

The waters surrounding Ireland support a rich diversity of marine life. The extensive offshore areas are generally not affected by pollution, while inshore, water quality in most estuarine and coastal waters remains high. A number of estuaries, however – mainly in the south-east and south of the country – continue to display symptoms of nutrient enrichment and have been classed as eutrophic.

Levels of PCBs, dioxins and other contaminants in fish and shellfish are very low and the overall quality of Irish seafood produce remains high. Radioactive substances from the nuclear reprocessing plant at Sellafield in England continue to be discharged to the Irish Sea, though exposure to these substances is not considered to pose a significant health risk to the Irish public. The quality of bathing waters is high, and while the bacteriological quality of shellfish in shellfish-growing waters is reasonably good, it is likely that additional measures will be required to prevent further deterioration in certain areas.

The greatest human impact on Ireland's marine environment continues to be commercial fishing. Most commercially targeted fish stocks in Irish waters are overexploited and in decline. Cod stocks in the Irish Sea are considered to be in a state of collapse. There is also mounting evidence that climate change has the capacity to alter the functioning of marine ecosystems by influencing the distribution and seasonality of a wide range of marine species.

The challenge of implementing an ecosystem-based approach to ensure the sustainable management of Ireland's marine environment, as envisaged by the new EU Marine Strategy Directive, will be made even more difficult by climate change, which is likely to add further complexity to the task of understanding how these systems function.

## ESTUARINE AND COASTAL WATERS



## Introduction

The coastal and offshore waters that surround Ireland contain a wealth of marine life. The rich productivity of these waters is mainly due to the seasonal cycling of nutrients and light that promote the abundant growth of plankton, which in turn supports large shoals of fish, benthic invertebrates, seabirds and cetaceans. The productivity of this region is further enhanced by the presence of frontal boundaries that separate coastal waters from more oceanic waters further offshore. Deep, nutrient-rich water mixes with well-lit surface waters at these fronts, fuelling additional phytoplankton growth. Along the coast, where rivers flow into the sea, estuaries are formed and these provide numerous habitats for a variety of animal and plant species.

Ireland's island location on the north-western edge of the European continent has meant that in comparison with many other European countries its marine environment has remained relatively unpolluted. In recent decades, however, the level of environmental stress from both internal and external sources has increased. Greater coastal urbanisation and industrialisation, particularly during the 1990s, has resulted in an increase in the range and magnitude of pressures that have the potential to impact negatively on the quality of Ireland's tidal waters.

Pressures have also stemmed from the intensification of agriculture and commercial fishing. The development and application of modern industrial fertilisers and changing farming practices have caused nutrient enrichment of surface waters, and in the fishing sector the use of new technologies and larger modern trawlers has allowed the capture

of unsustainable quantities of fish. Furthermore, pressures from external sources, such as transboundary pollution, accidental oil spills from ships and the future impacts of climate change, have the potential to degrade the quality of Ireland's marine environment.

In this chapter the results from various monitoring programmes undertaken by a number of public authorities are used to assess the impact of human activities on the tidal waters environment. The key pressures assessed include the

discharge of nutrients and other contaminants into estuarine and coastal waters, development in the coastal zone, dredging, marine aggregate extraction, marine litter, commercial fishing, aquaculture and the effects of climate change. Where available, information on these specific pressures and impacts is presented to provide an overview of the general environmental status of estuarine, coastal and offshore waters around Ireland. General habitat quality and species diversity in tidal waters is discussed in Chapter 13.





## Nutrients and Eutrophication in the Marine Environment

Internationally, evidence is mounting that nutrient inputs to estuarine and coastal waters are resulting in significant alterations to animal and plant communities (Smayda, 1990; Hallegraeff, 1993). The excessive growth of marine plants such as phytoplankton and seaweeds can eventually lead to oxygen depletion through respiration or following their eventual decomposition by bacteria. In extreme cases oxygen depletion can result in the mortality of organisms that live on or near the seabed such as benthic invertebrates and certain species of fish. Other potential deleterious effects include an increase in the frequency and duration of phytoplankton blooms, some of which may be composed of toxin-producing species. While the question of whether nutrient enrichment promotes the development of such species over other types is still debated, it is reasonable to suggest that any increase in phytoplankton productivity is likely to result in a proportional increase in toxin-producing and nuisance species. Long-term eutrophication effects may therefore lead to changes in the composition of marine plant and animal communities, leading to a loss of species diversity and in severe cases habitat degradation.

## Quality of the Marine Environment

### Trophic Status of Irish Estuaries and Nearshore Coastal Waters

The rivers that flow into estuaries can carry substantial loads of nutrients and organic matter from upstream sources. In addition, estuarine

waters receive the greater part of both urban and industrial effluents generated in Ireland due to the concentration of towns, cities and industry in coastal locations. Effluents by their nature, but particularly those from sewage treatment works, are typically rich in organic matter and in the nutrient elements nitrogen and phosphorus.

To assess the trophic status of these waters, the EPA monitors the water quality of 69 water bodies from 25 estuarine and coastal areas around Ireland. The surveys are carried out mainly in the summer months, the period when low water exchange and higher temperatures increase the likelihood of marked variations in oxygen levels and excessive levels of plant growth. Winter surveys are carried out in nearshore waters as well as in offshore waters in the western Irish Sea and eastern Celtic Sea to monitor levels of nutrients in the absence of significant biological activity.

A Trophic Status Assessment Scheme (TSAS) for the classification of these waters has been developed and is reported in detail in Toner *et al.* (2005). The scheme, which was designed to capture the cause-effect

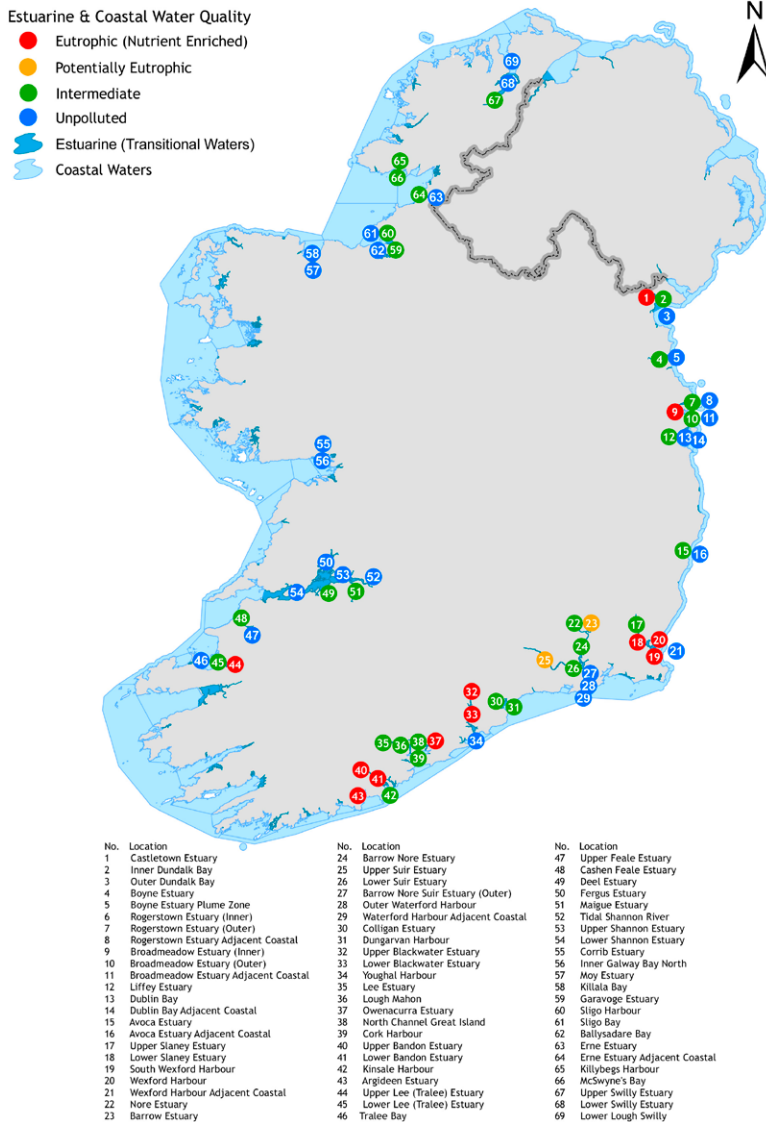
relationship of the eutrophication process as defined in the Urban Waste Water Treatment and Nitrates Directives (Council of the European Communities (CEC), 1991a, 1991b) comprises the following criteria:

1. enrichment of water by nutrients (as indicated by measurement of dissolved inorganic nitrogen and phosphorus concentrations)
2. accelerated growth of algae (mainly as indicated by measurement of chlorophyll concentrations)
3. undesirable disturbance (as indicated by measurement of oxygen status).

Threshold values in respect of each of the above criteria were derived with reference to levels that are typically observed in waters with very low levels of pollution or nutrient enrichment. Other aspects of eutrophication, such as the degree and frequency of macroalgal strandings, have yet to be formally integrated into the scheme but a fully quantitative assessment system based on the distribution and magnitude of macroalgae found in the intertidal zone will soon be in place for the purposes of the Water Framework Directive (WFD).



**Map 9.1 Estuarine and Coastal Water Quality (Trophic Status)**  
(Source: Clabby *et al.*, 2008)



TSAS was used to assess the trophic status of 69 water bodies based on water quality data collected over the period 2002–2006 (Clabby *et al.*, 2008). On the basis of the criteria, defined portions of 13 estuarine and coastal waters were classified as eutrophic, and sections of a further two waters were classed as potentially eutrophic (Map 9.1).

### General Water Quality

There has been little change in the water quality status of estuarine and coastal waters around Ireland since the previous reporting period (EPA, 2004). In that report, concern was expressed about a number of areas, particularly in relation to depressed oxygen levels and elevated nutrient concentrations.

It would appear from the most recent assessment (Clabby *et al.*, 2008) that oxygenation conditions in a number of these areas, such as the Castletown estuary (Dundalk), the Lee estuary (Cork) and the Munster Blackwater estuary, have improved. However, oxygen depletion is still evident in the Lee estuary in Tralee and in the Upper Swilly estuary in the vicinity of Letterkenny wastewater treatment outfall. The situation in the Swilly estuary appears to have further deteriorated since the previous assessment. Depressed oxygen levels continue to be observed in Killybegs Harbour and the adjacent McSwyne's Bay. It has been suggested that the hydrography of this area, which is characterised by strong water column stratification in summer, makes these waters more sensitive to organic inputs, and this may partly explain the frequent occurrence of depressed oxygen levels near the seabed. The lowest oxygen levels observed during the most recent assessment period were found in the upper reaches of the Avoca estuary in Co. Wicklow. In general, though, oxygen conditions in the majority of Irish estuaries and coastal waters remain high.

In relation to trophic status, the most seriously eutrophic water bodies were the estuaries of the major rivers of the south-east and south of the country such as the Slaney, Blackwater and Bandon. The Argideen estuary in West Cork was also seriously impacted due to the accumulation of extensive mats of green opportunistic macroalgae. The condition of Lough Mahon (Cork Harbour), which was assessed as strongly eutrophic in the last report, has improved substantially and is no longer classed as such. The present assessment of the Liffey estuary appears to confirm that water quality in the estuary continues to improve, although there are still concerns



over the stranding of opportunistic macroalgae, indicative of nutrient enrichment, along the south Dublin Bay shoreline.

### Winter Nutrients in the Irish and Celtic Seas

Since 1990, the Marine Institute has been carrying out intensive monitoring of winter nutrient levels in the western Irish Sea and, latterly, the eastern Celtic Sea. Winter nutrient data collected between 2001 and 2005 were used to assess the status of the coastal and offshore areas of the western Irish Sea and eastern Celtic Sea as part of the OSPAR Strategy to combat eutrophication in the waters of the North-East Atlantic. A key element of this strategy is the Common Procedure, which establishes a framework for the contracting parties to assess the eutrophication status of their parts of the OSPAR maritime area.

As in the previous assessment, there was little evidence of elevated nutrient levels in any of the Irish coastal and offshore areas assessed. Nutrient concentrations were consistently below the OSPAR thresholds and the ratios between the various nutrient elements, which can indicate anthropogenic

disturbance, were also generally below their respective OSPAR thresholds. These findings, together with the recent review of Gowen *et al.* (2008), which found little evidence of disturbance in oxygen conditions (except in the seasonally isolated western Irish Sea bottom water) or phytoplankton community structure or production, resulted in these areas being designated as non-problem areas with regard to eutrophication.

### Radioactivity in Irish Marine Waters

The Radiological Protection Institute of Ireland (RPII) undertakes radioactivity monitoring of the Irish marine environment. During 2003–2006, samples of fish and shellfish species were collected from commercial landings at major Irish fishing ports and aquaculture areas. Seawater, sediment and seaweed were also collected from coastal sites, while seawater and sediment samples were taken at offshore sites in the western Irish Sea (Ryan *et al.*, 2007; Smith *et al.*, 2007).

Radiation doses to people living in Ireland resulting from discharges at Sellafield, on the north-west English coast, are now very low and on the

basis of current scientific knowledge do not pose a significant health risk. Further reductions in these doses are being pursued through the implementation of the OSPAR Strategy with regard to radioactive substances. All signatories to the strategy are committed to progressive and substantial reductions in radioactive discharges from their facilities (Ryan *et al.*, 2007).

Caesium-137 continues to be the dominant radionuclide. The dose due to this radionuclide has declined significantly over the past two decades, corresponding to the reduction in discharges from Sellafield.

While the consumption of fish and shellfish from the Irish Sea continued to be the dominant pathway by which radioactive contamination of the marine environment resulted in radiation exposure of the Irish population, these doses are small by comparison with the doses received as a result of background radiation. The doses from the consumption of fish and shellfish, for example, at 0.86 microsieverts ( $\mu\text{Sv}$ ), are small compared with the estimated annual dose of 148  $\mu\text{Sv}$  received by the same consumer due to the presence of the naturally occurring radionuclide polonium-210 in seafood and with the average annual dose to a person in Ireland from all sources of radioactivity of 3620  $\mu\text{Sv}$ . In general, levels of radioactivity in the Irish marine environment remained fairly constant over this reporting period and were broadly consistent with levels reported during the previous period. The RPII continues to emphasise that the levels of radioactive contamination present in the marine environment do not warrant any modification of the habits of people in Ireland, in respect of either consumption



of seafood or any other use of the amenities of the marine environment.

### Metals and Chlorinated Compounds in Fish, Shellfish and Cetaceans

During 2004–2006, samples from a variety of finfish species were collected from five major Irish fishing ports and analysed for mercury content. The survey's findings were in line with those of previous studies, which showed that Irish seafoods are effectively free from mercury contamination (Tyrrell *et al.*, 2003). Selected samples were also analysed for other trace metals and chlorinated hydrocarbons, which showed the levels of these substances to be well below EC limits.

Approximately 30 sites within the major shellfish-growing areas were sampled on an annual basis between 2002 and 2006 in accordance with the monitoring requirements of the two Shellfish Directives (CEC, 1979, 1991c). As in previous years the water quality was good and conformed to the requirements of the 1979 directive. Petroleum hydrocarbons were not visible at any of the sites and levels of chlorinated hydrocarbons and trace metals in shellfish tissue were very low in all areas. As in previous studies in this series, the results confirm that contamination from trace metals and chlorinated hydrocarbons is low in shellfish waters and in the produce itself.

Cetaceans, the mammalian order that includes whales and dolphins, can often be positioned at the top of the marine food web, making them susceptible to the biomagnification of persistent organic pollutants. The analysis of tissue from a female killer whale (*Orca orcinus*) stranded in Cork Harbour in July

2001 showed that concentrations of organochlorine pesticides (OCPs), dichlorodiphenylethylene (p,p'DDE; the most stable and toxic of the DDT metabolites) and polychlorinated biphenyls (PCBs) were similar to those in a number of individuals stranded in UK waters. Levels were, however, much less elevated than those of an individual female from western Scotland waters which was suspected (as evidenced by stable isotope analysis) to have different dietary influences and a higher relative trophic status than the other individuals analysed (McHugh *et al.*, 2007).

### Dioxins, Polychlorinated Biphenyls and Brominated Flame-Retardants in Fish

In 2004 the Food Safety Authority of Ireland in collaboration with the Marine Institute and Bord lascaigh Mhara (BIM) carried out a surveillance study of levels of dioxins (polychlorinated dibenzo-p-dioxin (PCDD)), furans (polychlorinated dibenzofuran (PCDF)), PCBs and

brominated flame-retardants (BFRs) in a variety of fish species and fishery products (Tlustos *et al.*, 2006).

The study showed that the levels of PCDDs and PCDFs and the levels of the sum of PCDDs/PCDFs and dioxin-like PCBs in Irish fish and fishery products available on the Irish market were well below EC legal limits. Concentrations of BFRs were also low, and while no maximum limits are set for polybrominated diphenyl ethers (PBDEs) or hexabromocyclododecane (HBCD) (types of BFR), the levels of these contaminants found in the study were low, and are very unlikely to present a health risk to Irish consumers.

### Quality of Shellfish and Shellfish Waters

#### Classification

The Department of Communications, Marine and Natural Resources (DCMNR) was until 2007 the competent authority in Ireland responsible for classifying shellfish

**Table 9.1 Classification of Shellfish Waters, Indicating the Percentage of Areas Graded into Classes A, B and C in the period 1991–2006**

	2006	2005	2004	2003	2000	1998-99	1991-94
Total Number	57 <sup>1</sup>	57 <sup>2</sup>	61 <sup>3</sup>	58 <sup>4</sup>	61 <sup>5</sup>	58 <sup>6</sup>	58 <sup>7</sup>
Class A	24.5	29.8	22	21	34	24	55
Class B	56.1	54.3	60.6	62	54	60	29
Class C	0	0	0	2	2	2	0

Percentages do not add to 100 as sites with more than one class are omitted.

<sup>1</sup> Ten areas were classed as partly A and B; 1 as B and C.

<sup>2</sup> Eight areas were classed as partly A and B; 1 as B and C.

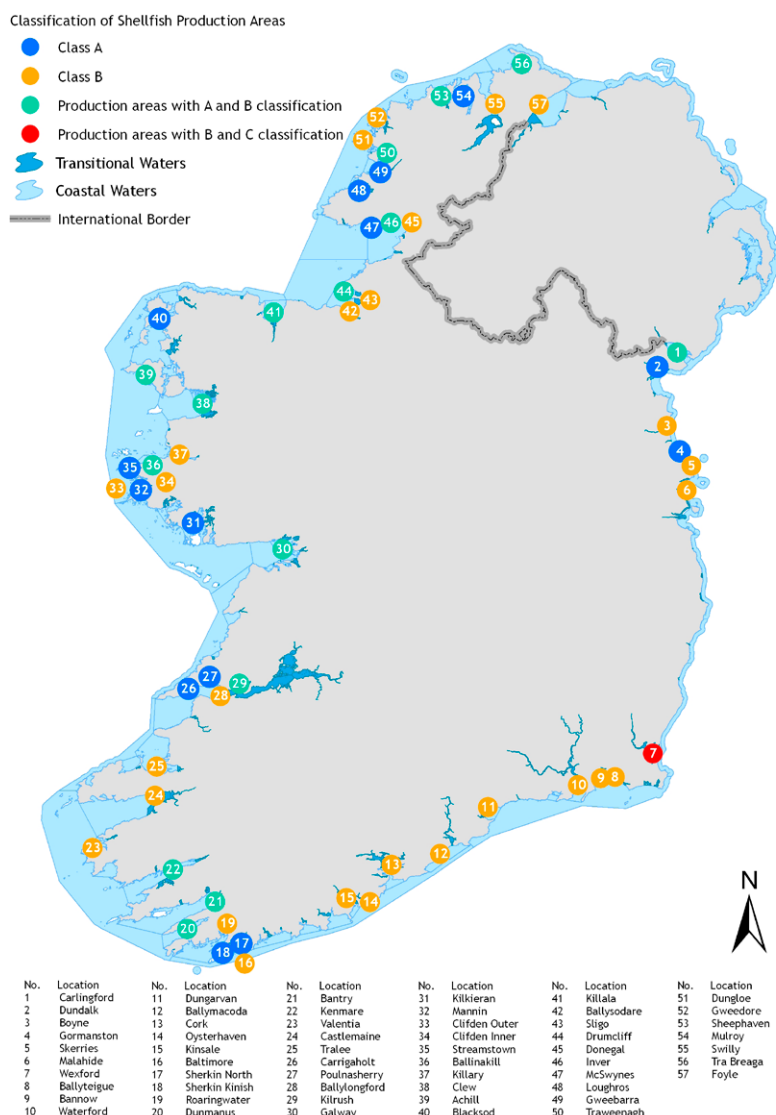
<sup>3</sup> Eight areas were classed as partly A and B; 1 as B and C.

<sup>4</sup> Eight areas were classed as partly A and B; 1 as B and C.

<sup>5</sup> Four areas were classed as partly A and B; 1 as partly A, B and C; 1 as B and C.

<sup>6</sup> Six areas were classed as partly A and B; 1 as partly A, B and C; 1 as B and C.

<sup>7</sup> Five areas were classed as partly A and B; 1 as partly A, B and C; 1 as B and C.

**Map 9.2 Shellfish Production Areas (Source: DCMNR, 2006)**

production areas as required under Directive (91/492/EEC) and by the 1996 Regulations (SI No. 147 of 1996). This role is now undertaken by the new Sea Fisheries Protection Authority (SFPA), which was established in January 2007. The directive and subsequent amendments categorise shellfish production areas based on the level of treatment (depuration) required before shellfish products can be placed on the market for human consumption.

Of the 57 shellfish production areas assessed in 2006, 24.5 per cent were graded as class A (i.e. shellfish may be sold directly for human consumption) and 56.1 per cent as class B (i.e. purification for 48 hours is required before shellfish can be placed on the market). No area was solely graded as class C, which would require relaying for a period of at least two months prior to sale. A summary of the most recent classification along with classifications for previous periods is given in Table

9.1. A full list of shellfish production areas with the 2006 classification is illustrated in Map 9.2.

The proportion of areas graded as class A in 2006, at 24.5 per cent, marks a substantial reduction on the 1991–1994 period, when over 50 per cent of the areas assessed were in this category.

### Shellfish Biotoxins

A small number of phytoplankton species that occur in Irish waters naturally produce compounds known as biotoxins that can accumulate in filter-feeding organisms such as shellfish. The consumption of contaminated shellfish flesh can cause serious human illness including nausea, vomiting, stomach pain, diarrhoea and in some cases neurological damage.

In Ireland, the occurrence of shellfish contamination is variable from year to year, with most of the resultant closures of production areas being attributed to *Dinophysis* species, the causative organism of diarrhetic shellfish poisoning (DSP). However, other toxic species, such as *Pseudo-nitzschia* (amnesic shellfish poisoning, ASP), *Alexandrium* (paralytic shellfish poisoning, PSP) and *Protoperidinium* species (azaspiracid shellfish poisoning, AZP) are also problematic.

### Monitoring of Harmful Phytoplankton and Shellfish Toxicity

The Marine Institute, which is the national reference laboratory for shellfish biotoxins, is contracted by the Food Safety Authority of Ireland to undertake monitoring of biotoxins in shellfish intended for human consumption. The institute has operated a national monitoring programme for the detection of potentially harmful phytoplankton species and biotoxins since 1984.



## An Exceptional Dinoflagellate (*Karenia mikimotoi*) Bloom in Irish Waters

During the summer of 2005 there was a very extensive bloom of the dinoflagellate *Karenia mikimotoi* along Ireland's western seaboard. The bloom began in late May or early June off the north-west coast and dissipated in July. It was very intense and resulted in water discolouration and foaming in coastal bays. A second bloom of the same species occurred in the south-west in late July. This latter event was not as persistent as the bloom in the north-west and dissipated during August. Concurrent with these blooms were mass mortalities of vertebrates and invertebrates along the entire western seaboard. Benthic organism mortalities were more severe than in previous blooms, and a visible effect of the bloom was the presence of dead heart urchins (*Echinocardium cordata*) and lugworms (*Arenicola marina*) on beaches in the affected areas.

During this time, low wind speeds and calm conditions allowed the bloom to grow. The onshore wind

led to an accumulation of high numbers of dinoflagellate cells in bays along the western seaboard. Cell numbers reached over 3 million cells/l in Donegal Bay in June; higher concentrations of up to 3.7 million cells/l were observed in the Glenbeigh area of Dingle Bay, Co. Kerry, in July. The extent of these blooms was also apparent from satellite images during the first half of June along the western seaboard. High chlorophyll levels were visible in Dingle Bay in August, which correlated with the high *Karenia* cell numbers observed. This species has bloomed in Irish waters in the past 30 years, but the scale of mortality associated with the 2005 bloom had not been recorded before.

A detailed report of this bloom event has been published by the Marine Institute (Silke *et al.*, 2005) and is available online at [www.marine.ie/home/publicationsdata/publications/MEHS.htm](http://www.marine.ie/home/publicationsdata/publications/MEHS.htm)

In 2006 there were 2091 bioassays, 2384 chemical analyses and 1740 analyses of phytoplankton samples.

The level of toxicity observed in shellfish between 2004 and 2006 was extremely variable. In 2004, which was considered a low-toxicity year, as were 2002 and 2003, less than 4 per cent of shellfish tested were positive for DSP. Levels of AZP were also low and did not lead to the closure of any shellfish production areas. In 2005 and 2006 there was a significant increase in shellfish testing positive for the presence of DSP toxins, with 17.5 per cent and 16.4 per cent, respectively, of bioassays proving positive. The proportion of mussel samples testing positive for toxins was 23 per cent in 2005 and 29 per cent in 2006.

In Irish waters there is little evidence that the variable occurrence of potentially toxin-producing species, or toxicity in shellfish, is related to nutrient enrichment or other forms of anthropogenic pollution. A number of studies suggest that many of these species originate offshore and are advected inshore by the wind (Raine *et al.*, 1993; Raine and McMahon, 1998; O'Boyle *et al.*, 2000). The occurrence of an exceptional bloom of the dinoflagellate *Karenia mikimotoi* in Irish waters in the summer of 2005 probably resulted from the advection inshore of established offshore populations.

**Figure 9.1** The Dinoflagellate, *Karenia mikimotoi* (42 µm x 43 µm) (Source: Marine Institute)



### Irish Shellfish and Public Health

The Irish authorities have put a number of measures in place to ensure that the presence of toxins in shellfish does not lead to human poisoning. Prior to harvesting, samples are tested for toxins. If the sample is positive for biotoxins the production area is closed for harvesting and is not reopened until

**Figure 9.2 Plankton Bloom (Source: European Space Agency)**



samples collected at a minimum of 48 hours apart are shown to be clear of toxins.

The Molluscan Shellfish Safety Committee (MSSC) was established to ensure that adequate controls are in place to guarantee the continued safety of shellfish for human consumption. The MSSC operates a management team to manage proactively the risk presented by marine biotoxins. Its objective is to facilitate rapid decision-making in non-routine situations such as borderline cases or anomalous biotoxin results. In 2006, the management team made over 100 risk-informed decisions in relation to the safety of Irish shellfish.

It would appear that in the absence of any reports of shellfish toxicity in consumers or recalls of shellfish from the market in the period 2003–2006, the monitoring programme and the management of closures have proved effective in protecting human health.

### Oil Pollution Incidents

The Irish Coast Guard (IRCG) investigated 59 oil pollution reports during 2004, 46 in 2005 and 44 in 2006. Mineral oils accounted for 95, 71 and 86 per cent respectively of the polluting material observed annually between 2004 and 2006, and of these, diesel and gas oils were the most frequently identified. An analysis of the incidents in 2005 and 2006 showed that almost a quarter were likely to have been caused by discharges from fishing vessels in

Ireland's Exclusive Economic Zone; in most cases the identity of the vessels could not be established. There were no prosecutions for illegal discharges during this period.

The majority of discharges occurred in smaller harbours and surrounding areas. Clusters of slicks were identified in bays and nearshore waters, with 15 to 22 per cent of pollution reported from the open sea. Most of these reports come from shipping and commercial air traffic and should therefore be treated with caution, as it was not always possible to confirm them.

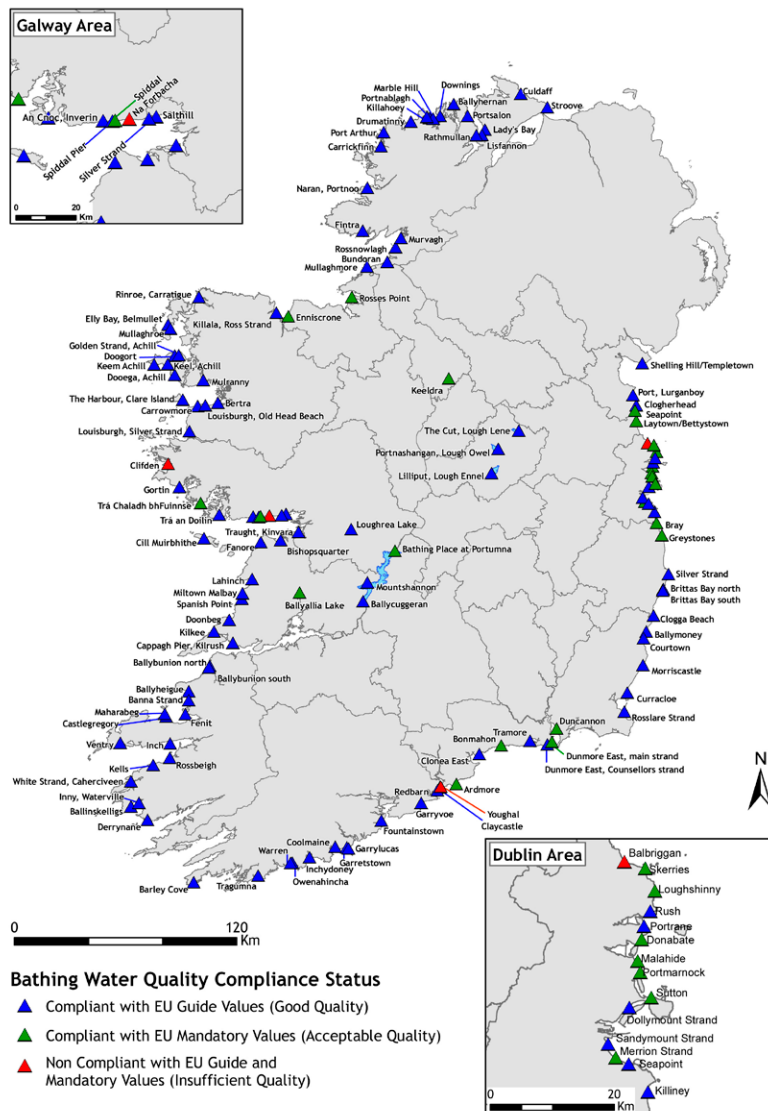
National oil spill contingency plans (NCPs) for 19 ports around Ireland are at various stages of development. The Coast Guard has also issued oil spill contingency plan guidelines to all maritime county councils, which were instructed to draw up contingency plans for the prevention and minimisation of damage arising out of oil and other spillages on the coast.

### Bathing Water Quality

Monitoring of water quality at designated bathing areas (Map 9.3) is undertaken annually by the local authorities in accordance with the requirements of the EU Directive



Map 9.3 Bathing Water Quality (Source: EPA, 2008)



concerning the quality of bathing waters (CEC, 1976). The purpose of the directive is to ensure that bathing water quality is maintained and, if necessary, improved, so that it complies with specified standards designed to protect public health and the environment. Since 1996, the EPA has been collating the water quality results from the local authorities and reporting these in summarised form.

Annual monitoring was carried out at 131 designated bathing areas (122 seawater, 9 freshwater) during the 2004-2007 review period. During each year of the review period, over 96 per cent of the seawater bathing areas complied with the minimum mandatory standards laid down by EU legislation. The proportion of seawater bathing areas complying with the more stringent EU guideline standards fluctuated during the review period, from 88 per cent in 2004 to 92 per cent in 2005, but decreasing to 81 per cent in 2007.

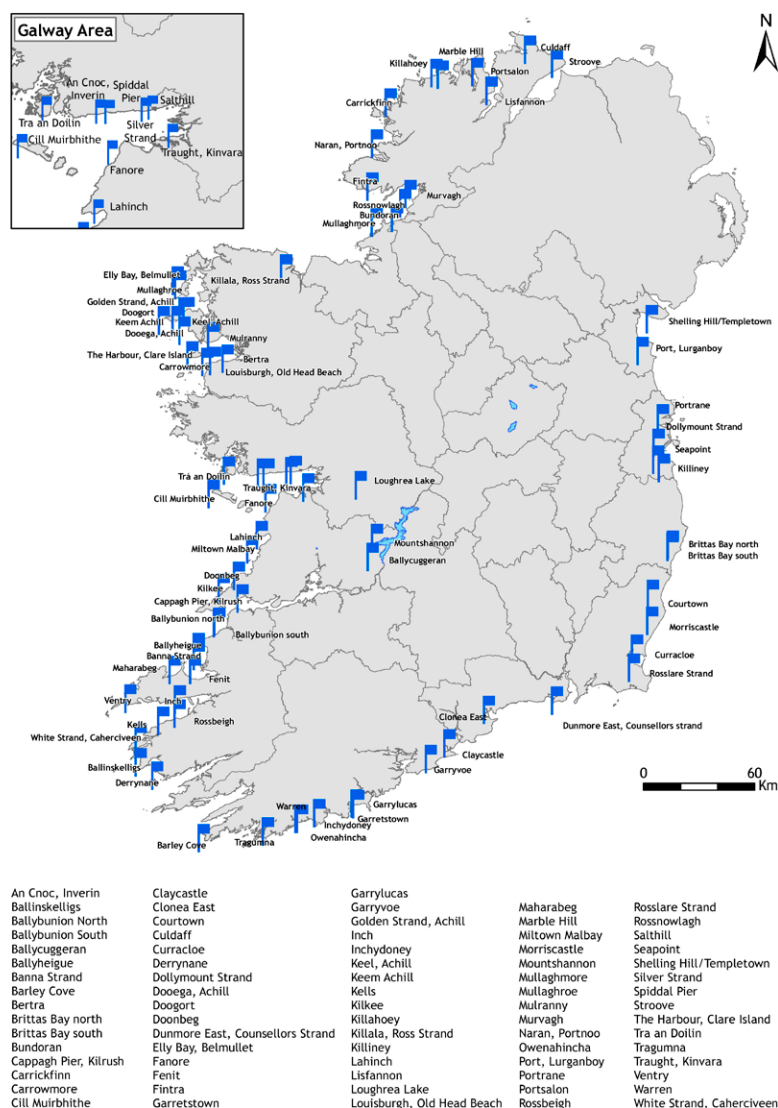
A new directive concerning the management of bathing water quality (European Parliament and Council, 2006) came into force in 24 March 2006 and will repeal the existing 1976 directive with effect from 31 December 2014. The new directive gives stronger focus to the protection of public health, a proactive approach to the management of bathing water quality and greater public participation. It establishes stricter microbiological standards for two new parameters, intestinal enterococci and *Escherichia coli* which will be used to classify bathing waters as 'poor', 'sufficient', 'good' and 'excellent'. The classification of bathing waters will be determined, in general, on the basis of a four-year period instead of a single bathing season result. This means that the classification will be less susceptible to bad weather or one-off incidents.

Analysis of bathing water quality in the context of the directive and the associated national regulations is separate from, though complementary to, the European Blue Flag Scheme, a voluntary public information and advice scheme administered in Ireland by An Taisce and, at European level, by the Foundation for Environmental Education in Europe. To receive a blue flag, a bathing site must, in addition to maintaining a high standard of water quality, meet specified objectives with regard to the provision of safety services and facilities, environmental management of the beach area and environmental education. The award is based on the performance and standards achieved during the previous bathing season.

A total of 73 beaches were awarded blue flags in 2004, rising to 79 and 81 in 2005 and 2006 respectively but decreasing to 78 beaches in 2008



Map 9.4 Blue Flag Beaches in Ireland 2008 (Source: An Taisce, 2008)



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(Map 9.4). Because of the level of public recognition of and reliance on the Blue Flag scheme, the clear desire among local authorities to achieve and maintain their Blue Flags and the evident improvement in standards and facilities that has been achieved at beaches, the scheme must be considered one of the most successful public awareness initiatives of its kind.

## Pressures on the Marine Environment

### Marine Litter

While marine litter can have a very obvious impact on the aesthetic quality of coastal amenities, the impact on marine life can be far more serious and insidious. It is estimated that plastic litter kills 100,000 marine mammals and turtles worldwide every year, including 30,000 seals and up to one million seabirds, through either entanglement or ingestion. Litter on the Irish coast comes from a variety of sources, both land and sea.

The last major survey of litter around the Irish coast, which included 782 sites north and south, was carried out by Coastwatch Ireland in October 2002 (Dubsky *et al.*, 2003). Large metal items (mainly abandoned motor vehicles) and landfill material were again found to be the most common forms of large waste debris, and were observed, respectively, at 19 and 18 per cent of sites around the coast. Drinks containers and plastics such as bottles and 'six-pack' holders were among the items regularly noted.

Items of lost and discarded fishing gear and other fishing-related waste items, such as fragments of oyster bags, nets, floats and ropes, have become the most commonly

observed category of litter on Ireland's shoreline. This is attributed at least in part to a continuing lack of waste receptacles at harbours and ports, as required under the recent Port Waste Management legislation (DCMNR, 2003).

### Coastal Zone Development

Ireland, like many other European countries, has experienced a disproportionate level of development along its coastline. Much of Ireland's coastal zone experienced a human population increase of between 10 and 50 per cent in the last decade of the twentieth century, a reflection of Ireland's economic growth over that period (EEA, 2006).

Increasing population trends and greater human use of the coastal zone create a range of pressures that may impact negatively on the quality of the coastal environment. The range of activities that take place along Ireland's coastline include the construction of marinas, coastal protection structures, port facilities and other structures related to urbanisation and tourism (and in particular the construction of holiday or second homes). Further activities such as dredging and land reclamation may also damage fragile coastal ecosystems.

In comparison to many other European countries, the proportion of Ireland's coastal zone that is considered to be 'built-up' is relatively small at less than 5 per cent. What is of concern, however, is that Ireland, along with Spain and Portugal, has the highest rate of coastal development in the European Union. The main driver of this change is the construction of residential properties, with over 50 per cent of newly developed coastal lands being used for this purpose.

### Marine Aggregate Extraction

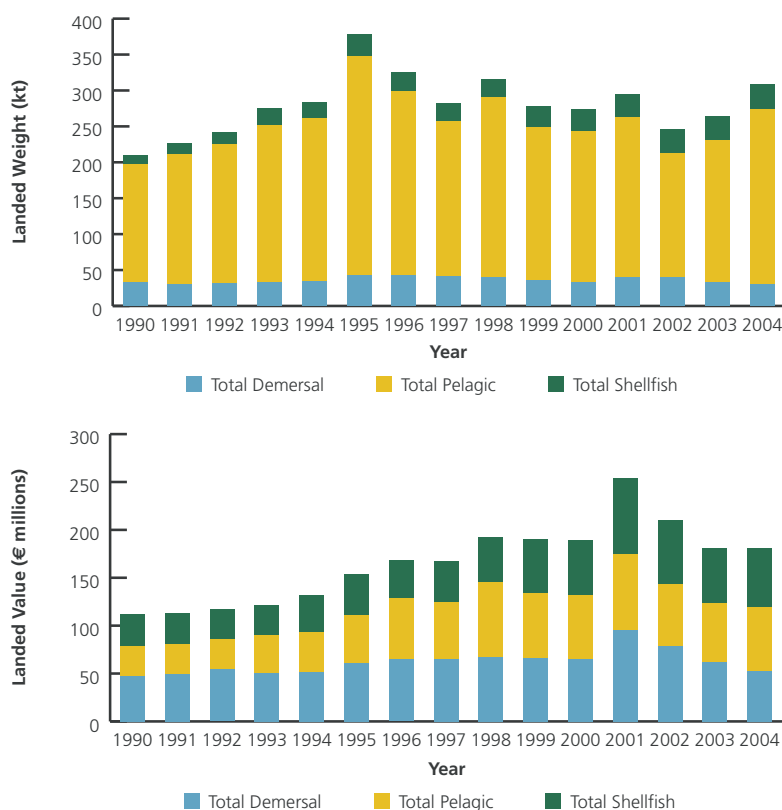
Since the early 1990s Ireland has experienced an unprecedented construction boom, which has greatly increased the value of remaining land-based resources of sand and gravel. Not surprisingly, this has increased the level of interest in exploiting offshore aggregate deposits. At present, however, there is no policy in place to regulate the commercial extraction of marine aggregates from Irish waters, and there are no commercially licensed aggregate extraction operations in Irish marine waters.

Previous surveys carried out by the Geological Survey of Ireland and others have revealed substantial glacial deposits of sand and gravel in relatively shallow waters (less than 20 m) along the western coast of the Irish Sea. More recently, the EU

INTERREG IIIA funded project Irish Sea Marine Aggregates Initiative (IMAGIN) has estimated that within the IMAGIN study area of the Irish Sea alone, the marine aggregates resource equates to approximately 5 to 7 billion m<sup>3</sup>.

The IMAGIN project commenced in 2005 with the overall aim of developing recommendations for a strategic policy framework for an administrative and regulatory process, and operational guidelines under which dredging for marine aggregates in the Irish Sea can be managed sustainably. This work has concluded that the sustainable development of marine aggregates in the Irish Sea is realistically achievable in the short to medium term, and that development of Irish Sea marine aggregates would provide an important contribution to sustaining economic development

**Figure 9.3 Weight (top) and Value (bottom) of Fish and Shellfish Landed by Irish Vessels 1990–2004 (Source: CSO, DCMNR, Marine Institute, 2007a)**



in both Ireland and Wales, while contributing to a reduction in carbon dioxide (CO<sub>2</sub>) emissions and environmental costs. The study recommended that a national statutory framework for this sector be created that is fully consistent with the principles of marine spatial planning and environmental protection (Sutton *et al.*, 2008).

### Offshore Oil and Gas Exploration

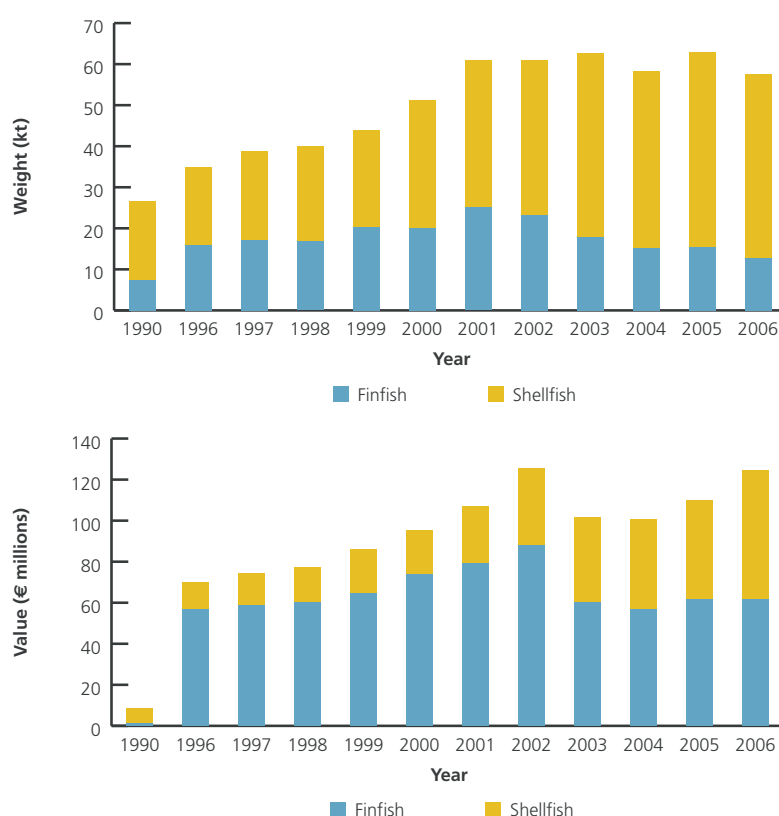
Offshore exploration licences are issued by the Department of Communications, Energy and Natural Resources (DCENR). The level of offshore oil and gas exploration in Irish waters varies from year to year, but is generally on the low side. In 2006, the first Irish Offshore Strategic Environmental Assessment (IOSEA1) was carried out for the Slyne Erris Donegal area. Four exploration licences were awarded for that



area. By the end of 2006, there were seventeen exploration licences active. Six seismic surveys were also undertaken, acquiring a total of 856 km<sup>2</sup> three-dimensional data and 2816 km of two-dimensional data, and in July of that year, the Petroleum Infrastructure Programme (PIP) carried out a shallow drilling programme on the Porcupine High.

Exploration drilling took place on prospects in the North Celtic Sea, and in the Donegal Basin. Appraisal and completion activities took place in the North Celtic Sea, and in the Slyne Erris Basin. Permit assessments, (permits are issued by the Petroleum Affairs Division of the DCENR) were carried out in accordance with the OSPAR Offshore Oil and Gas Industry Strategy, which sets the objective of preventing and eliminating pollution that may arise from offshore activities. As part of this strategy, chemical use and discharge figures are reported annually to the OSPAR Commission.

**Figure 9.4** Aquaculture Production (top) and Value (bottom) 1990–2002 (Source: BIM,CSO, Marine Institute 2007b)



### Dredging of Harbours and Marinas

The removal of seabed material for maintenance and navigational purposes is a common occurrence in harbours and marinas around Ireland. In 2006 approximately 911,000 t (dry weight) of material was dredged from two harbours and seven estuarine areas and deposited at nine licensed disposal sites around the Irish coast. As part of the licensing process, sediment chemistry of dredged material must be analysed to ensure that release of harmful contaminants at the disposal site is minimised.



### Pressures from Fisheries and Aquaculture

Ireland's extensive maritime area and heavily indented coastline of over 7500 km provide a wealth of natural resources that are exploited by the fisheries and aquaculture sectors. The value and weight of commercial fish landings and aquaculture production since 1990 are shown in Figures 9.3 and 9.4. The combined value of these sectors to the Irish economy in 2004 (the last year for which complete data is available for both sectors) was estimated to be €286.4 million in fish and shellfish production. A total of 264,581 t of fish and fish products was exported in 2004.

The most obvious pressure on the environment from the marine fishing industry is the harvesting of target species and the unintentional catching of non-target fish species and other species such as cetaceans, seals, seabirds and benthic organisms. Fishing activities such as trawling and dredging can cause injury or mortality to benthic organisms and can result in damage to and destruction of habitats.

The main issues in relation to aquaculture are the effects of discharges of uneaten fish-food

material and fish waste from fish farms, the introduction and spread of disease and parasites and the use of chemotherapeutics and antifouling agents. Other issues include the introduction of alien species, the impact of escaped farmed salmon on the genetic integrity of wild stocks, and the visual impact of aquaculture facilities on the aesthetic quality of the environment.

### Impacts of Fishing on Fish Stocks and the Environment

The assessment of the current state of marine fish stocks in Irish waters is based on information collected by the Marine Institute on fish landings, discards data and scientific research surveys (Marine Institute, 2007a). Information from Ireland and other countries is collated by the International Council for the Exploration of the Seas (ICES), which produces annual scientific and management advice on the state of the resource.

This advice includes information on the biological limits for each commercially exploited species, i.e. the minimum stock size below which replenishment by recruitment is likely to be insufficient to sustain a viable fishery. Many commercially important

fish species in Irish waters are heavily exploited. In terms of individual stocks, it is estimated that as much as 75 per cent is being harvested beyond safe biological limits.

### Pelagic Species

The most important pelagic (mid-water) species exploited by the Irish fishing industry include herring (*Clupea harengus*), mackerel (*Scumbr scombrus*), horse mackerel (*Trachurus trachurus*), blue whiting (*Micromesistius poutassou*), sprat (*Sprattus sprattus*) and tuna (*Thunnus alalunga*).

Following major stock collapses due to overfishing, many herring fisheries in western Europe were closed in the late 1970s. As a result, the stocks substantially recovered, but in recent years concern has been expressed again about many of them. The herring stock to the west and north-west of Ireland has decreased sharply from a recent peak in the late 1980s, and remains at a low level despite the reduction in catches in recent years. The stocks in the Celtic Sea and the Irish Sea also remain low and show no indication of returning to late 1980s levels. In fact, the Marine Institute has stated that the current herring stock size may be as low as it was when the stock collapsed in the 1970s. As a conservation measure, selected spawning areas off the south coast of Ireland are closed on a rotational basis to protect the spawning shoals.

The Irish fleet began to exploit mackerel following the collapse of the herring fishery in the late 1970s. Since the 1980s the Irish fishing fleet has focused its efforts on the overwintering populations in the North Sea and on the shoals that travel to and from spawning grounds located off the south-west and west coasts of Ireland. The combined Northeast Atlantic mackerel stock is currently being harvested at unsustainable levels.



The horse mackerel fishery off Ireland's western coast, which began in the early 1980s, is of significant importance to the Irish fishing industry. The catch of horse mackerel by the Irish fishing fleet peaked in the mid-1990s; catches have since declined and are now close to a third of what they were during peak years. In 1998 the EU fishery was closed for the first time when the total allowable catch was reached. The current status of this stock is unknown. There is an indication, however, that the size of the spawning stock has increased as a result of relatively strong recruitment in 2001. Nevertheless, the potential for the stock to return to mid-1990 levels is considered to be low.

The blue whiting fishery has increased dramatically in recent years, with most of the countries involved in the fishery doubling or trebling their catches. In 2005 the catch of blue whiting by both EU and non-EU states (Faroe Islands, Iceland and Norway) reached a record level of 2 million tonnes, and there are now serious concerns about the sustainability of this stock. ICES is recommending that there should be a substantial yearly reduction in the total allowable catch to decrease fishing mortality.

The Irish fishery for tuna exploits a species called albacore tuna (*Thunnus alalunga*), and the fishery mainly takes place over a large area stretching from 160 km off the southern coast of Ireland to the Bay of Biscay. The Irish fishery for albacore tuna developed during the 1990s and catches reached a peak of over 4800 t in 1999. However, since 2002 the fishery has been seriously affected by the EU ban on the use of driftnet fishing, on environmental grounds, and in 2005 the Irish catch was reduced to 306 t. In 2001 the EU introduced a total allowable catch (TAC) of 34,500 t for this species, to ensure that the stock could be harvested at the maximal sustainable level in the future. However, recent data indicates that the stock is being overfished and that the TAC should be further reduced until it begins to recover.

#### Demersal Species

In general, the landings of demersal species have decreased significantly over the past two decades and one of the worst affected species is cod (*Gadus morhua*). The cod stocks in the Atlantic waters to the west of Scotland and in the Irish Sea are considered to be in a state

of collapse and are expected to decline further in 2008 (Figure 9.5). Recovery plans were established for Irish Sea cod in 2000 and west of Scotland cod in 2004, but both have been ineffective. The Irish Sea plan, which involved the closure of spring spawning grounds, seems to have resulted in the displacement of fishing effort to surrounding regions and in some cases a switch in fishing gear to Nephrops (*Nephrops norvegicus*, Dublin Bay prawns) trawls, which under the derogation for this species can still be used in the closed area. The recovery plan for the west of Scotland stock has not reduced fishing mortality or effected an increase in the spawning stock. Given the perilous state of cod stocks in Irish waters it is likely that severe measures, such as multi-year closures in certain areas, will be required to ensure the longer-term sustainability of these stocks.

Whiting (*Merlangius merlangus*) stocks are also in a severe state of decline in the Irish Sea. The estimated landing of only 55 t of whiting by Irish vessels in 2006 is a hundred times lower than catches in the 1980s. The status of the haddock (*Melanogrammus aeglefinus*) in the Irish Sea is uncertain, and while

**Figure 9.5 Relationship of TAC and Landings of Cod in the Irish Sea between 1987 and 2006**  
(Source: ICES, Marine Institute, 2007a)



low in historic terms, there is some indication that recruitment to this stock has increased and this has led to an increase in the size of the spawning stock. The status of whiting and haddock stocks in other sea areas around Ireland is generally mixed. The Rockall haddock stock is being fished sustainably, while the west of Scotland whiting stock is at historically low levels due to overfishing and poor recruitment.

One of the most economically important demersal species to the Irish fishing fleet is northern hake (*Merluccius merluccius*). The Irish fishery for this species is mainly carried out along the western continental shelf, the Celtic Sea and the Stanton Bank west of Scotland.

Landings of this species in 2006 were two-thirds of what they were in the late 1980s; however, the establishment of a hake recovery plan has reduced fishing mortality in juveniles and increased the size of the spawning stock. ICES considers that this stock is now at full reproductive capacity and is being harvested sustainably.

### Shellfish

There are several important Nephrops fisheries around the Irish coast. The most productive fishery is in the western Irish Sea, where 2047 t (32% of the total Irish catch) was caught in 2006. The main issue in relation to the exploitation of Nephrops from the western Irish Sea is the associated

impact of the fishery on demersal fish species such as cod and whiting. Discarding of juvenile whiting in the Nephrops fishery has contributed significantly to the reduction of the whiting stock. In relation to cod, ICES has recommended that unless ways to harvest Nephrops without incidental catch or discards of cod can be demonstrated, fishing for Nephrops should not be permitted. The use of separator trawls, which reduce cod by-catch, is currently being developed by the industry with support from the Irish Sea Fisheries Board (BIM). Apart from the issue of cod by-catch, nearly all Nephrops fisheries around Ireland appear to be harvested at sustainable levels.

### Deepwater Species

The exploitation of deepwater species found in the waters to the west and north of Ireland by the Irish fishing fleet is a relatively recent development. Dwindling resources on the continental shelf and the increased ability of the Irish fishing fleet to operate at greater distances from land have encouraged the development of deepwater fisheries. A number of species are targeted, including ling (*Molva molva*), blue ling (*Molva dipterygia*), forkbeard (*Phycis blennoides*), black scabbard (*Aphanopus carbo*), orange roughy (*Hoplostethus atlanticus*), redfish (*Sebastes* spp.) and Greenland halibut (*Reinhardtius hippoglossoides*).

In 2002, the Marine Institute advised in its *Annual Review of Fish Stocks* that 'The vulnerability of deepwater species ... to exploitation, means that deepwater fishing is not likely to be a viable alternative fishery in the long-term'. Some species, such as blue ling and orange roughy, are known to aggregate in shoals, often in the vicinity of seamounts, increasing the probability of high catchability once the shoals have been located. Furthermore, the life-cycle characteristics of these species – extreme longevity, slow

### Orange Roughy Protection Areas

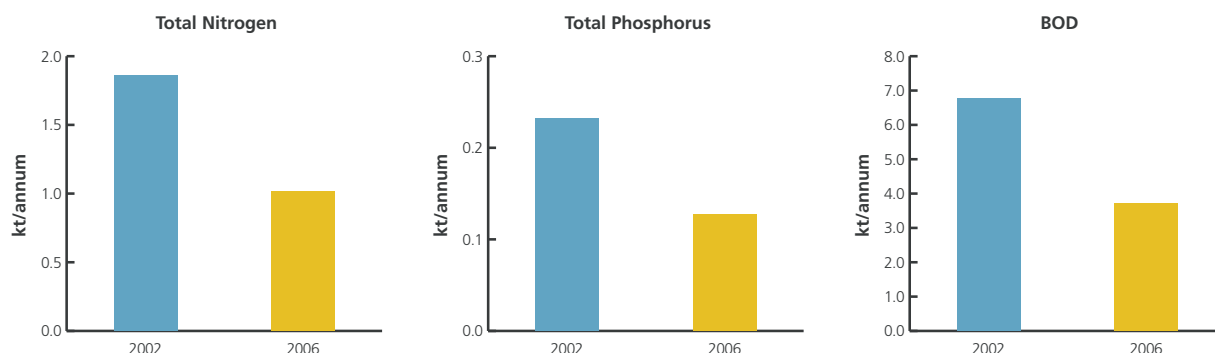
In December 2006 the European Commission established a number of areas off Ireland's Atlantic seaboard to protect the remaining stocks of orange roughy in these waters. The protection areas, which are vast, are located off the south-west and north-west Porcupine Bank and along the continental rise north-west of Ireland. To ensure that deep-sea fishing vessels entering these areas are not fishing for orange roughy, vessels' speed during transit must be at least eight knots (vessels have to travel much more slowly than this when fishing), and all fishing gear must be lashed and stowed. The vessels are also monitored when entering, transiting and exiting these areas.

### Special Areas of Conservation (SACs) for Deepwater Coral in Irish Waters

In October 2007 the European Commission adopted a proposal by Ireland to protect important sites for coldwater corals in the deep waters off Ireland's western coasts. The four sites, comprising an area of 2,500 km<sup>2</sup>, include the Belgica Mound Province, the Hovland Mound Province, the Southwest Porcupine Bank and the Northwest Porcupine Bank. The Irish government has proposed that under the Habitats Directive these sites should be designated as SACs in the Natura 2000 network. In order to guarantee protection from the impact of fishing before Natura 2000 is operational, provisional measures are to be implemented under the Common Fisheries Policy. Measures will include the prohibition to conduct bottom trawling and fishing with static gear including bottom set gill nets and longlines.



**Figure 9.6** Estimated Losses of Nutrients and Biochemical Oxygen Demand (BOD) from Finfish Aquaculture in 2002 and 2006 (based on 2002 and 2006 production figures) (Source: Data: CSO, BIM; Analysis: EPA)



growth and low fecundity – ensure that when the stocks have been fished out recovery will be very slow.

In European waters landings of deepwater species increased substantially during the 1990s, mainly as a result of French fisheries targeting stocks along the edge of the European continental shelf. In the early 2000s there was a further rapid increase in landings when deepwater species were targeted by the Irish fishing fleet. Since 2003, landings of certain species have plummeted due to the collapse in several deepwater stocks and the introduction of TAC and quota restrictions. For example, Irish landings of orange roughy, which is known to live to 180 years, were only 210 t in 2004 compared to a peak tonnage of 4,646 in 2002. These figures give a stark indication that the level of exploitation that took place in 2001 and 2002 was wholly unsustainable. In response to the near collapse of this stock, protection areas restricting fishing activities were introduced in 2006.

### Impacts of Aquaculture

In 2006, aquaculture production of shellfish and finfish species reached 57,442 t and had a value of €124.7 million. While this figure represents the second highest value achieved to date, there has been a substantial reduction in finfish production

(mainly of Atlantic salmon), which has fallen by nearly a half since 2001, when production peaked at 25,082 t. This fall had been influenced by a number of factors including disease outbreaks, external environmental pressures and financial constraints. This has been partly compensated by an increase in shellfish production (mainly in rope mussels, Pacific oysters and clams).

Inputs to the aquatic environment associated with this industry include feedstuffs, chemotherapeutants and antifoulant agents. A certain portion of these materials is likely to be lost to the waters and sediments in the vicinity of the fish farms. Estimated annual loads of organic matter and

nutrients entering marine waters from the finfish culture sector are shown in Figure 9.6.

The release of organic material in the form of fish waste and uneaten foodstuffs from fish farms in shallow-water environments has been shown to have a negative impact on the benthos in the vicinity of cage structures. While low levels of organic loading can encourage increased benthic productivity, the high levels associated with fish farming can result in reduced biodiversity and a shift of benthic production to bacteria. Increased bacterial activity can lead to hypoxic (low-oxygen) or even anoxic (no-oxygen) conditions



directly below the cages. Of the 29 licensed marine finfish sites surveyed in Ireland in 2006, 100 per cent were compliant with the conditions laid down by the Department of Communications, Marine and Natural Resources (DCMNR) for the status of the seafloor and benthic communities in the vicinity of finfish operations (Marine Institute, 2007b).

The high level of compliance achieved is largely due to the size (tonnage) and exposure characteristics of Irish marine fish-farm sites. In comparison to other salmon-producing countries such as Norway and Scotland, where a large number of fish-farm sites are located in sheltered fjords and sea lochs, a high proportion of Irish fish farms (47 per cent) operate in semi-exposed or exposed locations where the rate of water exchange is high (Aquafact, 2002). Irish production levels are considerably smaller than their Scottish and Norwegian counterparts and have continued to fall in recent years, with the number of finfish sites decreasing from 55 in 2002 to 36 in 2006 (Marine Institute, 2007b).

Another concern is the possible impact of nutrient enrichment that might occur on foot of the release of nitrogen and phosphorus from fish farm sites. In the case of Irish fish-farm sites, which are predominantly located in areas where the rate of flushing is high, resulting in the rapid dispersion of dissolved substances, evidence of eutrophication is limited. Furthermore, estimated loadings of both total nitrogen and total phosphorus (based on a comparison of 2002 and 2006 production values) have decreased by as much as a half as a direct result of falling production (Figure 9.6).

The types of chemicals used in the Irish marine aquaculture industry range from antibacterial agents used to treat certain diseases to treatments used to control sea-lice levels on salmon farms. In marine farms

antibiotics such as oxytetracycline and potentiated sulphonamides are used for disease control, but amounts have been drastically reduced following the introduction of vaccines. The most controversial issue has been the control of sea lice by chemicals. In Ireland, there are three authorised medicines for the treatment of sea lice, which contain cypermethrin, enamectin benzoate and teflubenzuron respectively. Concerns have also been voiced at European level about the use of toxic antifouling agents on cage structures. The situation regarding the use of antifouling agents on Irish fish farms is currently unknown.

One of the most contentious issues in relation to the mariculture of salmonids is the suggested link between the production of sea lice (*Lepeophtheirus salmonis*) on fish farms and the decline in wild sea-trout populations in the west of Ireland. Research carried out in Ireland and Scotland, which has investigated this issue, suggests that sea lice from salmon farms are a major contributory factor in the collapse of wild sea-trout populations (Gargan *et al.*, 2002; McKibben and Hay, 2002; Penstan *et al.*, 2002).

The initiation of sea-lice monitoring and the adoption of a number of measures based on a single bay management (SBM) approach have seen a downward trend in the levels of sea lice on salmon farms between 1991 and 2001. Since 2002, however, and with the exception of 2004, this downward trend has been reversed (Marine Institute, 2007b). In 2006, for example, the levels of egg-bearing and mobile sea lice were the highest recorded in 12 and eight years respectively. Possible reasons for this rise include the higher than average water temperatures, the occurrence of disease, the presence of harmful phytoplankton blooms, suspected reduced sensitivity to treatment and poor bay management. These factors combined to make the effective and timely treatment of fish more difficult.

The environmental impact of farmed fish escaping from aquaculture sites depends on the level of interaction that may take place with native stocks through interbreeding or through the spread of disease. The negative impacts of farmed fish interbreeding with wild fish include a reduction in the genetic diversity of wild stocks, which may decrease their ability to respond to environmental change and hence to survive in the wild. A study of the influence of farmed fish on wild populations in the Burrishoole River catchment in Co. Mayo found that 'hybrid' Atlantic salmon showed significantly reduced survival compared with wild fish (McGinnity *et al.*, 2003). The study also found that although the impact of a one-off incursion would eventually be bred out, the effects of repeated incursions could result in the extinction of vulnerable wild stocks. The level of fish-farm escapes in Ireland has been consistently low in recent years and therefore such escapes do not pose a significant threat to the wild population (Ó Maoiléidigh *et al.*, 2003).

The importation of shellfish seed and other aquaculture products carries the threat of the accidental introduction of non-native or alien species that may disrupt aquatic ecosystems. Examples of alien species that have been transported into Ireland, most likely by aquaculture, which have had a negative impact on the marine environment include the invasive seaweed *Sargassum muticum* and the protozoa *Bonamia ostrea* that devastated native oyster populations in the 1970s. Imports of shellfish are now subject to strict controls, which aim at restricting the introduction of diseases such as bonamiasis. However, the threat from the introduction of non-native species or disease remains high, particularly in the context of climate change and the predicted northward spread of potentially invasive species (EPA, 2003). This is just one of the



many potential impacts of global climate change; some of the others are discussed below.

### Climate Change and the Marine Environment

The particular aspects of climate change that are likely to impact on Ireland's marine environment include rising sea levels, increasing sea temperatures, changes in coastal and oceanic currents and ocean acidification. The following brief overview is included to give some indication of how these climate-driven changes could impact on marine species and habitats. In the absence of direct observations in Irish waters, inferences are drawn from studies carried out in the broader North-East Atlantic Ocean and regional seas such as the North Sea.

Rising sea levels in combination with increased storm events that are also predicted to happen are likely to impact not just on coastal cities and towns but also on many coastal habitats. An average sea-level rise of 50 cm by the end of the century, in combination with storm surge events, could result in approximately 300 km<sup>2</sup> of coastal lands around Ireland being inundated by the sea (EPA, 2003). The habitats most at risk include low-lying coastal

lagoons, saltmarsh and estuaries, particularly those that are prevented from extending landwards because of the presence of some fixed or artificial boundary. Many of the low-lying estuarine sandflats, mudflats and lagoons found along the southeast coast, some of which have been identified as SACs, could be threatened. These habitats provide rich feeding grounds for a variety of bird species as well as important nursery grounds for juvenile fish.

Rising sea temperatures are likely to influence the distribution, abundance and seasonality of a range of marine organisms that in turn could impact on the functioning of marine ecosystems. There is already considerable evidence that changes in the distribution of marine copepod species in the North Atlantic are linked to rising sea temperatures (Beaugrand *et al.*, 2002). Other studies are suggesting that future increases in sea temperatures could lead to species currently at the southern limit of their distribution moving northwards. It has been predicted, for example, that cod populations in the Irish and Celtic Seas could disappear from these waters by 2100 if bottom water temperatures were to increase by 1–2°C (Drinkwater, 2005).

Rising sea and air temperatures may also affect the pattern of seasonal stratification, which is of fundamental importance to the ecology of the marine waters surrounding Ireland. A study of plankton communities in the North Sea, for example, has linked the earlier occurrence of certain planktonic groups to rising sea temperature and the earlier onset of seasonal stratification (Edwards and Richardson, 2004). As suggested by the study, such changes have the potential to cause serious mismatches between different trophic levels that in turn could disrupt the normal functioning of marine food chains. It is already believed that changes in the abundance of certain planktonic groups and shifts in their seasonality have contributed to the decline of North Sea cod stocks (Beaugrand *et al.*, 2003). And while overfishing is still considered the main reason why stocks have declined since the 1960s, it has been suggested that fluctuations in plankton abundance and seasonality may be impacting on the development of young cod.

Another potential impact that may arise from global warming and rising CO<sub>2</sub> levels is ocean acidification. As CO<sub>2</sub> dissolves in seawater it releases hydrogen ions, making it more acidic (that is, decreasing its pH). Under normal circumstances increases in acidity would be buffered by the presence of strong alkaline ions, and in fact seawater is a slightly alkaline solution. Scientists are now concerned, however, that the pH of seawater may be disrupted by the increased amounts of anthropogenic CO<sub>2</sub> that are being absorbed by the oceans. If the concentrations of CO<sub>2</sub> increase in line with Intergovernmental Panel on Climate Change (IPCC) predictions, the average acidity of the oceans could increase by 0.5 units by 2100 (Royal Society, 2005). The predicted effects of this change on ocean chemistry could potentially be very damaging to marine organisms, and in particular



to those organisms that have hard outer shells or skeletons composed of carbonate such as corals, crustaceans and certain species of plankton such as the coccolithophorids.

There is little doubt then that these climate-driven changes, some of which are already taking place, will have serious consequences for the protection and management of Ireland's marine environment and natural resources.

### Marine Research and Development

A wide range of marine research is carried out in Ireland by government agencies, third-level institutes and commercial companies. The Marine Institute is coordinating and promoting the implementation of *Sea Change – A Marine Knowledge, Research and Innovation Strategy for Ireland 2007–2013*, which aims to maximise the benefits of Ireland's extensive maritime territory. A central theme of the strategy is the recognition that knowledge of the marine environment must inform environmental management and sustainable development.

Specifically, the Marine Environment Research Programme sets out to:

- enhance understanding of marine and coastal ecosystems as a basis for environmental policy and sustainable resource management;
- develop national collaborations and improved capabilities, methodologies and technologies for marine environmental monitoring;
- support the sustainable development of marine resources and sectors;
- protect, maintain and, where necessary, enhance marine biodiversity;

### EU Marine Strategy Directive

Alongside the Water Framework Directive (WFD), the recently agreed Marine Strategy Directive will provide a comprehensive framework for the protection and enhancement of Europe's marine environment. The main objective of the Directive is for all marine waters to achieve good environmental status by 2020.

This is to be achieved through a series of measures that is analogous to the approach taken by the WFD. The waters of the European maritime area will be divided into marine regions and sub-regions based on their environmental and geographical characteristics. These areas will provide the basis for an integrated approach to the management of the environmental status of these waters. In a similar fashion to the WFD, there will be a need to identify and apply measures, to ensure that the environmental targets that are devised can be achieved within the prescribed timeframe.

Each member state, in close cooperation with the other member states, will be required to develop Marine Strategies for its marine waters. These strategies will contain a detailed description of the state of the marine environment, an assessment of the impact of various pressures, a definition of 'good environmental status' for each area being assessed, and then the establishment of clear environmental targets and monitoring programmes.

The marine strategies will apply an ecosystem-based approach to the management of human activities to ensure that the collective pressure of such activities is kept within sustainable levels. The aim is to ensure that all marine waters – in all their ecological diversity – remain dynamic, clean, healthy and productive.

- support the implementation, on a multi-agency basis, of environmental legislation.

The Marine Climate Change Programme seeks to:

- increase our understanding of the drivers and regulators of climate and improve the accuracy and reliability of predictive models;
- downscale global climate model predictions to the regional/local level in order to refine local impact scenarios;
- develop and use real and proxy climate-change indicators.

### Conclusions

It is clear from this chapter that the human activity having the greatest and most extensive impact on the ecological quality status of Ireland's marine environment is commercial fishing. Most commercially targeted fish stocks in Irish waters are heavily overexploited and in decline, and many species are now being harvested outside safe biological limits. Recovery of these stocks will be slow, and substantial reductions in fishing pressure through reduced number of days at sea and greater enforcement of existing fishing regulations, which apply to both Irish and foreign vessels, are required to ensure the survival of the most vulnerable stocks.



The implementation of a recent government report on the future of the Irish fishing industry, which recommended substantial decommissioning of the Irish whitefish and shellfish fleet, together with the establishment of the Sea Fisheries Protection Authority, offers some hope in this regard. Further actions such as the establishment of recovery plans and the adoption of technical conservation measures have the potential to aid the recovery of the most vulnerable stocks. Other options such as the establishment of long-term or permanently closed areas may also have to be considered.

In terms of general water quality, environmental conditions in the majority of Irish estuaries and coastal waters remain high despite substantial population growth and economic development over recent years. Nevertheless, a number of areas continue to be seriously affected by direct municipal discharges and elevated

nutrient inputs from diffuse sources. A number of major estuaries, predominantly in the south-east and south of the country, have persistently displayed symptoms of nutrient enrichment since the EPA began to assess their trophic status in the early 1990s.

Most of Ireland's larger urban areas, including the nine largest cities and towns, are located beside tidal waters. It is clear that the provision of upgraded and new wastewater treatment infrastructure has resulted in improvements in certain areas. An important recent development has been the introduction in 2007 of a system for the licensing or certification of wastewater discharges from areas served by local authority sewer networks. It is being introduced on a phased basis starting with the larger cities and towns. The authorisation process provides for the EPA to place the necessary conditions on the operation of such discharges to ensure that potential effects on

the receiving water bodies are strictly limited and controlled.

Further measures such as the implementation of the Nitrates Action Plan will be required to ensure that the release of nutrients from diffuse sources is reduced.

Contaminant levels in fish and shellfish were again very low according to the most recently reported monitoring surveys, and the overall quality of Irish seafood produce remains high. The discharge of radioactive substances from the Sellafield reprocessing plant in England continues to contaminate the Irish Sea and Ireland's local marine environment, though exposure is not considered to pose a significant health risk to the Irish public. The quality of bathing waters remains high, and while the bacteriological quality of shellfish in shellfish-growing waters is reasonably good, it is likely that additional measures will be required to prevent further deterioration in certain areas.

Marine aquaculture production continues to expand (in monetary terms, at least), although most of the recent expansion has been due to increased shellfish production, with levels of finfish production falling by nearly half in recent years. While relatively small in European terms, the Irish aquaculture industry makes a significant contribution to the Irish economy by creating employment in remote coastal communities and generating export revenue. Given the sector's comparatively small levels of production (present and projected), its predominant location along Ireland's Atlantic seaboard and the regulatory environment in which it operates, there is considerable potential for the sector to develop in a sustainable way. However, this potential will be realised only if the impacts of aquaculture on the marine environment are fully addressed and managed so that they are maintained within acceptable levels.

Finally, the continued protection of Ireland's marine environment and the sustainable management of the natural resources it contains must take account of the changes that are likely to be brought about by global warming. Knowledge of what these changes will be, together with an understanding of their likely impact, will be absolutely essential in any attempt to mitigate the most serious impacts of climate-driven change.

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