National Development Plan 2007 - 2013

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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Biochange

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Environmental Protection Agency Programme
2007-2013

SSTI

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

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

The EPA is an independent public body established in July 1993 under the Environmental Protection Agency Act, 1992. Its sponsor in Government is the Department of the Environment, Heritage and Local Government.

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We license the following to ensure that their emissions do not endanger human health or harm the environment:

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- large scale industrial activities (e.g., pharmaceutical manufacturing, cement manufacturing, power plants);
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The organisation is managed by a full time Board, consisting of a Director General and four Directors.

The work of the EPA is carried out across four offices:

- Office of Climate, Licensing and Resource Use
- Office of Environmental Enforcement
- Office of Environmental Assessment
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet several times a year to discuss issues of concern and offer advice to the Board.

EPA STRIVE Programme 2007–2013

Biochange

Biodiversity and Environmental Change:
An Integrated Study Encompassing a Range of Scales,
Taxa and Habitats

(2005-CD-B2-M1)

Synthesis Report

End of Project Report available for download at *http://erc.epa.ie/safer/reports*

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The EPA STRIVE Programme addresses the need for research in Ireland to inform policy makers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Details of Project Partners

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Executive Summary

Biodiversity loss is the greatest environmental challenge facing humanity.

Biodiversity is currently declining at rates comparable to major extinctions in geological history, driven by anthropogenic impacts, yet biodiversity underpins the ecological functions that provide the many natural goods and services on which life, livelihoods and sustainable living depend. Understanding how human activities impact on biodiversity, developing effective methods to mitigate impacts and restoring degraded ecosystems are essential to major international policy objectives that aim to reduce the rate of biodiversity loss. Maintaining and enhancing provision of ecosystem goods and services will be key to delivery of the UN Millennium Development Goals.

BioChange was an interdisciplinary, multi-institutional study funded by the Environmental Protection Agency of Ireland (EPA) under its Environmental Research Technology Development and Innovation (ERTDI) programme. Its main aim was to develop an integrative research activity that would, now and in the future, address important issues affecting Irish biodiversity, with outputs directly linked to policy support both regionally and nationally. BioChange would also produce high-quality biological and sociological data. Four work packages addressed the main drivers of biodiversity loss – habitat loss and fragmentation, invasive non-native species, pollution and over-exploitation – in a variety of habitats and at differing spatial scales. Two cross-cutting projects provided accessible information on biodiversity, and made recommendations on improved biodiversity governance.

BioChange has produced numerous scientific outputs as described in the End of Project Report. In this Synthesis Report, the findings, recommend improved methods to deliver biodiversity policy and priority areas for future research effort are distilled. These findings are used to make 27 recommendations in Box 4 (in 'Conclusions', Section 9). The four main messages from these are as follows:

1. Understand Biodiversity and Communicate its Importance

There remains a need to promote to all people a better understanding of what biodiversity is, and why it is important. Ireland also needs to keep pace with the economic valuation of biodiversity now in progress elsewhere, and to include biodiversity value in any decisions with environmental consequences. The linkages between biodiversity and human well-being need to be communicated clearly. Novel economic opportunities can be developed around sustainable ecosystem goods and services, firmly embedded in a 'smart economy' and delivering sustainable livelihoods.

2. Develop and Implement Policy

Knowledge and research must support local, national and regional policy and planning, but, equally, policy development needs to be shaped by improved information. In many cases some relatively simple approaches can be taken at a local planning level that should provide support and enhance biodiversity.

At the regional and/or local level, it is recommended that:

1 Habitat diversity, including small habitat fragments, be retained as these may have ecological importance at the landscape scale;

2 The effect of ecological scale needs to be incorporated into regional and local planning, especially through Strategic Environmental Assessment (SEA);

3 Appropriate ecosystem management be maintained, and sustainable exploitation of biological resources ensured;

4 The impacts of developments on biodiversity are monitored adequately to ensure that both short-term changes and long-term trends are detected. Monitoring data should be stored centrally through the National Parks and Wildlife Service and/or the National Biodiversity Data Centre, and should be made readily accessible.

At a national scale, it is recommended that:

1 Improved frameworks for participation in the development and implementation of biodiversity policy be developed;

2 Biological indicators and metrics used for the assessment of environmental quality be experimentally verified and, if necessary, refined;

3 Early-warning systems for problematic invasive species be developed, and consideration be given to regulating the movement of these species;

4 The economic value of biodiversity and its links with livelihoods be better explained and rigorously promoted.

3. Deepen Understanding

There is insufficient knowledge of the factors and processes affecting biodiversity and its loss. Ireland lacks fundamental information on the distribution of species and habitats required to inform planning, and it is not possible to predict the impacts of environmental change on ecosystem functions and the economic value of the services that this provides. Basic research on biodiversity is essential to direct and respond to policy and to provide a sound scientific basis for sustainable development. Further research is recommended to:

1 Deepen understanding of interactions between biodiversity and ecosystem functioning through experimental manipulation and long-term observation, building on the baseline information and suite of sites developed in BioChange;

2 Establish and maintain baseline data on species and habitats to guide effective planning and support scientific research;

3 Develop appropriate control measures for invasive species, alongside methods to fully assess the economic and environmental consequences of the impact of invasive species and their control;

4 Further develop novel methods of biodiversity information delivery;

5 Link ecological, economic and social research to tackle biodiversity valuation and conservation.

Delivery of these research objectives is needed to support Ireland's environmental economy, rebuild its natural heritage and discharge its national and international legislative obligations. Funding for biodiversity research is limited. Given the requirement for basic biodiversity research to support policy and to develop sustainable living, dedicated funding, likely administered by the EPA, is essential.

4. Act Immediately

Having missed the 2010 target to halt biodiversity loss, all evidence is that Ireland's biodiversity capital is still dwindling rapidly, and some features risk being lost forever. Swift action and swift choices are needed to ensure that the people of Ireland can maintain a sustainable, healthy, high-quality life both now and in future. The protection of biodiversity is essential to avoid damaging future economic costs, to provide novel opportunities for the development of sustainable livelihoods and to provide future generations with social and economic choice. It is recommended that:

1 Biodiversity issues be mainstreamed politically alongside climate change;

2 The opportunities in biodiversity conservation for livelihoods and Ireland's green economy be explored more fully;

3 Positive action is taken *now* to reduce the rate of human-driven biodiversity loss, and to promote the world position of Ireland and its people as a sustainable, environmentally aware nation with thriving green resources.

1 Introduction – Biodiversity Loss in Context

Biodiversity, the diversity of all life on Earth (see Box 1), is currently being lost at an accelerating rate. All levels of organisation are being impacted, from erosion of the genetic diversity of wild species, through extinction of species and domesticated plants and animals, to the widespread degradation and fragmentation of naturally functioning ecosystems. It has been suggested that the current rate of species extinction may be approaching that of the major extinction episodes that occurred in past geological eras, and which lead to the complete elimination of certain evolutionary lineages. The problem with the current biodiversity crisis is that it is being driven by one small facet of global biodiversity: *Homo sapiens* (Fig. 1).

Box 1. Defining Biodiversity

There are common misconceptions or misunderstandings of the term 'biodiversity' – some of the research within BioChange has highlighted this. Definitions of biodiversity are varied and many are not easy to understand. A commonly quoted definition of biodiversity is that of the United Nations Convention on Biodiversity: 'The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.' Even this definition is not necessarily adequate, as ecosystems by their nature contain non-living components (rocks, soil matrix, water etc.). Here we adopt a simple definition: Biodiversity is the variety of life on Earth. This includes all levels of complexity and organisation, from genetic diversity and species diversity to aggregations of species into communities. This definition, of course, includes *Homo sapiens*.

Figure 1. Fire on blanket bog, Cashla Connemara, Co. Galway, presumably caused by deliberate burning. This is a major cause of damage and biodiversity loss in peatland ecosystems. Image: Louise Scally.

The evidence for anthropologically induced loss of biodiversity is compelling and comes from a variety of sources. Destruction of tropical forest by both legal and illegal clearance is a well-known example of habitat loss, but this also results in significantly increased extinction risks to individual species. Most examples of species extinction rates come from well-studied groups such as mammals or birds. Here, current rates of extinction are thought to be 100–1000 times the background rate of species turnover, and these are likely to increase by a further 10–100 times over the next 50 years (source: Millennium Ecosystem Assessment). Recent studies have argued that to avoid catastrophic environmental change humanity must stay within defined 'planetary boundaries' for a range of essential Earth-system processes. These studies have used the examples of species extinction rate as one of eight different measures of planetary boundaries required as a precondition for human development. Unlike most of the other boundaries considered, biodiversity loss currently greatly exceeds planetary boundaries, which set a 'safe operating space'

for global functioning. As yet there is little idea about extinction rates in most insects, nor any idea, even to an order of magnitude, of the number of species of insect, for example. Though significant gaps in understanding remain in many areas, what seems clear is that the current rate of biodiversity loss will result in a severe medium- to long-term erosion of ecosystem function.

One major concern is that a 'tipping point' may be reached – where biodiversity loss accelerates at a rate that cannot be controlled, and subsequently stabilises at a point with a considerably reduced level of biodiversity: fewer species, fewer functioning ecosystems and less ecological complexity – and, perhaps most importantly, a much lower provision of ecosystem goods and services (see Box 2). All human societies depend on ecosystem services to provide the basic conditions for healthy, secure lives. Maintenance of ecosystem services is therefore central to being able to deliver many aspects of the UN Millennium Development Goals, particularly those goals associated with health and environmental sustainability. The actions that the current generation take, or fail to take, to halt biodiversity loss will ultimately determine the quality of life and the options available to our descendants.

The strategic plan for the Convention on Biodiversity 2011–2020, published following the 10th meeting of the Conference of Parties (Nagoya, Japan, 2010), recognised that biodiversity loss is continuing at unprecedented rates and that urgent action is needed to ensure the resilience of people and nature, and to avoid catastrophic tipping points. As such, it clearly states that effective and immediate action is required to halt the loss of biodiversity, so that by 2020 all the necessary policies and actions are in place and are being implemented to ensure the continued provision of ecosystem services, prevent irreversible environmental change and avoid dangerous consequences for humankind and other life on Earth. The actions necessary to achieve this aim are set out in a clear list of 20 strategic targets (see Appendix 2).

In an intriguing recent study for the Global Economic Forum, PriceWaterhouseCoopers estimated the ongoing economic costs of carbon dioxide emissions and biodiversity loss from the year 2008. The economic impact of carbon emissions was estimated at a value of $2 trillion, while the costs of biodiversity loss were estimated at $3–4 trillion. Their analysis also puts biodiversity loss at the centre of many risks to global economic activity, these are as diverse as the slowing of the Chinese economy to increased droughts and desertification. What is perhaps most compelling about this study is that these potential impacts of biodiversity loss on human livelihoods are not being put forward here by the conservationists – they come from widely respected economic analysts.

Biodiversity loss is the greatest environmental challenge facing humanity. The major drivers of biodiversity loss have been identified through expert analysis and synthesis in the Millennium Ecosystem Assessment. This assessment, commissioned by the United Nations, reviews the current state of the world's ecosystems and provides a prognosis for future changes. It has identified four major drivers of recent, anthropogenically driven biodiversity loss:

Box 2. A Definition of Ecosystem Goods and Services

Ecosystem goods and services are the varied benefits that people obtain from ecosystems. Most obvious is the utilisation of biodiversity to provide various raw materials, but there are many other types of service provided by natural ecosystems on which we depend:

- Provisioning services
  - Food, medicines, materials, energy;
- Regulating services
  - Soil fertility, nutrient cycling, decomposition and detoxification, carbon sequestration, climate regulation, water supply;
- Supporting services
  - Pollination, pest and disease control, air and water purification;
- Cultural services
  - Recreation, scientific discovery, spiritual and intellectual;
- Preserving services
  - Genetic and species diversity, protection of options, accounting for uncertainty.

1 Habitat destruction and fragmentation;

2 The spread of non-native invasive species;

3 Pollution, including eutrophication;

4 Over-exploitation of natural resources.

The impacts of these drivers on the major biomes of the Earth were considered, including an estimation of their likely impacts into the future. Anthropogenic climate change, a relatively minor driver of biodiversity loss in the recent past, is anticipated to play a rapidly increasing role in driving biodiversity loss from most biomes in the future. The reports make sobering reading: biodiversity is in crisis, but unlike the economic recession currently being experienced, the recession in biodiversity is set to be very long lasting, and have a far greater impact on future human livelihoods.

In 2002 at the UN summit on sustainable development in Johannesburg, South Africa, signatories to the Convention on Biological Diversity agreed to *significantly reduce the rate of biodiversity loss by 2010*. In this International Year of Biodiversity it is prudent to enquire what progress towards this target has been achieved. Some answers come from a recent review for the Convention on Biological Diversity, the Third Global Biodiversity Outlook: *not a single signatory state reported any success in meeting the 2010 target*. Most indicators are negative, and most pressures on biodiversity are either constant or increasing. As the main findings of this outlook are so important, a summary of them is quoted here:

- Projections show continuing and accelerating extinctions, habitat loss, changes in distribution and abundance of biodiversity;
- There is a high risk of dramatic biodiversity loss and degradation of services from exceeding tipping points;
- Biodiversity loss is preventable and even reversible with strong, urgent action.

To undertake these strong urgent actions, considerable political will and public support is needed, as is a much greater appreciation of the value of biodiversity. The Economics of Ecosystems and Biodiversity (TEEB) is an important international initiative that aims to draw attention to the economic value of biodiversity and the considerable costs of biodiversity loss and ecosystem degradation by drawing together expertise from science, economics and policy. TEEB began work in 2007 and currently has produced, or is planning, specific outputs targeted at various groups – including ecologists and economists, national and international policy makers, local governments, businesses and members of the public. It is also hoped that the recently launched Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) will provide an impetus here in much the same way that the Intergovernmental Panel on Climate Change has done in the area of climate change. The Irish government is currently revising the National Biodiversity Plan, and this should provide a framework for revising conservation objectives and priorities in Ireland. However, to achieve environmental sustainability and to deliver a real reduction in the rate of biodiversity loss these priorities and policy decisions need to provide effective outcomes.

Achieving firm reductions in the rate of biodiversity loss will not come about simply through the refining of goals and targets. Major biodiversity policy decisions need to achieve tangible results, but knowledge gaps and lack of understanding of the complex processes of ecosystem functioning and its relationship to diversity hamper progress. Research is clearly needed to fill these gaps and to enable the delivery of an effective policy, but also to provide new information to develop more effective and appropriate policies. Research required to deliver positive policy outcomes will not only revolve around the generation of better biological knowledge, but must also interlink closely with social and economic research that links biodiversity with human livelihoods. A major challenge for Ireland is to develop linkages between its obligations under various EU environmental and conservation directives and sustaining livelihoods, particularly in rural communities.

2 BioChange – the Project and its Aims

There were two overall aims to the BioChange project:

1 To build an integrative cluster of research activity, addressing novel and important issues surrounding Irish biodiversity, focusing on the area of Co. Clare and Galway Bay (including the Aran Islands).

   The outputs of this fully collaborative research effort were directly linked to supporting policy both regionally and nationally, in addition to producing novel high-quality biological and sociological data. Four work packages addressed key research areas in habitat fragmentation and loss, the impact of invasive species, pollution and resource management in the face of climate change. Two cross-cutting research projects that interacted closely with all other work packages covered the areas of inventory and output of taxonomic data, and of biodiversity policy making, including public understanding of biodiversity protection and enhancement (see Box 3);

2 To build the foundation of collaborative biodiversity research capacity in Ireland by forming a network of researchers that will last well beyond the duration of this project. This was a very important strategic aim of the BioChange project. Given the poor levels of national funding available for biodiversity research in Ireland, this strategic aim is viewed as a crucial step in pressing the case for greatly increased funding for biodiversity research and infrastructural capacity, as outlined in the *Draft Framework for Biodiversity Research* produced by the National Platform for Biodiversity Research in 2006.

Full descriptions of the project outputs can be found in Appendix 3 of this report, while Appendix 4 summarises the main research findings from the project.

Figure 2 shows the BioChange study sites centred on Co. Clare.

Box 3. A Brief Description of the BioChange Work Packages

Work Package 1: Landscape Conservation – Loss and Fragmentation in a Habitat Mosaic

This work package examined: the effects of habitat loss and fragmentation on wetland, pond, woodland and grassland habitats; investigated the role of habitat mosaics in maintaining biodiversity in fragmented landscapes; and provided tools for predicting the effects of changes in habitat quantity and configuration on the biodiversity of semi-natural habitats.

Work Package 2: Non-native Species – Impacts on Biodiversity, Strategies for Management and Predictions of Future Invasions

This work package brought together expertise from several disciplines, academic institutions and government bodies, and linked with other projects within BioChange (Work Packages 3 and 4) to develop an integrated study of the impacts of different non-native species across a variety of habitats.

Work Package 3: Pollution as a Driver of Biodiversity Change – Impacts, Indicators and Long-Term Monitoring

This work package characterised the impacts of key pollutants on aquatic biodiversity. It developed cost-effective indicators and protocols to monitor impacts of and recovery from pollution, and conducted an initial assessment of likely impacts of the loss of elements of biodiversity on ecosystem functioning at a range of spatial and temporal scales.

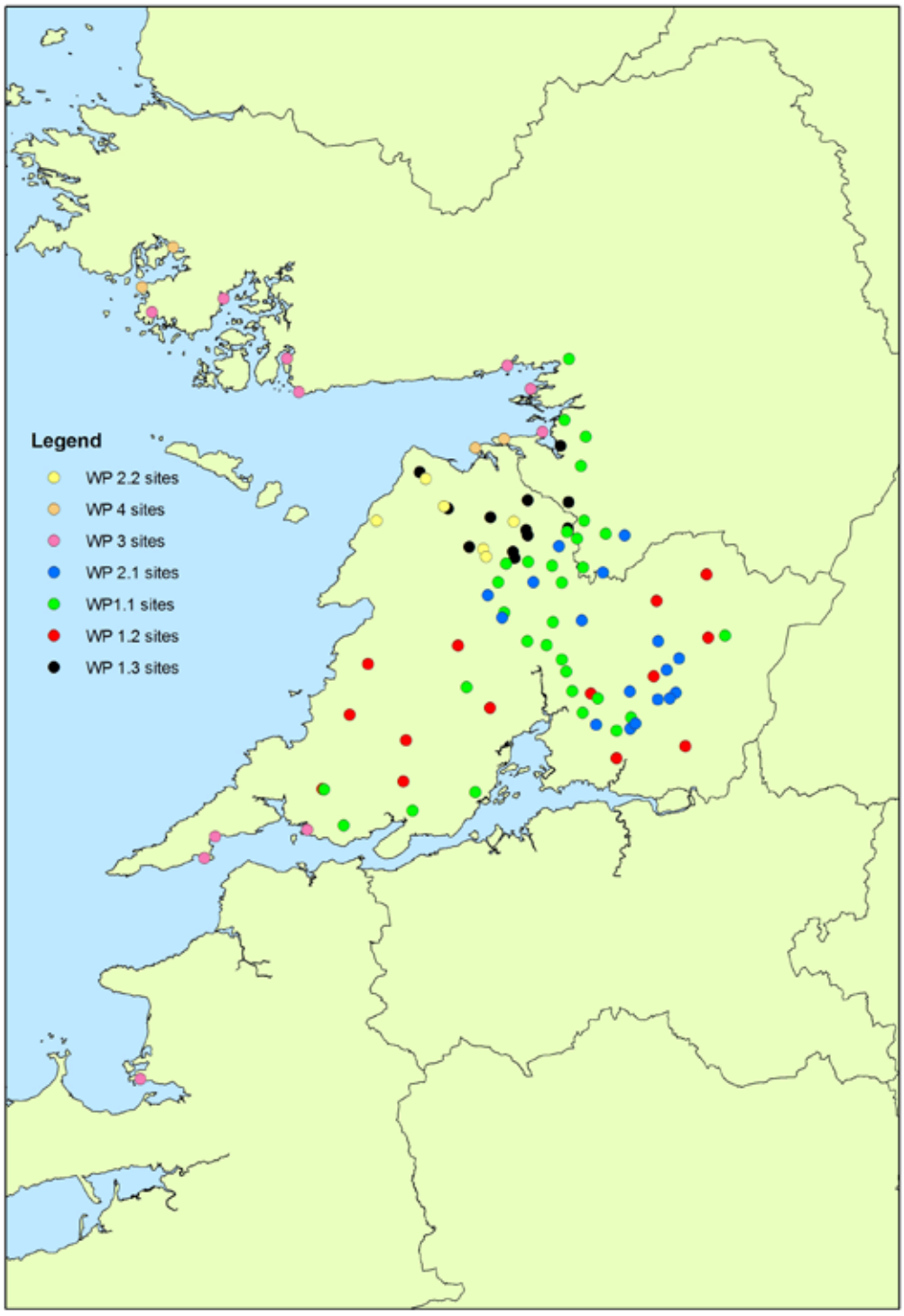


Figure 2. BioChange study sites centred on Co. Clare. The sites are identified here by work package sub-project. This network of potential monitoring sites is an important legacy of the BioChange project. A variety of baseline data have been collected from these sites; several of the sites involve experimental manipulations; and some have involved the construction of infrastructure to support experimental analysis and long-term data gathering. The sites provide an unrivalled opportunity to develop long-term studies on ecosystem function.

Work Package 4: Natural Resource Exploitation and Global Change – The Need for improved Sustainable Management to Protect Biodiversity

This work package examined an intertidal keystone primary producer (*Ascophyllum nodosum*), which has been commercially exploited for decades, as a model organism to investigate experimentally and model responses to climate change, and to predict potential change in associated biodiversity as a consequence of habitat change.

Cross-cutting Project 1: Biodiversity Politics – Policy, Planning and Public Understanding

This project qualitatively explored fundamental issues of policy, politics and participation in biodiversity planning, and provided recommendations for improved mechanisms to promote positive biodiversity management.

Cross-cutting Project 2: An Expandable Web-Enabled Organism Inventory, Including Keys to the Vascular Plants of Co. Clare and the Aran Islands

This project developed an interactive, publicly accessible, web-based inventory of species diversity, and includes interactive keys to the flowering plants of the Burren and of the Aran Islands.

Thematic Project: Species Distributions, Past, Present and Future

This project brought together groups of researchers from normally disparate areas to develop a coherent research framework with a view to making firm recommendations for future funding.

Information on staff, students and institutions involved in BioChange are given in Appendix 1.

3 Temporal Changes in Biodiversity in Response to Perturbations

3.1 Introduction

Biodiversity is not fixed in time. The patterns of genetic diversity within species and the distributions of species and of habitats all change over a variety of time scales through a number of natural processes. However, the rate of global environmental change – the rates of habitat loss and changes in land management, the spread of invasive species, environmental alteration through pollution (particularly nitrogen) and the non-sustainable rate of harvest of some species – all put severe pressures on different components of biodiversity. There is a growing fear that the accelerating rate and magnitude of anthropogenically driven environmental change may far exceed the natural resilience of biodiversity to accommodate such changes.

3.2 Land-Use Changes

BioChange documented some very slow responses of ecosystems to perturbations. A study that examined the invertebrate diversity in wetland fragments unexpectedly found very little effect of wetland habitat area and isolation of fragments on the diversity of invertebrate groups associated with wetlands. Higher diversities of wetland hoverflies and sciomyzid midges were found in landscape units that had a higher amount of *historical* wetland area. This may imply either resilience in these communities to historical fragmentation and habitat loss, or that the response of these communities to such habitat loss is very slow.

While the above findings may facilitate wetland conservation efforts, other slow responses of ecosystems to perturbation present conservation problems. The common brown seaweed *Ascophyllum nodosum* is extensively harvested from the mid-intertidal zones (Fig. 3) to supply material for alginate, fertiliser and animal feed production, and some, currently limited, applications in health care and the pharmaceutical industries. Cutting and harvesting the seaweed results in a predictable decline of biomass in this zone (Fig. 4). BioChange found a significant spatial variability in *Ascophyllum* productivity and responses to environmental stresses and harvesting. As the seaweed is harvested on a three-year cycle, this slow recovery has serious implications for the sustainability of this local resource. Additionally, the removal of large amounts of biomass represents a potentially significant local modification in coastal carbon budgets, with wider ecosystem impacts.

Figure 3. Effects of harvesting *Ascophyllum nodosum*. Biomass was significantly depleted after harvesting in October 2008 and had failed to recover by July of the following year, despite the cover of *Ascophyllum* recovering. Harvesting may have significant mid- to long-term consequences for faunal and algal communities on these shores, and the removal of large amounts of biomass may have a significant effect on local carbon budgets. The lower image shows cut-over *Ascophyllum* beds and stacks of cut fronds ready for removal. Image: Dagmar Stengel.

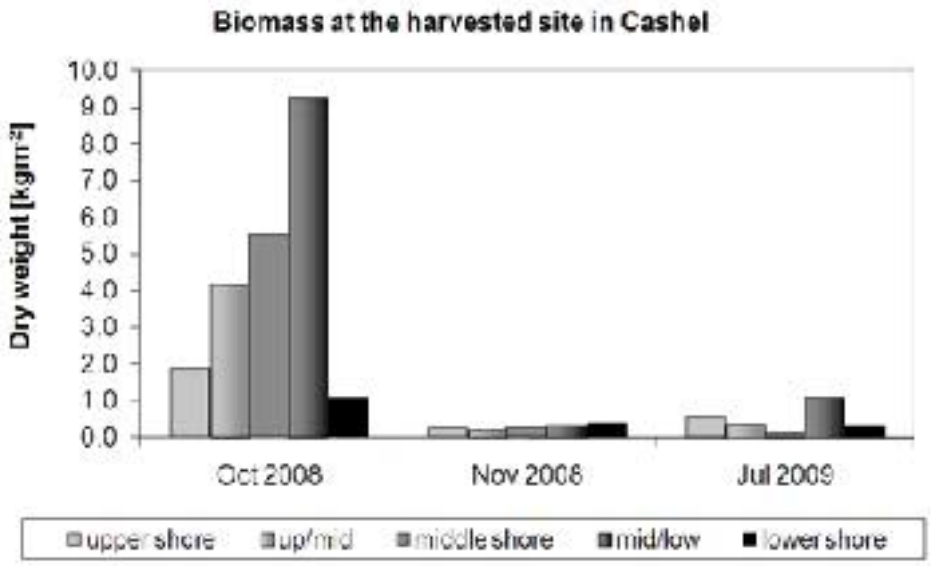


Figure 4. Biomass distribution at Cashel in October and November 2008 and July 2009 (kg dry weight m^{-2}).

In contrast to the two studies mentioned above, other BioChange projects demonstrated the unexpectedly rapid nature of ecosystem change to experimental perturbation. In fenced plots that excluded large vertebrate grazers from hazel-ash woodlands, there was a significant increase in vascular plant species diversity within two years of removing grazers (a 10% increase per 2 × 2 m quadrat). Especially noticeable was the spread of ivy (*Hedera helix*) in ungrazed plots. By contrast, the removal of grazing from grassland plots in the same region resulted in a decrease in plant species diversity and the very rapid loss of some characteristic grassland species (notably the hemiparasitic *Euphrasia* spp., *Odontites verna* and *Rhinanthus minor)*. Removal of grazing from scrub had varying effects, which seemed to depend on the cover of woody species in the particular patch of scrub. Rapid increases in the number of land snails were also seen. The dramatic build-up in plant litter in fenced grassland and grassy scrub samples over a two-year period had facilitated this increase in snail numbers.

3.3 Impacts of Invasive Species

One of the few species to increase in the ungrazed grassland plots mentioned above was bracken (*Pteridium aquilinum*). The effects of grassland invasion by the native bracken was compared with invasion by the non-native Japanese knotweed (*Fallopia japonica*) in another BioChange project. Bracken had little effect on plant species diversity, whereas invasion by Japanese knotweed resulted in a reduction in plant species richness of about 50% compared to uninvaded controls.

A notable finding of the grazing vegetation study is the paucity of alien plant species in semi-natural woodland, scrub and grassland in the Burren region. This is in contrast to most other regions of Ireland and, indeed, to some other important habitats in the Burren.

The zebra mussel (*Dreissena polymorpha*), native to south-east Russia, has colonised Irish lakes since the mid-1990s and is still spreading. Two BioChange projects have confirmed its major impacts on aquatic ecosystems, where filter feeding by the mussel reduces turbidity of the water column, reduces phytoplankton biomass and alters invertebrate community composition. Zebra mussels also appear to shift the nutrient composition in lakes from suspended solids to soluble nutrients through filtration and excretion. In addition, zebra mussels are likely to impact negatively on native *Anodonta* mussels whose shells are colonised by the invaders. Where zebra mussel infestation is high, *Anodonta* growth rate is low, their numbers are reduced greatly and there appears to be very little recruitment to the population. It is predicted that there is little possibility of recovery of *Anodonta* populations where zebra mussel infestation is high.

These examples illustrate the potentially serious impacts of invasive non-native species. Despite these potential problems, the project team is aware of further

deliberate introductions of zebra mussel to supposedly improve angling. The control and eradication of invasive species is costly and presents formidable challenges. One tool that may help control such species is the ability to better predict non-native species establishment and invasion. One of the BioChange projects examined the characteristics of invasive vascular plants in Ireland. Alien plants were found to be more likely to become naturalised if they showed clonal growth and were adapted to low nitrogen availability. The transition from the naturalised to the invasive state was more likely if the species were introduced for horticultural reasons, had hermaphrodite flowers, were not animal or self-pollinated, were invasive elsewhere and started flowering later in the year. Both establishment and transition to the invasive state were likely if the species had a preference for wetlands, had narrow native ranges and had been established in Ireland for some time. A combination of species-specific and non-specific traits is therefore likely to provide the most accurate prediction of vascular plant invasion. Consideration of these traits may help in predicting which casually occurring non-native species should be targeted for immediate control to prevent future problems with invasive species.

3.4 Response to Simulated Climate Change

Although anthropogenically induced global climate change is not considered to have had a significant impact on biodiversity loss in the recent past, it is predicted to play a major role in the future. There have been no previous studies in Ireland directly investigating the impact of climate change on semi-natural ecosystems, even though this information is crucial to our understanding of how biodiversity and the ecosystem goods and services it provides for us are likely to change in the future.

The project that compared invasion by bracken and Japanese knotweed mentioned above also looked at the impacts of simulated climate change by using small polythene tunnels to increase temperature, relative humidity and soil water deficit. The effects of these microclimate manipulations were subtly different for the different species, and suggest that while predicted climate change may reduce the impact of Japanese knotweed invasion, that of bracken may be stimulated. Simulated climate change (see Fig. 5) for only two seasons reduced plant species richness in both invaded and control bracken sites. Again, the speed of this response was unexpected. The decomposition of organic matter was reduced in invaded sites with manipulated microclimates, although there were complex interactions between invasion and experimental manipulation in the two species. These findings suggest that responses to changes in climate of the order that have been predicted for the next few decades may be more rapid.

Figure 5. Enclosures used to manipulate the microclimate over grasslands with and without invasion of bracken (*Pteridium aquilinum*) or Japanese knotweed (*Fallopia japonica*). These passive chambers reduced soil moisture content and relative humidity and increased temperature, broadly comparable to some predicted climate-change predictions. The microclimate was continuously monitored inside and outside the chambers. Images: Bruce Osborne.

3.5 Conclusions and Recommendations

BioChange has demonstrated that some changes in response to habitat perturbations may be far more rapid than was previously thought. Some care is needed, as it is unclear whether or not medium- and long-term changes will be similar – the effects observed in BioChange might be temporary, but this can be confirmed only by longer-term studies (see Section 8). BioChange also demonstrated some very slow recoveries from perturbation, suggesting potential problems for sustainability:

- Short-term changes in biodiversity in response to perturbations may be temporary, and therefore experimental verification of longer-term trends is essential;
- Regional planning should take into account temporal changes in biodiversity. Imposed changes in land use and developments should monitor impacts on biodiversity and ecosystem function to provide information to refine mitigation methods;
- Early-warning systems to detect potential invasive species need to be developed for a variety of taxonomic groups. Potentially problematic non-native species should be targeted for immediate management while there are still cost-effective opportunities to do so;
- Further research on the biology of invasive species needs to be linked with methods of control;
- Greater awareness of the biological and economic impacts of invasive species needs to be developed. For some particularly problematic species, the development of specific legislation regarding their movement should be investigated;
- There is a need for more research into the effects of climate change on Irish ecosystems and species, and of the interactions with ecosystem services, invasive species and land-use change.

4 Spatial Scale Effects and Biodiversity

4.1 Introduction

Ecological processes operate at a variety of spatial scales – from the local dynamics of a small population, through landscape effects on the variation of habitats, to larger-scale processes such as those involving climate influence and migration. Many processes are scale dependent: trends that might be obvious at the scale of a local patch may be very different or even totally absent at the landscape scale. This presents some difficulties for the conservation of biodiversity, particularly where actions have often been focused on species in relatively localised populations. Consideration of landscape-scale effects will be crucial in ensuring continuation of ecosystem functioning, and this has obvious implications for regional development and conservation planning. The EU Water Framework Directive utilises a landscape-level approach to the maintenance of good water quality by consideration of a catchment or river basin approach. BioChange aimed to examine impacts on biodiversity at a variety of spatial scales, and the project findings suggest that local biodiversity conservation initiatives could profitably be incorporated into broader-scale regional conservation initiatives.

4.2 Biodiversity Effects at Local and Landscape Scales

Several BioChange projects looked at the effects of habitat diversity on biodiversity. One project examined the effect of landscape heterogeneity – the variation of habitat patches within landscape units – on pollinator assemblages. The pollinator assemblages were sampled on selected farms. The CORINE (Coordination of Information on the Environment) Land Cover Programme 2000 and aerial photography were used to characterise habitat types within landscapes. The pollinator species recorded were bees (including bumblebees and solitary bees), butterflies and hoverflies. The abundance, richness and diversity of pollinators predictably increased with the amount of floral resources available locally. Higher numbers of pollinators and of foxglove (*Digitalis purpurea*) – one of the model insect-pollinated plants used in the study (for another example, see Fig. 6) – were found in landscape units that had a higher proportion of hedgerows and semi-natural habitat (Fig. 7).

Figure 6. Hawthorn (*Crataegus monogyna*) is a widespread shrub with massed flowering in late spring, although fruit set was limited by pollination in the Co. Clare study sites. Although pollinator numbers increased with increased land-use diversity, the fruit set in hawthorn decreased. Other species studied showed different trends in fruit and seed set, species-specific variation that may be linked to pollinator diversity. This indicates the level of complexity that needs to be considered when attempting to understand ecosystem functioning – networks of interactions between flowering plants and pollinator guilds need to be identified in order to determine (and accurately value) pollination services. Similar networks could be constructed between the flowering plants and biotic seed dispersers, and between the flowering plants and mycorrhizal fungi and soil organisms. Image: Stephen Waldren.

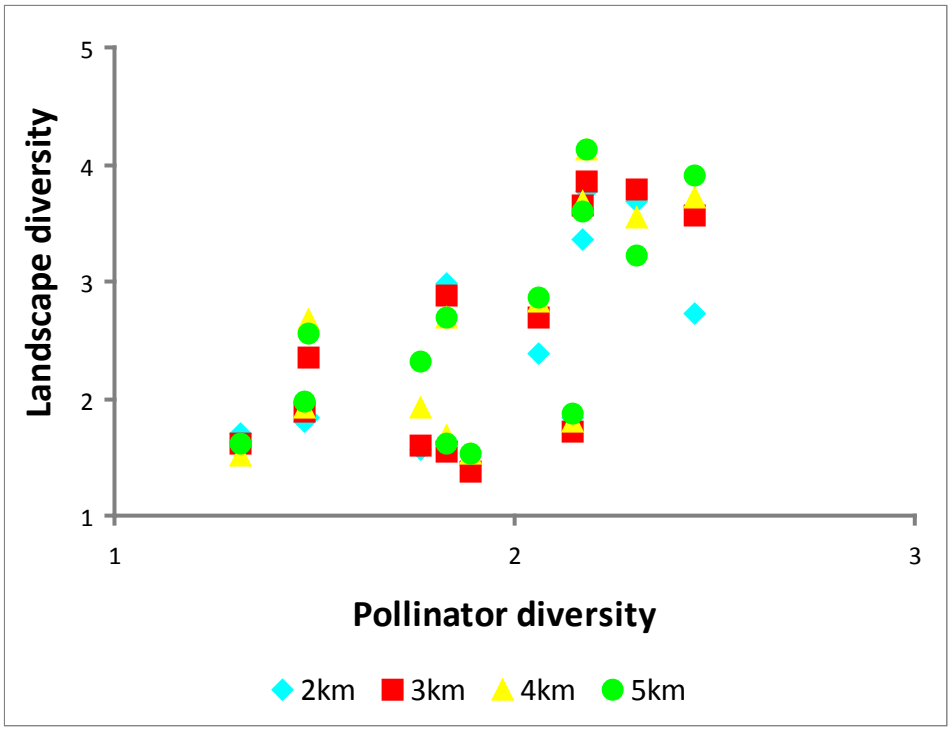


Figure 7. Relationship between landscape diversity and pollinator diversity at selected sites in Co. Clare. Landscape diversity is calculated as Simpson's Index (Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species) based on CORINE land-classification categories; pollinator diversity as Shannon's Index (Shannon's Index is a measure of diversity that takes into account subspecies richness and a proportion of each subspecies within a zone) based on pan-trap samples. As the diversity of habitats in a landscape unit increased, so did the diversity of pollinators – mainly bees and hoverflies. This is true of landscape units that vary from 2 km radius to 5 km radius. These results suggest that habitat variation in the broader landscape may strongly influence local patterns of biodiversity – with obvious practical implications for conservation that can be brought about by appropriate regional planning.

Figure 8. Sampling invertebrates in fragmented wetlands. The study found six species new to Ireland, and the presence of several nationally threatened species. Results suggest that small isolated wetland fragments may have similar invertebrate species richness to larger areas of protected wetland. Moreover, these small fragments of often unpromising habitat may be highly important at the wider level by providing increased levels of habitat diversity within a landscape. Image: Eoin O'Callaghan.

In another study that investigated invertebrate diversity in different wetland fragments (Fig. 8), the diversity of hoverflies associated with the wetland sites increased with the diversity of habitats present in each site. However, no other invertebrate group showed any relationship with habitat diversity, fragmentation or isolation. Species assemblages were generally rather similar among the wetland sites, indicating relatively little turnover among them.

4.3 Fragmentation and Habitat Heterogeneity

Perhaps surprisingly, the amount of wetland habitat in a landscape unit and the area of individual wetlands did not show any relationship to the diversity of wetland invertebrates. However, the amount of *historical* wetland in the landscape was positively related with the amount of wetland invertebrates, perhaps indicating a higher degree of resilience to environmental change among wetland invertebrates than might be expected.

Although the size, amount and isolation of the wetland fragments did not appear to influence the diversity of wetland invertebrates, these habitat fragments may play an important role in supporting other aspects of diversity at the landscape level. The diversity of pollinator assemblages increased with habitat diversity, and this relationship between pollinator diversity and landscape heterogeneity was apparent at all scales from 2 km to 5 km around sampling points (Fig. 7). These are the first results known to show an effect of habitat diversity on biodiversity in the landscape at the 5-km scale. The relationship between hoverfly diversity and landscape heterogeneity was also more pronounced over larger spatial scales. The implications are that even small fragments of varied habitat types may play an important role in supporting biodiversity in the wider landscape, and hence in promoting ecosystem functioning.

A survey of four rare woodland specialist plants confirmed the negative effects of historical fragmentation: one species, *Hypopitys monotropa,* was not re-found at any of its previously known locations. Habitat heterogeneity was found to be remarkably high in the Burren. Scrub, which was a mosaic of grassy and shrubby patches, was generally found to be richer in vascular plant species than either grassland or woodland, likely because it contains a mix of both woodland and grassland elements. However, in one grassland plot of 20 × 20 m, 96 species of vascular plants were recorded; this is over 10% of the entire vascular plant flora, and illustrates the conservation value of these unimproved species-rich grasslands. Small habitat fragments may have unexpectedly high levels of biodiversity, for example, the Glenquin woodland site in the grazing study which harboured a number of uncommon and rare species across a range of taxonomic groups.

4.4 Conclusions and Recommendations

Small habitat fragments may have unexpectedly high levels of biodiversity, and therefore may have intrinsic biodiversity value at a local scale. Perhaps more importantly, these fragments are likely to contribute significantly to a greater diversity of habitat types within a given area of landscape and hence may play very important roles at the landscape scale. We recommend that:

- A detailed survey of even small habitat fragments should be undertaken to reveal their biodiversity value, which may be surprisingly high;
- Small fragments of habitat should be retained where possible, and maximum habitat diversity conserved within landscape units, due to the important role these fragments are likely to play in ecosystem functioning at the landscape scale;
- The varied scales at which biodiversity operates – from local site to broad landscape – should be taken into account in regional planning and Strategic Environmental Assessments;
- Further studies are undertaken on the effects of habitat heterogeneity at differing scales within the wider landscape to determine both the generality of the BioChange results and whether there are more generalised trends.

5 Indicators and Metrics

5.1 Introduction

The Water Framework Directive requires management to bring all surface waters, which includes estuaries, lagoons and coastal waters, to at least 'good ecological status' and 'good chemical status' by 2015. The Marine Strategy Framework Directive has similar objectives for marine waters. The Habitats Directive requires management to deliver 'favourable conservation status' of Annex 1 habitats within Special Areas of Conservation (SACs), and all of these European directives require monitoring to assess the effectiveness of those management measures. All require careful consideration of habitat quality impacts on biodiversity.

In order to monitor the ecological quality of a habitat effectively, various monitoring tools are frequently employed. Bioindicators utilise the responses of various components of biodiversity to assess quality. Some indicators are multi-metric, combining assessment scores from various components of a habitat to provide a more integrated quality assessment. If such tools are to be effective, they should be reliable, simple and cost-effective. They can then provide part of the evidence to assess whether conservation and other management targets set have been achieved. A wide range of tools exists but the degree of verification and ground truthing varies considerably, and this is clearly of key importance in determining their appropriateness and effectiveness.

A number of BioChange projects examined environmental quality indicators either directly or as a consequence of other objectives, with the main body of work being undertaken by Work Package 3 which considered the impacts of pollution.

5.2 Appropriateness of Indicators

Contrary to expectation, designated wetlands in Co. Clare did not have a higher invertebrate diversity than non-designated sites. Many of these designated sites are likely to have been selected, based on their vegetation and plant-species richness, probably because the plant species of wetlands and the vegetation communities that they constitute are comparatively well known. The results suggest that these may not be the most reliable indicators for less-studied invertebrate diversity. Further detailed sampling of wetland invertebrates is needed across Ireland to verify the value of wetland invertebrate assemblages as indicators of biodiversity value, and hence determine whether or not there are any gaps in wetland conservation coverage.

In lakes, various widely used metrics of lake quality failed to detect eutrophication pressures in lakes invaded by zebra mussels (*Dreissena polymorpha*) due to their significant impact on the ecological structure of both open water and littoral communities.

Although assemblages of macroalgae have been suggested as potential indicators of marine pollution, one BioChange project found that the molluscan assemblages associated with the brown algae *Fucus serratus* showed greater differences in structure and diversity at sites with different measured pollution loads than macroalgae. These molluscan assemblages may prove useful bioindicators of the quality of rocky shores to aid classification of habitat quality. *F. serratus* is a widespread and abundant species of the lower shore, and is readily identified.

Scope for Growth (SFG) is a widely used tool to detect in situ physiological responses to contaminants. The studies carried out in the current project suggest that SFG measurements in common mussels (*Mytilus edulis*) (Fig. 9) are ineffective in indicating nutrient pollution, though other work has shown good correspondence between SFG and other types of pollution. Instead, it was found the population structure and Condition Indices of mussels are better predictors of nutrient pollution. Their potential as simple, cost-effective indicators of marine nutrient enrichment should be explored further.

Two multi-metric indices (Multivariate-AZTI Marine Biotic Index [M-AMBI] and Invertebrate Quality Index [IQI]), developed for the assessment of sub-tidal systems, were found to be effectively correlated with combined scores for dissolved inorganic nitrogen and organic matter in intertidal shores. These indices might be usefully employed in the intertidal zones to assign Ecological Quality Status; their use here would be far more cost-effective than in sub-tidal zones.

Figure 9. Common mussels (*Mytlius edulis*) on a rocky shore. This widespread species has been used as a bioindicator of marine pollution but BioChange found that some of the commonly used metrics based on mussels may not be very well correlated with pollution levels. Instead, relatively simple measurements of mussel population structure and the Condition Index may prove more effective indicators. Image: Louise Scally.

Experiments to exclude grazers from Burren grassland plots revealed a rapid loss of several vascular plant species, especially the eyebrights, *Euphrasia*. The potential of *Euphrasia* as an indicator of appropriate grazing management requires further study, this being a taxonomically complex genus.

Indicators of invasion potential in vascular plants have already been mentioned in Section 3.2. The development of these indicators is an important step in the provision of early-warning systems to identify potentially problematic non-native species, enabling control before serious and possibly irrecoverable problems develop. In the past, too often there has been a lack of swift action to deal with invasive species before they start to cause problems. These early-warning indicators should be useful in targeting decisive, cost-effective control actions.

5.3 Conclusions and Recommendations

The examples of findings from BioChange given above challenge the effectiveness of several widely used indicators of habitat quality, and demonstrate the importance of field verification. Furthermore, experimental manipulations on rocky shores indicated that complex responses to multiple pressures (nutrient enrichment, sedimentation and loss of gastropod grazers) are partly due to interactions among these pressures. Similar complex reactions of plant communities to combined pressures of simulated climate change and invasive species were documented in Work Package 2.2 of the Biochange project project. It is recommended that:

- Experimental verification of metrics widely used in the assessment of habitat quality is urgently required. Indicators and metrics should be critically reviewed and their suitability assessed before use;
- The indicators suggested in BioChange should be further refined and developed;
- Care should be taken when using indicators and metrics where several interacting environmental pressures are operating; more detailed knowledge of how ecosystems respond to multiple pressures is required. This will be especially important in understanding biodiversity responses to climate change;
- Results of studies that use indicators that are subsequently found to be inappropriate should be reviewed critically to substantiate the validity of their findings.

6 Developing More Effective Biodiversity Policy and Governance

6.1 Introduction

Effective biodiversity planning involves a detailed understanding of natural processes and ecosystem functioning. However, successful protection and enhancement of biodiversity is not simply a scientific endeavour; policy making is an inherently political process. Understanding how that political process is constructed – essentially, who is involved and influential in designing policies – is a crucial component of planning for biodiversity. Attention needs to be paid to the governance of biodiversity, where biodiversity governance is the sum of the ways in which biodiversity is managed.

The development of biodiversity policy in Ireland lies mainly with the National Parks and Wildlife Service of the Department of the Environment, Heritage and Local Government, though implementation of policy is cross-sectoral. As a signatory to the UN Convention on Biological Diversity, Ireland has produced a National Biodiversity Plan, currently going through a revision process. Many of the major biodiversity policies in Ireland are driven by European directives rather than national requirements, in particular the Birds Directive, the Habitats Directive, the Water Framework Directive and the EU's own biodiversity strategies.

One problem is that a multiplicity of agencies, institutions and actors influence negotiations about how policy should be implemented – there are many opportunities for policy to become derailed. Many of these influences are working to a very different agenda, leading to inevitable conflicts in the implementation of policy.

6.2 Developing Better Biodiversity Governance

BioChange research clearly demonstrated a degree of uncertainty with the definition of the term biodiversity across a wide section of the community. This does not imply a lack of knowledge about biodiversity issues. For example, the significance of threats to biodiversity was understood and well-communicated by a wide variety of Irish society. Personal experience seems highly important to shaping understanding of biodiversity. Efforts to promote understanding of biodiversity in Ireland (for example Notice Nature, www.noticenature.ie) should focus on the familiar and the tangible, emphasising links with everyday life experiences.

Although a wide variety of Irish society was able to express views on the value of biodiversity and the significance of threats to it, two important gaps remain. First, there was a perceived gap between policy intent and practical implementation, potentially rendering policies to be ineffective. Second, the research also demonstrated an obvious gap between public understanding of biodiversity values and the actions people take in their lives to protect or enhance biodiversity. By way of comparison, reducing carbon footprints is becoming widespread in both industry and among the public. Carbon taxes may not always be popular, but they are generally understood and accepted – people are still some way from the general acceptance that changes in lifestyle and related practices are needed to reduce anthropogenic impact on biodiversity. Mainstreaming biodiversity policy as a key component of environmental sustainability might be a useful way of stimulating better implementation of policy, and might help further emphasise how biodiversity value is linked with everyday livelihoods.

However, the current research found a strong perception that biodiversity policy was generated from the top down, with inadequate participation of a variety of stakeholders and the public. There is a clear need for far better participatory frameworks to determine biodiversity policy, facilitating a complete exchange of viewpoints and built on principles of inclusion. Some platforms exist for such exchange, but these need to be improved and made more inclusive. A perception that public participation in such frameworks may be ineffective was also detected, because powerful actors with vested interests are thought likely to push through their own agenda. There will be a need to secure balanced contributions and wide participation in order

to secure broad engagement of society in contributing to biodiversity governance.

Two good examples were identified where active participation in local biodiversity governance has developed strong linkages between biodiversity conservation and local livelihoods. The Burren Life Project (www.burrenlife.com) has developed programmes for grazing management to support biodiversity in the Burren region of Co. Clare in consultation with the local farming community, Teagasc and the National Parks and Wildlife Service. On Inis Oírr, local communities have been engaged in lobster-catch management, promoting sustainability of the resource. These projects illustrate potentially useful approaches to be adopted in the future; for example, in the development of new agri-environment schemes. Certainly, empowering communities to make responsible decisions about biodiversity management while sustaining their livelihoods is a major step forward. On the other hand, the harvesting of seaweed for commercial processing (Fig. 10) appears to have little community management and could benefit from similar community-based approaches to ensure sustainable management of the resource.

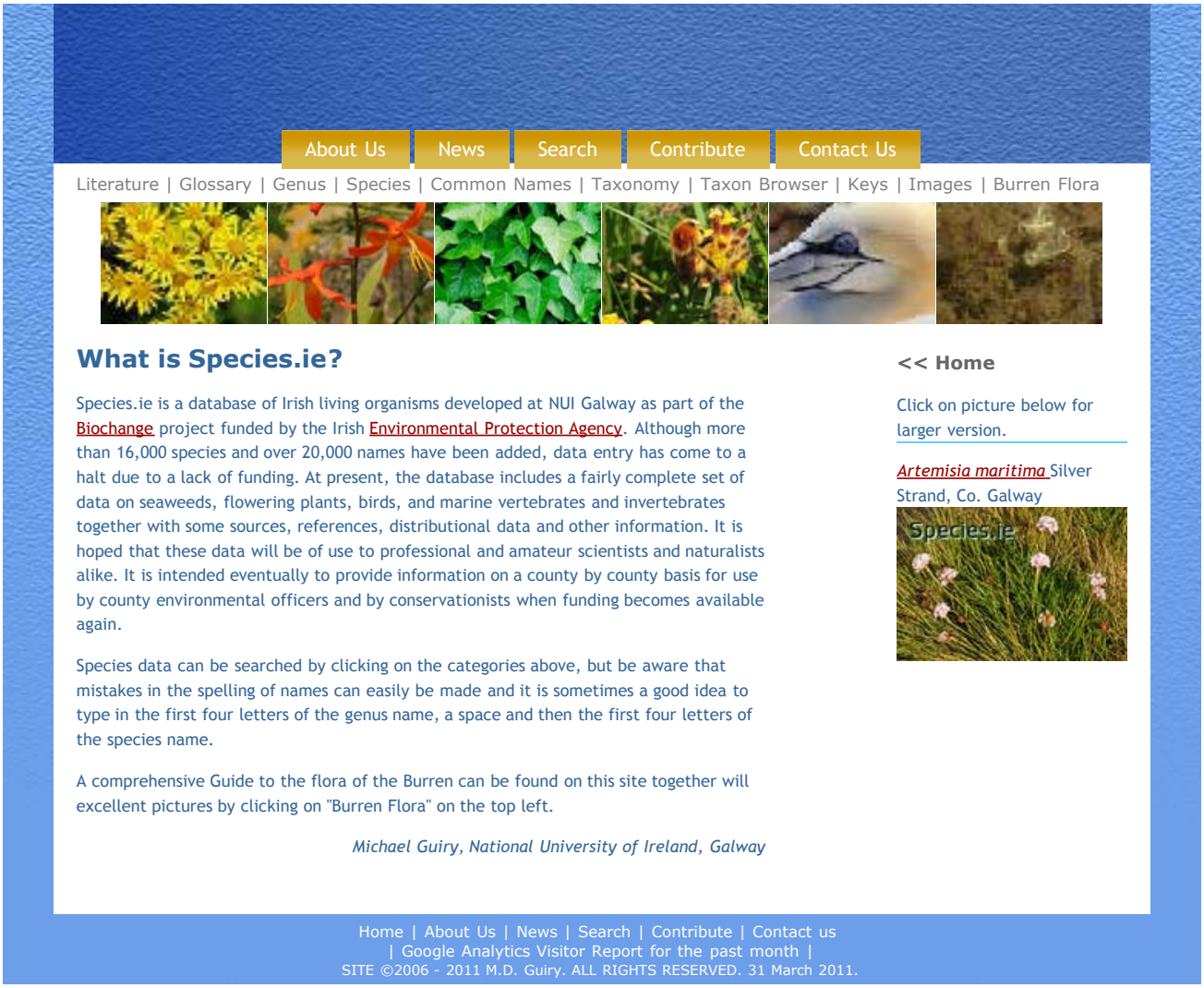
Figure 10. Harvesting *Ascophyllum nodosum* in Connemara. Biodiversity provides many benefits, including income generation as a result of the harvesting of natural biological resources. Placing an economic value on other ecosystem goods and services may be problematic, but it is essential that this is tackled in order to provide examples of the true value of biodiversity to society. Image: Dagmar Stengel.

6.3 Providing the Evidence Base to Support Policy

A limitation to the implementation of biodiversity policy is the frequent lack of fundamental information available to key actors. The results of biodiversity research are not always made relevant to those involved with policy development or implementation, resulting in obvious inefficiencies. The National Platform for Biodiversity Research has a clear role to play here, and many of the BioChange principal investigators are active members of that platform. Perhaps more fundamental is the need for a wide variety of biodiversity information to be made readily available to a varied group of users – from the general public to policy makers and regional planners. Such information must be relevant to the user and should include geographical distributions of habitats and species, designated areas, threats and conservation value, the value of ecosystem goods and services, and identification methods. Information should be provided in an accessible and usable format, and should take advantage of recent technological developments that provide information to new platforms, such as smartphones, palmtop computers and similar devices.

Several BioChange projects aimed to provide specific and novel ways of presenting important biodiversity information to support biodiversity conservation at national and regional levels. For example, the study on the traits displayed by naturalised and invasive non-native plants has been compiled into a database of information that will be publicly accessible through the National Biodiversity Data Centre).

Another BioChange project, Species.ie (www.species.ie), has compiled records in a MySQL database of taxonomic information for some 16,000 Irish species and 20,000 names (Fig. 11). At the time of writing, the database contains reasonably complete information for seaweeds, flowering plants, birds, marine vertebrates and invertebrates, and incomplete information for other groups. Images, descriptions and literature sources are provided. An interactive key to Irish seaweeds links though to images of these species.



http://www.species.ie/ [13/3/2011 15:24:04]

Figure 11. Home page of Species.ie, a database of Irish living organisms, along with images, taxonomic notes, relevant literature etc. 16,000 Irish species and 20,000 synonyms are currently included in the database, providing a rich resource of freely available information on Irish biodiversity. There needs to be an ongoing commitment to maintain and further enhance and develop this and similar resources produced by BioChange.

Taxonomic keys were further developed in another project that provided keys to the vascular plant flora of the Burren, Aran Islands and south-east Connemara. This key is available as a DVD and in web-based format, available at: www.species.ie/burren/index.php. The interactive flora provide identification keys, simple descriptions, images, literature sources and a glossary of terms, and is available to the public (Fig. 12).

These major outputs from BioChange provide essential sources of information for a variety of stakeholders on Irish biodiversity. Though not complete in either taxonomic or geographical coverage, they provide models for how provision of essential information can be streamlined and made readily accessible in visually appealing formats.

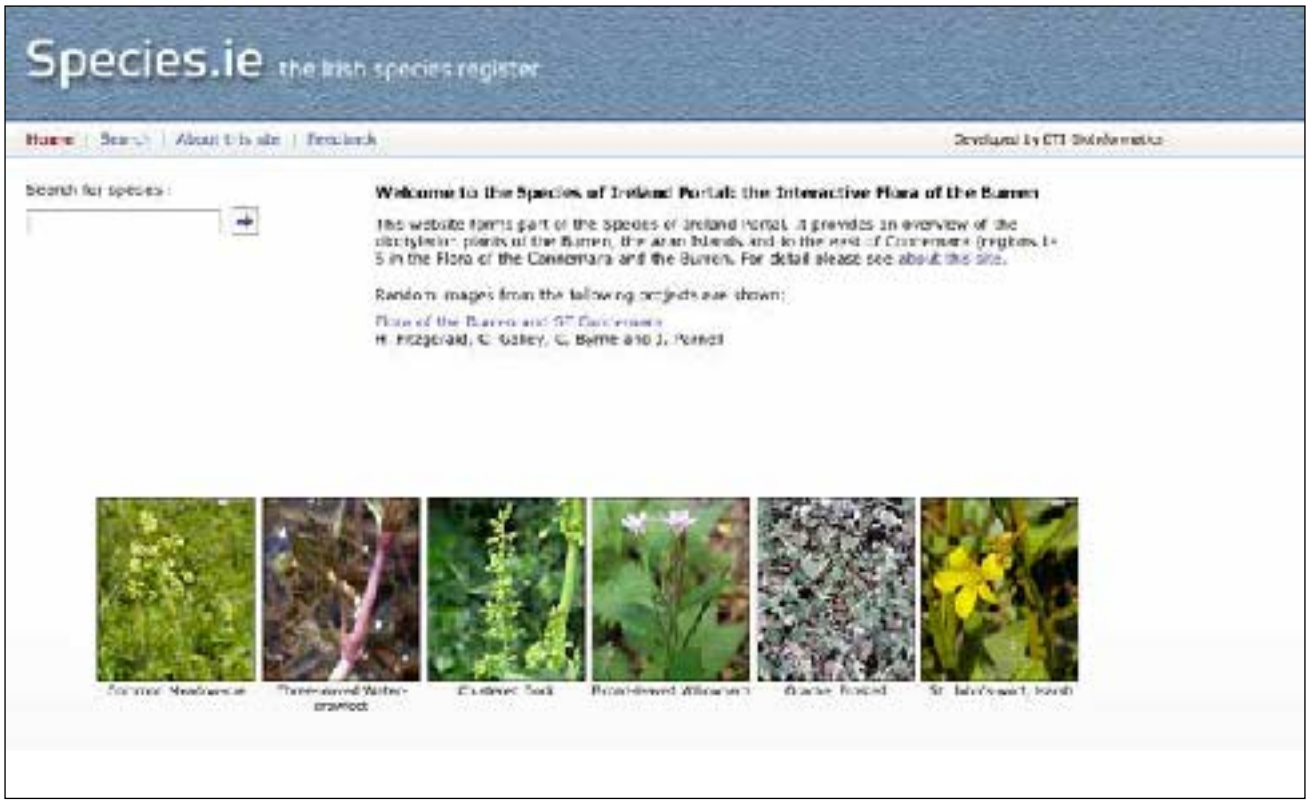


Figure 12. Home page of the interactive flora of the Burren and south-east Connemara, available via Species.ie. A DVD version of the flora is also available, providing keys to identify flowering plants of the region and a range of images of each species. This is another important resource generated by BioChange, providing a model for delivery of information to aid identification of species. The approach needs to be expanded to cover the whole island of Ireland, and to include more taxonomic groups. The system should further be developed to provide identification in the field by taking advantage of recent technological developments in smartphones and portable palmtop computers.

6.4 Conclusions and Recommendations

- More inclusive participatory frameworks are required for the development and implementation of biodiversity policy;
- The cost burden for maintaining biodiversity should not fall on those responsible for the management of land or seas; it could, for example, be achieved through targeted, outcome-oriented agri-environmental schemes and similar initiatives;
- Clearer linkages need to be made with biodiversity value and livelihoods, using a framework of sustainability to emphasise these linkages;
- The best examples of local community involvement in biodiversity management need to be identified and promoted widely as model studies that can be applied elsewhere;
- Further development of the interactive taxonomic keys to provide geographical and taxonomic completeness of coverage is urgently required;
- Further development of methods for the delivery of key biodiversity information to a variety of users, including the use of novel platforms, is required;
- Greater use of the National Platform for Biodiversity Research should be made to encourage biodiversity research to develop policy-relevant outputs and recommendations, and to ensure a dynamic exchange of information between policy makers and researchers.

7 Drivers of Biodiversity Loss and Links with Spatial Planning

7.1 Introduction

While development is a necessary and inevitable requirement for enhancing human well-being, developments have often placed considerable pressure on biodiversity. The effect of development resulting in fragmentation of terrestrial and coastal habitats is perhaps most obvious. However, development also has significant impacts on biodiversity through pollution and may also facilitate the spread of invasive non-native species. Future regional planning needs to take more cognisance of biodiversity and ecological processes at varied spatial scales, as mentioned above. Consideration of the economic and environmental value of functioning ecosystems should be taken into account when considering strategic environmental assessments for regional development. All too often in the past, biodiversity considerations have taken the back seat in development planning with unfortunate and avoidable consequences. In many cases, relatively simple pragmatic approaches can be taken that can provide positive outcomes for local and regional biodiversity. The development of evidence-based conservation is one way in which vitally important conservation prescriptions can be made available to support informed planning decisions (see www.cebc.bangor.ac.uk and www.environmentalevidence.org).

Although BioChange did not specifically address the integration of biodiversity considerations into local and regional planning, many of the project's findings and outputs have great relevance for both the implementation and further development of aspects of biodiversity policy. Significantly, many of the project findings have direct application in suggesting approaches to reducing the impacts of development on biodiversity; many examples have been briefly mentioned in the previous sections, and further details may be found in the project's technical report; summarised findings are given in Appendix 4. Here, some of the suggestions that have arisen from considerations of the project findings, and which have a practical application in enhancing local and regional biodiversity and its management are drawn together.

7.2 Minimising Impacts and Strengthening Local Policy – Recommendations

- Local/regional authorities should develop geographic information systems (GIS) containing layers of biodiversity information to aid spatial-planning processes. Researchers should be encouraged to submit relevant data to appropriate authorities; there is a role here for the National Platform for Biodiversity Research to act as a facilitator and a conduit of information;
- Ensure biodiversity officers, conservation rangers and related staff are in place to advise on biodiversity requirements. Develop closer co-ordination between local authorities in generating local or regional biodiversity action plans and promote more local authorities/county councils to produce local biodiversity plans;
- Ensure biodiversity components are fully integrated into all Strategic Environmental Assessments (SEAs), and mainstream biodiversity into all aspects of regional and local planning;
- Maximise habitat diversity and quality at the level of landscape. Maintain or increase semi-natural habitat area. Maintain connectivity through linear features, such as hedgerows and river corridors.
- Avoid fragmentation of large blocks of semi-natural habitat and explore the feasibility of habitat restoration;
- Incorporate the concept of irreplaceability into local planning – the loss of some sites are non-negotiable, as their loss would lead to local/regional/national species extinction;
- Maintain appropriate grazing regimes through close liaison with farmers and other landowners;

- Ensure sustainability of biodiversity resources and, where necessary, regulate the harvesting of biodiversity to achieve this;
- Provide information on the potentially serious impacts of invasive non-native species and, if necessary, regulate movement of problem species;
- Develop a series of case studies in cost-effective biodiversity conservation that involve broad participation, take into consideration people's livelihoods and utilise these as examples or models that might be used elsewhere or adapted to different situations.

8 Research Requirements

8.1 Introduction

Research provides society with fundamental and novel information about the world and our place within it. Unlike chemistry and physics, there are no laws in ecological science. At best, there are rules and principles that provide some generality, but there are many exceptions to these rules and principles. As a result, a considerable amount of fundamental ecological research in a variety of semi-natural habitats is needed to describe adequately the structure and functioning of ecosystems and to elucidate ecological principles. Research generates essential environmental understanding, underpinning sustainable economic development and informing the choices that will be available to the future.

The National Platform for Biodiversity Research (NPBR) (www.biodiversityresearch.ie) provides a forum for policy makers, researchers and other interested stakeholders in biodiversity research. The work of the platform includes making recommendations for future research directions, in order to make research relevant to the requirements of policy and to provide policy makers with information relevant for the development of refined or novel policies. BioChange developed very much out of collaborations within the NPBR, and the current research findings and recommendations on the future development of biodiversity research from BioChange are closely linked with the objectives of the NPBR.

Although BioChange received significant and welcome funding from the EPA, the research undertaken over such a broad spectrum of projects was never likely to provide all the required answers to questions about the impact of major threats to biodiversity in Ireland. This was never the intention in formulating the project. Instead, it was seen as the starting point from which many future avenues of biodiversity research could subsequently develop. Below some of the key research approaches that have been developed within BioChange that could provide the basis for ongoing integrated biodiversity research in Ireland are listed.

8.2 BioChange Research Activity and Future Research Directions

8.2.1 Establishment of Long-term Monitoring Sites

Too many studies on Irish semi-natural ecosystems have been driven by the three- to four-year cycle of PhD research. While this is in part inevitable, it represents a failure to tap into the potentially huge benefits of continuing long-term studies of selected sites. As mentioned above, short-term responses might be transient in nature and not indicative of long-term trends.

A major output from BioChange has been the setting-up of a series of sites that could and should form the basis for essential ongoing future research on biodiversity and ecosystem function. Few studies in Ireland have achieved this, i.e. a network of sites for long-term monitoring and for which there is detailed baseline information. In some cases, the development of these sites represents a major financial investment. To capitalise on this investment, it is vital that changes in the biodiversity of these sites continues to be monitored into the future. These include:

- A suite of fully surveyed wetland sites in Co. Clare, with baseline data on invertebrates and vegetation;
- Farm sites with baseline data with which to assess temporal changes in pollinator abundance and diversity;
- Experimental manipulations of grazing in woodlands, scrub and grasslands, with grazing exclosures and associated control plots (see Fig. 13);
- A suite of lake sites for monitoring the spread and impact of invasive zebra mussels;
- A suite of intertidal rocky and sedimentary shores for surveying and monitoring pollution impacts;
- Sites with *Ascophyllum nodosum* to record the impact of harvesting and response to environmental change.

Figure 13. A grazing exclosure in grassland. Notice the much taller vegetation to the left of the fence. There is an adjacent control, subject to grazing. These experimental manipulations of grazing produced some surprisingly rapid responses in the vegetation and among mollusc communities. Like many other BioChange projects, this grazing study has developed a network of experimental sites, with a variety of baseline data recorded. As such, these are valuable resources for the study of ecosystem responses to experimental manipulation. To take full advantage of the recording effort to date, provision needs to be made to secure the ongoing study and monitoring of these sites that could provide novel data on the causal effects of ecosystem change. Image: Maria Long.

8.2.2 Experimental Manipulations in Semi-Natural Ecosystems

Many ecological studies in Ireland (including many of the BioChange projects) have relied on correlations between ecological drivers and various biodiversity responses. One significant difficulty has been the inability to define causative roles for these drivers with certainty. Such certainty is deemed necessary in order to respond to or shape biodiversity policy effectively. Some of the BioChange projects where direct manipulations on semi-natural ecosystems were employed to provide novel ecological understanding include:

- The effect of grazing removal in woodland, scrub and grassland habitats;
- The effect of microclimate manipulation on the effect of invasive species in semi-natural grasslands;
- The effect of nutrient enrichment, sedimentation and grazing gastropod removal on algal and invertebrate assemblages in rocky shores;
- The effect of nutrient pollution and organic enrichment on macrofaunal assemblages on sedimentary shores;
- The effect of harvesting regimes on productivity of a macroalgal keystone species.

8.2.3 Improvement of Baseline Sampling and Habitat Mapping

There is a deficit of the most basic biodiversity information for many parts of Ireland. Distributions of some well-known groups of species – birds, vascular plants and mammals – are relatively well known. For other groups, notably invertebrates, cryptogamic plants and fungi, knowledge is very patchy. For example, the lack of historical and contemporary data on pollinator (especially bee and hoverfly) distributions limits our ability to quantify decline in Ireland, and this is an area of major international importance.

There is now a widely established system for classifying Irish habitats developed by the Heritage Council, yet still we do not have adequate habitat maps for most parts of the country. Lack of adequate habitat mapping is an even more acute problem in the marine environment. Such information is surely crucial to support sustainable development and to inform biodiversity policy implementation. In selecting a target area in which to focus the BioChange project, those counties where provision of biodiversity information was best were sought deliberately, the project team eventually settling for Co. Clare.

Several BioChange projects contributed novel information on the distribution of Irish biodiversity:

- Several rare species of wetland invertebrates recorded from Clare wetlands, including six species new to Ireland;
- Baseline data on local bee species abundance, including several threatened native bumblebee species recorded in the study of pollinator diversity in farmed landscapes;
- The distribution and ecology of rare woodland vascular plants;
- Threatened mollusc species recorded from the grazing exclosure experiment.

8.2.4 Links between Biological and Social-Science Approaches to Biodiversity Conservation

If biodiversity conservation is to be effective, it must not be seen solely as a biological discipline. As BioChange has shown, there is a great deal to be gained from collaboration between the biological and social sciences. Such cross-discipline collaboration needs to be strengthened, and further developed to include economists, social scientists, lawyers and others. Only in this way are we likely to achieve effective biodiversity conservation that is informed by science, accepted politically and socially and driven by the reality that it makes economic sense to conserve biodiversity.

8.2.5 Investigations of the Impacts of Climate Change on Biodiversity

Prior to the BioChange project, there have been relatively few studies that directly investigated the effects of simulated climate change in semi-natural ecosystems, and none on climate change and the associated impacts of invasive species from Ireland. Most of the information in this area comes from various models; for example, climate-change scenario models to predict the future range of particular species or agricultural systems. The result is that most attempts to predict the impact of climate change on species distributions in Ireland are pure conjecture, and this is even more true of impacts on ecosystems. Given the certainty of significant climate change in the near future and of the important role of biodiversity in providing ecosystem goods and services to support human livelihoods, it is essential that a better understanding is developed on how biodiversity will respond to predicted future climate change in Ireland.

8.2.6 Investigations of Ecosystem Functioning and the Goods and Services Provided by Ecosystems

A number of projects in BioChange examined aspects of ecosystem functioning. Some of these projects determined correlations between environmental pressures and ecosystem function, others examined causal effects through manipulative experiments. Relatively few projects were able to extend these outputs to consider the goods and services provided by Irish semi-natural ecosystems. This was never an explicit objective of BioChange, though it is being covered to some degree by the EPA-funded Simbiosys (Sectoral Impacts on Biodiversity and Ecosystem Services) (www.simbiosys.ie). Further work is needed that links detailed knowledge of ecosystem functioning, quantification of ecosystem goods and services, and socio-economic analysis to determine how these goods and services impact on human livelihoods. These should include detailed analysis of the consequences of degradation or loss of these services.

8.2.7 Invasive Species Colonisation, Impacts and Control

Several BioChange projects investigated the effects of invasive alien species (see an example of such a species in Fig. 14) in Ireland, including an attempt to predict the likelihood of invasion by non-native species. These approaches need further development to document the impacts of invasive non-native species on semi-natural ecosystems in Ireland accurately and to develop and refine protocols that can serve as early-warning systems of potential future problem species. No attempt was made within BioChange to investigate potential methods of control of invasive species, the environmental impact of control (which may be considerable), or the economic cost of invasive species control and eradication. All these are areas that require future concerted study. Further information on invasive aquatic species in Ireland, including methods of control, is being generated by the EPA STRIVE-funded project Alien Invasive Species in Irish Waterbodies co-ordinated from Queen's University Belfast (www.invasivespeciesireland.com).

8.2.8 Better Dissemination of Research Outputs

In addition to the provision of project data to the EPA's SAFER-Data facility, BioChange has produced a number of significant outputs as readily available resources for wide dissemination of information. These include:

- A web-based database of non-native vascular plant species that occur in Ireland, and various traits associated with them;
- A web-based catalogue of species native to Ireland and associated taxonomic information;
- An interactive key to the vascular plant flora of the Burren, Aran Islands and south-east Connemara, available as a CD and as a web interface;
- Numerous peer-reviewed scientific publications.

A complete list of outputs and publications produced by BioChange is given in Appendix 3.

Figure 14. Giant hogweed, *Heracleum mantegazzianum*, an impressive invasive plant growing up to 5 m tall. Native to the Caucasus and Central Asia, it is now widely naturalised in Europe and parts of North America. Predominantly found along streams and in damp waste ground, its large size tends to shade out many native plant species. Additionally the plant is phototoxic and can cause severe dermatitis when skin in contact with the sap is exposed to strong sunlight. It is regulated by the Wildlife and Countryside Act in the UK, and regulated as a federally noxious weed in the USA. Understanding the traits that are correlated with the likelihood of non-native plants becoming invasive may provide an effective early-warning system, facilitating more cost-effective control. Image: Steve Waldren.

These outputs provide biodiversity data to a variety of potential users. In many cases they provide models for how more complete data sets might be provided. For example, the interactive vascular plant flora could be expanded in geographical scope to cover the whole of Ireland, or expanded to include other taxonomic groups such as the non-vascular flora. In all cases, the security of web-based provision and hosting of these resources needs to be ascertained for the medium term, and funds need to be made available to expand and further develop these resources.

8.3 Conclusions and Recommendations

Many of the research areas mentioned above are clearly linked, and can be developed in the future in co-ordinated, integrated studies. Recommendations of how future Irish biodiversity research should be developed using BioChange as a springboard for such developments are as follows:

- *Establish long-term monitoring and experimental manipulation of semi-natural ecosystems*.

Existing long-term monitoring and experimental sites need to be secured for ongoing research in the future. New secure sites in semi-natural terrestrial, freshwater and marine ecosystems (possibly EU Annex I habitats) need to be determined to provide an experimental approach to understanding key ecosystem processes. Full understanding of ecosystem functioning will only come through medium- and long-term studies, and the potentially immense value of these studies must be taken into consideration. It is recommended that the National Platform for Biodiversity Research develops a strategy for long-term ecological and environmental monitoring on an all-Ireland basis, taking advantage of synergies with similar long-term monitoring efforts in the UK and elsewhere in Europe. Such studies could possibly link with the following points made below.

- *Develop causal understanding of the effects of climate change on biodiversity distribution and ecosystem functioning, linking with economics and human livelihoods.*

Understanding how biodiversity will respond to future climate change will potentially provide key understanding of how to adapt to climate-change pressures on ecosystem goods and services. The research needs to combine modelling approaches with experimental verification (using semi-natural ecosystems as noted above). It should also fully integrate socio-economic aspects of costs, benefits and novel opportunities arising from potential future climate-change impacts on biodiversity. Synergies must be developed between existing climate monitoring efforts and the need to understand ecosystem responses to climate change.

- *Complete national habitat surveys and provide mapped distribution of habitats.*

  This is currently a major gap in the provision of basic national biodiversity information and would provide essential information to a wide variety of stakeholders, from spatial planners to researchers. Standardised approaches need to be developed, and particular attention needs to be paid to the generation of marine habitat maps where there is currently an extreme paucity of information and no standardised approach or even guidelines for mapping.

- *Survey poorly studied groups*.

  Knowledge of the distribution and ecology of many taxonomic groups is poor – most arthropod groups, fungi, soil biodiversity, marine infauna and epifauna, etc. Further fundamental study on the distribution and ecology of these poorly studied groups is required because they are likely to play significant roles in ecosystem functioning such as, for example, the diversity of life in the soil.

- *Develop tools and protocols for the control of invasive species, including restoration and recovery.*

  Given the potentially serious threat posed by non-native species, more basic research is needed to understand the biology and ecology of invasive species, their impacts on ecosystems, and environmentally sensitive methods of control. These should be linked to analyses to assess the full economic impacts of invasive species on ecosystem processes and the costs of their control;

- *Develop more effective tools and approaches for explaining the importance of biodiversity conservation for sustainability*.

  This research is needed to determine the most effective and appropriate means of delivering key baseline biodiversity information to a variety of stakeholders. It should also develop more clear explanations of biodiversity concepts that can be presented to as wide a variety of public and political audiences. It should emphasise the economic value of biodiversity and its links with human livelihoods.

9 Conclusions

Biodiversity loss is the major environmental challenge to humanity. The accelerating rate of biodiversity loss is anthropogenically driven by major factors such as habitat loss and fragmentation, the spread of invasive non-native species, increasing pollution and unsustainable levels of exploitation. In the future, anthropogenic climate change will increasingly lead to biodiversity loss, possibly resulting in unexpected interactions with the previously mentioned drivers. This is likely to have major impacts on all human livelihoods, with possibly the greatest impacts on the poor and underprivileged who depend most on the goods and services provided by functioning ecosystems. However, all human livelihoods are to a greater or lesser degree dependent on such goods and services, and any diminution in the quantity or quality of these services will inevitably lower standards of living.

Major national and international policies have attempted to address the biodiversity crisis, with little effect to date. For example, the main international objective to halt the loss of biodiversity by 2010 was not reached. This has been recognised and addressed in the most recent 10th conference of parties to the Convention on Biological Diversity in Nagoya, Japan, 2010, where a new strategy of 20 targets have been agreed to attempt to halt the loss of biodiversity by 2020. The plan includes a vision 'Living in harmony with nature', where, 'by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people'.

The failure to reach these international targets may be because of knowledge gaps in understanding what needs to be done to live sustainable lives. It may also be because much of the biodiversity governance is poorly structured and cumbersome, as BioChange has demonstrated. New initiatives are needed that provide links between biology, economics and the social sciences to demonstrate effectively the value of biodiversity and its central role in sustainability.

BioChange attempted to investigate the impacts of major drivers of biodiversity loss in a variety of Irish habitats. A considerable amount of scientific findings have already been published, and more will surely follow over the next few years. BioChange has trained five postdoctoral researchers, seven PhD students, three MSc students and one research assistant. In addition to these researchers directly funded by the project, numerous other undergraduate and postgraduate projects not supported by the core project funding have been linked to a greater or lesser degree with BioChange. During the project, training has been provided for researchers in a number of areas, including GIS, desk study and report writing, effective presentations and statistical analyses. This training was provided at collective workshops and summer schools. The provision of well-trained and highly qualified researchers will increase Ireland's capacity to meet the needs of future biodiversity research, policy making and implementation, and practical management of Ireland's biodiversity resources.

The varied research outputs have directly furthered scientific knowledge in the areas of ecology and conservation. BioChange has also developed an invaluable suite of monitoring sites that, given adequate funding, can form the basis of ongoing experimentation and research to provide real insight into long-term impacts of pressures on biodiversity. Other major outputs include the provision of accessible biodiversity information. Many of the BioChange outputs and findings have direct relevance to policy implementation and in some cases illustrate the need to improve mechanisms for generating and implementing biodiversity policy.

Leading on from the specific research findings and the numerous discussions within BioChange around these findings, we draw a number of conclusions and make a series of recommendations. The following four broad, overarching recommendations are made:

- *The requirement to mainstream biodiversity considerations into all national, regional and local planning.*

  Protection of biodiversity is seen as being cross-sectoral within Ireland, yet is given little real consideration in many sectors. Due to the role of biodiversity in providing ecosystem goods and services, the consequent value of biodiversity needs to be given far greater emphasis. The value of biodiversity needs full consideration at all levels of planning;

- *Promotion of greater political understanding of biodiversity value, the links with sustainability and future options for society.*

  Linked with the last point, there is an urgent need for much greater political understanding of the value of biodiversity and the significant negative economic consequences of accelerated biodiversity loss. Biodiversity loss needs to be given the same political importance as anthropogenic climate change. Social, economic and scientific synergies need to be developed to inform policy makers;

- *Greater understanding and continued support within the EPA of biodiversity loss as the major environmental issue.*

  The importance of biodiversity loss as the major environmental challenge facing humanity needs to be accepted by the EPA. The EPA has played a critical role in promoting biodiversity research, but there is a fear that biodiversity may be lower placed on the agenda of EPA's STRIVE research programme than subjects such as climate change. It can be argued that there is a real need to integrate climate-change and biodiversity research and develop synergies between these research areas; both have the potential to cause huge environmental and economic consequences for Ireland. The EPA has a leading role to play here. While cutbacks are inevitable in the present economic climate, we express our concern at the cutbacks recently seen in environmental research in general and biodiversity research in particular.

- *Dedicated funding stream for biodiversity research*.

  Further research on biodiversity is essential in order to ensure effective delivery of policy and the discharge of international conservation obligations, and to provide the evidence base for the refinement and development of policy. Biodiversity research will also be a key requirement for the generation of sustainable living. At present there are significant gaps in knowledge, resulting in impediments to policy implementation. Synergies need to be fostered between biological sciences, economics, and the political and social sciences. The proposed centralisation of research funding will inevitably result in a polarisation of funding directed to areas of enterprise and innovation that produce short- or medium-term economic gain. Biodiversity conservation is a key pillar of sustainability, and further research is urgently needed to help attain this goal. Many of the research requirements have been documented by the National Platform for Biodiversity Research. The EPA should take a lead in securing dedicated biodiversity research funding as a mechanism for developing national capacity (through training), ensuring environmental protection and facilitating the development of sustainable livelihoods.

Finally, the current project's 27 recommendations and conclusions developed from the research findings in three main areas of local/regional planning and policy, national policy development and research requirements are summarised. These are presented in Box 4.

Box 4. Recommendations and Conclusions of the BioChange Research Project

1. Local/regional planning and policy implementation

Maintaining and enhancing habitat diversity

1.1 Small fragments of semi-natural habitat should be retained where possible, and maximum habitat diversity conserved within landscape units, due to the important role these fragments are likely to play in ecosystem functioning at the landscape scale;

1.2 The varied scales at which biodiversity operates – from local site to broad landscape – should be taken into account in regional planning and Strategic Environmental Assessments;

1.3 Incorporate the concept of irreplaceability into local planning – the loss of some sites would lead to local/regional/national species extinction;

1.4 Maintain appropriate grazing regimes through close liaison with farmers and other landowners;

1.5 Ensure sustainability of biodiversity resources and, where necessary, regulate the commercial exploitation of biodiversity to achieve this;

1.6 Maximise habitat diversity at the level of landscape (and appropriate spatial scale in the marine environment), and maintain or improve semi-natural and natural habitat quantity. Maintain connectivity through linear features, such as hedgerows and river corridors. Avoid fragmentation of large blocks of semi-natural habitat and explore the feasibility of habitat restoration. Ensure biodiversity components are fully integrated into all Strategic Environmental Assessments, and mainstream biodiversity into all aspects of regional and local planning.

Invasive species impacts

1.7 Early-warning systems to detect potential invasive species need to be developed for a variety of taxonomic groups. Potentially problematic non-native species should be targeted for immediate control and management while there is a still cost-effective opportunity to do so;

1.8 Provide information on the potentially serious impacts of invasive non-native species and, if necessary, regulate movement of problem species;

1.9 Report records of invasive species to the National Biodiversity Data Centre.

Monitoring biodiversity

1.10 Short-term changes in ecosystems in response to perturbations may not necessarily be maintained in the medium and long term. Verification of longer-term trends are essential and ongoing monitoring of the impacts of development projects is required;

1.11 Regional planning should take into account temporal changes in biodiversity, imposed changes in land use,. Development projects should monitor impacts on biodiversity and ecosystem function to provide information to refine mitigation methods;

1.12 Indicators and metrics should be critically reviewed and their suitability assessed before use, particularly where several interacting environmental pressures are operating. Results of studies that use inappropriate indicators should be critically reviewed to substantiate the validity of their findings.

Developing capacity and understanding

1.13 Local/regional authorities should develop GISs containing layers of biodiversity information to aid spatial-planning processes, and ensure biodiversity officers and other personnel are in place to advise on biodiversity requirements. Researchers should be encouraged to submit relevant data to appropriate authorities;

1.14 Use the National Platform for Biodiversity Research as a conduit to provide specific expertise where required;

1.15 Develop a series of case studies in cost-effective biodiversity conservation that involve broad participation and take into consideration people's livelihoods. Utilise these as examples or models that might be used elsewhere or adapted to different situations.

2. National policy development

2.1 More inclusive participatory frameworks are required for the development and implementation of biodiversity policy;

2.2 The cost burden for maintaining biodiversity should not fall on those responsible for management of land or seas. This could, for example, be achieved through targeted, outcome-oriented agri-environmental schemes and similar initiatives;

2.3 Clearer linkages need to be made with biodiversity value and livelihoods, using the concept of sustainability to emphasise these linkages;

2.4 Identify the best examples of local community involvement in biodiversity management and promote these widely as model studies that can be applied elsewhere;

2.5 Develop national approaches to delivery of key biodiversity information to a variety of users, including the use of novel platforms for delivering this information;

2.6 Use the National Platform for Biodiversity Research to encourage biodiversity research to develop policy-relevant outputs and recommendations, and ensure a dynamic exchange of information between policy makers and researchers.

3. Future research requirements

3.1 The establishment of long-term monitoring and experimental manipulation of semi-natural ecosystems. This includes securing existing long-term monitoring and experimental sites, and the establishment of new secure sites in semi-natural ecosystems (possibly priority EU habitats) to provide an experimental resource towards understanding key ecosystem processes;

3.2 Conduct research to allow the effects of climate change on biodiversity distribution and ecosystem functioning to be understood, including potentially altered impacts of invasive species and linkages with economics and human livelihoods;

3.3 Complete national habitat surveys and provide a mapped distribution of habitats to guide regional planning;

3.4 Survey species distributions and abundances of poorly studied groups;

3.5 Develop tools and protocols for control of invasive species, including restoration and recovery. Determine the full economic impacts of invasive species and the costs of their control, and develop effective early-warning systems to facilitate timely and cost effective control;

3.6 Develop more effective tools and approaches for explaining the importance of biodiversity conservation for sustainability and its links with human livelihoods. Develop a credible economic valuation of biodiversity. Develop novel methods for widespread dissemination of fundamental biodiversity information.

Figure 15. Storm clouds gathering over Carron turlough, the Burren, Co. Clare. Image: Steve Waldren.

10 References and Further Reading

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Acronyms and Annotations

CORINE	Coordination of Information on the Environment
EPA	Environmental Protection Agency (Ireland)
GIS	Geographic information system
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
NPBR	National Platform for Biodiversity Research
PI	Principal investigator
REPS	Rural Environment Protection Scheme
SAC	Special Area of Conservation
SFG	Scope for Growth (tool)
SEA	Strategic Environmental Assessment
Simbiosys	Sectoral Impacts on Biodiversity and Ecosystem Services
TEEB	The Economics of Ecosystems and Biodiversity (initiative)
UREKA	Undergraduate Research Experience and Knowledge Award (Ireland)

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Appendix 2 The Aichi Biodiversity Targets

Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society

Target 1

By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.

Target 2

By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.

Target 3

By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions.

Target 4

By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.

Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use

Target 5

By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

Target 6

By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

Target 7

By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

Target 8

By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

Target 9

By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

Target 10

By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity

Target 11

By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

Target 12

By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

Target 13

By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services

Target 14

By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

Target 15

By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

Target 16

By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation.

Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building

Target 17

By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.

Target 18

By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.

Target 19

By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.

Target 20

By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011-2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization, should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.

Appendix 3 BioChange Project Outputs

Peer Reviewed Publications

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Cunningham, C. 2009. *Impact of landscape composition on pollinator diversity and pollination services*. Unpublished MSc thesis, Trinity College Dublin.

Eschmann, C. *An evaluation of the effects of predicted climate change on* Ascophyllum nodosum. Provisional PhD thesis title, National University of Ireland, Galway.

Fitch, J.E. 2010. *Effective monitoring of marine ecosystems: the response of intertidal benthic communities to multiple stressors*. Unpublished PhD thesis, University College Dublin.

Grennan, J. *The impact of invasion by Zebra mussels* (Dreissena polymorpha) *in County Clare lakes*. Provisional PhD thesis title, National University of Ireland, Galway.

Kavanagh, R. 2010. *Biodiversity politics: Policy, planning and public understandings*. Unpublished PhD thesis, Trinity College Dublin.

Long, M. 2011. *Exclusion of large grazing animals: effects on biodiversity in three habitat types in a limestone landscape of high conservation value*. Provisional PhD thesis title,Trinity College Dublin.

O'Callaghan, E. 2008. *The diversity of aquatic macroinvertebrates in calcareous fen wetlands within an agricultural landscape.* Unpublished MSc thesis, National University of Ireland, Cork.

O'Mahoney, L. 2010. *The use of gastropod molluscs and vascular plants as indicators of the impact of cattle grazing on fens in Counties Clare and Galway, West Ireland*. Unpublished MSc thesis, National University of Ireland, Cork.

Rodríguez Tuñón, M.A. 2011. *Impact of field-based climate change simulations on ecosystems dominated by two invasive plant species,* Fallopia japonica *and* Pteridium aquilinum. Provisional PhD thesis title, University College Dublin.

Training

The BioChange project has trained seven PhD students, three MSc students, six postdoctoral researchers and one research assistant.

A BioChange summer school held in Carran, Co. Clare in June 2007 provided training for BioChange researchers on presentational and communication skills and hypothesis generation and experimental design.

A BioChange summer school hosted by the Institute for Urban Studies, University College Dublin in 2008 provided training for BioChange researchers in Geographical Information Systems.

A BioChange summer school in 2008 provided by Highland Statistics, Scotland, provided BioChange researchers with specialised training on the use of statistical methods for the analysis of biological data sets.

The hydro-acoustic surveys of Lough Doon Upper and lower in Sub-project 2.1 were undertaken in collaboration with a team from the Department of Applied Ecology, Lodz University, Poland. Mr J. Grennan, BioChange postgraduate student, undertook a one-month visit to that university to receive specialist training in zooplankton taxonomy.

Electronic Resources and Products

A GIS database has been prepared and submitted to the EPA via the EPA SAFER-Data archive. This database includes all the species data collected in all three sub-projects in geo-referenced format. This database will also be submitted to the National Biodiversity Data Centre.

An online database of alien plants) has been produced by Work Package 2, Sub-project 2 and will be available through the National Biodiversity Data Centre.

An interactive key and flora of the Burren and south-east Connemara was produced online and as a DVD by Cross-cutting Project 2.

An online database (www.species.ie) of seaweeds, flowering plants, birds, and marine vertebrates and invertebrates together with sources, references, distributional data and other information including a key to the Irish seaweed was created, and linked to available images.

Sites for Further Monitoring and Experimental Work

Several BioChange projects have defined or constructed experimental sites involving manipulations of ecosystems, or identified sites that are suitable for long-term monitoring. Baseline data have been assembled for all these sites, giving considerable added value to their inclusion in future research. We strongly recommend that these sites be utilised for future research, and that funding be made available to achieve this. The sites include:

- Wetlands for invertebrate monitoring (Work Package 1);

- Sites for pollinator abundance monitoring, especially important for baseline monitoring of bee abundance (Work Package 1);
- Grazing exclosures for experimental manipulation of grazing in grasslands, scrub and woodland (Work Package 1);
- Sites for monitoring the spread and impacts of zebra mussel infestation (Work Package 2);
- Intertidal sites for monitoring pollution (Work Package 3);
- Intertidal sites for monitoring growth and physiological responses of the alga *Ascophyllum nodosum* in response to harvesting and environmental change (Work Package 4).

Conference Oral Presentations

Atalah, J. and Crowe, T.P. 2006. Pollution as a driver of biodiversity change – impacts, indicators and long-term monitoring. 41st European Marine Biology Symposium. University College Cork.

Atalah, J. and Crowe, T.P. 2007. Pollution as a driver of biodiversity change – impacts, indicators and long-term monitoring. Environ 2007. Institute of Technology, Carlow.

Atalah, J. and Crowe, T.P. 2007. Pollution as a driver of biodiversity change – impacts, indicators and long-term monitoring. Marine Biological Association Postgraduate Workshop. University of Liverpool.

Atalah, J. and Crowe, T.P. 2007. Pollution as a driver of biodiversity change – impacts, indicators and long-term monitoring. Changes in aquatic ecosystems: natural and human influence. University of Plymouth.

Atalah, J. and Crowe, T.P. 2007. Pollution as a driver of biodiversity change – impacts, indicators and long-term monitoring. 42st European Marine Biology Symposium. IFM-GEOMAR, Kiel.

Cunningham, C., Brown, M.J.F. and Stout, J.C. 2008. Impact of landscape structure on pollinator diversity and pollination services. EURECO-GFOE 2008, proceedings; Verhandlungen der Gesellschaft für Ökologie, Band 38, 512.

Cunningham, C. 2009. How habitat loss contributes to the decline in pollinators. Trinity Science Speak. Science Gallery, Trinity College Dublin.

Davies, A. and Kavanagh, R. 2009. Challenges to public participation in biodiversity planning, three case studies from Co. Clare, Ireland. Annual meeting Society for Conservation Biology, Beijing, China.

Eschmann, C and Stengel, D. 2009. Natural resource exploitation and global change – the need for improved sustainable management to protect biodiversity (*Ascophyllum nodosum*). BioChange/Simbiosys meeting Galway.

Eschmann, C and Stengel, D. 2009. Effects of environment and impact of harvesting on different *Ascophyllum nodosum* populations. Postgraduate Ecology Forum, National University of Ireland, Galway.

Eschmann, C and Stengel, D. 2009. Effects of harvesting and predicted climate change on populations of the brown intertidal seaweed *Ascophyllum nodosum* in Ireland. Botanikertagung, Leipzig, Germany.

Fitch, J. and Crowe, T.P. 2009. Combined effects of inorganic nutrients and organic enrichment on littoral benthic macrofaunal communities: an experimental approach. 44th European Marine Biology Symposium, University of Liverpool.

Gittings, T., Harrison, S. and O'Halloran, J. 2009. Effects of habitat loss and fragmentation on the invertebrate biodiversity of remnant wetland habitats. Zoology, Ecology and Plant Science Seminar, University College Cork.

Gittings, T., Harrison, S. and O'Halloran, J. 2009. Effects of habitat loss and fragmentation on the invertebrate biodiversity of remnant wetland habitats. Sciomyzid and Syrphid workshop. National University of Ireland, Galway.

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Gittings, T., Harrison, S. and O'Halloran, J. 2009. Anthropogenic impacts and wetland invertebrate biodiversity. British Ecological Society Annual Meeting, University of Hertfordshire.

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Grennan, J., Higgins, T. and McCarthy, T.K. 2008. Effects of zebra mussels on ecological processes in Irish lakes. BioChange Annual Meeting, Kinvara. Co. Clare.

Grennan, J., Higgins, T. and McCarthy, T.K. 2007. Effects of zebra mussels on ecological processes in Irish lakes: Results of zebra mussel, eel and Anodonta surveys. BioChange Work Package 2 meeting, November 2007, National University of Ireland, Galway.

Grennan, J., Higgins, T. and McCarthy, T.K. 2007. A review of the distribution and ecological impacts of the zebra mussel (*Dreissena polymorpha*) in Ireland. The London Malacological Society Invasive Molluscs Conference, St Catherine's College, University of Cambridge.

Higgins, T., Grennan, J. and McCarthy, T.K. 2008. Zebra mussel-induced changes in phytoplankton community structure in a Co. Clare lake. 18th Environ Colloquium, Dundalk Institute of Technology.

Higgins, T., Grennan, J. and McCarthy, T.K. 2007. Effects of zebra mussels on ecological processes in Irish lakes: Water chemistry and phytoplankton. BioChange Work Package 2 meeting, November. 2007, National University of Ireland, Galway.

Higgins, T., Grennan, J. and McCarthy, T.K. 2007. Effects of zebra mussels (*Dreissena polymorpha*) on ecological processes in small Western Irish lakes. The London Malacological Society Invasive Molluscs Conference, St Catherine's College, University of Cambridge.

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Higgins, T., Grennan, J. and McCarthy, T.K. 2007. Assessing the effects of zebra mussels on the ecology of small Western Irish lakes. Meeting of the Western Region Zebra Mussel Control Initiative, Pontoon Bridge Hotel, Co. Mayo.

Kavanagh, R. and Davies, A. 2009. How the public become involved in biodiversity planning. Energy and Sustainability Public Lectures for Trinity Week, Trinity College Dublin.

Kavanagh, R. and Davies, A. 2008. Biodiversity politics and policy makers' understandings. 18th Environ Colloquium, Dundalk Institute of Technology.

Kavanagh, R. and Davies, A. 2008. Biodiversity politics and publics understandings. Conference of Irish Geographers, Liverpool.

Long, M.P. 2009. Long-term monitoring of the Irish farmed landscape – implications of land-use change. Trinity Week 2009 (www.tcd.ie/trinityweek/friday/).

Long, M.P. 2009. Effects of grazing cessation on plant and mollusc diversity in woodland and scrub habitats. British Ecological Society Monitoring Long-term Changes in British Woodlands Workshop, Cambridge.

Long, M. and Kelly, D.L. 2008. Grazing effects on plant and mollusc diversity in woodland and grassland habitats in north Clare and south Galway. Abstracts and Excursion Guides – 17th International Workshop, European Vegetation Survey. Milan Chytry (ed.) Masaryk University, Brno (www.sci.muni.cz/botany/chytry/EVS-Brno-2008-Abstracts.pdf).

Long, M.P. 2008. A study of mollusc diversity in woodland and grassland habitats in the west of Ireland. Royal Belgian Institute of Natural Sciences (RBINS), Brussels.

Long, M.P. (2007). Grazing effects on plant and mollusc diversity in woodland and grassland habitats in north Clare and south Galway. Postgraduate Ecology Forum, University College Dublin. (Received prize for best presentation.)

Milbau, A. and Stout, J.C. 2007. Predicting plant invasion – which taxa are the future invasive aliens? BioChange Annual General Meeting, Gort, Ireland.

Milbau, A. and Stout, J.C. 2007. What promotes successful plant invasion in Ireland? 17th Environ Colloquium, Carlow Institute of Technology.

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Milbau, A., Stout, J.C. and Nijs, I. 2007. Which traits promote successful establishment and spread? From native colonizers to alien invaders. Colonization versus invasion: Do the same traits matter? Ascona, Switzerland.

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Rodríguez Tuñón, M.A. and Osborne, B. 2009. Effects of invasive plant species on native biodiversity and the interaction with climate change. Environ, Ireland.

Waldren, S., Osborne, B. and Scally, L. 2010. The value of biodiversity and halting its decline in Ireland. EPA National Research Conference 2010, Dublin.

Poster Presentations

Eschmann, C. and Stengel, D. 2009. An evaluation of the effects of predicted climate change on *Ascophyllum nodosum*. Irish Plant Scientists' Association Meeting, Dublin.

Eschmann, C. and Stengel, D. 2008. An evaluation of the effects of predicted climate change on *Ascophyllum nodosum*. College of Science Research Day at National University of Ireland, Galway.

Eschmann, C. and Stengel, D. 2008. An evaluation of the effects of predicted climate change on *Ascophyllum nodosum*. Environmental Change Institute research day, National University of Ireland, Galway.

Grennan, J., Higgins, T. and McCarthy, T.K. 2008. Characterising the zebra mussel (*Dreissena polymorpha*, Pallas) population in Lough Doon, Co. Clare. Environ 2008, Dundalk Institute of Technology.

Grennan, J., Higgins, T. and McCarthy, T.K. 2008. Characterising the zebra mussel (*Dreissena polymorpha*, Pallas) population in Lough Doon, Co. Clare. Environmental Research Conference, Kilmainham, Dublin.

Long, M. and Kelly, D.L. 2007. Grazing effects on plant and mollusc diversity in woodland and grassland habitats in north Clare and south Galway. Irish Plant Scientists Association Meeting, University College Cork.

Long, M. and Kelly, D.L. 2007. Grazing effects on plant and mollusc diversity in woodland and grassland habitats in north Clare and south Galway. Conchological Society's Malacological Forum, Natural History Museum, London.

Long, M. and Kelly, D.L.. 2008. Grazing effects on plant and mollusc diversity in woodland and grassland habitats in north Clare and south Galway. Environmental Protection Agency Research Seminar.

Milbau, A. and Stout, J.C. 2006. Database of alien plants in Ireland. 4th European Conference of the working group NEOBIOTA on Biological Invasions, Vienna, Austria.

Rodríguez Tuñón, M.A. and Osborne, B. 2007. Effects of invasive plant species on native biodiversity and the interaction with climate change. Colonization versus Invasion: do the same traits matter? Ascona, Switzerland.

Rodríguez Tuñón, M.A. and Osborne, B. 2008. Effects of invasive plant species on native biodiversity and the interaction with climate change. Neobiota, 5th European Conference on Biological Invasions. Prague, Czech Republic.

Rodríguez Tuñón, M.A. and Osborne, B. 2008. Effects of invasive plant species on native biodiversity and the interaction with climate change. Climate Change and Systematics. Dublin.

Reports and Submissions to Policy Makers and Decision Makers

- Work Package 1 submission to the Clare Wetlands Survey.

  A submission was made to the Clare Wetlands Survey with details of 19 Co. Clare wetland sites surveyed in Sub-project 1 and another 20 Co. Clare wetland sites that were visited during site selection work. This information has been included in the *County Clare Wetland Survey* report published by Clare County Council in November 2008;

- Review of the integration of biodiversity related issues within the River Basin Management Plans.

  Results from BioChange Work Package 1, Sub-project 1, were used in a review of the integration of biodiversity/flora and fauna-related issues within the River Basin Management Plans;

- BioChange submission to the draft National Biodiversity Plan.

  A submission was made to the National Parks and Wildlife Service of the Department of the Environment, Heritage and Local Government by the BioChange project on the review of the National Biodiversity Plan 2008–2012;

- Two reference manuals: *Biodiversity – A Reference Manual* and *Recommendations for Educationalists Developing Curricula on Biodiversity and its Protection* have been produced by Cross-cutting Project 1. Both manuals have been disseminated to environmental non-governmental organisations, policy makers and interested individuals, providing a foundation for good practice in biodiversity communication.

Outreach

A number of participants in Work Package 1 appeared on an environmental programme (*EcoEye*) on national television to speak about the project and issues facing the Burren region.

A popular summary report on the results of Work Package 1, Sub-project 1 has been sent to all 104 landowners whose land was used and to other interested people.

Educational talks on pollinators were given to primary school children, courtesy of RDS (Royal Dublin Society) Science Live.

A number of site visits were made with both local and scientific groups to the permanent plots set up as part of Work Package 1, Sub-project 3.

An article on Work Package 1, Sub-project 3, has been published in the magazine *Burren Insight* (Summer/Autumn 2009).

A presentation on alien invasives was made as part of the Green Schools Initiative to St Anthony's Boys National School, Co. Wicklow by Work Package 2, Sub-project 1.

Workshops

A workshop on wetland conservation in Ireland presenting the results of Work Package 1, Sub-project 1 was held in January 2010. The workshop also included presentations from other wetland researchers to provide a wider perspective on wetland biodiversity and conservation in Ireland. This major output of the BioChange project provided information about the current state of knowledge of wetland biodiversity in Ireland to policy makers and provided a forum for scientists and policy makers to discuss requirements for wetland conservation (with particular reference to non-designated sites) and to identify information gaps.

A workshop for researchers and other interested stakeholders on the identification and control of invasive species was held in Trinity College Dublin in June 2009 as part of Work Package 2.

Associated Projects

Work Package 1, Sub-project 3, set up a number of ancillary projects that were focused on the permanent study plots and were complimentary to the work of the PhD project:

- The vegetation associated with anthills located in the Burren, Co. Clare (UREKA summer project, 2007);
- Assessing epiphytic lichens on hazel (*Corylus avellana* L.) in scrub and woodland habitats in the Burren, Co. Clare (MSc project, 2007);
- Soil characteristics in scrubland, woodland and grassland in the Burren region (UREKA summer project, 2008);
- Bryophyte diversity in three habitat types in the Burren region (MSc project, 2009; UREKA summer project, 2009).

Strategic Reviews

Two strategic reviews were undertaken as part of Work Package 3:

- D'Arcy, A. 2006. Desk study to review the current state of knowledge of actual and potential impacts of pollutants on Irish aquatic systems (with particular reference to Co. Clare) and to review the current status of potentially applicable bioindicators;
- O'Beirn, F. 2006. Review of impacts and indicators of pollution on marine biodiversity.

Appendix 4 Summary of Main Research Findings from BioChange

Work Package 1: Landscape Conservation – Loss and Fragmentation in a Habitat Mosaic

Sub-project 1.1: Effects of Habitat Loss and Fragmentation on the Biodiversity Maintenance Function of Remnant Wetland and Pond Habitats within Typical Irish Agricultural Landscapes

Small, isolated wetlands can have a high diversity of wetland and aquatic invertebrates, including habitat specialists and rare species.

No evidence was found of any relationship between wetland size or isolation and wetland invertebrate biodiversity. However, the structure of hoverfly and sciomyzid assemblages may be affected by historical amounts of wetland habitat in the landscape.

Other indicators of perceived habitat quality such as nature conservation designations, amount of habitat of recognised conservation importance and the degree of anthropogenic impact were not useful predictors of wetland invertebrate diversity.

Acid fens have distinct wetland invertebrate assemblages, but otherwise wetland invertebrate assemblages did not show strong relationships with habitat/vegetation composition or water chemistry. However, a strong relationship was found between water chemistry and the structure of macroinvertebrate assemblages of aquatic habitats.

Habitat isolation is not a major issue for wetland invertebrate biodiversity within the region of Co. Clare and south Galway that was studied. Further research would be required to establish whether this is true for other landscapes in Ireland and elsewhere in Europe.

Small, isolated wetlands often maintain high biodiversity. These sites are equally as worthy of conservation effort as the larger, more intact systems usually targeted for conservation action.

Sub-project 1.2: Habitat Mosaics and Biodiversity at the Landscape Scale

The levels of abundance, richness and diversity of pollinator taxa in an Irish agricultural landscape were dramatically lower than those seen in studies from central and western Europe, in both crop and pasture systems. While some of this may be due to differences in sampling protocols, and particularly wet weather during the sampling season of 2008, we believe that it does reflect the impact of the Irish climate on insects in general. This reduction in species richness, diversity and abundance suggests that the pollinator assemblage in Ireland is likely to exhibit lower redundancy and therefore less resilience to perturbation. Consequently, this enhances the need to understand the drivers of abundance, richness and diversity in this assemblage.

Despite the generally low species richness, rare and threatened species were found across the study sites. This suggests that the REPS (Rural Environment Protection Scheme) agri-environment scheme farms support rare pollinator species. However, in the absence of comparable data on non-REPS farms in the same area, it is unclear whether REPS supports a higher abundance or richness of rare species.

The significant positive relationships between floral resources and pollinator abundance, richness and diversity demonstrate that local-scale effects can have a significant impact on maintaining the pollinator assemblage. Consequently, schemes such as REPS, which lead to enhanced native wildflower provision, play an important role in supporting native pollinators.

At the landscape level, specific components of the habitat mosaic – e.g. hedgerows, semi-natural land and protected land – had a positive impact on the pollinator assemblage and pollination of one of the model plant species (foxgloves). Consequently, conservation and enhancement of these specific components within the broader landscape has a constructive role to play in maintaining Irish pollinators and the pollination services they provide.

Landscape diversity per se, at a range of spatial scales, had consistently positive effects on pollinator assemblages. Our results are the first to demonstrate that these effects still occur at the 5 km scale, extending the landscape that needs to be considered for managing pollinator assemblages. Despite these consistent effects, the exact relationships varied with pollinator taxa. Whilst the exact aspects of this diversity – e.g. structure and connectivity – remain unknown, this result argues for the maintenance of a diverse, heterogeneous landscape in agricultural areas, as opposed to the large-scale homogeneity favoured by increasing agricultural productivity.

Our results suggest that the local and landscape factors identified are likely to have similarly positive effects for other fauna. This will be particularly true for components that rely on pollinators for food (e.g. spiders and birds) or that have similar habitat requirements. While these correlations remain to be demonstrated, the relative ease with which pollinator assemblages can be quantified makes them an attractive group to use as an indicator of broader biodiversity.

We would suggest that managing the Irish pollinator assemblage requires consideration of local- and large-scale factors. Maximising wildflowers within agricultural landscapes and maximising landscape heterogeneity, particularly through the maintenance of semi-natural land and hedgerows, should lead to an increase in pollinator richness, abundance and diversity. This will, in turn, support the essential ecosystem service of pollination.

Sub-project 1.3: Effects of Grazing Cessation on Plant and Mollusc Diversity in Woodland, Scrub and Grassland Habitats, and the Effects of Habitat Fragmentation on Rare/Scarce Woodland Species

Removal of grazing animals has a significant impact on biodiversity. This impact is complex, however, and varies depending on the habitat being looked at, and the taxa being studied.

Cessation of grazing in Burren *grasslands* leads to a rapid and dramatic decrease in biodiversity, with the almost immediate loss of certain sensitive species

The effects of grazing removal in *scrub* are less clear-cut, but effects on grassy parts are likely to be very similar to those in grasslands. A longer timescale is needed to assess and quantify the rate of change in areas covered by pioneer scrub (i.e. *Corylus*) vegetation.

In *woodland* habitats, diversity increases on removal of grazers. This may be a short-term effect only, and longer-term study will be required to assess the effects satisfactorily.

Work Package 2: Non-native Species – Impacts on Biodiversity, Strategies for Management and Predictions of Future Invasions

Sub-project 2.1: Analysis of Effects of Zebra Mussels on Natural Community Composition in Co. Clare Lakes

Ongoing colonisation of small lakes in Co. Clare and Co. Galway by zebra mussels was noted, despite an active public awareness programme.

Surveys of 18 selected lakes revealed that, where present, densities of zebra mussels were still low to moderate by international standards, but the effects of zebra mussel filter feeding was significant in the pelagic zones of many lakes.

Reduced turbidity and reduced phytoplankton biomass were the most obvious effects of zebra mussels observed in the multi-lake survey.

An observed shift from particulate to soluble nutrient forms in infested lakes was interpreted as reflecting the coupled consumption and excretion by zebra mussels.

Analyses of lake zooplankton indicated that zebra mussels were associated with reductions in rotifer diversity and biomass, as well as reductions in populations of predatory Cladocera such as *Leptodora kindi* and larval Chaoboridae.

Zebra mussels were found to have resulted in severe declines in populations of unionid mussels *(Anodonta* spp.) and reductions in their growth rates.

An intensive study on two conjoined lake basins provided a greater understanding of the ecological processes affected by zebra mussels.

Little evidence of adverse effects of zebra mussels were noted in hydro-acoustic and direct sampling surveys of fish populations.

Sub-project 2.2: Effects of Invasive Plant Species on Native Biodiversity and the Interaction with Climate Change

For experimental sites invaded by the alien *Fallopia japonica*, there was a major reduction in plant species richness compared to uninvaded areas. In contrast, plant species richness was not affected by the presence of the native invader *Pteridium aquilinum* in the sites used.

The performance of *F. japonica* in experimental enclosures that passively increased temperature and water deficit suggests that this species may decrease in response to predicted climate change, whilst native vegetation showed no response to the combined impacts of reduced water availability and enhanced temperatures. If this is largely due to reduced water availability, similar responses may not be observed in all situations and would be dependent on rainfall and on substrate water-holding capacity.

Although rates of photosynthesis were consistent with the differences in biomass productivity, they were not directly related to the relative success of the two species, suggesting that photosynthesis per se may not be a good indicator of invasive plant species success under either current or future atmospheric conditions.

The current study showed changes in species composition over a short time scale, indicating that these may, under some circumstances, occur faster than often thought.

Contrary to expectations, however, microclimate alterations did reduce plant species richness in the *P. aquilinum* sites, both in invaded and in uninvaded plots, suggesting that climate change impacts under some circumstances can be rapid – in this case after two cycles of simulated warming and increased water deficits. Similarly, decomposition processes were altered in the *P. aquilinum* and *F. japonica* plots over the same time period, with the greatest impact in the *P. aquilinum* sites.

Sub-project 2.3: Predicting Plant Invasion – Which Taxa are the Future Invasive Aliens?

After species traits, attributes related to the invasion history, the native range and the ecology of the alien plant species were important predictors of the probability of these species becoming naturalised and, subsequently, invasive.

In comparison with studies that take only plant characteristics into account, our predictors explained a relatively high percentage of variance in the dependent variable for transitions from casual to naturalised and from naturalised to invasive, suggesting that a combination of species traits and non-specific traits is likely to produce the most accurate prediction of invasions.

Whereas the predictors related to native distribution and invasion might be important predictors for invasiveness worldwide, the significant species traits may be highly habitat dependent and/or only important for Ireland because of interacting climatic factors.

Work Package 3: Pollution as a Driver of Biodiversity Change – Impacts, Indicators and Long-term Monitoring

Variation in assemblages of molluscs corresponded well to variation in nutrient levels in a network of rocky intertidal sites. Components of intertidal molluscan assemblages have a good potential to serve as bioindicators. In the current study, neither variation in macroalgal assemblages nor Scope for Growth corresponded well with variation in nutrient levels.

On sedimentary shores, variation in macrofaunal assemblage structure was also associated with variation in levels of nutrients and organic matter, as well as sedimentary characteristics. No candidate bioindicator taxa emerged from analyses of these data. However, a number of metrics of environmental quality developed in sub-tidal benthic systems (e.g. AMBI, M-AMBI) were shown to be effective in intertidal systems, which are more accessible than sub-tidal systems and are perhaps more cost-effective target habitats for monitoring. These indices were sensitive to variation in a single taxon (*Capitella* spp.), which itself responded in complex ways to multiple stressors in experimental research, suggesting that current indices may be difficult to interpret and would benefit from further refinement.

Experimental research in rock pools and on sedimentary shores revealed complex interactions between multiple stressors (nutrients, sedimentation and loss of grazers in rock pools; nutrients and organic matter on sedimentary shores) in their effects on populations and communities. Many ecosystems are affected by

multiple stressors, and more experimental research is needed to characterise how effects of one stressor can be modified by the presence of others.

In lakes, new indices of environmental status were found to correlate well with nutrient levels. However, they lost explanatory power for eutrophication pressure in lakes that had been invaded by the zebra mussel *Dreissena polymorpha*. Again, these results highlight the need to consider the impacts of multiple stressors in developing tools for environmental monitoring and management.

BioChange has established several networks of sites of varying levels of environmental quality (particularly in terms of nutrient pollution). These sites, and the databases already available for them, can serve as valuable test beds for the development and ground truthing of cost-effective monitoring tools. They also provide opportunities for experimental research to establish causal links between stressors and reductions in environmental quality.

Work Package 4: Natural Resource Exploitation and Global Change – The Need for Improved Sustainable Management to Protect Biodiversity

Field measurements from four populations in Counties Clare and Galway suggest that productivity of the marine alga *Ascophyllum nodosum* exhibits strong seasonal fluctuations and spatial variability within and between shores. There was evidence that such variability could not exclusively be explained by local and seasonal environmental conditions in the field, but also by long-term population-specific adaptations.

Sensitivity to extreme environmental conditions under laboratory conditions confirmed the local adaptations of different species to different environmental pressures, suggesting there could be differential tolerances to future climate change scenarios.

Preliminary data suggest that recovery of *A. nodosum* after commercial harvesting was very slow. Population structure and biomass were significantly affected by the current practice of tri-annual harvesting regimes. This is likely to have significant impacts on other components of the *A. nodosum* habitats.

Preliminary data on seasonal productivity rates indicate a significant all-year-round contribution of *A. nodosum* to the coastal carbon budget. Biomass removal due to current harvesting practices has significant effects on local standing crops, vegetation cover and associated biodiversity, and also affects local carbon budgets.

Cross-cutting Project 1: Biodiversity Politics – Policy, Planning and Public Understanding

This research confirmed that decision making about the protection and enhancement of biodiversity is more than a purely scientific matter of identification and designation. A multiplicity of agencies, institutions and actors vie for space in negotiations about how international policy should be transposed into national and local governing environments. Equally, even when biodiversity policy has been established, and governing tools (such as platforms, plans and even officers) developed, biodiversity governance is fraught with conflicts. Most significantly, implementation and enforcement of biodiversity strategies, where multiple needs and interests collide, remain key sites of tension.

A groundswell of opinion indicates that good governance requires more inclusive frameworks for decision making that explicitly and transparently incorporate the views of the private and civil society sectors, as well as scientists and the public sector.

More transparent systems of governance do not mean that conflict will necessarily be removed, or even reduced, in the short term, but certainly those systems of governance will be more defensible.

In terms of public engagement there are certainly limits to awareness of scientific definitions and meanings of biodiversity, but this should not be conflated with a lack of knowledge or appreciation of local environments. Local people are often those most acutely aware of habitat destruction or species decline. Equally, the public involved in this research were intensely aware of the variety of values that biodiversity provides (in some cases they identified a greater range of values than stakeholders). That the wider demands of living in modern Ireland sometimes mean that their actions do not serve to protect or enhance those values is a common feature of environmental management. Indeed, the value–action gap, as it is commonly referred to, is often a rational, if not desirable, response to livelihood demands. Biodiversity governance certainly needs to face head-on the wider tensions presented by dominant patterns of economic development.

Cross-cutting Project 2: An Expandable Web-enabled Organism Inventory, Including Keys to the Vascular Flora of Co. Clare and the Aran Islands

This project delivered an interactive, publicly accessible, visually exciting, web-based inventory, with keys to the flowering plants and marine macroalgae of the Burren and the Aran Islands. The key is primarily directed at non-specialists and is made accessible via a new page on the species.ie website; the data set comprises 645 species and over 2800 images.

The project also developed a MySQL web-based database of 12,000 species of Irish living organisms. The database currently includes a preliminary set of reasonably complete data on seaweeds, flowering plants, birds and marine vertebrates and invertebrates, together with some sources, references, distributional data and other information. Incomplete entries include freshwater algae and terrestrial fungi and lichens. The database will eventually include conservation status, ecological preferences and taxonomy. It is hoped that these data will be of use to professional and amateur scientists and naturalists alike. It is intended eventually to provide information on a county-by-county basis for use by county environmental officers and by conservationists.

The accessible part of the database includes a Literature Module, a Glossary Module, a Genus Module, a Species Module, a Common Names Module, an interactive Taxonomy and Taxonomy Browser and an Images Module.

This project has demonstrated how essential biodiversity information – inventories and identification keys – can be provided to a variety of users in an effective and appealing format. There is an opportunity to make this biodiversity information more widely accessible through the use of mobile devices such as palmtops and smartphones.

Thematic Project: Species Distributions – Past, Present and Future

This project brought together researchers from a variety of different disciplines to develop a synergistic approach to future biodiversity research. The broad aim was to explore how past and present distributions could be used together with relevant ecological and physiological information to provide a framework for a future research programme to investigate the effect of climate change on species distributions.

The expert panel of researchers suggested some 30 taxa that would merit further detailed study. Information was collated on various aspects of the distribution, ecology and biogeography of these taxa. Gaps in knowledge were identified, and key research questions formulated.

Almost all taxa selected have interesting biogeographic distributions in relation to Ireland; many have a limited distribution in Ireland or in Europe, and most have particular ecological requirements, which may limit their distribution.

This suite of species will provide a particular Irish dimension to the response of biodiversity to climate change. This will be necessary if we are to develop robust national policies to fulfil our international commitments to reduce the rate of biodiversity loss in the near future.

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil agus Rialtais Áitiúil a dhéanann urraíocht uirthi.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail.
- Scardadh dramhuisce

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

NDP
National Development Plan 2007 - 2013

Science, Technology, Research and Innovation for the Environment (STRIVE) 2007-2013

The Science, Technology, Research and Innovation for the Environment (STRIVE) programme covers the period 2007 to 2013.

The programme comprises three key measures: Sustainable Development, Cleaner Production and Environmental Technologies, and A Healthy Environment; together with two supporting measures: EPA Environmental Research Centre (ERC) and Capacity & Capability Building. The seven principal thematic areas for the programme are Climate Change; Waste, Resource Management and Chemicals; Water Quality and the Aquatic Environment; Air Quality, Atmospheric Deposition and Noise; Impacts on Biodiversity; Soils and Land-use; and Socio-economic Considerations. In addition, other emerging issues will be addressed as the need arises.

The funding for the programme (approximately €100 million) comes from the Environmental Research Sub-Programme of the National Development Plan (NDP), the Inter-Departmental Committee for the Strategy for Science, Technology and Innovation (IDC-SSTI); and EPA core funding and co-funding by economic sectors.

The EPA has a statutory role to co-ordinate environmental research in Ireland and is organising and administering the STRIVE programme on behalf of the Department of the Environment, Heritage and Local Government.

epa
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An Ghníomhaireacht um Chaomhnú Comhshaoil

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