to the emergence of the parasitic disease toxoplasmosis amongst domestic animals and people. In many countries in the EU and worldwide, the spread of toxoplasmosis has been related to changes in mammal populations that have occurred as a result of urbanisation. It is important that similar situations are avoided in Ireland through a more holistic approach to both nature conservation and health protection.

9.6 ECONOMIC AND SOCIAL COSTS OF DISEASE AND ILLNESS IN IRELAND

Preventing the emergence and spread of disease through biodiversity conservation can be far more cost effective than developing vaccines in response to an outbreak. Certainly it is difficult, if not impossible, to quantify what episodes of disease emergence may be prevented by any specific conservation measures (the question of "how do you know if you've prevented a disease from emerging if it doesn't exist?" is a difficult one to address!). However, the lessons of recent experience, together with research into disease ecology, unequivocally show that impacts on biodiversity and ecosystems can and do cause disease outbreaks in man, wildlife and animals. Using the ecosystem or conservation medicine approaches to public health and nature conservation can help both to reduce the likelihood of disease outbreaks, or to restrict disease spread and impact on communities and economies. A cost benefit analysis is difficult to perform in hindsight, since it is difficult to put a definitive figure on the costs of the conservation strategies that may have prevented any given disease outbreak. However, some simple lessons can be learned.

As stated in section 9.5.2, the global costs of the HIV/AIDS pandemic have reached €1.2 billion in recent years. If it had been recognised early on in the 20th Century that increased human encroachment into forest habitats in Africa, and the butchering of wild primates for food, were high risk factors for the emergence of one of the most destructive diseases of recent history, and if appropriate counter-active conservation measures were then implemented, those costs could have been averted. Of course, the root causes of disease emergence are not so simply or easily addressed, since they are often related to broader social, economic and political elements. In the case of HIV/AIDS, social and political upheaval, human migration and economic changes in West and Central Africa may have been important factors, and would have made outright protection of habitats and species extremely difficult. However, a greater recognition of the links between ecosystem integrity and disease ecology within all sectors of government is clearly essential in light of this knowledge. Worldwide, integrating biodiversity conservation and impact assessment into the development of national strategies on social and economic growth, public health, food production and other sectors is no longer seen as optional, but an essential tool in protecting public health and avoiding economic costs.

Costs to be considered include those associated with sick leave, vaccine and immunisation expenditure, education and prevention programmes, monitoring, disinfection, and treatment. At the time of writing, no information was available on the costs of sick leave in Ireland, though a survey carried out by the UK Chartered Institute of Personnel and Development in 2006 estimated that absenteeism cost an average of £670 per employee per year (approx. €995) amongst 20 Irish employers (CIPD 2006). The National Immunisation Office of the Health Service Executive indicates that expenditure on vaccines in Ireland reached €20 million in 2005, while the total costs of immunisation schemes (including, for example, public information) reached €75.5 million the same year. These costs are largely associated with a small number of diseases that are long established in the human population, such as mumps, measles and rubella. However, if emerging diseases such as HPAI H5N1 become a more serious threat to human health in Ireland, or if other new diseases become endemic in Europe as a result of ecosystem disruption or climate change, these costs will rise.

Emerging disease outbreaks often have wider economic costs, for example in cases where businesses and tourism are affected. A notable recent example of this is the 2007 cryptosporidiosis outbreak in Galway City and County caused by pollution in the Corrib river catchment from sewerage and agriculture. Between February and the time of writing (July 2007), the outbreak has had significant costs for householders, hotels, clinics, restaurants and other public venues and organisations. Over €150,000 was being spent on supplies of bottled water each day with over €36,000 having been spent by the Health Service Executive to provide water to two Galway hospitals. The cost of emergency upgrades to wastewater treatment plants and drinking water treatment systems will run to millions of euro (Irish Independent, 26th June 2007).

9.7 THE IRISH COUNTRYSIDE – PUBLIC ACCESS, PHYSICAL HEALTH AND SOCIAL COHESION

Ireland's wild habitats and species have been of direct importance to Irish livelihoods for as long as people have inhabited this island. Our biodiversity has influenced the shapes and patterns of the countryside and has influenced many of our cultural, religious and social traditions. Although the substance and history of these connections has generally been forgotten, the Irish countryside is still of great importance to our concept of national heritage and to our individual and community "sense of place" and national identity. Many studies internationally have linked an awareness of endemism (in terms of the unique qualities of an area or landscape) or environmental values with greater social cohesion and well being (Karpela 1991, Pretty & Collette 1994, Horwitz 2001, Dixon & Durrheim 2000, Fried 2000, Kuo & Sullivan 2001, Bird 2004, 2005, 2007).

There is growing evidence that experience of open countryside, wildlife and natural landscapes promotes psychological wellness and physical health; avoiding modern "diseases of affluence", such as depression, diabetes, asthma, obesity and heart disease. This has lead to the development of the "Green Gym" programme in Northern Ireland, the "Natural Fit" programme throughout the UK, and the development of "Slí na Sláinte" walking routes in the Republic. Even passive appreciation of the natural world is a proven remedy for stress and anxiety. Research in the UK has shown that hospitalised patients suffering some form of morbidity following surgery or major illness, improve faster and experience shorter hospital stays and generally experienced better outcomes when they are afforded a view of the natural environment or green space from their windows (Ulrich 1984, Bird 2005).

Access to green space and an awareness of biodiversity in urban areas has also been linked with increased physical activity, longevity and reduced stress (Tanaka et al. 1996, De Vries 2001, Giles-Corti & Donovan 2003). Courneya et al. (2000) have also determined a link between access to green space, increased physical activity and improved pain management in cancer patients. Furthermore, the development of environmental values, which an awareness of the natural world can foster, has been linked to a reduced propensity to anti-social behaviour in children and young adults, and to an increased sense of social responsibility, community spirit, empathy and connection (Horwitz 2001, Korpela 1991, Kuo and Sullivan 2001). A recent study of the management, use and biodiversity of selected public parks in the Dun Laoghaire and Rathdown area found that park users who were questioned about their opinions and experiences generally felt that their local parks were an important social resource, and that the very existence of their park as an accessible local amenity had positive social and health benefits (Kretsch 2004). The survey found that people often felt a sense of ownership of the parks, and that the level and frequency of use of a park by families and individuals could in many cases be correlated with the level of biodiversity.

9.8 MEDICINAL RESOURCES AND IRISH TRADITIONAL KNOWLEDGE OF WILDLIFE

Throughout the developing world, many millions of people rely on indigenous knowledge for their health and livelihood security. This knowledge is associated with the gathering and cultivation of foods, clothing and building materials, with local cultural traditions, and with systems of traditional medicines. In Ireland, until as recently as the early 20th Century, traditional knowledge of wildlife, habitats and landscapes was an important aspect of everyday community life (Allen & Hatfield, 2004). The bulk of this knowledge has now been lost to society and is of little consequence to modern Irish lifestyles. Up to 80% of the medicinal compounds currently on sale in world markets have some basis or origin in exploration from wild species. Modern drugs derived from wild species include pain killers (e.g. Zinconitide from cone snail toxin), cardiac drugs (e.g. Lanoxin from Digitalis plants), anti-malarials (e.g. Quinine from Cinchona trees), and anti-cancer drugs (e.g. Taxol from Taxus trees). In recent years, research into peptides produced by sea anemones has revealed new therapeutic possibilities for treating diabetes and other hormone-related illnesses (Kem et al. 1999, Beeton et al. 2006). Many other potentially important species are yet to be investigated.

The importance of wild flora and fauna to the pharmaceutical health care sector is being increasingly recognised. Worldwide, a number of research funding programmes have been established to enhance cooperation between the pharmaceutical sector, drug research institutes, primary health care associations, biodiversity conservationists and local communities, with the aim of identifying, preserving and sustainably exploiting wildlife of potential medical and ultimately economic value. One such example is the International Cooperative Biodiversity Groups project initiated by the US National Institutes of Health, which commits several million dollars of funding in this area every year (Katz, 2005, Kursar et al 2006).

In Ireland, during the Celtic Revival of the 1930s, the Government compiled details of traditional herbal practices based on a survey of the parents and grandparents of school children. The results were compiled into over 1,000 volumes and are now stored in the Department of Irish Folklore in University College Dublin (Allen & Hatfield, 2004, Allen 2004). MacCoitir (2003, 2006) has assembled a large body of work on the folklore and practical uses associated with our native flora and fauna, showing that there is still a strong link between Irish wildlife, heritage and culture. However, the wider cultural and social links with biodiversity conservation have been poorly promoted elsewhere, and the potential values of Irish folklore to modern medicine remain almost entirely unexplored.

The value of biodiversity to drug discovery and technology lies not only in the diversity of species and the various chemical compounds which each species may contain, but also in the genetic variability within species which means that different individuals of a particular species may yield different forms of biochemically active compounds depending on the environment where a species lives. A result of this is that while a particular species may not have been determined to provide relevant yields of a given compound, samples from other locations may show that the species does have medicinal potential. For example, it has long been known that levels and potency of morphine which is obtained from the opium poppy Papaver somniferum (economically one of the most important plants in the world) varies widely from country to country (Ilinskaya & Yosifova, 1956). For Ireland, this means that our biodiversity may include species, or individual races, with potential medicinal value which may have been overlooked or deemed unimportant in other countries. It also highlights the further importance of an island-wide and ecosystem-based approach to wildlife conservation, conserving and enhancing genetic variability within species and preserving the geographic distribution and integrity of populations and habitats.

9.9. CONCLUSION

There is an unfortunate and widespread misconception that biological diversity in Ireland is greatly impoverished in comparison to other countries, and that our wild flora and fauna are of little importance to our economic strength and competitiveness. Certainly, the belief that our wildlife includes harmful pests and sources of disease is (understandably) more widespread in Ireland than any understanding of the importance of our nature conservation to sustaining our health. Such sentiments overlook the uniqueness of our biodiversity and the natural features which have evolved here, and the ecosystem services that support our health and well-being, which biodiversity provides. In general terms, it is difficult and sometimes impossible to ascribe a specific quantitative value to any individual species or habitat, excepting those that are harvested by man or that otherwise provide some form of marketable product. Ascribing a value to the protection of any individual species, especially those that have little aesthetic appeal to the wider population, is a difficult task. For example, in recent years, we have seen conflicts arise between the objectives of economic and social development and the aims of nature conservation in which the risks to individual species, such as a rare species of snail, have been highlighted. In an argument of "snail vs. motorway", major infrastructure development would seem to have the stronger position in terms of direct benefits to human well-being. Does it really matter if one particular species of snail disappears from Ireland as a result of our economic development? Surely, the loss of one tiny invertebrate will not impact on anyone's health? It is difficult to find a concrete economic argument in favour of conservation in this sense, however the focus must be on the wider values of biodiversity, and the functions of individual species as part of an ecological system that provides us with essential life-sustaining services. Earlier sections of this report have discussed issues such as redundancy and the functions of individual species within ecological systems. The examples in this chapter illustrate how diversity helps to protect against social and economic risks by providing the basis for a robust, resilient natural environment that can provide a defence against environmental stresses, while also having inherent value in supporting physical, psychological and social health.

In Ireland, we tend to feel relatively cosseted from the more harmful effects and threats of global environmental change. As discussed above, however, our reliance on ecosystem services derived from outside the state increases as we lose our own biodiversity. The recent rapid development of

Ireland's economy and improvements in standards of living, may also have reinforced a sense of protection and isolation from the wider threats of climate change, epidemic diseases, and economic instability. As is the case in most of the world, our well-being is measured more in terms of living standards and economic turnover rather than the availability and security of the life-sustaining resources which biodiversity provides. However, as demonstrated elsewhere in this report, the globalised nature of economic activity, the increased levels of international travel and commerce, and our increased dependence upon external natural resources for food, raw materials and fuel, exposes Ireland to a wide range of threats associated with human impacts on the natural environment.

Our biodiversity currently supports our health in a wide variety of ways, which cannot be replicated through technological development or replaced through economic growth. Negative impacts on Ireland's habitats and ecosystems that provide us with these essential services can threaten our quality of life, and our well-being. A holistic and collaborative approach involving all sectors of society and government is required to ensure that these benefits can be sustained, expanded and conserved.

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10. BIODIVERSITY AND CLIMATE CHANGE

10.1 THE CONTEXT

The recent Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) revealed a remarkable consensus that climate change is a reality and is being brought about by human induced changes in the atmosphere. The IPCC dispensed with its earlier more tentative acknowledgement of the probability of climate change to warn that without appropriate policies to control Greenhouse Gases (GHGs) temperatures could be expected to rise to between 1.8^{O}C and 4^{O}C by the end of the century, while sea levels could rise by as much as 43cm. Climate changes of this magnitude would lead to major social and economic disruption to human society. It also places 20-30% of global species at risk of extinction.

The IPCC findings were further reiterated by the Stern Review produced for the UK Government which reported, without ambiguity, that rising temperatures threatened essential life support mechanisms. It warned that temperatures could reach a threshold point at which catastrophic events could occur, including the melting of the entire Greenland icecap or changes in major oceanic currents such as that of the North Atlantic. These, in turn, could trigger further rises in temperature and sea levels. There includes the risk of positive feedback from potentially irreversible impacts such as the release of carbon and methane stores in bogs and tundra.

Ireland's response to the prospect of climate change has, so far, been lacklustre. The first National Climate Change Strategy was published in 2000 and predicted a redirection of economic growth towards sustainable development guided by the Precautionary Principle that economic development could not be allowed to risk catastrophic changes in climate. Various radical policy initiatives were promised, including emissions trading, carbon taxation, cross-sectoral instruments, fuel switching, energy efficiency and the closure of the coal-fired Moneypoint power station. In fact, GHGs have continued to rise inexorably, propelled by economic and demographic growth, particularly by growth in construction and transport. Emissions have already far exceeded the 13% increase over 1990 levels permitted under the UN Framework Convention on Climate Change at Kyoto.

The second National Climate Change Strategy, published this year, is upbeat about the prospect of GHG emissions mitigation. The new strategy anticipates a reduction in emissions of 17 million tonnes of CO_2 by 2012. Of this, 79% is expected to come from domestic action. Changes in energy generation in favour of renewable sources are principal amongst these domestic initiatives. A 15% target has been set for renewable energies such as wind by 2010 complemented by proposals to use 30% biomass in peat-fired power stations by 2015. Technological improvements in fuel use are also projected to make a significant contribution.

The National Climate Change Strategy anticipated that climate change impacts on Ireland could be relatively benign compared with poorer or more vulnerable countries. The recent Stern Report suggests that this view was complacent. A worst case scenario would involve a shift in the Gulf Stream which could, paradoxically plunge Ireland into colder winter temperatures. While there is no evidence yet of any such shift, the following impacts are now widely anticipated:

1. Rising temperatures. The recent EPA Report prepared by NUI Maynooth (Implications for the EU Climate Protection Target for Ireland) predicts an average rise in temperature of $2^{\circ}C$ and as much as $3^{\circ}C$ in the summer. Higher temperatures can be expected to lead to various health impacts and to significant biodiversity impacts as many cold climate bird and insect species are lost.

2. Changes in rainfall. As temperatures rise, there will be a greater capacity to store water in the atmosphere with the result that rainfall could increase by 17% in Western areas and possibly as much as 25% in places (McElwain & Sweeney, 2007; Murphy & Charlton, 2006). However, the impact could be seasonal with summers being generally drier. Summer rainfall could fall by up to 25% in the South and East. Drought, hitherto almost unknown, could become a regular event.

3. Increased frequency of storms. Rising temperatures will inject added energy into the atmosphere with the likely consequence of increased storm frequency and severity. The principal result will be a rising economic and social cost of damage to buildings and infrastructure, including coastal defences.

4. Rising sea levels. Rising sea levels threaten to overwhelm sea defences and could lead to the inundation of some of major cities. Low-lying or soft rock areas are at particular risk of erosion (Fealy, 2003).

5. Marine impacts. Temperature changes are anticipated to lead to changes in fish stocks. There is also a risk of more frequent and severe plankton blooms.

10.2 CLIMATE CHANGE AND BIODIVERSITY

"There are levels of biodiversity loss that cannot be sustained without incurring catastrophic change/fundamental reorganisation in all ecosystems." Perrings et al. (1995).

Natural systems have a remarkable resilience to withstand shocks (Holling, 1973). The complexity of the ecosystem allows particular species to quickly fill new opportunities that may have been vacated by others. Furthermore, natural systems have a direct input on climate. Forests, for example, regulate the world's climate through the absorption of carbon dioxide and release of oxygen, uptake and transpiration of water, trapping of sunlight, etc. At a macro level, the Amazon has a vital climatic role, but so too does the vast expanse of Taiga forest across Scandinavia and Siberia for Northern Europe. In Ireland, habitats such as peatlands and wetlands have an important influence on hydrology or micro-climates.

The problem with climate change is two-fold. Firstly, ecosystems have adapted gradually to climate change of millennia whereas the anticipated rate of temperature change far exceeds that experienced in the recent geological past. This will make it impossible for many species to adapt quickly enough. Secondly, due to human land use, natural habitats are now highly fragmented. Some species such as birds may be able to relocate, but for others this possibility no longer exists.

No determinate relationship has been uncovered between biodiversity and the stability of ecosystems (Johnson et al. 1996). Folke et al (1996) suggest that robustness may instead be more strongly linked with keystone species. There are many ecologists, however, who argue that stability depends less on keystone species and is rather dependent on a complex web of interactions between organisms. They argue that functional diversity depends on the capacity of new interactions to replace others in the event of an external shock (Turner et al. 1999).

There is still very little that we understand about the resilience of ecosystems. Many key ecosystem services such as the functioning of the soil biota or marine food chain depend on species and interactions that have been little researched. Indeed, we still barely have the capacity to identify many microbes living in the soil. In the context of this uncertainty, the adverse implications of climate change are multiplied. We simply do not know what thresholds could precipitate widespread collapse of life-sustaining ecosystem services. In such circumstances, the best policy is to adopt a precautionary principle and to take actions to remove the root causes of climate change.

10.3 CLIMATE CHANGE AND BIODIVERSITY IN IRELAND

There are various views on the risk of climate change to biodiversity in Ireland. On the one hand, Norton & Ulanowicz (1992) have argued that because ecosystems in Ireland are less complex than those of mainland Europe, they possess fewer interdependencies than larger systems. On the other hand, because Ireland is an island nation there is less capacity for species to relocate from abroad. Due to the loss of the land bridge following the Ice Age, Ireland already has a much diminished biodiversity compared with Britain, with only half as many plant and fern species. A lower variety of species means that Ireland's ecosystem may not have the same resilience as elsewhere as there will be less capacity for new or niche species to replace others that might be directly affected by climate change.

Berry et al. (2002) have modelled the possible future distribution of British and Irish flora, fauna and habitat in response to two climate change scenarios (high & low) up to 2050. Their results indicate a mixed response for most habitats, but suggest the loss of a number of species which currently coexist in, or characterise, these habitats.

More significant impacts are possible in the long-term. The loss of the Gulf Stream would be catastrophic for Ireland. However, the more likely changes will be serious enough if realised. These include:

- Higher temperatures which could lead to the loss of many cold climate species. Many species are already at the southern edge of their climatic range. The decline of the Ring Ouzel being one bird species that already appears to be affected by higher temperatures. Seabird colonies are also at risk from the migration of the fish supplies on which they depend. The impact on the soil biota and on nitrogen cycles is unknown. Many species are known to be sensitive to soil temperature and levels of CO_2. Given the high level of biodiversity present in most soils, an adjustment is likely, but cannot be assumed over more significant climate scenarios.

- Lower summer precipitation, combined with higher temperatures, would exacerbate problems in relation to the water balance with impacts on drinking water supplies, agriculture and aquatic ecosystem services. Lower water levels would mean that aquatic organisms would not only be able to cope with higher proportions of pollutants, but would themselves be threatened by this pollution and less able to recover in winter.

- Increased storms will also inevitably lead to damage to trees, particularly Ireland's ageing stock of mature deciduous trees.

Exotic or non-native species could become more a problem in the future. At best, these represent replacement of indigenous species with other more common types. At worst, these include opportunist species, prolific weeds or disease vectors that would benefit from lower likelihood of sub-zero winter temperatures. Some new arrivals have been welcome additions to our fauna, for example the little egret, now breeding widely along the south coast. Others such as rhododendron, Japanese knotweed, ragwort, flatworm or various shellfish diseases are already serious pests that exert an economic cost on forestry and farming. Higher temperatures, including sea temperatures, will favour the spread of many non-native species.

Concurrent with this threat, the movement of many indigenous or less common species is dependent on an availability of suitable habitat. While Ireland may still have a good network of hedgerows and aquatic habitats, other habitats such as broad-leaf woodland are very patchy. Many habitats have become fragmented by agriculture and roads. Some environments, together with their associated species, are directly at risk from climate change. Montane habitats will be limited in the degree to which they can retreat upwards or northwards. Ireland's peatlands, already severely damaged by peat extraction and drainage, will become further desiccated by rising temperatures and reduced summer rainfall. Salt marsh and dunes are also at great risk.

10.4 ECONOMIC AND SOCIAL VALUES

Loss of biodiversity due to climate change matters because of the ecosystem services provided, the value of which has already been discussed in preceding chapters.

- In agriculture, key species within the soil biota could be lost, reducing the decomposition of organic matter, particularly for land uses that are less protected by microclimate, for example pasture or crops. Replacement species would be unable to migrate from elsewhere. The implications of introducing species is unknown due to the complexity of the system and the minimal amount of research conducted. The damage presented by the introduced New Zealand flat worm demonstrates the problem.

- Aquatic systems would be under threat from increased temperatures and lower dilution of pollutants. The efficient functioning of these systems is already vulnerable to any increase in slight levels of nitrification. Water abstraction, particularly for drinking water, would be affected during summers that are forecast to become drier. Wetter winters would increase the vulnerability of the remnant corncrake population of the Shannon Callows to spring flooding. Even greater spending would be required under the Water Framework Directive and additional controls would be required on agricultural nitrates and phosphates.

- The marine ecosystem is at severe risk, threatening the food supply on which commercial fish species depend. Most of these species are at the top of the food chain so are especially vulnerable. Over-fishing has left many species highly vulnerable to environmental change. Other stocks, such as cod and salmon are sensitive to water temperatures and already appear to be moving northwards (McElwain & Sweeney, 2007). To an extent these stocks could be replaced by warmer water species such as bass, but both are vulnerable to falls in primary production. Phytoplankton is vulnerable to temperature change and could decrease by as much as 50% (Schmittner, 2005). So too is kelp, another commercial crop (Sweeney et al., 2003). Disruption to the ecosystem means that simple species such as jellyfish could proliferate while more regular occurrence of toxic plankton blooms are likely in the higher temperatures. While aquaculture provides a partial insurance against declining wild stocks, it is perpetually threatened by toxic blooms and parasites, including exotics, particularly as shallow coves and estuaries respond more rapidly to temperature change. Sea lice are already producing extra annual generations in response to higher temperatures (Tully, 1989).

- Human health is also at risk. Changes in climate will disrupt ecosystems, causing species to attempt to move to new locations. There could be increases in warm weather parasites responsible for transmitting diseases such as Lymes Disease.

Each of these threats presented very significant costs. New opportunities could arise in agriculture, but only if the soil biota continues to function. Any arrival of new fish species will not replace the traditionally high productivity of the Continental Shelf.

Social welfare will be directly affected. As a rule, humans are adverse to change (Samuelson & Zeckhauser, 1994). Global warming threatens sudden and major change. We value the environment with which we are familiar, both from our own lives and experiences and those recorded from the historical past. Our quality of life would be greatly diminished by the loss of the incredible sea bird colonies around the Irish Sea or by the disappearance of peatlands or of wild cultural landscapes such as Connemara. The features that attract tourists to Ireland and which maintain a multi-million euro industry would be lost, but this loss would be minor compared with the erosion of national identity and the quality of life.

Fromm (2000) argued that customary economic values based on production and personal utility omit a key security value of biodiversity. Without doubt it is difficult enough to quantify the risk of adverse change without quantifying the scale of this change, in terms of lost production, mitigation measures and personal economic utility. This does, however, indicate a substantial quasi-option value, i.e. the value of preserving natural assets until such time that we know their significance. This option value certainly could be represented by a sizeable proportion of Ireland's GDP.

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11. BENEFITS AND COSTS

11.1 VA LUING BENEFITS AND COSTS

Public policies which directly or indirectly protect biodiversity have a cost. It is therefore instructive to compare these with the benefits, be these in terms of biodiversity, in its own right, or for its contribution in terms of ecosystem services.

A fundamental problem is the difficulty of quantifying the benefits. In particular, we still have only a weak understanding of many ecological processes and a corresponding lack of data. Furthermore, many of the benefits are very indirect or non-market with price through which to indicate the scarcity of these services. A first step, however, is to identify as far as possible the range of benefits. The Total Economic Value (TEV) approach introduced in Chapter 8 helps to categorise what the benefits are and by whom they are received.

Use values

Under a TEV taxonomy, a direct use value could be the utility that people realise from activities that involve some direct connection with nature, for example angling, birdwatching or ecotourism. Using the aforementioned categories of provisioning, regulating, supporting and cultural services referred to by Kettunen and ten Brink (2006), direct benefits would include many of the 'provisioning' services. For instance, fish catches could be looked upon as being a harvest of biodiversity or, perhaps more correctly, as the final product of a food chain involving other non-harvested species.

Examples of an indirect use value could be where ecosystem services contribute 'regulating' and 'supporting' services that underpin productive activity or life systems. The wider understanding of biodiversity, including its full range of ecosystem services, is that which is now known to contribute to healthy fish populations. Similarly, biodiversity performs another regulating service by purifying water for consumption by farm animals or for irrigation. These indirect services present a challenge because it is so difficult to quantify their precise contribution compared with other inputs.

Other indirect values arise in terms of human utility. Some of these values can be substantial. They include 'cultural services' to any kind of recreation or leisure that has an indirect association with biodiversity. Water sports would be one example, in that the likes of kayakers or water skiers ideally require water that is clean. Likewise, almost any kind of countryside or coastal recreation involves biodiversity as an indirect use value because the whole character of these landscapes would be quite different, and much less attractive, without their distinct biodiversity.

Passive use values

Passive use values for biodiversity involve no interaction with nature, but could include the benefit of knowing that a valued wildlife species or valued landscape exists. From an economic perspective, these values are still instrumental, rather than intrinsic, in that a wildlife species is only valued insofar as people care about it. Passive use also includes the benefit associated with the value attached to knowing that others value a biodiversity-related good (a vicarious value) or valuing the knowledge that a healthy biodiversity can be bequeathed to one's children or to future generations (a bequest value). Although they might seem a little peripheral, bequest values have always been a significant motivator for the protection of the environment given the shortness of our lifespans. Much of the perceived value of planting trees, designing gardens or contributing to the purchase of nature reserves derives from the knowledge that these places are protected into a future time when we will not be here to enjoy them ourselves.

Option values are a related value in that these refer to an insurance value of protecting something that is not currently used, but which may be of use in the future. By taking measures that protect biodiversity against climate change we are acknowledging that biodiversity has an option value.

Similarly, there is a 'quasi-option value' to protecting biodiversity resources which we think have a direct or indirect value until such time that this value has been researched and understood. Much biodiversity, for example within the soil biota, has a quasi-option value in that, while we suspect it is of value, we cannot yet demonstrate this until such time as any redundancy in the ecosystem has been confirmed.

Essentially, option values arise from uncertainty. There is considerable uncertainty in relation to biodiversity loss because we know so little about ecosystem services. Furthermore, option values are likely to be greater the less certain we can be of our capacity to restore ecosystems, being especially high where there is a risk of irreversibility. Climate change, in particular, undermines our confidence in the future relevance of what we currently comprehend about biodiversity.

The level of uncertainty means that we only begin to address biodiversity impacts through scenario analysis, i.e. by examining the consequences of various scenarios such as "do nothing", "do minimum" or "do something". An important consideration for policy is the extent to which ecosystem services are threatened. If they are at risk, then current values should include a sizeable option value component.

11.1.1 Estimating the benefits and costs of biodiversity

Issues arise in estimating the benefits of biodiversity. In the first instance, providing a gross value for all biodiversity, or even for many ecosystem services, is of little practical value. Such estimates are static. A figure for the gross value of ecosystem services to agriculture depends on agricultural production and the consequent price of that output in relation to demand. If the earth had been poisoned to the extent that it was only able to produce a tiny amount of food, this food would have a near infinite value as would the remaining ecosystem services needed to produce it.

Various methods are available to estimate the benefits or costs of biodiversity. There are questions over which to choose or for which data exists. In the first instance, benefits include the marginal value of the current provisioning, regulating, supporting or cultural benefits of ecosystem services. Secondly, marginal benefits that cannot be expressed in relation to an improvement in biodiversity.

Costs include both public costs and private costs, although the former for policy costs is most relevant in this assessment. Costs can be related to either protection, and therefore to annual marginal benefits, or enhancement, and therefore to the additional marginal benefits, i.e.

- The implementation costs of policies which protect biodiversity
- The implementation costs of policies which enhance biodiversity.

Addition routes by which costs could be estimated include:

- The costs of future ecosystem restoration
- The cost of penalties due to our failure to protect biodiversity (e.g. fines for failure to implement EU Directives).

Often policies have other benefits or objectives too such as landscape, recreation or social benefits/ transfers to target groups (e.g. foresters or farmers). In this respect, it is useful to weigh the benefits associated with biodiversity specifically, although this is inevitably an approximation.

Marginal benefits and costs are of more interest to decision and policy making than gross values in that they account for existing levels of stock and use. They also allow policy makers to trade-off the benefits of protection against the costs.

However, for policy purposes it is insufficient to stop at an estimate of marginal benefits or costs. Of equal interest is the question of who realises these benefits and costs. Biodiversity provides numerous benefits that cannot be confined to agriculture, forestry, marine or water alone. If a water authority acts to clean a polluted river, the cost is a public one. The restored ecosystem services provide benefits to agriculture, forestry and human health. The beneficiaries therefore include the productive sector, specific sectors such as tourism, or private individuals involved in recreation. The result is a mix of public and private benefits. Consequently, it is important that estimates avoid double-counting.

Another relevant consideration is that of external costs (or benefits). If an individual or company pollutes the river, external costs are passed onto other sectors. As in the example above, the benefits and costs may affect a small number of identifiable individuals or the wider community. External costs affecting biodiversity are a mirror reflection of the benefits of lost ecosystem services. Once again, they can be compared with specific mitigation policies or policies that aim to restore biodiversity.

11.1.2 Benefits and costs

A comprehensive cost benefit analysis (CBA) of biodiversity policy is not practical as there is no single dedicated policy to protect biodiversity. Ireland does have a National Biodiversity Plan which requires government departments and agencies to consider and minimise impacts on biodiversity. However, outside of the National Parks and Wildlife Service there are few policies which directly aim to protect or enhance biodiversity. Therefore, there is little point in estimating a net present value (NPV) of biodiversity policy.

Nevertheless, the merit of a CBA framework is that it attempts - as far as is possible - to quantify benefits and costs across different sectors using a common medium, namely money. Although monetary values are used as a yard-stick, CBA is founded within a welfare economic framework in that it addresses benefits and costs from the perspective of society's wellbeing. The methodology must therefore account, not just for financial costs and benefits, but rather the full set of economic and social factors. The distribution of economic and social benefits and costs varies for particular topics, for instance between the public and private sectors, and between users, indirect users and non-users.

Adopting a CBA framework requires us to consider various issues such as the treatment of economic values, non-market benefits, future streams of benefits and costs, uncertainty and equity and efficiency.

1. As CBA must estimate true economic values, it is necessary to correct for market distortions. These include transfer payments such as subsidies, a typical and complex ingredient of state support to primary productive sectors such as agriculture, forestry and fishing. Product prices are therefore artificial and may little reflect true resource costs.

2. Non-market benefits and cost. The benefits (and costs) of biodiversity are not priced by the market. To a large extent this is due to a market failure in that, typically, there are no identifiable individuals with property rights to these ecosystem services. As a result, ecosystem services cannot be traded or priced within a market. The situation can be aggravated by an information failure in that the contribution of ecosystem services is little understood. Many ecosystem services therefore supply public goods for which no prices exist to indicate abundance or scarcity.

Non-market Valuation methods

As many of the benefits of ecosystem services are non-market, a first step is to identify, as far as possible, what the services are and who is affected. This also requires that account is taken of external costs and benefits. It then becomes necessary to input prices to ecosystem services. One method is to relate these services to a market good, such as food products, by establishing the contribution of ecosystem services along with other inputs. The lack of scientific knowledge of many ecosystem services makes this a challenging task. Alternatively, it is often possible to examine the implications of the loss of ecosystem services and to partially quantify the benefits in terms of the costs avoided.

In cases where benefits are realised by the public, in one form or another, it may be possible to use non-market valuation techniques. These include revealed preference methods such as travel cost estimation. Travel cost methods use journey and journey time costs to quantify the benefits of sites with high biodiversity in terms of the amount people are prepared to pay to visit them. Hedonic pricing is an alternative that can be used where biodiversity benefits are captured by particular markets, such as within house prices. More typically, these benefits are realised at a higher level as environmental benefits such as views of attractive natural landscapes, or factors such as clean air, low noise, etc. It would be difficult to attribute a contribution to biodiversity.

A further option is to use stated preference methods such as contingent valuation or discrete choice estimation. These methods use data from public surveys to determine people's willingness to pay for public goods, such as biodiversity benefits. Respondents state their willingness-to-pay directly as a hypothetical payment which represents income or utility foregone. Asking the public about biodiversity directly can be difficult given people's limited understanding of the concept, although there have been studies (e.g. Christie et al, 2005) that have attempted this through the use of presentations and discussion of biodiversity attributes (species, habitats, processes, etc). Most studies examine the marginal value that people attach to environmental assets such as valued landscapes or wildlife, specifically their willingness-to-pay for policies that protect or enhance these assets. Compared to travel cost or hedonic pricing, stated preference is better able to estimate total utility including non-use values. The survey method makes it easier to represent issues of biodiversity, but it is still difficult to attribute a figure to the contribution of biodiversity.

Whichever method is used, it is important to identify the relevant population. For example, perceived benefits (and costs) typically decline with distance from valued sites or lower familiarity. Values should also be lower where there are substitute sites and species (a question of relevance to species redundancy in ecosystem services).

A practical problem with all non-market valuation techniques is that they are time-consuming and costly. Furthermore, although a well-prepared study can provide a reliable indication of true economic benefits and costs, it must be acknowledged that these values have not always been appreciated by policy makers. Non-market valuation methods are being taken seriously in many countries, but few such studies have yet been undertaken in Ireland. As a consequence, it may be necessary to borrow results from abroad, a process called benefit transfer. This is only a second best option in that it can be difficult to know how transferable these studies are to similar environmental characteristics found in Ireland. It is important to calibrate such studies given information on the number of Irish beneficiaries and any known fundamental difference in people's preferences.

The subtlety of biodiversity loss

One example of the international variations in preferences that upset attempts at benefit transfer is that, until recently, many people believed Ireland to be "green and clean" (an image commonly promoted by the tourism and food industries). Environmental policies were low on the priority list. Myth or not, this complacency has been blown out of the water by the pressures placed on the environment by recent high rates of economic growth and development. One characteristic of biodiversity loss is that it has been gradual and largely unnoticed. We often only get an inkling of the problem when we draw comparisons with the natural world of our childhood.

The benefits of biodiversity are realised as a flow over time. Typically, CBA discounts future benefits on the basis that people attach a higher value to the near future. These discounted benefits then get compared with policies or investments that may involve an upfront cost. This comparison can disadvantage future generations. In some respects, we have a window on to these future costs in that we are already having to pay for past neglect by meeting the costs of the deficiencies in environmental infrastructure. It is generally accepted that further significant costs will follow due to inadequacies in our approach to planning. Nevertheless, progress is being made. Government has accepted a National Strategy for Sustainable Development and investment is being made to improve the infrastructure to supply clean drinking water. Other policies entail benefits and costs that are multi-year.

Efficiency and equity

Finally, there are issues of efficiency and equity. Biodiversity benefits and costs are not evenly spread. There are plenty of examples of environmental disasters impacting most heavily on the poorest in society. It is therefore important to correctly identify the population of users and non-users, as well as the creators and recipients of external benefits and costs.

Where necessary, the benefits and costs received by particular social classes can be allocated a higher weighting in a CBA or, otherwise, distinguished to ensure that they are given adequate consideration. For example, it has been argued that some use values, such as those for outdoor recreation, are held most strongly by the better off. On the other hand, it is worth noting that some of these activities are income elastic, i.e. greater participation will follow as income growth continues over time.

11.2 BIODIVERSITY BENEFITS

11.2.1 Agriculture

Without ecosystem services, agriculture would be unable to function, at least outside of a laboratory. However, a characteristic of modern agriculture is that it is able to substitute many ecosystem services through artificial means, for instance by the mechanical management of soil structure or through the application of inputs such as fertilizers and pesticides. Typically these methods contribute to high productivity, but at the risk of the loss of future sustainability of production from impacts such as the accumulation of chemical residue, loss of natural nitrogen, or soil erosion. Short-term high productivity also occurs at the expense of external costs in terms of the impact that chemical inputs have on the environment and on human health.

Consequently, the value of biodiversity can be looked upon as the baseline (often critical) contribution to largely artificial systems of agriculture output, the value of which is inflated by EU transfer payments to the sector, but simultaneously undermined by external costs and a long-term lack of sustainability.

Alternatively, the value of biodiversity can be realised in terms of its capacity to support sustainable farming systems. Under such systems, the volume of output could be less, but the contribution of biodiversity and value of output can be greater. Agricultural policy is beginning to acknowledge the value of long-term sustainability through measures to reduce the external costs of agriculture, through payments for agri-environmental measures and through support to organic farming.

The Rural Environmental Protection Scheme (REPS) provides an example of the value that society places on one aspect of sustainability. Its budget is upwards of €280 million per year. In itself, the budget is a poor indicator of the social value of biodiversity in that it partly represents a re-channelling of transfer payments to small and marginal farms. However, the budget can be justified in terms of its public benefit to the environment. According to O'leary et al. (2005) these benefits are worth €150 million per year as realised in terms of landscape, habitats and visible water quality alone. The researchers accept that there are other benefits that would be both additional and sizeable. These include ecosystem and health benefits, as well as the public perception of the social benefits.

The benefits of REPS were considered in the chapter on Human Welfare. There are other biodiversity benefits which provide a direct contribution to agriculture. To illustrate the benefits, the sub-chapter on Agriculture used three examples of ecosystem services, namely pollination, soil nutrient recycling and pest control.

Pollination

The obvious benefits of pollination in Ireland are more modest than for some other countries. Irish farming is principally grassland based. We only have a relatively small area of crops such as oilseed rape, fruit and vegetables needing pollination. The value of these crops was estimated at around €14 million per year, although it has the potential to expand considerably if oilseed production increases in response to expected growth in biofuel demand. In addition, the value would be greater were it not for the pollination role of domesticated bees. The vulnerability of both wild and domesticated bees to disease or parasites has recently been highlighted by some serious crop losses in the United States.

A further sizeable benefit is realised in terms of the contribution of pollination to clover, a forage crop and an alternative to nitrogen fertilizer. The value of clover to grassland farming is currently modest at around €29 million per year. The benefit can be substituted by the replacement of clover by other grasses supported with fertilizer inputs. On the other hand, the heavy reliance on fertilizers is ultimately unsustainable. Consequently, the value of clover, and therefore the value of its pollination, could become many times greater now that policy is beginning to encourage a shift away from excessive reliance on fertilizers. The external costs of nitrate pollution are significant and partly demonstrated by the amount that the Government is willing to spend on nitrate regulations under the Nitrates Directive.

Pollination is also of immense value to the preservation of Ireland's countryside. Only a fraction of the indirect value in terms of people's willingness-to-pay to protect this wider countryside is reflected in the Campbell at al. study of REPS. Firstly, only a minority of farms are signed up to REPS. Secondly, wild flora and hedgerows provide food and habitat to other species (e.g. pest predators) that are, on balance, beneficial to agricultural production. Ignorance of these benefits compared with more tangible benefit of the alternative of larger field size, means that many farmers are (in economic terms) free-riding on the external benefits of others who retain these features on their land.

Overall, the value of pollination is likely to be many times the €52 million per annum that was currently attributed to agriculture in Chapter 3. If nitrate regulations force two-thirds of grassland farms to consider clover, or if the oilseed area expands in response to biofuel demand, the value could rise to €220 million per annum. There is, though, no policy to protect pollinating insects except peripherally through the various measures contained in REPS. Therefore, there is no policy cost against which benefits can be compared. Despite this, the pollination service provided by wild bees is at significant risk from a variety of sources such as habitat loss, disease and pollution.

Soil biota

A functioning soil biota is critical to the break down of dead vegetation and to nutrient cycling. Although Ireland has a predominantly grassland system, this service is still of immense value to grass production, particularly in terms of nitrogen provision. A provisional estimate based on the impact of earthworms alone to livestock output would suggest that this contribution is worth €723 million per year. Were the contribution of all micro-organisms involved in nitrogen cycle to be included, this figure would surely be far higher. As with clover, this ecosystem service could be partly replaced by artificial fertilizer, albeit at the cost of a possible doubling of the current annual level of fertilizer purchases to €500 million. However, this would still fail to provide the continuous supply of nitrogen required by plants. Neither would such artificial intervention be able to replace the benefits that earthworms supply to soil structure or to expanding the area of available grass through the rapid disposal of animal waste. Consequently, it is not unreasonable to attribute a value to earthworms of around €1 billion per year.

The other significant value of earthworms is in their capacity to break down slurry. Through this service, earthworms are vital to a reduction in the external costs of eutrophication and the contamination of ground water. If the spreading of slurry is discouraged in the near future, this benefit would reduce. However, earthworms will continue to be important to any expansion of the area of clover intended to substitute for the nitrogen currently supplied through slurry spreading.

There is no figure for Ireland of the consumer surplus associated with the elimination of diffuse pollution of nitrates and phosphates from agriculture. However, if the figures estimated by Hartridge and Pearce (2001) for the UK are adjusted for Ireland's relative population, the external cost of nitrate pollution would be between €60 and €120 million per year. The external costs of phosphate run-off would likely be greater, although phosphates are more successfully reduced by environmentally sensitive farming and through plant growth than by transformation within the soil biota.

There is no public policy aimed at protecting the soil biota other than indirectly through the nutrient management measure in REPS. The most relevant policy is that the new Nitrate Regulations, the implementation cost of which will commence at €39 million per year. The budget provides an indicator of the value of biodiversity protection in that the regulations deal with the avoidance of pollution rather than the maintenance of soil fertility.

As with pollination, there is no policy to protect soil biodiversity per se. It could also be argued that, unlike bees, earthworms are not at risk and that a cost-benefit analysis is irrelevant. Although earthworms are a keystone species, the high level of species redundancy within the soil means that the ecosystem services or some species could possibly be replaced by others. However, this view is complacent. Earthworm populations are threatened by non-native species which do not have the virtue of performing the same ecosystem services. Ploughing and chemical inputs are also threats to healthy populations of earthworms. Neither do we understand enough about the soil biota to know how it is likely to respond to such exogenous shocks as future climate change. We do know, however, that the soil biota is the second biggest store of carbon after the oceans and that any change could have significant knock-on effects for agricultural productivity and climate. In such circumstances, it is as well to be cautious. A precautionary approach carries the lowest risks.

Pest control

Predators and parasitoids are highly important to crop production. Integrated pest management promises potentially huge benefits in tropical countries in particular. The benefits in Ireland are again, as for pollination and soils, somewhat diminished by the prevalence of grassland systems. Nevertheless, they are still significant. There is potential for environmentally sensitive farming to supply some savings on the approximate €3.3 million spent each year on insecticides together with associated savings in terms of health and ecosystem damage. These latter benefits are tentatively estimated as being €1 million per year. Benefits in terms of crop, biodiversity and health losses avoided through existing baseline predation are likely to be higher. These are conservatively estimated at €20 million per annum.

The public benefits are largely restricted to the avoidance of health risks together with the value placed on a functioning ecosystem. Both risks have diminished in Ireland as pesticide formulations have improved. They were significant in the past before the damage caused by DDT was fully realised. However, any increased need for pesticides due to the collapse of natural control would lead to a reappearance of external costs. Invariably, pesticides are highly toxic and measures to protect public health typically attract very high willingness-to-pay.

The population of natural predators and parasitoids is at risk from habitat loss, pollution and exogenous shocks. It is not inconceivable that pest populations could increase in response to climate change. These useful species have no specific policy protection, although agri-environmental measures such as REPS do help to protect habitat and reduce pollution. Ideally, it is farmers themselves who should weigh up the private costs and benefits of limiting pesticide applications and leaving suitable habitats uncultivated. Public intervention should be limited to ensuring that insecticide prices cover external costs.

Summary of benefits of selected ecosystem services to agriculture and policy costs

BENEFITS	Marginal annual value of status-quo	Possible full value inc. option values and external benefits	Threats / comments
Pollination	€53 million pa. (possibly €150+ by 2020)	€500 million pa. ???	At high risk from unsustainable farm practices, & disease.
Earthworms	€1 billion pa.	€1.5 billion pa.	At low, but increasing risk from unsustainable farm practices, alien species and climate change
Predation /pest control	€4 million pa.	€24 million pa.	Value will increase if farming required to become more sustainable. High risk from farm practices and climate change.
Public utility benefits of REPS	€140 million pa.	€500 million (if we're to include health and other benefits)	Policy becoming more pro-active. Benefits would be higher if account for other outputs and potentially greater participation.

POLICY COSTS	Marginal annual cost	Comments
REPS	€140 million pa.	Allowing a weighting of 50% to biodiversity. Currently only 25% of farms, but cross-compliance likely to be more prevalent in future.
Nitrate regulation	€39 million pa. (possibly €100m by 2020)	Will become more prevalent probably through cross-compliance

11.2.2 Forestry

Through the supply of nitrogen and other nutrients, the soil biota provides many of the same benefits for forestry as for agriculture. Given a total forest cover of 6.9 million hectares, annual cuts would be of the order of 138,000 hectares assuming an average rotation of 50 years. If biodiversity were to provide a similar contribution as for agriculture, the ecosystem service of earthworms could be worth in the order of €50 million per annum assuming a gross timber income per hectare of €16,000. However, this estimate could be rather academic in that this ecosystem service does not appear to be threatened in that same way as it is by intensive farming. On the other hand, both climate change and non-native species could be as much a threat to forest earthworms as they are to those on farmland.

Probably of more relevance to forests are the benefits and costs of measures to protect biodiversity. Bacon and Associates (2004) estimate the biodiversity benefits to public utility of the proposed forestry expansion programme could be €1.6 million per year, but that the industrial nature of the existing forestry estate means that it contributes only €5.4 million per year. Any passive use value, equivalent to those revealed in surveys of people's willingness to pay for agri-environmental measures, would be additional to this.

Private (grower) costs can be represented by the opportunity cost of the retention of mature trees. A genuine opportunity cost does arise in terms of the 15% area that is set aside although, in practice, this might only involve 5-10% of the area given that many such areas are selected because they are inherently not very productive or cannot be planted (overhead power lines, etc).

For Coillte, the State Forestry company, the annual opportunity cost of this set aside could be €16 million based on the size of the Coillte forest estate. The figure is, though, rather hypothetical in that very little new public planting is occurring at present. Of more relevance is that Coillte perceive a greater benefit from the improved accessibility to markets provided by FSC certification.

In either case, the cost of biodiversity measures borne by forestry companies is covered by the public grant available. Forestry grants have traditionally been provided as a rural development measure, rather than for environmental purposes. However, the difference in premia available for native hardwoods compared with softwoods, together with the area planted, does provide an indication of the environmental benefits as they are perceived by policy makers. This net cost would be around €12 million per year. In addition, there is the budget for the new Forest Environmental Protection Scheme (FEPS). Taking an average of the grants and premia available would result in a budget of €15 million over five years for the pilot FEPS scheme target of 2,700 hectares.

BENEFITS	Marginal annual value of status-quo	Possible full value inc. option values and external benefits	Threats / comments
Earthworms	€50 million pa.	€75 million pa.	At low, but increasing risk from alien species and climate change
Public utility	€5.4 million pa.	€7.0 million pa.	Planting policy improving

POLICY COSTS	Marginal annual cost	Comments
Broad-leaf supplements and schemes	€12 million pa.	A figure which can be attributed to biodiversity.
FEPS	€3 million pa.	Should increase over time. Does not make allowance for landscape benefits or social transfers

11.2.3 Marine

Of all economic and social sectors addressed in this report, it is the marine sector which has the most direct relationship with biodiversity in that fish species are harvested without any artificial inputs that contribute to productivity. In a sense it is self evident that the availability of commercial fish populations depends on the biodiversity of the marine ecosystem. However, it is only very recently, through studies such as that by Worm et al. (2006), that the character of this relationship has begun to be revealed. There is still remarkably little that we understand about the detail of these relationships, including, for example, species interactions or the role of deep water coral reefs.

We do now know that high levels of biodiversity are critical to the recovery of fish stocks. We also know that the marine ecosystem provides an essential, if often over-looked, function in assimilating huge volumes of waste from polluted rivers and coastal cities.

In Ireland, the wild fisheries sector is worth €180 million a year in terms of the quayside value of fish. Despite the shift to lower value pelagic species, the value of the catch has increased slightly in real terms over the last ten years. However, the value of exports of fish and fish products has increased significantly. The latter increase reflects a combination of higher value processing and the effect of supply and demand in the context of falling EU stocks. While the latter could mean that the same value increase may not have occurred had European stocks been sustainably managed, it is still true that Ireland is failing to realise the true potential value of its fish stocks under a sustainable system.

To an extent, aquaculture has the capacity to compensate for the decline in commercial species. Aquaculture in Ireland is now worth €85 million per year. The sector is growing, but has so far failed to realise its potential due to market conditions. However, aquaculture also depends on ecosystem systems, for the provision of fish food, for the natural control of parasites and for the assimilation of waste from farms.

As regards marine policy, this continues to be dominated by the needs of the fishing industry, although the extractive sectors, principally oil and gas, are of growing relevance. It is difficult to find anything positive to say about the manner in which fish stocks have been managed. The Marine Institute has argued that 75% of commercial species are outside of safe biological limits. The in-shore fishing sector is a fraction of its former self, while the vast majority of ports have ceased to land significant quantities of fish with consequent loss of traditional sources of employment. Large sums of public money have been spent on the modernization of vessels, but there are still too many vessels chasing too few fish. The largest quantities are caught by a handful of individual vessels which land a proportion of their catch abroad. Under-reporting, illegal catches and discards have been significant problems.

In terms of biodiversity, the populations of most demersal species and several pelagic species have declined significantly and are subject to quota. Slow recovery deep-sea species were briefly plundered in the early years of the century and catches are now controlled. By-catch continues to be a problem. Marine Special Areas of Conservation (SAC) have been identified, but are not yet operational.

Some of the public expenditure on vessel modernization and fisheries protection has benefited biodiversity, but this benefit has been a minor and indirect motivation. The proposed new round of decommissioning, at a projected cost of €45 million would have a more direct biodiversity benefit.

In terms of public costs, an increasing amount of European and national funding is being directed at research into marine ecosystems and ecosystem fisheries management. A few areas are already zoned for marine protection, but the identification of Marine Protection Areas has made slow progress and an application is only now being made to Brussels. Costs would apply principally to naval enforcement. At present, enforcement has been argued to cost as much as €100 million per year (half the value of output), although the rational has been strategic protection of commercial stocks rather than biodiversity. In principle, a private cost should be incurred in that privately owned vessels will need to adopt new environmentally-friendly fishing gear. However, past experience would suggest that this investment too will be underpinned by the state.

Summary of benefits of selected ecosystem services to marine fisheries and policy costs

BENEFITS	Marginal annual value of status-quo	Threats / comments
Fish catch	€180 million pa. (net exports €275 million pa.)	Could potentially be worth twice these amounts if sustainably managed, but values likely to fall in short term as quotas bite.
Aquaculture	€42 million pa.	Assume 50% contribution for biodiversity. Future largely dependent on wild fisheries & biodiversity
Seaweeds	€10 million	Value of sales. Precise biodiversity contribution not known. Threats from climate change.
Waste assimilation + HABs avoided	Unknown. Substantial.	Becoming less important with environment regulation, but still crucial after oil spills or in estuarine waters vulnerable to climate change

POLICY COSTS	Marginal annual cost	Comments
General fisheries protection	€25 million *	A proportion of total costs of around €100 million, but with biodiversity protection only an indirect benefit and mostly for species of commercial value
Fisheries protection Marine SACs	€1.5 million *	Marine SACs represent 2,542km2. Navy is charged with protecting 338,000km2
Decommissioning	Low weighting for biodiversity to date	Once-off cost of proposed decommissioning at €45 million does have biodiversity objectives largely absent from policy to date.
ICZM	negligible	Most expenditure by EU Interreg as pilot schemes

* largely reimbursed through EU

11.2.4 Water

Water provides for numerous economic and social uses and benefits and, for many of these, good, clean water is the standard required. The chapter on Water noted several key benefits due to the cleaning services performed by the aquatic ecosystem. These include provisioning services such as quality drinking water, supporting services to fisheries and other fresh-water produce, and regulating services such as the assimilation of domestic, agricultural and industrial waste.

Wetlands and flooding

In addition, wetlands perform important economic and social functions in the form of flood mitigation. For peatlands and fens, it is the ecosystem itself that performs the retention function, at least up to a saturation threshold. The economic benefits of flooding avoided are limited for lowland bogs in that most are surrounded by poorly productive pasture. However, upland blanket bogs may be more influential in reducing flash flooding of lowland towns. Flash floods in Boscastle, Cornwall, in 2004 and Carlisle, Cumbria, in 2005 (both beside rivers rising in upland areas) caused many millions of euro worth of damage. In Ireland, bog slides have been a recent phenomenon where the integrity of peatlands has been undermined by a combination of weather conditions, sub-soil, overgrazing and structural works. Flooding in October 2004 led to insurance claims of €38 million (Huyskes et al. 2006) causing companies to take climate change very seriously. The predicted drying out of upland bogs could lead to more frequent flooding in future. Indeed, peatlands provide for storage of carbon that would otherwise be lost to the atmosphere. While the living surface layer sequesters carbon only slowly, it does protect the underlying peat carbon store from dessication. This store has been estimated to total 1.07 billion tonnes (Tomlinson, 2005).

Fishing and recreation

Rivers and lakes are associated with significant public benefits. To avoid double-counting, the utility benefits of amenity and recreation are specifically dealt with under the section on Welfare below, but it is possible here to consider the amount that is spent on water-based recreation. Domestic spending is at least €70 million per year and that of foreign tourists is put at €65 million according to the Marine Institute (2003). Although much of the former may have resided within Ireland, it can nevertheless be linked to the aquatic ecosystem services.

Angling expenditure is included in the Marine Institute figures. Until very recently wild salmon supported a commercial industry, but falling stocks have led to the closure of the industry. If the recreational catch increases to fill the gap, the value of fish caught should increase to at least €15 million per annum. On top of this can be added the expenditure by foreign anglers which probably at least matches that of domestic anglers at €50 million. Inland trout production depends on clean water and is valued at €600,000 per year.

Waste assimilation

Waste assimilation is a tremendously valuable ecosystem service, even if it is one that can quickly be undermined by the quantity or toxicity of pollutants. Industry endures a private cost in that it is required to have on-site waste-water treatment to comply with EPA Integrated Pollution Control licensing. The private costs of this abatement have been estimated by Clinch and Kerins (2002) at anything between €0.08 and €4 per tonne depending of the nature of the industry. Inevitably, pollution regulations would need to be stricter without the subsequent purification provided by natural ecosystem services. Under-investment in municipal treatment plant means that many towns across Ireland depend on these same processes to clean up effluent that has been inadequately treated. Without this waste assimilation, further costs would be incurred for other water users down-stream. Likewise, diffuse pollution from agriculture and rural housing exerts an external cost where this exceeds the assimilation capacity of rivers. The value of the waste assimilation is realised in terms of the avoided cost of additional treatment down-stream. Unfortunately, it is a benefit that is impossible to value precisely, although it is certain to run into hundreds of millions of euro.

Industrial abstraction

Both industry and agriculture require clean water for abstraction. Water for most businesses typically requires treatment and, where provided by rural county councils, the supply cost is around €1 per m3. For a typical creamery, this would result in a cost of around €192,000 per year (Hayes, 2006). Clearly the cost would increase if source waters were more polluted.

Many farms abstract water directly from rivers or groundwater. Although there is only a limited amount of crop irrigation compared with other countries, clean water is needed for livestock. Assuming that one quarter of the national herd receive their water from natural sources, this represents a cost saving of €35 million compared with county water charges given average consumption per animal of 20m3 per annum.

Aside from agriculture and industry, water is used for domestic use. Artificial treatment is generally provided, but ideally the source should also be of high quality given that this water is used for drinking. No figures on the benefits are available, but the cost of water purification can be estimated in terms of on-going purification and capital expenditure. The former is estimated at €200 million per year assuming daily water consumption per person of 150 litres of which around one quarter would be for drinking/cooking. Given previous underinvestment in environmental infrastructure, capital expenditure is currently very high at around €500 million per year out of a Water Services budget of €860 million. When, finally, this belated investment has been made, the annual capital costs should fall over the long-term.

Summary of benefits of ecological services to water quality and policy costs

Table assumes that current expenditure on Water Services is broadly comparable with social benefits.

BENEFITS	Marginal annual value of status-quo	Threats / comments
Additional purification of piped water avoided	€100 million	Cost of additional water purification avoided through prevention of any deterioration in source waters due to diffuse pollution. This figure is an assumption based on 50% of existing spending.*
10% rural pop. drawing water directly	€22 million	If these households had to receive treated water based on the same assumptions as above given current spending on Rural Water Programme.
Agricultural water	€35 million pa.	Assuming natural supplies needed to be replaced with treated water.
Flood mitigation by wetlands	€20 million average year	Tenuous figure, but likely to rise steeply with climate change.
Carbon storage by peatlands	Zero value at present	But €80 million pa. if offsets permitted by Kyoto replacement equivalent (for example) to annual peatland restoration equal to current commercial peat output (4mt/pa) at carbon trading price of €20/t.
Expenditure on inland waterways recreation	€60 million pa.	Weighting contribution of water quality at 50% and assuming this expenditure would not be transferred to other sectors. Value is additional to utility benefits dealt with in Chapter 8.
Recreational salmon catch	€20 million pa.	Additional to above figure. Weighting 100%. Includes recreation expenditure and commercial netting (former value should now replace latter).
Fish farm production	€600,000 pa.	Clean water weighted at 100%.
Waste assimilation	Unknown, sizeable	Additional domestic and industrial waste water treatment avoided by ecosystem services where of benefit to wider environment. Current spend approx €220m.pa

* Further research could be undertaken to an provide improved estimate, i.e. based on differential costs of water purification from clean and polluted sources.

POLICY COSTS	Marginal annual cost	Comments
Catchment management	€16 million pa.	Annual costs identified for pilot WFD projects by just six counties in Water Services Programme 2005-07. Likely to increase to at least €50 m. pa.
Enforcement EPA	€5-10 million pa.	Not to double count with table for 11.2.6.
Nitrate Directive	€39 million pa.	Excluding REPS measures. Cost likely to increase.

11.2.5 Roads and infrastructure

Although the net impact of roads on biodiversity is evidently negative, a greater amount of attention is given to ecological protection associated with the construction of roads or other public infrastructure than is typically given to private development, including housing. Considerable effort is made to mitigate the adverse environmental impact of roads through the environmental assessment process. Inevitably these vary substantially from one road to the next depending on the environment through which it cuts. The National Roads Authority has not been able to supply an estimate of the average cost of these mitigation measures.

Biodiversity impacts are not included at the cost-benefit analysis stage of road design. Neither are the biodiversity implications of cumulative impacts taken into account, although this should change with the advance of Strategic Environmental Assessment (SEA). Arguably, inadequate consideration is given to the relative biodiversity impacts of alternative transport options, or to the effect that residential planning has on stimulating the need for new roads in the first place.

Summary of benefits of ecological services to roads and infrastructure and policy costs

MITIGATING BENEFITS	Marginal annual value	Threats / comments
Noise and dust mitigation	Not quantified.	Refers to ecosystem services which reduce net environmental impact of infrastructure
Roadside wetlands	Not quantified	Ditto

POLICY COSTS	Marginal annual cost	Comments
Ecological assessment (EIA)	Not quantified	Identifying impacts
Mitigation	Perhaps €40 million pa.	Direct ecological measures excluding re-routing, noise and landscaping.

11.2.6 Human Welfare

Benefits

Only a handful of environmental valuation studies have been undertaken in Ireland and none of these have been specific to biodiversity. Consequently, the summary table below is in no way comprehensive. Marginal values can be provided as annual estimates of public benefits, expressed as the consumer surplus of particular activities associated with biodiversity, e.g. angling. Alternatively, these marginal values can be expressed as the additional consumer surplus due to incremental improvements in the biodiversity resource, for example due to policies such as the Rural Environmental Protection Scheme (REPS) or water quality improvements. The latter is more reliable and more relevant to cost-benefit analysis.

Land use

A recent survey for the Heritage Council (2007) estimated the public benefit of increased government spending on heritage. Of the estimated annual value of €90 million, public preference was greater for spending on natural heritage features (at approx €65m pa.). The association between such features and biodiversity varies considerably, being high for wildlife sites, but less for others where geology, geomorphology or cultural practices play a significant part, e.g. the Cliffs of Moher.

Campbell et al. (2006) have estimated the aggregate value of REPS at €150 million per year. Again, this only provides a partial valuation of the welfare benefit of biodiversity, although the survey found that the greater part of the estimated benefits was associated with rivers and lakes, the quality of which supports biodiversity (and vice-versa).

Forestry

Various welfare estimates have been provided for forestry. The most recent of these by Bacon and Associates (2004) includes an annual value of biodiversity of €5.6 million per annum in relation to existing forestry or a marginal value €1.6 million per annum for the proposed expansion programme. Biodiversity also makes a significant contribution to forest recreational benefits estimated at €97 million per year (Coillte/Irish Sports Council, 2005). Few new areas of forest are being planted by the public agencies, and growth in future recreation benefits, together with the associated biodiversity benefit, is restricted by the lack of access to private forests. However, some new marginal benefits will derive from sustainable forestry guidelines applied to existing forest areas.

Water

Estimation of the welfare benefits associated with the recreational use (use value) of rivers and lakes is hampered by the absence of figures on the number of visits to such localities. The Marine Institute (2003) estimates that 190,000 people undertake water-based recreation each year. However, many more would be involved in more general recreation and leisure. It seems likely that, given the large number of rivers and lakes, together with the relative attraction of water, the number of trips is in excess of the estimated 18 million trips associated with forests (Coillte/Irish Sports Council 2005) or the 25 million trips associated with distinct heritage destinations (Heritage Council 2007). Excluding coastal trips, a possible figure might be 30 million trips. The total utility or consumer surplus associated with each individual trip is unlikely to be less than €10 and is probably significantly more (no estimates are available for Ireland). Biodiversity is likely to contribute strongly to any estimate of this consumer surplus.

The consumer surplus is additional to expenditure incurred. Domestic tourism (excluding angling discussed above) accounts for around €37 million of annual expenditure (Marine Institute, 2003). In principle, much of this spending should be discounted on the basis that it would otherwise be spent elsewhere in the economy (although not necessarily in areas with as high an economic multiplier). However, the amount spent by tourists from overseas represents a net addition.

As well as the expenditure and utility value, rivers and lakes can be expected to elicit substantial passive use (non-use) benefits given their importance to the Irish rural environment. These benefits have not been quantified, but would probably match those estimated for the farmed countryside, particularly given the importance attached to water by respondents to the REPS survey.

Ideally, for a cost-benefit approach, it is the marginal benefit of protecting or enhancing aquatic biodiversity that is most relevant to an assessment of new biodiversity policies. For the UK, the benefits of improvements in water quality have been estimated by Green and Tunstall (1991) at up to 97 pence per trip. This figure would likely have more than doubled to £2 per trip given income growth in the subsequent period. By comparison, most Irish rivers and lakes are already of relatively good quality compared with those in the UK. Seventy per cent of Ireland's rivers are described by the EPA as Class A (unpolluted) while 85% of lakes are good quality oligotrophic or mesotrophic (McGarrigle et al. 2002). Taking the proportion of moderately polluted rivers (13%) and assuming that these could potentially share in the presumed 30 million annual trips, such an improvement would be worth at least €10 million per year if transfer values can be based on current UK estimates. Indeed, as the proportion of moderately polluted rivers is higher (25%) in the Eastern Region where most people live, it is possible that actual use benefits could amount to between €10 and €20 million per year.

Welfare benefits would be higher on an individual level amongst specialist users such as anglers, boaters and kayakers. Curtis (2002) estimated total consumer surplus benefits, given current water quality, of between €62 and €185 per trip for anglers in Ireland. These anglers' valuation of marginal improvements in water quality from moderate to good quality could be estimated at between (at least) €3 and €28 (salmon) per trip based on UK figures (Environmental Agency, 2002).

For kayakers, Hynes and Hanley (2006) report values for improved water quality of €14.50 per trip. Given around 200,000 regular anglers and 50,000 regular kayakers in Ireland, the aggregated annual benefits of improved water quality can be estimated at €32 million. The values held by inland sailing or boating enthusiasts, or by naturalists, would surely double this value noting by their greater numbers, but lesser contact with the water.

Substantial welfare benefits also apply to knowing that drinking water quality is clean. Again, there is no estimate of this benefit, although the willingness of up to 50,000 Galway households to pay around €3 per day on bottled water during the current crytospordium crisis provides a minimum estimate of the value people place on clean drinking water. These purchases are founded in people's valuation of their good health, but additional benefits would be realised in terms of avoided hospital expenses and loss of work days. The €3 figure would exceed €1.4 billion per annum if aggregated to the total Irish population. It is, though, a figure that can only be indirectly equated to the value of ecosystem services in that these play only a partial role in purifying water, particularly of e-coli or cryptosporidium. Nevertheless, the figure does provide some indication of the benefits of sustaining the aquatic ecosystem.

Costs

The cost of policies that contribute to improved human welfare by protecting biodiversity amount to around €380 million per year. However, a substantial portion of this figure has been included under other sector headings. In addition, a significant amount of REPS benefits (perhaps half) could be attributed to landscape or social benefits rather than biodiversity. Excluding these factors, the net additional costs are around €50 million and can be attributed to relevant expenditure by the National Parks and Wildlife Service (NPWS) and by the Environmental Protection Agency (EPA). Much of this expenditure is directed at protection through enforcement, rather than active management for biodiversity and salary costs are a major component. Indeed, environmental protection is the principal objective of the EPA, much of whose annual income of €50 million is directed to areas that are only indirectly related to biodiversity, such as air quality and waste disposal.

Summary of welfare benefits of locations and activities of relevance to biodiversity
(Benefits of policies to improve quality. Estimates of annual consumer surplus (CS))

BENEFITS	Marginal annual value of status-quo	Threats / comments
Agri-environmental policy	On policy to protect/improve = €75million pa. (Campbell et al.) CS = perhaps €200 million pa.	Minimum figure is marginal value of improvement due to REPS assuming 50% can be allocated to biodiversity benefits. Higher figure is assumed value of benefits to wider countryside based on this figure, though this is not relevant to cost-benefit framework.
Forestry	Data on CS only €5.6 million pa. (Bacon & Assoc.)	Annual value. Rising to €7.2 million pa. with expansion and improved biodiversity policy.
Natural heritage (not agri or forest)	On policy to improve = €33m. pa. (Heritage Council)	Minimal estimate of marginal value of improvement based on "heritage features" of which biodiversity/wildlife perhaps 50%. No data on wildlife or specific natural habitats, although valuation of peatlands is on-going (www.ucd/boglands.ie).
Water quality: specialist users	On policy to improve = €45million pa. Data on CS = Anglers = €246m pa Kayakers = €15m pa. Boaters = €150m.	Annual consumer surplus estimates based on 10, 10 & 5 trips (with assumptions of consumer surplus to kayakers and boaters/sailors). Benefits of water quality improvements estimated at €45 million pa. for all groups.
Water quality general users	On policy to improve = perhaps €50 m. pa. Based on CS of €300 million pa.	Assuming consumer surplus of just €10 per trip. But some overlap with natural heritage above. Improvements to water quality perhaps €50m.
Coastal environment	No data or basis for assumption.	Substantial. Study on marine reefs on-going (NUIG).

POLICY COSTS	Marginal annual cost	Comments
Agri-environment	€140 million pa.	Full cost of €280 million includes value of social transfers to farmers as well as biodiversity benefits (again weighted at 50%).
Forestry biodiversity	€15 million pa.	Cost of biodiversity measures. Not to double-count with table for Water 11.2.4
Natural heritage	Approx €35m. NPWS + €2m. by Heritage Council	Figure includes large element of enforcement in addition to direct protection.
Water quality	€55 million	Catchment management and Nitrate Regulations Not to double-count with 11.2.4
Coastal environment	Negligible	No ICZM or Marine Protected Areas at present (see Marine 11.2.3)
Biodiversity protection by EPA	Approx. €10 million pa.	Emphasis on water quality, soils and biodiversity and relevant research. More indirect benefits attributed to waste and air quality.

11.2.7 Health

Biological diversity is of fundamental importance to human health on a variety of levels. The nature of this relationship with health is often complex, and often other inter-related factors are of equal or greater importance in determining the health status of a population. While the linkages between health and biodiversity have been clearly demonstrated in many parts of the world, here in Ireland there is not enough baseline information on biodiversity and ecosystem services to allow direct parallels to be drawn. Furthermore, there is little precise data on the amounts spent (for example, by the Department of Health and Children) on related areas of public health protection, such as prevention programmes for specific diseases, through which a link to biodiversity can begin to be quantified, or through which a basic "costs avoided" scenario for nature conservation can be developed.

The chapter on health identified several means through which biodiversity interacts with health, i.e.

- Food quality, nutrition security and dietary health
- Infectious diseases

- Physical and psychological health
- Medicinal Resources

Research has established that a diverse diet based on a wide variety of fresh foods can be associated with reduced incidence of diseases and other positive health outcomes. However, the economic link between high biodiversity and high food quality, nutrition security and dietary health is impossible to identify in the Irish context, even approximately, given the lack of available information on the costs associated with dietary deficiencies. Furthermore, certain diseases, such as cardiovascular disorders and other so-called "diseases of affluence", are clearly associated with other factors, such as physical exercise and living conditions, that must be factored into any such assessment. Similarly, the links between biodiversity and physical or psychological fitness, though easily demonstrated, are not easy to quantify. The Health chapter of this report has highlighted how an awareness and appreciation of the natural environment, and access to green space, can support individual well-being, social cohesion and overall community health. Unfortunately, not enough research has been carried out in Ireland to allow any direct connections to be drawn.

In terms of infectious diseases, the ecology of disease-causing organisms is directly associated with the functioning and sustainability of the ecosystems within which they circulate. The populations, distribution and dispersal of pathogens are regulated by biodiversity as is the case for all species. Globally, there are many cases where disease outbreaks in man, wildlife, livestock and plants have been directly or indirectly exacerbated by ecosystem disruption.

On another level, the genetic and species diversity within an ecosystem confers a degree of resilience against the impacts of major disease outbreaks. However, it is difficult to attribute a specific economic value to disease regulation within a diverse ecosystem. In the case of some familiar diseases, such as rabies or bovine TB, there are ongoing costs associated with disease control, treatment, or prevention, some of which can potentially be avoided if appropriate biodiversity conservation strategies are adopted within a health protection programme. In the case of emerging or re-emerging pathogens, costs are not incurred unless a disease outbreak arises, and it is difficult to assess the costs of an event which has not yet happened.

However, lessons from recent history give us many indications of the potential economic value of ecosystem approaches to health in preventing new disease outbreaks. For example, although no direct connection can be drawn between the status of biodiversity and the outbreak of foot and mouth disease in 2001, the huge social and economic damages incurred as a result of that outbreak clearly indicate the level of risks associated with future outbreaks of other infectious diseases of livestock, such as the blue tongue virus. Similarly, although we know little about the role of ecosystems in the influenza pandemic of 1918-19, we know that up to 5% of the world population died, while up to 1.5 million people died worldwide as a result of the flu pandemic of 1957-58. The costs of the current ongoing spread of H5N1 HPAI through Asia and Europe, for which possible links with human alterations to natural ecosystems have already been established, have already cost the global economy over $10 billion, even though the human death toll has been low.

The values of biodiversity to the fields of medicine and drug discovery are considerable, and include the market values of specific compounds, and the positive social impacts and health outcomes that may be derived as a result of research. The disappearance of any aspect of biodiversity means the permanent loss of any benefits that may have been gained from future research. As discussed in the Health chapter, the importance of biodiversity as a living library of information and medicinal resources is growing in the current era of emerging infectious diseases and increasing problems of anti-microbial resistance. As biodiversity loss in Ireland continues, so too does the loss of potential new and significant economic resources.

It is clear that the conservation and sustainable use of services provided by healthy, biologically diverse ecosystems can contribute to population health in many ways. It is equally clear that the loss of biodiversity and disruption of ecosystems can potentially have direct and severe negative consequences for human health. Therefore, perhaps the important point to consider is not how much the potential gains from biodiversity may be worth economically, but rather the nature and scale of potential losses that can be avoided. Although data is lacking, people are clearly willing to pay considerable amounts to ensure their family's good health. But how much would people in Ireland be willing to pay for nature conservation measures to ensure human health and well-being. In answering that question, an economist or accountant would want to know how value could be gained in return. The lack of information on the health-related costs associated with biodiversity loss in Ireland makes this impossible to answer at the present time. Nevertheless, the value placed on maintaining public health means that any positive contribution from biodiversity is significant in economic terms.

11.3 POLICY COSTS COMPARED WITH BENEFITS

Market failure means that the true scarcity value of biodiversity is unpriced by the market and often over-looked by society. At a time when ecosystem services are undermined by a multitude of threats, including over-development, over-exploitation, pollution, introduction of alien non-native species, and climate change, there is an urgent need for various policy strategies that can signal the true value of biodiversity to those whose activities either depend on or impact on it. These options include regulatory instruments such as:

- voluntary agreements,
- command and control mechanisms,

as well as economic instruments that include:

- subsidies or compensation,
- taxes or charges,

- tradable permits
- direct investment

The OECD (2004) has recommended the greater use of economic instruments to encourage biodiversity conservation. These include market-based instruments which attempt to change behaviour in a manner that accounts for true biodiversity values. Incentives supported by liability rules or the creation of property rights (for example transferable fishing quotas or development rights) are amongst the means available to achieve these ends.

The problem, as we have noted, is that attributing a value to biodiversity is very difficult. This is true even when regulatory or economic instruments seek marginal, rather than absolute, values. It can be almost impossible to identify the proportion of a marketable good's output that is contributed by ecosystem services. Even where direct valuation methods are used to measure utility benefits, these are rarely elicited just for biodiversity and, where this has occurred, these are only baseline values based on either the expert's, or the public's, very incomplete understanding of ecosystem services. Consequently, all the values provided in this report represent minimal and very approximate expressions of the value of selected ecosystem services or biodiversity benefits. Some significant benefits are also omitted because there are virtually unquantifiable, waste assimilation within aquatic ecosystems.

The same is true of policy costs. Very few policies are initiated with the express intent of preserving biodiversity. One of the better exemptions is REPS. Yet, while agri-environmental policy benefits biodiversity, this is but one of several objectives which include also landscape, human health, animal welfare and the protection of farm livelihoods.

A partial comparison of the marginal benefits of ecosystem services with current policy costs

BENEFITS	Marginal annual value of status-quo	Threats / comments
Agriculture	>€1200 million pa	Potentially significantly greater benefits from more sustainable agriculture
Forestry	€55 million pa.	Non-market benefits increasingly being recognized
Marine	€230 million pa.	Potentially significantly greater benefits from more sustainable resource management. Waste mitigation services not included.
Water quality	>€260 million pa.	Waste mitigation services not included.
Human welfare	>€920 million pa.	Selected benefits only
Health	unknown	Tens of millions.

POLICY COSTS	Marginal annual cost	Comments
Agriculture	€180 million pa.	Excluding a nominal proportion which is non-environment.
Forestry	€15 million pa.	Excludes additional premia costs (figure not forthcoming)
Marine	€30 million pa.	Much neglected in the past, but expenditure likely to increase significantly.
Water quality	€65 million pa.	Catchment management expenditure likely to increase and replace current emphasis on capital investment.
Roads (mitigation)	€40 million pa.	Biodiversity mitigation being made, but little strategic assessment of biodiversity.
Human Welfare	€260 million pa. (or €40m net of above figures)	Increasing expenditure of environmental policies generally, but often correcting other policies.
Health	negligible	

Given the partial nature and inadequacy of the figures, we do not attempt a comparison of the benefits and costs beyond what can be discerned from the selected examples in the table above. What is obvious is that we are spending very little on biodiversity protection compared with the benefits that we receive in return. Equally, though, we would not need so many environmental policies were resources managed in a way that respects biodiversity and ecosystem services. For example, a large part of the environment-related spending in agriculture and, increasingly in the marine sector, is actually correcting for the past poor management of biodiversity under the Common Agricultural Policy and Common Fisheries Policy respectively. Similarly, much of the current capital spending on water quality is correcting a deficit in environment infrastructure due to past under-investment or is attempting to mitigate the external costs that agricultural or planning policies have on aquatic ecosystems. Poor resource management presents two other observations:

- Firstly, lack of biodiversity protection means that there are some economic sectors that are functioning at well-below their potential value. Fisheries are one clear example given that catches are well below what they could be if the resource was properly managed.

- Secondly, poor management of biodiversity means that we have become reliant on production methods and inputs that present significant, but often unrecognized, external social costs and which, ultimately, are unsustainable.

Given that we appear to have raised the stakes by having unleashed threats to biodiversity which are now largely beyond our control, namely the unintentional introduction of alien species and the spectre of global warming, the urgency of proper resource and biodiversity management has never been greater.

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12. CONCLUSION

12.1 THE BENEFITS OF BIODIVERSITY

Fundamentally, biodiversity is so crucial to our own survival on this planet that efforts to place a value on it can never be sufficient. Nevertheless, water is crucial to our survival too, but we still price it for policy purposes. Just as with biodiversity, we cannot aim to demonstrate the absolute value of water. However, we do price water so as to manage supply and demand, and to ensure that it is used responsibly and not wasted.

The same considerations apply to biodiversity. If anything, biodiversity is more prone to market failure than water. Nobody supplies it as such. There are no costs to cover in the form of artificial reservoirs for its storage or pipes for its distribution. Rather the reservoir is provided by the natural environment, within soils, rivers, oceans, forests and the wider countryside. Biodiversity is simply all around us.

Or sometimes it is not! Where biodiversity has been diminished for any reason, for example from over-exploitation, pollution or through the introduction of alien species or disease, we begin to realise costs in terms of loss of ecosystem services. To pre-empt this situation, the best that we can do to rectify the market failure that applies to a non-market good like biodiversity is to provide examples of the benefits of ecosystem services. These benefits are best described as marginal values, as opposed to absolute values. Marginal values include the successive contribution of ecosystem services to plant yields, timber growth and quality, fish catches or water purity. Thus, the value of ecosystem services is revealed in terms of the marginal value of an extra unit of output. This value can be interpreted as a marginal gain where we are seeking to restore the functioning of ecosystems, or as a marginal loss avoided through biodiversity protection.

The difficulty is identifying the precise contribution of ecosystem services to market goods compared with other inputs. In fact this is extremely difficult and, even where possible, we inevitably have to fall back on a limited range of examples. So it has proven to be the case of this report.

What we have tried to do is to use examples from each productive sector to demonstrate the importance of biodiversity. The benefit estimates at which we arrive amount to at least €2.6 billion per year. They are, of course, partial estimates and very imprecise at that. Fundamentally, they omit some key biodiversity contributions such as waste assimilation, maintenance of human health, or the full range of benefits that the soil biota provides to productivity and carbon recycling and storage.

Some of the benefits of ecosystem services can be substituted. We have been extracting as much productivity as we can from natural systems for thousands of years. In more recent times, we have begun to substitute for these natural systems through the application of artificial inputs. Agriculture and forestry provide the obvious examples through their use of fertilizers and pesticides. In fisheries, we have been developing aquaculture systems, while in water supply we can substitute natural purification with chemicals and other processes. However, we can only substitute to a finite extent. There is much uncertainty over both the nature of ecosystem services and their interaction with artificial processes. We have also found out to our cost that artificial processes often have unwanted external costs such as pollution and toxicity. We can propel productivity through artificial means as in the case of monocultural farming systems, but ultimately this leaves us more dependent on artificial inputs and more vulnerable to problems such as pests or disease. Numerous studies have demonstrated that incomes are stabilised in the long-term by systems that produce diverse products or outputs and which protect the underlying natural diversity.

Such sustainable systems are not just good for the environment, but are also good for long-run productivity. The quality of output is often better as in cases where organic methods are used to produce food crops. Neither is gross productivity necessarily compromised even in the short-term. The case of fishing provides an obvious example where over exploitation of the system and neglect of biodiversity has led to a collapse in fish stocks around the world. We know hardly anything about the functioning of the marine ecosystem, but it is obvious that far higher catches are possible in a well-managed marine environment. Biodiversity therefore has a sizeable option value. We do not understand all ecosystem processes, but it is possible to place a provisional value on the potential output.

The final contributions of biodiversity are in terms of its contribution to human welfare and to health. In terms of the former, we can value biodiversity through those activities to which it makes a direct contribution, such as angling, birdwatching or ecotourism. We can also value the indirect contribution in terms of all types of countryside recreation or water sports. Where biodiversity is misused, external costs are passed on to society. Sometimes these external costs impact on a distinct population or economic sector. On other occasions, they impact on all of us given the utility that we derive from having access to the natural environment.

Where human health is concerned the contribution of biodiversity is less discrete and often little understood. The value that we place on our physical health is considerable, noting the amounts that we are prepared to spend on our own well-being and healthcare. Consequently, the economic benefit of disease prevention is huge. As noted above, careful management of ecosystem services can contribute to high quality food and that, of course, is good for health. Biodiversity is also integral to some environments such as sand dunes, salt marshes, estuaries or wetlands that are vital for buffering the effect of storms and flooding. Each of these is vulnerable to the effects of climate change. However, it is the relationship between disease, wild populations and ourselves that is least understood and so difficult to demonstrate. We understand the significant impact of diseases spread from wild populations. The economic and social costs of AIDS or avian influenza are huge.

We know much less about how such risks are controlled within ecosystems that are not compromised by human interference.

12.2 BIODIVERSITY POLICIES

Evidently, Government is spending very little on biodiversity in comparison with the benefits it provides. There is some direct expenditure on biodiversity protection, for example by the National Parks and Wildlife Service. There are also various policies which protect biodiversity indirectly, including any policies that aim to protect the environment, for example, by controlling pollution. Typically these policies are reactive in that they are aiming to mitigate threats to the environment. Often, the costs, or at least some of the costs, are borne by private companies and individuals in relation to the polluter pays principle. However, there are very few policies which aim to proactively protect biodiversity.

The chapter on benefits and costs identified policy costs of €370 million per year. Clearly, these are just a fraction of the benefits of the very limited range of ecosystem services that we have used as examples. It is clear that there are some sectors, such as the marine sector, where we obtain huge economic benefits from ecosystem services, and where we could be enjoying much greater benefits were biodiversity adequately managed. In other sectors, such as with agri-environmental policy, we are now spending significant amounts on policies that protect biodiversity, albeit indirectly. However, these amounts are being spent largely in response to previous mismanagement and also with ulterior objectives, including social benefits and transfers. The general perception, in terms of the very limited data that most government departments either possess, or were able to impart, is that there is lamentably little appreciation of the economic benefits of biodiversity.

Policies are needed to correct market failure and to ensure that both the productive and social value of biodiversity is realised through the sustainable management of resources. Generally, economists encourage the use of economic instruments to achieve these ends rather than command and control approaches such as regulation. Taxes or charges are the preferred approach in that these provide market signals which influence behaviour without the implications that subsidies have for income transfers. The greater use of taxes or charges to encourage biodiversity protection also imposes less costs on government. If these methods were used more extensively, we would have been giving more attention to private costs, rather than public costs and expenditure, in the chapter on Benefits and Costs.

In practice, governments tend to prefer subsidies and transfer payments as means to cajole economic agents into behaving in particular, in more desirable ways. Indeed, market exchanges and prices within primary productive sectors such as agriculture, forestry and fisheries, have become largely determined by complex systems of market protection, subsidies and grants. On the one hand, these artificial systems makes it possible to inject additional economic incentives to protect biodiversity. On the other hand, these same incentives must compete - even compensate - for other policies, some of which are actually undermining biodiversity objectives.

In the short-run, there will be occasions when biodiversity protection requires that economic agents are given economic incentives that influence behaviour even in the face of numerous similar incentives. However, we can achieve at least as much by removing the incentives which act contrary to biodiversity or which underpin less sustainable systems of production. Ultimately, this will allow economic sectors to become more conscious of their reliance on the provisioning and regulating services provided by biodiversity and do so without huge outlays in terms of Government expenditure.

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