Chapter 8
The Marine Environment

The Marine Environment

1. Introduction

Ireland's coastal and marine areas[1] provide us with vital environmental, recreational, cultural and economic goods and services. Approximately 40 per cent of the Irish population lives within 5 kilometres of the coast[2] and our actions, both positive and negative, can impact on the wellbeing of these important ecosystems. Our marine ecosystems can be damaged by human-induced pressures and pollution, which can be of both global (e.g. climate change, marine litter, fisheries) and local (e.g. industry, agriculture, domestic wastewater) origin. Although Ireland's offshore waters can be considered relatively clean and healthy, our nearshore coastal systems[3] are less so.

The European Union (EU) Marine Strategy Framework Directive (MSFD; 2008/56/EC)[4] aims to protect the marine environment beyond the areas considered under the Water Framework Directive (WFD; 2000/60/EC).[5] It requires the application of an ecosystem-based approach to the management of human activities, enabling sustainable use of marine resources, goods and services. The aim of the Directive is to achieve Good Environmental Status for our marine waters by 2020. This means that our marine waters should be clean, healthy, biologically diverse and productive. In Ireland, the Department of Housing, Local Government and Heritage is the lead body for the implementation of the MSFD and is supported by several other government departments and state agencies, in particular, the Marine Institute. The Marine Institute is the state agency responsible for marine research, technology development and innovation in Ireland. The Institute provides scientific and technical advice to the government to inform policy and support the sustainable development of Ireland's marine resources.

In this chapter we present information on the current status of Ireland's marine environment and discuss the main human activities that may damage the environmental status of these waters. The main legislative responses to these challenges are also discussed.

2. Current Health of Irish Marine Waters

Ireland's marine territory is one of the largest in Europe and, while it remains relatively unpolluted, our waters are vulnerable to damage.

The recent Marine Strategy Framework assessment of environmental status showed that our nearshore coastal and offshore marine waters are predominantly clean, healthy and biologically diverse; however, additional measures are required to protect our valuable ecosystems and species.

Ireland's MSFD assessment area is 488,762 km^2. It incorporates the exclusive economic zone and area of continental shelf that extends beyond 200 nautical miles into a region abutting the Porcupine Abyssal Plain. The overall health of Irish offshore marine waters is determined through the assessments undertaken under the auspices of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) and the MSFD, while the ecological health of nearshore coastal waters is assessed under the WFD. There is an overlap in the coverage between both Directives for 1 nautical mile from high water and certain pressures are only assessed under the MSFD.[6] In addition, the conservation status of protected habitats and species (except birds) is assessed under the Habitats Directive (92/43/EEC),[7] while the status and population trends for relevant bird species are assessed under the Birds Directive (2009/147/EC).[8]

1 *Ireland's maritime territory covers 880,000 km^2 and is one of the largest in Europe*

2 *https://www.cso.ie/en/releasesandpublications/ep/p-cp2tc/cp2pdm/pd/*

3 *For the purpose of this report Ireland's near shore coastal waters are defined as those within one nautical mile of the coast, while our offshore waters are beyond these limits.*

4 *https://eur-lex.europa.eu/eli/dir/2008/56/oj*

5 *https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1571840481303&uri=CELEX:32000L0060*

6 *MSFD Annex I – particularly marine litter and anthropogenic noise*

7 *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043*

8 *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0147*

Table 8.1 Environmental status of the 11 qualitative descriptors outlined in Annex 1 of the MSFD for the determination of Good Environmental Status (Source: DHPLG, 2020)

DESCRIPTOR	COMMON NAME	GOOD ENVIRONMENTAL STATUS (GES)
D1	Biodiversity	Some elements compatible with GES
D2	Non-indigenous species	Compatible with GES
D3	Commercial fish and shellfish	Some elements compatible with GES
D4	Food webs	Compatibility with GES not known
D5	Eutrophication	Compatible with GES
D6	Sea-floor integrity	Some elements compatible with GES
D7	Hydrographical conditions	Compatible with GES
D8	Contaminants	Compatible with GES
D9	Contaminants in seafood	Compatible with GES
D10	Marine litter	Compatible with GES for the elements assessed
D11	Energy, including underwater noise	Compatible with GES for the elements assessed

The Department of Housing, Planning and Local Government (DHPLG),[9] reported the environmental status for each of the 11 descriptors considered under the MSFD for the determination of Good Environmental Status (DHPLG, 2020; Table 8.1). Further information on the issues covered by these descriptors is provided in the following sections.

Ecological and Chemical Status of Nearshore Coastal and Transitional (Estuarine) Waters under the Water Framework Directive

Recent assessments show that 80 per cent of our coastal water bodies and 38 per cent of our transitional water bodies have a high or good ecological status.

Ireland's transitional (estuaries and coastal lagoons) and coastal (up to 1 nautical mile from the shore) waters contain 194 and 110 water bodies, respectively. These areas are assessed under the WFD. The latest assessment (2013-2018) indicates that only 30 (38%) of the transitional waters monitored in Ireland are of good or high ecological status, with 49 (62%) being of moderate, poor or bad ecological status (Figure 8.1; EPA, 2019a). Coastal waters are in a better condition, with 36 (80%) of those monitored being of high or good status (EPA, 2019a). This corresponds to 93 per cent of the surface area of coastal water bodies. Eight coastal water bodies (20%) are of moderate ecological status and a single water body is of bad status (Figure 8.1). The factors driving the ecological status of transitional and coastal waters include biological factors (phytoplankton, benthic invertebrates, macroalgae) and chemical factors (oxygenation conditions, nutrients, priority substances). Loading of nitrogen and phosphorus from Irish rivers into the transitional and marine environment has been monitored since 1990. This can provide a helpful indicator of the transfer of nutrients from anthropogenic sources (EPA, 2019a). Loads of nitrogen and phosphorus have increased by 16 per cent and 31 per cent, respectively, between 2012 and 2014 and between 2016 and 2018. Further information on the status of the supporting elements, trends in status, and drivers and pressures is provided in Chapter 7.

9 *DHPLG is now called the Department of Housing, Local Government and Heritage.*

Figure 8.1 Status of transitional (left) and coastal (right) waters during 2013-2018 by number (Source: EPA)

The chemical status[10] of coastal and marine waters is based on allowable concentrations of certain chemicals and substances. This aims to protect the most sensitive species from direct toxicity, including predators and humans, through secondary poisoning. A smaller group of 'priority hazardous substances' are identified in the Priority Substances (2013/39/EU)[11] as uPBT (ubiquitous, persistent, bio-accumulative and toxic). Under the WFD, Irish coastal areas are considered to have acceptable levels of priority substances (EPA, 2019a). Under the MSFD (Descriptors 8 and 9), initial assessment concentrations of contaminants in shellfish and commercial fish are generally above OSPAR background levels; however, they are not high enough to expect adverse effects (DHPLG, 2020).

Topic Box 8.1 TBT contamination in Irish Coastal waters

Imposex monitoring to assess the impacts of historical tributyltin (TBT) usage in Ireland has now been under way for around 30 years. Imposex is a disorder of sea snails resulting from the toxic effects of certain marine pollutants. These pollutants cause female sea snails (marine gastropod molluscs) to develop male sex organs. A 2018 assessment concluded that, with a small number of exceptions, there has been a dramatic reduction in TBT contamination around the Irish coast, with almost all locations found to be at, or close to, background levels, and there is little evidence of imposex. This demonstrates that measures taken nationally and internationally to phase out known toxic substances, in this case the use of TBT in anti-fouling paint for marine vessels, can be very effective at reducing marine pollution.

Dog whelks, a type of sea snail found on Ireland's rocky shore.

10 https://www.eea.europa.eu/themes/water/european-waters/water-quality-and-water-assessment/water-assessments/chemical-status-of-surface-water-bodies

11 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013L0039

Eutrophication Status of Marine Offshore Areas

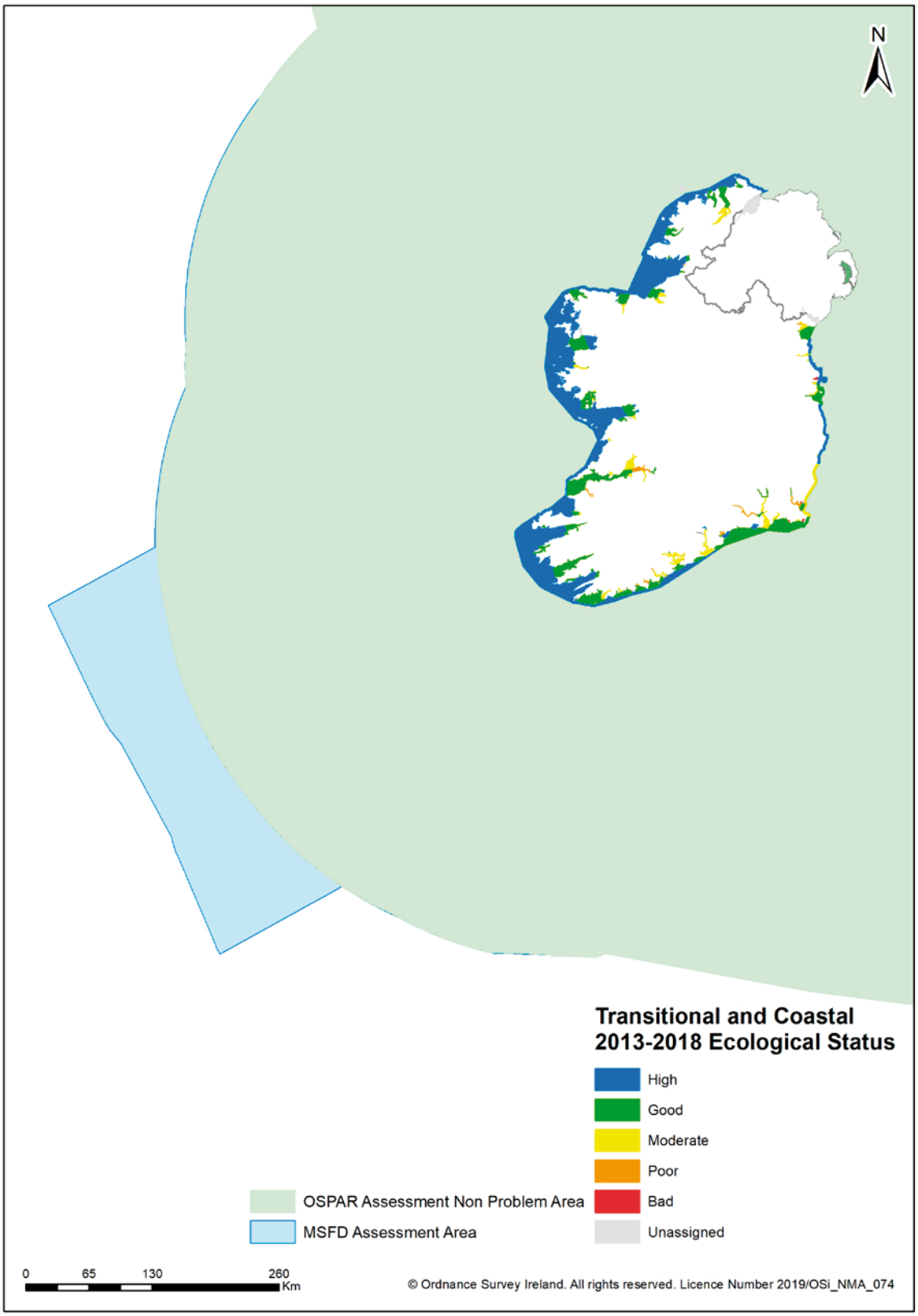
Assessment of Ireland's offshore waters indicates the absence of nutrient enrichment.

The OSPAR Convention, the Oslo Paris Convention for the Protection of the Environment of the North East Atlantic has worked since 1972 to identify threats to the marine environment and has organised, across its maritime area, programmes and measures to ensure effective national action to combat them. The OSPAR Comprehensive Procedure uses a set of indicators to evaluate the eutrophic status of marine waters. Ireland classified all its marine offshore waters as non-problem areas for the period between 2006 and 2014 (EPA and MI, 2016, Figure 8.2). Trend analysis indicates that there has been little change in nutrient levels between 1997 and 2014 and these levels do not exceed those expected in a healthy marine environment. The Comprehensive Procedure will be updated for Ireland in 2023.

Ireland's latest report on environmental status under the current cycle of the MSFD considered the OSPAR Comprehensive Procedure (2009-2014) (OSPAR, 2017). This indicates that all offshore areas have reached Good Environmental Status for eutrophication (DHPLG, 2020).

In European coastal and marine waters, for example the Baltic Sea, eutrophication can result in dead zones where oxygen levels are considered to be too low to sustain life. The expansion of these dead zones is a globally important issue. Dead zones have not been detected in Irish waters to date; however, continual monitoring should be carried out to enable any changes in oxygen levels to be detected should they arise.

Figure 8.2 Eutrophication status of transitional, coastal (WFD) and marine (OSPAR Common Procedure/ MSFD) waters. Eutrophication issues are nearly entirely restricted to transitional (estuarine) and coastal waters. The issue of nutrient enrichment is covered more extensively in Chapter 7



Biodiversity

Monitoring shows that several marine fish and bird species and some marine habitats are under threat or in poor condition.

The EU adopted the new 2030 biodiversity strategy in 2020 which aims to put Europe's biodiversity on the path to recovery by 2030 (see Topic Box 6.5 in Chapter 6 for more details) (EU, 2020). Ireland's National Biodiversity Action Plan aims to address the loss of biodiversity in Ireland. Reporting on marine biodiversity is challenging and providing conclusions on whether or not the loss of marine biodiversity has been halted is difficult. Several nationally important marine species are currently considered to be under threat (NPWS, 2019). Two species of the calcareous red algae maërl, which are found in ten marine Special Areas of Conservation (SACs), have an unfavourable bad status, while nine of these habitats are in an unfavourable condition (NPWS, 2019). The National Parks and Wildlife Service (NPWS) and Northern Ireland Environment Agency have recently updated the Red List, which identifies species in most need of conservation interventions (Chapter 6). The migratory fish, sea lamprey, and the twaite shad are listed as near threatened and vulnerable, respectively (King *et al.*, 2011). An assessment of 58 cartilaginous marine fish found that six were critically endangered: Portuguese dogfish (*Centroscymnus coelolepis*); common (blue) skate (*Dipturus batis* (= flossada)); flapper skate (*Dipturus intermedia*); porbeagle shark (*Lamna nasus*); white skate (*Rostroraja alba*); and angel shark (*Squatina squatina*). The angel shark is considered to be in danger of extinction (Clarke *et al.*, 2016). Five species were assessed as endangered and six as vulnerable. OSPAR has compiled a list of threatened and declining species and habitats in the North East Atlantic which are considered a priority for protection.[12]

Fish species in Irish marine waters that are not fished or sold on the market (non-commercial fish) are not all achieving Good Environmental Status under MSFD Descriptor 1 (biological diversity). Only 11 species achieve GES, 18 species are not achieving GES and the environmental status of a further 23 non-commercial species is unknown (DHPLG, 2020).

National surveys of seabird populations indicate that populations of 17 of the 20 species monitored have increased over the last 16 years, populations of two species are considered stable and the population of one species has decreased (Cummins *et al.*, 2019). Breeding pairs of the black-legged kittiwake, globally the most numerous gull species, have declined by 32 per cent from 1998-2002 to 2015-2018 (Cummins *et al.*, 2019; DHPLG, 2020). Numerous resident and migratory water bird species that spend the winter at coastal sites in Ireland, such as estuaries and lagoons, are showing significant and continued population declines (Lewis *et al.*, 2019). For example, the grey plover (*Pluvialis squatarola*) migrates from breeding grounds in Arctic Russia and Canada to overwinter on Ireland's coast. This species, which is monitored via the Irish Wetland Bird Survey (I-WeBS), underwent a population decline of 62 per cent between 1994 and 2016 (Lewis *et al.*, 2019). Unfortunately, until recently there has been comparatively little monitoring data on those species that overwinter offshore, such as seaducks and divers.

Long-term data on communities of offshore marine mammals, such as the migratory baleen whales or deep-diving toothed cetaceans (whales, dolphins and porpoises) are not yet available for all species. However, recent abundance data from Ireland's exclusive economic zone have indicated that some species' numbers are higher than previously thought (Rogan *et al.*, 2018; NPWS, 2019). The harbour porpoise is frequently recorded in Irish waters (Rogan *et al.*, 2018). Although accidental by-catches of this and other small cetacean and seal species during fishing operations do occur, for several species their relatively high abundance and spatial distribution suggest that such pressures are currently not impacting their populations (DHPLG, 2020). The grey seal and harbour seal have grown in number and distribution in recent decades and are considered to be achieving Good Environmental Status (Morris and Duck, 2019; NPWS, 2019).

Further information on wider biodiversity issues, policy and legislation covering this area is provided in Chapter 6.

Marine Protected Areas

Recent assessments indicate that 65 per cent of Ireland's coastal habitat types are considered to be in an unfavourable condition.

Currently, only 2.1 per cent of Ireland's maritime area has been designated for protection[13] under existing conservation-based legislation (e.g. Birds and Natural Habitats Regulations). This estimate of existing includes SACs under the Habitats Directive, 19 of which are also recognised as OSPAR Marine Protected Areas (MPAs). Ireland's 2019 Habitats Directive Article 17 report (NPWS, 2019) indicates that, of the 23 coastal and/or marine habitat types listed under the Habitats Directive, five have a favourable status nationally (Table 8.2). The remaining 15 types have either an unfavourable – inadequate (n = 12) or an unfavourable – bad (n = 3) status. In particular, lagoons, large shallow inlets and bays, halophilous scrub and fixed dunes are in an unfavourable-bad status and are declining. The causes of the unfavourable-bad status assignment in these nearshore areas are: persistent eutrophication issues (in lagoons, large shallow inlets and bays), loss of species (seagrass and maërl in large shallow inlets and bays), human-induced impacts and the presence of invasive species (in fixed dunes).

12 https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats

13 *The value if 2.1% is based on the existing marine component of Natura sites and Ireland's maritime area as the baseline (488,762 km²).*

Table 8.2 Assessment results for each habitat type listed under the Habitats Directive for 2007, 2013 and 2019 (Source: NPWS, 2019)

COMMON NAME	CODE	2007 OVERALL STATUS	2013 OVERALL STATUS AND OPERATOR	2019 OVERALL STATUS AND TREND
Sandbanks	1110	●	●	〓
Estuaries	1130	●	▲	▼
Tidal mudflats and sandflats	1140	●	▲	▼
Lagoons*	**1150**	●	〓	▼
Large shallow inlets and bays	1160	●	▲	▼
Reefs	1170	●	▼	〓
Submarine structures made by leaking gases	1180	●	●	〓
Drift lines	1210	●	▼	▼
Shingle	1220	●	〓	〓
Sea cliffs	1230	●	〓	〓
Salicornia mud	1310	●	▼	〓
Atlantic salt meadows	1330	●	〓	▼
Mediterranean salt meadows	1410	●	〓	▼
Halophilous scrub	1420	●	▼	▼
Embryonic shifting dunes	2110	●	〓	〓
Marram dunes (white dunes)	2120	●	〓	〓
Fixed dunes (grey dunes)*	**2130**	●	〓	▼
Empetrum dunes*	**2140**	●	〓	〓
Dune heath*	**2150**	●	〓	〓
Dunes with creeping willow	2170	●	〓	〓
Dune slacks	2190	●	▼	▼
Machair*	**21A0**	●	〓	〓
Sea caves	8330	●	●	〓

STATUS: ● Favourable ● Unfavourable-Inadequate ● Unfavourable-Bad ● Unknown
TREND: ▲ Improving 〓 Stable ▼ Declining
* priority habitat

Bathing Water

In total, 97 per cent of designated coastal bathing waters were classified as being of either 'excellent' or 'good' quality in 2019.

Ireland's coastal and inland bathing water quality can be considered to be very high, with 95 per cent (140 of 147 coastal bathing waters) meeting or exceeding the minimum EU standard for sufficient water quality (EPA, 2019b).[14] Of these, 131 bathing waters (89%) were classed as being of either excellent or good quality, with most of these (*n* = 107) being in the excellent category. Five locations were assessed to be of poor quality. In 2019 there was an increase in the number of 'prior warning' notices issued, which advise the public of possible short-term pollution events. This was probably the result of the wetter summer and more local authorities using this precautionary approach to protect bathers' health. Most of these warnings did not result in bathing water pollution incidents and, overall, bathing water quality continued to improve in 2019.

3. Drivers, Pressures and Impacts

Our marine areas are impacted by many human-induced pressures, including fishing, climate change, eutrophication, litter, noise and other forms of pollution. While independently these issues continue to put pressure on our fragile marine systems, their combined influence is difficult to accurately determine and needs further assessment.

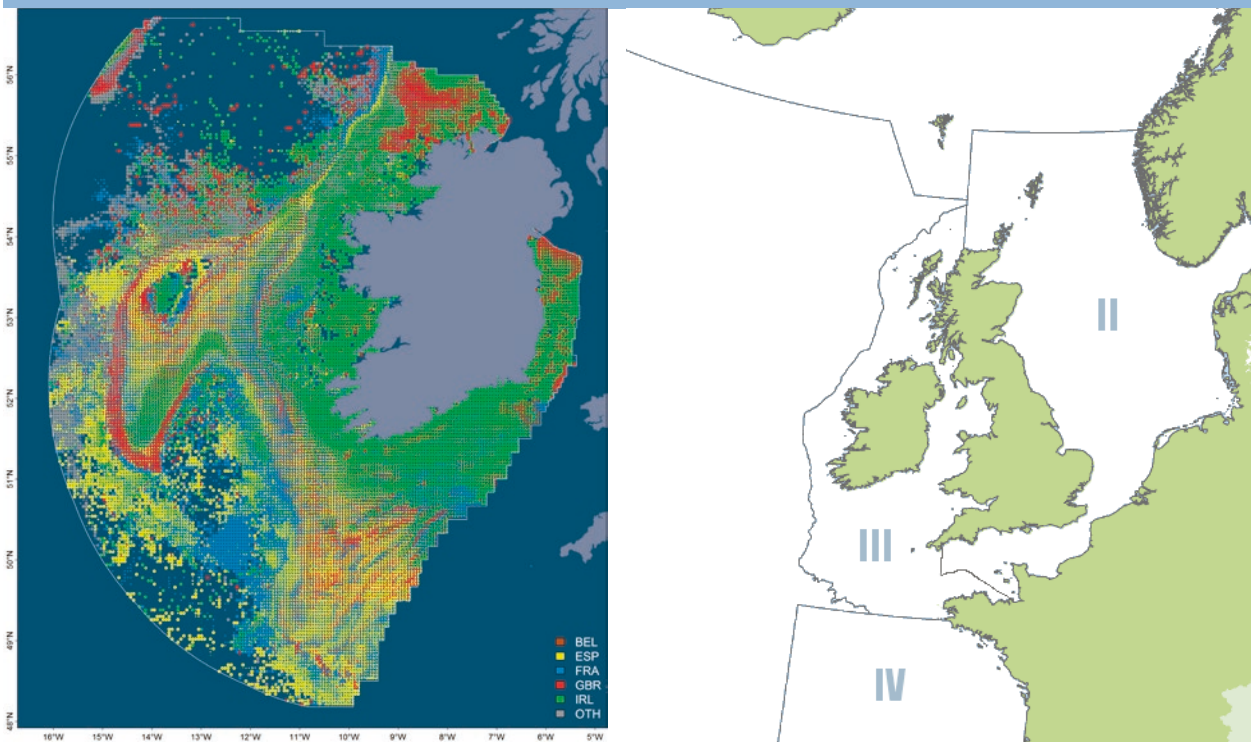
Marine Fisheries

Fish stocks in Irish waters have fallen because of pressures from overfishing, physical disturbance and damage to seafloor habitats.

Ireland's seafood sector was worth €1.25 billion in 2018 (BIM, 2019) and its marine area is considered to be an extensive resource for commercial fishing and aquaculture. However, extensive and prolonged overfishing has had a severe impact on commercial fish and shellfish stocks. The MSFD status results indicate that 34 stocks (18 per cent) of assessed fish and shellfish stocks have achieved Good Environmental Status; however, in the case of 44 stocks (22 per cent) Good Environmental Status has not been achieved. The environmental status of 99 stocks (60 per cent) is currently unknown (DHPLG, 2020). To rectify the impacts of fishing, catches of cod, haddock and herring are now limited. The use or location of nursery and feeding habitats is still poorly understood and many benthic habitats, including reefs, are thought to have been severely damaged by bottom-contacting fishing gears. Physical disturbance to the seabed from international fishing pressures is widespread in the continental shelf area surrounding Ireland within OSPAR Region III, occurring to some degree in 70 per cent of the assessed area, with a high level of disturbance recorded in 46 per cent of the area. This assessment is limited to OPSAR Region III only and does not cover all of Ireland maritime area (Figure 8.3). Physical disturbance occurs in 64,860 square kilometres or 13.29 per cent of the overall area (OSPAR Region III – Celtic Seas, and Region V-Wider Atlantic). OPSAR Region V accounts for 69 per cent of Irelands maritime waters, with the remainder lying in OSPAR Region III.

14 *Ireland's bathing waters include 138 coastal bathing waters (includes coastal and transitional waters) and nine inland bathing waters. The 2019 classification for inland waters classified eight as being of excellent quality and one as being of poor quality. The 2019 classification for coastal waters classified 123 as being of excellent or good quality, 9 as being of sufficient quality and four as being of poor quality, and two new bathing waters which will be classified in 2020.*

Figure 8.3 Pressure map of fishing efforts in Irish waters on the left (Gerritsen and Kelly, 2019). OSPAR Region III is shown on the right



Aquaculture

Aquaculture is an important sector that can potentially impact the marine environment through a number of pressures.

In Ireland, aquaculture mainly consists of shellfish (oysters and mussels) and finfish (mostly salmon) farms. Ireland has 64 designated shellfish growing areas, which have specified water quality requirements to support shellfish life and growth. The Irish aquaculture output in 2017 was worth €208.4 million, with production relatively constant over the last decade. Aquaculture can impact the marine environment through escaped farmed salmon, spreading of disease to native populations, disturbance to and displacement of fish, shellfish, birds and other wildlife populations, and water pollution and is considered a pressure for a number of protected habitats (Bresnihan, 2016; NPWS, 2019). Recent Irish research has indicated that wild Salmon smolts (young Salmon which are ready to migrate to the sea) with mild-to-moderate lice infestations from coastal aquaculture may show greater sensitivity to ocean warming and fewer returns to rivers in following years (Shepard and Gargan, 2020). Pollution risks to shellfish water and environmental health aspects are discussed in Chapter 14.

Climate Change and its effects on the Marine Environment

Since 1994, temperatures in Irish coastal waters have increased at a rate of 0.6°C per decade. Climate change can impact ocean and coastal processes through changes to their, physico-chemistry and temperature and have effects on ecosystem components including valuable commercial fish stocks.

Climate change impacts on the coastal and marine environment manifest through a shift in the baseline conditions for ecosystem structure (coastal erosion, sea level rise), physico-chemical conditions (temperature and ocean acidification) and the transport of anthropogenic pressures, such as nutrients, from land-based sources. These shifts can have very clear, and in some cases, irreversible impacts on marine ecosystems including the organisms that live in them.

Ocean Warming, Sea Level Rise and Coastal Erosion

Evidence of warming waters and sea level rise has been recorded around Ireland's coasts and poses a serious risk to Ireland's coastal areas, particularly major coastal cities.

Global sea surface temperature has been increasing consistently over the last three decades and the world's oceans were the warmest in recorded human history in 2019 (Cheng *et al.*, 2020; von Schuckmann *et al.*, 2020;). Since 1994, temperatures in Irish coastal waters have increased at a rate of 0.6°C per decade (Nolan *et al.*, 2010), which is unprecedented in the 158 years of observational records available. Warm water organisms, such as certain species of zooplankton, jellyfish and comb jellies, have been more evident since 1997, particularly in warm years (Nolan *et al.*, 2010). A number of warm water fish species have also become more abundant around the northern-most coasts of Ireland and in the Celtic Sea. This phenomenon is expected to continue as temperatures increase.

Increasing temperatures have also been shown to alter kelp forests globally (Krumhansl *et al.*, 2016). At the warmest edges of their range, some of these forests are decreasing in size, while in Arctic regions the geographical distribution of certain species has increased (Filbee-Dexter *et al.*, 2019). Estimates based on seabed type indicate Ireland has abundant kelp forests (Werner and Kraan, 2004). These are not only an important food source and habitat for many types of flora and fauna but also capture and store carbon. While no large-scale changes have been recorded thus far, a southern European kelp species (*Laminaria ochroleuca*, Bachelot de pylaie) was recently identified in Béal an Mhuirthead, County Mayo, suggesting the possible movement of the species northwards (Schoenrock *et al.*, 2019). A possible threat to Ireland's kelp forest from changes in geographical range due to increasing temperatures has not yet been identified but may need to be considered in future scenarios.

Future warming is expected to increase the intensity of storms (Desmond *et al.*, 2017). Coupled with this, sea level rise has been recorded globally (3.3 ± 0.4 mm per year since 1993, Von Schuckmann *et al.*, 2020), in Ireland (2-3 mm per year since the early 1990s) using satellite data[15] and in the south-west of England (3.8 mm per year since 1993) using tide gauges (Bradshaw *et al.*, 2016). Under current scenarios, the sea level will continue to rise (Flood and Sweeney, 2012). According to the latest report from the Intergovernmental Panel on Climate Change, the sea level is predicted to rise by between 0.43 metres and 0.84 metres by the end of the century, based on emission scenarios compatible with achieving the long-term temperature goal set out in the Paris Agreement (IPCC, 2019). Incidents of coastal erosion and flooding from increased storm activity will be magnified by sea level rise and pose a serious risk to Ireland's coastal areas, particularly major coastal cities. Increasing annual mean river flows have also been recorded (DCCAE, 2018). If this continues, it could exacerbate the transport of nutrients from soil and anthropogenic sources to coastal and marine areas, as well as increasing the risk of flooding.

Ocean Acidification

Increasing seawater acidity, caused by carbon emissions, could particularly impact Ireland's shellfish industry.

The oceans currently absorb a quarter of anthropogenic carbon dioxide emissions, resulting in them becoming more acidic. This progressive acidification can make it difficult for organisms such as corals, shellfish and crabs to build their outer calcium carbonate shells. This in turn can impact the functioning of the food web, including structural changes in phytoplankton communities and keystone species, alteration of fish populations through habitat modification, and the potential to disrupt nutrient and carbon cycles (Mostofa *et al.*, 2016).

Seawater acidity increased in the Labrador Sea waters of the Rockall Trough between 1991 and 2010 at a rate of 0.02 pH units per decade (McGrath *et al.*, 2012). If this rate continues it could have an impact on the Irish shellfish aquaculture industry, particularly on high-value rope mussels and Pacific oysters. A recent study of Irish coastal and transitional (estuarine) systems indicates that local vulnerability to future acidification will be dependent on geology, freshwater discharge and biological activity (McGrath *et al.*, 2019).

15 *Information and data from the European Space Agency's Climate Change Initiative, the Sea Level project, are available at http://www.esa-sealevel-cci.org/.*

Marine Litter

Marine litter, including plastics and microplastics can be found throughout our marine waters; more research to assess their impact on marine life, food webs and human health is required.

Public awareness of the impacts of marine litter and, including, microplastics on marine ecosystems and life forms has been growing over the last few years. Marine litter, including microplastics have been recorded in every part of the world's oceans (Lusher, 2015), on our beaches, and in many marine organisms.

The EU Commission's Joint Research Council Technical Report on the Harm Caused by Marine Litter (Werner *et al.,* 2016) concluded that, 'although the extent of harm of marine litter to ecosystems has yet to be determined there is evidence of harm to individuals or groups of marine animals or plants'. Ingestion may also provide a pathway for the transport of harmful chemicals into marine food webs. These harmful chemicals include persistent organic pollutants such as polychlorinated biphenyls (PCBs) which can bioaccumulate in apex predators such as killer whales (Schlingermann *et al.*, 2019). Laboratory tests suggest that high levels of exposure to harmful chemicals under specific circumstances can result in physical and chemical toxicity (SAPEA, 2019). Chapter 14 provides further details on plastic pollution.

Nutrient Enrichment

While eutrophication is currently not a major concern for coastal and marine waters, future warming due to climate change could increase the impacts of nutrient enrichment.

Excess nutrients in coastal and offshore marine areas can stimulate the growth of aquatic plant life and result in the depletion of oxygen, leading to eutrophication. This reduction in oxygen can have negative knock-on effects for fish and marine fauna living in these areas and can result in the loss of sensitive aquatic species. The build-up of phytoplankton blooms and large green seaweed in coastal areas can also be detrimental for tourism, recreation and fisheries. In Ireland, eutrophication increases with proximity to human activity and land-based sources of nutrients (see Chapter 7 for further details). While our estuaries are affected by eutrophication, our coastal regions are healthier, and no eutrophication issues have been found in outer marine areas. Coastal and marine systems benefit from their proximity to the Atlantic Ocean, which can dilute nutrients and decrease contaminant loads originating from land-based sources.

However, in coastal and marine systems eutrophication impacts could be exacerbated by warmer growth conditions for phytoplankton and seaweed. A recent analysis of long-term monitoring data indicates that, after nutrient concentrations, temperature is the factor that most influences the health of the phytoplankton community in Irish transitional and coastal waters (Ní Longphuirt *et al.*, 2019). Similarly, global warming scenarios are expected to have an impact on green tides (opportunistic algal blooms) in Irish coastal areas if nutrient conditions are not improved (Bermajo *et al.*, 2019). Consideration of the combined impact of pressures such as climate change and eutrophication is essential to understand the future health of marine ecosystems.

Dredging and Dumping at Sea

Material that is dredged at sea must be disposed of under permit in authorised locations.

The removal of seabed material for maintenance and navigational purposes is a common occurrence in harbours around Ireland. The disposal at sea of this dredged material can occur only under a Dumping at Sea permit authorised by the Environmental Protection Agency (EPA). Permit returns show that, in 2018, over 2.8 million tonnes of material were dredged and deposited at 12 licensed disposal sites around the Irish coast (Figure 8.4). Traditional technologies such as trailing suction hopper dredging and plough dredging account for most dredging operations in Ireland. Water injection dredging, an alternative technology, has been partially utilised in Cork Harbour and the Malahide Marina. Several nationally significant infrastructure expansion projects are under way in the marine sector that involve the dredging of uncontaminated sediments from ports and their disposal at sea in authorised locations.

- In Dublin Port, preparatory works for the redevelopment of the Alexandra Basin are under way. This involves deepening of the navigation channel and the construction of new berths and ancillary facilities to accommodate larger ships. This €230 million redevelopment project will be the largest strategic infrastructure project in the port's history.
- In Cork, relocation of the Port of Cork has commenced at a cost of €100 million. This will transpose the port 10 kilometres from the city centre to the Ringaskiddy Terminal, which has adequate water depths, channel width and space to accommodate larger vessels.
- Development works are also proposed for Shannon Foynes Port as part of a €64 million development plan. The Shannon Foynes Port Company intends to convert over 33 hectares east of its existing port into a site for marine-related industry, as well as implement changes to its existing jetties and quays. This work will be the biggest infrastructure development programme ever undertaken by the company.
- In County Donegal, construction work on Killybegs Fishery Harbour Centre costing €6.5 million is also scheduled to commence. This will provide an additional 120 metres of berthing space by extending the quay wall and deepening the berthing pocket.

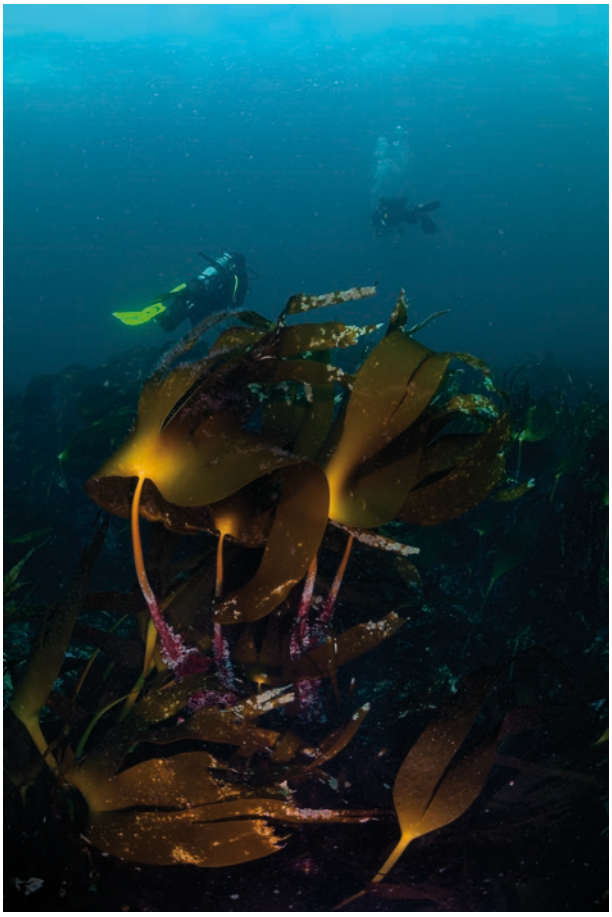
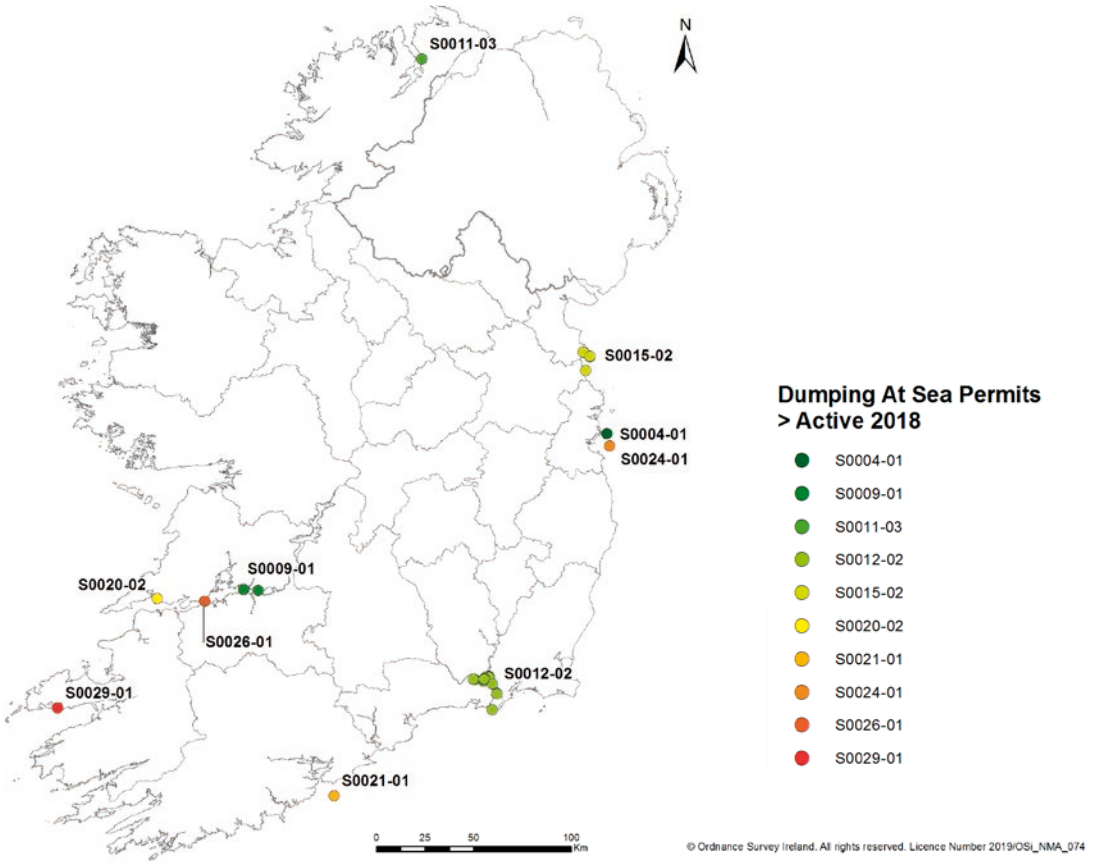


Figure 8.4 This table provides a list of dumping at sea permits and areas where dredging occurred in 2018 (confined or unconfined)[16]



NO.	REG NO.	ORGANISATION	LICENCE NAME	DREDGES IN 2018	TONNAGES
1	S0004-01	Dublin Port Company	Dublin Port	Yes	178,558
2	S0009-02	Shannon Foynes Port Company	Shannon Foynes Port Company	Yes	168,020
3	S0011-03	Donegal County Council	Buncrana Harbour	Yes	5335
4	S0012-02	Port of Waterford Company	Port of Waterford	Yes	295,881
5	S0015-02	Drogheda Port Company	Drogheda Port	Yes	236,649
6	S0020-02	L&M Keating	Kilrush Marina	Yes	834
7	S0021-01	Port of Cork Company – East	Ringaskiddy	Yes	193,067
8	S0024-01	Dublin Port Company	North Wall Quay Extension in the River Liffey Channel	Yes	1,625,937
9	S0026-01	Aughinish Alumina Limited	Aughinish	Yes	1677
10	S0029-01	Department of Agriculture, Food and the Marine	Dingle Harbour	Yes	95,325

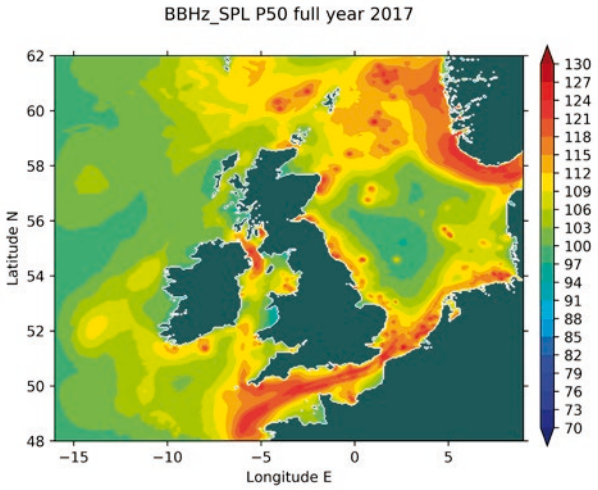
16 *Confined dumping relates to material that is excavated at one site (by trailing suction hopper dredging or grab dredging) and dumped at a designated offshore site. Unconfined dumping relates to plough dredging or water injection dredging where dredged material remains at the site.*

Underwater Noise

Anthropogenic underwater noise can interfere with the navigation, communication and prey location of marine mammals, but is not considered a significant threat in most of Ireland's marine waters.

Anthropogenic underwater noise related to vessel movement, seismic surveys, drilling, use of sonar, pile driving, underwater explosions and dredging has increased as these sectors expand. This noise can interfere with the habitat condition, navigation, communication and prey location of marine animals up to tens of kilometres from the noise source. Recent research on underwater noise has produced noise risk maps for high-, medium- and low-frequency cetacean groups (Sutton *et al.*, 2014). A map of shipping noise has been produced by the UK Centre for Environment, Fisheries and Aquaculture Science (CEFAS) for Irish and UK waters (Farcas, *et al.*, 2020). This indicates that the areas with the greatest shipping noise in Irish waters are located on the south-west and north-east coasts of Ireland (Figure 8.5). The levels of impulsive underwater noise-causing activities within Ireland's maritime area were considered low during 2016-2018 and Good Environmental Status is currently being achieved (DHPLG, 2020), although gaps in knowledge on the impacts of this pressure are acknowledged. Work continues through the EU Technical Group on Noise and the OSPAR Group on Noise to address the knowledge gaps and to create harmonised assessments and standards.

Figure 8.5 Map of shipping noise produced by CEFAS. The map was produced using data captured by microphones placed on the seabed (Farcas *et al.*, 2020). Annual P50 total noise; colour scale shows sound pressure level in units of dB re 1 µPa



Seaweed Harvesting

Traditional hand harvesting of intertidal seaweed takes place in Ireland but interest in mechanical harvesting has increased.

Traditional seaweed harvesting and processing has been carried out on the west coast of Ireland for many centuries. This involves the collection of bladder wrack (*Ascophyllum nodosum)* at low tide with the use of sickles, knives and, in some cases, rakes. Local harvesters leave a section of the root to ensure that this renewable resource is maintained. Currently, in areas where existing rights to harvest are in place, seaweed harvesting licences cannot be given to new applicants.[17] While traditional harvesting has generally been focused on intertidal wrack species, more recently interest in using mechanical means to harvest subtidal kelp communities has increased. Additional pressures on habitats and marine biodiversity and loss of storm surge protection are associated with mechanical harvesting (Smale *et al.*, 2013). KelpRes[18] is a recently funded project that will investigate the diversity and resilience of these ecosystems in Ireland.

17 https://www.housing.gov.ie/planning/foreshore/minister-english-clarifies-legal-position-around-seaweed-harvesting-and

18 http://www.nuigalway.ie/zoology/research/kelpres/

4. Responses

Irelands' marine area includes many nationally and internationally important ecosystems, communities and species. Protection, recovery and expansion of these will be achieved only by recognition of their importance, identification of their geographical range and the creation of a legislative structure for their sustainable protection.

The Strategic Plan for Biodiversity 2011-2020[19] of the Convention on Biological Diversity has set Aichi biodiversity targets that aim 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'. These targets are mainly aimed at protecting and restoring marine ecosystem functioning and biodiversity.

The United Nations Sustainable Development Goals (SDGs), developed in 2016, include SDG 14 (Life Below Water), which focuses on the conservation and sustainable use of the oceans, seas and marine resources for sustainable development. SDG 14 has several targets, which include preventing and reducing marine debris and nutrient pollution; sustainably managing, protecting and restoring marine and coastal ecosystems; minimising and addressing ocean acidification; regulating and ending overfishing and destructive fishing practices; and conserving at least 10 per cent of all coastal and marine areas (also included in Aichi target 11). The recent EU Biodiversity Strategy for 2030 aims to increase the area legally protected to a minimum of 30 per cent of the EU's sea area and integrate ecological corridors as part of a Trans-European Nature Network (EU, 2020).

The SDGs global initiative is being delivered in the EU through a series of EU policies and legislation, which includes the MSFD, the EU Integrated Maritime Policy and the Habitats and Birds Directives. This work is further supported through the long-term efforts under the OSPAR Convention. Ireland has produced a National Implementation Plan 2018-2020[20] to move towards implementing the 17 SDGs. Information on the progress of Ireland's SDGs can be tracked on the SDGs data hub.[21]

19 https://www.cbd.int/sp/

20 https://www.gov.ie/en/publication/7cde9f-the-sustainable-development-goals-national-implementation-plan-2018-/

21 https://irelandsdg.geohive.ie/

The EU recently reported on implementation of environmental policy and law in Ireland (EC, 2019). Within this, priority actions for Ireland in relation to the marine sector were identified and can be considered as a template for future measures, particularly in relation to the MSFD. These are stated in the report as follows.

- 'Determine the timelines for achieving good environmental status, when these have not been reported.
- Provide more information about measures. Decide on more measures that directly impact the pressures on marine and coastal habitats. Quantify the expected level of reduction in the pressure as a result of these measures.
- Ensure regional cooperation with Member States sharing the same marine (sub) region to address the leading sources of pressures.
- Ensure reporting of the different elements under the Marine Strategy Framework Directive by the set deadline.'

Several solutions for halting the loss of marine biodiversity and restoring ecosystem resilience are available and need to be implemented so an equilibrium between our economic expectations of our seas and the long-term policy vision for clean, healthy and productive seas is to be found (EEA, 2019).

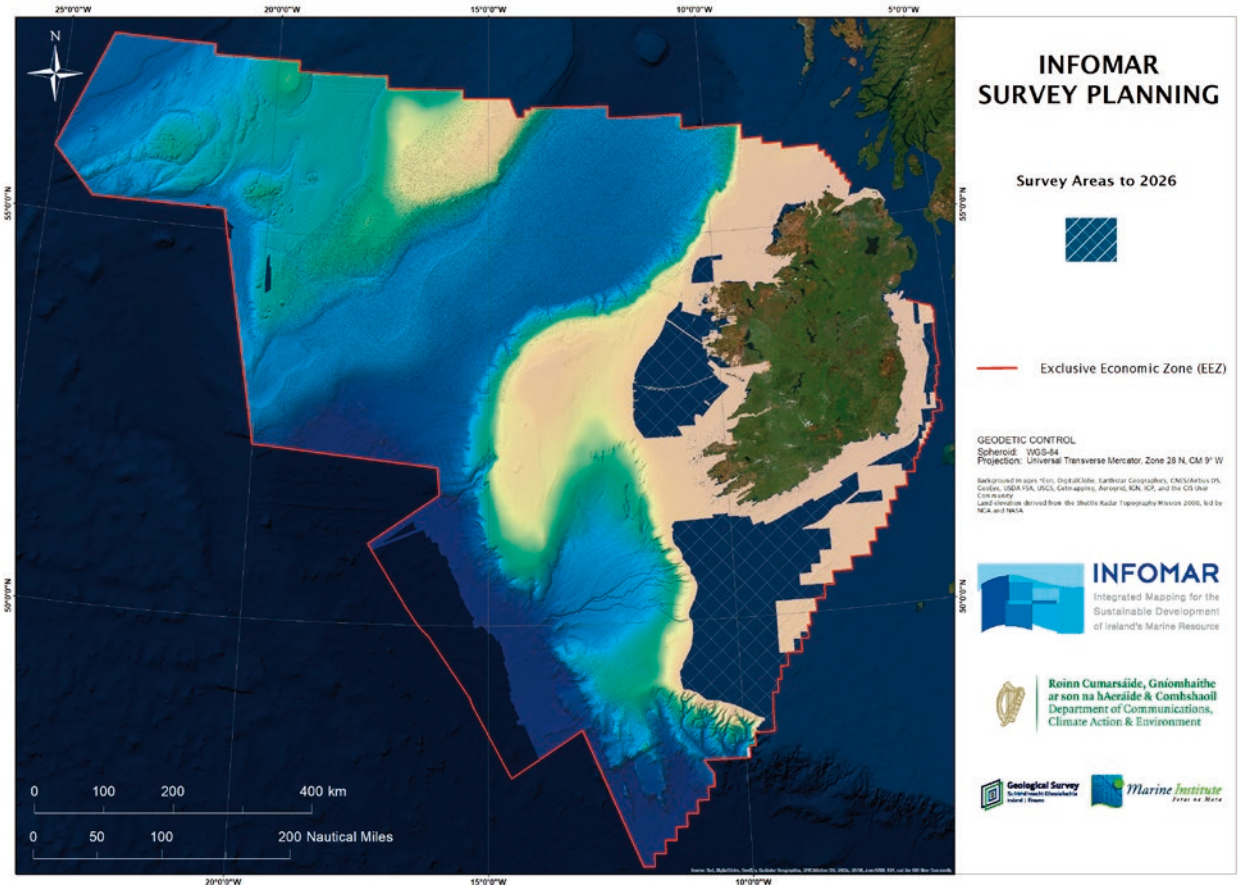
Spatial Planning

Detailed spatial plans and seabed mapping are key tools needed to protect the marine environment.

Ireland is developing a National Marine Planning Framework (NMPF) as part of the Marine Spatial Planning Directive (2014/89/EU). This framework will provide guidance on the sustainable planning and management of marine resources, balancing ecological, economic and social objectives in relation to aspects such as the environment and biodiversity, commercial fisheries, and renewable energy and hydrocarbons. According to the directive, the Marine Spatial Plan must be in place by March 2021. A roadmap for this plan was developed in 2017 (DHPLG, 2017).

Public consultation on the draft National Marine Planning Framework was launched in November 2019 and consultation closed in April 2020 (DHPLG, 2019). The draft sets outs supporting policies around a range of marine activities and environmental areas. The 'Programme for Government June 2020' reported that the government will bring forward Ireland's first ever National Marine Planning Framework, as well as publishing Ireland's first ever marine spatial planning policy, setting out a clear vision for the future development of our marine planning system. This will be part of 'Project Ireland Marine 2040' (Government of Ireland, 2020).

Figure 8.6 INFOMAR survey mapped areas to date and survey planning to 2026



The NMPF is supported by INFOMAR (Integrated Mapping for Sustainable Development of Ireland's Marine Resource). This 20-year programme aims to map Ireland's seabeds, such as vulnerable offshore reefs (Topic Box 8.2 and Figure 8.6). INFOMAR provides information for Ireland's Marine Atlas,[22] which is a publicly accessible reporting and investigative tool. The atlas includes marine data on, for example, administrative boundaries, ocean features, fisheries and aquaculture sites, marine monitoring, seabed habitats, tourism and leisure, transport, infrastructure, discharge point sources and Natura sites.

22 https://atlas.marine.ie

Topic Box 8.2 INFOMAR and Ireland's Coral Reefs

The European Maritime and Fisheries Fund (EMFF) Offshore Reef project has shown the wealth of biodiversity in Ireland's offshore habitats and will contribute to our understanding of these little-studied habitats, thus helping us to afford them better protection.

An extensive offshore reef survey of Ireland's north-west continental margin was commissioned in 2017 by the NPWS. It was funded by the EMFF and coordinated and led by INFOMAR (Integrated Mapping for the Sustainable Development of Ireland's Marine Resources) and the Marine Institute.

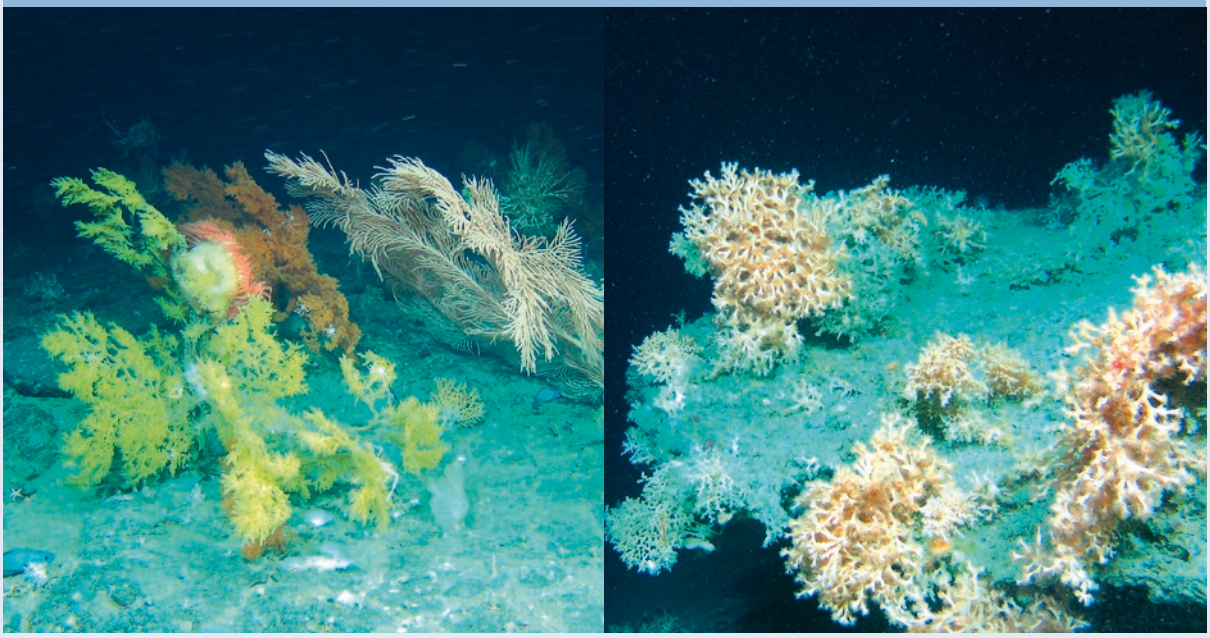
The objective of the 3-year project was to implement the EMFF's Marine Biodiversity Scheme, 'Fisheries Natura', by mapping offshore reef habitats to protect them from deterioration as a result of fishing pressures. The Offshore Reef project aligns with subarticle 6.2 of the Habitats Directive, which requires Member States to take measures to avoid the deterioration of protected habitats. The first two SeaRover surveys[23] were completed in 2017 and 2018 using the Marine Institute's remotely operated vehicle, Holland 1 (Figure 8.7). In addition to mapping reef habitats, the following discoveries were made:

- previously unknown vulnerable marine ecosystems
- cold-water coral species forming reefs at depths greater than 1600 m
- coral species previously unrecorded in Irish waters, including one species that may be new to science
- previously undocumented habitats off Ireland's north-west continental shelf, for example underwater sea mountains and steep cliff faces.

Some of the cold-water coral species grow at a rate of 1 mm per year and locating reefs that are thousands of years old was an important scientific find.

INFOMAR is a 20-year programme to map the physical, chemical and biological features of Ireland's seabed. The project is funded by the Department of the Environment, Climate and Communications and jointly managed by Geological Survey Ireland and the Marine Institute.[24]

Figure 8.7 Images of 'Coral Garden' and 'Lophelia Reef' (Source: ©SeaRover survey/Irish Government/European Maritime and Fisheries Fund)



23 https://www.infomar.ie/rd-and-education/case-studies/deep-water-coral-reefs

24 https://www.infomar.ie/about-us

Marine Fisheries

Quota management and monitoring are key to protection measures covering commercial fisheries.

The Common Fisheries Policy (CFP) governs the fishing sector in Ireland. A number of historical and recent measures have been developed under this policy to ensure that fishing, and aquaculture, are environmentally, economically and socially sustainable. Since 2014 CFP reform has led to the phased introduction of landing obligations for species subject to catch limits. This aims to eliminate the practice of discarding unwanted catches. It is expected that these obligations, together with changes in fishing gear and fishing methods, could lead to an improvement in fish stocks and a more sustainable fishing industry. The recent EU Biodiversity Strategy also outlines the need for marine resources to be harvested sustainably and the need for zero-tolerance for illegal processes (EU, 2020). Bord Iscaigh Mhara (BIM) has produced a fisheries management chart that details the landing obligations and quotas for 2019.[25]

Fishing vessels over 18 metres have been excluded from trawling within 6 nautical miles of the coast since January 2020.[26] This measure, regulated by Inland Fisheries Ireland, aims to protect coastal marine areas and, specifically, juvenile fish, which often spend their nursery years in shallower waters around the coast. Similarly, since 2003 the level of fishing effort has been regulated in an area off the south-east coast of Ireland called the Irish Conservation Box, which follows the 200 metre bathymetric contour. It was defined on scientific grounds by the Marine Institute because of its importance for spawning and as a nursery area for certain commercially exploited fish.

The Marine Institute also produces the *Stock Book* (Marine Institute, 2018), an annual review of commercial fish stocks in Irish waters. This informs fisheries quota management for the year ahead. Additional measures that aim to protect and manage marine ecosystems include the restriction of bottom trawling below a depth of 800 metres on deep sea reef habitats designated under the Habitats Directive (EU Regulation 2016/2336).[27] The 800 metre limit builds on existing industry-led voluntary measures that are applied in EU waters and considers the specificities of deep-sea fisheries in these waters.

Under the CFP, the UK and Ireland have historically fished in each other's waters for Atlantic mackerel and Dublin Bay prawns. As the UK withdraws from the EU, any exclusion of fishing effort from UK waters may displace the EU fishing effort from UK waters to Irish national waters, resulting in an increased burden on Irish ecosystems. The future of fishing rights is likely to depend on decisions made as part of Brexit negotiations between the EU and the UK (O'Higgins and O'Hagan, 2019).

Aquaculture

Monitoring and regulation are important for minimising the impact of the aquaculture sector on the environment.

A national strategic plan for aquaculture[28] was developed in 2015; this aims to sustainably grow the aquaculture sector while ensuring environmental protection of marine ecosystems. However, this growth will have to be considered in relation to its impact on environmental status under the WFD and MSFD, as well as on the conservation objectives and status of sites protected under the Habitats Directive (SACs) and the Birds Directive (Special Protection Areas – SPAs). Aquaculture licensing is administered through a substantial appraisal system by the Department of Agriculture, Food and the Marine (DAFM) and includes the requirement for an appropriate assessment (Bresnihan, 2016).

To minimise any potential impact of aquaculture activities on the environment, the DAFM has developed a range of Marine Finfish Protocols to which each licensed producer must adhere. These protocols cover areas such as benthic monitoring, water quality monitoring, sea lice monitoring, fallowing and structural design.[29] Benthic and sea lice surveys are carried out at each active marine finfish culture site annually. The latest survey indicates that sea lice levels on salmon smolts (age 1-3 years) are below treatment trigger levels, suggesting that control methods and practices can have a positive impact on the control of sea lice in Irish salmon farms (O'Donohoe *et al.*, 2019).

In relation to disease prevention, all aquaculture production businesses are regulated for fish health purposes through EU Directive on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals (2006/88/EC)[30] and Statutory Instrument No. 261 of 2008. The Marine Institute monitors aquaculture sites using risk-based surveillance programmes incorporating planned periodic site inspections and sampling. In addition, outbreaks of disease are investigated by the Marine Institute, as required.[31]

25 https://www.agriculture.gov.ie/seafood/marineagenciesprogrammesdivision/aquaculturepolicy/http://www.bim.ie/media/bim/content/downloads/BIM-fisheries-management-chart-2019.pdf

26 *This Policy Directive was deemed void and of no legal effect following an application of a judicial review in 2020.*

27 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R2336&rid=4

28 https://www.agriculture.gov.ie/seafood/marineagenciesprogrammesdivision/aquaculturepolicy/nationalstrategicplanforsustainableaquaculturedevelopment/

29 https://www.agriculture.gov.ie/seafood/aquacultureforeshoremanagement/marinefinfishprotocols

30 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32006L0088

31 https://www.fishhealth.ie

Climate Mitigation and Adaptation

Ireland needs to adapt and plan for the risks of floods, storms and erosion in coastal areas and their impact on communities.

The Climate Change Advisory Council,[32] an independent advisory body tasked with reviewing national climate policy, has outlined the need to consider coastal issues relating to climate change, such as erosion, in sectoral adaptation plans (CCAC, 2019).

The National Adaptation Framework (DCCAE, 2018) acknowledges that 'the most immediate risks to Ireland which can be influenced by climate change are predominantly those associated with changes in extremes, such as floods, precipitation and storms'. This is extremely relevant to the coastal and marine environment. Managing the response to climate change requires mitigation of carbon dioxide emissions, nature-based solutions, emergency planning and long-term adaptation solutions. In the case of coastal erosion, regional flood hazard mapping, assessment and strategy formulation have been carried out under the Irish Coastal Protection Strategy Study (ICPSS). This study considered the current level of hazard and projected future climate change scenarios. Guidelines on coastal erosion risk management allow for assessment of a range of potential solutions that may be required in response to climate change, including 'hold-the-line', managed realignment and managed retreat (see Topic Box 8.3).

The 2019 Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan (DAFM, 2019b) aims to build resilience to the effects of climate change and weather-related events in the agriculture, forestry and seafood sector. Through case studies it outlines the possible implications of, and the steps required to build resilience to, increases in harmful algal blooms, shifts in fish stock distributions, increases in ocean acidification and shifts in the composition of plankton communities (including copepods and jellyfish). It is hoped that these steps will allow Ireland to plan effective and anticipatory adaptive responses to the impacts of the changing climate. The plan also makes the link between biodiversity, climate change and fish stocks, recognising an increase in the numbers of warm water marine fish species in Irish waters and increased sightings of exotic fish. In 2019, the Department of Culture, Heritage and the Gaeltacht also published the Biodiversity Climate Change Sectoral Adaptation Plan (DCHG, 2019), which includes a number of actions relevant to the marine area.

32 http://www.climatecouncil.ie/

Topic Box 8.3 Sea Level Rise: Coastal Protection and Managed Realignment

Projections for the influence of climate change in Ireland include the effects of sea level rise, coastal erosion and flooding. Supported by the Local Authority Climate Action Regional Offices, several local authorities have recently released climate adaptation and mitigation plans (Chapter 2). These have considered areas identified to be at risk by the ICPSS to formulate policy and planning solutions to tackle storm surges and sea level rise. Solutions can include coastal defences (sea walls, beach groynes, beach supplementation), zoning to restrict further development in flood risk areas and nature-based solutions.

The Office of Public Works provides funding to local authorities to carry out minor coastal protection projects. In 2018, ten projects were approved, with just under half of these being flood risk management studies and the other half relating to the construction or repair of hard engineering coastal defences, such as rock revetments and sea walls. However, the cost of installing or maintaining these defences must be balanced against the value of the land that is being protected (Nottage and Robertson, 2005). In addition, it could result in coastal habitat loss or 'coastal squeeze', where intertidal habitats are lost because the high-water mark is fixed by a defensive structure such as a sea wall and the low water mark moves landwards towards this structure in response to sea level rise.

One nature-based solution to projected sea level rise and flooding is managed realignment. This allows previously reclaimed land in coastal areas and estuaries to be surrendered back to natural tidal processes. This can improve coastal protection while at the same time providing intertidal habitats for protected species. The recent EPA-funded SAMPHIRES (Saltmarsh Function and Human Impacts in Relation to Ecological Status) project has reviewed a number of systems in Ireland where managed and unmanaged (or unplanned) realignment has occurred (Perrin *et al.*, 2020).

One such example is Harper's Island in Cork. This system was managed as farmland until its abandonment in 2006 (Figure 8.8). Following this, a subsurface breach in a levee allowed saline waters to enter and saltmarsh vegetation rapidly established itself on the island. Cork County Council now own and manage the island as a bird reserve in partnership with Birdwatch Ireland and Glounthaune Community Association. Other examples of managed and unmanaged realignment include projects carried out in Kilmacleague West Wetlands (Co. Waterford), Ballymacoda (Co. Cork), Rogerstown Estuary (Co. Dublin) and Tramore Strand (Co. Waterford).

Managed realignment may result in the creation or movement inland of saltmarshes, mudflats or lagoons, all of which are habitats protected under the Habitats Directive Annex 1. Indeed, modelling studies suggest that, in future sea level rise scenarios, managed realignment and long-term planning will be necessary to ensure conservation in terms of both species present and habitat extent (Perrin *et al.*, 2020). Although Ireland has yet to adopt managed realignment as a mainstream coastal engineering option, evidence from other EU countries suggests that this could be a proactive and cost-effective management option to adapt to, and protect from, climate-driven coastal flooding (Esteves and Williams, 2017).

Figure 8.8 Aerial images of the site at Harper's Island from 2003 (left) and 2017 (right), before and after the unmanaged realignment of the system, respectively (Source: Google Earth from *Perrin et al.*, 2020)

Research

Marine EPA Research Programme 2014-2020 covering key challenges and emerging issues.

Research into the resilience, vulnerability and adaptation of Ireland's coastal and marine systems to climate pressures is ongoing and is supported by maintaining the marine observation network (marine data buoy, tide gauge and wave buoy networks). Ireland also contributes to the annual International Council for the Exploration of the Seas (ICES) Report on Ocean Climate. Some recent and current Irish research projects on coastal and marine systems include:

- Challenges of Transformative Climate Change Adaptation: Insights from Flood Risk Management (Clark and Murphy, 2019)
- Achieving Resilience in the Marine and Coastal Environment in Ireland (EPA funded)
- Integrating Multidisciplinary Geoscientific Data into Forecasting Models to Monitor and Predict Coastal Change: Proof of Concept in Dublin Bay (PREDICT Project) (Science Foundation Ireland, Geological Survey Ireland and Marine Institute funded)
- Mapping, Modelling and Monitoring Key Processes and Controls on Cold-water Coral Habitats in Submarine Canyons (MMMonKey_Pro) (Science Foundation Ireland, Geological Survey Ireland and Marine Institute funded)
- Ireland also has representation at an international level on the Joint Programming Initiative Health and Productive Seas and Oceans (JPI Oceans).[33]

Additional information on climate mitigation and adaptation is provided in Chapter 2.

Since 2016, the EPA has funded up to 13 new research projects relevant to the Marine area; a commitment of €2.6 million. These projects were funded mostly under the Water Pillar of the EPA Research Programme 2014-2020.

These EPA-funded projects included research on:

- Nutrient Dynamics and Ecophysiology of Opportunistic Macroalgal Blooms in Irish Estuaries and Coastal Bays (Sea-MAT) http://www.seamatproject.net/home.html
- Algal blooms in transitional and coastal waters https://macromanproject.com/
- Coastal lagoons https://www.projectclear.ie/
- Physico-chemical cycling of nutrients and carbon in marine transitional zones http://www.nuigalway.ie/science/school-of-natural-sciences/disciplines/earth-ocean-science/research/nutsbolts/index.html
- Partial funding of a project on Integrated modelling of consequences of terrestrial activities and climate change for freshwater and coastal marine biodiversity and ecosystem services https://www.biodiversa.org/1424
- Saltmarsh Function and Human Impacts in Relation to Ecological Status (SAMFHIRES)
- Ecosystem Tipping Points: Learning from the Past to Manage for the Future https://ecosystemtippingpoints.com/

Marine system-related EPA Research Reports are available at http://www.epa.ie/pubs/reports/research/water/

Further information on EPA-funded environmental research is available at http://www.epa.ie/researchandeducation/research/researchpublications/researchreports/

Marine Litter and Plastics

Plastic and marine litter needs to be tackled at source so that it does not end up on beaches or in the ocean.

Knowledge and understanding of the overall ecological impacts of marine litter and plastics is evolving rapidly. It is projected that if current usage patterns and trends continue then impacts may become insurmountable (SAPEA, 2019). It is therefore considered prudent to adopt a precautionary principle when it comes to marine litter and, in particular, plastics. Several regulatory and legal frameworks exist or are emerging that are of relevance to marine litter and microplastics (SAPEA, 2019).

The MSFD includes several goals that are relevant to marine litter and states that Member States must ensure that levels of litter do not cause harm to the coastal and marine environment. OSPAR has also produced a Marine Litter Regional Action Plan, which includes various actions and goals to reduce marine litter. Ireland is leading several actions under the plan, which include investigation of the use of alternatives to polystyrene, investigation of wastewater and stormwater as vectors for litter and assessment of economic and regulatory measures to deal with single-use plastics.

Ninety vessels and 12 ports are taking part in the BIM initiative, Fishing for Litter. This encourages fisherfolk to take ashore the litter they encounter at sea while fishing and to manage their onboard waste appropriately.

33 *http://www.jpi-oceans.eu/*

Irish institutes and researchers are involved in two large projects funded by the INTERREG Atlantic Area funding programme. Clean Atlantic[34] is a project focused on gathering and assessing data, knowledge and gaps relating to marine litter in the Atlantic area. Ocean Wise[35] is aimed at developing long-term measures to reduce the impact of polystyrene, the most common item found in beach surveys, in the North-East Atlantic. Additional information on land-based initiatives can be found in Chapter 14.

Marine Communities, SPAs, SACs and MPAs

The expansion of MPAs for Ireland's coastal and marine ecosystems is an ongoing process.

Ireland's third National Biodiversity Action Plan 2017-2021[36] has been developed to protect and enhance Ireland's biodiversity. Objective 5 of the plan aims to 'conserve and restore biodiversity and ecosystem services in the marine environment'. The full implementation of the MSFD, WFD, Habitats and Birds Directives and revised CFP is considered the conduit for achieving this objective.

In Ireland, the Habitats Directive is currently the only legislative instrument providing protection to habitats in the marine environment, through the designation of SACs. These have been chosen to represent a sample of important habitats and species populations under Annex I and Annex II of the Directive, respectively. Ireland is committed to maintaining or restoring the protected habitats and species within these sites to 'favourable conservation status'. INFOMAR (Section 3.1) provided a platform for the designation of seven new marine SACs, which were proposed in 2012 and 2015.

Special Protection Areas are designated under the Birds Directive for the protection of particular species or communities of birds and/or wetland areas that provide essential resources for resident or migrating birds. These are either intertidal or coastal areas and are mainly coincident in their boundary with SACs (Figure 8.9).

Under the OSPAR Convention, Ireland has 19 MPAs, which cover 4135 square kilometres. All of Ireland's OSPAR sites are also either SACs or SPAs and so currently they do not have any legal protection outside that associated with their SAC designation.

A European network of important ecological sites, the Natura 2000 network of SACs and SPAs, is managed through the development of site-specific conservation objectives (SSCOs) (see Chapter 6 for further details). The NPWS is delivering a programme of work to finalise the SSCOs for all SPAs and SACs. Generic conservation objectives are in place for those sites that remain without SSCOs. Ensuring that the current and future SACs and SPAs are properly managed and supported as a network was highlighted in *Ireland's 6th National Report to the Convention on Biological Diversity* (DCHG, 2019). This would serve to increase resilience in the face of anthropogenic pressures.

The need to protect marine mammals such as harbour porpoises, dolphins and seals from active acoustic surveys has been recognised through the restriction of these activities in 24 SACs. This includes the Lower River Shannon SAC and its resident bottlenose dolphin population, and Lambay Island SAC and its population of grey and common seals. It is an offence to carry out the specified activity within the 24 SACs without the consent of the Minister for Culture, Heritage and the Gaeltacht.[37]

Ireland is committed to the Convention on Biological Diversity and adopted target 11, that 10 per cent of all coastal and marine areas are conserved through well-connected systems of protected areas, in 2010 (Aichi target 11, SDG 14.5). The EU Biodiversity Strategy 2030 has committed to a minimum of 30 per cent protection of EU's Sea areas, with strict protection for a third of these areas (EU, 2020). Currently, only 2.1 per cent of our marine areas are protected. The MSFD recognises that one measure for achieving Good Environmental Status is the establishment of a representative and coherent network of MPAs to preserve marine biodiversity[38]. In general terms MPAs are identifiable coastal/marine areas that, among other features, are considered to be of particular importance for ecosystem functioning, natural ecology and biological diversity. In Ireland there is currently no legal definition of the term Marine Protected Area however, nor specific stand-alone legislation underpinning the designation or management of such sites.

34 http://www.cleanatlantic.eu/packages/

35 https://ocean.org/

36 https://www.npws.ie/legislation/national-biodiversity-plan

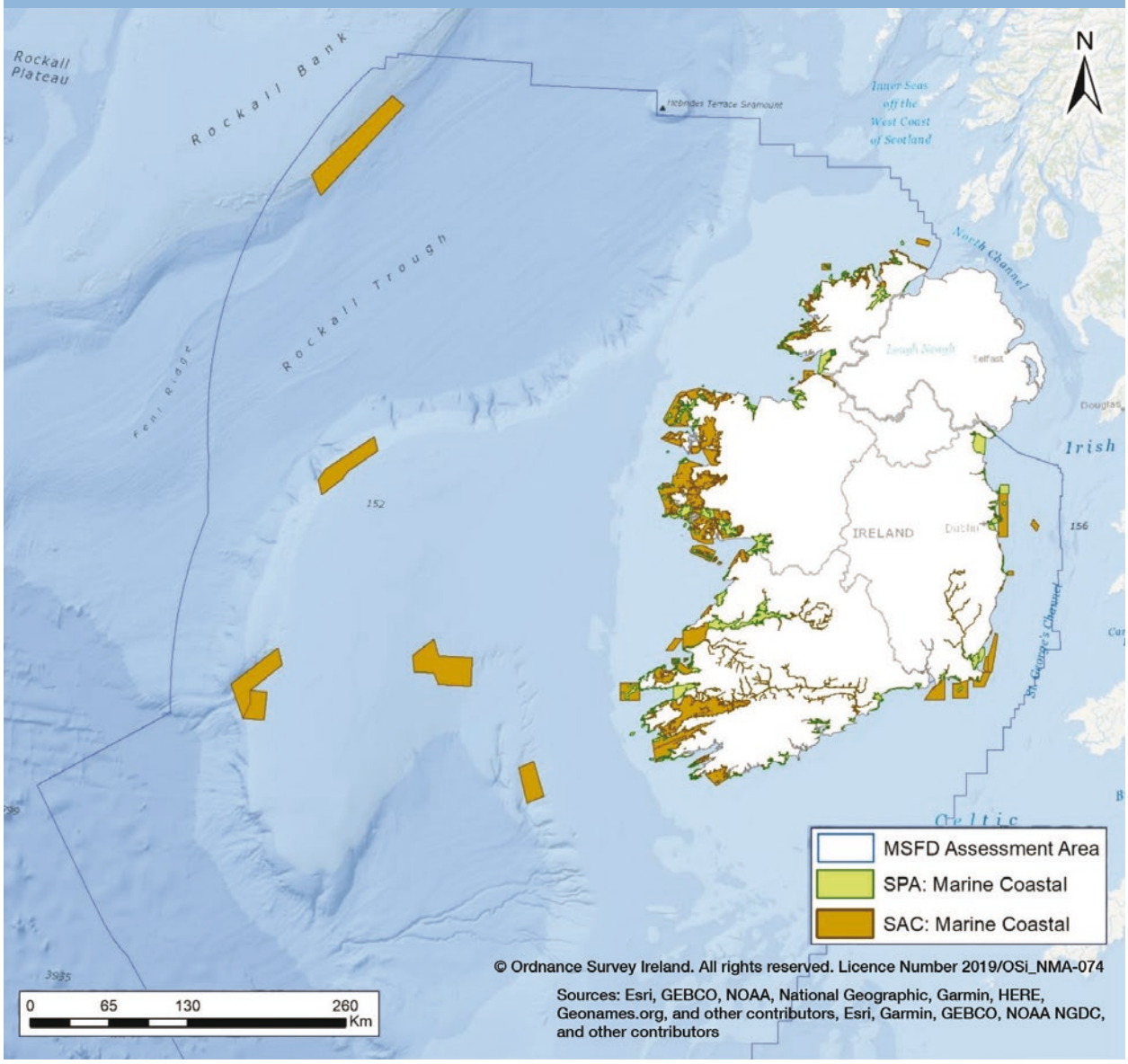
37 *Further information on activities requiring consent (ARCs) is available at https://www.npws.ie/farmers-and-landowners/activities-requiring-consent.*

38 *2008/56/EC Article 13.4*

An expert advisory group was established in late 2019 by the government to produce a report containing advice and recommendations that will support the expansion of Ireland's network of Marine Protected Areas. The ongoing work of the MPA Process Advisory Group is an initial component that is intended to focus and facilitate implementation of national obligations around area-based protection under the National Biodiversity Action Plan 2017-2021, in addition to the MSFD and Ireland's responsibilities under the OSPAR Convention. Protection of the network of MPAs in Ireland should consider, among other things, the connectivity, representativity and replication of areas to allow for the coordinated support of systems (Rees *et al.*, 2015).

The protection of marine communities in areas beyond the national jurisdiction is currently being considered by the United Nations. This includes an area of 230 million square kilometres, or about 45 per cent of the surface of the planet. This ongoing process will consider recommendations to develop an international legally binding instrument or treaty under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity in areas beyond national jurisdictions.

Figure 8.9 Map of Ireland's marine SPAs and SACs. The blue line indicates Ireland's maritime area which encompasses the MSFD assessment area



Mapping of the Seabed, Ecosystems and Communities

The mapping of Ireland's sensitive marine habitats and species will help to protect them.

A classification of marine benthic communities is currently being finalised by the Department of Culture, Heritage and the Gaeltacht and the National University of Ireland Galway in accordance with the pan-European EUNIS classification system. A number of sensitive marine communities, including maërl beds and seagrass meadows, have been mapped to date. These communities, with a few exceptions, occur within SACs and should be afforded the highest degree of protection, with no disturbing activity allowed within a 50 metre buffer zone. Offshore reef habitats have also been mapped (see Topic Box 8.2).

This survey work is complemented by ongoing environmental research, for example research into the distribution and abundance of protected vertebrate species as part of the government-funded ObSERVE Programme.[39]

Citizen Science

We need the support of the public and communities to collect important data on marine biodiversity.

Several marine-related citizen science projects and initiatives are currently under way in Ireland.

- Explore your Shore[40] is a citizen science project funded by the EPA and coordinated by the National Biodiversity Data Centre. It aims to increase our knowledge of the distribution of intertidal species, exploring their potential as bio-indicators of water quality and climate change.
- The Irish Whale and Dolphin Group[41] is dedicated to the conservation and better understanding of whales, dolphins and porpoises in Irish waters. It provides courses on marine mammal observation and records sightings and strandings of marine whales, dolphins and porpoises with the help of the public.
- Coastwatch[42] is a voluntary organisation that has carried out annual surveys of Ireland's coast for the last 30 years. The long-term data are available at https://coastwatch.org/europe/all-ireland-historical-data/
- Seasearch Ireland[43] is a citizen science biodiversity recording scheme for divers and snorkelers. The scheme uses volunteer recreational divers to record subtidal species at dive sites around Ireland and Britain.
- The Big Jellyfish hunt,[44] Purse Search Ireland,[45] the Irish Basking Shark Project[46] and KelpRes[47] are all projects that include a citizen science component asking the public to record sightings of specific flora and fauna on Ireland's shoreline and in coastal waters.

39 https://www.gov.ie/en/publication/12374-observe-programme/
40 https://exploreyourshore.ie/
41 https://iwdg.ie/
42 http://coastwatch.org/europe/
43 https://diving.ie/seasearchireland/
44 https://records.biodiversityireland.ie/record/jellyfish#7/53.455/-8.016
45 https://marinedimensions.ie/purse-search-ireland/
46 https://www.baskingshark.ie/
47 http://www.nuigalway.ie/zoology/research/kelpres/

5. Conclusions

Pressures on the Marine Environment

Ensuring that our marine ecosystems are clean, healthy, biologically diverse and productive requires more than the restriction of nutrient pollution and sustainable fishing and aquaculture levels. A myriad of pressures such as climate change, mechanical destruction, physical disturbance, noise, toxic substances and litter will impact and interact to threaten the health of such ecosystems. These pressures need to be considered through an integrated approach to ensure the long-term health of both local and global oceans.

An Island Nation

Ireland is an island nation with a rich biodiversity, a strong cultural linkage between people and the sea, and proud coastal communities and, as such, we have lots to protect. Initiatives such as the Wild Atlantic Way[48] have served to focus and highlight these attributes. As an island nation with an extensive marine area we need to ensure that the proper legislative framework supported by sufficient knowledge, is in place to protect our marine ecosystems, as well as the goods and services they provide. Ongoing research and monitoring programmes, many under existing EU and international laws, should provide the evidence to support the legislative process and allow the level of protection required for different parts of our maritime area. This will need to consider not only current conditions but also the future implications of climate-driven pressures and alterations to our ecosystems and the communities and species they contain.

Water Quality

Overall, assessments of ecosystem status show that, in terms of eutrophication, our coastal and marine waters are considered to be healthy. However, additional measures and mitigation are required to protect our valuable ecosystems, habitats and species from anthropogenic pressures. The latest WFD assessment (2013-2018) indicates that only 30 (38%) of the transitional water bodies (estuaries) monitored in Ireland are of good or high ecological status, with 49 (62%) being of moderate, poor or bad ecological status. The specific factors causing the decline in ecological status of estuaries should be addressed through the action programmes developed under the WFD.

Environmental Status

The MSFD environmental status for Ireland indicates that, although five descriptors are fully compatible with Good Environmental Status, two others are considered to have achieved Good Environmental Status for the primary criteria assessed (marine litter and noise) while three are only partially compatible (biodiversity, commercial fish and shellfish and sea floor integrity). Information on Descriptor 4, food webs, is not sufficient to make an assessment. Overall, the assessment outlines the gaps in knowledge for some descriptors and the improvements required to bring them to Good Environmental Status.

Marine Habitats

A substantial proportion of the protected marine habitats underpinned by Ireland's Natura 2000 network has not yet achieved favourable conservation status, as required under the Habitats Directive. This is particularly evident in habitats such as lagoons, large shallow inlets and bays and fixed dunes. The expansion of a network of MPAs underpinned by legislation to protect these areas may act as a key conservation measure to enable the achievement of favourable conservation status, Good Environmental Status and other environmental comitments such as those for the OSPAR's list of threatened and/or declining species and habitats.

Climate Change

Climate-induced changes in sea temperature and pH have been recorded in Irish marine waters. Continuous monitoring, assessment and modelling of the impacts of climate change are essential to ensure proper adaptation to future scenarios.

Fish Stocks

Of the commercial fish and shellfish stocks assessed, 34 are considered to be compatible with Good Environmental Status, while 44 are not. The compatibility of 99 stocks with Good Environmental Status is unknown. Overall, the status of commercial fish and shellfish stocks is not fully compatible with Good Environmental Status. However, of the main stocks assessed in recent years, there has been an 80 per cent improvement in the number harvested sustainably. Ensuring that Ireland implements a transition to sustainable fisheries, and heeds scientific advice and catch limits, is crucial to ensure not only the continued availability of this resource but also the health of the associated food webs.

48 https://www.wildatlanticway.com/home

Endangered and Threatened Species

A number of non-commercial fish species (e.g. sea lamprey, twaite shad, angel shark) are threatened because of habitat loss/disruption and by-catch. Several elasmobranch species, including the sharks, rays and skates, are listed as critically endangered under Ireland's Red List while other comparatively long-lived protected species remain vulnerable to environmental degradation from human activities in Ireland's maritime area (e.g. some marine bird species and other top predators, migratory baleen whales, deep-diving cetaceans).

Protecting Marine and Coastal Areas

Our marine and coastal areas are impacted by several human-induced pressures, including fishing, eutrophication, climate change and litter. While independently these issues continue to put pressure on our fragile marine systems, their combined impact is not fully understood and needs to be assessed through additional research and monitoring. Programmes of measures for the marine environment rely heavily on existing measures under the WFD and Common Fisheries Policy. While the integration of measures under instruments and Marine Strategy Framework, Birds and Habitats Directives are important, measures that directly protect the marine water column and wider seabed habitats need to be implemented.

Chapter Highlights for Marine Environment

Ireland's marine waters are clean and reasonably healthy but not as biologically diverse and productive as they could be. They are affected by several human-induced pressures, including fishing, climate change and marine litter such as plastics.

The area covered by Marine Protected Areas needs to be expanded significantly to meet the international requirement to conserve 10 per cent of all coastal and marine areas, rising to 30 per cent in future targets under the EU Biodiversity Strategy 2030. The expansion will promote the remediation of environmental damage and the protection of marine ecosystems and biodiversity.

As an island nation with an extensive marine area, Ireland needs to ensure that robust governance and legal frameworks are in place to protect marine ecosystems and the services they provide to society. There needs to be governance systems in place that coordinate and integrate the implementation of directives where there are crossovers, such as those covering marine strategy, marine spatial planning, water quality, waste, biodiversity and protecting fish stocks.

References

Bermejo, R., Heesch, S., O'Donnell, M., Golden, N., MacMonagail, M., Edwards, M., Curley, E., Fenton, O., Daly, E. and Morrison, L., 2019. *Nutrient Dynamics and Ecophysiology of Opportunistic Macroalgal Blooms in Irish Estuaries and Coastal Bays (Sea-MAT)*. Environmental Protection Agency, Wexford, Ireland.

BIM (Bord Iscaigh Mhara), 2019. *The Business of Seafood 2018*. http://www.bim.ie/media/bim/content/publications/corporate-other-publications/7097-BIM-Business-of-Seafood-2017.pdf (accessed 19 October 2020).

Bradshaw, E., Woodworth, P.L., Hibbert, A., Bradley, L.J., Pugh, D.T., Fane, C. and Bingley, R.M., 2016. A century of sea level measurements at Newlyn, Southwest England. *Marine Geodesy* 39: 115-140. https://doi.org/10.1080/01490419.2015.1121175

Bresnihan, P., 2016. *The Dynamics of Environmental Sustainability and Local Development Aquaculture*. National Economic and Social Development Office, Dublin, Ireland.

CCAC (Climate Change Advisory Council), 2019. *Annual Review 2019*. CCAC, Dublin, Ireland.

Cheng, L., Amraham, J., Zhu, J., Trenberth, K.E., Fasullo, J., Boyer, T., Locarnini, R., Zhang, B., Yu, F., Wan, L., Chen, X., Song, X., Liu, Y. and Mann, M.E., 2020. Record-setting ocean warmth continued in 2019. *Advances in Atmospheric Sciences* 37: 137-142. https://doi.org/10.1007/s00376-020-9283-7

Clarke, D. and Murphy, C., 2019. *Challenges of Transformative Climate Change Adaptation: Insights from Flood Risk Management*. Environmental Protection Agency, Wexford, Ireland.

Clarke, M., Farrell, E.D., Roche, W., Murray, T.E., Foster, S. and Marnell, F., 2016. *Ireland Red List No. 11: Cartilaginous Fish (Sharks, Skates, Rays and Chimaeras)*. National Parks and Wildlife Service, Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs, Dublin, Ireland.

Courtene-Jones, W., Quinn, B., Ewins, C., Gary, S.F. and Narayanaswamy, B.E., 2019. Consistent microplastic ingestion by deep-sea invertebrates over the last four decades (1976-2015), a study from the North East Atlantic. *Environmental Pollution* 244: 503-512.

Cummins, S., Lauder, C., Lauder, A. and Tierney, T.D., 2019. *The Status of Ireland's Breeding Seabirds: Birds Directive Article 12 Reporting 2013-2018*. Irish Wildlife Manuals No. 114. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Dublin, Ireland.

DAFM (Department of Agriculture, Food and the Marine), 2019a. *Harnessing our Ocean Wealth. An Integrated Marine Plan for Ireland. Review of Progress 2018*. DAFM. Dublin. Available online: https://www.ouroceanwealth.ie/publications (accessed 19 October 2020).

DAFM (Department of Agriculture, Food and the Marine), 2019b.*Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan*. DAFM, Dublin, Ireland. https://www.agriculture.gov.ie/publications/2019/ (accessed 19 October 2020).

DCHG (Department of Culture, Heritage and the Gaeltacht), 2019. *Ireland's 6th National Report to the Convention on Biological Diversity*. DCHG, Dublin, Ireland.

DCCAE (Department of Communications, Climate Action and Environment), 2018. *National Adaptation Framework: Planning for a Climate Resilient Ireland*. DCCAE, Dublin, Ireland. Available online: https://www.gov.ie/en/publication/fbe331-national-adaptation-framework/ (accessed 19 November 2020).

Desmond, M., O'Brien, P. and McGovern. F., 2017. *A Summary of Knowledge on Climate Change Impacts for Ireland*. Environmental Protection Agency, Wexford, Ireland.

DHPLG (Department of Housing Planning and Local Government), 2017. *Towards a Marine Spatial Plan for Ireland*. DHPLG, Dublin, Ireland. https://www.housing.gov.ie/sites/default/files/publications/files/towards_a_marine_spatial_plan_for_ireland.pdf (accessed 19 October 2020).

DHPLG (Department of Housing Planning and Local Government), 2019. *Draft National Marine Planning Framework*. DHPLG, Dublin, Ireland. https://www.housing.gov.ie/sites/default/files/public-consultation/files/draft_national_marine_planning_framework_final.pdf (accessed 19 October 2020).

DHPLG (Department of Housing, Planning and Local Government), 2020. Marine Strategy Framework Directive 2008/56/EC–Article 17 Update of the Assessment (Article 8), Determination of Good Environmental Status (Article 9) and Environmental Targets (Article 10). DHPLG, Dublin, Ireland.

EC (European Commission), 2011. *Our Life Insurance, Our Natural Capital: An EU Biodiversity Strategy to 2020*. Office for Official Publications of the European Communities, Luxembourg. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0244&from=EN (accessed 19 October 2020).

EC (European Commission), 2019. *The EU Environmental Implementation Review 2019. Country Report – Ireland*. Commission Staff Working Document. European Commission. https://ec.europa.eu/environment/eir/country-reports/index_en.htm (accessed 19 October 2020).

EEA (European Environment Agency), 2019. Marine message II. Navigating the course towards clean, healthy and productive seas through implementation of an ecosystem based approach. EEA Report No. 17/2019. Available online: https://www.eea.europa.eu/highlights/europes-seas-face-uncertain-future (accessed 19 October 2020).

EPA (Environmental Protection Agency), 2019a. *Water Quality in Ireland Report*. EPA, Wexford, Ireland.

EPA (Environmental Protection Agency), 2019b. *Bathing Water Quality in Ireland*. EPA, Wexford, Ireland.

EPA and MI (Environmental Protection Agency and Marine Institute), 2016. *National Eutrophication Assessment Report under the Common Procedure: Ireland. Report on the Third Application of the Comprehensive Procedure*. https://www.ospar.org/site/assets/files/37302/national_common_procedure_report_2016_ireland.pdf (accessed 19 October 2020).

Esteves, L.S. and Williams, J.J., 2017. Managed realignment in Europe: a synthesis of methods, achievements and challenges. In Bilkovic, D.M., Mitchell, M.M., Toft, J.D. and La Peyre, M.K. (eds), *Living Shorelines: The Science and Management of Nature-based Coastal Protection*. CRC Press, Boca Raton, FL, pp. 157-180.

EU (European Union), 2020a. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. EU Biodiversity Strategy for 2030 – Bringing nature back into our lives. EU, Brussels. https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm (accessed 19 October 2020).

Farcas, A., Powell, C., Brookes, K.L., Merchant, N.D. 2020. Validated shipping noise maps of the Northeast Atlantic. *Science of the Total Environment* 735. https://doi.org/10.1016/j.scitotenv.2020.139509

Filbee-Dexter, K., Wernberg, T., Fredriksen, S., Norderhaug, K.M. and Pedersen, M.F., 2019. Arctic kelp forests: diversity, resilience and future. *Global and Planetary Change* 172: 1-14.

Flood, S. and Sweeney, J., 2012. Quantifying impacts of potential sea level rise scenarios on Irish coastal cities. In Otto-Zimmermann, K. (ed.), *Resilient Cities 2: Cities and Adaptation to Climate Change – Proceedings of the Global Forum 2011*. Springer, London, pp. 337-352.

Gerritsen, H.D. and Kelly, E. 2019. *Atlas of Commercial Fisheries around Ireland*. 3rd edition. Marine Institute, Ireland. Available online: https://oar.marine.ie/handle/10793/1432 (accessed 19 October 2020).

Government of Ireland, 2020. *Programme for Government Our Shared Future, June 2020*, Merrion St, Dublin, Ireland.

IPCC (Intergovernmental Panel on Climate Change), 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Pörtner, H.-O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B. and Weyer, N.M. (eds). Available online: https://www.ipcc.ch/srocc/ (accessed 19 October 2020).

King, J.L., Marnell, F., Kingston, N., Rosell, R., Boylan, P., Caffrey, J.M., FitzPatrick, Ú., Gargan, P.G., Kelly, F.L., O'Grady, M.F., Poole, R., Roche, W.K. and Cassidy, D., 2011. *Ireland Red List No. 5: Amphibians, Reptiles & Freshwater Fish*. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Krumhansl, K.A., Okamoto, D.K., Rassweiler, A., *et al.*, 2016. Global patterns of kelp forest change over the past half-century. *Proceedings of the National Academy of Sciences of the United States of America* 113: 13785-13790.

Lewis, L., Burke, B., Fitzgerald, N., Tierney, T. and Kelly, S., 2019. *Irish Wetland Bird Survey 2009/10-2015/16*. Irish Wildlife Manuals No. 106. National Parks and Wildlife Service, Dublin, Ireland.

Lusher, A., 2015. Microplastics in the marine environment: distribution, interactions and effects. In Bergmann, M., Gutow, L. and Klages, M. (eds), *Marine Anthropogenic Litter*. Springer, Heidelberg, Germany, pp. 245-307.

McGrath, T., Kivimae, C., Tanhua, T., Cave, R.R. and McGovern, E., 2012. Inorganic carbon and pH levels in the Rockall Trough 1991-2010. *Deep Sea Research Part I: Oceanographic Research Papers* 68: 79-91.

Marine Institute, 2018. *The Stock Book 2018: Annual Review of Fish Stocks in 2018 with Management Advice for 2019*. Marine Institute, Galway, Ireland.

Mostofa, K.M.G., Liu, C., Zhai, W., Minella, M., Vione, D., Gao, K., Minakata, D., Arakaki, T., Yoshioka, T., Hayakawa, K., Konohira, E., 2016. Reviews and syntheses: ocean acidification and its potential impacts on marine ecosystems. *Biogeosciences* 13: 1767-1786.

Morris, C. and Duck, C., 2019. *Aerial Thermal-imaging Survey of Seals in Ireland, 2017 to 2018*. Irish Wildlife Manuals No. 111. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Dublin, Ireland.

Ní Longphuirt, S., McDermott, G., O'Boyle, S., Wilkes, R. and Stengel, D.B., 2019. Decoupling abundance and biomass of phytoplankton communities under different environmental controls: a new multi-metric index. *Frontiers in Marine Science* 6: 312. https://doi.org/10.3389/fmars.2019.00312

Nolan, G., Gillooly, M. and Whelan, K. (eds), 2010. *Irish Ocean Climate and Ecosystem Status Report 2009*. Marine Institute, Galway, Ireland. Available online: http://oar.marine.ie/handle/10793/81?mode=full (accessed 19 October 2020).

Nottage, A. and Robertson, P. 2005. *The Saltmarsh Creation Handbook: A Project Manager's Guide to the Creation of Saltmarsh and Intertidal Mudflat.* The Royal Society for the Protection of Birds, Sandy, Bedfordshire

NPWS (National Parks and Wildlife Service), 2019. *The Status of EU Protected Habitats and Species in Ireland. Volume 1: Summary Overview*. Unpublished NPWS report. Lynn, D and O'Neill, F. (eds).

O'Donohoe, P., Kane, F., Kelly, S., McDermott, T., Casserly, J., D'Arcy, J., Downes, J., McLoughlin, S. and Jackson, D., 2019. *National Survey of Sea Lice (*Lepeophtheirus salmonis *Krøyer and* Caligus elongates *Nordmann) on Fish Farms in Ireland – 2018*. Irish Fisheries Bulletin No. 49. Marine Institute, Galway, Ireland.

O'Higgins, T. and O'Hagan, A.M., 2019. A return to the tragedy of the commons? Brexit trade-offs and spatial analysis, an Irish perspective. *Marine Policy* 26: 103524. https://doi.org/10.1016/j.marpol.2019.103524

OSPAR, 2017. *Intermediate Assessment 2017*. OSPAR Commission, London. Available online: https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017 (accessed 19 October 2020).

Pagter, E., Frias, J. and Nash, R., 2018. Microplastics in Galway Bay: a comparison of sampling and separation methods. *Marine Pollution Bulletin* 135: 932-940.

Perrin, P.M., Waldren, S., Penk, M.R. and O'Neill, F.H., 2020. *Saltmarsh Function and Human Impacts in Relation to Ecological Status (SAMFHIRES)*. Environmental Protection Agency, Wexford, Ireland.

Rees, S., Foster, N., Langmead, O. and Griffiths, C., 2015. *Assessment of the Ecological Coherence of the MPA Network in the Celtic Seas*. A Report for WWF-UK by the Marine Institute, Plymouth University and The Marine Biological Association of the United Kingdom. WWF-UK, Surrey, UK.

Rogan, E., Breen, P., Mackey, M., Cañadas, A., Scheidat, M., Geelhoed, S. and Jessopp, M., 2018. *Aerial Surveys of Cetaceans and Seabirds in Irish Waters: Occurrence, Distribution and Abundance in 2015-2017*. Department of Communications, Climate Action and Environment and National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Dublin, Ireland.

SAPEA (Science Advice for Policy by European Academies), 2019. *A Scientific Perspective on Microplastics in Nature and Society*. SAPEA, Berlin. https://doi.org/10.26356/microplastics

Schlingermann, M., Berrow, S., Craig, D., *et al.*, 2020. High concentrations of persistent organic pollutants in adult killer whales (Orcinus orca) and a foetus stranded in Ireland. *Marine Pollution Bulletin* 151: 110699. https://doi.org/10.1016/j.marpolbul.2019.110699

Schoenrock, K.M., O'Callaghan, T., O'Callaghan, R. *et al.*, 2019. First record of Laminaria ochroleuca Bachelot de la Pylaie in Ireland in Béal an Mhuirthead, County Mayo. *Marine Biodiversity Records* 12: 9 (2019). https://doi.org/10.1186/s41200-019-0168-3

Smale, D.A., Burrows, M.T., Moore, P., O'Connor, N. and Hawkins, S. 2013. Threats and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective. *Ecology and Evolution* 3: 4016-4038.

Shephard, S., and Gargan, P., 2020. Wild Atlantic salmon exposed to sea lice from aquaculture show reduced marine survival and modified response to ocean climate. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsaa079

Sutton, G., Jessopp, M., Clorennec, D. and Folegot, T., 2014. *Mapping the Spatio-temporal Distribution of Underwater Noise in Irish Waters*. Environmental Protection Agency, Wexford, Ireland.

Von Schuckmann, K. *et al.*, 2020. Copernicus Marine Ocean State Report, Issue 4. *Journal of Operational Oceanography* 13: 1-160. https://doi.org/10.1080/1755876X.2020.1785097 (accessed 19 October 2020).

Werner, A. and Kraan, S., 2004. *Review of the Potential Mechanisation of Kelp Harvesting in Ireland*. Marine Environment and Health Series No. 17. Marine Institute, Galway, Ireland.

Werner, S., Budziak, A., van Franeker, J., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J. and Vlachogianni, T., 2016. *JRC Technical Reports – Harm caused by Marine Litter*; Joint Research Council, Ispra, Italy.

WHO (World Health Organization), 2019. *Microplastics in Drinking-Water*. WHO, Geneva, Switzerland.