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 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 species 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.

1) 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 RELVANT SPECIES AND FUNCTION

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 over. 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

Coittle 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 or 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, so they 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. A indicator of the potential damage is provided from Britain where a North American beetle was responsible for the virtually 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).[1] 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

[1] http://www.chm.org.uk/library/ecosys/forest/

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 been 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.

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 tress 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 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 broad-leafs. 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 Coittle 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).

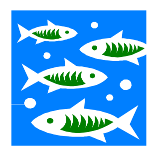
Capture fisheries in coastal waters alone contribute $34 billion to gross world product annually. However, the financial value alone belies the importance of the sector for employment and livelihoods. Ninety per cent of the world's fishermen and women operate at the local community level, and bring in 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)

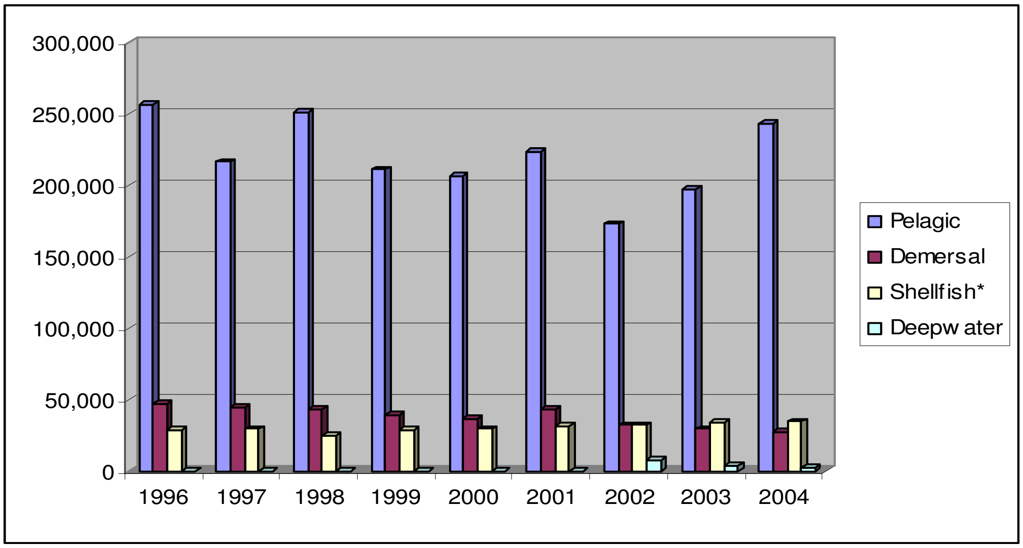
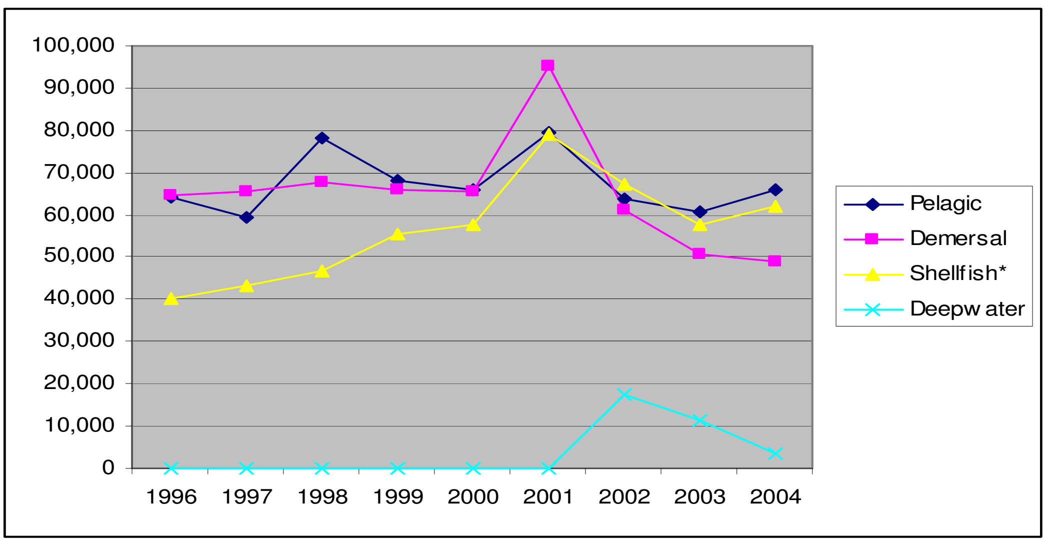


Figure 5.1b Value of fish landings (home ports)

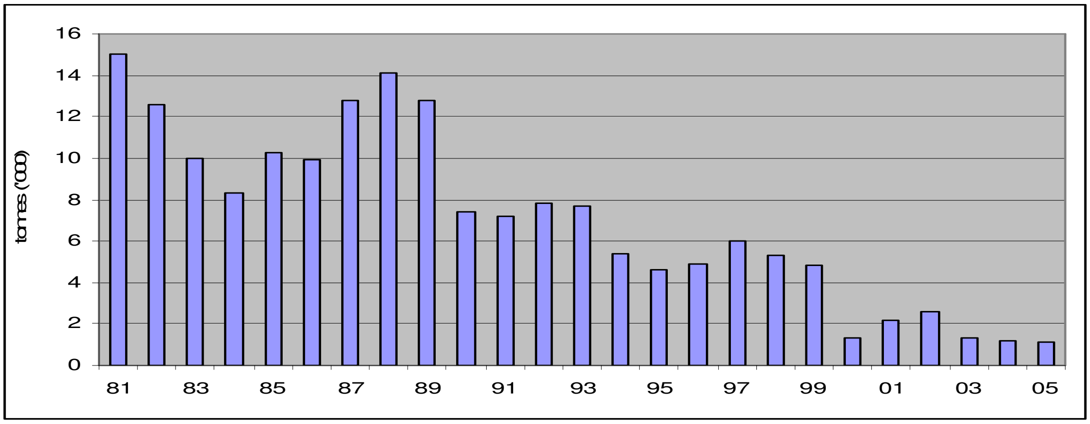


*** Source: CSO. Farmed shellfish not included**

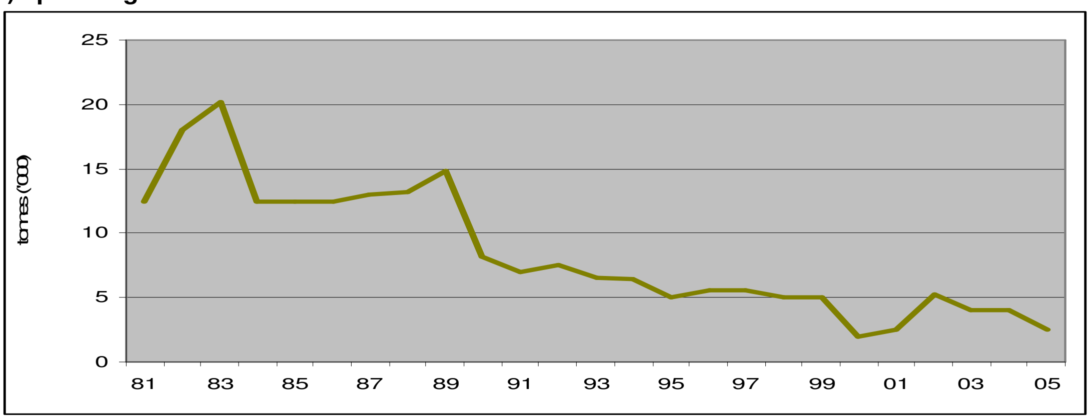
By comparison, the catch of familiar demersal species, often termed white fish, has decreased significantly in response to cuts in quota. In 2004, landings of cod were just 1,246 tonnes compared with 4,984 tonnes in 1994 and 8,001 tonnes in 1996. Catches of haddock and whiting have also fallen significantly. 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 of 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 though 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 represents an opportunity to reduce the pressures on wild fish stocks while meeting increased consumer demand (Millennium Ecosystem Assessment 2005). The industry expanded substantially in the 1990s but, despite its potential, output has since shown little or no growth throughout the EU (EC 2007).

Although aquaculture has, to an extent, compensated for the decline in the fishing sector, it still relies heavily on the quality of the supporting ecosystems and its sustainability is ultimately tied to that of wild capture fisheries. The productivity of the aquatic environment, its ability to sustain a diversity of life, mitigate and assimilate pollutants, and 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 activities 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 have a range of debilitating impacts on 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 sector has grown in output value 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 pose to marine or freshwater ecosystems are well documented. At the most basic level, aquaculture appropriates a range of services and products provided by the supporting ecosystem (e.g. Bunting 2001; Beveridge, Phillips & Macintosh 1997). It also interacts with surrounding ecosystems through a range of 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, much of the aquaculture activity in northwest Europe is dependent on capture fisheries to supply fish-meal. This has 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 constitutes a large proportion of the Mid-Western regional fishery, fell from an annual average of 9,570 sea trout between 1974 and 1988, to 646 sea trout in 1989 and 240 in 1990. This collapse has had significant impacts on angling tourism and related economic activities in the region. Similar serious declines of wild salmon and sea trout 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 general terms, it is accepted 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 ensure more coordinated 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 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	• 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

• Changes in sediment character; • Increased suspended solid levels	and within the water column	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 including 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 oft 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.

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 fisherman 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 roughly 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 thereat. As noted above, these habitats are now understood to be highly important to marine biodiversity, including the survival of many commercial species.

5.5 COSTS OF PROTECTION

Four marine SACs are in the process of designation covering 2,542km^2. Although additional survey work will be needed over time, the principal management cost of these SACs will be ensuring that fishing are not using bottom-dragging gear within the area. This responsibility will fall to the Naval Service which is charged with patrolling 338,000km^2 of sea. Allowing for some more active patrolling in the vicinity of the SACs, it is possible that the protection cost will come to between €1 and €2 million per year on this basis. Given that marine SACs are only now being established, this is a responsibility and cost that has yet to be realised.

For the present, the main form of biodiversity protection is that provided within the Common Fisheries Policy, albeit an imperfect level of protection that extends only to commercial species. The CFP includes a mix of measures including resource allocation (Total Allowable Catch and quotas), restrictions on numbers of vessels/fleet size, and technical controls such as those on the use of certain fishing gear. The objective is to bring stocks to within Safe Biological Limits. However, there is a general acceptance that the CFP is failing to resolve the problems in the sector. For a long time, politicians have failed to face up to the problem of declining stocks despite the obvious impact that will have on the industry's raw material. The catch of most species has not decreased significantly despite the reduction in the number of vessels and the concentration of the fishing 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 in 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 of 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

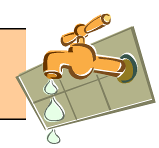
Good water quality is a two-way process. Numerous species are involved in cleaning water. These can be classified according to feeding groups and include vegetation shredders such water lice and crayfish (Gammanus sp.), collectors/filterers such as blackfly and mayfly, larvae grazers such as snails and 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.[2]

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 a sponge, absorbing water at times of high rainfall and so acting as a buffer

[2] 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.

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 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 spend on distribution as on 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/m^3 (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 spend under the WFD on catchment management are yet available aside from the modest amounts (c€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 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.[3] 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 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).

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

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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. The impact on biodiversity is not always as overtly negative as for landscape. 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. Many species are unconcerned by noise and some species have even used this to their advantage, notably the kestrel which is commonly seen hovering 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 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 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 Act of 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.[4] 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.

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

[4] Newsletter of the Irish Waterways Association of Ireland (2004).

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.[5] 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.

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

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.

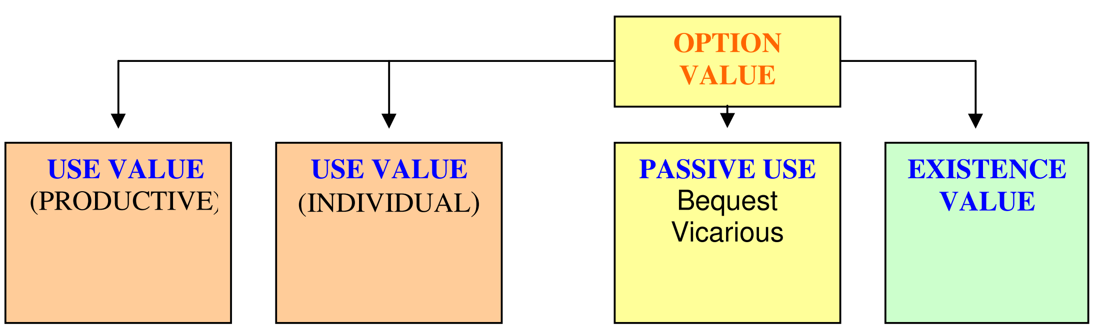
In addition, there is a direct benefit where human activity responds and benefits from biodiversity as, for instance, with recreational angling, bird-watching, dolphin watching or similar activities. These benefits are realised by individuals and become part of their preference structure and decision 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**



Direct:
e.g. food supply

Indirect:
e.g. ecosystem services for food production

Direct:
e.g. wildlife watching

Indirect:
e.g. countryside recreation

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 of 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".[6] 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 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.

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

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 Campbell et al. (2005, 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 el. 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 landownings 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 sitings 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 give 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/100m^2) (trout = average density > <0.8 fish per 100m^2)	£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/100m^2) (trout = 0.8-2 fish per 100m^2)	£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/100m^2) (trout = >2 fish per 100m^2)	£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 €248 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 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 by 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 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 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.

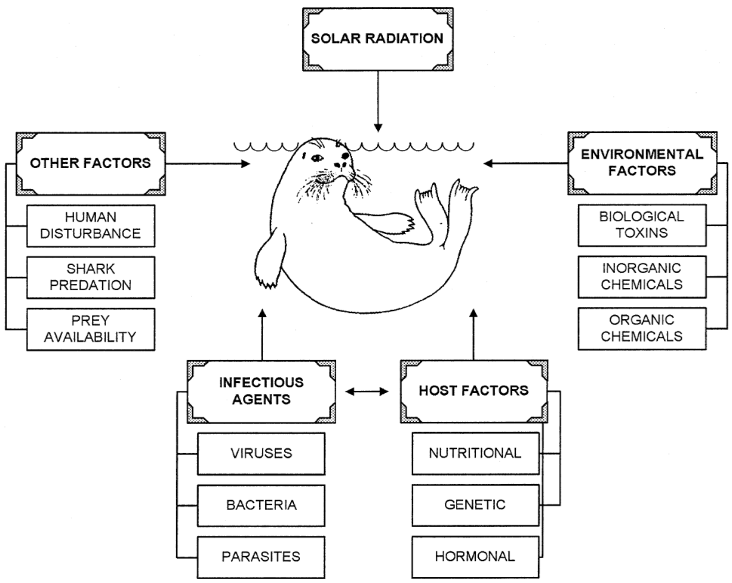
In Ireland, diseases such as tuberculosis, leptospirosis, toxoplasmosis, cryptosporidiosis, brucellosis and salmonellosis have known links with wildlife. There is also the risk that previously unknown diseases, or diseases which are recognised in wildlife but have not been identified as important threats 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 if 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 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. However, its potential value to science and to our health and economic development. 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 that without appropriate policies to control Greenhouse Gases (GHGs) temperatures could be expected to rise to between 1.8˚C and 4˚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˚C and as much as 3˚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 being 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, others 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 VALUING 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. Benefits include the marginal value of the current provisioning, regulating, supporting or cultural benefits of ecosystem services. The benefit of policy can be measured by the degree to which it avoids damage to biodiversity and the consequent avoided loss of ecosystem services.

Costs can include:

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

Potentially, each of these costs can be represented as marginal values. Hence, the contribution of ecosystem services and the benefit of on-going policies to protect them are equivalent at the margin if the former are at risk and the latter are effective. Marginal values 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 than 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 people involved in recreation. The result is a mix of public and private benefits. Consequently, it is important to avoid double-counting.

Another relevant consideration is that of external costs and benefits. If an individual or company pollutes the river (using the example above), external costs are passed onto other sectors (external benefits could be realised under a different set of circumstances). External costs are a reflection of the benefits of biodiversity and 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 impute 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 its residual (though sometimes critical) contribution to largely artificial systems of agriculture, 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 is 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 in 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 Campbell et al. (2006) 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 weight 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	Direct marginal value	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	€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	€150 million pa.	€500 million (if were 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	Direct marginal cost	Comments
REPS	€280 million pa. (altho 50% of this could be ascribed to social objectives)	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.

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

BENEFITS	Direct marginal value	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	Direct marginal 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 inputs that contribute to productivity aside from the means by which fish are caught. 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 this value increase may not have occurred to the same extent 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. In terms of the sustainability of the former, it is difficult to be positive. 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 pubic 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.[7] It is likely that private vessels will need to adopt new environmentally-friendly fishing gear, although past experience would suggest that this investment will be underpinned by public investment.

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

[7] Figures quoted by Eamon Ryan TD in Dail debate 17/11/2005

BENEFITS	Marginal annual value	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 envir regulation, but still crucial after oil spills or in estuarine waters vulnerable to climate change

POLICY COSTS	Direct marginal cost	Comments
Fisheries protection	€25 million *	Assuming actual costs of €100 million, but biodiversity protection only indirect benefit. Uncertain effectiveness.
Decommissioning	Net benefit minimal to date	Once-off cost of proposed decommissioning at €45 million has biodiversity objectives largely absent from policy to date.
ICZM	negligible	Most expenditure by EU Interreg as pilot schemes
Marine Protection Areas	Not yet established	Perhaps €25 million pa. in terms of naval enforcement

* 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 is supported by 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. Industrial businesses endure a private cost in that they are 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 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 (Clinch & Kerins, 2002), 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 m^3. 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 $20m^3$ 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 as 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. Given previous underinvestment in environmental infrastructure, the latter 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, but only over the long-term.

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

BENEFITS	Marginal annual value	Threats / comments
Water treatment + treatment plant	€50 million pa+ €100 million pa. (baseline value)	Representing society's willingness-to-pay for clean water provision (assuming one quarter domestic consumption is required to be drinking standard) + approximate long-term spending on water treatment plant
10% rural pop. drawing water directly	€5.5 million + €50 million pa.	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 pa. on average	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 by foreign tourists on water-based recreation	€115 million pa.	Likely to be an under-estimate.
Recreational fish catch	€15 million pa.	May increase following closure of commercial salmon netting.
Fish farm production	€600,000 pa.	Ecosystem service could only be partially replaced by treated water.
Waste assimilation	Unknown, sizeable	Additional domestic and industrial waste water treatment avoided. Current spend approx €220m.pa

POLICY COSTS	Direct marginal cost	Comments
Catchment management	€16 million pa. + relevant spending by EPA.	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.
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. Unfortunately, the National Roads Authority does not have an estimate of the average cost of these mitigation measures.

Furthermore, biodiversity impacts are not included at the cost-benefit analysis stage. Neither are the biodiversity implications of cumulative impacts taken into account despite the emergence of strategic environmental assessment (SEA) process. 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	Direct marginal cost	Comments
Ecological assessment (EIA)	unknown	Identifying impacts
Mitigation	Perhaps €39 million pa.	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 consumer surplus for particular activities associated with biodiversity, e.g. angling, or as the value of incremental improvements due to policy, e.g. REPS, 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 Mohar.

Campbell et al. (2006) have estimated the aggregate value of Rural Environmental Protection Scheme 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 of rivers and lakes is hampered by the absence of figures on the number of visits to such localities. The Marine Institute 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. Biodiversity is likely to contribute strongly to the relative attraction of rivers and lakes.

Domestic tourism (excluding angling discussed above) accounts for around €37 million of annual expenditure (Marine Institute, 2003). While much of this spending can be discounted on the basis that it would otherwise be spent elsewhere in the economy, around the same amount again would be contributed by overseas tourists. This expenditure represents an additional benefit.

As well as use values, rivers and lakes can be expected to elicit substantial passive use benefits too 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.

Once again, it is the marginal benefit of protecting or enhancing aquatic biodiversity that is relevant to a cost-benefit approach given the need for comparisons with policy expenditure. 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 doubled to £2 per trip given income growth in the subsequent period. By comparison, most Irish rivers and lakes are 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 around €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 €18 million per year.

Welfare benefits would be higher on an individual level amongst specialist users such as anglers, boaters and kayakers. Curtis (2002) estimated consumer surplus benefits of between €62 and €185 per trip for anglers in Ireland. 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). Hynes and Hanley (2006) report values for kayakers' perceptions of 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 sailing or boating enthusiasts, or by naturalists, would surely boost this value towards €50 million.

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	Marginal annual value	Threats / comments
Agri-environmental policy	€150 million pa (biodiversity=x%) (Campbell et al.)	Marginal value of improvement due to REPS policy, part of which value can be allocated to biodiversity. Valuation of biodiversity's full contribution to the countryside would be greater.
Forestry	€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)	€65 million pa. (biodiversity=x%) Heritage Council Less expenditure	Minimal estimate of marginal value of improvement based on "heritage features". No studies of wildlife. Studies of peatlands on-going.
Water quality	a. Anglers = €123 million pa. b. €50 million pa. (biodiversity=x%)	a. Marginal annual value assuming average of consumer surplus estimate & 5 trips pa. b. Minimum estimate of marginal value of improvements in quality to water recreation.
Coastal envir	No data	Studies on marine reefs on-going.

POLICY COSTS	Marginal cost	Comments
Agri-environment	€280 million pa.	Figure includes value of social transfers to farmers as well as environmental benefits.
Forestry biodiversity	€3 million pa.	Cost of FEPS (noted also above). Private costs too, though covered by grant programme.
Natural heritage	Approx €35m. NPWS + €2m. approx by Heritage Council	Figure includes large element of enforcement in addition to direct protection.
Water quality	€55 million	Catchment management and Nitrate Regulations (see Water)
Coastal environment	Negligible	No ICZM or Marine Protected Areas at present (see Marine)
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.

10.2.7 Health

Biodiversity contributes to good public health on a variety of levels. However, the nature of its relationship with health is complex and but one of many, often inter-related, factors. Furthermore, there is little precise data on the amounts spent by the Department of Health on particular diseases and ill-health through which a link to biodiversity can begin to be quantified.

The chapter on heath identified several means through which biodiversity interacts with health, namely:

- Food quality and dietary health
- Infectious diseases
- Physical and psychological health

A positive link between high biodiversity and high food quality clearly exists, but is impossible to identify, even approximately, given other interrelated socio-economic factors. Diseases, such as cardiovascular disorders, are clearly associated with other factors such as physical exercise and living conditions.

Disease pathogens are kept in check by a functioning biodiversity, and disruptions to natural systems clearly affect the spread of disease. There are indications that new diseases are being spread to Ireland because of impacts on biodiversity. However, it is, again, difficult to attribute a precise impact to biodiversity.

Although data is lacking, people are clearly willing to pay considerable amounts to ensure their family's good health. The severe implications that would follow a possible pandemic due, for example, to avian influenza have caused great concern. An indication of the potential costs is provided by the impact that *cryptosporidium* has had in Galway this year even though this has resulted in rather few hospitalisations. The links to biodiversity in the case of this particular parasite are slight. For other disease vectors, the link is greater but difficult to identify and generalisations are to be avoided. Relevant economic data in Ireland does not appear to be available. 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, even where this has occurred, these are only baseline values based on the either the expert's, or the public's, very incomplete understanding of ecosystem services. Consequently, all the values provided above represent minimal and very approximate expressions of the value of selected ecosystem services or biodiversity benefits. In particular, a major virtually unquantifiable, but huge benefit of both freshwater and the marine environment is waste assimilation which, in principle, reflects the additional costs avoided on end-of-pipe pollution abatement.

The same is true of policy costs. Very few policies are initiated with the express intent of preserving biodiversity. One of the better examples referred to in this report is REPS. Yet, while agri-environmental policy can be expected to benefit 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	Minimum marginal annual value	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	€400 million pa.	Waste mitigation services not included.
Human welfare	€340 million pa.	Selected benefits only
Health	unknown	Tens of millions.

POLICY COSTS	Marginal cost	Comments
Agriculture	€180 million pa.	Excluding a nominal proportion which is non-environment.
Forestry	€3 million pa.	Excludes additional premia costs (figure not forthcoming)
Marine	€25 million pa.	Much neglected in the past, but expenditure likely to increase significantly.
Water quality	€55 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	€380 million pa. (or €50m 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 it 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 €2.3 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 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 €350 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, more desirable ways. Indeed, market exchanges and prices within primary productive sectors such 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, these same incentives must compete - even compensate - for other policies, some of which are actually undermine 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.