Rialtas na hÉireann
Government of Ireland

Biodiversity

Climate Change Sectoral Adaptation Plan

Prepared under the
National Adaptation Framework

Prepared by the Department of Culture, Heritage and the Gaeltacht

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**An Roinn Cultúir,
Oidhreachta agus Gaeltachta**
Department of Culture,
Heritage and the Gaeltacht

Cover image: Green Shieldbug (*Palomena prasina*) was confined to south of Dublin and Galway but has moved north in last few decades and now is found as far north as Belfast and Lough Neagh. (Photographer: Brian Nelson)

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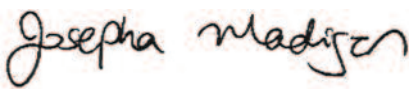
Minister's Foreword

Biodiversity provides us with clean air, water, food, materials, medicines and health benefits. It supports pollination and soil fertility, regulates climate and protects us from extreme weather and other impacts arising from climate change. Biodiversity contributes to health, wellbeing and sustainable development as set out in the United Nations Sustainable Development Goals. Despite the important role that biodiversity plays in underpinning our economy, health and resilience to climate change, we are losing biodiversity at a rate seen only during previous mass extinctions. By the end of the century, climate change is likely to become the most significant driver of biodiversity loss. Increases in temperature will change the timing of life cycle events and the distribution of species. The physical impact of more intense storms and increased winter/spring rainfall will accelerate the degradation of habitats that are already compromised by unsustainable practices.

The conservation and sustainable use of biodiversity needs to be escalated. Actions within this Biodiversity Sectoral Climate Change Adaptation Plan build on the foundations of the National Biodiversity Action Plan (2017-2021) and are aimed at improving sustainable agriculture and fisheries, better soil and land management and, most urgently, the restoration of natural systems. The Biodiversity Adaptation Plan also emphasises the need to consider biodiversity as an adaptation tool for other sectors. Investing in the restoration of ecosystems will have multiple additional co-benefits including water regulation, water purification and carbon sequestration.

The oversight of this plan will be led by my Department, however its implementation will require commitments and collaborations with many sectors, local authorities, business, academia and citizens. A consultation process consisting of workshops, seminars and online submissions has informed the development of this Plan, including coordination with other sectors, particularly those working on the other statutory adaptation plans.

This is a five-year Plan and it is a working, living document. Climate change adaptation is based on learning by doing and a flexible and reactive approach will be key to its success. The implementation of the Plan will be monitored and reviewed closely by my Department.



Josepha Madigan, T.D.
Minister for Culture, Heritage and the Gaeltacht

Executive Summary

Climate change is now affecting every country on every continent. It is disrupting national economies, affecting lives, and is a major and growing driver of biodiversity loss. Headline results from the 2018 Living Planet Report, published by the World Wildlife Fund, reveal that Earth is currently losing biodiversity at a rate seen only during mass extinctions. We are the first generation that has a clear picture of the value of nature and its integral link with human well-being. We are also the last generation that has the opportunity to prevent the collapse of our planet's biodiversity in the face of habitat destruction and climate change.

Irish biodiversity is vulnerable to the impacts of climate change but also has a key role to play in building adaptive capacity. The declaration of a climate change and biodiversity emergency by Dáil Éireann in May 2019 recognizes the urgency to act on these interconnected global crises. The Citizens Assembly on climate change, the report for the Joint Oireachtas Committee on Climate Action and the government's Climate Action Plan seek to address the emergency and increase Ireland's climate ambition. Climate change has major indirect impacts on Irish biodiversity through its interaction with other stressors, in particular habitat fragmentation and loss; over-exploitation; pollution of air, water and soil; and the spread of invasive species. This Biodiversity Sectoral Climate Change Adaptation Plan considers terrestrial, freshwater and marine biodiversity and ecosystem services. The purpose is to identify adaptation options that will help to protect biodiversity and ecosystem services from the impacts of changing climate and to enable ecosystems to play their role in increasing resilience to climate change.

The Goal of this Plan is to protect biodiversity from the impacts of climate change and to conserve and manage ecosystems so that they deliver services that increase the adaptive capacity of people and biodiversity while also contributing to climate change mitigation.

This Plan contributes to commitments made under the 2015 Climate Paris Agreement and is part of the statutory response to the Climate Act 2015. Furthermore, the Plan champions biodiversity's role and continued potential as a contributor to health, wellbeing and sustainable development, as set out in the Sustainable Development Goals.

The objectives set out in this plan are to:

1. Protect, restore and enhance biodiversity to increase the resilience of natural and human systems to climate change;
2. Improve understanding of the impacts of climate change on biodiversity;
3. Improve landscape connectivity to facilitate mobility in a changing climate;
4. Engage society and all sectors to protect biodiversity to enhance resilience;
5. Ensure sufficient financing is available to implement the Biodiversity Climate Change Adaptation Plan; and
6. Put adequate monitoring and evaluation measures in place to review the implementation of the Biodiversity Climate Change Adaptation Plan

It is important that all sectors recognise their role in reducing the pressures on biodiversity, protecting and restoring ecosystem services and contributing to adaptation measures to increase resilience to climate change. For example, the potential avenues for the spread of invasive species should be considered by the transport sector; local and national planning authorities should incorporate green infrastructure into future development plans; and authorities in agriculture, forestry and fisheries should continue to evaluate measures undertaken in government programmes to ensure no further degradation of biodiversity occurs. All sectoral and local adaptation plans should take account of this Plan and the actions that intersect with the decision making under their control. This responsibility is shared with the citizens of Ireland, state agencies, business, local authorities and all government departments.

1 Introduction

Many upland habitats regulate the flow of water and sequester carbon (Photographer: Jenni Roche)

"Biological diversity" or biodiversity means 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 (CBD Secretariat, 1992).

Biodiversity plays a key role in the functioning of *ecosystems*, their resilience and their continuing ability capacity to provide "*ecosystem services*" (Seddon *et al.*, 2016; Oliver *et al.*, 2015; Isbell *et al.*, 2015). Biodiversity provides us with, for example, clean air, water, food, materials, medicines, health benefits, and recreation. It supports pollination and soil fertility, regulates climate and protects us from extreme weather and other effects of climate change. It is these benefits that underpin our economy, health and wellbeing (IPBES, 2019; MEA 2005).

The scientific evidence indicates that the Earth's climate is changing (IPCC, 2014a) and, without taking appropriate and early action, climate change will have severe impacts on many of the planet's species and habitats and their capacity to provide adaptation and other benefits to people (COM, 2009; Scheffers *et al.*, 2016). The 2006 Stern Review emphasises that the benefits of strong early action on climate change outweigh the costs, and values the cost of inaction at 5% of global GDP each year indefinitely (Stern, 2006). However, the true monetary value of global biodiversity is not captured in this figure, or the financial implications incurred when ecosystems degrade so badly they cross critical thresholds, leading to habitat loss, loss of key ecosystem functions and the widespread proliferation of invasive species. Yet research into the value of ecosystem services reveals that eco-services contribute more than twice as much to human well-being as global gross domestic product

(GDP) (Constanza, *et al*., 2014) and greater investment into ecosystem services can increase resilience to climate change (TEEB, 2010).

A recent report by the Intergovernmental Panel on Climate Change (IPCC) indicates significant impacts to biodiversity and other sectors are set to occur even if we keep climate change to 1.5°C over preindustrial levels, which are below business-as-usual global average temperature increases by mid-century (IPCC, 2018). Headline results from the 2018 Living Planet Report, published by the World Wildlife Fund (WWF, 2018), reveal that Earth is losing biodiversity at a rate seen only during mass extinctions. The report finds that global losses in populations of vertebrate species - mammals, fish, birds, amphibians and reptiles - have averaged 60% between 1970 and 2014. Overexploitation of species, agriculture, land conversion, and climate change are the main drivers of biodiversity decline, with climate change becoming a growing threat.

The 2019 report from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reports similar findings to the WWF Living Planet report, highlighting the critical role of biodiversity and ecosystems functions and services for human well-being. However, the Earths ecosystems are deteriorating at a rapid rate, and only through 'transformative change' can nature be conserved, restored and used sustainably (IPBES, 2019). Transformative change should be understood as a fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms, goals and values (IPBES, 2019). It is also recognised that climate change is a major and growing driver of biodiversity loss, and that biodiversity and ecosystem functions and services, significantly contribute to climate change adaptation, mitigation and disaster risk reduction.

The Intergovernmental Panel on Climate Change's Special Report, Global Warming of 1.5°C, published in October 2018, confirmed that the international community has a limited window for real action to reduce emissions to ensure that current and future generations can live sustainably in a low-carbon and climate-resilient world. Ireland must be part of the global effort to reduce greenhouse gases by 45% by 2030 to be on track for net zero emissions by 2050, consistent with the 1.5°C goal.

Most recently, the IPCC 2019 Special Report on Climate Change and Land states with high confidence that increasing impacts on land, ecosystems and biodiversity are projected under all greenhouse gas emission scenarios with cascading risks occurring across systems and sectors (IPCC, 2019). It states with high confidence that near-term actions to promote sustainable land management will help reduce land and food-related vulnerabilities, provide both short-term positive economic returns and longer-term benefits for climate change adaptation and mitigation, biodiversity and enhance ecosystem functions and services.

1.1 Ireland's climate change policy

Ireland's national policy in response to climate change is the Climate Action and Low Carbon Development Act 2015. The Climate Act sets out a National Transition Objective with the goal of achieving a "low carbon, climate resilient and environmentally sustainable economy by the end of the year 2050" (Office of the Attorney General, 2015; DECLG, 2016). A Climate Resilient Ireland is a nation that is on a pathway to sustainable development. That is, climate resilient pathways are being actively pursued that reduce climate change and its impacts, manage risk, and promote sustainable development. This includes a coherent approach to adaptation and mitigation with effective institutions, governance, adequate resources, legal and regulatory frameworks, regular vulnerability assessments, climate action planning (national, sectoral and local level), access to information and strengthened adaptive capacity in place (EPA, 2018).

Box 1: Definition of adaptation, maladaptation and mitigation

To address the challenges and opportunities of climate change and the protection of biodiversity and ecosystem services two types of action are required: adaptation and mitigation. The Intergovernmental Panel on Climate Change (IPCC) define adaptation as "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2014a).

The IPCC define mitigation as "a human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs)", which is likely to be the dominant cause of the observed warming since the mid-20th century (IPCC, 2014a). Mitigation is not the focus of this plan but it is recognised that there are many synergies between mitigation and adaptation actions. For example, important land management decisions may exacerbate or reduce GHGs and some actions proposed may contribute to mitigation. Meanwhile, efforts to protect ecosystems from the effects of climate change may enhance the capacity of the land to provide adaptation benefits to people (European Commission, 2013c).

Maladaptation is defined by the IPCC as "a negative outcome that arises not only from inadvertent badly planned adaptation actions, but also from a deliberate decision where wider considerations place greater emphasis on short-term outcomes ahead of longer-term threats, or that discount, or fail to consider, the full range of interactions arising from the planned actions" (Noble *et al.*, 2014). For example, afforestation schemes that plant monoculture non-native species impact negatively on native biodiversity, increase the risk disease and pest damage and compromise carbon storage as they are less resilient to the impacts of climate change (and so more vulnerable to damage from climate events) than heterogeneous, connected and diverse forest habitats (Seddon, 2019).

The 2015 Act includes the development of a National Mitigation Plan and the submission of iterative National Adaptation Frameworks (NAFs). The National Mitigation Plan published in 2017 recognises the role of biodiversity in carbon sequestration and contains actions related to land management and biodiversity to maximise carbon storage (DCCAE, 2017). Under the statutory National Adaptation Framework (NAF) Government Departments have to prepare Sectoral Adaptation Plans (DCCAE, 2018a). The Adaptation Framework builds on the earlier non-statutory National Climate Change Adaptation Framework of 2012 (DECLG, 2012). Twelve sectors including Biodiversity have been selected for consideration. While biodiversity is included as a sector (along with health, water quality, transport, infrastructure and electricity and gas networks) it does not fit neatly into sectoral bounds. Biodiversity is a cross-cutting issue with implications for all sectors and all levels of decision making. Actions in this Plan are thereby informed by, and intersect with, the Sectoral and Local Adaptation Plans (final plans to be submitted by September 30th 2019). The Climate Change Advisory Council note, in their annual 2019 review, that although biodiversity and health do not fit neatly into sectoral bounds, this does not diminish the responsibilities of Ministers (preparing plans under the Climate Act and Framework) to consider what actions they can put in place to increase Ireland's overall climate resilience (p101, CCAC, 2019).

Furthermore, the 2019 Climate Action Plan recalls the statutory obligations related to adaptation in the Climate Act and creates a new mandate for

government departments to develop decarbonisation strategies which will complement these adaptation plans. It states that 'Climate proofing' Ireland is a collective responsibility for which every member of Irish society is responsible' (p145, Government of Ireland, 2019).

All this is in the context of the National Planning Framework and Project Ireland 2040, which is the Government's strategic plan for the development of Ireland, guiding public and private investment, 'to create and promote opportunities for our people, and to protect and enhance our environment - from our villages to our cities, and everything around and in between' (Government of Ireland, 2018; page 10). By 2040 there will be an additional one million people living in Ireland (ESRI, 2017) and this will undoubtedly increase pressures on biodiversity. Identification of investments that protect biodiversity, while increasing resilience, reducing emissions and benefiting the growing population will be key.

The science is clear that climate change will exacerbate the threat facing biodiversity. Furthermore, biodiversity is highly vulnerable to the impacts of climate change. A stakeholder survey carried out in 2013 ranked biodiversity and agriculture as the economic sectors most vulnerable to climate change (Coll and Sweeney, 2013). It is also well documented that degraded habitats are less resilient to the impact of climate change and are less able to provide the ecosystem services humans need to survive. Ireland is committed to safeguarding biodiversity – under the Convention on Biological Diversity (CBD) and the Sustainable Development Goals (SDGs) – and is required to do so under European and national law. Biodiversity needs to be safeguarded against climate change and in turn can increase our resilience to the impacts of climate change (e.g. healthy dune systems give protection from increased storminess and well vegetated uplands reduce the risk of soil erosion and landslides following intense rainfall).

Due to the cross-cutting nature of biodiversity it is vital that all sectoral and local adaptation plans:

1) Emphasise the importance of natural capital, including biodiversity, to resilience building in all sectors;
2) Systematically evaluate and implement (where viable) nature-based adaptation actions that increase resilience and capture mitigation benefits, where applicable.

Therefore ownership of this plan must be shared with the citizens of Ireland, state agencies, local authorities and all government departments.

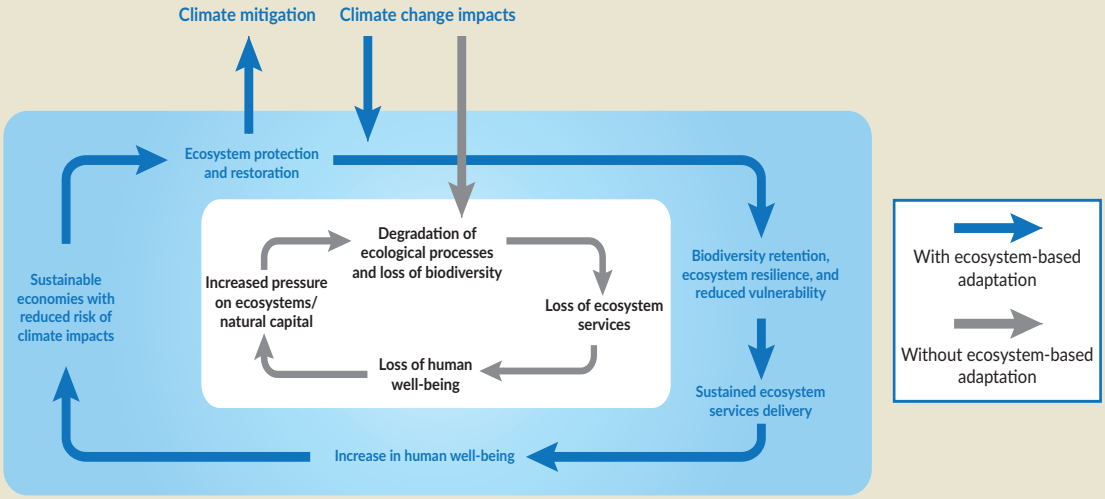
The Goal of this Plan is to protect biodiversity from the impacts of climate change and to conserve and manage ecosystems so that they deliver services that increase the adaptive capacity of people and biodiversity while also contributing to climate change mitigation.

Box 2: Adapting to climate change

Options to reduce the vulnerability of biodiversity to the adverse impacts of climate change can be grouped as:

1. Actions to help species and ecosystems adapt to specific climate change impacts, such as reducing habitat fragmentation, maintaining genetic diversity, assisting migration (translocation) and manipulating disturbance regimes; and
2. Ecosystem-based approaches (EbA) to adaptation, which refer to the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. Such approaches include: management and establishment of protected areas and conservation agreements, coastal and wetland maintenance and restoration, adaptive forest management, the use of agro-ecosystems in farming systems, ecotourism activities and direct species management (CBD Secretariat, 2016).

The Figure below illustrates how EbA uses the capacity of nature to buffer human systems from the negative impacts of climate change (IPCC, 2014b). Maintaining ecosystem resilience helps to reduce the vulnerability of ecosystems by increasing their ability to adapt to changes. Integrated approaches to ecosystem management are a key feature of many EbA projects. They can contribute to the ability of EbA to deliver additional social and environmental benefits. Further, where the value of ecosystem services have been recognized, EbA is often a cost effective response to many climate change challenges (CBD Secretariat, 2016).



Ecosystem-based adaptation uses the capacity of nature to buffer human systems from the adverse impacts of climate change. Source: IPCC, 2014b.

Ecosystem conservation, restoration and management can contribute to climate change mitigation in addition to adaptation, biodiversity conservation and sustainable development. For example, increasing carbon storage through the restoration of degraded peatlands and grasslands, which also helps control flood waters (Dadson *et al.*, 2017). Further, as mitigation reduces the rate and magnitude of warming, it increases the time available for climate change adaptation (CBD Secretariat, 2016).

1.2 Developing this Plan

Development of this sectoral plan responds to the statutory requirements of the Climate Act 2015 and follows the stepwise methodology proposed in the Sectoral Guidelines for Climate Change Adaptation published by DCCAE in May 2018. The five-step process set out in the Guidelines has guided the development of this Plan (DCCAE, 2018b):

1. Building the adaptation team
2. Assessing the adaptation baseline
3. Assessing future climate risk
4. Identifying, assessing and prioritising adaptation options
5. Implementation, Monitoring and Review

At the outset of any adaptation planning process it is important to ensure that the foundations for designing and delivering an effective adaptation planning process are established. With this in mind a Sectoral Adaptation Planning Team that comprises of a Core Team and a Planning Team was established by the National Parks & Wildlife Service (NPWS) within the Department of Culture, Heritage and the Gaeltacht to ensure that a broad spectrum of relevant knowledge, know-how and technical expertise was considered in the development of this Plan.

The Core Team

The Core Team was responsible for overseeing, coordinating and advocating climate change adaptation from planning through to implementation and beyond. The Core Team established to draft the Biodiversity Climate Change Adaptation Plan consisted of Dr Deirdre Lynn, Dr Shane Regan, Dr Andy Bleasdale and Dr Ciaran O'Keeffe of the NPWS. NPWS brought in consultancy support for the development of the first draft of the Sectoral Adaptation Plan, Dr Eugenie Regan with academic assistance from Dr Alison Donnelly and Prof Nathalie Seddon. Dr Tara Shine, environment and development consultant, assisted by Dr Stephen Flood, Research Scientist at Centre for Marine and Renewable Energy at University College Cork were engaged to support the development of the consultation draft and final version of this Plan, as well as the facilitation of the stakeholder workshop and the consultation process.

Key responsibilities of the Core Team were:

- Identifying stakeholders and assembling the Planning Team;
- Developing the plan to engage and involve stakeholders, including identifying their specific roles and supporting capacity building;
- Communicating goals and parameters;
- Creating working groups and designating leaders;
- Establishing roles and responsibilities and defining expectations;
- Setting a schedule and managing the process.

The Planning Team

The first task of the Core Team was to establish a Planning Team representing a wide variety of partners, sectoral interests and activities. These partners provide technical know-how and information, and expertise on applying the science to decipher the sensitives within the sector. The Planning Team consisted of the Irish Biodiversity Forum (Appendix IV) and the Irish Biodiversity Working Group (Appendix V).

Developing understanding, engagement and collaboration

An integral component of any sectoral climate change adaptation plan is the development of shared understanding of climate change and the creation of an overall vision/goal for adaptation. It was important to communicate a common understanding of the adaptation planning process and communicate process goals and parameters to stakeholders. In developing the Biodiversity Climate Change Adaptation Plan this shared understanding was facilitated by holding a stakeholder workshop that provided feedback on the initial draft plan (see Appendix II for workshop participants and Appendix III for workshop agenda).

Other inputs include a survey to collect information on the impacts of extreme weather events on Irish biodiversity which was sourced from National Parks and Wildlife Conservation Rangers and Divisional Ecologists, and Irish Academics.

A draft Plan was published for consultation in February 2019 and 13 responses were received. The consultation process also included a parallel session on planning for climate change adaptation at the 2019 National Biodiversity Conference, where the draft Plan was presented to c 180 delegates. Inputs

including priority actions for the Plan were collected from participants. The session maximised the information collected from participants through an interactive format and the use of Slido, an audience interaction tool that allows people to submit their comments online during the event (Figure 1). Finally, inputs received from the Climate Change Advisory Council and were addressed in the final version of the report.

Workshop participants, the Planning Team, members of the Biodiversity Working Group, the National Climate Change Steering Committee, the Climate Change Advisory Council and other identified stakeholders provided feedback that helped to shape this Plan and prioritise the adaptation actions, with a conscious effort to capture and maximise cross-sectoral linkages. Consultation drafts of the sectoral plans that were available at the time of writing were consulted as were a number of the local authority adaption plans.

The next section in this Plan provides a background to Irish biodiversity, including biodiversity policy in the context of climate change.

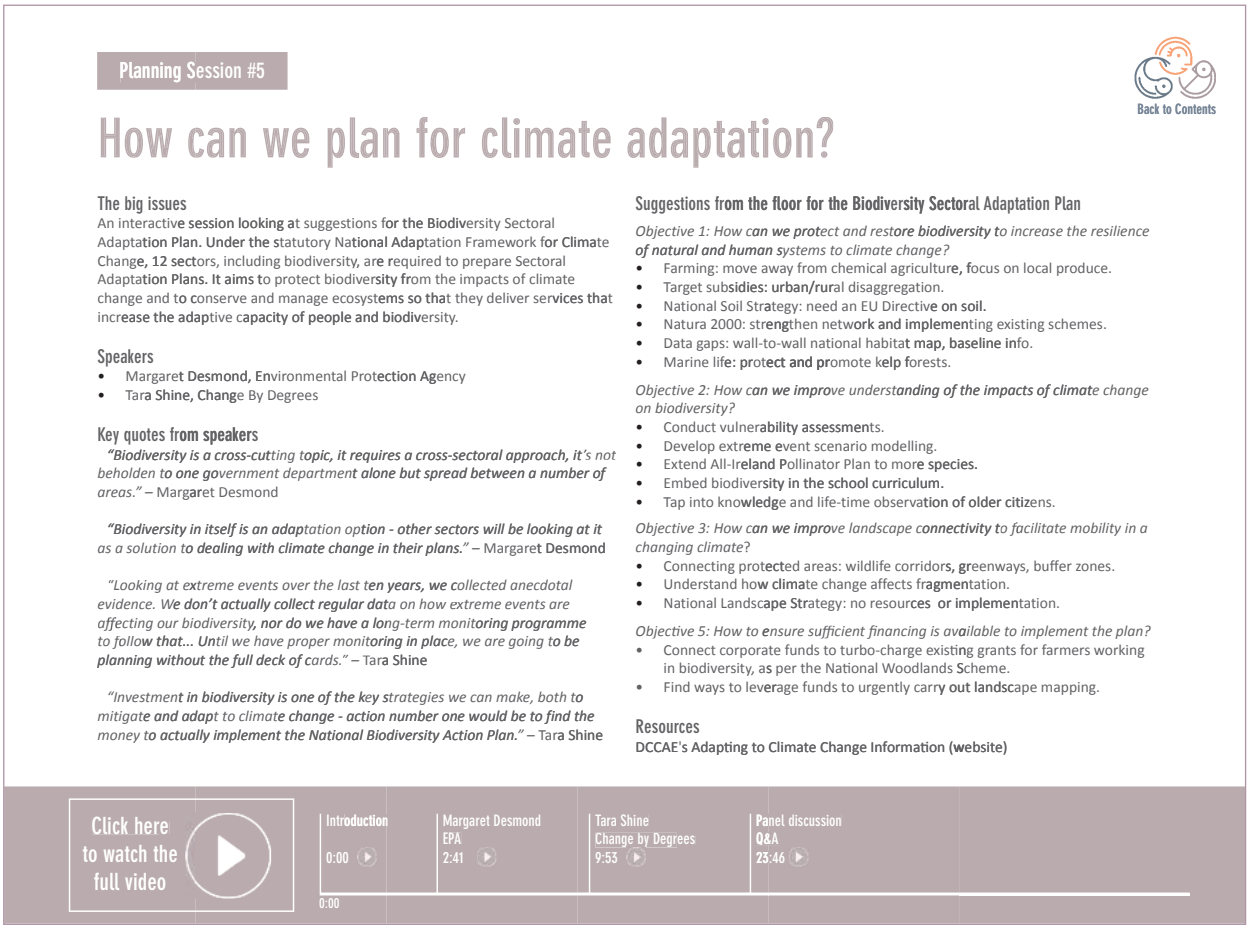


Figure 1. National Biodiversity Conference 2019: Consultation on the draft Biodiversity Sectoral Climate Change Adaptation Plan (DCHG/IFNC, 2019).

2 Ireland's Biodiversity and Climate Change

2.1 Ireland's biodiversity

Ireland's biodiversity has an intrinsic value and also contributes at least €2.6 billion each year to the Irish economy through the ecosystem services it provides (Bullock, *et al.*, 2008).

Marine, freshwater, and terrestrial habitats

Ireland's terrestrial, freshwater and marine environment encompasses a diverse range of habitats (NPWS, 2019). Habitats such as limestone pavements, turloughs, active peatlands, species-rich grasslands, offshore reefs and intact dune and machair systems are of particular significance because of their scarcity in both Ireland and/or the rest of Europe.

Ireland is required to monitor habitats and species that are considered threatened across Europe and are listed in the Habitats Directive (92/43/EEC). Figure 2 shows the current status and trends of Ireland's 59 habitats protected under the EU Habitats Directive (NPWS, 2019). Only 15% of habitats assessed have a 'favourable' conservation status, although the condition of 55% of habitats is either 'improving' or 'stable'. The habitats of greatest concern are those that have reduced range and/or area, such as raised bogs and species-rich grasslands (NPWS, 2019). Agricultural practices such as ecologically unsuitable grazing regimes and pollution were reported as impacting over 70% of habitats. Although climate change was only reported as currently negatively impacting sea cliffs, imminent impacts were reported for a further 10 habitats.

Due to its climate and topography, aquatic and wetland habitats are well represented in Ireland. As a consequence, Ireland supports internationally significant populations of several aquatic species such as the otter (*Lutra lutra*), Atlantic salmon (*Salmo salar*), freshwater pearl mussel (*Margaritifera margaritifera*), white-clawed crayfish (*Austropotamobius pallipes*) and some endemics including the amphipod (*crustacean*) Niphargus wexfordensis, Killarney shad (*Alosa fallax killarnensis*) and pollan (*Coregonus autumnalis pollan*) (DCHG, 2014). Ireland is also relatively rich in bryophytes, algae and lichens (DCHG, 2014).

Most of Ireland's known species are invertebrates totalling over 19,000 species (Ferriss *et al.*, 2009). Ireland maintains important populations of certain butterfly species, for example, the wood white (*Leptidea sinapsis*) and the marsh fritillary (*Euphydryas aurinia*), which is protected under the EU Habitats Directive (NPWS, 2019). Figure 3 shows the current status and trends of Ireland's species protected under the EU Habitats Directive (NPWS, 2019). Fifty-seven percent of species assessed have a 'favourable' conservation status and the condition of 72% of species is 'improving' or 'stable'. Climate change was reported as currently impacting 4 fish species.

A total of 211 species of birds breed in Ireland. These species mainly comprise common and widespread birds that have adapted to agricultural landscapes (BirdWatch Ireland, 2012; Birdlife International, 2017).

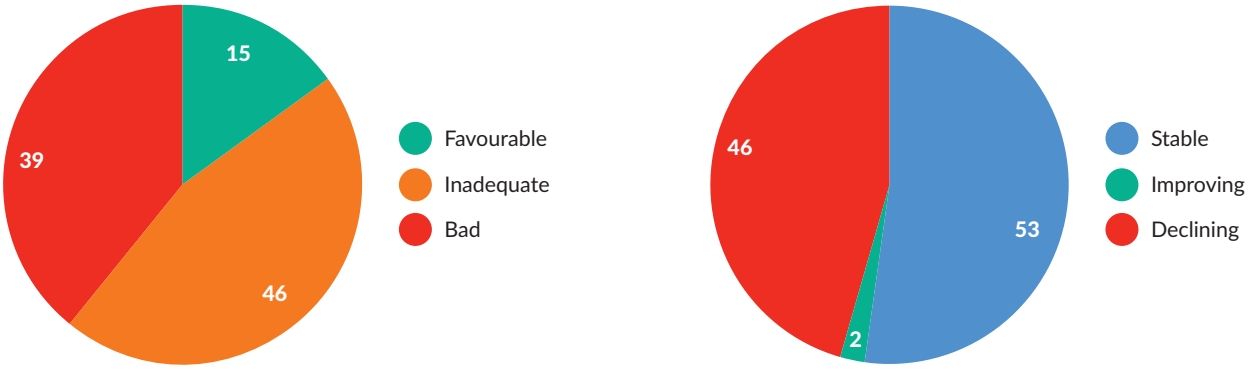


Figure 2. a) Percentage of habitats in Favourable, Unfavourable-Inadequate or Unfavourable-Bad condition b) Percentage of habitats with Stable, Improving or Declining trends. n=59 for 2019.

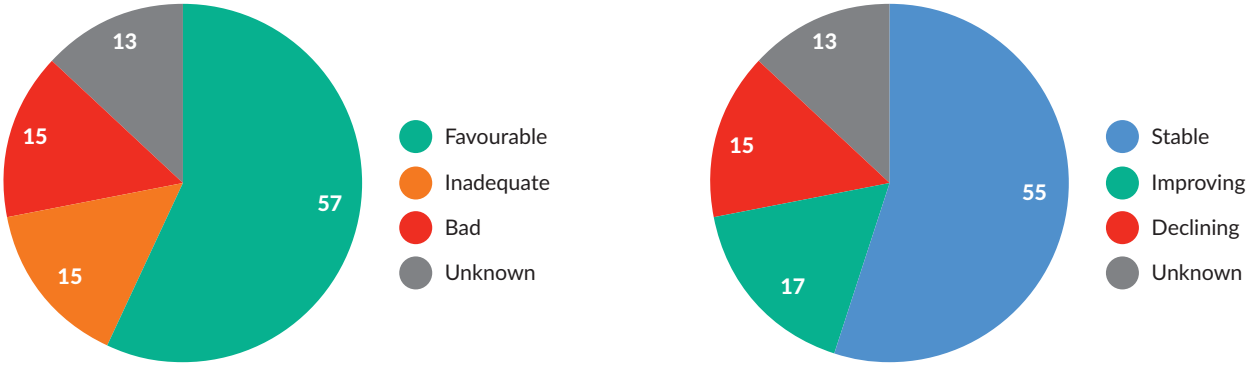


Figure 3. a) Percentage of species in Favourable, Inadequate or Bad condition. b) Percentage of species with Stable, Improving or Declining trends. n=60 for 2019.

Ireland is also required to report on the progress made with the implementation of the Birds Directive (2009/147/EC). Ireland reported to the EU on the long-term trends of Ireland's breeding and a selection of wintering bird populations for the period 2013 - 2018 (EEA, unpublished data/in prep). It found that 20% of breeding bird populations and 21% of wintering bird populations were either 'increasing or 'stable'. However, the trend in a large proportion of breeding and wintering bird populations could not be assessed and were recorded as 'unknown' (57% and 67% respectively). Short term assessments were also undertaken for both breeding and a selection of wintering populations and respective declines of 18% and 52% were recorded.

2.2. Biodiversity policy in the context of Climate Change

As a Party to the UN Convention on Biological Diversity (CBD), Ireland must report on its progress towards implementation of the Strategic Plan for Biodiversity 2011-2020, which seeks to "take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication" (CBD Secretariat, 2010). The Strategic Plan outlines 20 Aichi Targets, with Target 15 focusing on climate change. It states "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". Ireland's 6th National Report to the Convention on Biological Diversity was submitted in 2019 (DCHG, 2019), which reported on progress with achieving national and global targets.

The EU Biodiversity Strategy to 2020 reflects the commitments made in the global Strategic Plan and aims to halt the loss of biodiversity and ecosystem services in the EU and help stop global biodiversity loss by 2020 (European Commission, 2011).

National Biodiversity Strategies and Action Plans are the principal instruments for implementing the CBD at the national level. Figure 3 illustrates biodiversity policies from the global to national scales. Climate change is a pressure that is already impacting on habitat and species in Ireland and as a result it is cross-cutting with many of the objectives, targets and actions of Ireland's National Biodiversity Action Plan 2017-2021. As our understanding of climate change risks and impacts increases more actions can be integrated into future updates of Ireland's NBAP.

As a Party to the United Nations Framework Convention on Climate Change (UNFCCC) Ireland has committed to "promoting sustainable management, and to promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems" (UNFCCC Secretariat, 1992). In December 2015 countries adopted the first-ever universal, legally binding global climate deal - the Paris Agreement. It aims to strengthen the global response to the threat of climate change by limiting global temperature rise this century to less than 2 degrees Celsius and to pursue 1.5 degrees Celsius. In their efforts to limit global temperature rise Parties must "note the

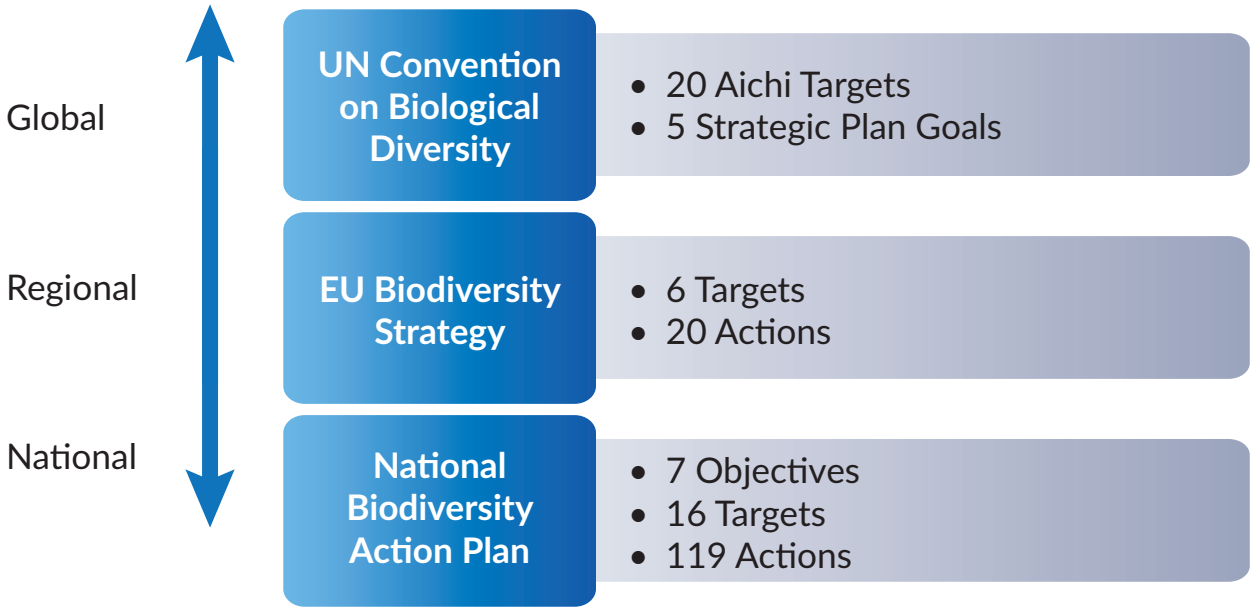


Figure 4. Biodiversity policies from a national to global scale. These policies set out the goals and planned activities at the national, regional, and global scales and are often achieved through institutional and legal frameworks such as the EU's Habitats Directive and Ireland's Wildlife Act.

importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity" (UNFCCC Secretariat, 2015).

The Paris Agreement addresses adaptation, with the aim of "enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal" (Article 7.1). The agreement calls on its parties to pursue actions "on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty" (Article 4.1). There is growing awareness amongst policy makers and practitioners that strategic conservation of biodiversity and ecosystem services can strengthen human resilience and reduce vulnerability to climate change, so-called "ecosystem-based adaptation" (EbA). Therefore, to meet commitments mandated under the Paris Agreement, Ireland will need to scale-up the conservation and restoration of biodiversity and ecosystem services within the context of adaptation.

Biodiversity features within the SDG framework as Goal 15 (protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss), and is implicit in Goal 14 (conserve and sustainably use the oceans, seas and marine resources for sustainable development). Furthermore, the conservation and restoration of biodiversity and ecosystems is fundamental to meeting many other societal goals including food security (Goal 2), water security (Goal 6), mitigation and adaptation to climate change (Goal 13) and livelihood diversification (Goal 8).

The 2013 EU Strategy on Adaptation acknowledges that the impacts of climate change are accelerating the decline of biodiversity and reducing its ability to buffer natural extremes (European Commission, 2013a). It also acknowledges that climate change adaptation concerns for biodiversity have been mainstreamed into existing European legislation through the EU Biodiversity Strategy (European Commission, 2011).

In November 2018, the European Commission published an evaluation of the EU strategy on Adaptation (European Commission, 2019). One of the principle findings was that adaptation must support and be supported by the protection of the

EU's biodiversity through nature-based solutions and green adaptation actions.

In May 2019, when endorsing the report of the Joint Oireachtas Committee on Climate Action (Government of Ireland, 2019), Dáil Éireann declared a climate and biodiversity emergency. The 2019 Climate Action Plan acknowledges the important role of biodiversity. Specifically, in relation to agriculture the Climate Action Plan "supports the diversification of agriculture and land use to develop sustainable and circular value chains … (that) enhance biodiversity and water quality" (p12, Government of Ireland, 2019). Agriculture and Land use are also linked with biodiversity by the Climate Change Advisory Council in their 2019 report, where the co-benefits of hedgerow planting are highlighted (p83, CCAC, 2019). Under Rural Environment Protection Schemes they note that while support for new hedgerow planting is primarily addressed at supporting biodiversity and natural heritage, new hedgerows are also effective at carbon sequestration to biomass and soils.

The Action Plan also acknowledges the value of sustainable communities "integrating ecology and biodiversity" (p45, Government of Ireland, 2019). Furthermore, the Action Plan supports focusing funding on climate action including on biodiversity as linked with the next EU Common Agricultural Policy (CAP), where 40% of the overall CAP budget will contribute to environmental or climate action. The Action Plan notes that once the CAP negotiations are completed, they will be implemented in Ireland through the development of a strategic plan (for the period 2021 to 2027). In developing this strategic plan, "in close consultation with stakeholders through a new Consultative Committee, the Department of Agriculture, Food and the Marine will mainstream climate action opportunities which optimise synergies for the delivery of environmental benefits in the areas of climate, water and biodiversity" (p109, Government of Ireland, 2019).

Biodiversity is mentioned further in relation to engagement, capacity building and local action, specifically in connection with the Green Schools scheme. An enhanced Green Schools programme will specifically discuss "planting for biodiversity" as linked with climate action (p137, Government of Ireland, 2019). The Climate Change Advisory Council also highlight the role of citizen engagement and just transition, focusing on Bord na Móna's Eco-Rangers schools programme that teaches students about the biodiversity in wetlands and the role of the next generation in re-establishing peatlands places of ecological importance rather than sources of combustible energy (p53, CCAC, 2019).

The Climate Change Advisory Council's 2019 report acknowledges multiple co-benefits within the Agriculture, Forestry and Land Use sector both advance climate action and protect and enhance biodiversity (CCAC, 2019). The CCAC also notes, under longer-term actions, that a reduction in the national herd is necessary to significantly help combat localised environmental degradation, for example reducing ammonia emissions and improving water quality and biodiversity (p116, CCAC, 2019). Furthermore, extensification, a potential means of achieving national herd reductions, could be encouraged by linking part of the Common Agricultural Policy payments to stocking limits of maximum nitrogen fertilizer applications per hectare as well as management of biodiversity habitats (p117, CCAC, 2019).

The CCAC also welcomes the Department of Public Expenditure and Reform's introduction of 'Green Budgeting' in Budget 2019. This process has begun with estimates of 'climate-related Exchequer expenditure' defined as: 'Any expenditure which promotes, in whole or part and whether directly or indirectly, Ireland's transition to a low carbon, climate-resilient and environmentally sustainable economy' (p61, CCAC, 2019). However, the CCAC suggests that a more refined definition may lead to a more targeted approach in spending as 'Green Budgeting' as currently framed casts to wide a net. Tagging of biodiversity expenditure following the international methodologies used by Morrison and Bullock (2018) could be considered.

Dog's Bay, Galway following Storm Darwin 2014.
Photographer Karen Gaynor

3 Current and future climate impacts

In order to plan for the consequences of changes and impacts on Ireland's biodiversity it is essential to assess the current and future vulnerability of biodiversity to climate change.

3.1. Screening for current climate impacts

In screening for sectoral vulnerability and consequences of current climate impacts on biodiversity the methodologies require the Core Team in conjunction with the Planning Team to identify past weather events and periods of climate variability that have had an impact on Irish biodiversity. Specifically, this task entails providing an overview of an impact (accounting for the exposure, sensitivity and adaptive capacity) and outlining the consequences of these changes on Irish biodiversity. This exercise is carried out with reference to a relevant weather event, or period of climate variability or change. If possible, this exercise also provides an estimate of the magnitude of the impact in terms of social, environmental and economic impact.

Identifying past weather events, periods of climate variability and change that have impacted upon biodiversity

As referenced above (Section 1.2) an exercise in the identification of past extreme weather events and their impact on Irish biodiversity was carried out through an online request issued by the NPWS to 182 NPWS staff, 6 Environmental NGOS, 4 academics, and 1 ecological consultancy. Full results of this information request are presented in Appendix VI. In summary, the results present qualitative details on a series of extreme events from a ten-year period from 2008 to 2018 (Figure 5). In addition to the date of occurrence and event name (if a named storm), each record includes a brief description of the main climatological features (such as precipitation, wind and temperature extremes) along with observed impacts on habitats and species, the impacts the event had on capacity to carry out work (and associated impacts on operations, resources and infrastructure) as well as the source of the particular observed impact/s. Over 90 impacts (either directly on habitats or on provision of services) are listed in the complete table.

Identifying magnitude of impact

Ideally the magnitude of impact on the sector under consideration is listed under the categories of environmental, economic and social. In the impacts of extreme weather events examples (Appendix VI) respondents have primarily indicated qualitative environmental impacts. Qualitative social and economic impacts are captured though reported work days lost as a result of winter storms, and inability to access nature sites. These qualitative data can form a basis for the development of quantitative impacts through delving deeper into impact specifics such as number of days lost, impact on nature site species and potential irrecoverable loss of habits as associated economic and social costs.

3.2. Observed impacts of climate change on biodiversity

There is consensus among scientists globally that climate change has direct and indirect effects on biodiversity (Table 1) and that by the end of the century it is likely to become one of the most significant drivers of biodiversity loss (CBD Secretariat, 2016; Segan et al., 2016). There is clear evidence to show that biodiversity is already responding to climate change and will continue to do so. An average warming of ~1°C, has documented impacts across every ecosystem on Earth (Scheffers *et al.*, 2016). These impacts have been recorded at different levels of biological organisation from genes, to communities to ecosystems. Of the 94 identified ecological processes, across terrestrial, marine and freshwater ecosystems, that underpin ecosystem functioning and support services to people, 82% showed evidence of impact from climate change (Scheffers *et al.*, 2016).

The main observable direct impacts of climate change on species and communities are changes in phenology, species abundance and distribution, community composition, habitat structure and ecosystem processes. Although such impacts have been documented in many species and habitats, there remains great uncertainty about the timeframes over which these impacts will unfold across whole biological communities. Some biological responses will be rapid, others may take decades to materialise. Species respond to changes in their environment in their own individual ways. Some species may be able to move if local conditions become unsuitable.

Evolutionary change and adaptation, however, is thought to occur more slowly than current and predicted rates of climate change (Hoffman & Sgro, 2011). This means that if species do not have the capacity to move at the rate dictated by climate change (due to poor dispersal capacity or an impermeable landscape) then they will go locally extinct. Variation in rates of movement and extinction can result in the decoupling of present day interactions between species and the disassembly of communities. It can also result in the creation of novel communities, which may not be stable or able to provide ecosystem services.

Temperature plays a key role in the timing of phenological processes in the annual cycle of plant species, such as the start of the growing season and the timing of fruit set. Shifts in the annual cycle of organisms can lead to mismatches in the interactions between species, for example in the relations between predators and their prey and between plants and their pollinators, which can cause structural changes in the functioning of ecosystems (Ockendon *et al.*, 2014). An ecosystem consists of relations between species in various functional groups. A functional group consists of species that perform more or less the same function in an

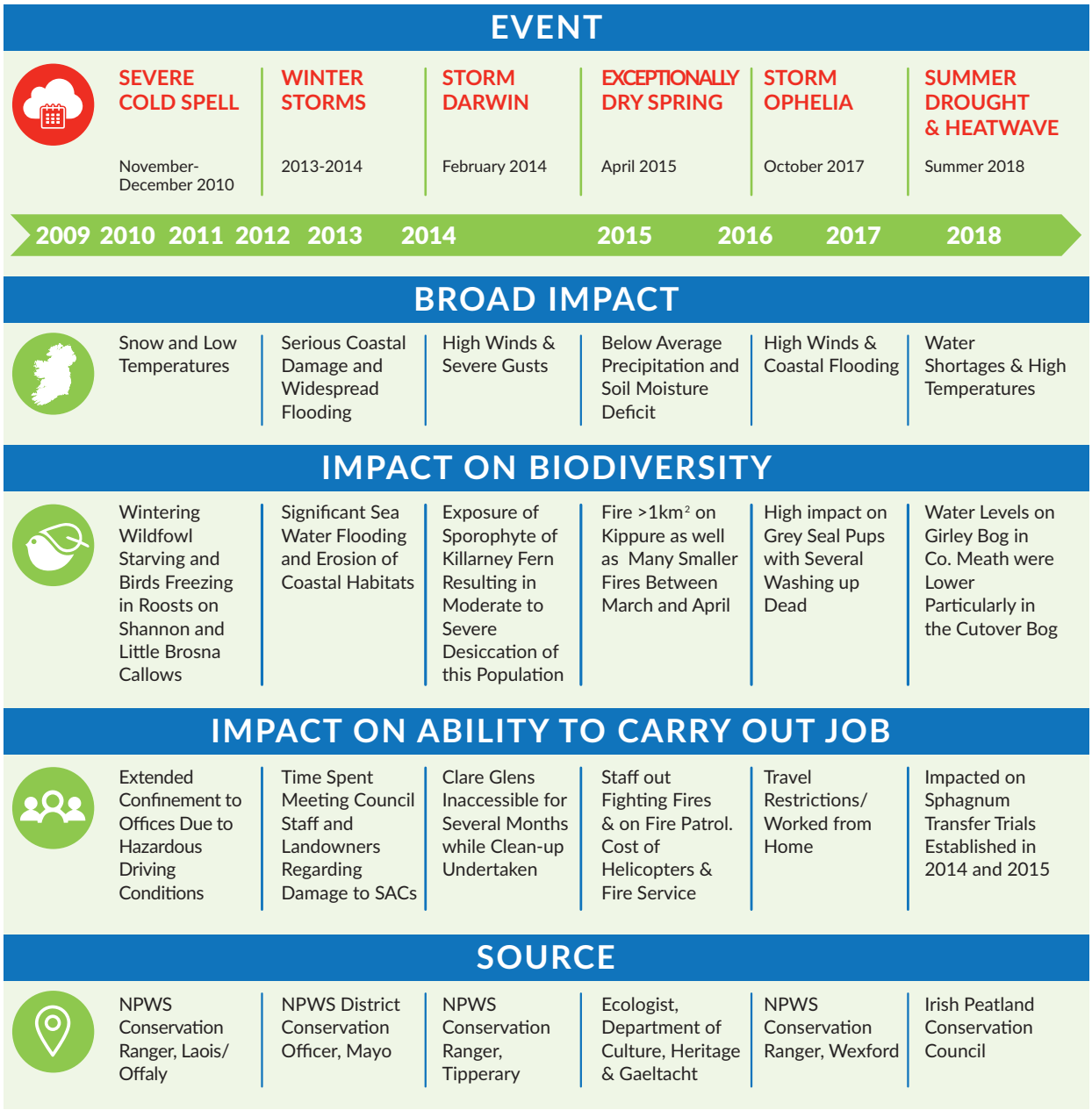


Figure 5. Ten-year extreme event timeline with examples of observed impacts on Biodiversity.

ecosystem, such as pollinators, litter decomposers, herbivores and insectivores. There is a risk that key representatives of functional groups or even whole functional groups will disappear locally as a result of extreme weather events, such as flooding, leading to impaired ecosystem functioning (Scheffers, 2016).

Extreme weather events and more erratic weather patterns may cause population sizes to fluctuate, which may increase the likelihood of small populations becoming extinct (Bellard *et al.*, 2012). Populations may also take longer to recover from the effects of extreme weather when their habitat is fragmented.

Climate change will have a significant impact on the freshwater environment. For example, increases in the variability of river flows, wetland inundation and groundwater recharge will influence aquatic biodiversity (Hall *et al.*, 2012; Jones *et al.*, 2013), particularly species that respond to seasonal flow or inundation cues, such as fish and aquatic plants. Meanwhile, marine ecosystems are impacted by warming temperatures, changing wind patterns, shifting oceanic circulation patterns, increasing acidification and altering precipitation rates and hence salinity. These changes have the potential to change the distribution, abundance, size and behaviour of aquatic organisms, including economically important fish (Molinos *et al.*, 2015). For example, intertidal and coastal ecosystems will be at risk from rising sea level, with the risk that intertidal habitats will be permanently under water over time, losing their intertidal nature and the species that depend on this diurnal change.

Climate change also has major indirect impacts on biodiversity through its interaction with other stressors, in particular habitat fragmentation and loss; over-exploitation; pollution of air, water and soil; and spread of invasive species. Some land use practices and planning decisions, as well as unsustainable use of the sea have rendered ecosystems and socioeconomic systems more vulnerable to climate change and thus less capable of adapting. These indirect, amplifying effects may be more damaging than the direct impacts due to their scale, scope and speed (Buma, 2015). They will further reduce the resilience of ecosystems to climate change and their capacity to deliver essential services, such as climate regulation, food, clean air and water, and control of floods or erosion (Box 3).

3.3. Future climate change impacts and consequences on Irish biodiversity

Once known impacts and consequences of past extreme events have been identified and assessed in terms of their impact on biodiversity, the potential future impacts and sectoral consequences of projected changes in Ireland's climate can be assessed and should be carried out in consultation with the Planning Team. This task involves assessing how projected changes in climate might affect current levels of impact (causing increases or decreases), the sectoral consequences of these changes, and whether projected climate change will result in any other emerging impacts with consequence for sectoral activities.

In line with global patterns of climate change, the last century has been a period of unprecedented climate change in Ireland (Climate Ireland, 2017a). Box 4 provides a synopsis of evidence of climate change in Ireland and projects how the climate is expected to change in coming decades. The climate projections and scenarios are drawn from work by Sweeney *et al.* (2002), McElwain and Sweeney (2007), and the C4I project outputs (Dunne *et al.*, 2009).

Box 3: Case Study - North Bull Island and Dublin Bay

Dublin Bay is bisected by the shipping lane of Dublin Port. The North Bull Island is the most designated site in the Republic of Ireland and has been officially recognised for its important biodiversity for a century. North Bull Island was designated as a UNESCO Biosphere Reserve in 1981 and was extended and re-designated in 2015 as Dublin Bay Biosphere Reserve to create a model for managing biodiversity at a landscape level in an urban area (http://www.dublinbaybiosphere.ie/about).

The Biosphere is composed of a core area of wetland areas designated as part of the EU's Natura 2000 network. North Bull Island has two Natura 2000 sites: Special Protection Area (SPA) for birds under the Birds Directive and a Special Area of Conservation (SAC) under the Habitats Directive. Additionally, South Dublin Bay also has both an SPA and SAC. The core is supported by terrestrial buffer zones of parklands, greenbelts, golf courses and greenspace along watercourses that directly supply the protected wetlands and a marine buffer. A transition zone surrounds the core and buffer and is where people live and work sustainably to manage the Bay.

Dublin Bay comprises a wetlands complex of international importance for its coastal and estuarine habitats and its overwintering migratory bird populations. The Biosphere Reserve has recorded 180 species of birds. It provides habitat for 30 species of water birds, with in excess of 37,000 water birds spending the winter in the bay complexes each year (30,000 in Dublin Bay and 7,000 in Baldoyle Bay) (Birdwatch Ireland). It is internationally important for Light-bellied Brent Goose, Knot, Black-tailed Godwit and Bar-tailed Godwit, and supports nationally important numbers of a further 18 species. These birds are protected under the EU Birds Directives and covered by the African-Eurasian Migratory Waterbirds Agreement (AEWA) of the Bonn Convention. There are two wetland complexes designated under the RAMSAR Convention - North Bull Island and Sandymount Strand - in Dublin Bay. North Bull Island alone has five Red Data Book vascular plant species, four rare bryophyte species, and is nationally important for three insect species (McCorry and Ryle, 2009).

Many plants in the Biosphere Reserve are known to show great adaptation to extreme coastal conditions and variations of microclimate, and significant genetic variation and hybridisation can occur (Dublin Bay Biosphere Partnership, 2016).

Management of the Biosphere Reserve takes climate change impacts such as flooding and coastal erosion into account. The management strategies aim to strengthen the resilience of the ecosystems and species to climate change, while maintaining the ecosystem services the reserve provides to local communities (e.g. protection from storms)

Dublin Bay Biosphere Reserve (photo courtesy of Dublin Port Company)

Box 4: A selection of observed and projected climate changes in Ireland. Source: Desmond *et al.* (2017)

Observed	Projected
Mean annual temperature increase of 0.8°C between 1900 and 2011.	Mean annual temperature increase of 1-1.6°C by 2050
The number of warm days increased. The number of frost days decreased	Increased frequency of heatwaves. Decrease of 50% of frost days by 2050
Increase in mean annual rainfall	Up to 20% decrease in summer rainfall by 2050 and 35% increase in extended dry periods
Increased mean annual flow	Increasing seasonality in hydrological regimes, with increases in winter/spring and decreases in summer
	Fewer more intense storms
0.8°C increase in sea surface temperature since 1982	Ongoing increases in mean temperature
Increased seawater acidity	Ongoing increases in acidity
Sea level rise of 3.4 mm per year	Sea level rise of 25-44 cm by 2080
Increase in significant wave heights of 20 cm per decade since 1950	Surge events are likely to increase by c9mm per year

The observed and projected climate change impacts on Ireland's biodiversity can be categorised into four broad categories:

a) Changes in phenology (the timing of lifecycle events);
b) Changes in the geographical range of species;
c) Increased degradation of habitats and changes in ecosystem processes;
d) Increased occurrence of invasive species;

An overview of these impacts is shown in Table 1.

Table 1: An overview of priority impacts of climate change on biodiversity

Category	Priority impacts
Phenology	• Changes in the timings of seasonal events • Disruption of species interactions
Geographical range and species abundance	• Shifts in suitable climate conditions for individual species leading to change in abundance and range • Loss of species (especially range restricted species) • Increased stress on species from more frequent extreme events (drought, flooding, fire, disease)
Loss and/or degradation of habitats and changes in ecosystem processes	• Loss or changes in the structure and functionality of the habitats which species occupy due to a changing climate • Changes to the composition of plant and animal communities • Loss of space due to sea level rise and associated salt water intrusion • Increased ocean acidification
Invasive species	• Arrival of new species better able to survive the changed climate conditions, some may have negative impacts on the economy (e.g. via impacts on farming/fishing)

Changes in phenology

The impact of climate change on a range of plant and animal phenologies in Ireland has been established (EPA, 2013). Increasing spring temperature in recent decades has been shown to impact the timing of key life-cycle events (phenology) in a range of plant (Donnelly *et al.*, 2004 & 2006; Carroll *et al.*, 2009; Gleeson *et al.*, 2013), bird (Donnelly *et al.*, 2009 & 2016; Carroll *et al.*, 2009; Stirnemann *et al.*, 2012) and insect (O'Neill *et al.*, 2012) species in Ireland. The timing of leaf-out of a range of deciduous tree species at a number of locations has become earlier since the 1960s (Figure 6). The arrival time of a number of sub-Saharan migrant bird species, such as the barn swallow (Hirundo rustica), has also become earlier since the 1970s; Greenland White-fronted geese departed the Wexford Slobs 22 days earlier in 2012 than in 1969 (Fox *et al.*, 2012) while the departure of an over-wintering bird, the Whooper Swan (*Cygnus cygnus*), has shown a similarly early trend. In addition, analysis of 59 moth species over a 36-year period (1974–2009) revealed that many of the common moth species in Ireland, such as the flame carpet moth (*Xanthorhoe designata*), are emerging earlier now than in the 1970s and have a longer period of activity (O'Neill *et al.*, 2012). Issues facing Arctic breeding wading birds as a result of climate change include suitable habitat shifting, contracting and declining (Wauchope *et al.*, 2016) and timing mismatches between chick hatching and peak food abundance (e.g. McKinnon *et al.*, 2012; Reneerkens *et al.*, 2016). Along the migration route there is a risk that climate change will reduce the availability of suitable habitat at stopover sites and a bird's ability to build up adequate nutrients and fat stores, thus reducing survival (Studds *et al.*, 2017) or impacting an adult's ability to reproduce successfully following spring migration (Drent *et al.*, 2007). In addition to the immediate and short-term impacts of climate change at specific life history stages or locations along the migratory flyway, there are also cumulative effects to consider as well as the likelihood of negative carryover effects manifesting later in the year, or in subsequent years (O'Connor & Cooke, 2015).

Overall, there is strong evidence that spring warming is having a detectable impact on the timing of phenological phases of Irish wildlife which is likely to continue as temperatures rise (Caffarra *et al.*, 2011a&b; 2014). The implications of these changes may be reflected in our biodiversity in a number of ways including a disruption to previously synchronized ecosystem functioning which could lead to a change in species composition and ecosystem functioning.

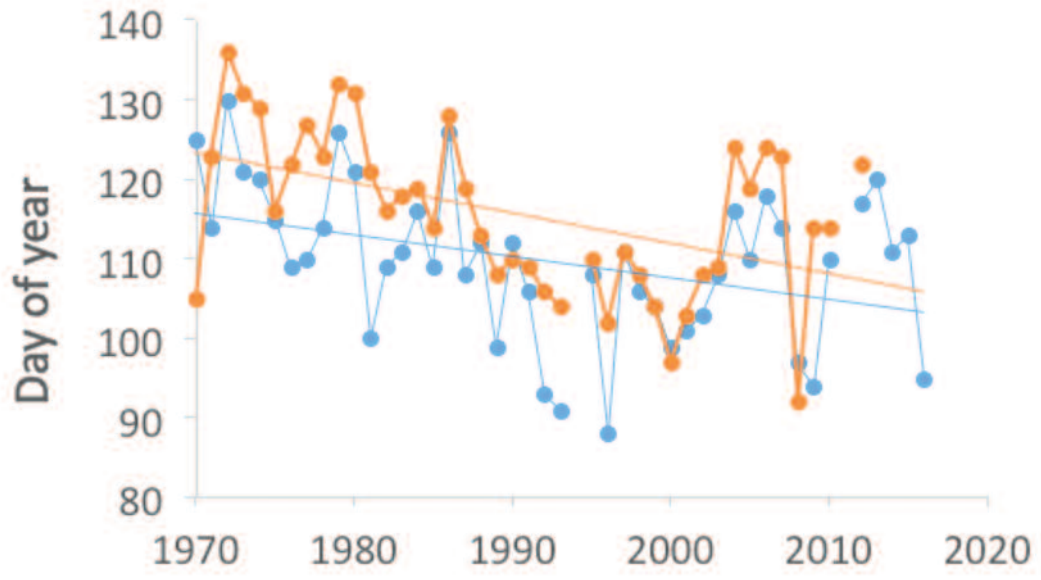
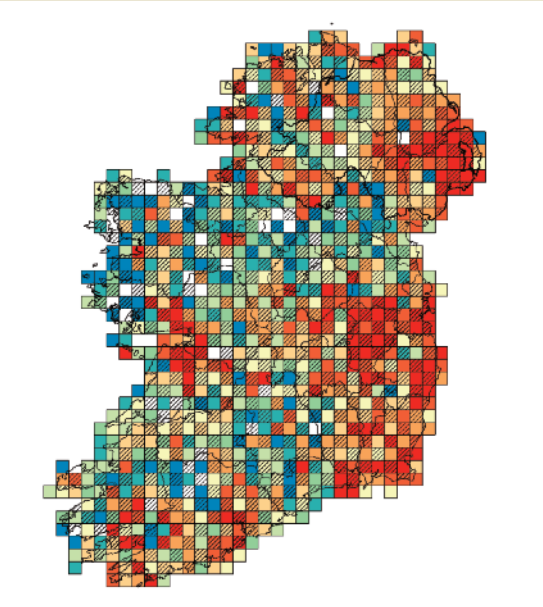


Figure 6. Increasing spring temperatures has impacted upon the phenology (the timing of lifecycle events) of species native to Ireland. For example, leaf unfolding of two varieties of Beech in Ireland has steadily occurred earlier since the 1970s. Source: Donnelly *et al.*, 2006.

Box 5: Phenology Monitoring Case Study - National Biodiversity Data Centre Butterfly Atlas



Butterfly recording effort (Red=higher effort).

Small copper butterfly: Liam Lysaght

More information available from: http://www.biodiversityireland.ie/record-biodiversity/butterflyatlas/about/

Running from 2017 to 2021 the Butterfly Atlas Project collates information from all butterfly recording activities into one overarching project. The project is an all-island initiative being co-ordinated by the National Biodiversity Data Centre in collaboration with Butterfly Conservation Ireland, Butterfly Conservation UK, the Centre for Environmental Data and Recording, supported by the Department of Culture, Heritage and the Gaeltacht and the Northern Ireland Environment Agency.

To maximise the quality of butterfly data being gathered a 'checker-board' sampling design has been implemented that aims to evenly collect systematic population data in every alternate 10 km square in parallel to qualitative butterfly recording. These data are then validated annually by a panel of species experts in Northern Ireland and the Republic of Ireland, with the Republic of Ireland data made available under an open licence via the National Biodiversity Data Centre.

As well as facilitating the prioritisation of conservation on declining species, the successful completion of the Butterfly Atlas 2021 project will quantity landscape- and climate-driven changes to butterfly populations across Ireland. In addition, as an 'umbrella group' of species changes in common butterflies reflect broader changes in insect populations and the completed atlas will identify indicative hot- and cold-spots of insect diversity. Similarly, migratory butterfly species signal changes in abundance and routes of climate-driven migration of new insect species colonising Ireland.

Changes in the geographical range of species

Increasing temperatures will impact upon the geographical range of species. Sightings of some bird species typical of warmer climates have increased in Ireland in recent decades even though a suitable food source and habitat has always been present. A warmer climate may certainly contribute to an increase in the frequency of birds such as the Mediterranean Gull (*Larus melanocephalus*) (Donald and Bekhuis, 1993). The expansion northwards in Europe of the Little Egret (*Egretta garzetta*) has been attributed to the absence of severe winters (Voisin, 1991) and it has been breeding in Ireland since 1997 (Smiddy and O'Sullivan, 1998). According to Huntley *et al.* (2007) Ireland has the potential to gain at least 20 new breeding species over the next 100 years based on species climate response models.

In a review undertaken by Lewis *et al.* (2019), the authors state that given that Ireland is at the western edge of the wintering range for many waterbird species that breed in Scandinavia, Northern Europe and Arctic Russia, it is likely that the effects of climate change and increasing winter temperatures are making it increasingly disadvantageous for many species to migrate as far as Ireland for the winter. The most notable example of this is the Bewick's Swan, whose numbers have been declining here since at least the 1980s despite flyway population increases until the early 2000s. There are only c. 20 Bewick's Swans remaining in Ireland (Crowe *et al.*, 2015; Burke *et al.*, 2018b), wintering in the south-east in county Wexford, and it is likely that this species will cease to winter here in the coming years. Rising temperature is therefore both a high-level pressure and threat for Ireland's Bewick's Swan population.

Lehikoinen *et al.* (2013) demonstrated strong north-eastwards shifts in the wintering range of three diving duck populations along the North-West European flyway in response to changes in temperature since 1980. Numbers of Tufted Duck, Goldeneye and Goosander increased by over 140,000 in the north-east part of their wintering range (Finland, Sweden), as rising temperatures have provided more ice-free habitat closer to their breeding grounds. Over the same period, countries such as Ireland, France, the Netherlands and Switzerland in the south-west of the flyway have lost in the region of 128,000 individuals (Lehikoinen *et al.*, 2013). Many climate change scenarios predict a continued increase in winter mildness (IPCC, 2012), which suggests that continued north-east shifts of the ranges of many of Ireland's wintering waterbirds are likely (Pavón-Jordan *et al.*, 2018).

The Emperor Dragonfly *(Anax imperator)*, the largest dragonfly in Ireland, arrived in 2000 and has since spread to most of the island. This is part of a trend that has occurred across northern Europe since the 1980s (Photographer: Colin Stanley)

Deraeocoris flavilinea, a true bug, once confined to Sicily has undergone a major expansion into Europe since 1980 reaching Ireland in 2017 (Photographer: Brian Nelson)

Modelling of species and habitat distributions project that under future climate scenarios many species in Ireland will experience significant changes to their ranges (Coll *et al.*, 2013; EPA, 2012b; MONARCH partnership, 2007). For example, in general, moss, liverwort, and fern species will experience range contractions, while angiosperm species will see more variation in their response, with some angiosperms expanding while others contract. Species most vulnerable to climate change will include those representatives of arctic-montane, boreal-montane and boreo-arctic montane biomes (Coll *et al.*, 2013).

Within Ireland's protected habitats, plant communities are likely to see significant changes in their composition with the addition of some species and the loss of others. The EPA report (2012b) indicated that the current protected area network would need to adapt to these changes. It also highlighted the habitats most vulnerable to climate change impacts are upland habitats (siliceous and calcareous scree, siliceous and calcareous rocky slopes, alpine and subalpine heath); peatlands (raised bog, blanket bog); and coastal habitats (such as fixed dunes and salt marshes) which have the additional threat of sea-level rise.

Changes in species abundance

In Ireland, the main three species of diadromous (migratory) fish (salmon, sea trout and eels) have all shown a decline in numbers and marine survival over the past three decades (Limburg & Waldman, 2009). It is thought to be at least partly related to the interactive effects of changing climate and oceanic conditions, along with human impacts such as pollution, habitat loss and over-exploitation (Marine Institute, 2009). Fish stocks of commercial interest to Ireland may be adversely impacted by climate change in ways that are not yet fully understood. This could have implications for quota-sharing and relative stability that may put stress on fisheries management systems. For instance, cold water species for which Ireland has an important quota share, like cod and herring, may dwindle, whilst warmer water species, for which Ireland have either a small share or no track record, like hake, Bluefin tuna and sardine, may increase in our waters.

Johnson *et al.* (2013) projected future abundance of wintering waterbirds in north-west Europe under a scenario of increased global mean temperature of 2.8°C by 2050 and 4.4°C by 2080. They found that climate change has already been a significant driver of large-scale population trends and that most

species are likely to undergo large population declines under the projected scenarios, with a mean population trends of -33% to 2080 across 45 species. Interestingly, there were projected to be 58% more birds in the entire wintering waterbird assemblage in 2080, with a small number of species benefitting significantly from the changes.

To obtain a clearer view of the likely changes in the Irish flora composition over the next few decades and thereby guide plant conservation priorities, an assessment of the possible impact of climate change on the native flora was undertaken (Wyse Jackson, 2007). This assessment revealed that 20% of Ireland's total native flora are particularly vulnerable to climate change in the period up to 2050. As a result of climate change, 74 out of a total of 143 species (52%) currently included in the Irish threatened plants list, may have their situation made potentially worse due to climate change. In addition, 28 (3%) species currently not threatened in Ireland are likely to become so. A recent study by BirdWatch Ireland, funded by the Department of Culture, Heritage and the Gaeltacht (DCHG), details a 40% decline in water bird species in less than 40 years with a 15% decline in 5 years (Burke *et al.*, 2018). Climate change has been identified as a significant factor in these dramatic declines.

Box 6: Change in Species Distribution Case Study – Ireland's Fish Stock

In 2017, scientists from the International Council for the Exploration of the Seas (ICES), examined evidence of distributional shifts in 21 commercially exploited fish species in the North East Atlantic. An analysis of bottom-trawl survey information identified species with substantial changes in distribution. This was supplemented with a literature review for all species. Distributional changes were found for 16 of the 21 fish species analysed. The drivers for these changes in distribution of most of the analysed species are linked to the environmental conditions (i.e. mostly through sea temperature), but for some species fishing also played an important role. Eight species (anchovy, cod, hake, herring, mackerel, plaice, horse mackerel, and common sole) have shifted their distribution in relation to their management areas since 1985. Of these, the greatest shifts occurred for hake and mackerel. For all species that showed substantial changes in distribution, the literature indicates that the main factor influencing the locations of suitable habitats was environmental conditions, mainly through climate induced changes in sea temperature. Species interactions with predators or competitors might influence the extent to which the species is actually able to utilize particular locations. Conversely, expansion of the species distribution could be inhibited if the species is particularly dependent on specific and restricted habitats, or has especially strong geographical attachment to particular sites, such as spawning grounds. It is reasonable to assume that these changes will challenge some assumptions underlying the current management areas for some Northeast Atlantic fisheries. Continued monitoring of the spatial distributions of fish stocks is essential to support future management.

Scientists have evidence of a northward shift in the cod stocks in the waters around Ireland and a north west expansion in the north Atlantic mackerel stock.

More information on this Case Study is available within the Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan which is available at:
https://www.agriculture.gov.ie/ruralenvironmentsustainability/climatechangebioenergybiodiversity/

Increased degradation of habitats and changes in ecosystem processes

Projected increases in the occurrence of extreme weather events, such as heat waves, droughts, floods and storms, may have devastating consequences for Ireland's habitats (Climate Ireland, 2017b). All habitats will need to adapt to climate change but fragmented, isolated habitats are likely to be the most vulnerable (Segan *et al.*, 2016).

At coastal sites, storm surges and flooding events can temporarily result in intertidal areas being unavailable for foraging waterbirds (Lewis, 2019), while over time these events can affect the shape of estuaries and the nature and distribution of sediments (e.g. Stevens, 2010; Jang *et al.*, 2013) with knock-on effects on the distribution and abundance of invertebrates, thus potentially affecting the numbers and composition of waterbirds supported by an estuary. Predicted changes to the Irish coastline are expected to result from a combination of sea level rise, increasing frequency of storm surge events and from coastal erosion. Flooding at coastal locations is likely to be exacerbated by predicted increases in rainfall and consequent enhanced river flow (Crowe *et al.*, 2013). An average sea level rise of 0.5 to 1 m by the end of the century, in combination with storm surge events, could result in approximately 300 to over 1,000 km2 of coastal lands around Ireland being inundated by the sea (DeVoy, 2008). A rise of 1 m in sea level would see 30% of existing wetlands disappearing (DeVoy, 2008). The habitats most at risk include low-lying coastal lagoons, saltmarsh and estuaries, and of particular vulnerability are those that are prevented from extending landward because of the presence of some fixed or artificial boundary (Wall *et al.*, 2016).

It has been projected that 40% of the suitable climatic areas for peatlands in Ireland will be lost by 2075 (Jones *et al.* 2006; Donnelly *et al.*, 2008). More recent predictive analyses, undertaken by Coll *et al.* (2014), indicate that the distribution of active blanket bog in Ireland is regionally sensitive to climate change, most notably for lower-lying areas in the south and west of the country. Increasing temperature and precipitation changes will reduce the area that is suitable for active blanket bog. This could have major implications for the lowland blanket bog distribution along the western Atlantic sea-board where the projected losses are greatest. In addition, current models predict that drier summers and higher levels of more intense rainfall, which are likely to result in bog bursts and landslides, may, as well as damaging the bog, indirectly impact other habitats such as lakes (Kiely *et al.*, 2010).

Storm damage to coastal habitats in the west of Ireland (Photographer: Karen Gaynor)

Increased levels of winter precipitation may result in increased nutrient runoff, affecting water quality and fish survival; and soil erosion, possibly impacting upon salmon and trout spawning areas (Climate Ireland, 2017b).

Given that two thirds of Ireland is covered by grassland, there is an enormous potential to improve carbon storage in the soils (Royal Irish Academy, 2016). This requires selection of grassland species and ryegrass varieties that are adapted to a future Irish climate, and optimise species mixtures that sequester more carbon in the soil, are more climate resilient and support higher biodiversity.

Furthermore, a greater focus is needed on interactions of agriculture/forestry with climate and potential impacts on biodiversity. Most of the Irish land cover is directly shaped by humans (e.g. pastureland, cropland, forestry) with substantial implications for carbon budgets, climate resilience and biodiversity. In addition to trophic interactions and the threat of phenological mismatches, the importance of plant biodiversity as a buffer for phenological mismatch should be recognised. Overall, it is important to focus on vulnerability resulting from monocultures and the potential to improve ecosystem stability through increased cultivated plant biodiversity and selection of the most suitable species, varieties or provenances. It should also be recognised that biodiversity at a regional scale (i.e. landscape homogeneity) has effects on ecosystem functioning and stability (Mori *et al.*, 2018; Oehri *et al.*, 2017).

The impact of monocultures (such as grasslands dominated by perennial ryegrass or tree monocultures in forestry) on biodiversity is another important factor to consider. This is of importance since more diverse plant communities support higher animal biodiversity in general and provide a more continuous source of food, thus reducing vulnerabilities arising from phenological mismatch in response to climate change. In addition, grasslands (Isbell *et al.*, 2015) and forests (Liang *et al.*, 2016; Jactel *et al.*, 2018) with a larger number of plant species are more productive, capture more carbon and therefore have a higher potential to mitigate against climate change. For example, species-rich grasslands were shown to increase soil microbial activity and soil carbon storage (Lange *et al.*, 2015).

Furthermore, plant species richness increases climate resilience and supports high grassland productivity during climate-related stress (Isbell *et al.*, 2015).

Increased occurrence of invasive species

Terrestrial and freshwater

Despite there being significant knowledge gaps in our understanding of the relationships between climate change and invasive species, climate change has been highlighted as having a major impact on the distribution and spread of invasive species (Kernan, 2015; Mainka & Howard, 2010). Projected shifts in climate, temperature and precipitation, will likely result in the increased occurrence of invasive species and competitive pressures for Ireland's native species. Specific habitat types currently under threat in Ireland from invasive species include freshwater river systems, ponds, mesotrophic lakes, native woodland, lowland heath, coastal floodplain, coastal salt marsh and coastal sand dunes (Kelly *et al.*, 2013). However, to date only 13% of the invasive species recorded are considered to be high impact (O'Flynn *et al.*, 2014). Although the majority of invasive species in Ireland are plants, the future trend may be towards animal species comprising a greater percentage of all new arrivals. The threat from high impact invertebrates is of greatest concern for freshwater environments (O'Flynn *et al.*, 2014).

Marine

Bord Iascaigh Mhara (BIM) is undertaking a significant programme of work in relation to marine invasive species. They have set up a cross department and inter agency working group to examine invasive alien species in the context of aquaculture and have committed resources to baseline studies, risk assessments and training until 2020. Climate change will bring about increased occurrences of invasive species in the marine environment and BIM's work to develop a marine baseline for alien species will provide critical information for their management.

Box 7: Habitat Degradation and Restoration Case Study - Ireland's Raised Bogs

Raised bogs are accumulations of deep acid peat (3-12m) that originated in shallow lake basins or topographic depressions left behind by retreating glaciers in the last Ice Age. They are among Europe's oldest near-natural eco-systems, with some dating back over 10,000 years. As Sphagnum moss-rich raised bogs grow upwards from the surface they typically develop an elevated dome, which is primarily rainwater-fed (ombrotrophic) and isolated from groundwater. This gives rise to a nutrient-deficient, acidic habitat, which supports a distinctive suite of specialised vegetation assemblages and wetland fauna. Raised bogs are more abundant in the lowlands of central and mid-west Ireland where, according to Hammond (1979) they once covered an area of over 310,000 hectares. The main pressures on raised bog come from peat extraction for fuel and horticultural use, drainage, afforestation and burning. Climate change is recognised as an additional threat in the future. As a result the overall status of Irish raised bogs is assessed as bad and deteriorating (NPWS, 2019).

It is estimated there has been a 99% loss of the original area of actively growing raised bog in Ireland. What little remains is in need of restoration and conservation.

However, there is some good news with a significant Irish raised bog restoration project currently taking place from 2016-2020. 'The Living Bog' (LIFE14 NAT/IE/000032) is the largest single raised bog restoration project ever undertaken in Ireland. 53 raised bogs in the country are designated as Special Areas of Conservation (SAC) and Natura 2000 sites. 12 of these raised bog SAC's in seven counties are being brought back to life by 'The Living Bog' between 2016 – 2020. Restoration work on these Natura 2000 sites will improve over 2,600 hectares of threatened raised bog habitat and 18% of the national high bog area. Further restoration works to other sites is planned by NPWS.

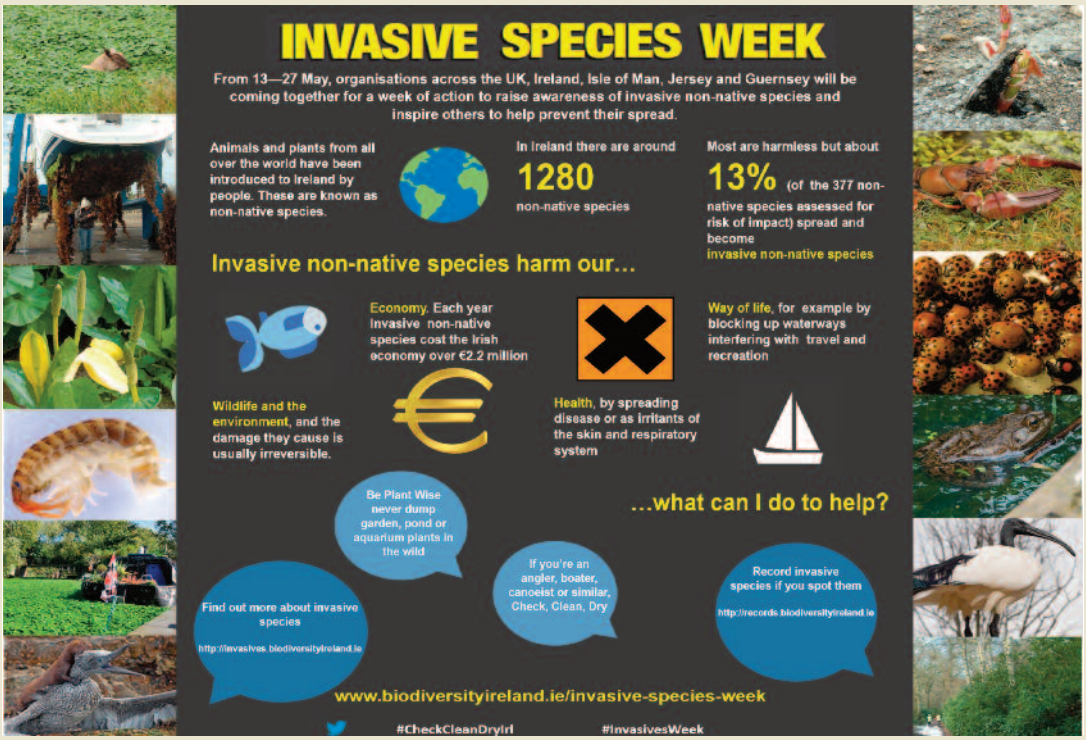
Peat dams being placed into a drain by 'The Living Bog', blocking the drain to keep water on the raised bog. For more information go to http://raisedbogs.ie/

Box 8: Invasive Species Education Case Study - Invasive Species Awareness Week

Many non-native species contribute greatly to national economies and society at large however, those species that become invasive can have a major impact on biodiversity. Article 8h of the Convention on Biological Diversity requires signatories to 'prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species'. Our activities are the main cause of the arrival of invasive species. Many species are deliberately released, like species of fish for angling. Others have escaped from our gardens, like giant rhubarb or fur farms like the American mink. Some arrive as hitch hikers and stowaways with imported goods. Climate change is also increasing the number of invasive species through changes in ecosystems. Increases in annual average temperatures, for example, can lead to physiological stress on nature flora and fauna resulting in reduction in species numbers or migration to new more suitable climatic habitats, if available. This opens up a window of opportunity for non-native species to invade ecosystems once introduced.

Invasive Species Week was established to raise awareness and provide guidance and advice on how to manage for invasive species. The annual week-long event brings organisations across Ireland and the British Isles together to work towards raising awareness and educating participants on how best to help the stop the spread of invasive species. Each day of the event focuses on a different theme. In 2018, it focused on the pathways of how invasive species are introduced and spread. In 2019, it focused on invasive species in different environments of concern; including: freshwater and riparian environments, urban location, the marine, and woodlands and bogs. Increasing awareness of invasive species and how they can be controlled can help to build capacity to manage them in the future as climatic conditions make conditions conducive to the spread of particular species.

More information can be found at: www.biodiversityireland.ie/invasive-species-week



Aillebrack, Galway following Storm Darwin 2014.
Photographer Karen Gaynor

4 Prioritisation and Planning

Through the climate impact screening carried out and presented in the previous section, an initial understanding of Irish biodiversity's vulnerability to climate change and associated impacts has been developed. This next step prioritises these vulnerabilities and impacts and identifies ways to adapt.

Irish biodiversity is highly vulnerable to the impacts of climate change and has a low adaptive capacity compared to other vulnerable sectors (Coll and Sweeney, 2013). As biodiversity systems are highly interconnected and interdependent it is challenging to list specific priorities in relation to vulnerabilities and impacts. The ecological impacts associated with climate change will not occur in isolation; rather climate-driven changes will combine with, and exacerbate, existing stresses on Ireland's natural systems. An understanding of those interactions will become increasingly critical in defining and implementing effective conservation measures. As a result, conservation in an era of climate change will require that not only are the environmental problems of the past acknowledged and addressed, but that those of an increasingly uncertain future are also anticipated and prepared for.

It is projected that many species in Ireland will experience significant changes to their ranges under future climate scenarios. Species with disjunct and narrow distributions are projected to experience the largest range changes, contracting and expanding, respectively. In general, moss, liverwort, and fern species will experience range contractions, while angiosperm species will see more variation in their response, with some angiosperms expanding while others contract (Coll and Sweeney, 2013). Species representative of arctic- montane, boreal-montane and boreo-arctic montane biomes will be most vulnerable to climate change. On the island of Ireland, these species do not have higher altitudes and latitudes to move to. Plant communities from many of Ireland's protected habitats are likely to see significant changes in their composition. Although not all species in the plant communities of these habitats were modelled, the following habitats may be the most vulnerable to climate change impacts (Coll and Sweeney, 2013):

- Upland habitats (siliceous and calcareous scree, siliceous and calcareous rocky slopes, alpine and subalpine heath);
- Peatlands (raised bog, blanket bog); and
- Coastal habitats (fixed dunes – combined with the additional threat of sea-level rise to coastal habitats).

Coll and Sweeney's findings reinforce the strongly emerging global consensus in conservation science, whereby rapid climate change is widely considered to be the defining conservation issue for this generation. They find that:

- Widespread changes are already occurring in natural systems and these will continue;
- These changes will accelerate in scope and scale in the coming decades due to greenhouse gases already in the atmosphere;
- The scale and extent of changes will continue to accelerate over longer timescales if greenhouse gas emissions continue unabated or increase; and
- Conservation decisions will have to be made based on longer timescales than has traditionally been the case.

Most of the actions that can be taken to protect species and habitats from climate impacts are similar to those currently being implemented, or at least being provided for in the National Biodiversity Action Plan (2017-2021), to counter other pressures on natural systems. Nevertheless, climate change vulnerability assessments facilitate adaptation planning (Dale *et al.*, 2000; Hulme, 2005), and should be considered in conjunction with, for example, the guiding principles in Hopkins *et al.* (2007).

The prioritisation of impacts and actions in this Plan is constrained due to a) a lack of data; b) the absence of a comprehensive vulnerability assessment for ecosystems and biodiversity and c) the cross-cutting nature of biodiversity which assigns ownership and responsibility across multiple sectors. While prioritisation of both impacts and actions was informed by the consultation process and the workshops conducted to inform the Plan, it remains provisional and should be revisited in light of a comprehensive vulnerability assessment.

4.1 Cross-sectoral considerations

Biodiversity is a cross cutting issue with implications for all sectors and all levels of decision making. As such ownership for this plan is shared with the citizens of Ireland, business, state agencies, local authorities and all government departments. Effective biodiversity adaptation requires bottom up and top down planning across all sectors based on coordination and cooperation.

Many of the adaptation actions identified in Section 5 of this Plan are cross-sectoral in nature. Where engagement with other agencies/departments and stakeholders is required, this has been indicated. A suite of sectoral Climate Change Adaptation Plans has been drawn up across sectors and those available were reviewed as part of the development of this Plan. It is imperative that other sectors recognise their role in reducing the pressures on biodiversity and contributing to adaptation measures in their respective plans. For example, the potential avenues for the spread of invasive species should be considered by the transport sector; Local and national planning authorities should incorporate green infrastructure into future development plans (Regional Economic and Spatial Strategies are currently in development, which will impact on the potential for saving spaces and making space for biodiversity under a range of climate change scenarios); Agriculture, forestry and fisheries should evaluate measures undertaken in government programmes to ensure no further degradation of biodiversity occurs; A cost benefit analysis of employing nature-based solutions should always be undertaken before any major operations are undertaken (e.g. for flood defence) and sectors should work together to garner the necessary funds to facilitate implementation of adaptation actions.

A special relationship exists between health, wellbeing and biodiversity. From a public health perspective biodiversity is very important in maintaining a safer healthier environment for all. Therefore, biodiversity resilience to climate change is vital for public health. A recognition of the biodiversity's importance in health policies, such as Healthy Ireland (Department of Health, 2013), could lead the way towards potential interdependency studies such as a public health risk assessment on the risk of biodiversity loss. This type of study would highlight the public health benefits of flourishing

Box 9: Flood Resilience Case Study – FloodResilienCity Outcomes Dublin

Dublin City Council participated in the EU Interreg project FloodResilienCity (FRC) from 2008-2012 which aimed to make Dublin a more flood resilient capital. The project developed a tidal flood forecasting and warning system, emergency response procedures and coastal flood maps. The results of FRC have informed Dublin City Council's strategy to mitigate and adapt to pluvial flood risk. The innovative elements of the project were its three categories of measures that include both hard and soft solutions incorporating green responses, such as green infrastructure such as bioswales and vegetation management.

The project identified opportunities to enhance existing urban biodiversity while increasing overall flood protections resilience. It helped to plan for the future impacts of climate change in a heavily populated urban location while considering urban ecosystems and biodiversity. Specific approaches, such as Room for Rivers, 'GreenWaterSpace', and bioswales (channels to convey storm water) increase carbon sequestration, green spaces, and habitat connectivity resulting in net biodiversity gains.

More information available from:
https://www.dublincity.ie/sites/default/files/content/WaterWasteEnvironment/WasteWater/Documents/EUIVB%20FloodResilienCity%20Report_NonTechnicalSummary.pdf

biodiversity. It should also be noted that a Public Health aim is for "Health in all Policies". This type of approach is not uncommon in government policy. Good practice examples exist of integrated and all of governmental approaches. For example, Our Ocean Wealth is an integrated marine plan that was developed under the leadership of the Taoiseach, supported by the Marine Coordination Group (MCG) and two operational Task Forces on Enabling actions and Development actions. The implementation of Harnessing Our Ocean Wealth is a whole-of-Government initiative under the supervision of the Marine Coordination Group, with strong horizontal coordination and collaboration between government ministries and agencies.

Adaptation and mitigation options from other sectors can have positive and negative impacts on biodiversity. The development of seawall defences, for example, is a climate change adaptation option addressing rising sea levels but it can have negative effects on biodiversity and may not offer the optimal long term defence against climate change. Likewise flood defences schemes may alter water flows and habitat characteristics with impacts on biodiversity. Box 9 illustrates the potential for synergies between adaptation and biodiversity action in the case of flood relief.

Strategies should be advocating in concert for sustainable, carbon-neutral land-use that promotes the livelihoods of farming communities. Forestry provides another example of the potential synergies between biodiversity and sustainable land use. Through afforestation, the area of Ireland covered by forests Ireland has increased to 11% (DAFM, 2018), and it is important that the climate resilience of these forests as well as their potential to support biodiversity in a changing climate are considered, with the aim of choosing the best species/provenances and tree species mixtures that support biodiversity and other ecosystem services such as carbon sequestration.

Table 2 highlights where biodiversity links are indicated in the existing draft sectoral plans. It illustrates the common and overlapping issues that arise when other sectors consider biodiversity issues in their plans.

The clear connection between water, land use and biodiversity is evident. It manifests through forestry, bogs and flooding and river management. In addition to these issues, fishery management, tourism, transport and heritage all identify important links and interdependencies with biodiversity. Land management practices can be identified as an overarching nexus linking water management and biodiversity conservation.

Forestry can have significant net benefits on biodiversity gain through the planting of native species in well managed forests. The risks of maladaptation actions in forestry highlighted by the Agriculture, Forestry & Seafood draft Sectoral Plan includes biodiversity loss. The clear benefits of planting native species noted by the AFS draft Sectoral plan include pest control, increased carbon sequestration potential and the development of green infrastructure initiatives. Hedgerows act as an interface between agriculture and forestry and provide significant biodiversity and cultural heritage benefits. The Built Heritage draft Sectoral Plan highlights the value of traditional land use in enhancing the resilience of landscapes and in benefiting both tangible and intangible cultural heritage. Hedgerows preserve a sense of place, slow flood waters, provide vital habitats for biodiversity and act as carbon sinks.

The Agriculture Forestry and Seafood draft Sectoral Plan also makes the link between biodiversity, climate change and fish stocks. The plan recognises an increase in warm water marine fish species in Irish waters and increased sightings of exotic fish. Furthermore, they recognise the importance of cold-water corals in supporting the rich biodiversity that is vital to fisheries. With climate change drivers increasing sea temperatures in Irish coastal waters the loss of fish stock is identified as a significant commercial risk.

The Water Quality and Water Services Infrastructure draft Sectoral Plan makes the explicit link between peatland restoration projects and the protection of water quality. They also make the link between peat fires, post-fire habitat degradation and impacts on water quality, including the loss of peatland soil structure, and the release of stored carbon and peat sediment. This provides an excellent example of the impact chain across a landscape that leads to multiple interlinked outcomes. In this case the initial peat fire

Table 2. Cross-sector links to biodiversity as identified in draft Sectoral Adaptation Plans.

SECTOR	CROSS-SECTOR LINKS TO BIODIVERSITY
Agriculture, Forest & Seafood (DAFM, 2019)	Timing of bud burst in phenological gardens and associated changes in growing seasons noted
	Increase in warm water marine fish species in Irish waters and increased sightings of exotic fish noted
	Potential maladaptation actions in forestry leading to risks to habitats and biodiversity losses
	Increasing threat of non-native invasive species as a result of biodiversity and native species loss
	Central role of forestry noted in potential development of green infrastructure initiatives and protecting biodiversity
	Connections between water, biodiversity and flooding noted
	Importance of land practices for biodiversity highlighted
	Emphasis placed on the compatibility of agri-food production needs with biodiversity conservation
	Potential for biodiversity to help with pest control in agricultural and forest systems noted
	Importance of cold-water corals supporting rich biodiversity that is vital to fisheries
	Importance of habitats to the geographical range of fish species and how these are affected by climate change
Built & Archaeological Heritage (DCHG, 2019)	Invasive species potential impact on marine archaeology, cultural landscapes, and built or movable heritage with organic components (wood, thatch, collections) noted
	Landscapes, archaeology, and environmental data connections highlighted
	Potential of ecosystem-based approaches to protecting coasts to benefit cultural heritage by slowing erosion and loss
	Potential to share information between fields (including biodiversity) using traditional knowledge, research, monitoring and citizen science noted
	Potential of enhancing the resilience of traditional land use to benefit both tangible and intangible cultural heritage (e.g. hedgerows preserve sense of place and also slow flood waters)
Electricity and Gas Networks (DCCAE, 2019)	Noted that the EU Commission has issued 'Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment' aiming to help member states improve how climate change, both mitigation and adaptation, are integrated in Environmental Impact Assessments (EIAs)
Flood Risk Management (OPW, 2019)	Natural Water Retention Measures highlighted as having wide-ranging benefits for water quality, sediment control, climate mitigation through carbon sequestration, biodiversity and flood reduction
	Increased fluvial and groundwater flooding linked with potential biodiversity loss, habitat reduction, distribution of invasive species, and impaired site access.
	Increased coastal flooding leading to damage to sand dune habitats, erosion of coastal habitats, loss of species and habitats due to coastal squeeze, loss of species and habitats due to saltwater intrusion
	The improvement or creation of wetland habitats can improve natural water retention measures reducing runoff and flooding downstream
	The improvement or creation of wetland habitats can act as a potential barrier to physical flood risk management interventions
Transport (DTTS, 2019)	Destination attractions such as Skellig Michael in Co. Kerry and the Burren in Co. Clare represent key cultural and natural assets (biodiversity). These sites are especially vulnerable to the impacts of climate change and highlight the important shared agenda between the tourism sector, the built and archaeological heritage sector and the biodiversity sector
	The implementation of adaptive measures to transport infrastructure should take the preservation of co-located biodiversity and heritage sites into account
Water Quality and Water Services Infrastructure (DHPLG, 2019)	Explicit connection made between water quality and changes in species distribution and phenology
	Importance of research highlighted in understanding impacts that non-native and invasive species are having on the environmental status of waterbodies and biodiversity
	Impact of peat fires (for example, at Liffey Head Bog, Co. Wicklow in summer of 2018) and subsequent post-fire habitat degradation on biodiversity, peatland soil structure, release of stored carbon and peat sediment, and water quality
	Peatland restoration projects (for example, under the Bord na Móna Biodiversity Action Plan) highlighted as important actions to ensure the resilience of these environments in the face of climate change and the protection of water quality

impact has a cascading impact on water quality and habitat destruction leading to biodiversity loss. Another explicit link is made between water quality, changes in species distribution and phenology. An improved understanding on the impacts that non-native and invasive species are having on the biodiversity and water quality is required.

Transport and Built & Archaeological Heritage both focus on the value and fragility of natural and cultural landscapes. The example of Skellig Michael in Co. Kerry and the Burren in Co. Clare neatly captures the vulnerability of such unique locations to the impacts of climate change, and highlights the important shared agenda between the tourism sector, the built and archaeological heritage sector, transport and the biodiversity. The Transport sectoral adaptation plan recommends that the implementation of adaptive measures to transport infrastructure should take the preservation of co-located biodiversity and heritage sites into account highlighting the strong interlinkages between these three aforementioned sectors and biodiversity. The Transport plan signals the value of green adaptation measures (nature based solutions) as measures to protect transport infrastructure, an important cross link with this Plan. Some aspects of the Transport adaptation plan, and inputs from the consultation on this Plan, signal the need to plan for adaptation in the Tourism sector and to understand the role of biodiversity in this regards.

The Flood Risk Management (FRM) draft sectoral plan acknowledges that Natural Water Retention Measures have wide-ranging benefits for water quality, sediment control, climate mitigation through carbon sequestration, biodiversity and flood reduction. It also highlights the connection between increased fluvial and groundwater flooding potential, biodiversity loss, habitat reduction, distribution of invasive species, and impaired site access.

The FRM draft sectoral plan also raises the issue of vulnerable coastal systems. Increased coastal flooding and the associated saltwater intrusion leads to damage to coastal habitats and the loss of species. The FRM points towards a potential solution in the form of wetland habitat creation. These wetland habitats can be coastally located or inland. There creation improves natural water retention measures by reducing runoff and downstream flooding. However, there are also risks to biodiversity from flood management works and coastal defences as engineering works may create barrier to species movement, require landuse change and damage habitats

Finally, the Electricity and Gas Networks draft Sectoral Plan makes reference to EU Commission 'Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment' aiming to help member states improve how climate change, both mitigation and adaptation, are integrated in Environmental Impact Assessments (EIAs). It is also important to note that nature-based solutions can play a role in protecting critical energy infrastructure from climate impacts.

Cross-sectoral considerations that link with biodiversity are not only reflected in the draft sectoral adaptation plans but are also relevant in relation to the Local Authority Climate Change Adaptation draft plans. Table 3 provides a sample of biodiversity considerations as recognised in a number of Local Authority Climate Change Adaptation draft plans. The development of Local Biodiversity Plans in particular is an opportunity to strengthen the role of biodiversity in building resilience.

A range of biodiversity concerns and considerations are highlighted in each of the draft Local Authority plans. Key overlapping biodiversity issues raised across plans include: the implementation of Local Biodiversity Action Plans; the establishment of invasive species programmes; native tree planting strategies; the development of climate risk registers to measure impact of climate change on biodiversity; the All Ireland Pollinator Plan; and the establishment or green infrastructure (including Greenways). Adaptation actions are primarily local in nature so the role of Local Authorities delivering adaptation actions will be key to the successful implementation of this and other sectoral plans.

Table 3 Biodiversity Considerations in draft Local Authority Adaptation Plans.

LOCAL AUTHORITY	SAMPLE OF BIODIVERSITY CONSIDERATIONS
Cork City Council (Cork City Council, 2019)	Objective identified to review, manage and protect biodiversity and natural heritage within the natural environment
	Recommendation to include climate adaptation concerns within the Cork City Council Biodiversity Plan
	Proposal to work with communities and schools to create and implement Local Biodiversity Action Plans
	Suggestion to collaborate with NPWS and research organisations when reviewing biodiversity plans and habitat conservation strategies to identify risks for adverse climate change impacts
Donegal (Donegal County Council, 2019)	Recognition of the significant area of Donegal subject to conservation including SACs, SPAs, NHAs or proposed NHAs and the presence of extensive areas of peatlands, which are of high biodiversity value and well as acting as important carbon sinks
	Recommendation to work with national and regional agencies to develop climate risk registers to monitor the effects of climate change on natural heritage
	Recommendation to build awareness of nature-based adaptation solutions including: strengthening habitat networks; promoting restoration of natural processes as a means of increasing climate resilience; and supporting initiatives to increase the awareness of the value of natural capital
	Recommendation to review Donegal Biodiversity Action Plan having regard to the National Biodiversity Action Plan and likely climate changes
	Activity to support biodiversity though natural pollination by considering the All Ireland Pollinator Plan to explore how Donegal County Council can support a diversity of plant species to increase food sources and habitats for pollinators
Dublin (Dublin City Council, 2019)	Consideration given to the potential challenges for Dublin City in terms of the urban heat island effect and biodiversity
	Acknowledgment of the impact of flood events on habitats and ecosystems
	Recognition of the opportunity for biodiversity though flood risk management that considers both engineered and natural solutions
	Highlights the Dublin City Biodiversity Action Plan (2015-2020), the Dublin Bay Biosphere Biodiversity Conservation and Research Strategy (2016-2020); and the Dublin City Invasive Alien Species Action Plan (2016-2020)
	Recognises the biodiversity of Dublin City including: wildlife and habitats found at North Bull Island and along the city's coastline; the rivers and canals that cross the city; open spaces linked to historic, educational and other public buildings; roadsides, railway tracks, and footpaths; residential 'greens', private gardens, walls and buildings
Kildare (Kildare County Council, 2019)	Recommendation to develop a native tree planting strategy in conjunction with an awareness campaign that informs of the benefits to communities in improving air quality, offsetting carbon emissions, promoting biodiversity, limiting flood risk, reducing urban heat, as well as aesthetic value
	Suggestion to develop policy provision and development standards for the integration of green infrastructure into private development sites in the County Development Plan
	Recommendation to make provision for natural borders/buffers and include as integral component of the design of greenway/blueway, tracks, trails, amenity and tourism areas
	Research and map areas considered beneficial for use as local carbon offset through carbon sequestration and include in Green Infrastructure Strategy
	Recommendation to review and assess choice of seeds and plants for planting in parks with the aim of maintaining and increasing native biodiversity
Mayo (Mayo County Council, 2019)	Establishment of an invasive species programme to monitor the spread of terrestrial, aquatic and marine invasive species
	Undertaking natural capital accounting to ensure that Ecosystem Based Adaptation and green infrastructure options are being employed
	Proposal to identify and implement measures to reduce the barrier effects of roads, railways and technical objects in rivers and streams to facilitate species spatial responses to climate change
	Recommendation to identify protective measures and acquisitions to manage ecosystems in buffer zones along rivers, lakes, reservoirs and coasts for flood control and water quality management

Migrating Greenland white-fronted geese.
Photographer Lorcan Scott

5 The Climate Change Adaptation Plan for Biodiversity

The culmination of the analysis and data presented to date is captured in this, the Climate Change Adaptation Plan for Biodiversity.

5.1. Goals and objectives

Biodiversity is already under threat and climate change will exacerbate these threats. Degraded habitats are less resilient to the impacts of climate change and they are less able to provide the ecosystem services humans need to be resilient to climate change. Healthy ecosystems and the full diversity of natural life need to be conserved to increase resilience to climate impacts. This is in the interests of people and the planet. Climate change creates another imperative to safeguard biodiversity and increase resilience and nature-based solutions offer win wins for adaptation, mitigation & the SDGs.

Goal: To protect biodiversity from the impacts of climate change and to conserve and manage ecosystems so that they deliver services that increase the adaptive capacity of people and biodiversity, while also contributing to climate change mitigation.

The **objectives** set out in this plan are to:

1. Protect, restore and enhance biodiversity to increase the resilience of natural and human systems to climate change;
2. Improve understanding of the impacts of climate change on biodiversity;
3. Improve landscape connectivity to facilitate mobility in a changing climate;
4. Engage society and all sectors to protect biodiversity to enhance resilience;
5. Ensure sufficient financing is available to implement the Biodiversity Climate Change Adaptation Plan; and
6. Put adequate monitoring and evaluation measures in place to review the implementation of the Biodiversity Climate Change Adaptation Plan

Table 4 highlights the link between the SDGs, the National Biodiversity Adaptation Plan objectives and relevant sectoral plans.

5.2. Adaptation Actions

Adaptation actions deliver progress in responding to climate change and build adaptive capacity. The Actions needed to achieve the objectives of this Plan are set out in this section.

The Actions are informed by existing national policy, for example the Climate Change Act, National Biodiversity Action Plan, and EU Directives. They have been shaped by the consultation process and the inputs received and they take into account cross sectoral linkages, the draft sectoral and local adaptation plans available at the time of writing and the decentralised nature of responsibility for biodiversity conservation.

Great care was taken in defining these adaptation actions not to replicate the objectives of the National Biodiversity Action Plan and to focus on the *additional actions* required to strengthen resilience to climate change. Each action has been scrutinised to ensure it relates directly to resilience building and adaptation to climate change. Nevertheless, the implementation in full of the National Biodiversity Plan is a precondition for the resilience of ecosystems and species in a climate constrained future.

Do to the complexity of the natural world it is difficult to link the priority impacts with specific weather events, for example the degradation of habitats and changes in ecosystem process may be as a result of a combination of increasing temperature, more intense storms and increased winter/spring rainfall. Therefore these adaptation actions focus on restoring natural systems to increase resilience (see box 10) to climate change, increasing the permeability of the landscape to allow the movement of species in response to climate change and understanding the value of nature to ensure appropriate planning decisions are made.

Implementation of these actions requires input across Government and society. A list of the main actors associated with each action is provided with the lead actor in bold.

As this is a 5 year Plan the associated timeline should be interpreted as follows: Short – 1 year; Medium – 2-3 years; Long 4-5 years and beyond with some actions ongoing.

Table 4. National Biodiversity Adaptation Plan objectives, corresponding objectives from the National Biodiversity Action Plan, relevant Sectoral Adaptation Plans and the SDGs.

National Biodiversity Adaptation Plan Objectives	Relevant objective of the National Biodiversity Action Plan*	Relevant Sectoral Adaptation Plans	Relevant SDGs
1. **Protect, restore and enhance biodiversity to increase the resilience of natural and human systems to climate change;**	Objective 4 & 5	• Health • Agriculture, Forestry and Seafood • Water Quality and Water Services • Built and Architectural Heritage • Transport Sector • Local Authority Adaptation Strategies	
2. **Improve understanding of the impacts of climate change on biodiversity;**	Objective 2		
3. **Improve landscape connectivity to facilitate mobility in a changing climate;**	Objective 4, 5, 6		
4. **Engage society and all sectors to protect biodiversity to enhance resilience;**	Objective 3		
5. **Ensure sufficient financing is available to implement the Biodiversity Climate Change Adaptation Plan;**	Objective 1		
6. **Put adequate monitoring and evaluation measures in place to review the implementation of the Biodiversity Climate Change Adaptation Plan**			

*National Biodiversity Action Plan Objectives. Objective 1 Mainstream biodiversity into decision-making across all sectors; Objective 2 Strengthen the knowledge base for conservation, management, and sustainable use of biodiversity; Objective 3 Increase awareness and appreciation of biodiversity and ecosystem services; Objective 4 Conserve and restore biodiversity and ecosystem services in the wider countryside; Objective 5 Conserve and restore biodiversity and ecosystem services in the marine environment; Objective 6 Expand and improve management of protected areas and species; Objective 7 Strengthen international governance for biodiversity and ecosystem services

The associated Resources refer whether the action can be carried out within current budget allocations (Low); whether additional human and/or financial resources would be needed (Medium); whether significant additional resources are needed (High).

Box 10: Ecosystem Resilience

Ecosystem 'resilience' is a concept that has been applied to ecological systems for some time and is generally considered to be the capacity of an ecosystem to absorb various disturbances and reorganize while undergoing state changes to maintain critical functions (e.g. Walker and Salt, 2006; Côté and Darling, 2010; Sasaki *et al.*, 2015). In other words, it is the ability of an ecosystem to continue to function and maintain its regular patterns of biogeochemical cycling and biomass production when subjected to environmental stress. The time taken for an ecosystem to recover from a disturbance, or environmental stress, is also considered a measure of resilience. The resilience of an ecosystem disturbance is a function of the ecosystems key attributes and influenced by its ecological attributes and abiotic factors such as physiographic, geological and climatic conditions. When ecosystem resilience is sufficiently degraded or lost by disturbances (anthropogenic or natural), the ecosystem is exposed at high risk of shifting from a desirable ecosystem state to an undesirable state (Sasaki *et al.*, 2015).

There has been a state-shift in ecosystems which is due mainly to disturbances associated with anthropogenic activities such as land drainage, eutrophication of water, unsuitable grazing levels and the proliferation of invasive species. Whilst changes in land and water use are the primary drivers of global ecological change (IPBES, 2019; FAO, 2019; NPWS, 2019), climate change is now also a significant diver of ecological degradation, exacerbated by local environmental disturbances already impacting on the stability of ecosystems and their resilience.

Ecological thresholds represent points where an ecosystem can switch between states and changes in biotic/abiotic interactions and feedback functions. Whilst ecosystems naturally fluctuate, a critical threshold may be passed where a different set of feedbacks become dominant, and the system experiences a large, often abrupt change in structure and function – or a "regime shift".

The exceedance of such thresholds is damaging to the functioning of the ecosystem and is reflected by the presence or abundance of its indicator species (plant or animal), and may be quantifiably linked to changes in prevailing environmental conditions, such as soil chemistry, geomorphology, water availability, water quality and water table fluctuation dynamics. This is particularly the case for aquatic and terrestrial ecosystems where hydrology is an essential driver of soil and ecosystem conditions. Understanding the environmental supporting conditions of an ecosystem is thereby fundamental to the understanding of any observed or predicted ecological changes (which may be identifiable as 'damage' or environmental impact).

Within the global carbon cycle, marine and terrestrial ecosystems are particularly important reservoirs for anthropogenic carbon emissions, with a gross sequestration of 5.6 gigatons of carbon per year (the equivalent of some 60 per cent of global anthropogenic emissions) (IPBES, 2019). A terrestrial ecosystem of particular importance is peatland, which meter for meter, store more carbon than any other terrestrial ecosystem (Dise, 2009) and twice as much carbon stored in the earths forests combined (Ise *et al.*, 2008). This is despite covering only about 3% of Earth's land area. In Ireland, peatland covers > 21% of the landscape, but only 17% is considered to be in its 'natural' form (NPWS,

2015). A long history of land management has fragmented this peatland expanse and damaged their structure and water retention properties. This alteration in hydrology has thereby transformed peatlands in Ireland, and across Western Europe, from long-term carbon sinks into sources as the water table (an ecological threshold) is the primary determinant of soil-organic-carbon dynamics and ecological change. Whilst peatlands are typically considered resilient to climate change, due to the capacity of peat to store water through dry periods, degraded systems are much more vulnerable to climate induced hydrological change due to their compromised resilience. Restoration of terrestrial ecosystems such as peatland is thereby important for climate adaptation and mitigation strategies, as well as for conserving their unique biodiversity.

Ecosystem restoration is understood as assisting the recovery of degraded, damaged and destroyed ecosystems to regain ecological functionality and provide the goods and services that people value. The alleviation of local drivers of ecological deterioration through restoration and conservation management can increase the resilience of damaged ecosystems to climate change and help revert it back to its ecological state pre-disturbance.

Peatland (Clara Bog) pre (left) and post (right) disturbance (due to drainage; Regan *et al.*, 2019). Pre-disturbance (2009), the peatland is dominated by *Sphagnum* spp and a consistent sink for CO_2. Post disturbance (2016), the peatland is dominated by heather and white beak-sedge, with no *Sphagnum* spp., and a persistent source of CO2.

Objective 1: Protect, restore and enhance biodiversity to increase the resilience of natural and human systems to climate change

Ecosystem 'resilience' is the ability of an ecosystem to continue to function properly when subjected to environmental stress.

Many habitats are reported to be in an unfavourable status, with almost half undergoing ongoing declines from previous assessments (NPWS, 2019). We are therefore witnessing a state-shift in Ireland's ecosystems which is due mainly to disturbances associated with anthropogenic activities such as land drainage, eutrophication of water, unsuitable grazing levels and the proliferation of invasive species. Whilst changes in land and water use are the primary drivers of ecological change, climate change is now also a significant diver of ecological degradation, exacerbated by local environmental disturbances already impacting on the stability of ecosystems and their resilience.

Ecosystem restoration assists the recovery of degraded, damaged and destroyed ecosystems to regain ecological functionality and provide the goods and services that people value. The alleviation of local drivers of ecological deterioration through restoration and conservation management can increase the resilience of damaged ecosystems to climate change.

The actions under this objective aim to build on past, existing or imminent policies and measures that are being, or have been, pursued to increase the resilience of natural systems. These will include ongoing peatland restoration, implementation of the All Island Pollinator Plan, building on the EPA soil protection strategy, rejuvenation of Invasive Species Ireland, consideration of coastal zone management that will be embedded in relevant policies including the National Marine Planning Framework (Ireland's National Marine Spatial Plan), the incentivisation of farmers and land owners to protect biodiversity and the use of existing data to inform future management.

Raised bog cut by machine. The Living Bog Restoration Project

1. **Protect, restore and enhance biodiversity to increase the resilience of natural and human systems to climate change**	Actors	Timeframe	Resources
1.1 Resource and implement the National Biodiversity Action Plan 2017-2021	**DCHG** and All relevant Government Departments, Local Authorities, citizens, NGOs, Academia, Business, NBDC,	ongoing	High
1.2 Restore and enhance natural systems to increase resilience – starting with managing hydrological processes, carbon processes and pollination	**DCHG, DAFM**, MI, BIM, OPW, DCCAE (IFI), LAs, Bord na Móna, Coillte, eNGOs	ongoing	High
1.3 Develop and implement a National Soil Strategy to increase the resilience of soils to climate change and to capture co-benefits for carbon sequestration	**DAFM**, Teagasc, EPA, DCCAE	Medium term	High
1.4 Promote ecosystem restoration and conservation through Payment for Ecosystem Services and investment in actions that increase carbon sinks while promoting biodiversity (e.g. woodlands, bogs, soil management, hedgerows).	**DAFM**, DCHG, Teagasc, DCCAE, EPA	Short term	Medium
1.5 Strengthen the Natura 2000 network by providing additional funding to incentivise land and ecosystem restoration by farmers and land owners and increase capacity for enforcement of habitat regulations	**DCHG**, DAFM, DCCAE. LAs, Farmers and Land owners	ongoing	High
1.6 Establish and implement an all-island invasive species programme to monitor the spread of terrestrial, aquatic and marine invasive species in a changing climate and control invasive species where their spread is considered problematic	**DCHG**, DAERA (NI), DAFM, BIM, DCCAE (IFI), TII, NBDC, LAs, EPA, WI	Short term	Medium
1.7 Use OPW and GSI flood maps to assess exposure of biodiversity and Natura sites to current and future flood risk and use assessments to inform future management	**DCHG**, OPW, DCCAE	Short term	Low
1.8 Develop an integrated coastal management strategy which includes ecosystem based adaptation actions to manage climate risk and build resilience to climate change	**DHPLG**, DAFM, DCHG, GSI, OPW, DCCAE, Academia, Marine Institute, DTTAS, EPA, LAs	Short term	Medium

Objective 2: Improve understanding of the impacts of climate change on biodiversity

The action that underpins all others for this objective is the execution of a comprehensive vulnerability assessment of biodiversity in Ireland, including a priority impact assessment to determine the factors that contribute to exposure and sensitivity and to identify the most at risk species and habitats for priority attention. The EPA, with support from DCHG, have ring fenced funding to undertake these assessments.

An essential element of national adaptation planning is addressing the risks posed by a changing climate to the natural environment. Long-term multidisciplinary observational data is essential for the sustainable management of ecosystems and tackling the challenges resulting from land management and climate change. However, currently neither the data nor sufficient observational infrastructure exists in Ireland for addressing current and future risks. The NPWS, in collaboration with other state agencies such as EPA, GSI and OPW, can address this deficit by establishing an ecohydrological monitoring network at a suite of key ecosystem sites, such as priority peatlands, rivers, lakes, turloughs, dune slacks and woodlands. The collection of long-term, and consistent, hydrological datasets will allow trends to be identified and their implications assessed with respect to the ecosystems dependent ecology. This will greatly improve the national capacity to understand how ecosystems respond to climatic stresses and improve the reliability of planning and predictions. Existing monitoring programmes by DCHG and the EPA may indirectly establish connections between trends in status and climate change. Dedicated programmes on species sensitive to changes in climate (e.g. butterflies and fish) are being undertaken by NBDC and IFI respectively; however these need to be expanded and use citizen science where appropriate.

Studying plant and species phenology is a powerful way to improve understanding of the impacts of climate change on biodiversity. The EPA has recently re-established funding for phenology research in Ireland, with the following departments and organisations involved on the steering committee: DAFM, DCCAE, National Biodiversity Data Centre, Central Statistics Office, OPW and Met Éireann. OPW and Met Éireann also contribute data to the International Phenological Gardens of Europe (IPG), but coordination at the national level between the phenological gardens in Ireland and better access to the data for Irish researchers is required. Improved access to phenological data will be helped by a long-term commitment to a National Phenological Network and central coordination of all phenological data by an established organisation. It should also be noted that the monitoring of phenological change at a national scale can potentially benefit from remotely sensed data (from satellites and drones).

Following the monitoring of current impacts on climate change on biodiversity scenario planning should be undertaken to assess the projected impacts of climate change on biodiversity to inform strategic decision-making. In terms of assessing the impact of climate change adaptation actions on biodiversity and to reduce the risk of maladaptation, additional impact screening should be developed, including as part of EIA and building on the EU Guidelines on integrating climate change and biodiversity into EIA (European Commission, 2013b).

Raising awareness on the links between Biodiversity and Climate Change is required throughout the education system. Education and training can be provided through existing programmes.

2. **Improve understanding of the impacts of climate change on biodiversity**	Actors	Timeframe	Resources
2.1 Undertake a comprehensive vulnerability assessment of biodiversity in Ireland, including a priority impact assessment to determine the factors that contribute to exposure and sensitivity and to identify the most at risk species and habitats for priority attention	**DCHG, EPA**, BIM, MI, DCCAE, Academia, DAFM, Teagasc	Short term	Low
2.2 Monitor the current impacts of climate change on biodiversity including the establishment of an ecohydrological monitoring network at representative sites, with all data made available to inform adaptation and conservation action	**DCHG**, DCCAE, EPA, OPW, GSI, BIM, MI, LAs, NBDC, Academia	Ongoing	Medium
2.3 Undertake scenario planning to assess the projected impacts of climate change and climate responses (e.g. flood management plans and renewable energy installations) on biodiversity to inform strategic decision-making	**DCHG**, DAFM, DCCAE, EPA, BIM, DHPLG, OPW, LAs, Coillte, Bord na Móna	Medium term	Low
2.4 Monitor phenological change including in phenological gardens	**EPA**, DAFM, DCCAE, NBDC, OPW, Academia, Met Éireann	ongoing	Medium
2.5 Develop an impact assessment tool to screen for potential maladaptation impacts (with negative consequences for biodiversity) of climate change adaptation actions across all sectors	**EPA**, DCHG, BIM, MI, LAs, NBDC, Academia	Short term	Medium
2.6 Establish a citizen science programme to collect data on how climate change and extreme weather is affecting biodiversity	**DCHG**, DCCAE, NBDC, eNGOs, Academia, Citizens	Medium term	Medium
2.7 Conduct research into the ecological and social effectiveness of ecosystem-based approaches to climate change adaptation to inform actions to safeguard ecosystem services in Ireland	**DCHG**, EPA, DCCAE, DAFM, MI, OPW, Academics and students	Medium term	Low
2.8 Collate and share information on biodiversity and ecosystem based adaptation actions being implemented in Ireland to facilitate policy review and contribute to better implementation of actions	**DCHG**, MI, EPA, DCCAE, LAs, CAROs, NBDC, eNGOs, Climate Ireland	Short term	Low
2.9 Educate school children through existing (Heritage Schools Programme, An Taisce Green Schools, Clean Coasts) and additional educational programmes to raise awareness of the links between biodiversity and climate change	**DCHG**, Dept Education, An Taisce, Heritage Council, eNGOs	Short term	Medium
2.10 Provide training for educators on biodiversity and climate related issues and create synergies between biodiversity education initiatives at primary, secondary and 3rd level	**Dept Education**, DCHG, Academia, eNGOs	Short term	Low

Objective 3: Improve landscape connectivity to facilitate mobility in a changing climate

Fragmentation of natural habitats hinders the adaptive capacity of species that need to spread to new areas in response to a changing climate. Objective 58 of the National Planning Framework recognises the importance of Green Infrastructure and calls for integrated planning for Green Infrastructure and ecosystem services to be incorporated into the preparation of statutory land use plans. However approximately two-thirds of the terrestrial area of Ireland is used for agriculture and forestry and is not conducive to the movement of many of the species susceptible to climate change.

The actions under this Objective will determine what species and habitats are vulnerable to fragmentation and look at ways of enhancing connectivity across the landscape and reducing barriers to movement. The connectivity of coastal and marine protected areas will also be considered.

3.	**Improve landscape connectivity to facilitate mobility in a changing climate**	Actors	Timeframe	Resources
3.1	Assess the risks associated with a changing climate in the context of landscape fragmentation and in order to inform site designation, protection and connectivity and to prevent the spread of invasive species	**DCHG**, EPA, WI, OPW, DHPLG, Academia	Short term	Low
3.2	Identify vulnerable ecosystems and species that through enhanced landscape connectivity would be more resilient to climate change	**DCHG**, DHPLG, MI, BIM, EPA, OPW (BG) LAs, DAFM, DCCAE (IFI), Academia	Short term	Low
3.3	Design corridors to enhance the resilience of protected areas and increase opportunities for dispersal across the landscape	**DCHG**, LAs, DAFM, DCCAE (IFI), WI	Medium term	Medium
3.4	Design and implement measures to reduce the barrier effects of roads, railways and technical objects in rivers and streams to facilitate species spatial responses to climate change	DTTAS, TII, OPW, DCCAE (IFI), LAs	Medium term	Medium
3.5	Consider the use of Agri-environment measures to maintain heterogeneity and connectivity in the wider landscape	**DAFM**, DCHG, Teagasc	Short term	Low
3.6	Conduct research to understand the role of Marine Protected Areas and coastal zones in landscape connectivity for greater climate resilience	**DPHLG**, MI, DCHG, Universities	Medium term	Medium

Objective 4: Engage society and all sectors to protect biodiversity and enhance resilience

Given the increased prevalence of flooding, as well as the predictions for future sea level rise, there has been a greatly increased focus on flood defence and relief schemes around the country, with some coastal works under construction, others at planning stage, as well as plans to modify rivers, lakes and turloughs in the midlands and west (Lewis *et al.* (2019). In many cases this involves dredging to deepen river channels, removal of trees, building concrete walls, constructing earth embankments and pumping stations and other similar solutions. Hard engineering responses to flooding have the potential to significantly impact biodiversity, particularly where man-made structures prevent natural coastal habitats (e.g. saltmarsh, intertidal habitat) from moving landward as sea level rises, squeezing them against the hard defences. This is known as 'coastal squeeze' and means the extent and functioning of the coastal habitats reduce over time, along with the habitats and species that they support. Therefore the consideration of nature based solutions together with screening for maladaptation is very important to increase the potential of low cost win-win climate actions.

Engaging the public, schools, businesses and local community organisations will be key to creating a better understanding of the impacts of climate change on biodiversity and to building support for investment in biodiversity as a key asset in resilience building. Designing and managing green and blue spaces that allow people to enjoy nature, while sequestering carbon and increasing resilience is a win-win for biodiversity, human health, eco-tourism and climate action.

4.	**Engage society and all sectors to protect biodiversity to enhance resilience**	Actors	Timeframe	Resources
4.1	All relevant sectors to consider nature based solutions as potential low cost win-win climate change adaptation and mitigation solutions, screen for maladaptation and report on relevant action as part of the review of this and other sectoral adaptation strategies	All relevant sectors	Short term	Medium
4.2	Build and strengthen governance arrangements and promote cross-sectoral communication and cooperation to strengthen nature based adaptation solutions and avoid maladaptation	**DCCAE**, CCAC, DCHG, Biodiversity Working Group, Biodiversity Forum, OPW, All relevant sectors	ongoing	Low
4.3	Design and implement a citizen engagement and awareness campaign on climate change and biodiversity conservation to capture case studies, tell stories and engage citizens in data collection and monitoring	**DCHG**, DCCAE, LAs, NBDC, EPA, An Taisce, Tidy Towns, CAROS	Short term	Low
4.4	Co-design green spaces and wildlife refuges in cities and peri-urban areas with local communities to provide habitats for species under threat from climate change and to connect people to biodiversity	**LAs**, DCHG, DHPLG, MI, Tidy Towns, eNGOs, Schools	Short term	Low
4.5.	Engage stakeholders in all sectors to protect biodiversity in order to increase resilience to climate change	**DCHG**, all stakeholders	Ongoing	Low

Objective 5: Ensure sufficient financing is available to implement the Biodiversity Climate Change Adaptation Plan

DCHG and the Irish Research Council are currently funding a Financial Needs Assessment to determine the costs of fulfilling national biodiversity policy objectives. The research will assess the effectiveness of the use of current funding streams and provide an extensive assessment of the full range of potential financing mechanisms (e.g. payments for ecosystem services, biodiversity offsets, restoration of carbon sinks, fiscal transfers, etc.), together with improved targeting of existing measures for biodiversity. This assessment will include consideration of the pros and cons of developing synergies with social and economic objectives through funding related to ecosystem services, including an extension to regulating ecosystem services to address such aspects as water quality, flooding and climate change adaptation. A financial strategy will be developed to address the finance gap combining suitable and nationally-adapted mechanisms and to achieve cross-departmental buy-in. A Policy and Institutional Review will analyse positive and negative policies and subsidies to fully outline the challenge of not only mobilising finance, but of ensuring policy and environmental fiscal reform.

It is important to value our natural assets and ensure that cost benefit analyses are considered to promote Ecosystem Based Adaptation options. This will increase the visibility of the importance of ecosystem services in cross-sectoral policy considerations. The CAROS note that while local authorities recognise the worth of this emerging concept and have a role in contributing to it, there is a requirement for guidance, leadership and relevant case studies in the area of natural capital accounting. Ongoing research such as the EPA funded project 'Irish Natural Capital Accounting for Sustainable Environments 2019-2023' should help to fill this gap. In the meantime, local authorities are advancing such measures as ecosystem services scoring and communicating the benefits of biodiversity to citizens.

An analysis of the effectiveness of the Common Agricultural Policy Greening rules and measures under the European Maritime and Fisheries Fund to protect biodiversity and increase climate resilience (building on Regulation (EU) No 1303/2013 which sets down common provisions for a number of European funds) is also considered under Objective 5. DCHG will work closely with DAFM to maximise the CAP greening rules and measures under the European Maritime Fisheries Fund (EMFF) on climate change and biodiversity. DCHG is on the Operational Programme Monitoring Committee for the EMFF and therefore has the opportunity to influence the scope of measures being approved. DCHG also has access to the Marine Biodiversity Scheme, which is funded by the Irish Government and the EU and is housed in the Marine Institute. The scheme has three priorities, including the protection and restoration of aquatic biodiversity and ecosystems.

5. Ensure sufficient financing is available to implement the Biodiversity Climate Change Adaptation Plan	Actors	Timeframe	Resources
5.1 Develop a financial strategy to implement this plan which includes public and private funds innovative financial mechanisms and enables investment from national to local level	**DCHG**, DPER, Private sector, LAs	Short term	Low
5.2 Commission research to explore the potential for innovative finance for biodiversity conservation to increase resilience to climate change e.g. Green Bonds, Payment for Ecosystem Services, carbon offsetting, business investment	**DCHG**, DPER, EPA, Academia	Short term	Low
5.3 Undertake natural capital accounting in all sectors to ensure natural capital is being valued and cost benefit analyses are undertaken to promote Ecosystem Based Adaptation options where appropriate	**EPA**, DPER, DCHG, DHPLG, OPW, DAFM, MI, BIM, DCCAE, LAs, Academia	ongoing	Low
5.4 Analyse the effectiveness of the Common Agricultural Policy Greening rules and measures under the European Maritime and Fisheries Fund to protect biodiversity and increase climate resilience	**DAFM**, DCHG, Academia	Medium term	Low
5.5 Set up an interdepartmental group to advise on priorities under the EU LIFE Climate sub-programme	**DCCAE**, DCHG, DAFM, DHPLG, OPW	Short term	Low

Objective 6: Put adequate monitoring and evaluation measures in place to review the implementation of the Biodiversity Climate Change Adaptation Plan

The first and underpinning action for this objective is to collate and cross-reference actions in other sectoral plans to realise synergies, avoid maladaptation actions and monitor their contribution to this Plan. This exercise can be carried out once the sectoral plans are finalised and when new governance arrangements foreseen under the Climate Action Plan are in place. To be effective, a common set of adaptation indicators should be developed across sectors to minimise duplication and to reduce the need for parallel monitoring and review systems. Indicators should build on existing frameworks such as the National Biodiversity Indicators (https://indicators.biodiversityireland.ie/).

The Climate Change Advisory Council advises that an agreed set of climate change adaptation indicators needs to be developed and implemented as soon as possible and reported on through the Annual Transition Statement Process (Climate Change Advisory Council, 2019). Ongoing EPA funded research work (Policy Coherence in Adaptation Studies) is focused on developing adaptation indicators to be applied in an Irish context and is due for completion in mid-2020. This will be an important resource to all sectors and should inform the development of common set of national adaptation indicators.

Finally, developing an information portal to allow relevant stakeholders to upload and access collated information would provide a valuable resource to support monitoring and evaluation actions. This portal could be hosted on Climate Ireland with the potential to link with the National Biodiversity Data Centre datasets.

6.	**Put adequate monitoring and evaluation measures in place to review the implementation of the Biodiversity Climate Change Adaptation Plan**	Actors	Timeframe	Resources
6.1	Collate and cross-reference actions in other sectoral plans to realise synergies, avoid maladaptation actions and monitor their contribution to this Plan	All relevant sectors, CAROs, Dept Finance, Climate Change Advisory Council, EPA, Academia	Short	Low
6.2	Monitor climate change risks and associated costs and adaptation actions, costs and outcomes related to biodiversity on a regular basis	All relevant sectors	Medium	Medium
6.3	Develop monitoring and evaluation indicators, including cross sectoral indicators, that streamline reporting and avoid duplication	**DCCAE**, CSO, CAROs, Climate Change Advisory Council, EPA, Academia, NBDC, DCHG, OPW, DAFM, MI, BIM, Las	Short	Low
6.4	Establish a portal on Climate Ireland to direct decision makers to relevant biodiversity databases to facilitate monitoring	**DCCAE**, DCHG, OPW, Academia, EPA, NBDC, eNGOs.	Short	Low

6 Implementation, evaluation and review

Implementing this Plan requires resources, human and financial, close collaboration with other government departments and local authorities. Effective governance and oversight of the Plan will be critical to its success as will regular monitoring and evaluation. Adaptation is a new process and requires a flexible learning-by-doing approach. This Plan is a working document, designed to accommodate revisions and updates when and where necessary and to remain responsive to other sectoral pan and local authority plans. The Plan will be widely disseminated and communicated with a review in 2021 and a new, updated plan expected in 2024.

The day to day implementation of this Plan will be the responsibility of the Planning Team – now named the Implementation team.

6.1. Strategic Environmental Assessment and Appropriate Assessment

A range of adaptive measures are proposed in the Plan which will be implemented by a wide variety of organisations through a series of plans and programmes. It is through the widespread integration of these adaptive measures into local and sectoral planning that biodiversity will be protected and in so doing increase the resilience of natural and human systems.

It is the expectation of the DCHG that where plans and programmes are developed by plan and programme makers and, where necessary, issued for approval to consenting authorities, compliance with the Strategic Environmental Assessment Directive (2001/42/EC), the Habitats Directive (92/42/EEC) and the Birds Directive (2009/147/EC) and transposing national legislation will be adhered to where relevant.

In accordance with the SEA Directive, competent authorities (plan/programme makers) must subject plans and programmes related to or impacting on biodiversity to an environmental assessment where they are likely to have significant effects on the environment.

Article 6(3) of the Habitats Directive requires that competent authorities assess the potential impacts of plans and projects on the Natura 2000 network of European protected sites to determine whether there will be any 'likely significant effects' as a result of a plan's or project's implementation (either on its own or 'in combination' with other plans or projects); and, if so, whether these effects will result in any adverse effects on the site's integrity.

This Plan has undergone screening for SEA and AA. These reports will be published separately from this Plan and made available on the npws.ie website.

6.2 Implementation

The Minister for Culture, Heritage and Local Government provides leadership and has responsibility for overseeing the implementation of this Plan, which will require the full cooperation and participation of other Departments, Local Authorities and the CAROs. The risk of low levels of commitment or capacity to implement this plan from the multiple responsible bodies will be a challenge. As a result, a flexible and collaborative approach will be critical.

Business has a role to play in climate change adaptation by assessing their exposure to climate risk and investing in risk reduction and adaptation actions. Business also has a role in protecting, conserving and restoring biodiversity. The BITCI Biodiversity Handbook for business, identifies actions businesses can take through their core operations or Corporate Social Responsibility to promote and create diverse natural habitats that yield economic benefits and increase resilience to climate change – such as tree and meadow planting, pollinator projects and degraded land restoration (Hamilton *et al.*, 2019). A 2010 report by Forfás reviewed adaptation issues for business in Ireland and found that business is risk from climate impacts on supply chains, markets, production, premises, insurance costs and investments (Forfás, 2010). The report also assesses the opportunities for business in adapting to climate change and the role business can play in building resilience. For example, the need to make business infrastructure resilient, like water supplies, flood protection, energy services, transport and communications. Green infrastructure and nature based approaches to adaptation can be invested in by businesses to protect their supply chains and operations. Business can also invest in ecosystem

resilience to protect infrastructure, including building, from climate risk, and invest in ecosystem restoration to create new business and employment opportunities and to absorb carbon. Engaging business in a dynamic way in the implementation of adaptation actions can both reduce their exposure to risk and reduce emissions, e.g. though afforestation, ecosystem restoration and habitat conservation.

The **public** have an important role to play in collecting data and observations as citizen scientists and in promoting healthy ecosystems on their land and in their communities. **Community groups and NGOs** from Tidy Towns to youth and sporting clubs play an important role in designing and implementing biodiversity projects and in raising awareness of the role of biodiversity in climate change adaptation. Implementation of this plan will depend on the effective engagement of society, as envisaged in Objective 4. As part of this it will be important to understand motivations to engage in adaptation actions and to change behaviours. Research has found that economic considerations like saving money to avoiding costs are not the only motivation to adapt. Citizens are also motivated by the potential of adaptation actions to contribute to green, biodiverse surroundings and to actions that also reduce emissions (Brink and Wamsler, 2019). Many of the adaptation actions in this plan fit this description and should be appealing to members of the public.

6.3. Monitoring, evaluation and review

This plan will be will reviewed on an ongoing basis (see Objective 6). Adaptation is a process of learning by doing and documenting actions, reviewing their impacts and sharing experience is key to effective action (Climate Adapt, n.d). Reviewing, monitoring and evaluation are key elements of an iterative adaptation process as they help us to understand progress and performance, learn and share lessons and inform future policy and practice. Lessons learned are shared across EU member states allowing Ireland to learn from experiences in other countries (EEA, 2015b)

The plan will be reviewed in full in 2021 to coincide with the end date of the National Biodiversity Action Plan. The review will take on board lessons learned and to reflect the changing policy context. Monitoring will be the responsibility of the Implementation Team with oversight by the Biodiversity Working Group (strengthened as advised above) and the Minister.

Annual updates of the adaptation actions will be overseen by the Implementation Team to monitor progress, obstacles and successes. These updates will be shared with the Minister and the National Adaptation Steering Committee as well as the Biodiversity Forum. These updates will inform the Annual Transition Statements that will be submitted by the Minister.

Indicators

The Climate Change Advisory Council advises that an agreed set of climate change adaptation indicators needs to be developed and implemented as soon as possible and reported on through the Annual Transition Statement Process (Climate Change Advisory Council, 2019). They suggest a suite of possible indicators primarily focused on mitigation related measures and actions and could also consider the established list of headline biodiversity indicators for Ireland as monitored by the Biodiversity Data Centre (National Biodiversity Centre, 2018). The Agriculture and Land Use focused indicators proposed by the CCAC provide some potentially useful information for biodiversity including total forestry cover in hectares, number of dairy cows and sheep, nitrogen fertiliser use, and total area of drained organic soil. Some of these could be amended to better capture co-benefits for biodiversity. For example, the forestry cover indicator could be augmented to include an indicator on native forestry planted.

It is important to note that whatever set of additional biodiversity indicators are agreed upon need to be practical in so far as they should capture cross-sectoral issues as mentioned in Section 4.1 and outlined under Objective 2. For example, existing water quality indicators could be linked with indicators on peatland fires and resulting biodiversity impacts. Clearly there are data, funding, and time constraints associated with creating composite indicators of this nature but having the tools available to map such impacts and interactions will be vital in protecting, restoring and enhancing biodiversity to

increase the resilience of natural and human systems to the impacts of climate change. The need for integrated fit-for purpose indicators should be tempered by the need to streamline existing reporting, where possible, and build on existing data. As aforementioned, indicators should ideally ensure coherence between sectoral plans, and keep monitoring and evaluation costs to a manageable level and appropriate to the capacities available at local level. Biodiversity indicators should ideally build on the existing monitoring and evaluation work carried out for the National Biodiversity Action Plan and existing reporting to the European Union and Convention for Biological Diversity, and be aligned with the reporting needs of the Sustainable Development Goals. It should be noted that current EPA funded research work (Policy Coherence in Adaptation Studies) is focused on developing adaptation indicators to be applied in an Irish context. The research is due for completion in mid-2020.

Drawing on the key biodiversity impacts outlined in this Plan provides an initial basis for deciding on an indicator set that captures the key present and future climate change driven impacts on Irish biodiversity. Key indicators should refer to: changes in phenology, changes in geographical range of species, changes in species abundance, increased degradation of habitats and changes in ecosystems processes, and changes in numbers of invasive species. There is a clear need to identify relevant indicator species sensitive to the impacts of climate change, for example butterflies and pollinators. Biodiversity indictors also need to capture the both slow onset climate changes and extreme events, and be fit-for-purpose in realising proactive rather than reactive biodiversity monitoring objectives. For example, a fit-for purpose climate change focused biodiversity indicator will pick up on the likelihood of ecological system tipping points before they occur and hence allow proactive management action. Climate change relevant biodiversity indicators also need to contain the appropriate combination of process, pressure and response indictors (DCHG, 2017).

Any set of indicators will need to be embedded in an appropriate reporting framework if the objectives, and associated actions, within the Plan are to be realised. A reporting mechanism for each objective would help once the actors know what they need to achieve. Targets, timelines, and details on resources will need to be made available to help to facilitate this process.

7 References and Appendices

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Appendix I: List of Acronyms

AEWA	African-Eurasian Migratory Waterbirds Agreement
BIM	Bord Iascaigh Mhara
BnM	Bord na Móna
BWG	Biodiversity Working Group
C4I	Community Climate Change Consortium for Ireland
CAP	Common Agricultural Policy
CAROs	Climate Action Regional Offices
CBD	Convention on Biological Diversity
CCAC	Climate Change Advisory Council
CCMA	County and City Management Association
CIEEM	Chartered Institute of Ecology and Environmental Management
CFP	Common Fisheries Policy
CSO	Central Statistics Office
DAFM	Department of Agriculture, Food and the Marine
DAHG	Department of Arts, Heritage and the Gaeltacht
DBBR	Dublin Bay Biosphere Reserve
DCHG	Department of Culture, Heritage and the Gaeltacht
DCCAE	Department of Communications, Climate Action and Environment
DECLG	Department of the Environment, Community and Local Government
DHPLG	Department of Housing, Planning, Community and Local Government
DPER	Department of Public Expenditure and Reform
DTTAS	Department of Transport Tourism and Sport
EbA	Ecosystem-based Approaches
EC	European Commission
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EMFF	European Maritime and Fisheries Fund
ENGO	Environmental Non-Governmental Organisation
EPA	Environmental Protection Agency Ireland
EU	European Union
FRC	FloodResilienCity
FRMPs	Flood Risk Management Plans
GHGs	Greenhouse gases
GIS	Geographic Information System
GLAS	Green Low-Carbon Agri-Environment Scheme
GSI	Geological Survey of Ireland
ICES	International Council for the Exploration of the Sea
IFI	Inland Fisheries Ireland
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC	Intergovernmental Panel on Climate Change
IPG	International Phenological Gardens of Europe
LAWCO	Local Authorities Water and Communities Office
LGMA	Local Government Management Authority
LLAES	Locally Led Agri-Environmental Schemes
MaREI	Marine and Renewable Energy research, development and Innovation centre
MCG	Marine Coordination Group
MEA	Millennium Ecosystem Assessment
MI	Marine Institute
MSFD	Marine Strategy Framework Directive
NAF	National Adaptation Framework
NBAP	National Biodiversity Action Plan
NBDC	National Biodiversity Data Centre
NBG	National Botanic Gardens
NESC	National Economic and Social Council
NGO	Non-Governmental Organisation
NPBR	National Platform for Biodiversity Research
NPWS	National Parks and Wildlife Service
NSPC	National Strategy for Plant Conservation
NSS	National Soils Strategy
NWRMs	Natural Water Retention Measures
OPW	Office of Public Works
OSI	Ordnance Survey Ireland
OSPAR	Convention for the protection of the marine environment in the North-East Atlantic
RBMP	River Basin Management Plan
RDP	Rural Development Programme
SAC	Special Area of Conservation
SDGs	Sustainable Development Goals
SEA	Strategic Environmental Assessment
SEEA	System for Environmental-Economic Accounting
SFPA	Sea Fisheries Protection Authority
SPA	Special Protection Area
TII	Transport Infrastructure Ireland
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WFD	Water Framework Directive
WI	Waterways Ireland
WWF	World Wildlife Fund

Appendix II: Workshop Participants

Biodiversity Climate Change Adaptation Workshop Invited Participants List, Oct 16th, 2018, Collins Barracks, Dublin 7

1. Ciaran O'Keeffe (NPWS)
2. Deirdre Lynn (NPWS)
3. Andy Bleasdale (NPWS)
4. Ferdia Marnell (Species, NPWS)
5. Caitriona Douglas (Peatlands, NPWS)
6. Tara Shine (Facilitator)
7. John O'Neill (DCCAE)
8. Avril Rothwell (DAFM)
9. Cliodhna Tuohy (DTTAS)
10. Stephen Flood (MAREI, UCC)
11. Yvonne Buckley (Biodiversity Forum, TCD Academic)
12. Mike B Jones (TCD Academic)
13. Harriet Walsh (EPA)
14. Gerry Gallagher (OPW)
15. Jacqui Donnelly (DCHG, Built Heritage)
16. Cathal Gallagher (IFI)
17. Fiona Kelly (IFI)
18. Paul Nolan (Irish Centre for High-End Computing (ICHEC) and Met Éireann)
19. Paul Greene (An Garda Síochána)
20. Martin Hehir (DHPLG)
21. John Coll (Maynooth Academic)
22. Katharine Duff (DAFM, Forest Service)
23. Paul Harris (Bank of Ireland)
24. Vincent Upton (Forester, DAFM)
25. Tomás Murray (NBDC)
26. Niamh Ní Cholmáin (Climate Adaptation Regional Office, Dublin)
27. David Dodd (Climate Adaptation Regional Office, Dublin)
28. Eamonn Aylward (DAFM, Marine)
29. Hannah Denniston (DAFM, Farm biodiversity)
30. Maurice Clarke (Marine Institute)
31. Maria Talbot (DAFM, Climate and Bioenergy)
32. David Mellett (Climate Adaptation Regional Office, Mayo)
33. Jenny Neff (CIEEM)
34. Gerry Clabby (NPWS, Ecological Assessments)
35. Tony Brew (OPW, Engineer)
36. Phillip O'Brien (EPA, Climate Change Advisory Council)
37. Noeleen Smyth (Taxonomist, National Botanic Gardens)
38. Caroline Engel Purcell (Carrig Consultants)
39. Matthew Jebb (Director, National Botanic Gardens)
40. Enda Mullen (NPWS, Ecological Assessments)

Appendix III: Workshop Agenda

Stakeholder workshop: Developing a Biodiversity Sectoral Climate Change Adaptation Plan for Biodiversity
Date: Tuesday 16th October 2018
Venue: Collins Barracks, Dublin

Time	Description	Responsible
09.50 - 10.00	Registration and tea / coffee available	
10.00 – 10.10	Welcome	*Dr Ciaran O'Keeffe*
10.10 – 10.20	Introductions, agenda and objectives of the workshop	*Dr Tara Shine – facilitator*
10.20 - 10.35	National Adaption Framework	*John O'Neill, DCCAE*
10.35– 10.50	Sectoral Adaptation Guidelines	*Dr Stephen Flood, MARel, ERI, UCC*
10.50 - 11.05	Ireland's changing climate – what can we expect?	*Paul Nolan, ICHEC*
11.05 – 11.20	Biodiversity Adaptation Plan: the process to date	*Dr Deirdre Lynn, NPWS*
11.20 – 11.40	Questions and discussion - experiences from the processes to develop other sectoral climate change adaptation plans	*Facilitator*
11.40 – 11.45	Introduction to group work	*Facilitator*
11.45 – 12.30	Group work: Observed and future impacts and consequences Inputs: - Draft Biodiversity Sectoral Climate Change Adaptation Plan - Excel tool of impacts and consequences Discussion questions: • What is the state of knowledge based on current and past climate events? • What are the future climate change impacts for the sector? What are the consequences? • What is missing from the draft plan? • What additional sources of information can be identified?	*All participants*
12.30 – 1.15	Lunch	
13.15 – 13.30	Feedback from group discussions	*Group facilitators*
13.30 – 13.40	Biodiversity Sectoral Climate Change Adaptation Plan: goals, objectives and actions	*Dr Deirdre Lynn, NPWS*
13.40 – 13.55	Plenary discussion: reactions to proposed goals and objectives (10 mins) Introduction to group work (5 mins)	*Facilitator*
14.00 – 15.00	Group work: Adaptation actions Inputs: As before Discussion questions: • What actions are missing from the proposed action plan? *Consider:* • *existing / ongoing adaptation actions* • *additional actions required to cope with existing conditions* • *actions to build capacity to ensure long-term climate resilience* • *actions to raise awareness around climate change and biodiversity* • *actions to deliver long-term climate resilience* • *actions related to NPWS resources and operations*	*All participants*

Time	Description	Responsible
15.00 – 15.15	Coffee	
15.15 – 16.00	Plenary: Feedback from group work (10 mins) Discussion on the cross sectoral implications of proposed actions - Opportunities and risks - Duplication and redundancies - Gaps	*Group facilitators* *Facilitator*
16.00 – 16.15	Take aways, follow up actions and close	*Facilitator* and *Dr Deirdre Lynn*
16.15 – 16.30	**Closing remarks**	*Dr Ciaran O'Keeffe*

Appendix IV: Biodiversity Forum Members

(members during initial stages of Plan development)

Name	Affiliation
Yvonne Buckley	Trinity College Dublin
Simon Berrow	Irish Whale and Dolphin Group
Séamus Boland	Irish Rural Link
Ken Bradley	Department of Environment (Northern Ireland)
Tasman Crowe	University College Dublin
Padraic Fogarty	Environmental Pillar
Paul Giller	University College Cork
Paul Harris	Bank of Ireland, Global Markets
Brendan Joyce	Irish Natura & Hill Farmers Association
Elaine McGoff	An Taisce
James Moran	Galway-Mayo Institute of Technology
Jenny Neff	Chartered Institute of Ecology and Environmental Management
Aoife O'Donovan	Irish Business and Employers Confederation
Mark Robins	Birdwatch Ireland
Siobhán Ryan	Heritage Council, Sligo

Appendix V: Biodiversity Working Group Members

(members during initial stages of Plan development)

Name	Affiliation
Ciaran O'Keeffe	Department of Culture, Heritage and the Gaeltacht
Deirdre Lynn	Department of Culture, Heritage and the Gaeltacht
Alan Moore	Department of Culture, Heritage and the Gaeltacht
Ciaran Wrenn	Department of Culture, Heritage and the Gaeltacht
Laura Behan	Department of Transport, Tourism and Sport
Tony Brew	Office of Public Works
Yvonne Buckley	Biodiversity Forum
Colin Byrne	Department of Housing, Planning and Local Government
Brian Deegan	Irish Water
Kathrine Duff	Department of Agriculture, Food and the Marine
Cathal Gallagher	Inland Fisheries Ireland
Margaret Gormley	Office of Public Works
Paul Greene	An Garda Síochána
Harry Harris	Department of Health
Georgina Hughes-Elder	Department of Public Expenditure and Reform
Karen Hynes	Department of Business, Enterprise and Innovation
Catherine Keena	Teagasc
Colin Kelleher	Office of Public Works
Liam Lysaght	National Biodiversity Data Centre
Finola Moylette	Department of Rural and Community Development
Anne Murray	Department of Education and Skills
Jack Nolan	Department of Agriculture, Food and the Marine
Francis O'Beirn	Marine Institute
Tadhg O'Mahony	Environmental Protection Agency
Brian O'Malley	Department of Public Expenditure and Reform
Ruairi O'Rua	Department of Public Expenditure and Reform
Owen Ryan	Department of Communication, Climate Action and Environment

Appendix VI: Extreme events timeline 2008-2018: Impacts and consequences for biodiversity

Date	Event	Description	Observed impacts on habitats and species	Impacts on your capacity to do your job, on NPWS (or another organisation) operations, resources and infrastructure	Source
2018	Summer drought and heat wave	Water shortages, high temperatures	Noticeable increase in aquatic plant growth on Lough Ennell (persistence of this process coupled with lower water levels could lead to future eutrophication issues) Scorched vegetation in calcareous species rich grassland	Could not access Lough Ennell by boat to conduct summer breeding bird surveys as water levels were so low. Could not access some areas on Lough Ree due to low water levels during summer breeding bird surveys	Conservation Ranger, South Westmeath, NPWS
			Water levels on Girley Bog in Co. Meath were lower particularly in the cutover bog Water levels in Lodge Bog Co. Kildare were significantly lower than usual for a long period of time. On Lullymore West Bog in Co. Kildare water levels in a pond and drain were dropped well below the surface	Impacted on Sphagnum transfer trials established in 2014 and 2015 This may have had knock on effects for breeding curlew on site. It was not possible to monitor invertebrates which we do on a regular basis.	Irish Peatland Conservation Council
			Low water levels at Lady's Island Lake facilitated terrestrial predators access to islands where Tern colonies located, predators included Pine Marten, American Mink, Hedgehog. Impacts on Arctic, Common & Roseate Terns. https://www.npws.ie/protected-sites/spa/004009	Low water levels hampered boating	Conservation Ranger, Wexford, NPWS
			Vegetation showing drought stress. Low lake levels, increased levels of filamentous algae	Heat stress impairing work rate	Conservation Ranger, Killarney National Park
			Earlier start to turf cutting and second cut in some areas, prolonged disturbance to ground nesting birds in SPA and NHA. Very low water levels in rivers and lakes.		Conservation Ranger, Monaghan, NPWS
			Fires on Liffey Head Bog and L. Bray that went on for weeks in May, burned into the peat and kept re-igniting. In heath away from those fires, bilberry plants died if they were on any rocky areas	Huge cost for helicopter, Fire Service etc. Staff got no other work done, were exhausted, one suffering from smoke inhalation and worked many, many more hours than normal working week	Ecologist, Department of Culture, Heritage and Gaeltacht

Date	Event	Description	Observed impacts on habitats and species	Impacts on your capacity to do your job, on NPWS (or another organisation) operations, resources and infrastructure	Source
			Breeding wader chick rearing habitats drying out Intense Fires on Slieve Blooms SPA/SAC – ground nesters and young deer Bog Fires e.g. Mouds Bog	Water pumped to wader scrapes on the Shannon Callows Very dry vegetation led to very intensive fires that were difficult to control by authorities	Conservation Ranger, Laois Offaly, NPWS
			Resident breeding bird populations reduced. CES ringing at Cabragh Wetlands (13 years now) showed that resident bird numbers were the lowest since we began ringing at the site. Also migrant numbers to the site were lowest recorded too. Either upon arrival birds moved elsewhere/did not breed/or habitat never fully established due to cold spring and dry summer combo. Certainly the reed bed at the Cabragh Wetlands is beginning to be succeeded by Greater Willow Herb as it appears the site is drying out.		Conservation Ranger, Tipperary, NPWS
				Increased mortality of tree seedlings	Wildlife Inspector, Dublin, NPWS
			Exceptionally low, and prolonged, water tables recorded at Clara Bog SAC. This resulted in the first recorded absence of runoff (near 2 months) from the bog (since 1991). This means that there was no water held in 'storage' on the bog near-surface. This affects the habitat and its keystone species, *Sphagnum*, as there was no water availability for its growth and maintenance. Similar observations were recorded at Abbeyleix Bog (NHA); and presumably all midland raised bogs. Immediate impact on *Sphagnum* (active raised bog) unknown; but will be assessed in near-future ecotope surveys. The resilience of *Sphagnum* to regular 'drought' events such as this is also unknown; again, periodic monitoring is necessary to quantify this.		Ecologist, Offaly, NPWS
			Numerous fires on the sand dunes noted in areas outside the Natura site boundary. Boyne Coast and Estuary 001957 None recorded inside the Natura site as I was no longer a Conservation Ranger for Meath but I expect there were fires within the designated areas.		Conservation Ranger, Meath, NPWS

Date	Event	Description	Observed impacts on habitats and species	Impacts on your capacity to do your job, on NPWS (or another organisation) operations, resources and infrastructure	Source
			Increased fire and possibly increased regeneration of Bracken post-fire in Co. Wicklow. Desiccation of habitats – short turf on an area of Bull Island (Co. Dublin) that has been monitored for many years showed almost complete die back of above ground biomass (apart from Salvia verbenaca): subsequent recovery (as of 13/11/18) seemed patchy and may facilitate establishment of Salvia seedlings - several fens dried, e.g. water levels very low at Scragh Bog (c. Westmeath)		Researcher, Trinity College Dublin
			Lake and river levels low, any nests on exposed rocks, likely to be inundated with water again. Impact on fisheries and therefore food sources. Low number of salmonids running until late season. Native woodland establishment projects sustained increased losses. Wet and marginal pasture land bordering National Park in better condition this autumn due to dry summer. Higher risk of fires Ponds drying up – impacting on newts and frogs	Staff availability to respond to extreme events, for example bog fires, needs to be considered Important to prepare and pace correctly for field survey work. More water required than normal, sun block etc. Risk of over exposure/sun stroke. Fire management strategy highlighted	District Conservation Officer, Mayo, NPWS
2018	Spring late arriving	Slower growth, wet ground, cool temperatures	Waterlogged soils, complicated grazing at Ballyteige NNR. https://www.npws.ie/nature-reserves/wexford/ballyteigue-burrow-nature-reserve		Conservation Ranger, Wexford, NPWS
			Low butterfly numbers (Butterfly survey)		Conservation Ranger, Killarney National Park
			Delayed breeding of some bird species.		Conservation Ranger, Monaghan, NPWS
			Small mammal populations were reduced or breeding delayed resulting in numbers peaking later. Underweight Barn Owl Chicks (based on nest recording in Tipperary) and several phonecalls in September of dead or underweight Barn Owl Chicks.		Conservation Ranger, Tipperary, NPWS

Date	Event	Description	Observed impacts on habitats and species	Impacts on your capacity to do your job, on NPWS (or another organisation) operations, resources and infrastructure	Source
			Late nesting for curlew and other birds	Delays in survey dates impact work scheduled later in the season	District Conservation Officer, Mayo, NPWS
2018	Storm Emma	Feb / March – Snow and cold temperatures	Trees blown over in publicly accessible woodland trail (split Hills & Long Hill esker SAC). Bats may have been disturbed or damaged as one tree had a bat box attached to it and inspection of the bat box showed it had been recently occupied.	Could not drive for work during the storm.	Conservation Ranger, South Westmeath, NPWS
				The Bog of Allen Nature Centre was closed to visitors and we lost revenue as a result as groups could not reschedule. Also the officer was closed for three days which prevented four staff from working on site	Irish Peatland Conservation Council
			Fallen trees	Travel restrictions, worked from home. Confined to offices	Conservation Ranger, Monaghan, NPWS Conservation Ranger, Laois Offaly, NPWS
			A number of bird species accessing supplementary feeding at Bird Feeders. Fieldfare/Redwing feeding on apples provided at feeding station in my back garden. Lapwing also observed foraging in garden in areas cleared of snow where my children had made snowmen.	Several days off work due to being snowed in. Road conditions not great.	Conservation Ranger, Tipperary, NPWS
			Snipe seen in the garden in Co Meath not normal habitat for this species	Unable to get to work for three days	Conservation Ranger, Meath, NPWS
			Many overwintering birds seen close to urban areas, farmyards – exposure to predators greater. Trees windthrown around perimeter of Moorehall coach house. Increased risk of mortality for all species	Requires GO to cut down trees undermining SAC structures for Lesser horseshoe bats. Could not go to the field two days due to ice and snow. Staff notified to stay at home.	District Conservation Officer, Mayo, NPWS
			Trees broken and had to be felled in hedges at the Bog of Allen Nature Centre		Irish Peatland Conservation Council

Date	Event	Description	Observed impacts on habitats and species	Impacts on your capacity to do your job, on NPWS (or another organisation) operations, resources and infrastructure	Source
				Trees down, internal roads and paths closed, time taken up monitoring storm damage, clearing branches etc.	Conservation Ranger, Killarney National Park
			Fallen trees	Travel restrictions, worked from home.	Conservation Ranger, Monaghan, NPWS
				Confined to offices.	Conservation Ranger, Laois Offaly, NPWS
			A number of bird species accessing supplementary feeding at Bird Feeders. Fieldfare/Redwing feeding on apples provided at feeding station in my back garden. Lapwing also observed foraging in garden in areas cleared of snow where my children had made snowmen.	Several days off work due to being snowed in. Road conditions not great.	Conservation Ranger, Tipperary, NPWS
			Snipe seen in the garden in Co Meath not normal habitat for this species	Unable to get to work for three days	Conservation Ranger, Meath, NPWS
			Many overwintering birds seen close to urban areas, farmyards – exposure to predators greater. Trees windthrown around perimeter of Moorehall coach house. Increased risk of mortality for all species	Requires GO to cut down trees undermining SAC structures for Lesser horseshoe bats. Could not go to the field two days due to ice and snow. Staff notified to stay at home.	District Conservation Officer, Mayo, NPWS
2017	Storm Ophelia	October – high winds, coastal flooding	Trees broken and had to be felled in hedges at the Bog of Allen Nature Centre		Irish Peatland Conservation Council
				Trees down, internal roads and paths closed, time taken up monitoring storm damage, clearing branches etc.	Conservation Ranger, Killarney National Park
			Fallen trees	Travel restrictions, worked from home.	Conservation Ranger, Monaghan, NPWS
				Confined to offices. Post-Storm clean up	Conservation Ranger, Laois Offaly, NPWS

Date	Event	Description	Observed impacts on habitats and species	Impacts on your capacity to do your job, on NPWS (or another organisation) operations, resources and infrastructure	Source
			High impacts on grey Seal pups. Having just surveyed them before the storm several washed up alive and dead on mainland, after storm. Full scale of impact, unknown. https://www.npws.ie/protected-sites/sac/000707	Travel restrictions, worked from home.	Conservation Ranger, Wexford, NPWS,
				Two days off work due to weather conditions. Caution exercised thereafter accessing woodland areas.	Conservation Ranger, Tipperary, NPWS
			Trees down within natural heritage area along an amenity walkway. Girley Bog NHA 001580	Some roads blocked into the site that needed to be cleared	Conservation Ranger, Meath, NPWS
			Removal of annual vegetation and a lone Lavatera arborea at the N end of the developing spit and sand dune at Booterstown (Co. Dublin): subsequent development of this community which had increased and spread N over past three years was checked back. Deposition of sediment and algae on beachfront communities and some erosion of these communities at the south end of the same site.		Researcher, Trinity College Dublin
			Trees windthrown around perimeter of Moorehall coachouse and Manor House.	Requires GO to cut down trees undermining SAC structures for Lesser horseshoe bats. Couldn't launch boat for lake patrols. District office and Visitor Centre more exposed to power cuts etc Risks for all staff when driving	District Conservation Officer, Mayo, NPWS
2016	Storm Barbara	December – high winds, especially Northern Ireland		Post Storm clean up on Woodland sites	Conservation Ranger, Laois Offaly, NPWS
				District office and Visitor Centre more exposed to power cuts etc Risks for all staff when driving	District Conservation Officer, Mayo, NPWS
2015	Storm Eva	December – high winds	Flooding along the River Boyne and River Blackwater SAC 002299. Flooding the Boyne canal towpath		Conservation Ranger, Meath, NPWS

Date	Event	Description	Observed impacts on habitats and species	Impacts on your capacity to do your job, on NPWS (or another organisation) operations, resources and infrastructure	Source
				District office and Visitor Centre more exposed to power cuts etc Risks for all staff when driving	District Conservation Officer, Mayo, NPWS
2015	Exceptionally dry spring	April – Dry spring	Fire >1km2 on Kippure as well as many smaller fires between March and April. The first fire was lit during a Yellow wind warning on 6/3/15. 30,000+ young trees burned. Nesting areas of rare Whinchats burned at Coronation	Staff out fighting fires, and on fire patrol. Cost of helicopters, Fire Service etc.	Ecologist, Department of Culture, Heritage and Gaeltacht
	Storm Frank	December – high winds. North West	Multiple trees down – severe damage to woodlands in places.	Trees down, internal roads and paths closed, time taken up monitoring storm damage, clearing branches etc.	Conservation Ranger, Killarney National Park, NPWS,
2014	Storm Darwin – February	High winds, severe gusts, trees down.	Lots of damage to trees	Had to send staff home and cancel education programme. No electricity for a number of days	Ecologist, Department of Culture, Heritage and Gaeltacht
			Grantstown Lake NNR flooding	Little Brosna Bird Hide (IWeBS VP) Tipp side obliterated by storms Grantstown NNR Fishing stands damaged by flooding	Conservation Ranger, Laois Offaly, NPWS
				Trees down, time taken up monitoring storm damage, clearing branches etc.	Conservation Ranger, Killarney National Park, NPWS
			Tacumshin Water outlet blocked, huge flooding. https://www.npws.ie/protected-sites/sac/000709		Conservation Ranger, Wexford, NPWS
			Large number of trees downed in the Clare Glens (SAC). Exposed the sporophyte population of Killarney Fern resulting in moderate to severe desiccation of this population.	Clare Glens inaccessible for several months while clean-up undertaken.	Conservation Ranger, Tipperary, NPWS
			Extensive erosion along the Nanny SPA 4158 and Boyne Coast and Estuary 001957.		Conservation Ranger, Meath, NPWS

Date	Event	Description	Observed impacts on habitats and species	Impacts on your capacity to do your job, on NPWS (or another organisation) operations, resources and infrastructure	Source
2013/14	Winter Storms	An exceptional run of winter storms, serious coastal damage and widespread, persistent flooding.	Jan 2013 Flock of fieldfares but no small birds. Feb-Mar 13 snow in Wicklow Mountains with road closures. Floods 22/3/13 on top of snow drifts. Landslide near Enniskerry Buzzard appeared a number of times at Kippure in March 2013. First regular appearances of this species here. May 2013 Grasshopper warbler called but disappeared unlike previous years when they seem to have bred. Three merlins fledged in the locality and I saw a female hen harrier hunting in August 13. Good year for wheatear. Jan 14 saw juvenile White-tailed eagle at Luggala	Worked from home last week of March 13 when roads impassable with snow. Many "snow tourist" vehicles stuck on Sally Gap, meaning staff involved in Mountain Rescue called out regularly.	Ecologist, Department of Culture, Heritage and Gaeltacht
			Woodland Nature Reserves in Laois had a lot of trees down. Grantstown Lake NNR flooding	A lot of resources activated to clear woodland sites of storm damage and reopen to the public Extended period of flooding due to lake outfalls being blocked led to some standing trees being adversely affected	Conservation Ranger, Laois Offaly, NPWS
			The highest flood spates I have seen in the Liffey in all the years I have been here. In the flood event 24/10 25m of track was washed into the Liffey at Gamekeeper' Cottage September 2011 3 bats moved into my garage. This has since become a hibernacula and I've installed a hibernation box	Death of a local off-duty Garda trying to prevent people crossing a bridge. Very tragic human cost Cost of repairing this track	Ecologist, Department of Culture, Heritage and Gaeltacht
			Coastal damage along Boyne coast and estuary SAC/SPA. Coastal damage along the Nanny Estuary and Shore SPA		Conservation Ranger, Meath, NPWS
			Significant flooding and inundation of seawater of coastal habitats (machair, sand dunes). Significant erosion of these dynamic systems. Movement/changes of shingle barriers.	Large scale infrastructural damage resulted in requirement for emergency works by CoCo. Large amount of time involved in site inspections and meeting CoCo staff and landowners regarding damage to SACs.	District Conservation Officer, Mayo, NPWS

Date	Event	Description	Observed impacts on habitats and species	Impacts on your capacity to do your job, on NPWS (or another organisation) operations, resources and infrastructure	Source
			Significant amounts of rubbish and plastics washed onto lands and deposited above the high tide lines Grey seal pups separated from mothers	More time required to process ARCs and to review CoCo screening documents. District office and Visitor Centre more exposed to power cuts etc Risks for all staff when driving	
2011	Intense rainfall Dublin - 24 October	Flooding in the greater Dublin area	Change in bat distribution in winter sites – moved to the most well buffered sites.	Dangerous driving conditions.	Conservation Ranger, Killarney National Park, NPWS
2010	Severe cold spell - Nov/Dec	Snow and low temperatures	Shannon and Little Brosna Callows. Wintering wildfowl starving and birds freezing into roosts, Passerine die off	Extended Confinement to offices due to hazardous driving conditions	Conservation Ranger, Laois Offaly, NPWS
			A report Re. Pollution incident within the River Boyne and River Blackwater SAC/SPA. The clean-up could not be completed until after the freeze. Photo 8	Burst pipes in the Bog of Allen Nature Centre, centre closed and staff off Field visits postponed due to road conditions	Irish Peatland Council Conservation Ranger, Meath, NPWS
2009/10	Coldest winter for almost 50 years[1]	Lowest temperatures December – January. Air temp fell below -10°C. Long period high pressure	Deer suffered from lack of food. Deer culled after the snow were very thin. They gathered under the trees in Coronation, scraping to try to get to the grass underneath, calling the whole time.	I was snowed in during December and then out for 3 weeks in January 10. Trying to work remotely	Ecologist, Department of Culture, Heritage and Gaeltacht
				Access to large proportion of work area prevented due to flooding	Conservation Ranger, Killarney National Park, NPWS
			Many birds found dead having starved. Stonechat and Grey wagtail effectively wiped out in Tipperary – based on observations and ringing effort.	Road conditions in Tipperary extremely challenging making working difficult.	Conservation Ranger, Tipperary, NPWS
2009	Severe flooding – November	Twice average monthly rainfall. Heavy rainfall > 100ml / day.		Record flood levels on Shannon and Little Brosna Callows leading to an increase in (misplaced) public complaints on NPWS management of the Callows	Conservation Ranger, Laois Offaly, NPWS

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