MEFEPO
Making European Fisheries Ecosystem Plans Operational
EC FP7 project # 212881

Work Package 1

TECHNICAL REPORT

A technical review document on the ecological, social and economic features of the North Western Waters region

Nolan, C.[1], Kelly, E.[1], Dransfeld, L. [1], Connolly, P.[1], van Hoof, L.[2], Hegland, T.[3], Aanesen, M.[4], Armstrong, C.[4] & Raakjaer, J.[3]

1. **The Marine Institute, Rinville, Oranmore, Co. Galway, Ireland**
2. **Institute for Marine Resources and Ecosystem Studies, PO Box 68, 1970 AB, IJmuiden, The Netherlands.**
3. **Aalborg University, Fredrik Bajers Vej 5, 9220 Aalborg ø, Denmark.**
4. **Norwegian College of Fishery Science, University of Tromsø, N-9037, Tromsø, Norway.**

Table of contents:

List of Figures

List of Tables

1 Overview of North Western Waters

1.1 Study area

Figure 1.1.1 shows the MEFEPO study area which incorporates 12 ICES Regions: VIa, VIb, VIIa, VIIb, VIIc, VIId, VIIe, VIIf, VIIg, VIIh, VIIj, and VIIk. These 12 regions cover an area of approximately 1.15 million km^2.

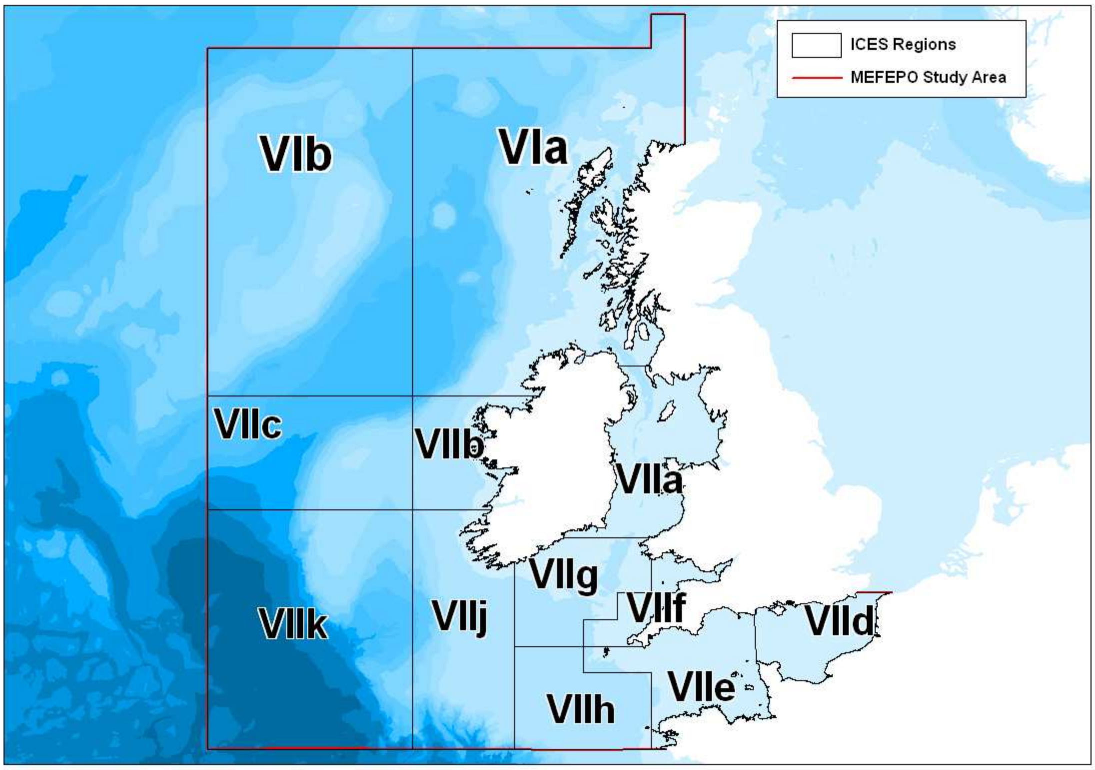


Figure 1.1.1: MEFEPO Study Area incorporating 12 ICES Regions.

The MEFEPO study area lies within three OSPAR Regions, the Wider Atlantic Region V, the Celtic Seas Region III and the Greater North Sea Region II (See Figure 1.1.2).

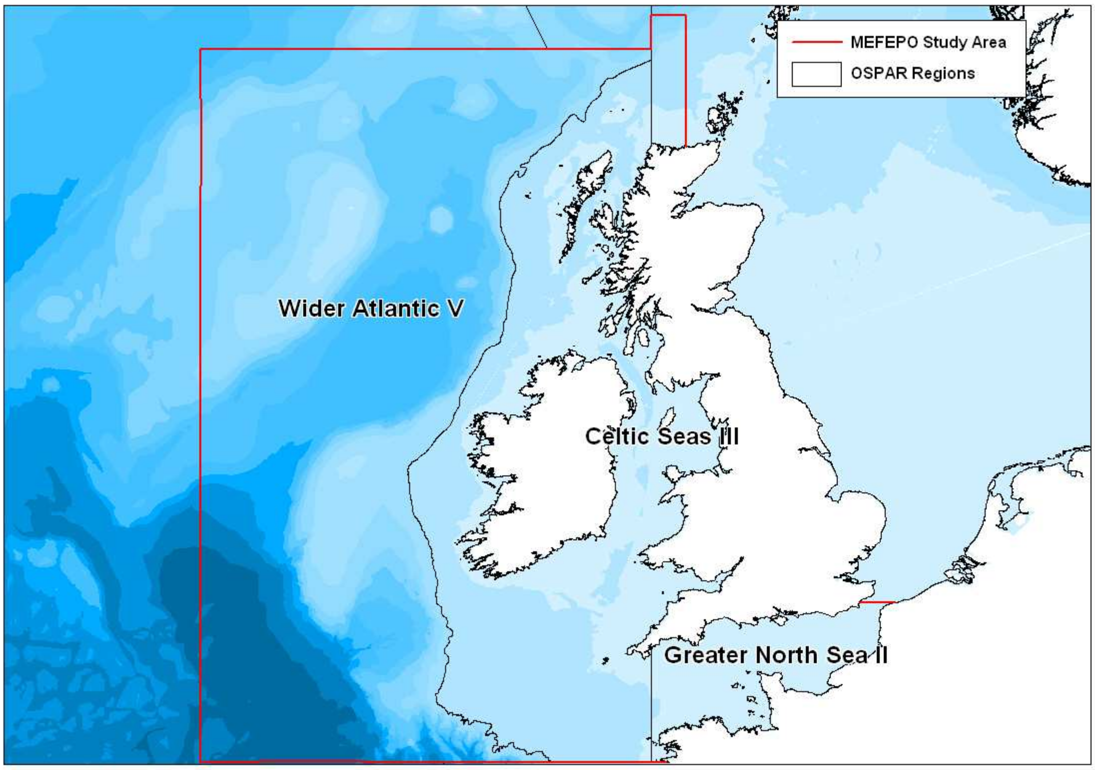


Figure 1.1.2: OSPAR Regions within the MEFEPO Study Area.

Figure 1.1.3 shows the Exclusive Economic Zones (EEZ's) for Ireland, the UK and France lying within the MEFEPO study area. All EEZ data was downloaded from the VLIZ Martiime Boundaries Geodatabase (www.vliz.be). The UK EEZ covers an area of 763,422 km^2 (including the Channel Islands EEZ), the Irish EEZ covers an darea of 408,500 km^2 and the French EEZ covers an area of 333,700 km^2.

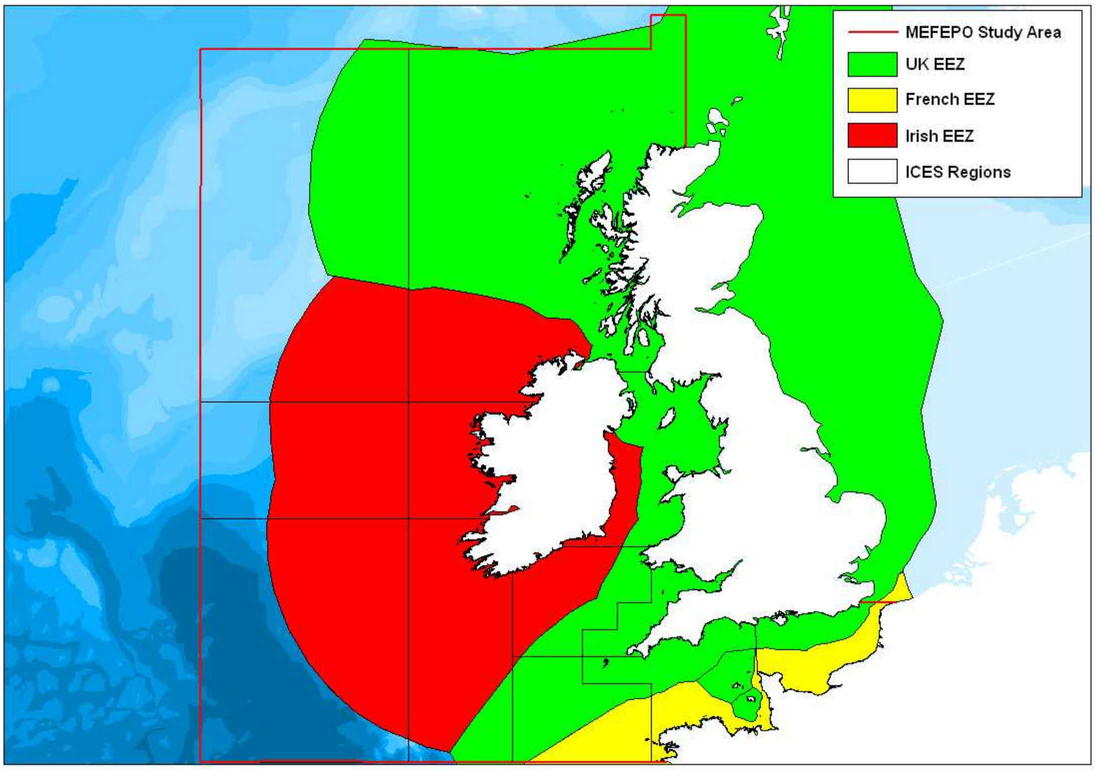


Figure 1.1.3: Exclusive Economic Zones within the MEFEPO Study Area (Source: www.vliz.be).

Figure 1.1.4 shows the bathymetry of the MEFEPO Study Area.

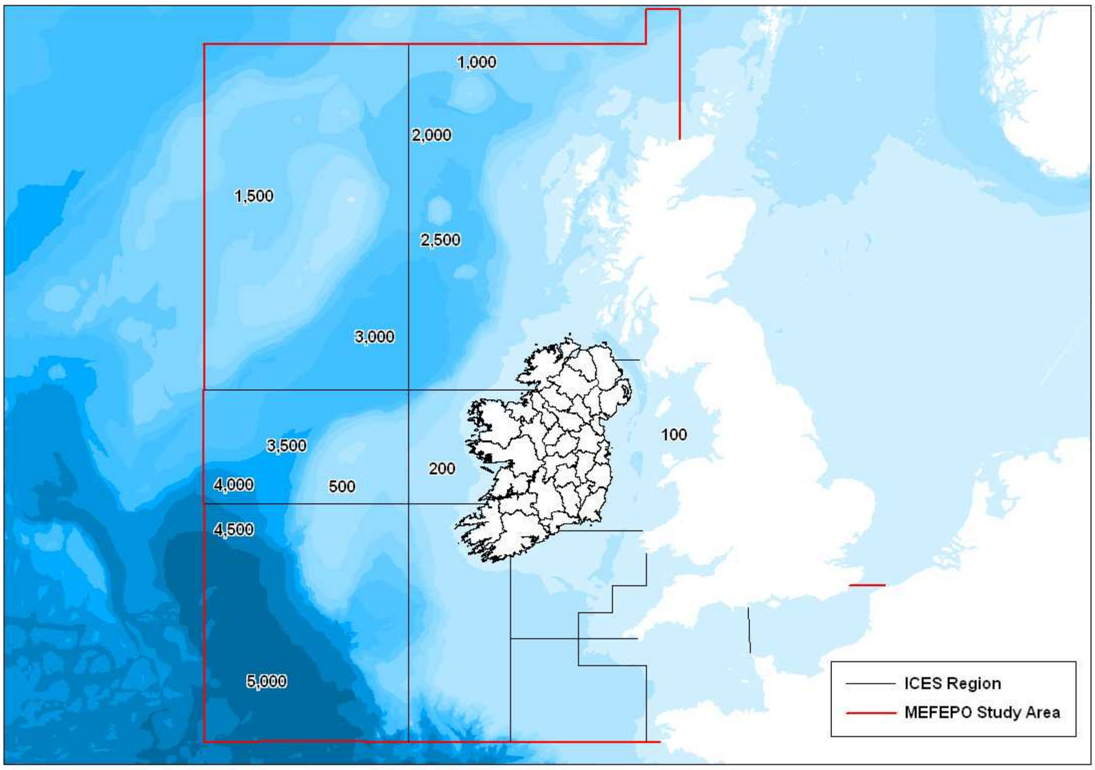


Figure 1.1.4: Bathymetry for the MEFEPO Region (Source: GSI updated GEBCO data).

Figure 1.1.5 shows the marine basins within the MEFEPO Study Area (Source: Marine Institute). The Hatton Basin is located along the western boundary of the MEFEPO Study Area, covers an area of 38,920km^2 and ranges in depth from 1000 to 2000m. The Atlantic Basins cover an area of 254,400km^2 and ranges in depth from 100m along the Continental Shelf to 4500m over the Porcupine. The Celtic Sea Basin covers an area of 37,040km^2 and ranges in depth from <100m in the Irish Sea to 200m in the Celtic Sea. The Kish Basin is located in the Irish Sea, off the Co. Dublin coast in water depths of <100m to 200m and covers an area of 1,452km^2. The Cockburn Basin, located approximately 200km south of the Co. Cork coast is located in 200m of water and covers an area of 1,594km^2.

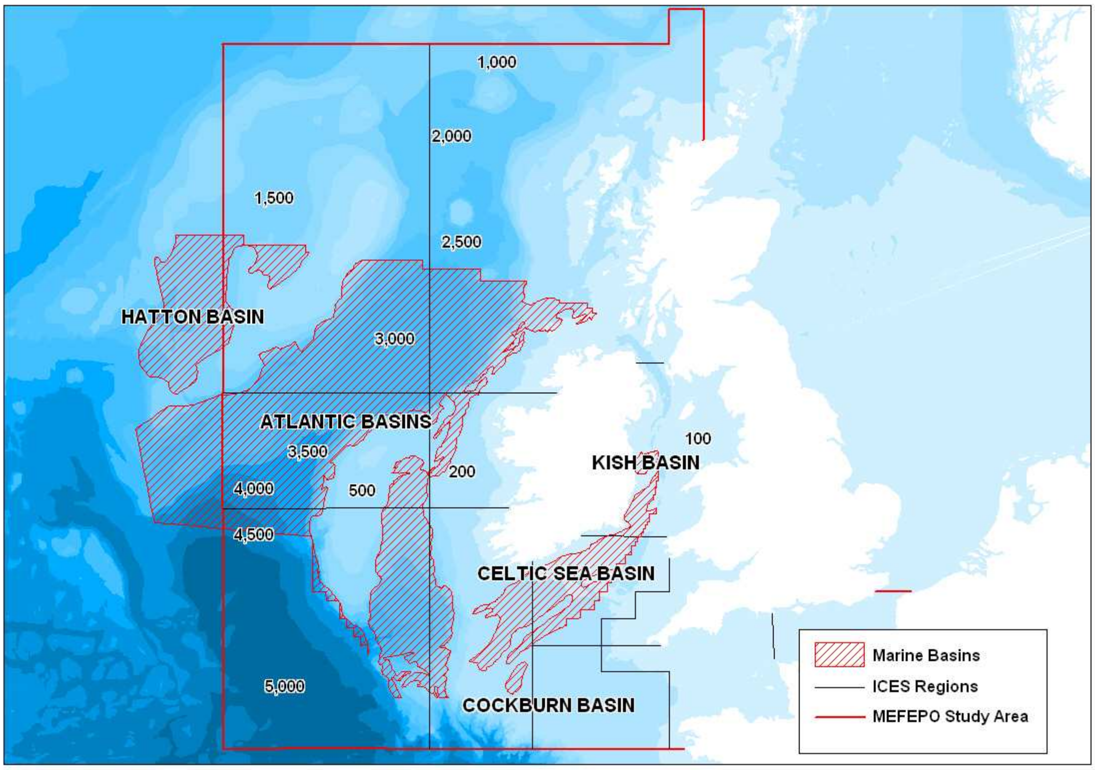


Figure 1.1.5: Marine basins within the MEFEPO Study Area (Source: Marine Institute).

1.1.1 Ecosystem overview and advice for the Irish Sea

Summary table of the ICES Ecosystem overview for the Irish Sea

Information condensed from ICES WGRED, 2008. See WG report for further details and reference list.

Physics	
Bathymetry	Shallow sea (less than 100m deep in most places), largely sheltered from the winds and currents of the North Atlantic.
Circulation	An inshore coastal current carries water from the Celtic Sea and St. Georges's Channel northwards through the North Channel, mixing with water from the outer Clyde. A seasonal gyre operates as a local retention mechanism in the western Irish Sea.

Fronts	The Celtic Sea front is situated at the southern entrance to the Irish Sea and the Islay Front is found between Islay and the Malin Shelf.
Temperature ***Salinity***	Time series from the SW coast of the Isle of Man (the Cypris station), western Irish Sea (Gowen, AFBI, Belfast), and two series of combined satellite and ship-recorded indicate a general warming trend in the Irish Sea since 1960, with particularly high temperatures in 1998 (see fig. 1).
Biology	
Benthos, larger invertebrate, biogenic habitats	The main commercial invertebrate species is Norway-lobster (*Nephrops norvegicus*). There are distinct benthic assemblages with plaice and dab on fine substrates in inshore waters and sea urchins and sun-stars on coarser substrates further offshore. Thickback sole (*Microchirus variegates)* and hermit crabs dominate the transitional zone, while Norway-lobster and Witch (*Glyptocephalus cynoglossus*) dominate on the muddy sediments in the central Irish Sea. Beds of *Alcyonium digitatum* (Dead man's finger) occur on coarse substrates throughout. Biogenic reefs of horse mussels *Modiolus modiolus*, maerl and Serpulid worms occur in specific locations.
Fish Community	There are commercial fisheries for cod (*Gadus morhua)*, plaice (*Pleuronectes platessa)* and sole (*Solea solea)*. The most abundant species in trawl surveys are dab (*Limanda limanda)*, plaice *(Pleuronectes platessa),* solenette (*Buglossidium luteum)* and common dragonet (*Callionymus lyra)* along with large numbers of poor-cod, whiting and sole. In recent years, abundance of dab, solenette and scaldfish (*Arnoglossus laterna*) and red gurnards *Aspitrigla cuculus* increased, whereas hake, dragonets and pogge *Agonus cataphractus* decreased. Lesser spotted dogfish Scyliorhinus canicula is abundant throughout. There are also ray assemblage on sand hills in Southern Irish Sea, and Cardigan Bay.
Birds, Mammals & Elasmobranches	Basking shark (*Cetorhinus maximus*) occur from April through to October but the stock seems severely depleted. Grey seals (*Halichoerus grypus*) are common and 5000-7000 individuals are thought to exist in the Irish and Celtic Seas. Gulls predominate the seabird populations, in particular black-headed, lesser black-backed and herring gulls as well as guillemots.

Environmental signals & implications	There has been a steady warming of sea surface temperatures (SSTs) in the area. Irish Sea cod recruitment exhibited a decline in the 1990s, coincident with an increase in sea surface temperatures. There has been a northward shift in the distribution of some fish such as an increase of seabass *Dicentrarchus labrax* and red mullet *Mullus surmuletus* populations around British coasts
Fishery effects on benthos and fish communities	This area has a number of severely depleted stocks e.g. cod, whiting and sole. Significant proportion of the catch of the demersal fleets is discarded.

Irish Sea - Ecosystem considerations

The following considerations should be taken into account in developing ecosystem based advice for fisheries in the Irish Sea:

- Fishing has impacted a number of commercial species, with some commercial species such as cod, whiting and sole being overexploited and severely depleted. A cod recovery plan is currently in place.
- Some fisheries including the Nephrops and beam trawl fisheries have high whiting discarding rates. The effect of discarding on the Irish Sea Whiting stock and the ecosystem is not fully understood, however the stock seems to suffer from increased mortality and a decline in biomass.
- A reduction in the abundance of large piscivorous fishes such as cod and whiting, and an increase in species which feed at a lower trophic level, such as Nephrops, has resulted in a marked decline in mean trophic level of the fish community over time.
- There has been an increase in water temperatures in this ecoregion which is likely to affect the distribution area of some fish species, and some changes of distribution have already been noted. Temperature increase is likely to affect stock recruitment of some species. In addition, the combined effects of overexploitation and environmental variability might lead to a higher risk of recruitment failure and decrease in productivity.
- Some localized fisheries are believed to have significant a negative impact on the seabed. These include hydraulic dredging of the seabed for razor clams which results in considerable damage to the associated fauna (see inshore section for further details).

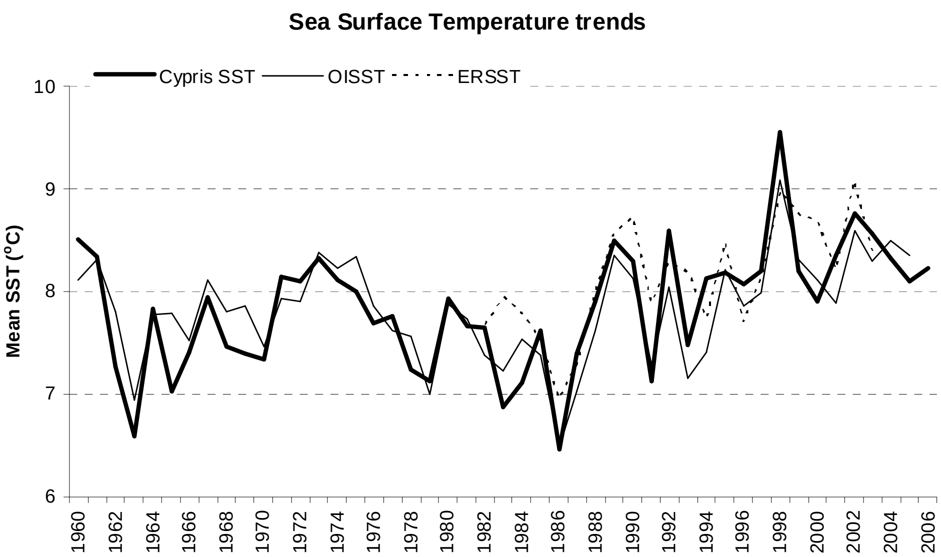


Figure 1.1.6: Sea surface temperature in the Irish Sea from 1960 to 2006 (ICES 2006).

References:

ICES. (2008). Report of the Working Group for Regional Ecosystem Description (WGRED).

ICES (2006) Report of the Working Group on the Assessment of Northern Shelf Demersal Stocks (WGNSDS). ICES ACFM:30

1.1.2 Ecosystem overview and advice for the Celtic Sea

Summary table of the ICES Ecosystem overview for the Celtic Sea

(Information condensed from ICES WGRED, 2008. See WG report for further details and reference list)

Physics	
Bathymetry	Shelf sea south of Ireland, limited to the west by the slope of the Porcupine seabight and the Goban Spur.
Circulation	Along the shelf edge, there is a poleward flowing 'slope current'; on the shelf a weaker current flows north from Brittany across the mouth of the English Channel. Thermal stratification and tidal mixing generates the Irish coastal current which runs westwards in the Celtic Sea and northwards along the west coast of Ireland. Several rivers discharge freshwater into the ecoregion and influence the circulation patterns, these are notably the River Loire, the Severn and the Irish rivers Lee and Blackwater.
Fronts	The Irish Shelf Front is located to the south and west of Ireland (at c. 11°W), and consists of a tidal mixing front existing all year-round. On shelf, there are the Ushant Front in the English Channel and the Celtic Sea front at the southern entrance to the Irish Sea.
Temperature	Sea surface temperatures measured in coastal stations northwest of Ireland since the 1960s show a trend of sustained positive temperature anomalies from 1990, while CTD measurements made along a section at 53° N since 1999 show warmer conditions in 2003 and 2004, broadly consistent with other regions of the NW European shelf. A time series of combined satellite and *in-situ* records shows that this trend extends across the Celtic Sea (fig. 1.1.7).
Biology	
Phytoplankton	Productivity is reasonably high on the shelf with a rapid decrease west of the shelf break. Continuous Plankton Recorder data suggests a steady increase in phytoplankton over at least the last 20 years. Toxic algal blooms occur around Irish coasts esp. along the southwest of Ireland.
Zooplankton	CPR data suggest an overall decline in the abundance of zooplankton in recent years. *Calanus* abundance is now below the long term mean.

Benthos, larger invertebrate, biogenic habitats	The major commercial invertebrate species is Norway lobster (*Nephrops norvegicus*). Two epibenthic assemblages predominate in the Celtic Sea: one along the shelf edge and the slope, dominated by the anemone *Actinauge richardi* and a more widely distributed assemblage on the continental shelf, dominated by *Pagurus prideaux* and other mobile invertebrates (shrimps and echinoderms).
Fish Community	The area is a spawning area for key migratory fish species, notably mackerel *Scomber scombrus* and horse mackerel *Trachurus trachurus.* On the continental shelf the main pelagic species are herring *Clupea harengus*, sardine *Sardina pilchardus* and sprat *Sprattus sprattus*. The groundfish community consists of over a hundred species with the most abundant 25 making up 99% of the total biomass. Surveys revealed a downward trend in the biomass and abundance of cod, whiting and hake.
Birds, Mammals & Elasmobranches	Basking shark (*Cetorhinus maximus*) is seen throughout area but the stock seems to be severely depleted. Blue shark, *Prionace glauca*, are found during the summer. The Harbour porpoise *Phocoena phocoena* is the most numerous cetacean in the region. Bottlenosed dolphin *Tursiops truncatus* occur in large numbers while the common dolphin *Delphinus delphis* is also widely distributed in the area. White-beaked dolphin and White-sided dolphin (*Lagenorhynchus albirostris* and *L. acutus*) occur over much of the shelf area. Grey seals (*Halichoerus grypus*) are common in many parts of the area. Petrels (fulmar and storm-petrel) dominate the seabird populations in the west of Ireland and Celtic Sea region but there are also large breeding colonies of kittiwake, guillemot and gannet.
Environmental signals & implications	Increasing temperature and changes in zooplankton communities are likely to have an impact on the life histories of many species. Although it is uncertain, Drinkwater (2005) has predicted that a sustained 1^{o}C rise in sea bottom temperature, over the course of this century, could result in the disappearance of cod stocks from the Celtic Sea and the English Channel. Already there has been a northward shift in the distribution of some fish with an increase of seabass *Dicentrarchus labrax* and red mullet *Mullus surmuletus* populations around British coasts. The region also recently experienced an unprecedented increase in the numbers of snake pipefish, *Entelurus aequoreus*. Abundance of herring *Clupea harengus* and pilchard *Sardina pilchardus* occurring off the south-west of England, has been shown to correspond closely with fluctuations in water temperature. Sardines were generally more abundant and their distribution extended further to the east when the climate was warmer, whilst herring were generally more abundant in cooler times. The migration timing of squid (*Loligo forbesi*) and flounder (*Platichthys flesus*) off the south-west of England has also been linked to temperature (Sims et al. 2001;2004).
Fishery effects on benthos and fish communities	The area has a number of severely depleted stocks e.g. cod, whiting and plaice. A significant proportion of the catch of the demersal fleets is discarded. Fishing has impacted due to high levels of exploitation. The size structure of the fish community has changed significantly over time, and a decrease in the relative abundance of larger fish has been accompanied by an increase in smaller fish (4–25g) Temporal analyses of the effects of fishing and climate variation suggest that

	fishing has had a stronger effect on size-structure than changes in temperature. A marked decline in the mean trophic level of the fish community over time has been documented and this has resulted from a reduction in the abundance of large piscivorous fishes such as cod and hake, and an increase in Nephrops and smaller pelagic species such as boarfish, *Capros aper* which feed at a lower trophic level. Cetacean bycatch has been noted in some fisheries, including the pelagic trawl fishery for mackerel and horse mackerel in the SW of Ireland, although the numbers caught were low.

Celtic Sea - Ecosystem considerations

The following considerations should be taken into account in developing ecosystem based advice for Celtic Sea fisheries:

- Fishing has impacted a number of commercial species, with some commercial species such as Cod, Plaice and Herring now severely depleted.
- A reduction in the abundance of large piscivorous fishes such as cod and hake, and an increase in smaller pelagic species and Nephrops, which feed at a lower trophic level has resulted in a marked decline in mean trophic level of the fish community over time.
- There has been a change in the size structure of the fish community over time with an increase in smaller fish and a reduction in larger fish. Temporal analyses of the effects of fishing and climate variation suggest that fishing has had a stronger effect on size-structure than changes in temperature.
- The inshore areas of the Celtic Sea contain some important spawning grounds for herring. Aggregate extraction and dumping of dredge spoil are likely to have negative affects on Herring recruitment due to perturbation of the spawning beds and an increase in turbidity.
- There has been an increase in water temperatures in this ecoregion which is likely to affect the distribution area of some fish species. Evidence to date suggest that a changing environmental regime can have an impact on recruitment and stocks in the southern end of their geographical species range might be particular vulnerable. In addition, the combined effects of overexploitation and environmental variability might lead to a higher risk of recruitment failure and decrease in productivity.

References:

ICES. 2008. Report of the Working Group for Regional Ecosystem Description (WGRED).

Drinkwater, K.F., 2005. ICES Journal of Marine Science, 62: 1327-1337

Sims, D.W., et al. 2004. Journal of Animal Ecology **73**, 333–341

Sims, D.W., et al. 2001. Proceedings of the Royal Society of London B. 268, 2607-2611

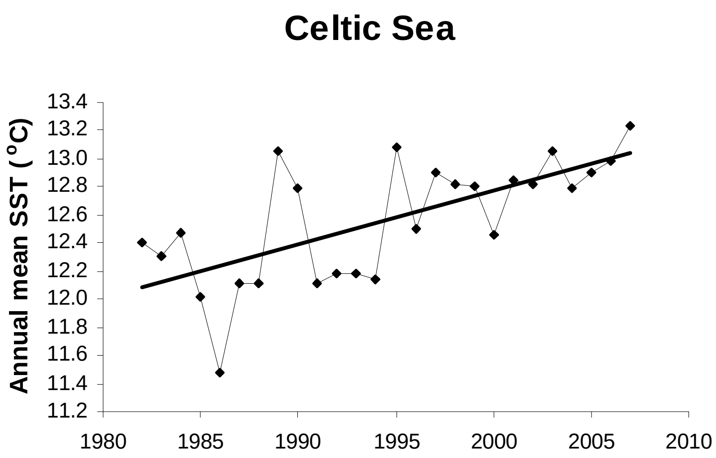


Figure 1.1.7: Annual mean sea surface temperature in the Celtic Sea (50.0 to 52.5 N and 12 to 3 W) showing positive linear trend. Generated from OIv2SST data (from U.S. National Oceanic and Atmospheric Administration's, National Weather Service).

1.1.3 Ecosystem overview and advice for West of Scotland and Rockall

Summary table of the ICES Ecosystem overview for West of Scotland and Rockall

(Information condensed from ICES WGRED, 2008 see WG report for further details and reference list)

Physics	
Bathymetry	This area is limited to the southwest by the Rockall Trough, where the transition between the Porcupine Bank and the trough is a steep and rocky slope with reefs of deepwater corals; further north, the slope of the Rockall Trough is closer to the coast line; west of the shelf break is the Rockall Plateau with depths of less than 200m. The shelf area consists of mixed substrates, with soft sediments (sand and mud) in the west and rockier pinnacle areas to the east. The area has several seamounts: the Rosemary Bank, the Anton Dohrn sea mount and the Hebrides, which have soft sediments on top and rocky slopes.
Circulation	The shelf circulation is influenced by the poleward flowing 'slope current', which persists throughout the year north of the Porcupine Bank, but is stronger in the summer. Over the Rockall plateau, domes of cold water are associated with retentive circulation. Thermal stratification and tidal mixing generate a northwards running coastal current.
Fronts	The Islay Front is situated between Islay and the Malin shelf.
Temperature	There has been a steadily warming of surface waters in the Rockall Trough over the last decade with the highest record in 2006 (Fig.1). Inshore waters off the west of Scotland also continued to warm with more rapid warming taking place since the mid 1990s.
Biology	
Phytoplankton	The productivity is reasonably high on the shelf but drops rapidly west of the shelf break.
Zooplankton	As is true of the adjacent North Sea, the overall abundance of zooplankton in this region has declined in recent years. Continous Plankton Recorder data in the area show substantial drops in *Calanus* abundance and these are now below the long term mean. *Calanus finmarchicus* is known to overwinter in the Faroe-Shetland channel and the abundance of these is known to have been reduced in recent years.
Benthos, larger	The main commercial invertebrate species is Norway-lobster (*Nephrops norvegicus*),

invertebrate, biogenic habitats	which is targeted on the continental shelf west of Scotland and on the Rockall plateau. Fisheries dredging for scallops and some smaller bivalves exist west of Scotland, as well as Pot fisheries exploiting lobster *Homarus gamarus* and brown crab *Cancer pagurus.* Biogenic reefs of horse mussels *Modiolus modiolus*, maerl and Serpulid worms occur in specific locations.
Fish Community	The shelf edge is a spawning area for mackerel *Scomber scombrus* and blue whiting *Micromesistius potassou*. Historically, there were important commercial fisheries for cod, haddock and whiting and a number of flatfish species. Hake *Merluccius merlucius* and angler fish *Lophius* spp. are also fished across the whole area. The Rockall plateau has important haddock *Melanogrammus aeglefinus* and angler fish fisheries. On the shelf, the main resident pelagic species is herring *Clupea harengus*. Scottish groundfish surveys between 1997 and 2000 revealed declines in most commercial fish stocks, including haddock, whiting, Norway pout, herring and hake.
Birds, Mammals & Elasmobranches	Basking shark (*Cetorhinus maximus*) occurs from April through to October but the stock seems severely depleted. The harbour porpoise *Phocoena phocoena* is the most numerous cetacean and minke whale *Balaenoptera acutorostrata* is found throughout the region. In this area, the Grey seals (*Halichoerus grypus*) have their largest population in the Northeast Atlantic with the majority of individuals found in the Hebrides. Common seals (*Phoca vitulina*) are also widespread. There is a high abundance of breeding seabirds, predominantly the common guillemot (*Uria aalge*), razorbill (*Alca torda*) and the Atlantic puffin (*Fratercula arctica*) as well as petrels (including fulmar, *Fulmarus glacialis*; storm petrel, *Hydrobates pelagicus;* Manx shearwater, (*Puffinus puffinus*); northern gannets (*Morus bassanus*) and gulls (Laridae).
Environmental signals & implications	Surface waters of the Rockall trough have been steadily warming for some years and are currently at an all time high. The general and continuing reduction of copepod abundance and recent changes in zooplankton composition throughout the region are also causes of major concern given the key role that these organisms play in the food web. Increasing temperature and changes in zooplankton communities are likely to have an impact on the life histories of many species.
Fishery effects on benthos and fish communities	The impact of fishing activities on shelf fish communities is unclear, although there are numbers of severely depleted stocks e.g. cod and whiting. Furthermore, the level of discarding in some fisheries can be significant. The effect of fishing on benthic communities is not yet fully understood.

West of Scotland and Rockall Ecosystem Considerations

The following considerations should be taken into account in developing ecosystem based advice for fisheries in the West of Scotland and Rockall:

- Fishing has adversely impacted on a number of commercial species, with some commercial species now being severely depleted such as cod and whiting; a recovery plan is currently in place for cod.
- A reduction in the abundance of large piscivorous fishes such as cod, and an increase in smaller pelagic species which feed at a lower trophic level has resulted in a marked decline in the mean trophic level of the fish community over time.
- There has been an increase in water temperatures in this ecoregion which is likely to affect the distribution area of some fish species. In addition, the combined effects of overexploitation and environmental variability might lead to a higher risk of recruitment failure and decrease in productivity.
- This ecoregion harbours extensive populations of grey and common seals which are increasing in abundance. It is not known what effect this increase has on local fish populations, however recent studies of seal diets off western Scotland revealed that grey seals may be an important predator for cod, herring and sandeels in this area.

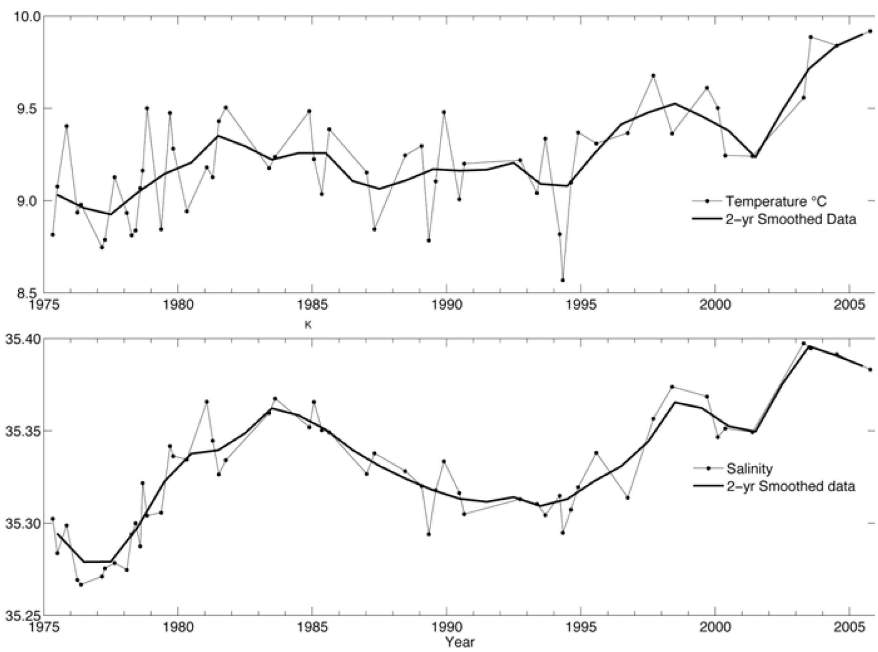


Figure 1.1.8: Rockall Trough temperature and salinity anomalies for the upper ocean (0–800 m) of the northern Rockall Trough. Average across section, seasonal cycle removed from WGRED, 2007.

References:

ICES. 2007. Report of the Working Group for Regional Ecosystem Description (WGRED), 19 - 23 February 2007, ICES Headquarters, Copenhagen. ICES CM 2007/ ACE:02. 153 pp.

1.1.4 Ecosystem overview and advice for Deepwater

This description covers the benthic deepwater ecosystem and its associated species; for a description of the oceanic water column habitat, please refer to the section of widely distributed and migratory species.

Summary table of the ICES Ecosystem for the Deep Sea

(Information condensed from ICES WGRED, 2008 see WG report for further details and reference list)

Physics	
Bathymetry	Most of the surface is abyssal plain with an average depth >ca 4 000 m. The continental slope is rocky hard substrate from Ireland southwards and covered with sediment west of the British Isles. Two offshore banks, the Rockall and Hatton Banks are separated from the continental shelf by the Rockall Trough. The north of this advisory region is marked by the Wyville Thomson and Iceland-Faroe Ridges and the south by the Azores. To the west is the mid-Atlantic Ridge (MAR), stretching from Iceland to the Azores. Isolated seamounts occur over the whole basin.
Circulation	The general circulation in the epipelagic zone (0-200m) is a warm current flow from the south-west North Atlantic towards the European coast with several side branches. Cold currents flow south from the Labrador Sea and Irminger Sea and also as a strong deep water flow between Shetland and the Faeroes.
Temperature ***Salinity***	Below about 700m there is little seasonal variation in temperature, average temperatures are 7°C to 8°C at 1000m depth and less than 4°C below 2000m.
Biology	
Phytoplankton	Photosynthetic primary production at the surface is limited in many areas by nutrient availability, except near seamounts and other topographical features that cause upwelling. The depth of primary production is limited to the euphotic zone which reaches a maximum depth of 200m and only a small proportion (1%-3%) may arrive in deeper waters as ‘planktonic snow’. This and descents of carcasses down the

	slopes bring organic matter to the deep environments.
Benthos, larger invertebrate, biogenic habitats	There is little commercial exploitation of large invertebrates in this region. Some bycatch of cephalopods and crabs (*Chaceon affinis)* occurs in deep-water fisheries. Biogenic habitats occur along the slope, such as those formed by the scleractinian *Lophelia pertusa* a colonial coral, forming large bioherms or reefs along the slope, on the offshore banks, on the mid-Atlantic Ridge and on seamounts. Dense and diverse fauna associated with such reefs include fixed (e.g.anthipatarians, gorgonians) and mobile invertebrates (e.g. echinoderms, crustaceans) and has species richness up to three times higher than on the surrounding sedimentary seabed.
Fish Community	The midwater pelagic or *mesopelagic* zone (200-1000 m) has a high diversity and abundance of small fish species, notably Myctophidae, Gonostomatidae and Stomiidae, most of which migrate diurnally and thus bring nutrients into deeper water layers. Fish communities above the abyssal plane in the bathypelagic zone (1000-3000m) include Bathylagidae, Platytroctidae and Searsidae. The species composition of demersal deep water fish community depends on depth. Dominant commercial species at 200-2000m include species such as ling, tusk, roundnose grenadier, orange roughy, deepwater sharks, chimaeriforms and other species such as redfish, monkfish and Greenland halibut. All deepwater shark species and most larger deepwater demersal fish are assumed to be highly vulnerable to overexploitation, having a low reproductive capacity. Most fisheries are occurring on the continental slopes, the seamounts and the MAR.
Elasmobranches	Amongst sharks, *Centroscymnus coelolepis* and *Centrophorus squamosus,* the two main commercial species (1 to 1.5 m long) are seriously depleted. The status of a number of smaller or less common species (*Centroscymnus crepidater*, *Deania calcea*, *Dalatias licha*, *Scymnodon ringens*, *Etmopterus* spp. *Galeus* spp. *Apristurus* spp.) is less clear.
Environmental signals & implications	The deep sea environment is considered to be less variable than surface systems. Moreover, due to the long life span of exploited species, variations in annual recruitment have a relatively minor effect on the standing biomass so short-term variability in the environment is unlikely to have great effects on stocks. Abundance of some deepwater invertebrate species has been linked to the North Atlantic Oscillation but overall it is not known how climate change might change the deep seas in the longer term.
Fishery effects on benthos and fish communities	Modern fishing fleets have caused significant reduction in demersal deepwater fish biomass in just a few years; resulting in the collapse of several fisheries. In addition to catching target species, deepwater fisheries by-catch unwanted species that are either too small or currently unmarketable and discarding rates are often high (in the order of 50%). Deepwater trawling can damage deep sea benthic communities, impacting particularly on structurally complex habitats such as *Lophelia* reefs. Deep-water set nets can also have a negative impact, both on the fish community due to ghost fishing and targeting vulnerable species such as sharks. Long-line fishing can

	also have negative effects on the ecosystem through breaking off branches of coral, overturning large sponges and may also have some bycatch of seabirds. The degree of perturbation and damage caused by deepwater fisheries depends on their spatial extend and the frequency of their activites.

Deepwater - Ecosystem considerations

The following considerations should be taken into account in developing ecosystem based fisheries advice for deepwater fisheries:

- Due to their low reproductive output and high longevity, many deepwater fish species are very vulnerable to overfishing. Populations of fish that aggregate on oceanic bathymetric features such as seamounts are particularly sensitive to overfishing, due to high catchability. Most commercial deepwater species are now severely depleted. This depletion has lead to changes in demersal deep sea fish communities due to the loss of their larger predators.
- Many demersal slope species are not commercial because they do not reach sufficient size or have low marketability resulting in the bulk of the catch being discarded. As the deepwater fish community is very species rich, this is likely to affect a large number of species.
- Deepwater species are dependant on nutrient input from the upper ocean layers via planktonic snow, mesopelagic species and fall of carcasses. This should be taken into account when considering fisheries for mesopelagic species.
- The human exploitation of the deepwater ecosystem has been a relatively recent event when compared to the long history of human activities on the shelf. Thus, the pristine nature of many of its habitats should be taken into account when considering any exploitation of deepwater resources.
- Biogenic habitat such as those formed by the cold water coral *Lophelia pertusa* occur along the slope, on the offshore banks (Rockall and Hatton), on the mid-Atlantic Ridge and on seamounts supporting rich and diverse faunal assemblages. Deepwater trawling as well as set nets and longlining are known to have negative impacts on these habitats and closed area have already been set up for their protection (see further details in this chapter). However, many areas in the deepsea ecoregion remain to be surveyed for *Lophelia pertusa*. In addition, the impact of fishing on other biogenic habitats such as deepwater sponge beds should be considered and further evaluated.
- The deep sea is a very stable system that is less exposed to environmental variability than the shallow shelf seas. As a consequence, benthic faunal assemblages in general may be less resilient to perturbation caused by fishing than their shelf sea counterparts.

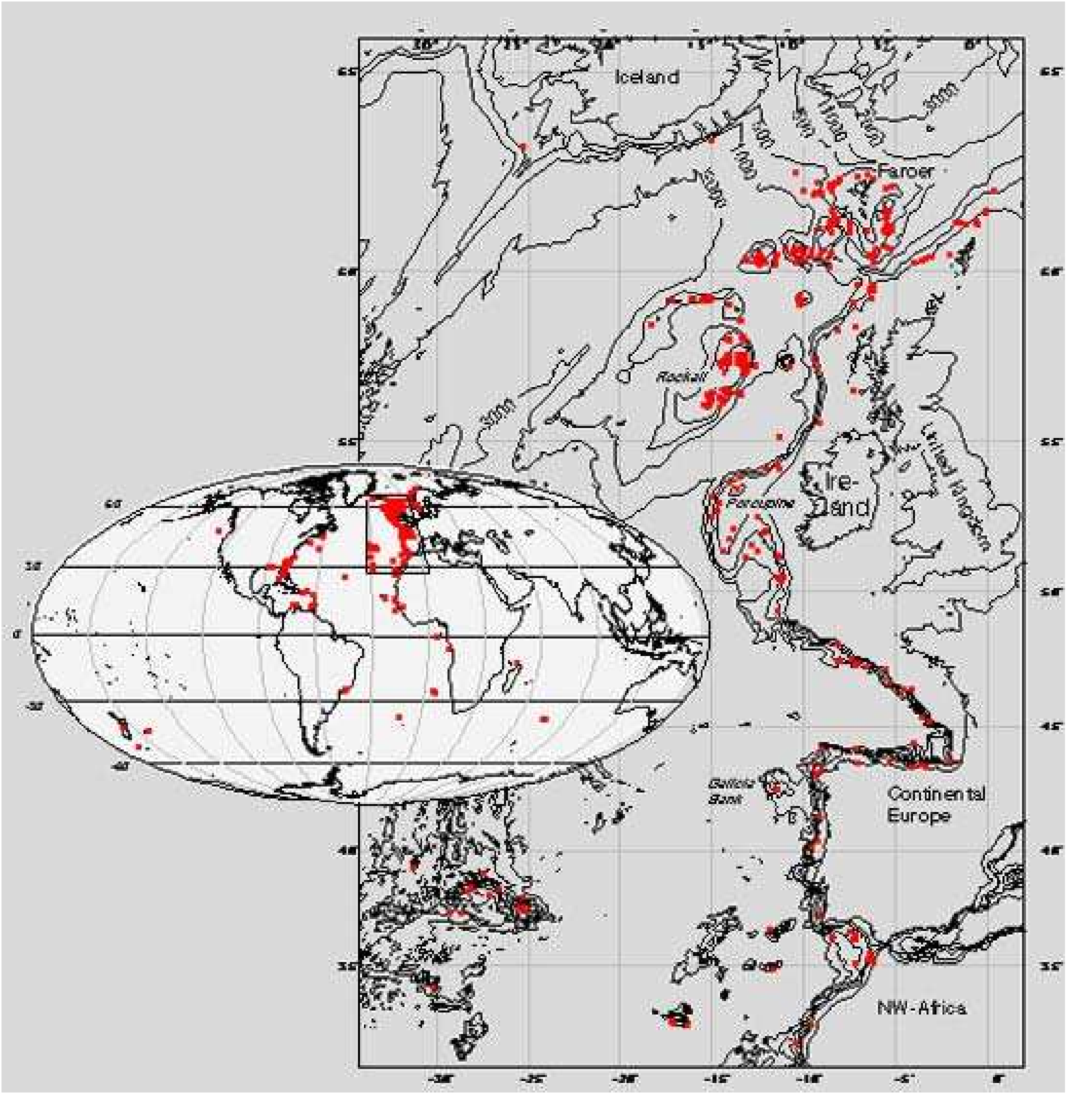


Figure 1.1.9: Distribution of deepwater Lophelia reefs in the North East Atlantic and wider (WGRED, 2007 reproduced from Freiwald, 1998).

References:

Freiwald, A. and Wilson, B.J., 1998. Taphonomy of modern deep, cold-temperate water coral reefs. Historical Biology, 13: 37-52.

ICES. 2008. Report of the Working Group for Regional Ecosystem Description (WGRED).

1.1.5 Ecosystem overview and advice for Widely Distributed and Migratory Stocks

Summary table of the ICES Ecosystem overview for Widely Distributed and Migratory Stocks

(Information condensed from ICES WGRED, 2008. See WG report for further details and reference list)

Physics	
Bathymetry	Widely distributed and migratory stocks are considered here in terms of pelagic stocks, generally in waters < 400m depth.
Circulation	The circulation of the North Atlantic Ocean is characterized by two large gyres: the subpolar and subtropical gyres. The anticyclonic subtropical gyre owes its existence to the low-latitude trade winds and mid-latitude westerlies. Some of the water in the subtropical gyre is re-circulated to the west of the Mid Atlantic Ridge (MAR) and some water continues east and crosses the MAR in the Azores Current and the remainder forms the North Atlantic Current (NAC). The NAC looses its jet signature as it turns east and the waters are transported eastward in the Sub Polar Front (SPF). It crosses the MAR in 2 to 4 branches between 45°N and the Charlie Gibbs Fracture Zone. The northern branch that is the main pathway for waters crossing the MAR from the western to the eastern North Atlantic. East of the MAR the SPF makes a sharp turn toward the north.
Fronts	In the northern part of the Barents Sea fresh and cold Arctic water flows from the northeast to southwest. The Atlantic and Arctic water masses are separated by the Polar Front, which is characterized by strong gradients in both temperature and salinity. In the western Barents Sea the position of the front is relatively stable, although it seems to be pushed northwards during warm climatic periods.
Temperature	The increase in sea surface temperature (SST) at several of the monitoring stations in the NE Atlantic is up to 3°C since the early 1980s. This rate of warming is very high relative to the rate of global warming. Surface waters of the Rockall trough have been steadily warming for some years and are currently at an all time high. In the waters to the west of the Porcupine Bank, a new record was set in 2006 with an SST of 11.3°C, 0.5°C warmer than the previous record. In the Norwegian Sea, and especially in the eastern part, Atlantic water has been

	extraordinary warm and saline since 2002.
Biology	
Phytoplankton	Phytoplankton abundance in the NE Atlantic increased in cooler regions (north of 55°N) and decreased in warmer regions (south of 50°N). The effects propagate up through herbivores to carnivores in the plankton food web (bottom-up control), because of tight trophic coupling.
Zooplankton	Broad scale changes have occurred showing that over the last decade there has been a progressive increase in the presence of warm-water/sub-tropical species into the more temperate areas of the northeast Atlantic. In the Norwegian Sea the total zooplankton biomass in May was the lowest on record since 1997. In the area west of 2°W (cold water mass) the biomass equaled the mean for the time series while in the eastern region (warm Atlantic water) it was low, as was the case in 2006.
Fish Community	**Blue whiting** is distributed in European waters from the western Mediterranean Sea to the Barents Sea, around the Canary Islands and the Azores, in the North Sea, west of the British Isles, around the Faeroes, east and south of Iceland, and westwards beyond Cape Farewell. The main spawning area extends from southwest of Ireland, over the Porcupine Bank and further north along the slope to north of the Hebrides. Spawning also takes place in the Rockall Bank area, in the Bay of Biscay and off the Iberian coast, and on a minor scale off the Norwegian coast, in Faroese waters and off the southern coast of Iceland. The **Norwegian Spring Spawning Herring** (NSS Herring) has its distribution area in the Norwegian Sea, the Barents Sea and along the Norwegian coast south to 59ºN. During long periods it has also been found north of Iceland during the summer. It is potentially the largest of the herring stocks in the northeast Atlantic. The **North East Atlantic mackerel** stock ranges between the Iberian Peninsula and the Norwegian Sea and changes with life history stage and migration patterns. NEA Mackerel is divided into three spawning components depending on location of their spawning grounds. Spawning of the North Sea component is concentrated in the western and central part of the North Sea in June. The southern component spawns along the coast of the Iberian peninsula between January to May, while the western component spawns along the European shelf between the Bay of Biscay and the west

	of Scotland. Timing of spawning is between March and July with peak spawning usually occurring in April to May. Spawning on the shelf is concentrated along the 200 m contour line whereby mackerel are migrating northwards and progressively releasing their eggs. The **western horse mackerel stock** is distributed along the Bay of Biscay, south and west off the British Isles, in the western Channel, the northern North Sea, the Norwegian Sea and the western part of Skagerrak. Like NEA mackerel, western horse mackerel are closely connected to the shelf contour, and shows distinct areas for spawning, feeding and over-wintering. The **southern horse mackerel** stock is distributed within the West Iberian Atlantic.
Birds, Mammals & Elasmobranches	The bottlenosed dolphin *Tursiops truncatus* occur in large numbers in the area, while the common dolphin *Delphinus delphis* is also widely distributed. White-beaked dolphin and white-sided dolphin (*Lagenorhynchus albirostris* and *L. acutus*) occur over much of the shelf area. Large baleen whales are found offshore throughout the area and several species have migration routes through these areas. Beaked whales are found in the deep canyons along the continental edge. Seabirds are less common offshore, but closer to land petrels (fulmar and storm-petrel) dominate the seabird populations in the west of Ireland and Celtic Sea region but there are also large breeding colonies of kittiwake, guillemot and gannet.
Environmental signals & implications	Increasing temperature and changes in zooplankton communities are likely to have an impact on the life histories of many species, but particularly on the migratory pelagic species; mackerel, horse mackerel and blue whiting. The ICES WGMHSA has put forward a hypothesis that an overall northerly shift in the distribution of NEA mackerel has taken place in 2005–2007. There is also a westerly shift in the northern part of the spawning and feeding areas. If such a large-scale change in distribution and migration pattern really has occurred it is assumed this may have substantial consequences for future abundance, spawning, growth and recruitment of the NEA mackerel stock. The reasons to the observed changes in distribution are likely to be found in recent changes in the hydrographic conditions in the spawning area. It is well known that there have been large changes in the size and distribution of blue whiting stock since the mid 1990s, especially in the western distribution area. Mackerel uses more or less the same areas to spawn, thus it is likely that these large-scale changes in the

	environment would also affect mackerel. For Norwegian spring-spawning herring it has been demonstrated that the tendency of retention of larvae in warm water to the south may increase larval survival, i.e., the larvae stay for a longer period in warmer water, drifting slower towards the north. The environmental conditions also affect the condition of the fish, which again may cause reduced fecundity. The strong year classes have occurred in periods of good condition and high temperatures.
Fishery effects on benthos and fish communities	As most fishing for widely distributed and migratory stocks is pelagic in nature, there is little or no effect on the benthic community. Cetacean bycatch has been noted in some fisheries, including the pelagic trawl fishery for mackerel and horse mackerel in the SW of Ireland, although the numbers caught were low.

Ref: ICES. 2008. Report of the Working Group for Regional Ecosystem Description (WGRED).

1.2 Ecological Environment

1.2.1 Physical and chemical features

This section draws from the ICES Working Group on Regional Ecosystem Descriptions (WGRED 2008; 2007), the OSPAR Quality Status Report of 2000, various ICES Report and publications.

For the purposes of the technical Report, North Western Waters are divided into four distinct areas. These areas facilitate the fisheries case studies (Mackerel, Nephrops, Scallop, mixed trawl for hake monk and megrim) and correspond with the areas used by WGRED. The areas are:

(1) Celtic Seas Area (including the Irish Sea)

(2) English Channel

(3) Pelagic Waters to the west of Ireland and Scotland

(4) Deep waters off the west of Ireland and Scotland

1.2.1.1 Celtic Seas

From WGRED 2008

1.2.1.1.1 Topography and Bathymetry of the Seabed

The 'Celtic Seas' comprise the shelf area west of Scotland (ICES Subarea VIa), the Irish Sea (VIIa), west of Ireland (VIIb), as well as the Celtic Sea proper (VIIf-k) and western Channel (VIIe). Throughout this ecoregion the continental shelf is of variable width. The Celtic Sea south of Ireland is an extended shelf within which most of the area is shallower than 100 m. It is limited to the west by the slope of the Porcupine seabight and the Goban Spur. To the west of Ireland, the Porcupine bank forms a large extension of the shelf limited to the west by the Rockall Trough, the transition between the Porcupine bank and the trough is a steep and rocky slope along which reefs of deepwater corals occur. Further North, to West of Scotland the slope of the Rockall Trough is closer to the coast line, particularly off NW Ireland, and the Hebrides. West of the shelf break is the Rockall Plateau with depths of less than 200m. The shelf area itself contains mixed substrates, generally with soft sediments (sand and mud) in the west and tending to rockier pinnacle areas to the east. The Irish Sea is shallow (less than 100 m deep in most places) and largely sheltered from the winds and currents of the North Atlantic. The English Channel is a shallow (40–100 m) part of the continental shelf. Its hydrology is marked by a west to east general circulation disrupted by strong tidal current. To the west of the region there are several important seamounts, notably the Rosemary Bank, the Anton Dohrn sea mount and the Hebrides, which have soft sediments on top and rocky slopes.

1.2.1.1.2 WATER CIRCULATION

Water circulation on the shelf is strongly influenced by the poleward flowing 'slope current'. This persists throughout the year north of Porcupine Bank, but is stronger in the summer. South of the bank the current breaks down in the summer, when flow patterns becomes complex. Over the Porcupine Bank and the Rockall plateau, domes of cold water are associated with retentive circulation. On the shelf there is also a weaker current flowing north from Brittany across the mouth of the channel (source; OSPAR QSR 2000; Young *et al.*, 2004). Thermal stratification and tidal mixing generates the Irish coastal current which runs westwards in the Celtic Sea and northwards along the west coast of Ireland (Fernand, *et al*., 2006). In the Irish

Sea, an inshore coastal current carries water from the Celtic Sea and St. Georges's Channel northwards through the North Channel, mixing with water from the outer Clyde.

The main oceanographic front in the NE Atlantic region is the Irish Shelf Front that occurs to the south and west of Ireland (at c. 11°W), and exists all year-round. This front marks the boundary between waters of the shelf (often mixed vertically by the tide) and offshore North Atlantic waters. The turbulence caused by the front introduces nutrients from deeper water to the surface where they promote the growth of phytoplankton, especially diatoms in spring, but also dinoflagellates especially where there is pronounced stratification. These are in-turn be fed on by cohorts of zooplankton and associated with these, aggregations of fish (Reid *et al.*, 2001).

On the shelf, tidal mixing and thermo/saline fronts occur at several locations immediately to the west of Britain, including the Ushant Front in the English Channel, the Celtic Sea front at the southern entrance to the Irish Sea, and the Islay Front between Islay and the coast of Northern Ireland. The Islay Front persists throughout the winter, due to stratification of water masses of different salinity. Similarly, where tides are moderate, uneven bottom topography can have a considerable mixing effect, for example in the seas around the Hebrides.

1.2.1.1.3 TEMPERATURE AND SALINITY

The ICES Annual Ocean Climate Status Summary (IAOCSS) provides longterm timeseries for temperature amd salinity anomalies from the Rockall Trough situated west of Britain and Ireland dating back to 1975. Shorter data series are given for the western Irish shelf since 1999 (ICES, 2007).

The Rockall Trough is an important pathway by which warmer North Atlantic surface waters reach the Norwegian Sea, where they are converted into cold dense overflow water as part of the thermohaline circulation in the North Atlantic. In 2006, the warm and saline conditions persisted in the upper ocean of the Rockall Trough, though salinity has been decreasing since a peak in 2003. The notable decrease in mean salinity in 2006 was caused by the presence of fresher water between the Anton Dohrn Seamount (11°W) and the Rockall Bank (13°W); however, the shelf edge current (at 9°W) had persistently high salinities. Temperatures once again reached record levels, though most of the additional warming since 2005 was confined to the upper 400 m. Upper ocean temperatures (0–800 m) were 0.8°C and salinity 0.04 above the long-term mean (1975–2000).

Summer CTD measurements made along a section at 53° North on the western Irish shelf since 1999 show warmer conditions in 2003 and 2004, broadly consistent with other regions of the NW European shelf while cooler conditions were observed in 2001 and 2002. Salinity also exhibits strong inter-annual variability along this section depending on the timing and magnitude of discharges both locally from Irish rivers and from rivers to the south of the section in the UK and France.

Sea surface temperatures measured in coastal stations northwest of Ireland since the 1960s show a trend of sustained positive temperature anomalies from 1990 (Nolan and Lyons, 2006).

Inshore waters off the west of Scotland have also continued to warm, consistent with open-ocean conditions. At Millport, where monitoring has been conducted since 1953, gradual warming is apparent, and the more rapid warming that has taken place since the mid 1990s continued until the time of the last reported data in 2003 (FRS, 2005). Similarly, inshore temperature data from Wylfa Power Station and Amlwch in North Wales showed a pattern of warming from 1967 onwards as did temperatures at Port Erin in the Isle of Man (Joyce 2006, www.cefas.co.uk/data/seatempandsal/).

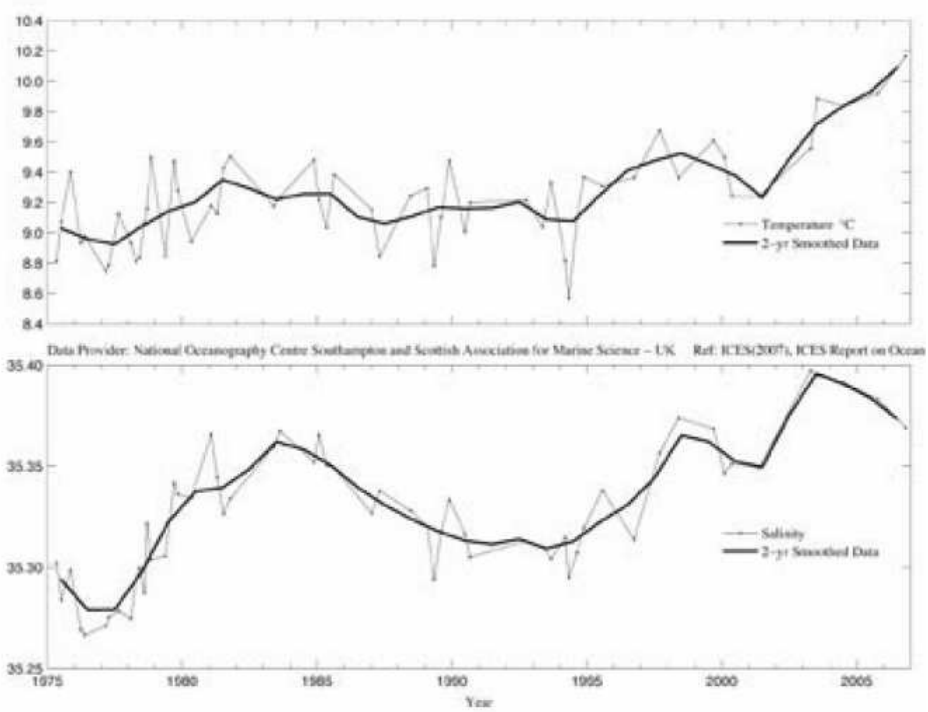


Figure 1.2.1: Rockall Trough temperature and salinity anomalies for the upper ocean (0–800 m) of the northern Rockall Trough. Average across section, seasonal cycle removed.

Several temperature time-series, including fortnightly records from a fixed station off the SW coast of the Isle of Man (the Cypris station), a more recent shorter series from a mooring in the western Irish Sea (Gowen, AFBI, Belfast), and two series of combined satellite and ship-recorded data compiled by the Climate Diagnostics Center, National Oceanographic and Atmospheric Administration of the US Department of Commerce (Figure 1.2.2) indicate a general warming trend in the Irish Sea since 1960, with particularly high temperatures in 1998 (ICES, 2006b).

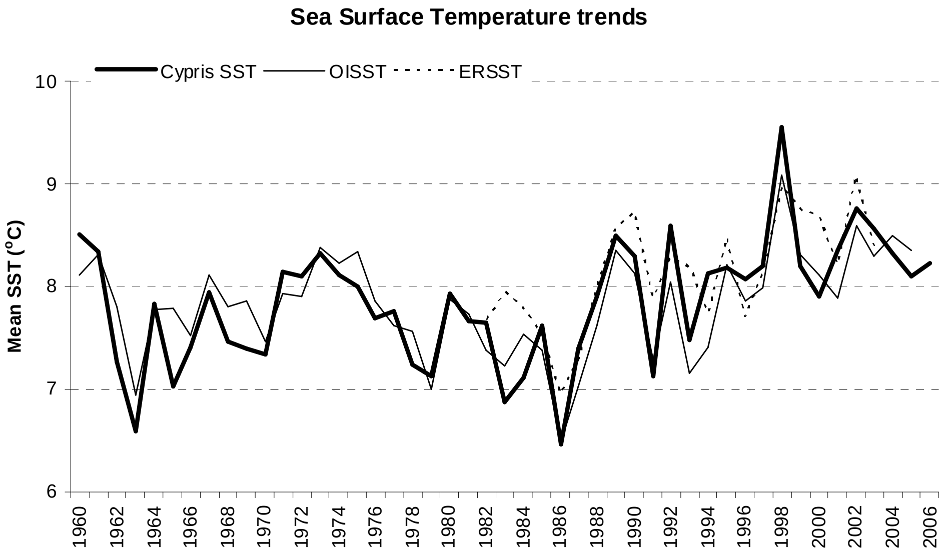


Figure 1.2.2: Sea surface temperature in the Irish Sea from 1960 to 2006 (ICES 2006b).

High-intensity, near 'real-time' temperature (and in some cases salinity) data are available from monitoring buoys in the Irish Sea (Liverpool Bay, Aberporth,, M2), the Bristol Channel/Celtic Sea (M5, Pembroke, Scarweather) and west of Ireland (M1, M3, M4, M6, K2, K4), operated by the Marine Institute (Ireland), CEFAS (UK) and the UK Met. Office (see www.cefas.co.uk/WaveNet/default.htm). Scottish monitoring stations exist at Loch Maddy (North Uist), Mallaig and Loch Ewe (www.frs-scotland.gov.uk).

The North Atlantic Oscillation index (NAO) is a measure of the difference in normalized sea level pressure between Iceland and the subtropical eastern North Atlantic. When the winter NAO index is positive, this coincides with colder and drier conditions over the western North Atlantic and warmer, wetter conditions in the eastern North Atlantic. During a negative NAO, a weakening of the Icelandic low and Azores high decreases the pressure gradient across the North Atlantic and tends to reverse the effect. The winter NAO experienced a strong negative phase in the 1960s, becoming more positive in the 1980s and early 1990s. It remained mainly negative from 1996 to 2004, but became positive in 2005 (6.7 mbar).

Input of Freshwater

Several rivers discharge freshwater into the ecoregion and influence the circulation patterns, these are notably the River Loire, the Severn and the Irish rivers Lee and Blackwater in the Celtic Sea (Figure 1.2.3). To the west of Ireland, fresh water discharges from Irish rivers (e.g. Shannon and Corrib) and those further afield (e.g. Loire, Severn) interact with Eastern North Atlantic

Water. River inputs into the Irish Sea and The Malin Sea north of Ireland are locally important in reducing salinity in these areas. Because of the complex fjordic nature of west coast of Scotland there is also a substantial freshwater input from the numerous sea-lochs, notably the Firth of Lorne sealoch system (Nolan and Lyons, 2006).

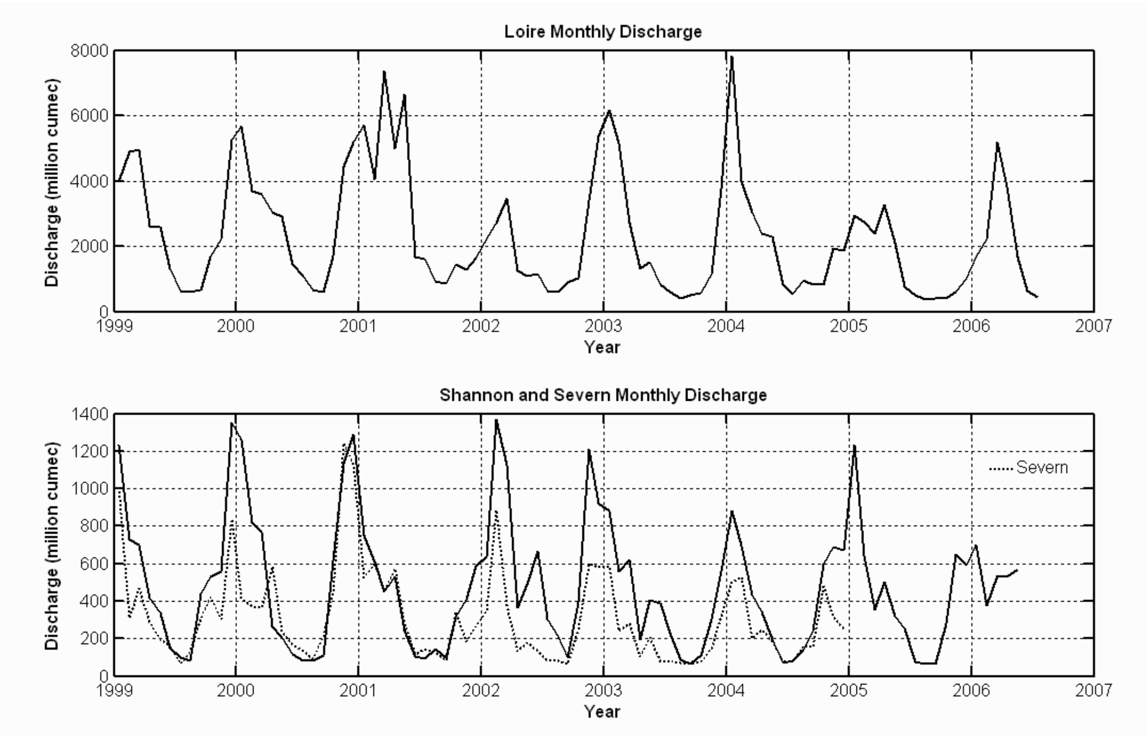


Figure 1.2.3: Discharges from rivers affecting the western Irish Shelf, river Loire (upper panel) and rivers Shannon and Severn (lower panel). Note different scales on Y axes.

1.2.1.2 English Channel

From WGRED 2008

1.2.1.2.1 Topography and Bathymetry of the Seabed

The English Channel is a shallow epicontinental sea separated from the Atlantic by the Celtic shelf. It stretches over 500 km (about 77 000 km²) from the Dover strait to the east to an arbitrary limit with the Celtic Sea to the west. It is characterized by its particular morphology (causing a strong Atlantic influence to the west) and a diversified coast line. Toward its western limit, the depth is about 100 m (at longitude 5°W) reaching 180 m in its central trench which extent into this zone. It then diminishes towards the east (40 m in the center of the Dover Strait (Figure 1.2.4). The Channel can also be defined as a biogeographical transition zone for numerous species as it is situated between Lusitanian (to the south) and boreal (to the north) provinces. This transition status enables the early detection of trends in ocean climate between the two provinces.

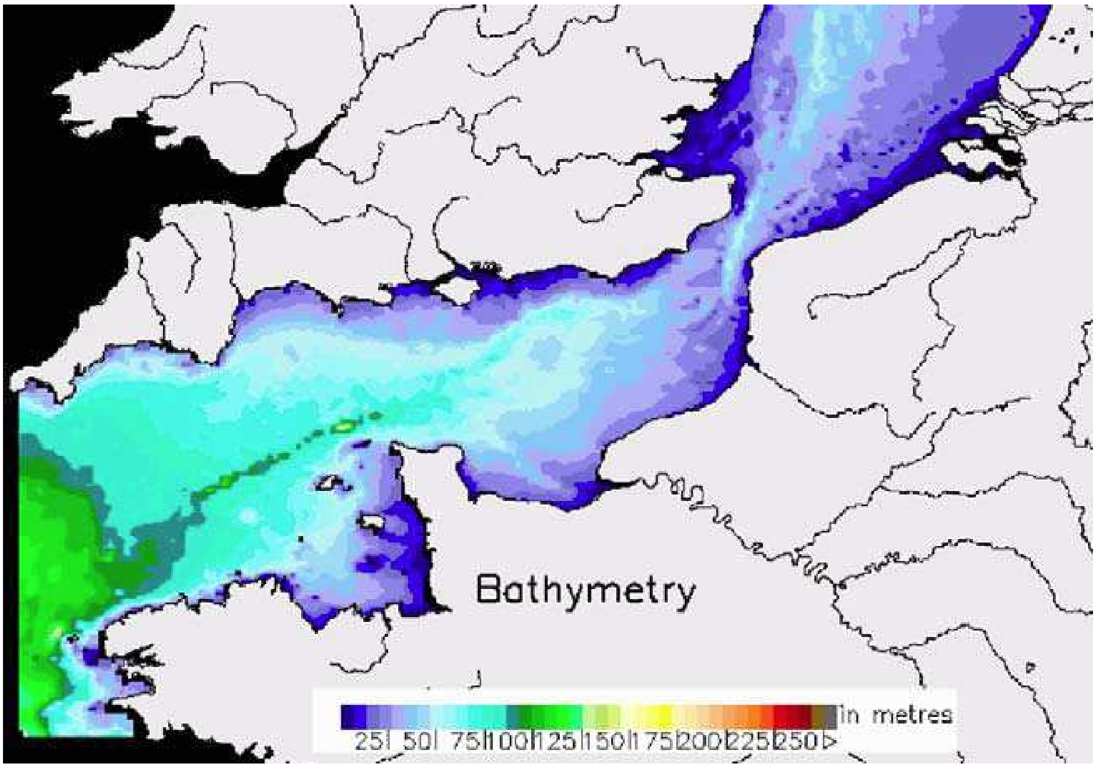


Figure 1.2.4: Bathymetry of the Channel (source IFREMER, http://www.ifremer.fr/cersat/facilities/browse/del/roses/browse.htm).

1.2.1.2.2 General Oceanography

The Channel is a forced passage for the water masses between the Atlantic and the North Sea and its configuration (bathymetry, coastline) causes the formation of particular structures (fronts, gyres) that control advection and dispersion of suspended material. Hydrology and tidal conditions are also very particular with medium to large amplitude tides (from 5 to 12 m) and varying tidal current speeds that can reach 3 to 10 knots along the French coasts (due to Coriolis force) making the Channel predominantly a macro- to megatidal area. In the Dover strait, which is a narrow (bottom neck) between France and UK at the boundary between the Channel and the southern North Sea, the tidal currents increase dramatically.

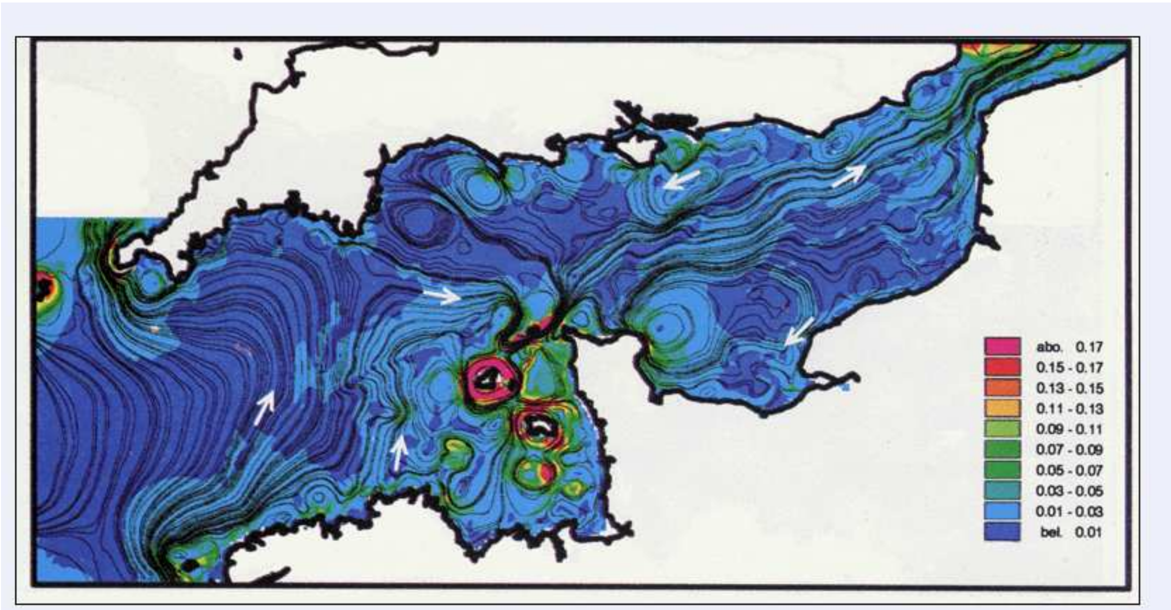


Figure 1.2.5: Residual lagrangian trajectories (average vertical speed for tide coefficient 70 in the absence of wind, after Salomon and Breton, 1991).

The study of the residual tidal currents highlights marked retention, dispersion and advection areas (Figure 1.2.5). The long term displacement of the water masses is illustrated by a 600 km long axial water stream progressing at ca. 2 cm. s^{-1} towards the Dover strait and by gyres generated by the topography. Depending on their flow speed, these structures may resist strong wind events for some time (Salomon and Breton, 1993). In the Dover strait, the residual tidal circulation contributed up to 30% to the total flow rate (on average 120.103 m^3s^{-1}) entering the North Sea. Although the general progression of Atlantic waters towards the North Sea are determined by tides, eastern wind regimes lasting several days may induce an inversion of the general flow direction.

The bedstress (Figure 1.2.6) resulting from tidal currents determine a sediment succession from gravels and pebbles in areas with strong currents to fine sediments locked in bays and estuaries. Because of the relatively large tidal forcing (bed shear stress), rocky and gravelly bottoms dominate in the Channel (Figure 1.2.7).

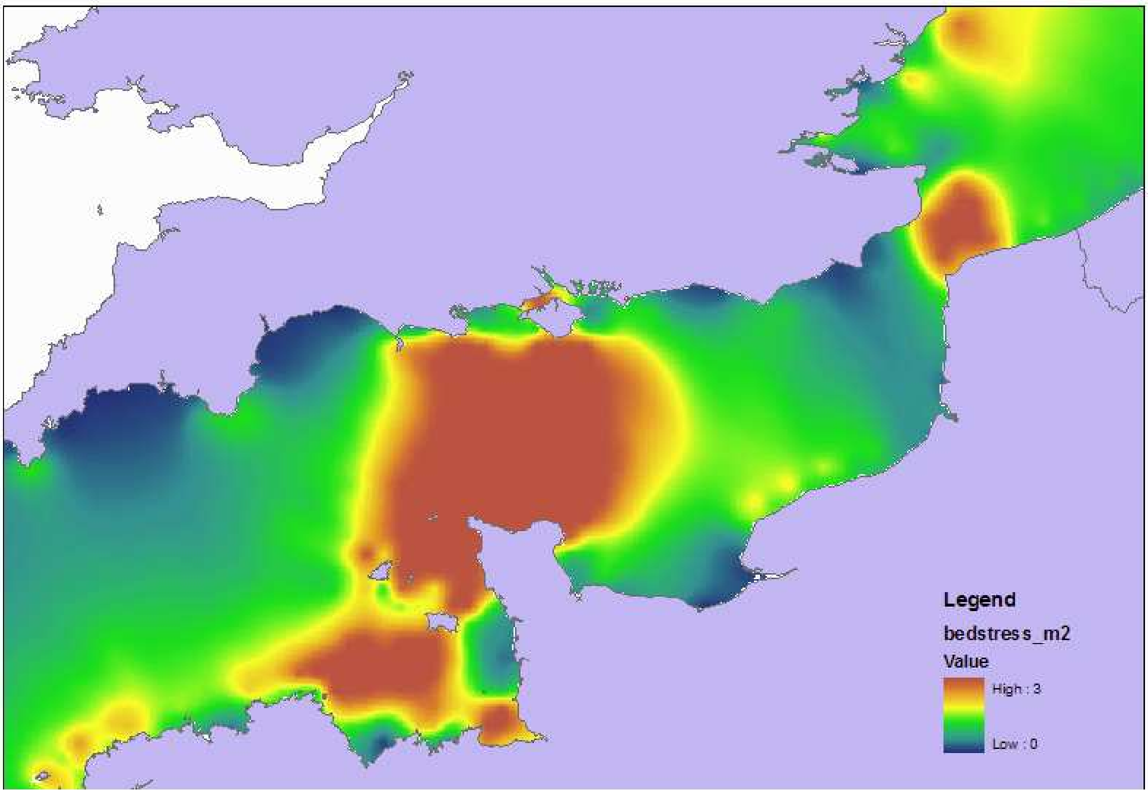


Figure 1.2.6: Estimates of bed shear stress (in N m^2) came from an 8km resolution hydrodynamic model (Aldridge and Davies, 1993).

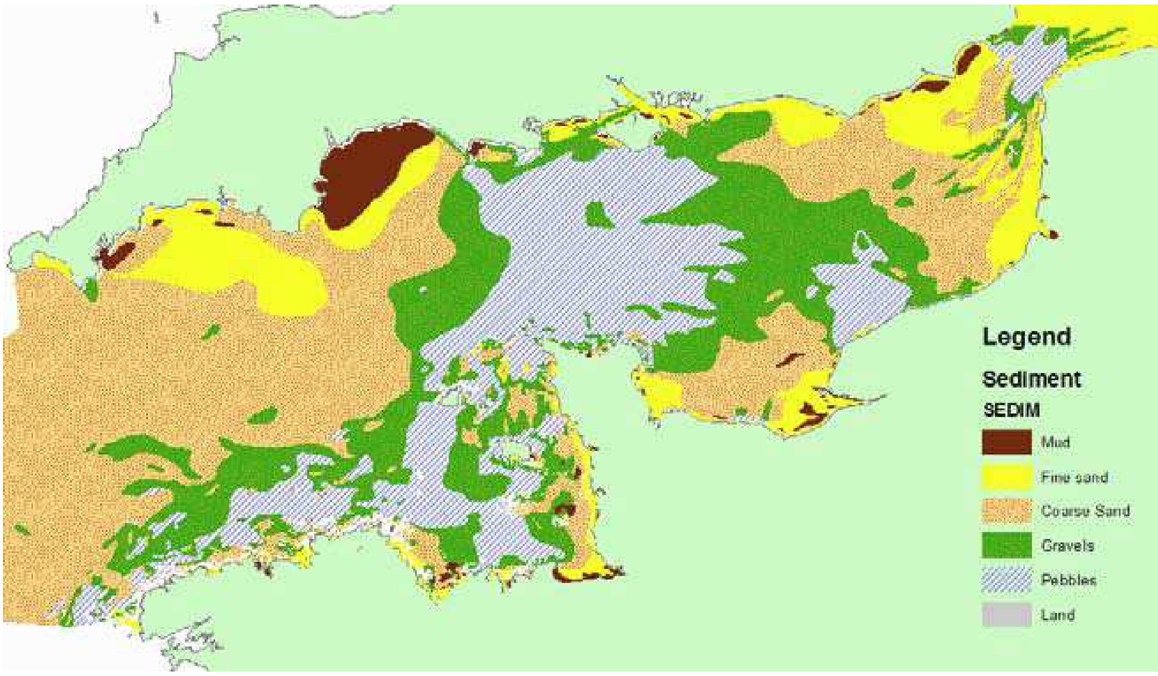


Figure 1.2.7: Seabed sediment types extracted from a digital version of the sediment map of the English Channel developed originally by Larsonneur *et al*. (1982).

The hydrological conditions are not identical in the western and eastern part of the Channel. In the shallower eastern part of the Channel, the bed-shear stress resulting from the tidal currents and the winds mix the water column. Fresh water inflow from coastal rivers pour into a "coastal flow" parallel to the French coast and situated north to the Seine River (Figure 1.2.8).

To the west, where the depth increases, a summer thermocline may establish (Figure 3.10.6). This results into a marked thermal gradient between the western side under oceanic influence and the eastern side under continental influence (Figure 1.2.8). The temperature pattern in the Channel is also influenced by the seasonal fluctuations of the coastal waters temperature as well as rivers inflow (Castel *et al*. 1997).

The warming of the Channel area regionally is consistent with the global warming signal observed over the whole North East Atlantic over the last decades (Castel *et al.*, 1997, Woehrling *et al*., 2005). Figure 1.2.10and 11 illustrate the sea surface temperature evolution in Western and Eastern Channel.

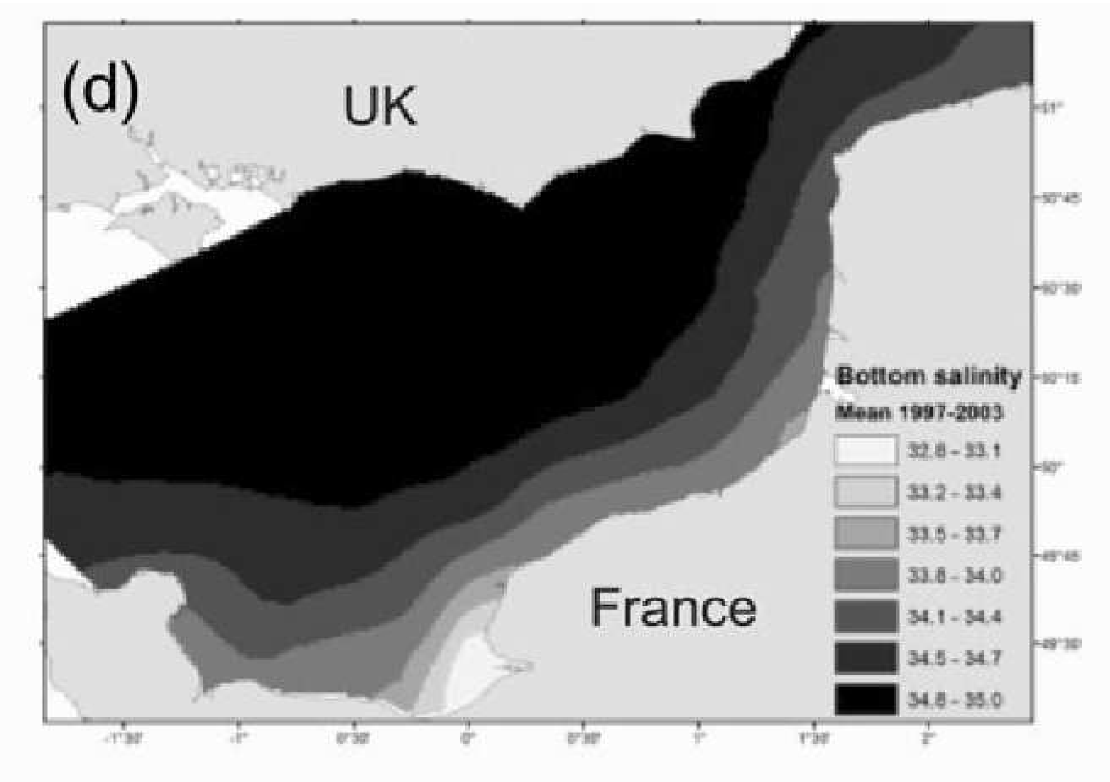


Figure 1.2.8: October mean bottom salinity from 1997 to 2004 (source Vaz *et al.*, 2007).

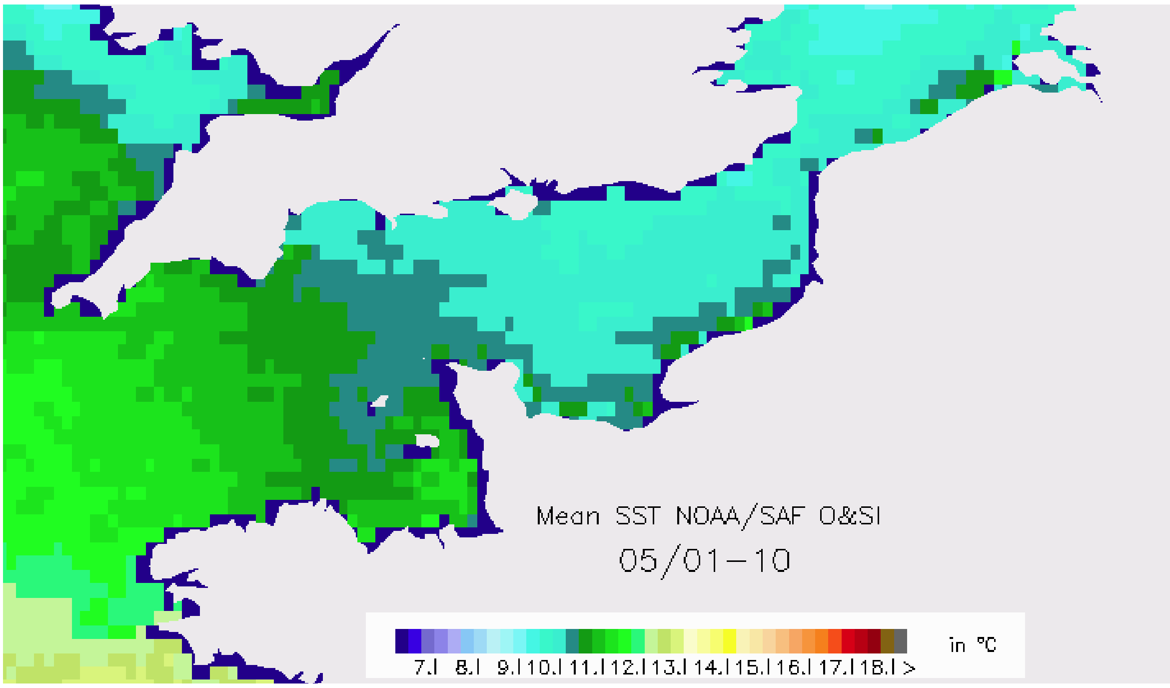


Figure 1.2.9: SST climatology in May (10 day average of satellite images over several years, after Faugere *et al*., 2001, source http://www.ifremer.fr/cersat/facilities/browse/del/roses/browse.htm).

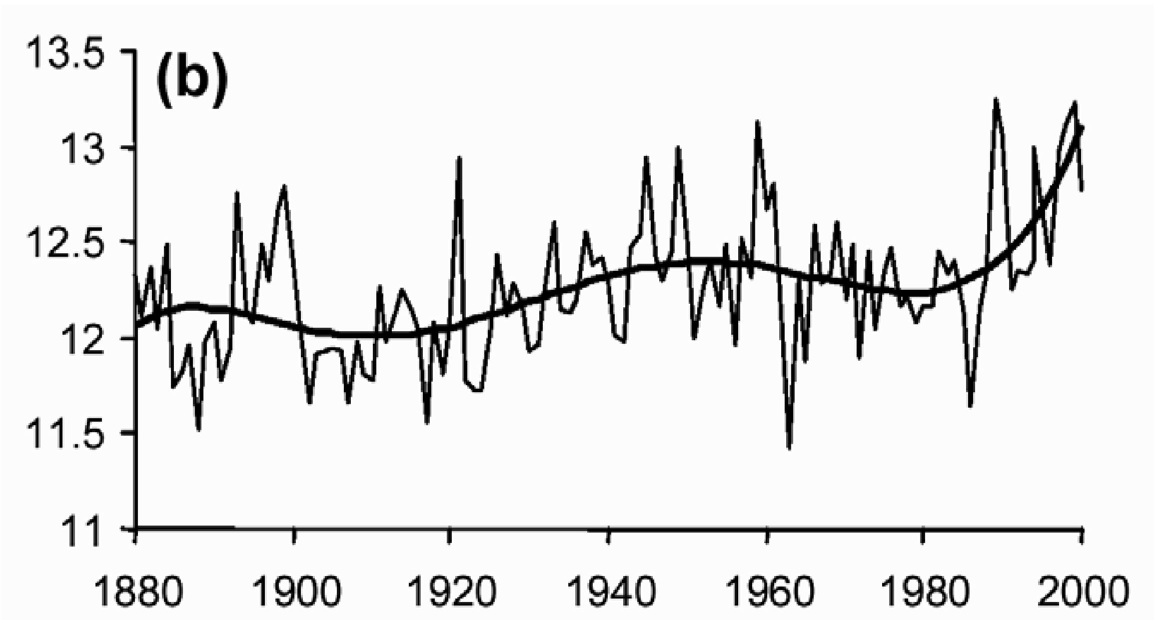


Figure 1.2.10: Mean annual sea surface temperature in western English Channel off Plymouth (from Hawkins *et al*., 2003).

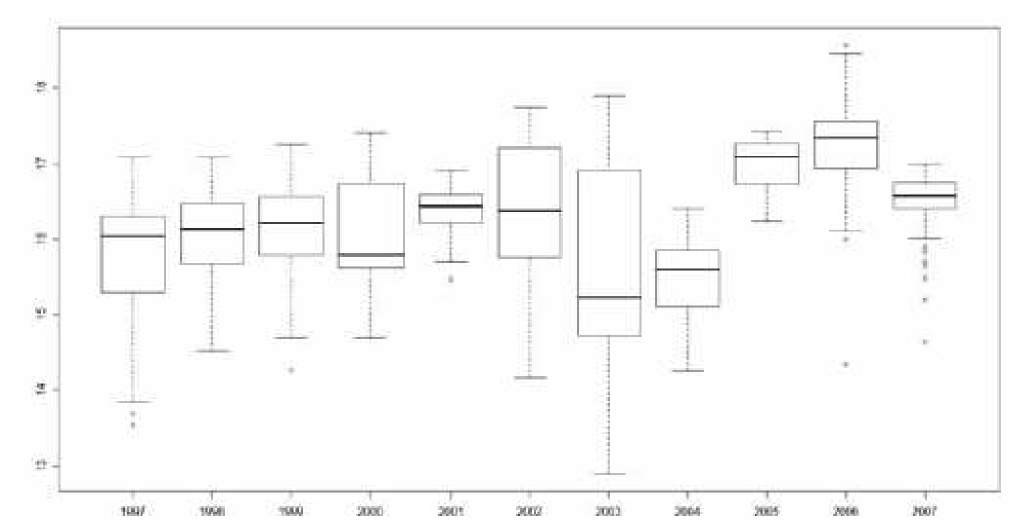


Figure 1.2.11: Surface temperature in the Eastern Channel in October from 1997 to 2007 (observed during the Channel Ground Fish Survey onboard the Ifremer RV "Gwen Drez").

Currents also contribute to the turbidity of the coastal waters by favouring the resuspension of mineral and organic particles and the diffusion of continental intake (Figure 1.2.12). This turbidity limits the light penetration into the water column and alters the light energy both quantitatively and qualitatively (Frontier and Pichot-Viale, 1995).

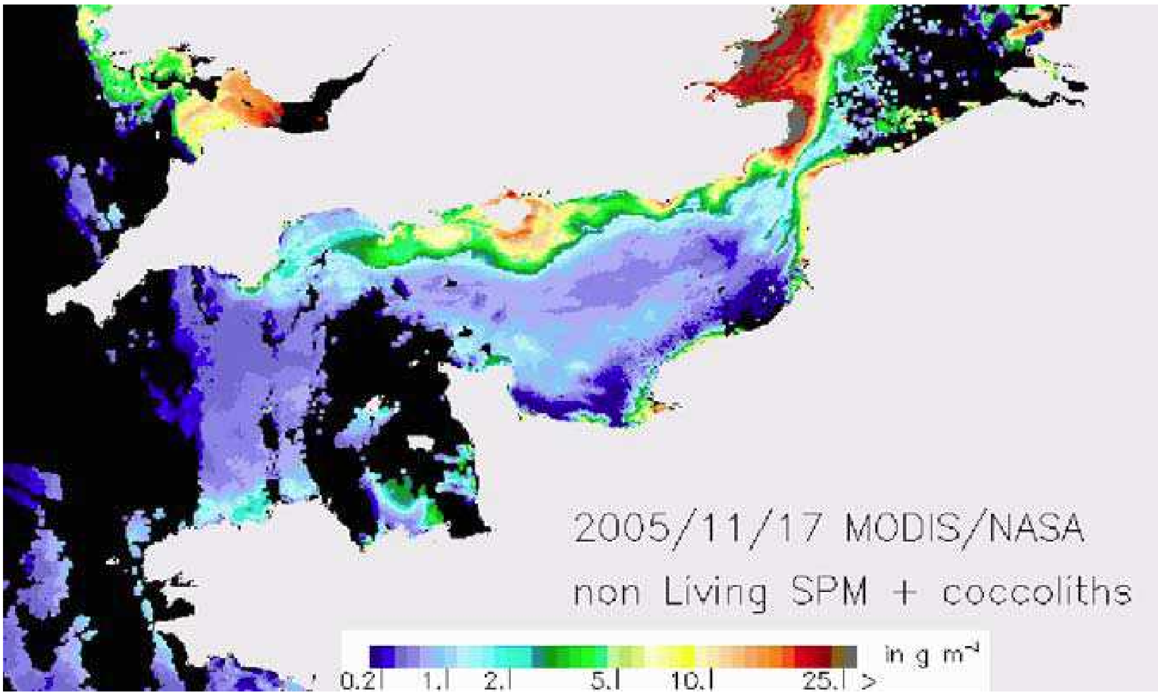


Figure 1.2.12: Suspended matter distribution in November 2005 from satellite images (calculated after Frondefroid *et al*., 2002, source http://www.ifremer.fr/cersat/facilities/browse/del/roses/browse.htm).

More generally, three large hydrographical entities may be distinguished in the Channel: the western Channel under Atlantic water influence with a stratified NW part in summer and low continental intake; the Normand-Breton Golf where eddies slow the water renewal and with low continental intake and the eastern Channel up to the Dover Strait receiving through the Seine estuary most of its continental intakes with increased turbidity (Figure 1.2.12).

Figure 1.2.13 shows the sea surface salinity evolution in October in the Eastern Channel over the last decade. These illustrate salinity decline correlated to the large river Seine outflow from 1999 to 2001 followed by a relative stability of the salinity in recent years.

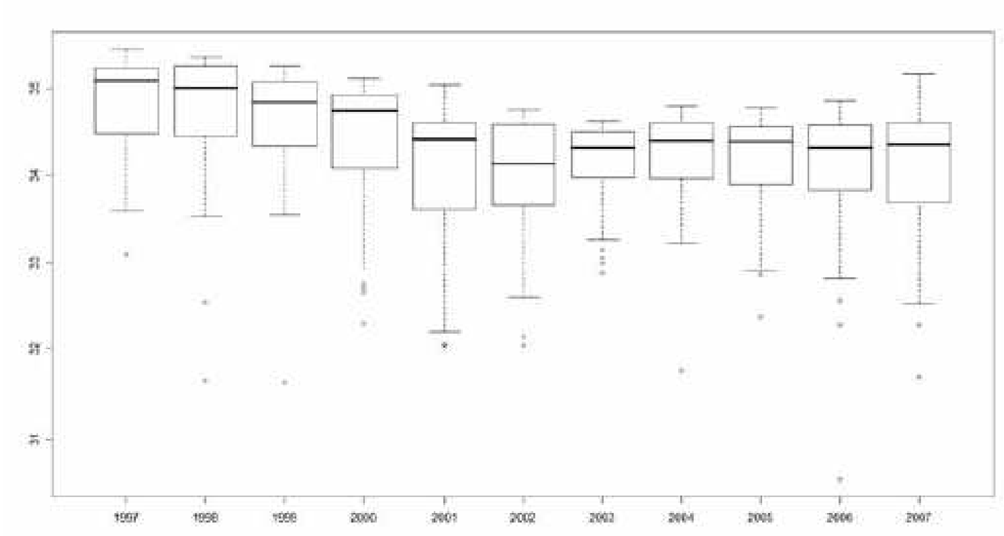


Figure 1.2.13: Sea surface salinity in the Eastern Channel in October from 1997 to 2007 (observed during the Channel Ground Fish Survey onboard the Ifremer RV "Gwen Drez").

1.2.1.3 Pelagic waters to the west of Ireland and Scotland

From WGRED 2008

1.2.1.3.1 Surface Circulation and Hydrography

The circulation of the North Atlantic Ocean is characterized by two large gyres: the *subpolar* and *subtropical* gyres (Figure 1.2.14). The anticyclonic subtropical gyre owes its existence to the low-latitude trade winds and mid-latitude westerlies. Some of the water in the subtropical gyre is re-circulated to the west of the Mid Atlantic Ridge (MAR) and some water continues east and crosses the MAR in the Azores Current and the remainder forms the North Atlantic Current (NAC). The NAC looses its jet signature as it turns east and the waters are transported eastward in the Sub Polar Front (SPF), which is the boundary between the warm water in the subtropical gyre and the cooler and less saline water in the subpolar gyre to the north (Rossby, 1999). It crosses the MAR in 2 to 4 branches between 45°N and the Charlie Gibbs Fracture Zone (CGFZ, ~52°N; Harvey and Ahran, 1988). Sub surface (Bower *et al*., 2002) and surface drifters (Fratantoni, 2001) indicate that the northern branch that is tied to the CGFZ, is the main pathway for waters crossing the MAR from the western to the eastern North Atlantic. East of the MAR the SPF makes a sharp turn toward the north. On the cold side of the SPF low salinity Sub Arctic Intermediate Water is transported into the eastern North Atlantic.

In the Iceland Basin there is a cyclonic circulation and relatively warm and saline water is transported from the eastern side of the North East Atlantic southwestward on the eastern side of the Reykjanes Ridge (Pollard *et al*., 2004). This water crosses the Reykanes Ridge and is transported northeastward on the western side of the ridge. Thus above the Reykanes Ridge relatively warm and saline modified North Atlantic Water is found whereas further west the waters are colder and less saline. The Rockall Through is an area of mode water formation and an 8–900 m thick layer of modified NAW is observed there. In the Iceland Basin the layer of modified NAW is about 500 m. Further south there is a warm and saline upper layer that reaches a thickness of 8–900 m in the south. Along the eastern boundary there is a warm and saline slope current flowing northward from the Biscay to the Polar Ocean.

The circulation in the Norwegian Sea is strongly affected by the topography. On the continental shelf at the eastern margin of the area flows the low salinity Norwegian Coastal Current. It enters the area from the North Sea in the south and exits to the Barents Sea in the north east. The inflow of water from the north Atlantic to the Norwegian Sea takes place through the Faroe-Shetland Channel and flow over the Iceland-Faroe Ridge. At the northern slope of the ridge the warm Atlantic water meets the cold Arctic water and the boundary between these waters are called the Iceland Faroe Front. The major part of the warm and high salinity Atlantic Water continues northward as the Norwegian Atlantic Current along the Norwegian shelf, but parts of it branches into the North Sea and also to the more central parts of the Norwegian Sea. At the western boundary of the Barents Sea, the Norwegian Atlantic Current further bifurcates into the North Cape Current flowing eastwards into the

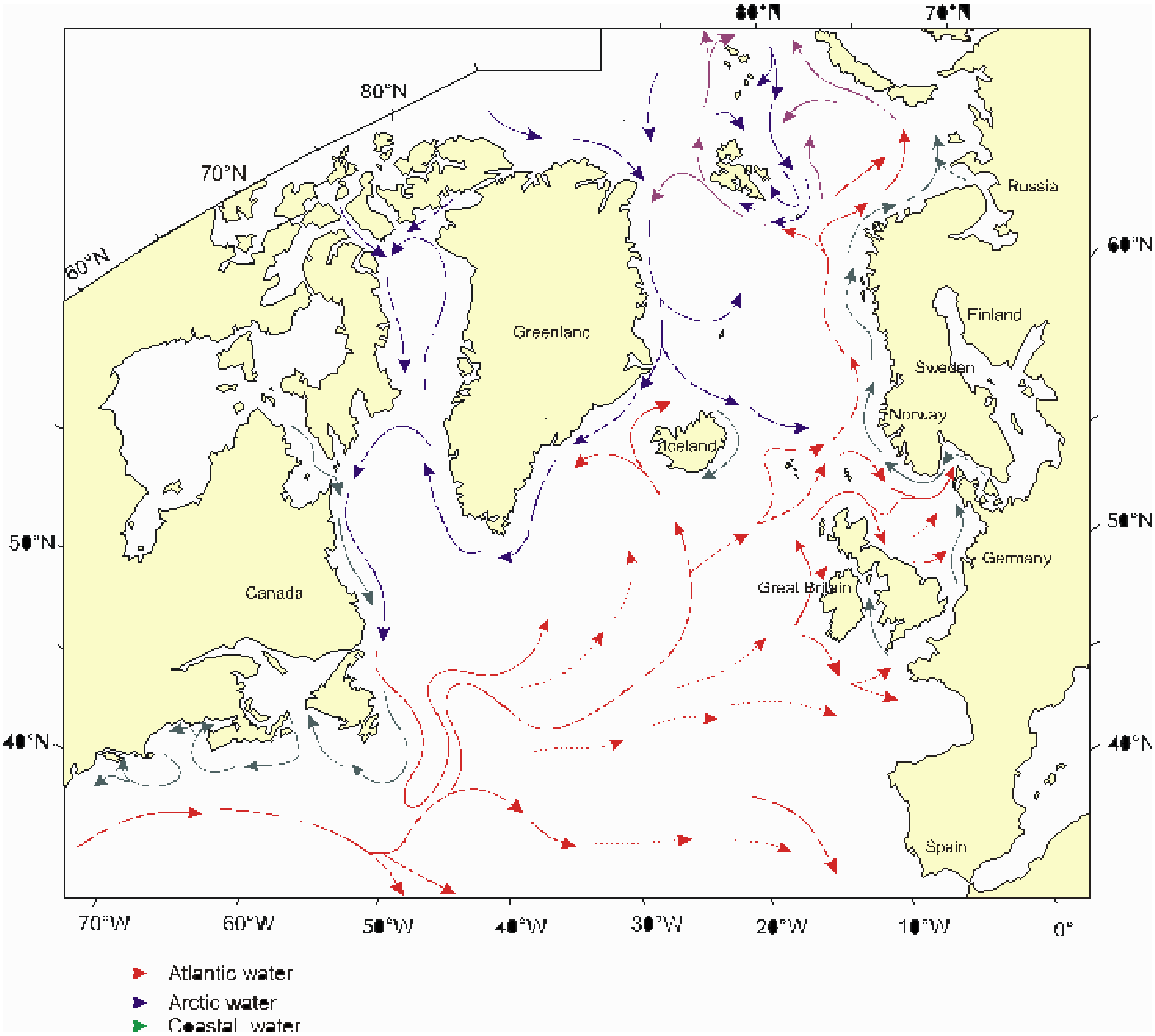


Figure 1.2.14: Surface current patterns in the North Atlantic (courtesy of Svein Sundby).

Barents Sea and the West Spitsbergen Current flowing northwards into the Fram Strait (Furevik, 2001).

The general circulation pattern in the Barents Sea is strongly influenced by topography. Warm Atlantic waters from the Norwegian Atlantic Current defined by salinity higher than 35 flow in through the western entrance. The Coastal Water is fresher than the Atlantic water, and has a stronger seasonal temperature signal. In the northern part of the Barents Sea fresh and cold Arctic water flows from the northeast to southwest. The Atlantic and Arctic water masses are separated by the Polar Front, which is characterized by strong gradients in both temperature and salinity. In the western Barents Sea the position of the front is relatively stable, although it seems to be pushed northwards during warm climatic periods. In the eastern part the position of the front has large seasonal, as well as year-to-year variations. Ice conditions show also large seasonal and year-to-year variations. In the winter the ice can cover most of the northern Barents Sea, while in the summer the whole Sea may be ice-free.

1.2.1.3.2 Recent oceanographic trends

The ICES Report on Ocean Climate (ICES, 2007a) provides summaries of long-term observations of environmental conditions to the end of 2006. The time-series from 29 standard stations and sections across the whole North Atlantic show generally rising trends in sea surface temperature (SST) and salinity. The increase in SST at several of the stations in the NE Atlantic is up to 3oC since the early 1980s. This rate of warming is very high relative to the rate of global warming.

Surface waters of the Rockall trough have been steadily warming for some years and are currently at an all time high. Hydrographic observations obtained during the blue whiting surveys uses mean temperature and salinity from 50 to 600 m of all the stations in deep water west of the Porcupine Bank (ICES, 2006a). This data show that after some years with temperatures around 10.1°C in the 1980s, an increase in temperature is seen after 1994 to a temperature above 10.5°C in most of the recent years. In 2006, a new record has been set with

11.3°C, i.e. 0.5°C warmer than the previous record. Similar changes are seen in the other boxes, indicating that the box discussed above is representative for the region along the continental slope south of the Wyville Thompson ridge. The mean salinity in the box off Porcupine Bank is 35.51 this year. This is the highest value in the more than 20 years long time-series.

In the Norwegian Sea, and especially in the eastern part, Atlantic water has been extraordinary warm and saline since 2002. During this period record-high values of both temperature and salinity have been observed. In 2006, temperature values were between 0,6oC and 1,1oC warmer than normal with highest anomaly in the north. The volume transport of Atlantic water into the Norwegian Sea increased considerably during 2005 and record-high transport values were observed during winter 2006.

The inflow of Atlantic Water to the Barents Sea was higher and warmer than ever recorded and the ice cover was the lowest on record for the winter of 2006. In 2007 the temperature in the inflowing water is colder and less saline than in the previous year and at about the same level as 2005, but still above the long term average.

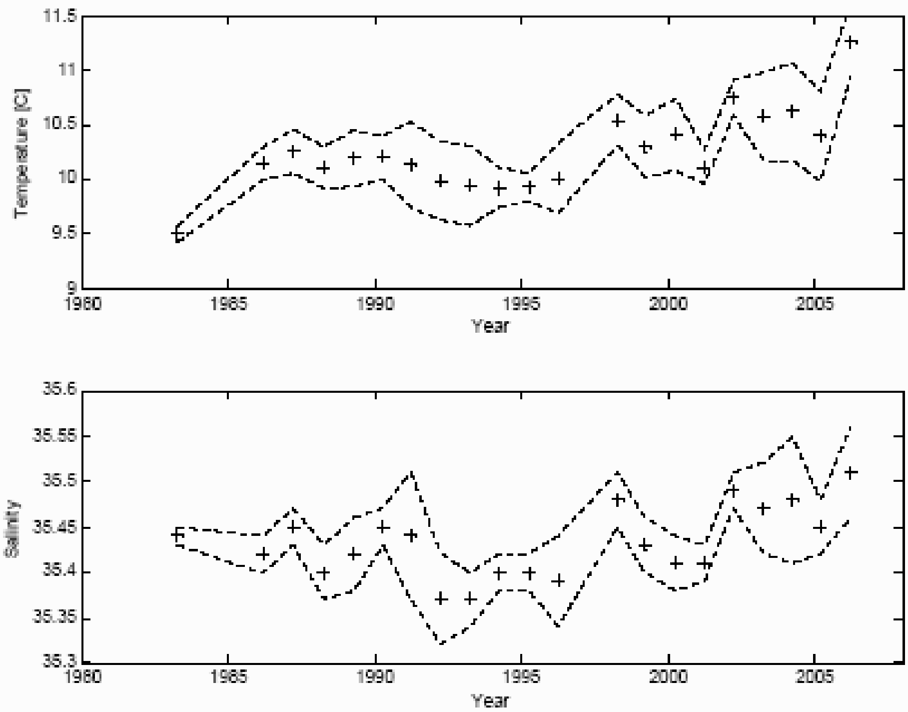


Figure 1.2.15: Yearly mean temperature and salinity from 50–600 m (crosses) of all stations in box with bottom depth>600 m, west of Porcupine Bank bounded by 52 to 54 and 16–14 W. Dotted lines are drawn at plus-minus standard deviation of all observations in each box, each year (from ICES, 2006a).

1.2.1.4 Deep Water

From WGRED 2008

1.2.1.4.1 Topography and Bathymetry of the Seabed

Most of the seabed to the west of the continental slope is abyssal plain with average depth 1000 to 4000 m. To the east the continental slope of Europe is mainly rocky and hard from the latitude of Ireland southwards, further north sediment cover occurs to the west of the British Isles. To the west of Scotland, topography is variable with two portions of detached continental shelf-ockall and Hatton Banks separated from the European continental shelf by the Rockall Trough. The north of this advisory region is marked by the Wyville Thomson and Iceland-Faroe Ridges. In the west, the major topography feature is the mid-Atlantic Ridge (MAR) that follows a sinuous course southwards from Iceland (where it is known as Reykjanes Ridge), to the Azores. At the ridge new oceanic floor is formed and the western and eastern parts of the North Atlantic basin are separating at a speed of 2–6 m/year. The MAR has a rugged topography with numerous peaks of variable height occurring. Isolated seamounts occur over the whole basin. The European continental slope is comparatively gentle. The western part of the advisory region extends beyond the MAR over north-west Atlantic deep basin. Along the ridge, the Charlie Gibbs Fracture Zone (CGFZ) is a major transversal feature comprising a system of two main parallel deep rift valleys running perpendicular to the main MAR axis at about 52°N. The axis of the ridge south of the CGFZ is about 6° east of that of the ridge to the north. The main flow of deep-water between the western and eastern deep-sea basins of the North Atlantic occurs through these deep channels and affects the whole North Atlantic circulation (see http://www.mar-eco.no). If advisory region K were to be split in the future, the CGFZ might prove a suitable dividing feature.

The general circulation in the epipelagic zone (0–200m) is well understood. A warm current flows from the south-west North Atlantic towards Europe coast with several side branches. Cold currents flow south from the Labrador Sea and Irminger Sea (Figure 1.2.16) and also as a strong deep water flow between Shetland and the Faroes.

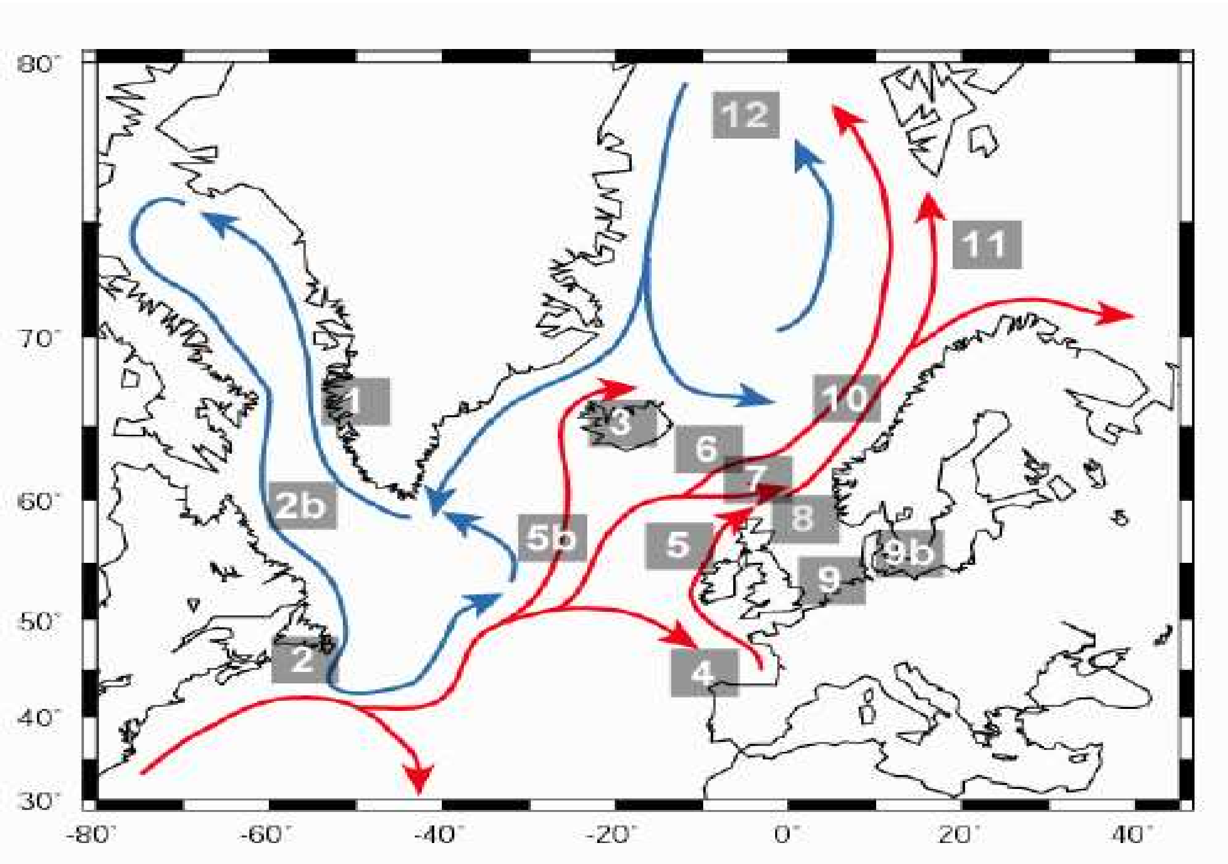


Figure 1.2.16: The general circulation of the North Atlantic in relation to the numbered areas presented in the Annual ICES Ocean Climate Status Summary 2006/2007 (ICES, 2007a). The blue arrows indicate the cooler waters of the sub-polar gyre. The red arrows show the movement of the warmer waters in the sub-tropical gyre.

1.2.1.4.2 Temperature, Salinity and Nutrients

Below about 700 m there is little seasonal variation in temperature and spatial variations within the advisory region are small. Average temperatures are 7°C to 8°C at 1000 m depth and less than 4°C below 2000 m (Figure 1.2.17).

At depth, primary production occurs only at hydrothermal vents and cold seeps from chemo-autotrophic bacteria and archaeas either as free cells or symbionts of larger organisms. This primary production is fuelled by the oxidation of fluids flowing from the seabed. Although this deep primary production supports exceptionally dense, diverse and unique communities including a nimals unknown in any other ecosystem

(e.g. vestimentifer worms), these vents are not believed to produce a significant part of the total primary production at the advisory region's scale.

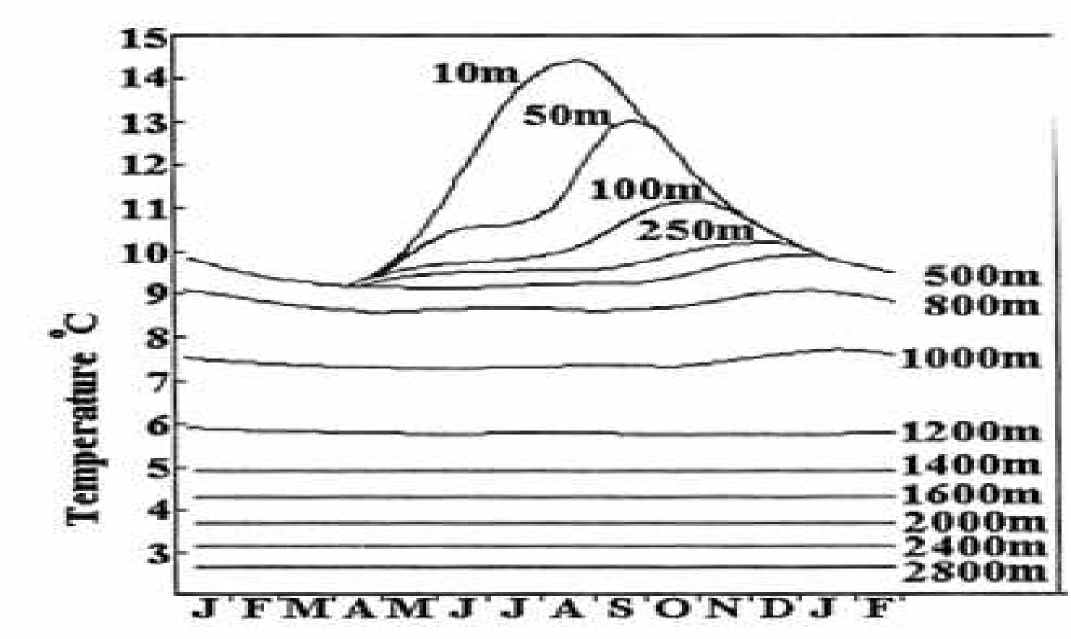


Figure 1.2.17: Seasonal variations of the sea temperature by depth in the Rockall Trough, west of Scotland (Gordon *et al*., 1995).

Photosynthetic primary production at the surface is limited in many areas by nutrient availability. Exceptions exist near seamounts and other topographical features that cause upwelling from the nutrient rich deeper waters. Most primary production in the ocean is limited to the euphotic zone that reaches a maximum depth of 200 m. A small proportion (1%–3%) of this surface production may eventually arrive back in deeper waters when phytoplankton and other particles sink forming 'planktonic snow' (Gage and Tyler, 1991). This process, together with rare falls of carcasses of large animals and particulate organic matter flowing down slopes from shelves and continental bring organic matter to the deep environment (Figure 1.2.18). Flux of this organic matter varies both seasonally and from year to year.

The use and gradual depletion of this organic matter is reflected in the logarithmic decline in the concentration of plankton as depth increases (Angel and Baker in Merret and Haedrich, 1997). However, this pattern does not explain the distribution of fish biomass at depth along the slope. For example, to the west of Scotland, biomass reaches its maximum level at around 1200 m (Gordon and Bergstad, 1992; Gordon and Duncan, 1985), while primary production at the surface directly above the continental slope is insufficient to maintain the total biomass below (Koslow, 1997). Other processes bring food to the fish living along the slope, primarily from elsewhere in the oceans (Figure 3.13.3). Such processes are also involved in the distribution and density of deep water corals (Genin *et al*., 1986). Fish over the slope feed on meso- and bathy-pelagic fauna brought to the slope by tidal currents (Gordon, 1979; Koslow, 1997).

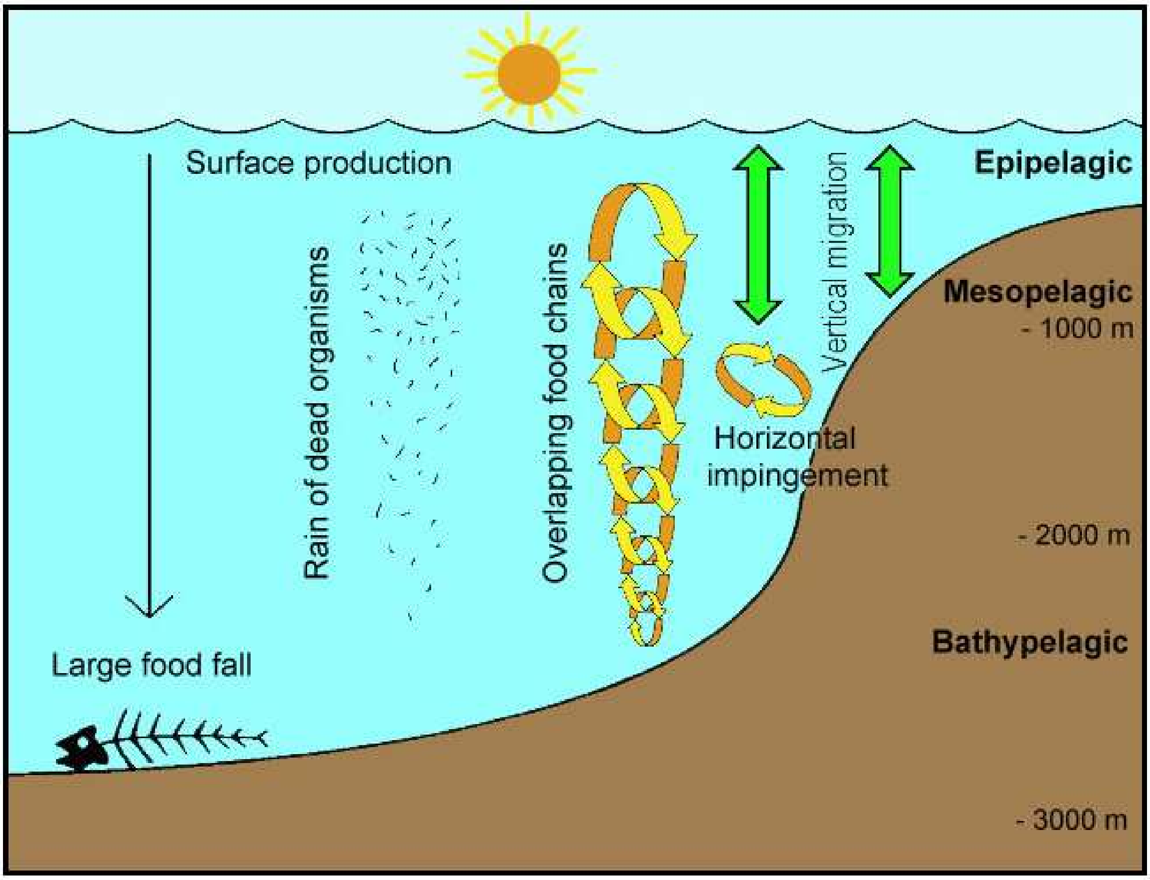


Figure 1.2.18: Trophic transport in the deepwater ocean (courtesy John Gordon, Scottish Association for Marine Science, see also Gordon, 1979).

The North Atlantic Oscillation (NAO, Figure 1.2.19) is known to control or modify three of the main parameters which drive the circulation in the ocean area covered by this summary (wind speed, air/sea heat exchange and evaporation/-precipitation). The Hurrell index of the NAO (Figure 1.2.20) is closely correlated with conditions over the eastern North Atlantic. Following a long period of increase from an extreme and persistent negative phase in the 1960s to an extreme and persistent positive phase during the late 1980s and early 1990s, the Hurrell NAO index underwent a large and rapid decrease during the winter preceding 1996. Since 1996 the Hurrell NAO index has been fairly weak but mainly positive, except for the winter preceding 2001, 2004 and 2006 (ICES, 2007).

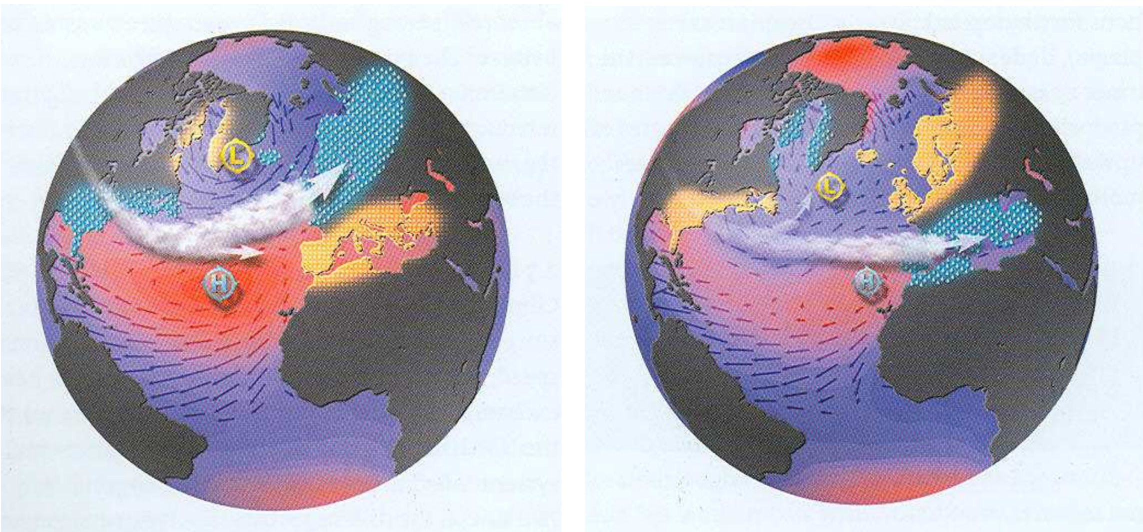


Figure 1.2.19: Positive (left) and negative (right) NAO Index (ICES 2003)

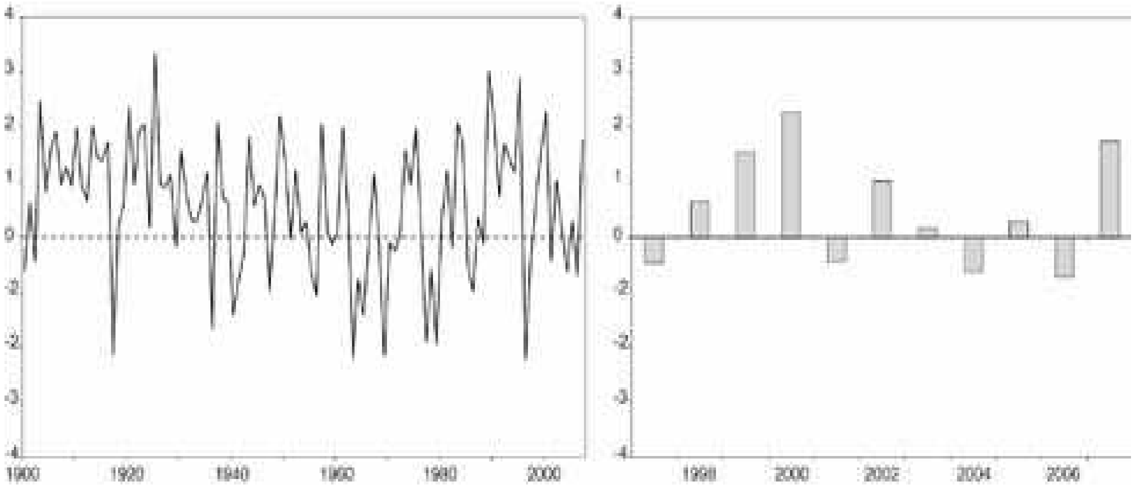


Figure 1.2.20: The winter NAO Hurrell index (see text) in terms of the present decade (left) and the last 100 years (right-a two-year running mean has been applied), (from ICES, 2007). The effect of the NAO on deep layers is poorly known.

1.2.1.5 Overall

1.2.1.5.1 Topography and bathymetry

The bathymetry data is GSI updated GEBCO data and can be seen in Figure 1.2.21. Table 1.2.1 shows the percentage area in each depth zone.

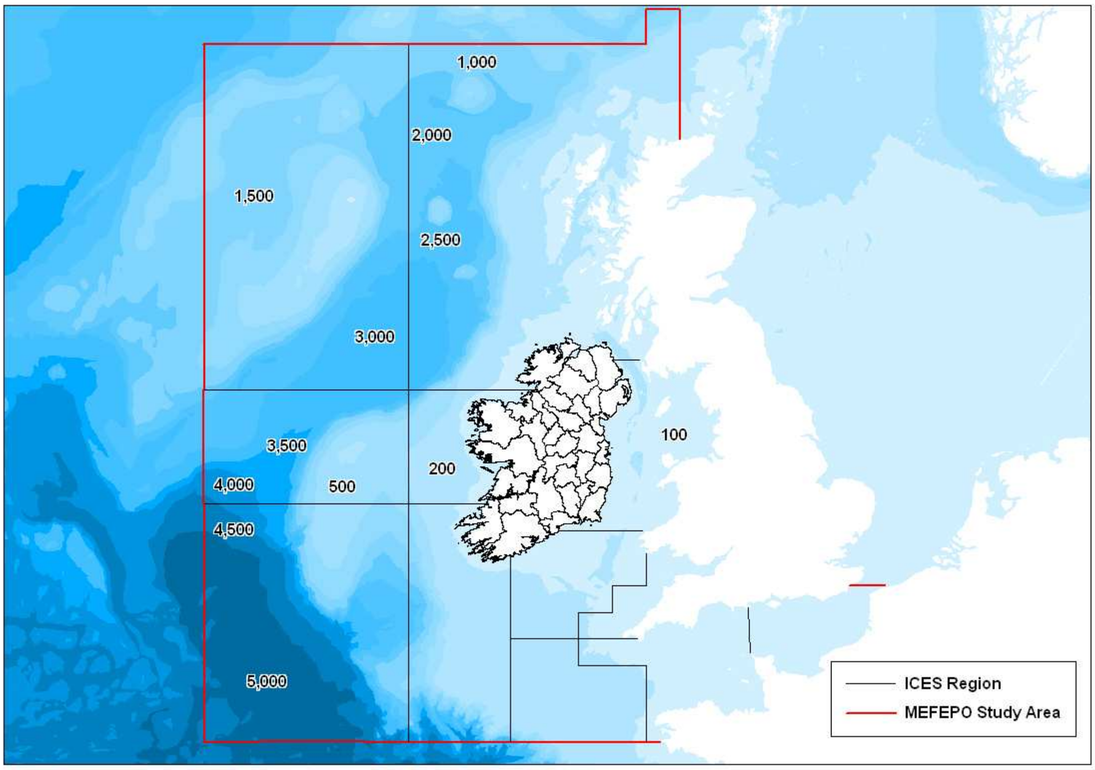


Figure 1.2.21 Bathymetry for the MEFEPO Region (Source: GSI updated GEBCO data).

Table 1.2.1: Percentage of the MEFEPO Study Area in each depth zone.

Depth Zone	Area (km^2)	%
100m	248970.44	19.15
200m	218896.37	16.83
500m	85493.9	6.57
1000m	89192.98	6.86
1500m	258638.97	19.9
2000m	78836.55	6.06
2500m	78295.3	6.02
3000m	78242.52	6.02

3500m	23849.34	1.83
4000m	20730	1.59
4500m	37706.59	2.9
5000m	80548.18	6.19

The dominant topographic feature of the western part of the MEFEPO Study Area is the Rockall Trough, a steep-sided elongate depression in the Continental Shelf, over 1,000 km long and approximately 250 km wide, orientated approximately northeasterly-southwesterly (Naylor *et al,* 2002). The trough ranges in depth from 1,000 m to 1,500 m at its northern end west of Scotland (59° to 60°N), where it is bounded by the Wyville-Thomson Ridge and a chain of sea mounts, to 3,500 to 4,000m at the southern end (approximately 53°N) where it opens onto the Porcupine Abyssal Plain. In Irish waters, it is bounded to the west by the Rockall Bank and to the east by the Erris and Slyne Ridges, northern slopes of the Porcupine Bank and the Porcupine Ridge.

Further south, another deep water embayment, the Porcupine Seabight, also opens onto the Porcupine Abyssal Plain. The Seabight ranges in water depth from about 350m at its northern end to over 3,000m in the south, and is bounded to the east by the Irish Mainland Shelf and the Celtic Shelf, to the north and west by the Porcupine Bank and Porcupine Ridge, and to the south by the Goban Spur. The Porcupine Bank and Ridge, and the Rockall and Hatton Banks, remain as shallower plateau areas separated from the continental shelf by the deep waters of the Rockall Trough and Porcupine Seabight.

Inshore of these topographical features is the Continental slope. This extends the full length of the NWW Study Area and seperates the deeper offshore waters with shallower (<200m) more coastal waters.

In the Irish Sea, east of 5°W all depths are <60m. The seafloor shelves gently westwards from the British coast to water depths of approximately 60m (Holt *et al*., 1990). This Eastern Shelf is mostly flat and featureless although bathymetric highs and lows occur locally. Shoals with islets and sandbanks occur inshore in the broad bays and estuaries and offshore sandbanks occur as coast parallel features off North Wales and Pembrokeshire and as banner banks northeast off the Isle of Man. In Cardigan Bay, there are three shallow water (0-10m) moraine ridges, which extend from the coastline to approximatelly 15km offshore. Enclosed deeps up to 25km long and 3km wide, with water depths up to 50m greater than the surrounding seabed, occur in Morecambe Bay (Lune Deep), west of Anglesey (Holyhead Deep) and south of Lleyn (Muddy Hollow).

The western or Irish Shelf, shallower than 60m, extends for <20km offshore. South of Rockabill and Lambey Islands the Irish Shelf is distinguished by a series of linear, coast parallel, sand banks for its whole length to Carnsore Point, Co. Wexford. The Lambey Deep and Codling Deep are up to 134m deep.

Between the Eastern and Irish Shelves, the Celtic Trough is up to 70km wide and has water depths greater than 60m. The trough runs from the Celtic Sea to the Malin Sea through St. George's Channel, the western Irish Sea and the North Channel.

Water depths in the southern part of St. George's Channel are generally approximately 100m. The seabed is mainly smooth except for locally developed sandwave fields and rare enclosed deeps of approximately 125m. The bathymetry of the northern part of the channel is more complex with general depths ranging from 60 to 120m. There are many sandwaves, some up to 40m in height and numerous localised enclosed deeps between 130 and 180m. The area west of the Isle of Man has a smooth, rolling, seabed down to 120m deep, with rare rocky prominences and enclosed deeps to the north. In the North Channel, the seabed is rough with many rocky outcrops. General depths in the trough are from 60 to 160m, but there are also both upstanding areas and smaller prominences, some forming rocky islets and the notable complex of enclosed deeps of Beaufort's Dyke, which has a maximum water depth of 315m. The volume of the Irish Sea is approximately 2,400 km^3, of which 80% lies to the west of the Isle of Man (CEFAS, 2000).

Figure 1.2.22 shows the marine basins within the MEFEPO Study Area (Source: Marine Institute). The Hatton Basin is located along the western boundary of the MEFEPO Study Area, covers an area of 38,920km^2 and ranges in depth from 1000 to 2000m. The Atlantic Basins cover an area of 254,400km^2 and ranges in depth from 100m along the Continental Shelf to 4500m over the Porcupine. The Celtic Sea Basin covers an area of 37,040km^2 and ranges in depth from <100m in the Irish Sea to 200m in the Celtic Sea. The Kish Basin is located in the Irish Sea, off the Co. Dublin coast in water depths of <100m to 200m and covers an area of 1,452km^2. The Cockburn Basin, located approximately 200km south of the Co. Cork coast is located in 200m of water and covers an area of 1,594km^2.

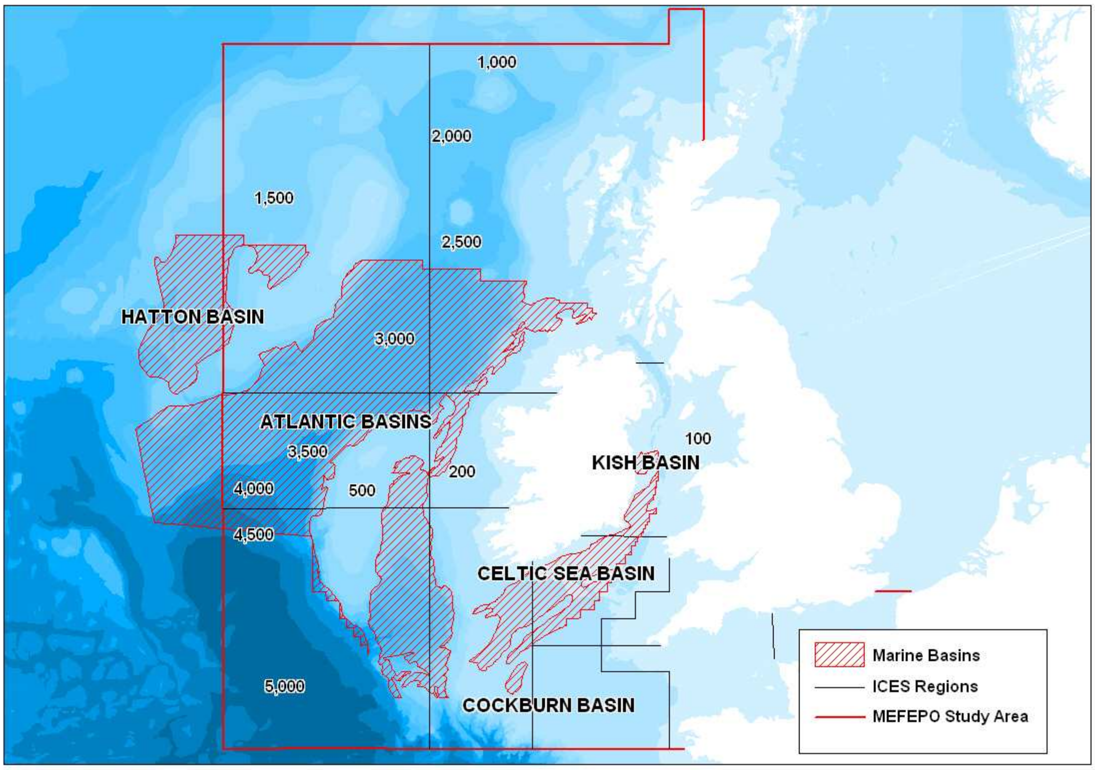


Figure 1.2.22 Marine basins within the MEFEPO Study Area (Source: Marine Institute).

1.2.1.5.1.1 Seabed Features

1.2.1.5.1.1.1 Seamounts

(EUNIS Code: A6.72; http://eunis.eea.europa.eu/habitats-code-browser.jsp)

Seamounts are underwater mountains, often of volcanic origin, which rise relatively steeply from the sea floor. The summits of seamounts are beneath the surface of the sea and they are defined as having a vertical elevation of more than 1000m with a limited extent across the summit region (White & Mohn, 2004). Seamounts can be found throughout the world's oceans and within the Atlantic, over 800 have been documented, many of which are associated with the Arctic Mid-Ocean Ridge, the Mid-Atlantic Ridge (MAR), and the Greenland-Iceland/Iceland-Faeroe Rise. Within the North Western Waters RAC, clusters of seamounts occur away from the MAR in areas around the Rockall Bank and Trough. (Gubbay, 2003). The locations of these seamounts are illustrated in Figure 1.2.23 and listed in Table 1.2.2 below.

Seamounts can be of varying size and shape. Flat-topped seamounts such as that at Anton Dohrn in the Rockall Trough are called guyots (or tablemounts). The flatness of their summits due to wind, wave and atmospheric erosion are evidence of the seamount having been above sea level at some stage. Others can be pinnacle or cone shaped (Rosemary bank), circular, elongated or elliptical (Hebrides Terrace) and can often have an associated moat (Rosemary Bank).

The structure of a seamount influences the dynamics of the surrounding environment. Physical features such as summit height and extent, summit depth, geographic location (latitude and distance from the continental shelf) and slope as well as physical processes such as water stratification and far field flows (stable or variable flow direction/strength) all play a part in the dynamics around seamounts (White & Mohn, 2004).

Hydrography around seamounts depends on current speed, stratification, latitude and the morphology of the seamount which can influence upwelling, eddy formation, internal wave formation and can cause Taylor columns. Taylor columns are closed circulation systems which form when eddies are trapped at the summit of seamounts. They are associated with upwelling of nutrient rich water from the deep ocean causing increased productivity and in addition are believed to trap the plankton over the seamount and retain the eggs and larvae of seamount fauna in the vicinity of the seamount rather than transporting them into the open ocean (Dower *et al.,* 1992)

As the currents around seamounts can be enhanced, and due to their volcanic origins, much hard substrate tends to be exposed on their flanks and summits which provides living space for many sessile filter-feeders such hard and soft corals (gorgonian, scleractinian and antipatharian corals), molluscs and crinoids. Concentrations of commercially important fish (such as the Orange Roughy, *Hoplosteuthus* atlanticus) gather around seamounts.

Table 1.2.2: Occurrence of seamounts in the North Western Waters RAC (source IOSEA; GSI data).

Seamounts	**Location and water depth**	**Description of features**
Hebrides Terrace	West of the Hebrides within the Rockall Trough, 1,650 to 2000m	An elliptical seamount approximately 40km by 27km with a minimum depth of 1000m. Deeper and closer to continental

		shelf than the other seamounts. Volcanic in origin.
Anton Dohrn Seamount	West of the Hebrides within the Rockall Trough, 600 to 2100m	A guyot (truncated cone shape) with an average diameter of 45km capped by a sedimentary layer approximately 100m thick which lies on the erosion surface of the guyot. A moat is present around the base. Seamount is volcanic in origin.
Rosemary Bank	120km west of the UK mainland in the northern Rockall Trough, 300 to 2,300m	Broadly conical and elongate with moat structures around it, ca 70 km diameter with area of 5400km^2. Summit covered in sediment with numerous pinnacles. Volcanic in origin
George Bligh Bank	North eastern margin of the Rockall bank,	With sculpted deeps (50-75m deep, 1-1.5km wide and 2->12km long) on the northern flank between 700 and 900m

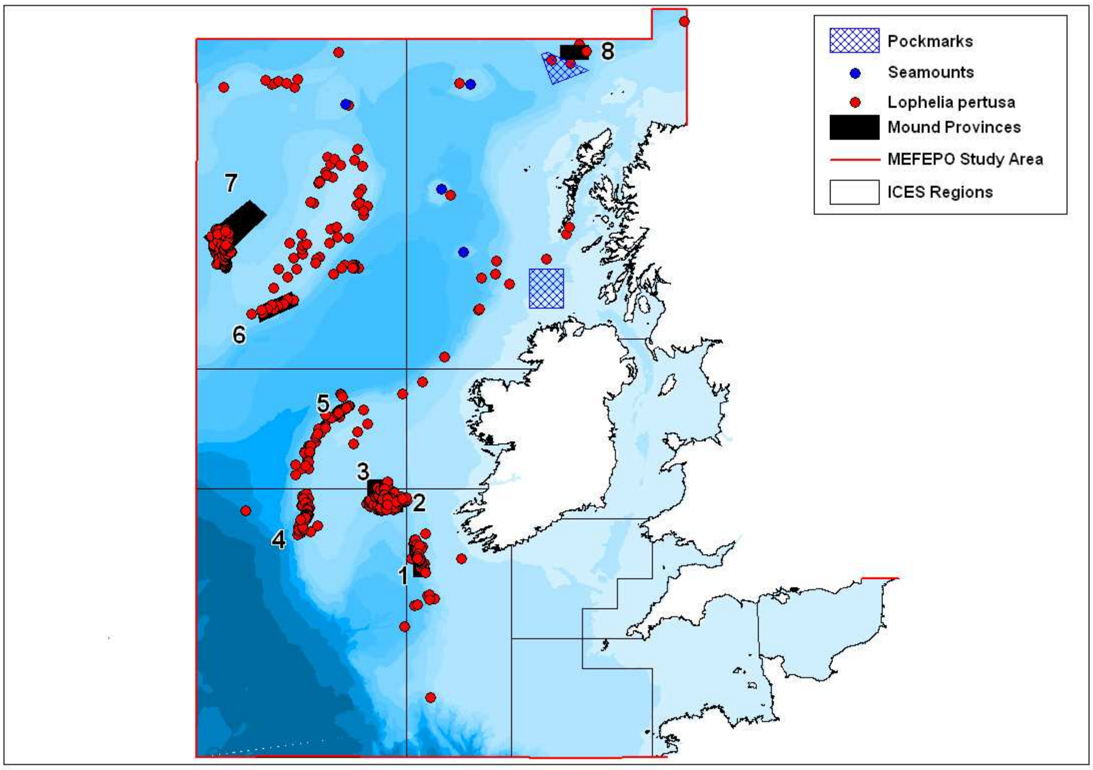


Figure 1.2.23: Location of *Lophelia pertusa*, seamounts, pockmarks and Mound Provinces. 1. Belgica Mound Province; 2. Hovlund Mound Province; 3. Magellan Mound Province; 4. Porcupine Bank Canyon Mounds; 5. Pelagia mounds; 6. Logachev mounds; 7. West Rockall Bank mounds; 8. Darwin Mounds (source: http://data.nbn.org.uk ; O' Reilly *et al.*, 2001; MacAodha *et al.*, 2005; WWF, 2001; GSI &PAD data; IOSEA3).

1.2.1.5.1.1.2 Coral Carbonate Mounds

(EUNIS code: A6.75 , http://eunis.eea.europa.eu/habitats-code-browser.jsp)

Within the last decade deep-water geographical surveys have identified regions with numerous seabed mounds on the continental slope within the North Western Waters RAC area. These features are known to be carbonate mounds and are formed from the accumulated growth over millions of years of cold water corals (in particular *Lophelia pertusa* and *Madrepora oculata*). They form by successive periods of coral reef growth, sedimentation and erosion, forming clusters or provinces in regions where specific hydrographic and food availability conditions favour coral growth. The locations of carbonate mounds in the NWW RAC are illustrated in Figure 1.2.23 and listed in Table 1.2.3 below.

The temperature range for cold water corals (such as *Lophelia pertusa* and *Madropora oculata*) is between 4º and 12º C. These conditions can be found in shallow waters at high latitude (~ 50 to 1,000m) and in very deep waters (up to 4,000m) beneath warm water masses at low latitudes (Murray Roberts *et al.*, 2006). They require a hard substrate to settle on and strong currents seem to be required for growth. The importance of current regime in shaping coral carbonate mound development has become apparent in recent years with evidence that the strongest near-bed current direction correlating with the orientation of mound clusters where enhanced diurnal tidal currents have been measured in the east Porcupine Seabight (Belgica Mounds) and south east Rockall Bank (Logachev mounds) (see Figure 1.2.23) (Roberts *et al.,* 2008).

Table 1.2.3: Occurrence of carbonate mound provinces in the North Western Waters RAC (source: IOSEA; GSI data; Expedition Scientists, 2005).

Carbonate Mound Province	**Location and Water depth**	**Mound characteristics**
Belgica Mounds	Eastern Porcupine Seabight	About 66 mounds (up to 166m high and mean width of 1100m) mapped of which 20 are buried mounds.
Hovland Mounds	Northern Porcupine Seabight, 600 to 800m	14 seabed mounds (mean width 1315m) and 27 large buried mounds (mean width 600m). average height of the seabed mounds is 200m
Magellan Mounds	Northern Porcupine Seabight, north and west of Hovland Mound province, 500 to 700m	>1,500 buried mounds (average width of 250m and a height of 70m) with a N-S elongated trend
Porcupine Bank Canyon Mounds	Western margin of the Porcupine ridge, associated with the Porcupine Bank Canyon, 700 to 1,100m	A dense association of conical mounds with occasional isolated ones with average height of 200m
Pelagia Mounds	Northern Porcupine Bank, 500 to 1,200m	Giant mounds (100 to >300m across and up to 250m high) ranging in shape from ovoid, to ridged shaped running sub-parallel to the isobaths, to complex forms and covering a few square kilometres

Logachev Mounds	Western margin of Rockall Trough, 500 to 1,200m.	A complex arrangement of mound clusters (diameters ranging from hundreds of metres to a few kilometres)
West Rockall Bank Mounds	Southwest of the Rockall bank, 550 to 850m	>1000 mounds. Generally relatively low conical mounds with occasional giant mounds (>200m high)

The Belgica mound province located on the eastern flank of the Porcupine Seabight (Irish continental slope), between 51°0′ N–51°36′ N and 11°30′ W–11°48′ W in water depths ranging from 550 m to 1,025 m. This cluster of partly buried and outcropping mounds has an elongated shape with an overall length of 45 km and a maximum width of 10 km (Fig. 6). The mound structures are associated with cold- or deep-water corals including *Lophelia pertusa* and *Madrepora* sp. (de Mol *et al.,* 2007) and have been designated as a Special Area of Conservation (see section 1.2.2.5 later). Small (tens of metres across and a few metres high), relatively young mound features (called the Moira mounds) are located in areas between the giant Belgica mounds and it is thought that they represent the early stages of mound development. These mounds occur in areas with active hydrodynamics where environmental conditions seem to be optimal for dense coral colonisation and contemporary coral growth (Wheeler *et al.,* 2005a).

The Hovland mound province is situated in the north of the Porcupine Seabight, between 52°06′N–52°22′N and 12°52′W–12°05′W (Figure 1.2.23) in water depths ranging from 500 to 1,000m. This site has also been selected as a Special Area of Conservation (see section 1.2.2.5 later). The seafloor in the region is cut by 6 depressions or blind channels (between 10 and 17km long) generally running north-south and are thought to be a result of current scouring by a northerly directed current (De Mol, 2002). Carbonate mounds have been identified around these channels.

The Magellan mound province is located directly to the north of the Hovland mound province between 52°12′N–52°38′N and 12°22′W–13°08′W (Figure 1.2.23) in water depths ranging from 250m in the north to more than 3000m at the mouth of the Porcupine Seabight (de Mol *et al*., 2002). Unlike other carbonate mound provinces, the majority of the Magellan mounds are buried although a few do reach the seabed (Huvenne *et al.,* 2007).

Pelagia Mound Province (Figure 1.2.23) is located on the north western edge of the Porcupine bank between 52°51′ 29.4′′N–53° 24′ 3.3′′N and 13° 49′ 17.6 W–14° 32′ 19′′W. The mounds here exist between 500 and 1200m deep in an area of the Bank where there are fast northerly currents. They occur downslope on a zone of iceberg ploughmarks and upslope of submarine canyons and slope failures. Numerous giant steep-sided cold-water coral carbonate mounds have been identified here (Kenyon *et al.,* 1998; Akhmentzhanov *et al.,* 2003; van Weering *et al.,* 2003; Wheeler *et al.,* 2005b). The cold- water coral mounds within the Pelagia province are generally between 100 and 300m in diameter and up to 250m tall with coral colonisation by *Lophelia* and *Madrepora* mainly restricted to their summits (Wheeler *et al.,* 2007). Further south from the Pelagia mounds, in a major area of canyon systems, are another cluster of giant carbonate mounds, the Porcupine Bank Canyon Mounds (Figure 1.2.23) located between 51° 54′ 35.3′′ N – 52° 42′ N and 14° 55′ 14.7′′ W – 15° 10′ 9.7′′ W. This area has been designated as a SAC – the South West Porcupine Bank SAC (see section 1.2.2.5 later).

Logachev Mound Province (Figure 1.2.23) exists on the south eastern Rockall Bank between 55° 16′N – 55° 35′ N and 16° 14′ W – 15° 13′W in seas between 500 and 1200m deep. This complex arrangement of coalescing mound clusters are aligned both up- and down- slope and are generally several kilometres long and up to 380m high (Mienis *et al.,* 2006; Akmetzhanov *et al.,* 2003; Kenyon *et al.,* 2003; Van Weering *et al.,* 2003a,b). The North East Atlantic Fisheries Commission (NEAFC) has closed an area over the Logachev mound to demersal fishing.

West Rockall Bank mounds province is situated around the west and south western slope of the Rockall Bank between approximately 56º 30′N -57º 15′N and 17º 30′W -16º 45′W (Figure 1.2.23) between 550 and 850m water depth. This area is also a NEAFC fishing area, which is closed to protect cold water corals.

1.2.1.5.1.1.3 Darwin Mounds

The Darwin mounds (Figure 1.2.23) are not formed by the accumulation of coral reefs. Instead they are small sand mounds (up to 5m high and ca. 70m in diameter) that are colonised by cold water corals (principally *Lophelia pertusa*). They lie approximately 185km to the northwest of Scotland within the Northeast Rockall Trough to the south of the Wyville Thompson Ridge (the centre of the site is located at 59º45'30" N, 07º-13'0" W) in waters of about 950m deep (Wheeler *et al.,* 2008). The site, which covers an area of around 100 km², has two main 'dense' fields referred to as Darwin Mounds East (ca. 13 km x 4 km with about 75 mounds) and Darwin Mounds West (ca. 13 km x 9 km with about 150 mounds). The hundreds of mounds present support large amounts of *Lophelia pertusa* and associated biodiversity, including sessile and hemi-sessile invertebrates and the giant protozoan xenophyophores (*Syringammina fragilissima* Brady, 1883) (De Santo & Jones, 2007). It is thought that the Darwin Mounds are sand volcanoes that resulted from fluidised sand "dewatering", possibly following sediment slumping on the south-west side of the Wyville Thomson Ridge (Gubbay *et al.,* 2002). No mounds of a similar type have been discovered elsewhere in the NWW RAC, although *Lophelia* has been found subsequently growing on sand at a site off Spain (Masson *et al.*, 2003) The occurrence of *Lophelia pertusa* reef as thickets capping sandy mounds is believed to be unique due to the particular geological processes which formed the mounds and the fact that the coral is growing on sand rather than a hard substratum (JNCC, 2008a; Masson *et al*, 2003). As such it has been selected as a candidate Special Area of Conservation under the Habitats Directive (see section 1.2.2.5).

1.2.1.5.1.1.4 Pockmarks

Pockmarks are small depressions associated with soft mud, which are thought to have formed at times of fluid/gas escape at the seabed. When associated with modern fluid/gas escape, they may contain carbonate material formed by the biogenic oxidation of methane (Hartley Anderson, 2005). Buoyant fluid movement in active pockmarks consists of mixtures of gas, sub-sea-bed liquids entrained with the ascendant gas and sea water entrained with gas and formation fluids. The sea bed is eroded into craters because the fluids entrain sediment grains into suspension and the grains are then transported away from the site of sea-bed fluid expulsion by near-bed currents. Pockmarks typically occur in fields with crater densities of 5-40 per square kilometre in muds, sandy muds and muddy very fine-grained sands (Holmes *et al.,* 2007). Certain types of pockmarks may qualify for protection as an EC habitats Directive Annex I habitat, *Submarine structures made by leaking gases*. Data on the presence and distribution of pockmarks in the NWW RAC is restricted largely to depths of less than 200m, although the ongoing INSS may improve this situation. Potential areas of pockmark activity have been observed in the northern and eastern Porcupine Seabight in the vicinity of the Hovland and Belgica mound provinces, but they are most abundant in the Connemara Field in the north of the Porcupine Basin and to the south of the Darwin mound province (Figure 6) (Games, 2001; Hartley Anderson, 2005; Huvenne *et al.,* 2003). The Darwin Mounds are thought to have a relationship with pockmarks. Masson *et al.,* (2003) proposed that the mounds might have a formed as a result of fluid escape and the eruption of sand on the seafloor and that their higher elevation above the seafloor would have attracted coral colonisation. A newly discovered pockmark field has been discovered on the Malin Shelf to the north of Ireland Within this area (55º 30’ N to 56 º 10’N; 7 º 30’W to 8 º 30’W) the pockmarks are distributed in clusters and number about 220 (Garcia *et al.,* 2007). Their occurrence has also been linked to the presence of iceberg ploughmarks in the area (Excerpt from ERT & Aquafact, 2007).

1.2.1.5.2 Temperature and hydrography

1.2.1.5.2.1 Temperature

Figure 1.2.24 shows temperature data locations from 1994 to 2007 taken from the Lough Beltra (1994 to 1998), the Celtic Voyager (1999 to 2007) and the Celtic Explorer (2003 to 2007). In addition, there are 6 weather data buoys located around the Irish coast (M1, M2, M3, M4, M5 and M6). The temperature data seen in the subsequent figures below is mapped seasonally (Spring: March, April, May; Sumer: June, July, August; Autumn: September, October, November; Winter: December, January, February). Given the nature of the weather buoy data, it would not have been accurate to average the point data over a three month period and for this reason the buoy data has not been included in the maps below. The same applies for the salinity maps.

Figure 1.2.25 to 1.2.27 show monthly data for 2004, 2005 and 2006 from both the Celtic Explorer and Celtic Voyager.

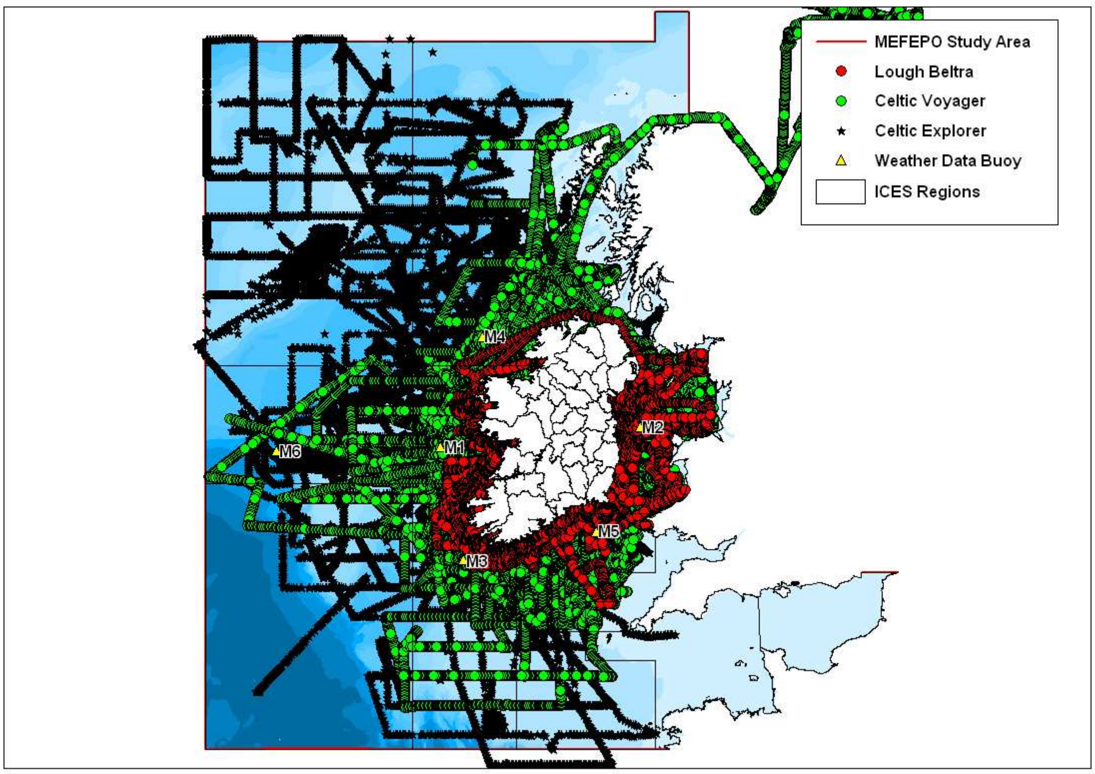


Figure 1.2.24: Celtic Voyager (1999-2007), Celtic Explorer (2003-2007), Lough Beltra (1994-1998) temperature data and weather data buoy locations (Source: Marine Institute).

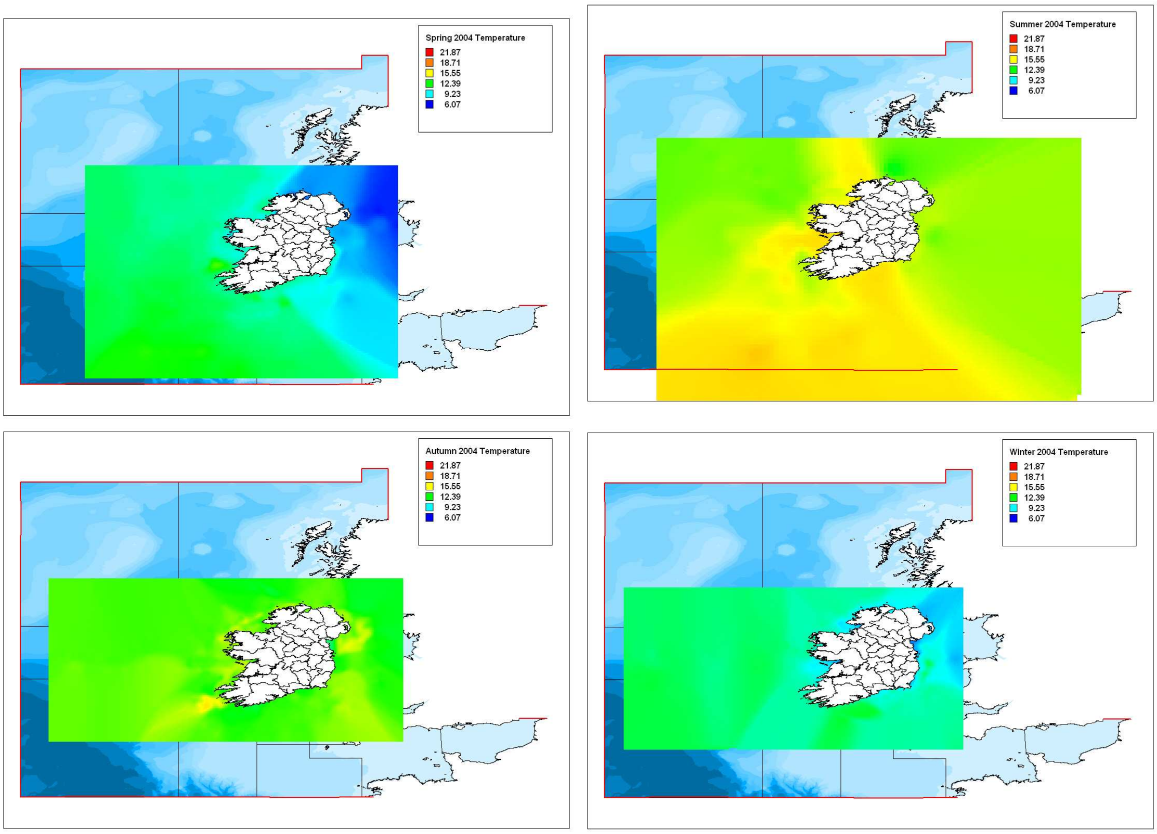


Figure 1.2.25: Seasonal temperature data 2004 (Source: Marine Institute)

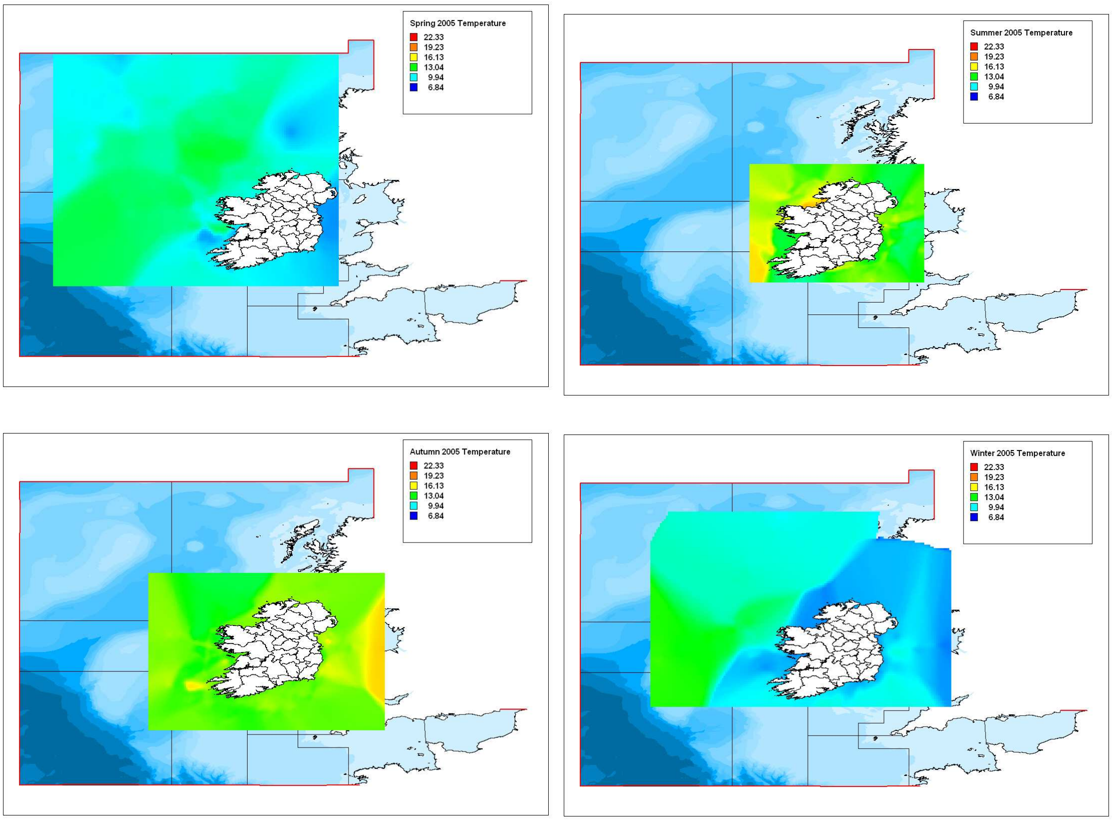


Figure 1.2.26: Seasonal temperature data 2005 (Source: Marine Institute)

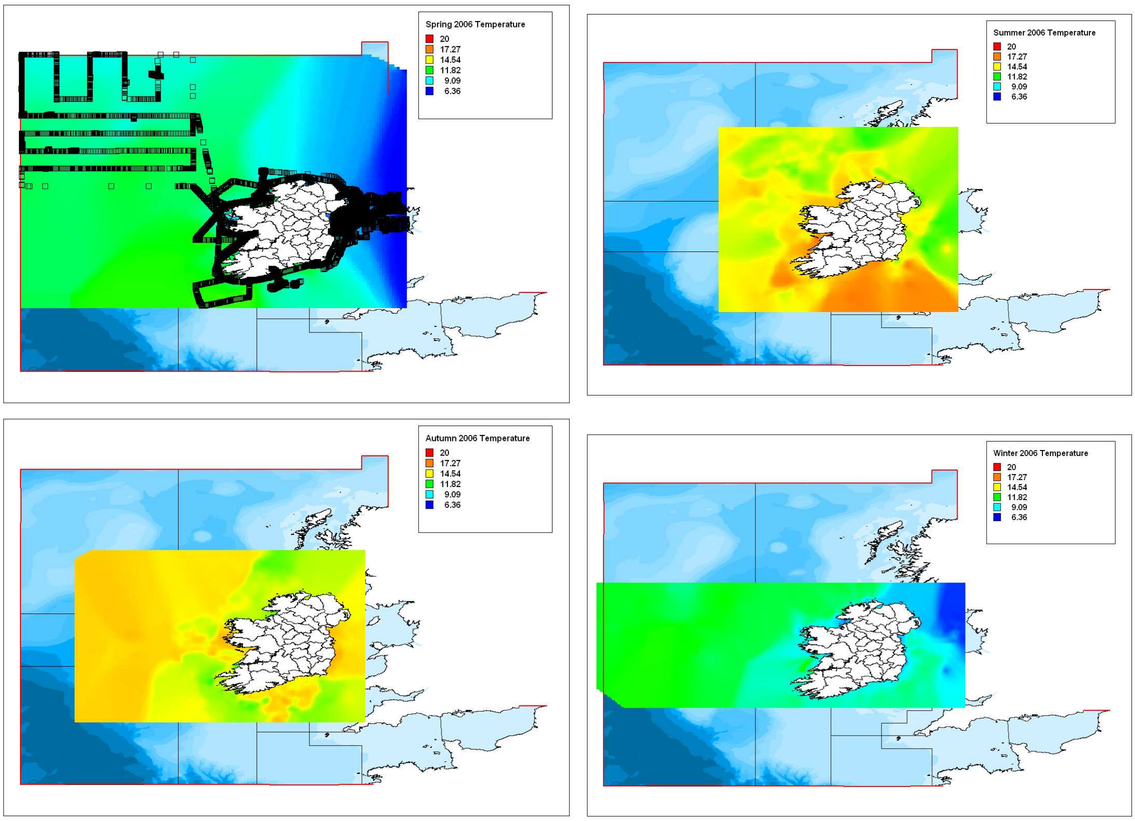


Figure 1.2.27: Seasonal temperature data 2006 (Source: Marine Institute)

1.2.1.5.2.2 Hydrography of OSPAR Region V (Wider Atlantic)

Ocean currents are primarily driven by surface winds and latitudinal differences in heat input and the balance between rainfall and evaporation. They are modified by the earth's rotation (Coriolis Effect) which in the northern hemisphere deflects their flow clockwise.

Upper layer circulation

The upper layer circulation in the NWW RAC is dominated by the North Atlantic Current (NAC) which is formed from the northern slit of the Gulf Stream at Newfoundland and the Northwest European slope current or Shelf edge current (Figure 1.2.28) which flows poleward along the continental margin which declines in flow northwards until it is supplemented by a branch of the NAC. The slope current has a major impact on the biology of the shelf-break and contributes to the formation and maintenance of the shelf-break front (OSPAR, 2000a).

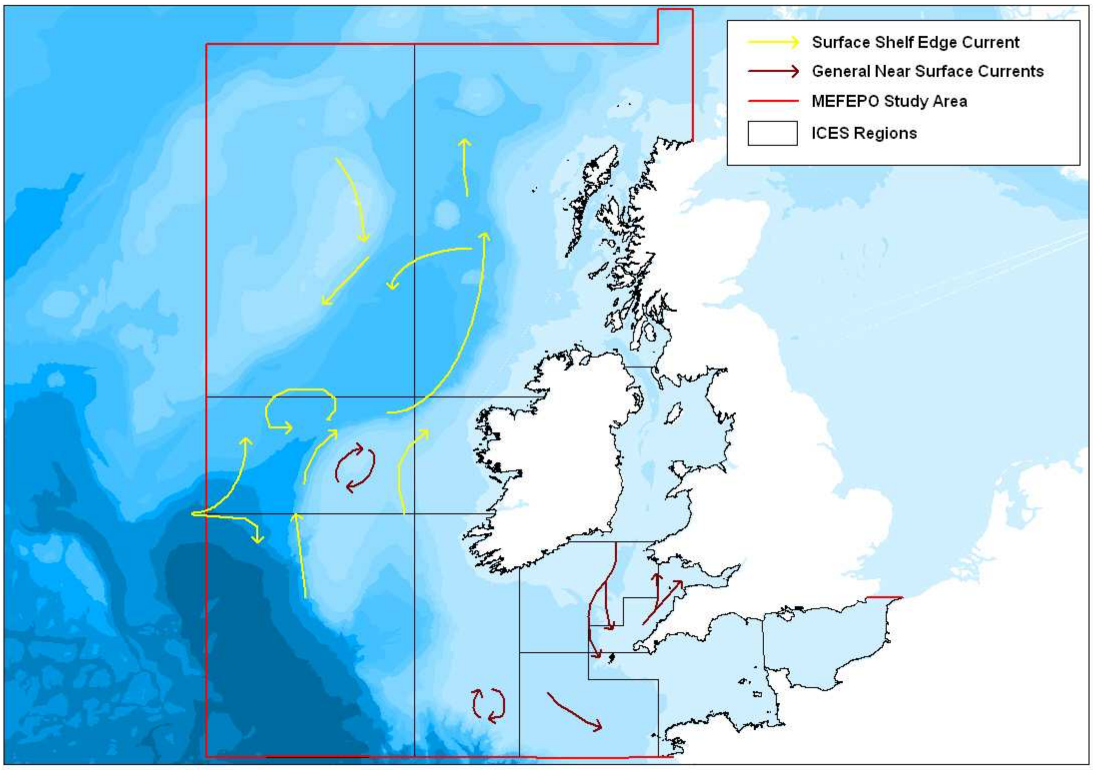


Figure 1.2.28: Surface and near surface currents in the NWW RAC (source M. White pers. comm..; OSPAR, 2000).

Mid Depth Water Masses

Labrador Sea Water (LSW)

During winter in the Labrador Sea, severe cooling of the upper layers of water makes them unstable and storms result in extensive convection to considerable depths. The sinking of the surface cold water to depth is compensated for by relatively warmer salty deep water being moved towards the surface. The characteristic properties of LSW (about 3.4° C and 34.9S) makes it the coldest, freshest and most highly oxygenated water mass at intermediate depth in the North Atlantic. It generally circulates around the sub-polar gyre, passing through the Newfoundland and Irminger Basins flowing either directly southwards, or north-eastwards entering the Icelandic and North European Basins. The general circulation of LSW within the NWW RAC can be traced by its salinity and density and is depicted in Figure 1.2.29 below (White, pers comm.; New & Smythe-Wright, 2001). Within the Rockall Trough area LSW can be found at depth between 1700m and 2200m with a strong cyclonic gyre in the central Rockall Trough with flow speeds up to 7cm s^{-1} which is fed from the south west by an inflow along the

54°N, and from the north by overflows from the Wyville-Thomson Ridge along the 12°W. The inflow of relatively fresh LSW from the west along 54°N occurs almost directly below the inflowing surface waters of the Shelf Edge Current and impacts on the northwestern Porcupine Bank. Much of the LSW turns to the southwest and some moves northwards into the Trough and feeds the central gyre (New & Smythe-Wright, 2001).

Mediterranean Water (MW)

Mediterranean Water (Mediterranean Overflow Water) is a thin, narrow intense current that spills over the Strait of Gibraltar sill. Although its properties change rapidly as it becomes diluted due to mixing and entrainment while flowing along the northern Gulf of Cadiz shelf slope, the MOW remains well defined as a deep, warm salty current between 1000 m and 1200 m depth all around the Atlantic coast of the Iberian Peninsula, and its deep water mass signature is seen over much of the central North Atlantic Ocean basin (Dietrich *et al.,* 2008; Curry et al., 2003). It is dense because of its high salinity and it is much warmer than the ambient North Atlantic Central water near the 300–400m depth sill level (Levitus & Boyer, 1994). Most of the MOW flows north into OSAPR region IV where it spreads into region V (Figure 1.2.29). Some can be traced moving northwards parallel to the Iberian Peninsula and spreading to higher latitudes. By the time it reaches the Rockall Trough its salinity maximum is no longer so pronounced so that further to the north west it competes with LSW coming from the western basins at slightly deeper depths (OSPAR, 2000a; Paillet & Arhan, 1996).

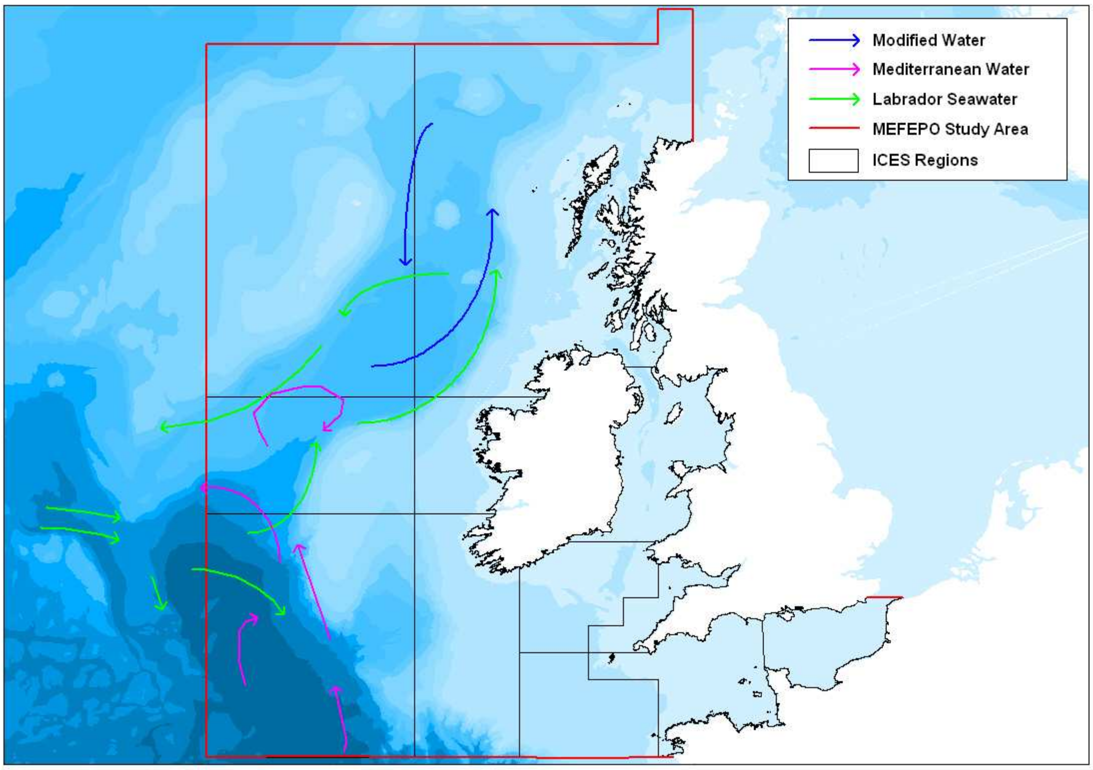


Figure 1.2.29: Mid-depth Water Masses in the NWW RAC (source M. White pers. comm.; OSPAR, 2000).

Deep Water Masses

North East Atlantic Deep Water can be identified in the Rockall Trough by its salinity maximum near 2500m. It is thought that the NEADW in the southern Rockall area could be formed (at least partially) by overflows of saline water masses from the Nordic Seas which cross the Iceland-Scotland Ridges and circulate southwards down the western side of the Hatton and Rockall Banks (Figure 1.2.30) (Ellett & Martin, 1973; Ellett *et al.,* 1986; New & Smythe-Wright, 2001). These flow patterns are similar to those for the LSW which occur higher in the water column.

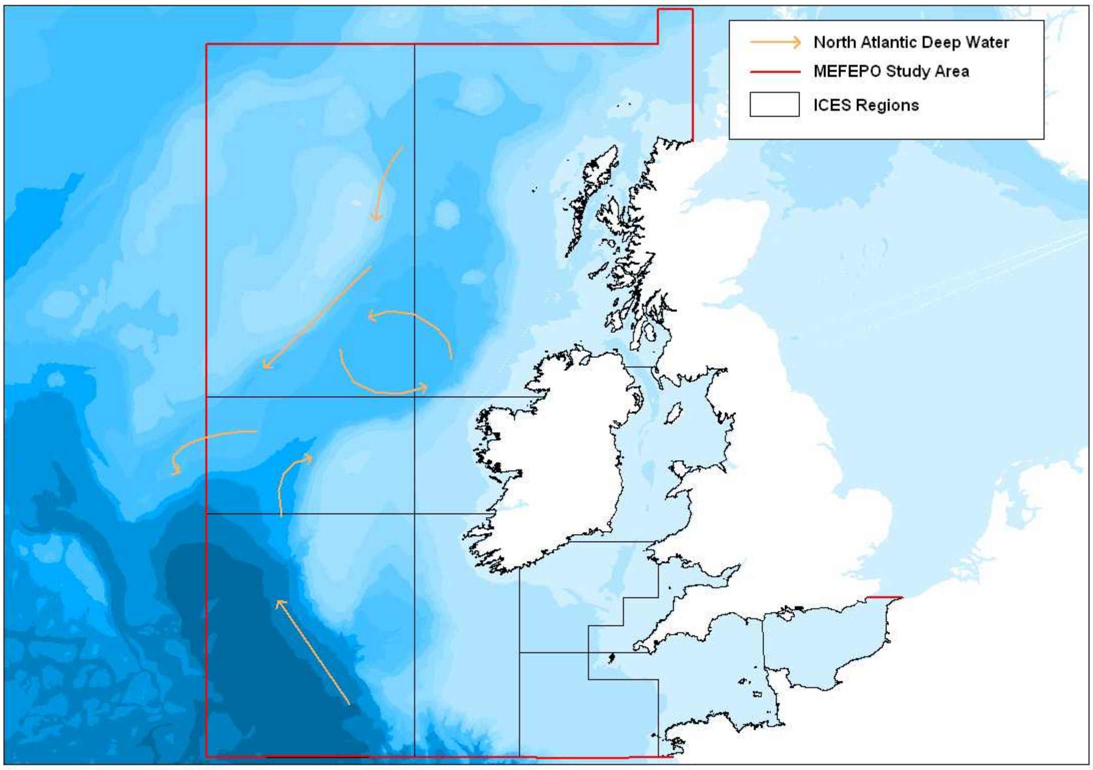


Figure 1.2.30: Deep water masses in the NWW RAC (source M. White pers. comm.; OSPAR, 2000).

1.2.1.5.2.3Hydroggraphy of OSPAR Region III (Celtic Seas)

(from OSPAR 2000b)

OSPAR Region III extends from oceanic conditions at the shelf break to the west, through the relatively shallow semi-enclosed Irish Sea, to the estuarine and fjordic inlets of the UK on its eastern boundary. The Irish Sea and Celtic Sea hydrography and circulation will be examined in detail below. In very general terms the overall water movement is from south to north, with oceanic water from the North Atlantic entering from the south and west of the region and moving northwards through the area, to exit into Region I (Arctic Waters) to the north or, after flowing around the north of Scotland, to enter Region II (the Greater North Sea). There are however, complex intermediate water movements, particularly within the Irish Sea (see below). The numerous offshore islands of the Malin Shelf tend to shelter the Scottish mainland from the extremes of the generally westerly airflow and also tend to segregate the northward flow of water out of the Irish Sea from the oceanic current to the west

The general pattern of salinity distribution derived from long-term data sets shows that, in winter, near shore salinities to the west of Ireland and eastwards to approximately 8° W, average 35 or greater, indicating the water is mainly of Atlantic origin. In summer the 35 isohaline moves offshore and a band of surface water in the range 34.5 – 35.0 surrounds the Atlantic and Celtic Sea coast of Ireland. Surface salinities increase steadily towards the open ocean reaching approximately 35.5 at the shelf break. Partly due to lack of data, the general pattern of bottom water salinities is more difficult to define, but there is a tendency for Atlantic water to extend somewhat further eastwards at the bottom than at the surface. This results in pronounced vertical salinity gradients, especially in early summer when warmer stratified water overlies the cooler mixed Atlantic water.

On the Malin Shelf off Scotland there are three water masses. The main body originates in the North Atlantic and has a salinity > 35.0. Water flowing north out of the Irish Sea has a salinity that is normally 34.0 – 34.5 and inshore of this lies coastal water with an even lower salinity due to land run-off. These three water masses also show different seasonal variations in temperature; the Atlantic water temperature ranges from 8 to 13 °C, whereas the inshore waters range from 6.5 to 13 °C and in sea lochs the range can be even greater. In the Malin Sea area haline stratification is relatively weak. However, as in the Irish Sea, stratification due to surface heating develops over much of the Malin Shelf during late spring and summer. In the Atlantic water zone the thermocline is very marked (4 – 5 °C temperature difference) and usually lies at 30 – 50 m. Inshore the temperature difference between surface and bottom waters is less and in the Minch and Sea of the Hebrides the water column may remain mixed even in summer, leading to the development of fronts. Fronts tend to inhibit lateral dispersion and are often marked by along-front currents and a high phytoplankton standing crop. The Islay front, which runs from Tiree to Malin Head, separating the Atlantic water from Irish Sea water and deflecting the latter into the Sea of the Hebrides, is a typical example and has an along-front current of 20 cm/s. Sea surface temperatures on the shelf, both to the west and south of Ireland, are several degrees warmer in winter than those found in the comparatively shallow Irish Sea, which loses heat more rapidly than the waters west of Ireland and Scotland, that are both deeper and influenced by warmer Atlantic water derived from the North Atlantic Drift. During the summer, bottom temperatures in stratified areas may be 5 – 6 °C cooler than the overlying surface water. Frontal systems tend to develop in late spring at the confluence of mixed and stratified areas, for example the Celtic Sea front (see below) to the south of the Irish Sea and the Irish Shelf front to the west of Ireland. These break down with the onset of winter cooling and increased wind-induced mixing. Stratification also occurs in the Irish Sea, especially to the west of the Isle of Man where the water is deeper and the tides weaker than to the east of the island. This stratification is due primarily to the strong temperature differences that develop between surface and bottom waters because the tides are not strong enough to cause mixing throughout the water column. The resultant thermocline lies between 20 and 40 m depth depending on the year and breaks down in autumn and rebuilds in spring.

The long inlet of the Bristol Channel between south Wales and the south-west of England peninsula, is exposed to the mainly south-westerly winds from the Atlantic and strong tidal flows (the tidal range being among the largest in the world e.g. 12 m at Avonmouth near Bristol). As a consequence there is intense vertical mixing throughout the estuary east of 5° W. There is substantial freshwater input to the Bristol Channel from the River Severn, accounting for 60% of the total freshwater input at the extreme east of the inlet, and the Welsh rivers to the north account for a further 30%. The consequence is that salinity throughout the area is typically < 35 with a clear north-south gradient. West of about 5° W stratification does occur in summer months with surface waters reaching 17 °C or more and waters below the thermocline remaining < 11 °C.

IRISH SEA

The principal driving forces for the movement of water are tides, weather and density differentials (Bowden, 1980). Tidal movement is the most energetic and the large spatial variation in the amplitude of the tidal current determines many of the processes and distributions within the Irish Sea. (Boelens *et al.* 1999). Cumulatively, wind-related movement caused by surface waves (with periods of 3-15s), inertial currents (with periods of approximately 15h), storm surges (with periods of 2-10 days) and residual (long-term) currents (at periods of 1-10 days) contribute to the overall long-term (>2 months) mean circulation of the region. In general, the weakest response is to water density differences between the saline oceanic inflows and freshwater inputs from rivers. Although the resulting currents are weak the density effects are persistent and make a major contribution to the residual flow, especially in the eastern Irish Sea. More notable are strong, persistent circulations associated with summer heating and stratification of the water column, particularly in the deep basin of the western Irish Sea.

The tide propagates into the Irish Sea from the Atlantic Ocean through St. George's Channel and the North Channel (Robinson, 1979). The tidal waves from both directions meet to the south west of the Isle of Man, causing this to be an area of very weak tidal currents (<35 cm/s). The majority of the tidal energy flux (water volume) into the Irish Sea is through St. George's Channel. This is largely dissipated in St. George's Channel, off Anglesey and off the Mull of Galloway, where tidal currents are strong and peak flows exceed 120 cm/s. The configuration of tides means that the tidal range is less on the Irish Side (Sager, 1963). The maximum range occurs on the Lancashire and Cumbrian coasts where the mean spring range is 8m, compared to for example, Carnsore Point on the Irish coast where the mean tidal range is 1.75m. In shallow waters, sudden changes in bathymetry and/or topography may generate locally high velocities near headlands, islands and estuaries. Tidal amplitudes are greatest west of the Isle of Man and west of Morecambe Bay.

Storm surges are manifested by water piling up at the coast through the combined actions of wind and atmospheric pressure variations (Boelens *et al.* 1999). The largest surges in the Irish Sea are generally associated with storms tracking eastward between Inverness and Shetlands. Maximum surge levels of about 2m are predicted to occur on the Lancashire and Cumbrian coast and levels between 1.25 and 0.75m are predicted to occur on the Irish coast and across St. George's Channel (Flather, 1987). As the Irish Sea is semi-enclosed the associated currents are weak, arising both directly from wind drag at the sea surface and indirectly from sea surface gradients. The former are limited to a surface layer about 10m in depth and have a maximum speed at the surface of about 3% of the wind speed (Brown, 1991). The latter are predicted to have a maximum depth-mean current away from the coast of 50 cm/s (Flather, 1987). Their direction is largely determined by topography rather than by the wind.

At time scales of several days, meteorologically induced flow, which may result from depressions for example, may have a dramatic effect on the transport of material and the remobilisitation and fate of sediments (Boelens *et al.* 1999). However, such events are inherently unpredictable and incoherent, although the long term mean circulation is often said to be driven by the cumulative effects of such events (e.g. Prandle, 1984). Largely on the basis of tracer budgets, the net long-term circulation through the Irish Sea is characterised as weakly northward at speeds of typically 1-2 cm/s (Wilson, 1974; Bowden, 1980).

In the western Irish Sea, the combination of deep water and weak tides means that this area stratifies (surface warm water – bottom cold water) during the spring and summer heating cycle. The upper water becomes separated from deeper layers by a strong thermocline at 20-40m depth, whilst the boundary with vertically well mixed waters is marked by a surface front. In the deep basin of the western Irish Sea a dome shaped pool of cold water sites below the thermocline and is separated from the surrounding waters by strong temperature gradients (fronts). These fronts drive strong narrow (~10km) currents, which dominate the region in the summer months (Hill *et al.* 1994; Hill, 1996; Hill *et al.* 1997). Flows at the core of these currents exceed 20cm/s and the circulation acts to retain material in the region (Brown *et al.,* 1995; Hill *et al.* 1996). Following the breakdown of stratification in autumn, the mean flow is then weakly northward until the following spring.

Thermal stratification in Cardigan Bay, areas of Liverpool Bay and the northeastern Irish Sea during summer is transient and its strength and duration depend on periods of low wind mixing. The temporary nature of this stratification means that it plays little part in determining the residual circulation, particularly in Cardigan Bay. However, in the shallow waters of Liverpool Bay, discharges from the Rivers Dee, Mersey, Lune and Ribble and resulting horizontal and vertical density gradients, play a significant part in controlling stratification and the overall pattern of low frequency flow. Further north in the eastern Irish Sea, low frequency flow is highly correlated with wind stress (Howarth, 1984). However, radio-nuclide distributions arising from the Sellafield discharge (Jefferies *et al.,* 1982; Leonard *et al.* 1997) clearly demonstrate a long term mean northward flow bordering the coastline and exiting through the North Channel. In the vicinity of Sellafield, depth mean tidal residual flows indicate a weak (>2.5 cm/s) flow to the southeast running parallel to the coast (Aldridge & Davies, 1993; Howarth, 1864). The cumulative effect of short term depressions and horizontal density gradients is to produce an overall north-westward flow.

Mean flow through the North Channel is northwards with a volume transport of approximately 100,000m^3/s (Howarth, 1982; Brown & Gmitrowicz, 1995) occurring as a series of pulses in response to the effects of far field, as well as direct, wind forcing. Extreme wind events may induce flows throughout the water column of up to 50cm/s for periods of several days (Howarth *et al.* 1995). Overall outward flow is strongest on the eastern side of the channel but there is evidence of a weaker return flow along the Irish coast. Freshwater discharge from the east coast of Ireland might be expected to have a role in determining residual flow. There is little direct evidence of a persistent southward flowing current, perhaps because of insufficient observations and perhaps because the volume of discharge is too little and episodic. However, the buoyancy of the freshwater associated with the Irish coastal zone can play a part in assisting in the initial formation of stratification in the north-western Irish Sea in spring and early summer (Dickie-Collas *et al*., 1997).

Fringing the eastern Irish Sea are a series of shallow estuaries and embayments, the largest of which are the marco-tidal estuaries of the Solway Firth and Morecambe Bay (Aldridge, 1997) with extensive areas of intertidal mudflats. Both areas are relatively open to wave action and the impact of storm surges and these cause significant sediment resuspension. At spring tides, the tidal range and currents exceed 9m and 130 cm/s, respectively. In Morecambe Bay tidal transport plays a dominant role in transporting material and the direction is controlled by asymmetry between the flood and ebb tides.

Figures 10 to 13 show the seasonal water bodies within the Irish Sea. These maps were reproduced from data downloaded from the UKSeaMap interactive web based mapping system (Connor *et al*., 2006). The UKSeaMap project follows on from the Irish Sea Pilot study (ISP), which tested a regional seas approach to marine conservation management (Vincent *et al.*, 2004). Part of the ISP investigated the concept of 'marine landscapes' (coastal, seabed and water column) and their ecological relevance (Golding *et al.*, 2004). For the ISP, water column marine landscapes were based on two 'model derived', raster datasets for salinity and stratification (both supplied by Proudman Oceanographic Laboratory). The datasets used to define water column characteristics were surface salinity, surface to bed temperature difference and frontal probability.

Salinity was selected as the initial classification parameter used for generating water column types, as it has a major role in determining biological character, varying from inshore estuarine and coastal conditions through to fully saline oceanic waters.

The following categories in the salinity data were adopted:

- Estuarine (<30‰)
- Coastal or Region of Freshwater Influence (ROFI) (>30‰, but <34‰)
- Shelf (>34‰, but <35‰)
- Oceanic (>35‰)

Surface to seabed temperature difference data has been used to distinguish three classes which reflect the degree of stability in the water column, namely thermally stratified and well-mixed waters on the continental shelf, together with an intermediate transition zone.

Fronts are an important zone of rapid change in hydrographic and biological character, often separating shelf sea regions from the open ocean. Front probability data was therefore included in the water column classification process to illustrate the likelihood of a front being present within a particular area. Table 1.2.4 shows the classification of water column features and their main characteristics.

Table 1.2.4: Classification of water column features.

Water Column Type	*Salinity (‰)*	*Surface to Seabed Temperature*	*Fronts (% probability)*

		Difference (°C)	
Estuarine Water	Estuarine (≤ 30)		
Well-Mixed ROFI	ROFI (>30 and ≤ 34)	Well-Mixed (≤ 0.5)	
Weakly-Mixed ROFI	ROFI >30 and ≤ 34)	Frontal (> 0.5 and ≤ 2.0)	No Front (≤ 0.15)
Frontal ROFI	ROFI >30 and ≤ 34)	Frontal (> 0.5 and ≤ 2.0)	Front (> 0.15)
Stratified ROFI	ROFI >30 and ≤ 34)	Stratified (>2.0)	
Well-Mixed Shelf Water	Shelf (>34 and ROFI >30 and ≤ 34) 35)	Well-Mixed (≤ 0.5)	0
Weakly-Stratified Shelf Water	Shelf (>34 and ROFI >30 and ≤ 34) 35)	Frontal (> 0.5 and ≤ 2.0)	No Front (≤ 0.15)
Frontal Shelf Water	Shelf (>34 and ROFI >30 and ≤ 34) 35)	Frontal (> 0.5 and ≤ 2.0)	Front (> 0.15)
Stratified Shelf Water	Shelf (>34 and ROFI >30 and ≤ 34) 35)	Stratified (>2.0)	
Well-Mixed Oceanic Water	Oceanic (>35)	Well-Mixed (≤ 0.5)	0
Wealky-Stratified Oceanic Water	Oceanic (>35)	Frontal (> 0.5 and ≤ 2.0)	No Front (≤ 0.15)
Frontal Oceanic Water	Oceanic (>35)	Frontal (> 0.5 and ≤ 2.0)	Front (> 0.15)
Stratified Oceanic Water	Oceanic (>35)	Stratified (>2.0)	

In spring (Figure 1.1.4) the majority of the Irish Sea is well mixed. There is well mixed shelf water (salinity >34 to ≤ 35‰, temperature difference ≤0.5°C) extending from the Celtic Sea, through St. George's Channel and up past Anglesey. This water body also enters the North Channel from the Malin Sea. There is well-mixed ROFI waters (salinity >30 and ≤ 34‰, temperature difference ≤0.5°C) along the east coast of Ireland, in Cardigan Bay and up along the west coast of Britain, around the Isle of Man and into the North Channel. There is a small body of weakly-stratified ROFI (salinity >30 to ≤ 34‰, temperature difference >0.5°C and ≤ 2.0) along the south coast of Ireland which extends from the Celtic Sea.

In the summer months (Figure 1.2.32) a number of frontal systems develop. A frontal ROFI system (salinity >30 to ≤ 34‰, temperature difference >0.5°C and ≤ 2.0) develops in the North Channel and extends down the Irish east coast to Co. Wicklow and down past the west coast of the Isle of Man where it links in with a frontal shelf water system (salinity >34 to ≤ 35‰, temperature difference >0.5°C and ≤ 2.0), which extends south past Anglesey. Another frontal ROFI system develops along the south coast of Ireland as well as a frontal shelf water system extending from the Celtic Sea into St. George's Channel (see below). The remainder of St. George's Channel is well mixed (salinity >30 and ≤ 34‰ and >34 to ≤ 35‰, temperature difference ≤ 0.5°C) and this extends up to Co. Dublin along the east coast of Ireland and up to Scotland along the west coast of Britain. There are a number of bodies of weakly stratified ROFI (salinity >30 and ≤ 34‰, temperature difference > 0.5°C to ≤ 2.0°C), in the North Channel and east of the Isle of Man and there is stratified shelf (salinity >34 and ≤ 35‰, temperature difference > 2.0°C) and ROFI (salinity >30 and ≤ 34‰, temperature difference > 2.0°C) waters west of the Isle of Man, off the east coast of Ireland extending from Co. Down to Co. Wicklow.

By Autumn (Figure 1.2.33), the frontal systems (salinity >34 to ≤ 35‰, temperature difference >0.5°C and ≤ 2.0) have broken down except for the frontal shelf waters in St. George's Channel. Accompanying this front is a small body of weakly stratified shelf water (salinity >34 and ≤ 35‰, temperature difference > 0.5 and ≤ 2.0°C). The remainder of the Irish Sea is made up of well mixed ROFI and shelf waters.

In Winter (Figure 1.2.34), the water column is quite similar to the Autumn months, except with the notable absence of the frontal system in St. George's Channel.

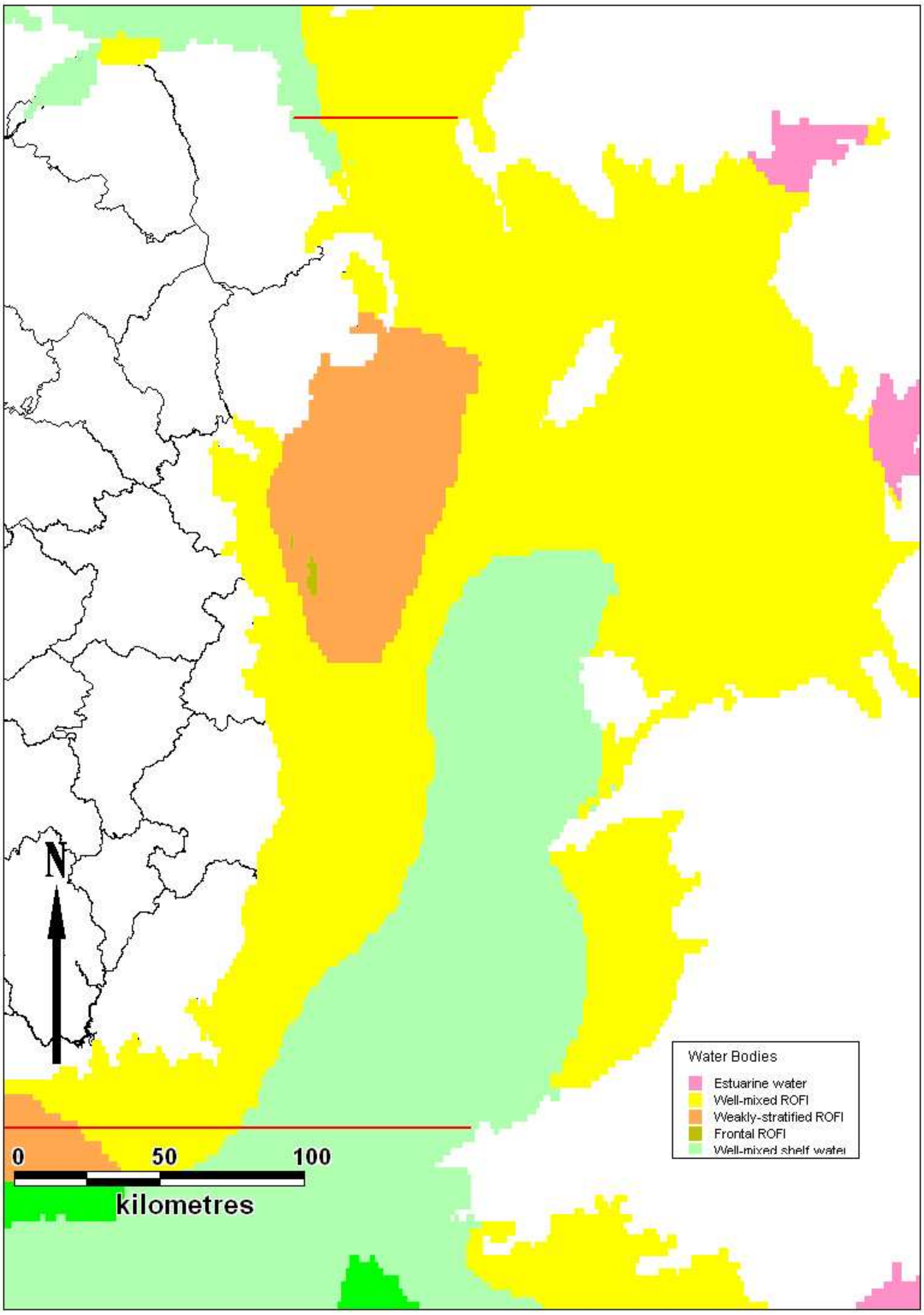


Figure 1.2.31: Irish Sea Spring Water Bodies (source: UKSeaMap project)

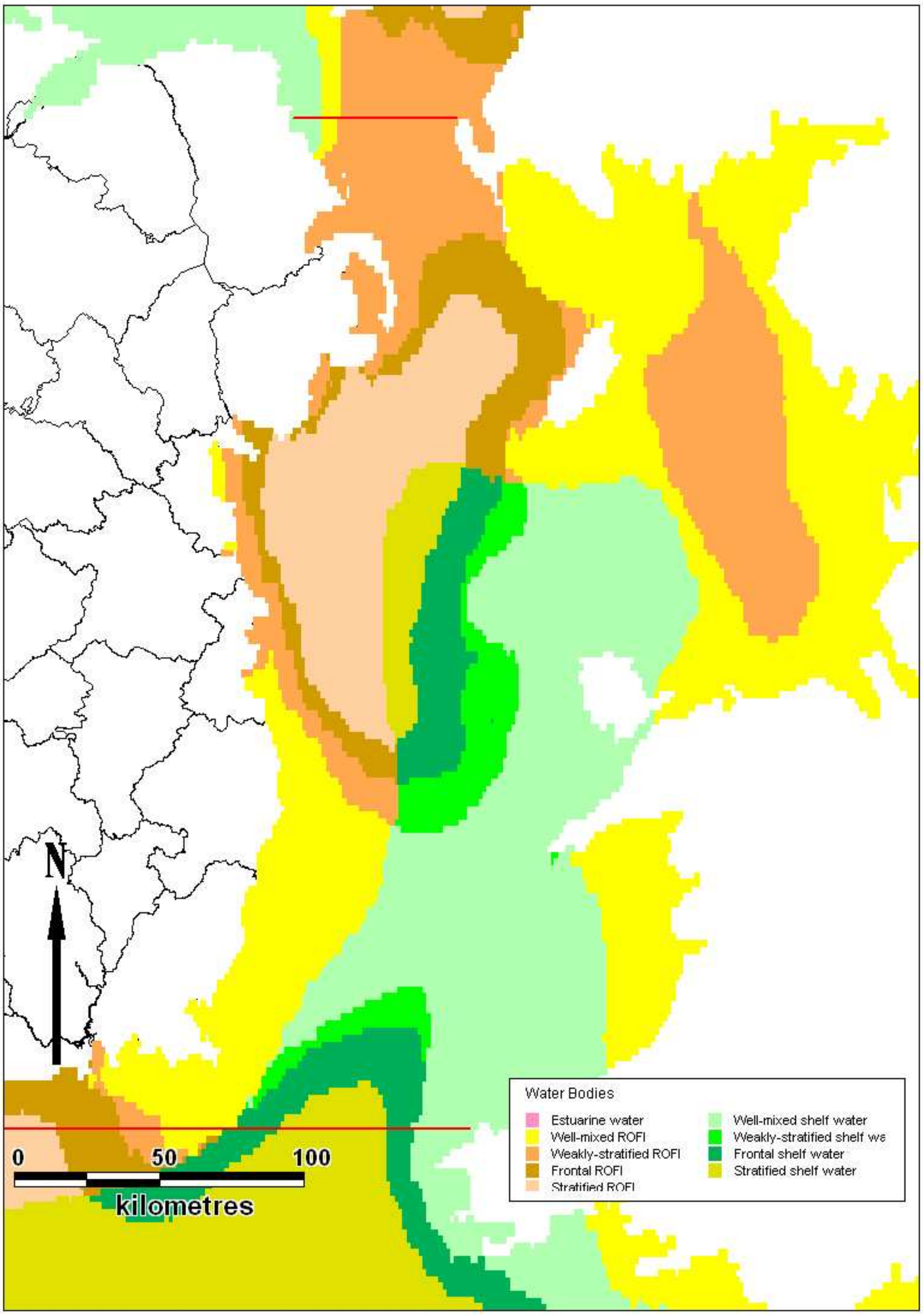


Figure 1.2.32: Irish Sea Summer Water Bodies (source: UKSeaMap project).

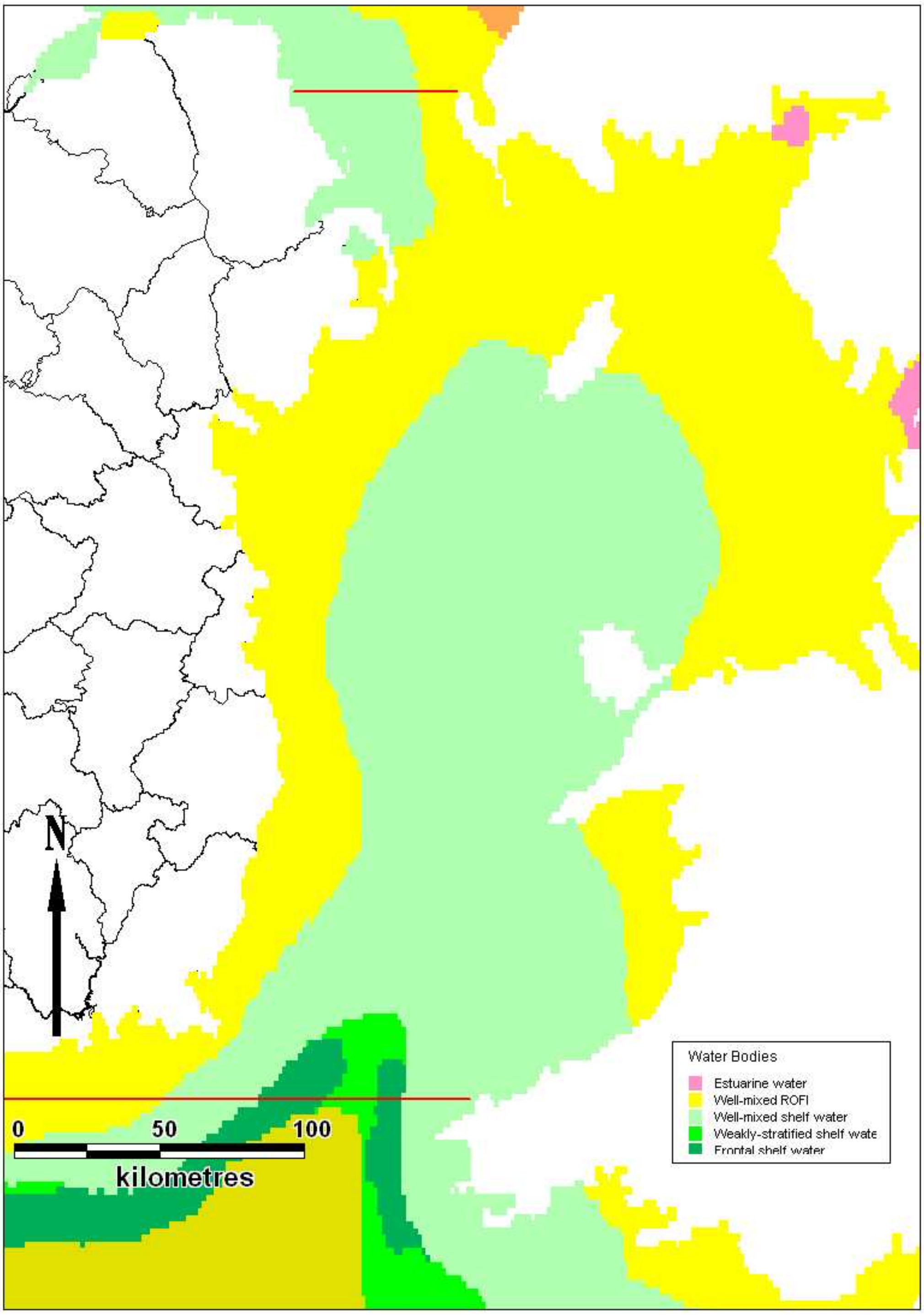


Figure 1.2.33: Irish Sea Autumn Water Bodies (source: UKSeaMap project).

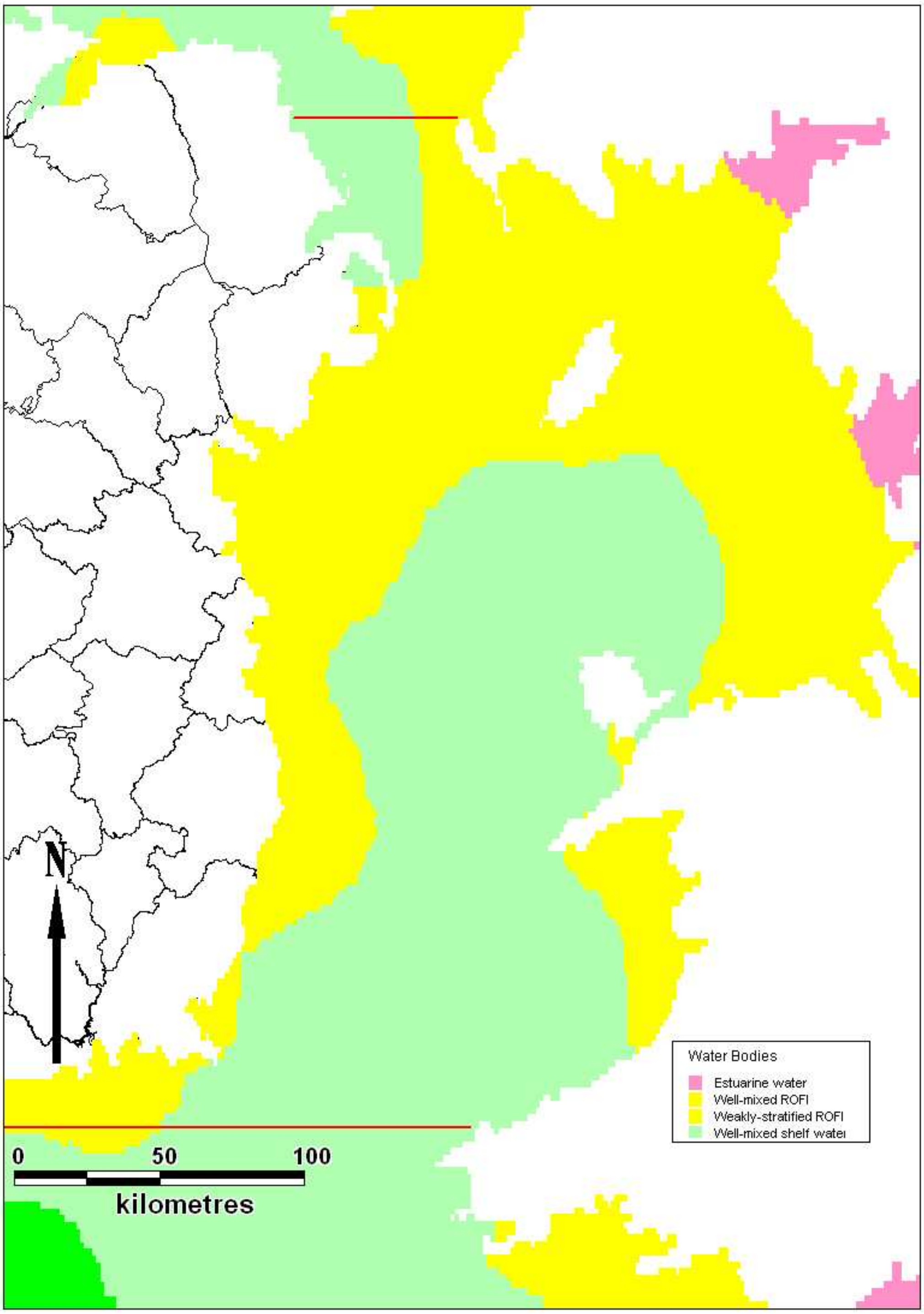


Figure 1.2.34: Irish Sea Winter Water Bodies (source: UKSeaMap project).

CELTIC SEA

The Celtic Sea (located in the North Atlantic between southern Ireland and southwest England approximately between 48° and 51.5° N latitude and 5° and 12° W longitude) is an extended shelf within which most of the area is shallower than 100m. A deep trough, the Celtic Deep, exceeds 130m deep and extends from St George's Channel into the Celtic Sea. The extent of the Celtic Sea is defined in the west by the continental slopes of the Porcupine Seabight and the Goban Spur. Water circulation on the shelf is strongly influenced by the poleward flowing 'slope current'. The slope current has been measured at 6cm s^{-1} at 500m depth at the Goban Spur (Pingree & LeCann, 1989), 8–9cm s^{-1} between 500 and 780m on the Porcupine Bank slope (James, 1992) and between 10 and 20cm s^{-1} in the slope region south of the Malin Shelf (White & Bower, 1997).

The Irish Shelf front is located to the south west of Ireland (~ 11° W) and consists of a tidal mixing front which occurs year round. This front marks the boundary between the neritic waters of the Celtic Sea (which are often vertically mixed by the tide) and offshore oceanic North Atlantic waters. The Ushant front is located at the mouth of the English Channel from the Lizard Peninsula to Brittany and the Celtic Sea Front (located across St. George's Channel, approximately 52° North, 6° West) is located at the entrance to the Irish Sea. Thermal stratification and tidal mixing generates the Irish coastal current which runs westward in the Celtic Sea and northwards along the west coast of Ireland (Isla & Anadon, 2004). Both the Ushant and the Celtic Sea frontal systems develop in late spring at the confluence of mixed and stratified areas and break down with increased wind-induced mixing following the onset of winter cooling.

The Ushant and Celtic Sea fronts are part of a continuous oceanographic pathway that is established from early summer to autumn. Stratification causes the formation of large dense pools of cold saline bottom water in the central Celtic Sea with a strong (0.2ms^{-1}) narrow (10-20km wide) baroclinic jet-like circulation associated with the margins of these pools. Bottom fronts can extend continuously for hundreds of kilometres and can be present without a surface front. They appear to be more stable than surface fronts and are persistent, remaining geographically fixed because of the stabilising influence of associated bottom slopes and tidally generated bottom friction (Brown *et al.,* 2003 and references therein). Density driven pathways such as those in the Celtic sea exist from Brittany to Scotland. Figure 1.2.35 and Figure 1.2.36 illustrate these flows from the NW of Brittany, across the English Channel, along the south coast of Cornwall, across the Bristol and St. George's Channels and then around the SW and W coasts of Ireland. The flows occur along the boundaries of stratified regions with significant magnitude (~ 0.1 – 0.2 x 10^6 m^3/s) and as a result limit the transport between adjacent eco-hydrodynamic regions. Following the establishment of the Celtic Sea Front, transport between the Celtic and Irish Seas is very limited. However, transport along the pathway is substantial and this is especially important when considering the transport of Harmful Algal Blooms (HABs) or alien species

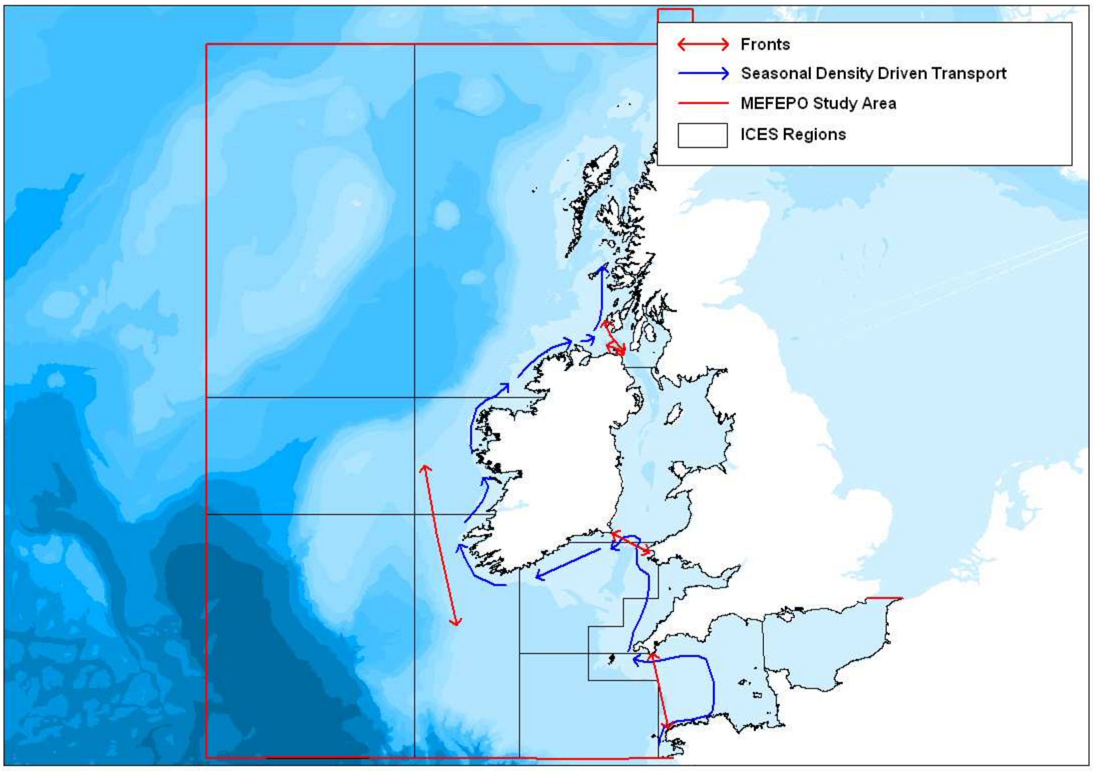


Figure 1.2.35: Seasonal fronts and seasonal density driven flow in NWW RAC (source M. White, pers. comm.; OSPAR 2000).

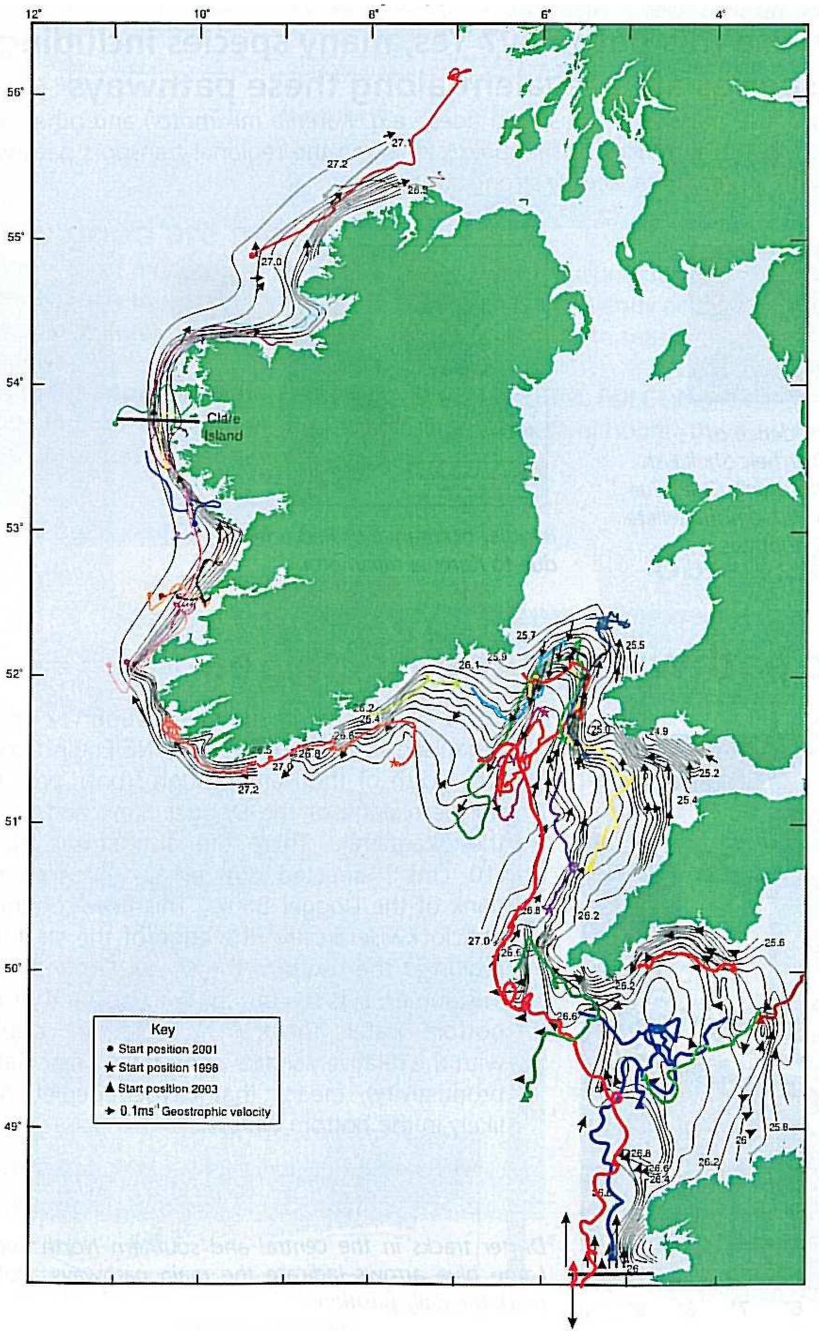


Figure 1.2.36: Northward seasonal density driven transport from Brittany to Scotland. (source: CEFAS - marine pathways and oceanographic structure project).

ENGLISH CHANNEL

The English Channel is part of the Northwest European continental shelf; it connects the Atlantic Ocean to the North Sea. Its boundaries are normally defined as the Dover Strait in the east, with the western end marked by the Isles of Scilly (UK) to Ushant (France). This system receives significant freshwater and nutrient inputs, in the east, from the river Seine (mean flow about 600 m3 s −1). However, the rivers that discharge into the western English Channel contribute very little to the overall input of nutrients compared to loadings of water masses coming from the Atlantic. The strong tidal regime leads to a range of hydrographic features, such as the high tidal range in the region of the Normand-Breton Gulf (Figure 1.2.37), a complicated gyre system around the Channel islands of Jersey and Guernsey (Salomon et al., 1988), strong tides in the Dover straits with the residual circulation generally directed to the North Sea (Prandle et al., 1993). North of the Bay of Seine, along the French coast of the eastern English Channel, a front limits a narrow strip of fresher and chl-a richer waters called the “coastal flow” (Quisthoudt, 1987; Brylinski et al., 1991). In the Bay of Seine, high river flows induce a plume with strong horizontal and vertical gradients. Further west with weaker tides the waters stratify, where the Ushant Tidal Front (Figure 1.2.35 and Figure 1.2.36) separates well mixed waters along the north-western coast of Brittany, from summer stratified shelf waters of the central English Channel (Pingree, 1975). (Excerpt from Vanhoutte-Brunier *et al.,* 2006.). Low salinity (<35) surface waters have also been observed at the southern entrance to the western English Channel (48.5ºN, 5.1ºW, near Ushant) during late winter (March - April). The source of this water is the northward spreading plumes from the Loire (47.5ºN, 2.5ºW) and the Gironde (45.6ºN, 1.2ºW) rivers along the French Atlantic coast (Kelly-Gerreyn *et al., 2*006).

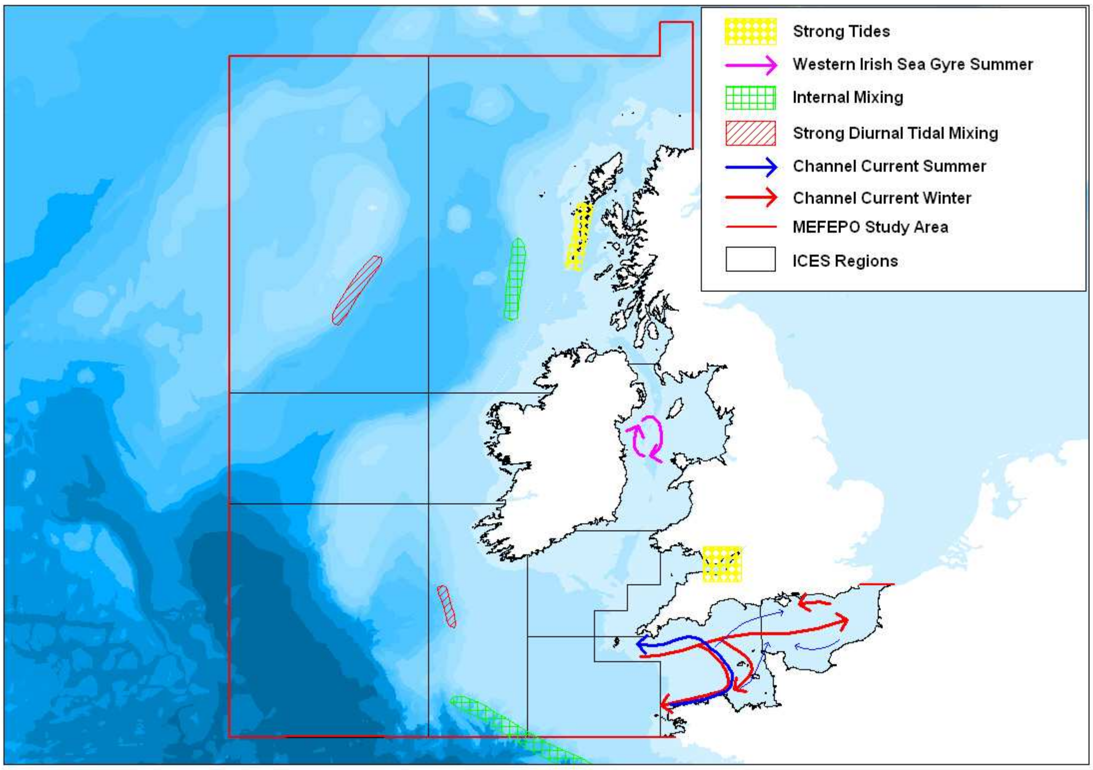


Figure 1.2.37: Seasonal currents, tidal and internal mixing areas in NWW RAC (source M. White, pers. comm.; OSPAR, 2000).

1.2.1.5.2.4 Waves

A complete wave energy atlas for Irish Territorial waters (Figure 1.2.38) is freely available on the Marine Institute website (http://www.maps.marine.ie/wave/default.aspx) and the weekly Wave Forecast predicts the wave height, direction, speed and period on a 1km grid for the west coast of Ireland (http://www.marine.ie/home/services/operational/oceanography/WaveForecast.htm). In addition, PRISM (Predictive Irish Sea Models) consists of a series of computer models of the Irish Sea. The models provide predictions on wind and waves, currents, tidal water levels, storm surge and water quality within the Irish Sea and selected sub-regions (www.prism.ie).

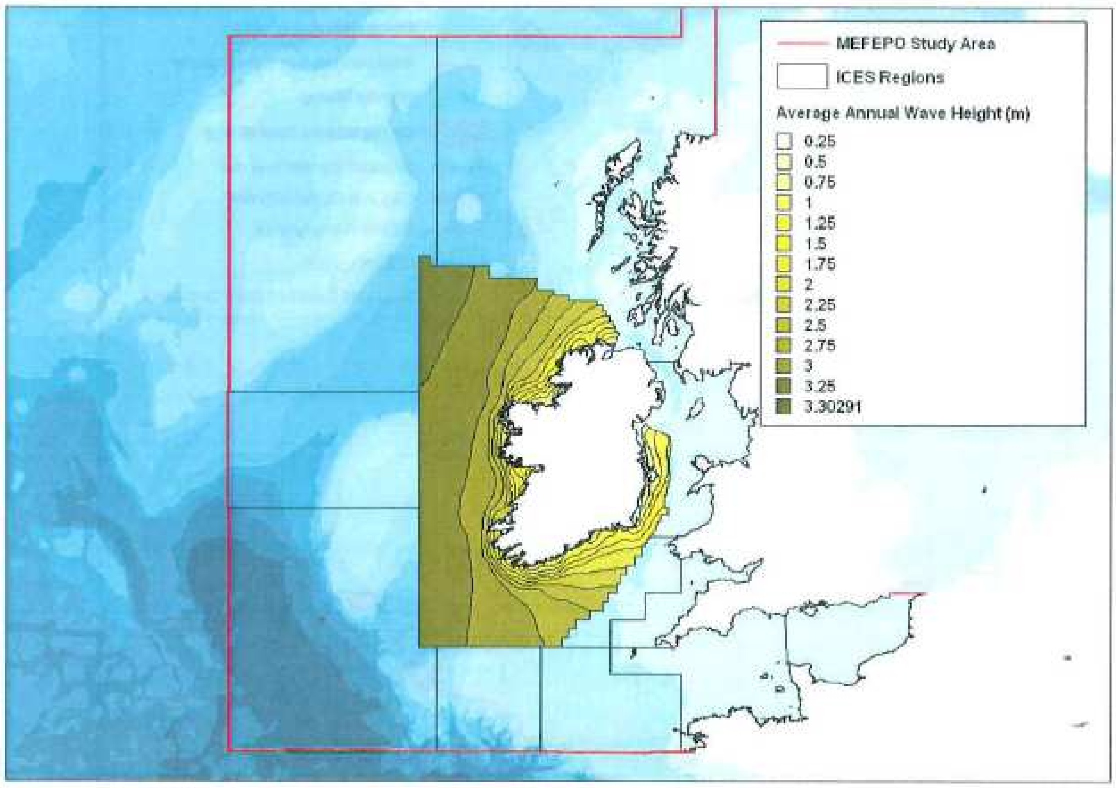


Figure 1.2.38: Average annual wave height in the NWW area (source: Marine Institute Wave Atlas)

The main source of wave information for the UK area (Figure 1.2.39) has been operational forecast models developed by the Met Office, incorporating Global, European and UK waters wave models at respective grid resolutions of 60, 35 and 12km. The wave models are forced by the National Weather Prediction Model (NWP) with data archived at 3 hourly intervals and include quantification of significant wave height, zero up-crossing period and mean direction for each of wind-sea, swell and resultant wave components (Cooper *et al.*, 2006).

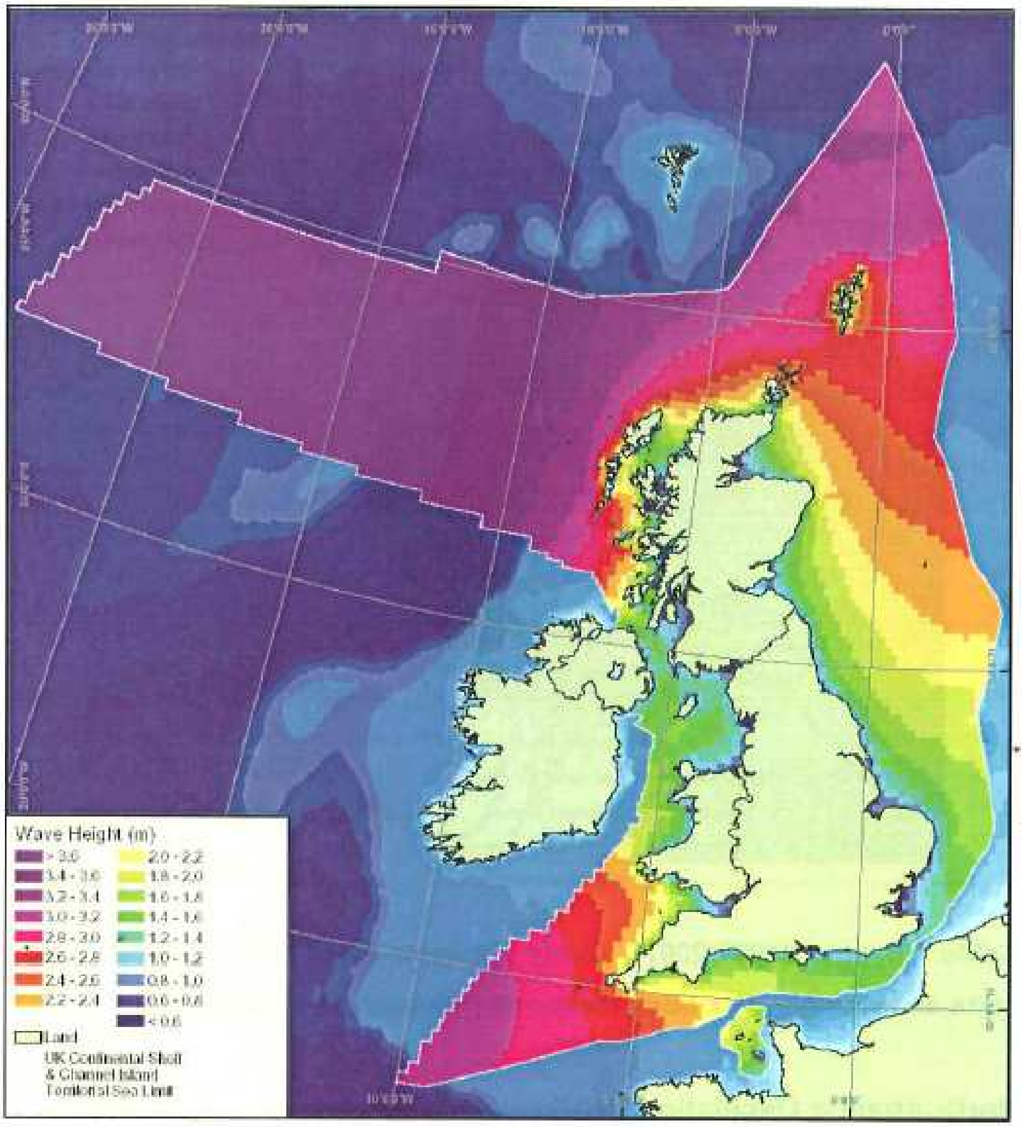


Figure 1.2.39: Mean annual wave height for UK Continental shelf and Channel Island Territorial Sea Limit (source: *Cooper et al*., 2006).

1.2.1.5.3 Acidification

Increasing levels of atmospheric carbon dioxide (CO_2), primarily from human fossil fuel combustion, reduces ocean pH and causes wholesale shifts in seawater carbonate chemistry (Caldeira & Wickett, 2003, 2005; Feely *et al.*, 2004; Orr *et al.*, 2005). Acidification alters seawater chemical speciation and biogeochemical cycles of many elements and compounds. One well-known effect is the lowering of calcium carbonate saturation states, which impacts shell-forming marine organisms from plankton to benthic molluscs, echinoderms, and corals. Many calcifying species exhibit reduced calcification and growth rates in laboratory experiments under high-CO2 conditions (Doney *et al.*, 2009).

The majority of research on the effect of marine acidification on marine organisms have focussed on tropical coral reefs and planktonic coccolithophores. Little information is available for other important taxa, for processes other than calcification or for potential ecosystem-level consequences emerging from the oceanic pCO_2 predicted to occur over the next 100 years. On a global basis, coccolithophores and foraminifera are thought to produce the majority of pelagic $CaCO_3$, while the labile aragonitic shells of pteropods account for a smaller fraction of the total $CaCO_3$ produced by planktonic organism (Fabry *et al* 2008).

Deep water scleractinian corals (such as *Lophelia* and *Madrepora* sp.) thrive in the subphotic waters of continental slopes, usually in depths of 200–1000m. They are slow-growing and often long-lived, up to 1500 years old, and form habitats that support high biodiversity and fisheries. The maximum depth of these communities appears to coincide with the depth of the aragonite saturation horizon (Guinotte *et al.*, 2006), which reaches an average depth of >2000m in the North Atlantic. Under increasing ocean acidification, the deepest communities of cold water corals will be the first to experience a shift from saturated to unsaturated aragonite conditions (Doney *et al.*, 2009)

Many benthic calcifying fauna are prominent in nearshore communities and are economically and/or ecologically important. Bivalves such as oysters and mussels have a high commercial value as fisheries and are also important ecosystem engineers in coastal areas, providing habitat and other services for a rich diversity of organisms (Gutiérrez *et al.*, 2003). Recent work suggests that benthic adult molluscs and echinoderms are sensitive to changes in seawater carbonate chemistry. In response to an elevated pCO_2 level (~740ppmv in 2100) projected to occur under IS92a[1] emissions scenario, calcification rates in the mussel *Mytilis edulis* and the Pacific Oyster *Crassostrea gigas* decreased by 25 and 10% respectively (Gazeau *et al.*, 2007). Early calcifying stages of benthic molluscs and echinoids demonstrate a strong response to increased seawater pCO_2 and decreased pH, CO_3^{2-} concentration, and $CaCO_3$ saturation state (Fabry *et al.*, 2008). Dupont *et al.* (2008) report that experiments on the impact of CO_2–driven marine acidification on larval survival and development in brittlestars (*Ophiothrix fragilis*), exhibited pH-induced changes in skeletogenesis (abnormalities, asymmetry, morphometric changes) due to the disruption in one or more molecular mechanisms involved in calcification. Green *et al.*(2004) found that newly settled juveniles of the hard-shell clam *Mercenaria mercenaria* revealed a substantial shell dissolution and increased mortality when they were introduced to surface sediments that were under-saturated with respect to aragonite (Ω_{arag} ~0.3), a level that is typical of near-shore, organic-rich surficial sediments. Within two weeks of settlement the shells were completely dissolved, leaving only the organic matrix of the shell. Fertilisation rates and early development are also negatively impacted by high CO_2 conditions in a number of groups such as sea urchins, molluscs and copepods (Fabry *et al.*, 2008).

"Although the changes in seawater chemistry that result from oceanic uptake of anthropogenic CO2 are well characterised over most of the ocean, the biological impacts of ocean acidification on marine fauna are only beginning to be understood. Nevertheless, sufficient information exists to state with certainty that deleterious impacts on some marine species are unavoidable and that substantial alteration of marine ecosystems is likely over the next century" (Fabry *et al*. 2008).

1.2.2 Habitats

Geophysical features are important in determining the nature of biological communities. As biological information is often lacking on a large scale, the classification of marine landscapes within the NWW RAC is based on the assumption that geophysical and hydrographical information can be used in lieu of biological information to classify medium scale marine habitats and to set marine nature conservation priorities. Seabed and coastal marine landscapes were derived by integrating a number of geophysical attributes including bathymetry, seabed sediments, bedforms, maximum near-bed stress and other data. This broad-scale mapping approach is essentially a modelling technique, based on the integrated analysis in a GIS environment of a series of environmental data sets to derive a series of broad-scale mapped classes of seabed features. The ecological relevance of the derived marine landscape units was tested for its ecological validity by interfacing the mapped classes with ground-truth biological sample data (such as from grabs and underwater video records). The Irish Sea Pilot established that the marine landscapes defined were on the whole ecologically meaningful and at a scale which was relevant to the management of activities and to the identification of conservation measures at the regional sea scale (Golding *et al.*, 2004).

By linking the available biological data to the marine landscapes and identifying areas where further groundtruthing was necessary, the Irish Sea Pilot identified three main groups of marine landscape within the Irish Sea. These are:

- Coastal (physiographic) marine landscapes such as Rias and Estuaries where the seabed and water body are closely interlinked. In this group, both the seabed and the overlying water are included within the marine landscape.
- Seabed marine landscapes which occur away from the coast, i.e. the seabed of open sea areas. In this group, the marine landscapes comprise the seabed and the water at the substrate/water interface.
- Water column marine landscapes of the open sea areas, such as mixed and stratified water bodies and frontal systems. In this group, the marine landscapes comprise the water column above the substrate/water interface.

In relation to the coastal and seabed marine landscapes, the results of the Irish Sea Pilot (ISP) show that just four of the 18 marine landscape types make up 77% of the area of the Irish Sea Pilot study area. In contrast, 12 of the marine landscape types make up less than 10% of the Irish Sea, and seven of these marine landscape types each cover less than 0.5% of the study area. Such scarce types could well merit special protection measures and warrant consideration in the current review of habitats listed on Annex I of the Habitats Directive (EC, 1992) (*Rias* and *Lagoons* already appear in Annex I).

Figure 1.2.40 shows a seabed map of benthic habitats within the NWW RAC. This map was reproduced from data downloaded from the MESH Project (**M**apping **E**uropean **S**eabed **H**abitats) where the focus is on mapping according to the EUNIS habitat classification (and subsequent correlation to Annex I habitats, OSPAR and BAP priority habitats). In addition to the EUNIS classification, each EUNIS habitat type can be linked to different biotopes around the British Isles. Detailed descriptions of the biotopes and how they relate EUNIS classification can be found on the JNCC website (www.jncc.gov.uk). The descriptions include physical characteristics (including wave exposure, tidal stress, salinity etc.), distributions and biological characteristics (including species compositions, frequency and similar biotopes).

In order to illustrate the relationships between the different habitat maps, habitat classifications and their associated biotopes, three examples have been shown:

- SS.SCS.CCS.PomB (*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles) which is characteristic of coarse sediment;
- SS.SMu.CsaMu.AfilMysAnit (*Amphiura filiformis, Mysella bidentata* and *Abra nitida* in a circalittoral sandy mud) which is found insandy sediments and
- SS.Smu.Omu.AfalPova (*Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy sediment near margins of deep stratified seas) which can be found on muddy sediments.

In addition to these habitat maps, predictive habitat maps for the southern Irish Sea have been added. These maps have been developed by the HABMAP project using a combination of real and modelled data and care must be taken in their interpretation because of gaps in knowledge.

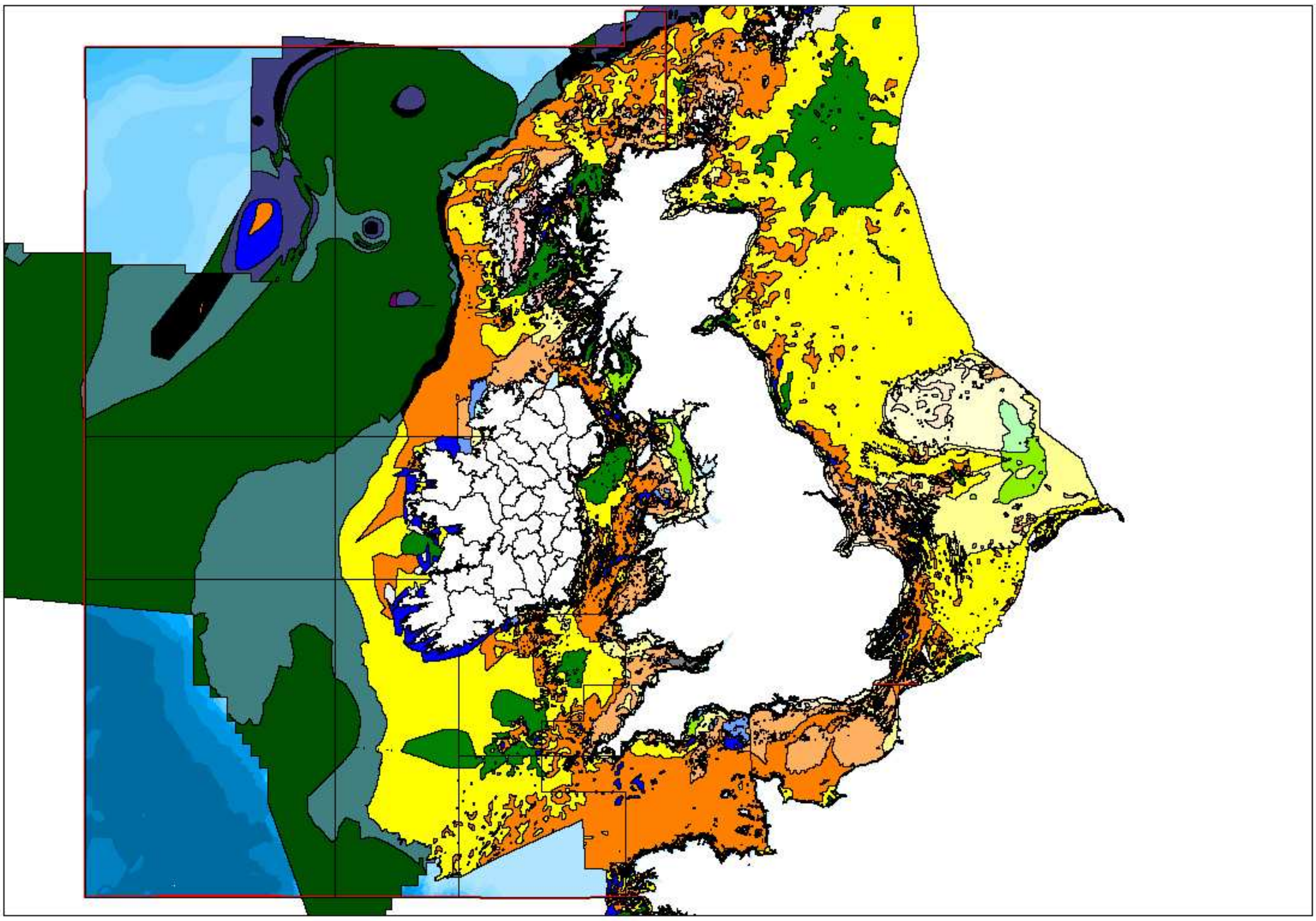


Figure 1.2.40: Seabed sediments and biotopes for the MEFEPO Study Area (Source: MESH).

1.2.2.1 Coarse Sediment

Gravelly sediments (labelled 'as 'Infralittoral coarse sediment', Circalittoral Coarse Sediment', 'Deep Circalittoral Coarse Sediment' and 'Deepsea Coarse Sediment' in Figure 1.2.40) occur extensively in the Irish Sea, English Channel and Malin Shelf. Within the Irish Sea they occupy a broad belt in the centre of the northern Irish Sea extending from Scotland, past the Isle of Man, to Anglesey and are predominant in the Northern Channel, Cardigan Bay and St. George's Channel. There are also large areas of exposed till in St. George's Channel and areas of exposed bedrock occur locally in the North Channel and between Anglesey and the Isle of Man. The gravelly areas and the areas of exposed till and bedrock mainly occur in regions dominated by strong tidal currents or wave action and it is likely that the strong currents prevent the deposition of fine material. An example of a corresponding EUNIS code is A5.13 Circalittoral coarse sediment.

EUNIS habitat **code and names** A5.13 Circalittoral coarse sediment

Description

Tide-swept circalittoral coarse sands, gravel and shingle generally in depths of over 15-20m. This habitat may be found in tidal channels of marine inlets, along exposed coasts and offshore. This habitat, as with shallower coarse sediments, may be characterised by robust infaunal polychaetes, mobile crustacean and bivalves. Certain species of sea cucumber (e.g. *Neopentadactyla*) may also be prevalent in these areas along with the lancelet *Branchiostoma lanceolatum*.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)

Legal instruments

Legal instrument	Legally designated habitat	Code
Council of Europe Bern Convention Res. No. 4 1996	Sublittoral soft seabeds	11.22

Descriptive or diagnostic parameters

Parameter	Value(s)

Altitude zones (terrestrial and marine):	Circalittoral (marine)
Depth zones (for marine habitats):	5 – 10m; 10 – 20m; 20 – 30m
Exposure characteristics:	Exposed to wind action; Moderately exposed to wind action; Moderately strong tidal stream; Weak tidal stream; Very weak or no tidal stream; Exposed to wave action; Moderately exposed to wave action
Substrate types:	Gravel; Sand
Salinity levels:	Fully saline

SS.SCS.CCS.PomB

***Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles (source JNCC).**

<u>Habitat (physical) description</u>

Salinity	Full (30-35 ppt)
Wave Exposure	Very Exposed, Exposed, Moderately exposed
Tidal streams	Strong (3-6 kn), Moderately strong (1-3 kn)
Substratum	Cobbles and pebbles with sand
Zone	Circalittoral
Depth Band	5-10m, 10-20m, 20-30m, 30-50m
Other features	Mobile substrata
EUNIS code	A5.131

Biotope description

This biotope is characterised by a few ubiquitous robust and/or fast growing ephemeral species which are able to colonise pebbles and unstable cobbles and slates which are regularly moved by wave and tidal action. The main cover organisms tend to be restricted to calcareous tube worms such as *Pomatoceros triqueter (*or *P. lamarcki)*, small barnacles including *Balanus crenatus* and *Balanus balanus*, and a few bryozoan and coralline algal crusts. Scour action from the mobile substratum prevents colonisation by more delicate species. Occasionally in tide-swept conditions tufts of hydroids such as *Sertularia argentea* and *Hydrallmania falcata* are present. This biotope often grades into SMX.FluHyd which is characterised by large amounts of the above hydroids on stones also covered in *Pomatoceros* and barnacles. The main difference here is that SMX.FluHyd, seems to develop on more stable, consolidated cobbles and pebbles or larger stones set in sediment in moderate tides. These stones may be disturbed in the winter and therefore long-lived and fragile species are not found.

Situation

This biotope is found on exposed open coasts as well as at the entrance to marine inlets.

Similar biotopes

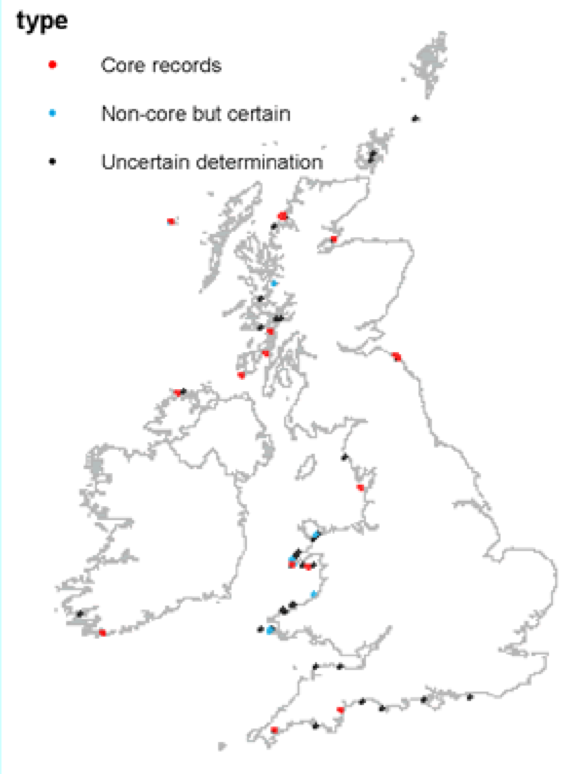
IR.FIR.SG.CC.Mo : A similar shallow water biotope occurring on cobbles at the base of surge gullies

SS.SMx.CMx.FluHy : As substratum stability increases (larger rocks and less turbulent wave action) more species are able to colonise the sea bed. FluHyd, FluCoAs.SmAs and ByErSp.DysAct in that order, represent the progression from PomB to more stable mixed substrata although still with a high proportion of scour- and sand-tolerant species.

Characterising Species

Taxa	Frequency	Typical Abundance	% Contribution to similarity
Lanice conchilega	●●	O	1
Pomatoceros	●	C	4
Pomatoceros triqueter	●●●●	F	61
Balanus balanus	●●	O	2
Balanus crenatus	●●	F	3

Bryozoa indet crusts	●●	F	5
Asterias rubens	●●●	O	6
Echinus esculentus	●●●	O	7



Distribution of habitat SS.SCS.CCS.PomB *Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles, based on records on the JNCC marine database. Red dots represent records on which the biotope is based. Blue dots show orther certain records, black dots show records tentatively assigned to this biotope.

A predictive map of the distribution of this biotope within the southern Irish Sea can be seen in Figure 1.2.41 below. This biotope is supposed to be found in areas of unstable pebbles and cobbles, in areas of strong tidal flow. This map, produced by the HABMAP project, has predicted its distribution here on a wider range of sediments than it would actually be associated with (e.g. sand, gravely sand and sandy gravel), and in areas of weaker than expected tidal flow. The predictions made into Eastern Liverpool Bay and on sandy ground to the West of Anglesey are highly unlikely (Robinson *et al., 2007).*

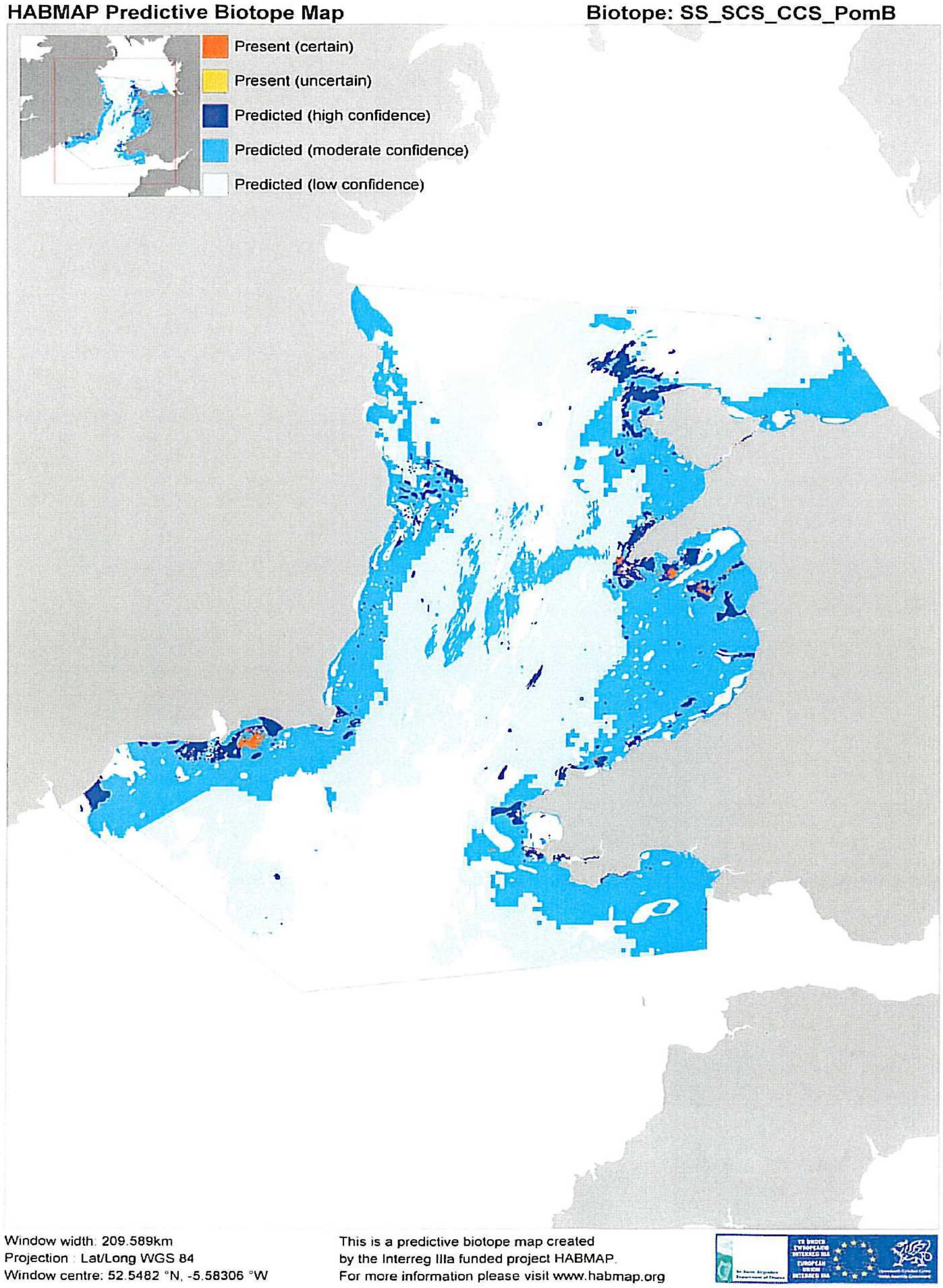


Figure 1.2.41: Predicitive Habitat map for SS.SCS.CCS.PomB biotope from HABMAP project (2007).

1.2.2.2 Sandy Sediment

Areas of sand (labelled as ‘Infralittoral Fine Sand/Muddy Sand’, ‘Circalittoral Fine Sand/Muddy Sand’, ’Deep Circalittoral Sand’ and ‘Deepsea Sand/Muddy Sand in Figure 1.2.40) in NWW RAC occur extensively on the Porcupine and Rockall Banks, the Celtic Sea and areas of the Irish Sea, where areas of sandwaves and megaripples occur north of the Isle of Man, in Liverpool Bay and Cardigan Bay and also in St. George’s Channel. Tidal sand banks and sand ridges occur in the Solway Firth, north of the Isle of Man, in Liverpool Bay, south of Lleyn Peninsula and off the east coast of Ireland. An example of a corresponding EUNIS code is A5.35 Circalittoral sandy mud.

EUNIS habitat **code and names** A5.35 Circalittoral sandy mud

Description

Circalittoral, cohesive sandy mud, typically with over 20% silt/clay, generally in water depths of over 10 m, with weak or very weak tidal streams. This habitat is generally found in deeper areas of bays and marine inlets or offshore from less wave exposed coasts. Sea pens such as *Virgularia mirabilis* and brittlestars such as *Amphiura* spp. are particularly characteristic of this habitat whilst infaunal species include the tube building polychaetes *Lagis koreni* and *Owenia fusiformis*, and deposit feeding bivalves such as *Mysella bidentata* and *Abra* spp.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)

Legal instruments

Legal instrument	Legally designated habitat	Code
Council of Europe Bern Convention Res. No. 4 1996	Sublittoral soft seabeds	11.22

Descriptive or diagnostic parameters

Parameter	**Value(s)**
Altitude zones (terrestrial and marine):	Circalittoral (marine)
Depth zones (for marine habitats):	10 - 20m; 20 - 30m; 30 - 50m; 50 - 100m
Exposure characteristics:	Exposed to wind action; Moderately exposed to wind action; Sheltered from wind action; Very sheltered from wind action; Moderately strong tidal stream; Weak tidal

stream; Very weak or no tidal stream; Exposed to wave action; Moderately exposed to wave action; Sheltered from wave action; Very sheltered from wave action

Substrate types:
Mud, Silt

Salinity levels:
Fully saline

Salinity	Full (30-35 ppt)
Wave exposure	Exposed, Moderately exposed
Tidal streams	Weak (>1kn), very weak (negligible)
Substratum	sandy mud
Zone	circalittoral
Depth band	10-20m, 20-30m
EUNIS code	A5.351

SS.SMu.CSaMu.AfilMysAnit

Amphiura filiformis, Mysella bidentata **and** ***Abra nitida*** **in a circalittoral sandy mud (source JNCC)**

Habitat (physical) description

Biotope description

Cohesive sandy mud off wave exposed coasts with weak tidal streams can be characterised by super-abundant *Amphiura filiformis* with *Mysella bidentata* and *Abra nitida*. This community occurs in muddy sands in moderately deep water (Hiscock 1984; Picton *et al.* 1994) and may be related to the 'off-shore muddy sand association' described by other workers (Jones 1951; Thorson 1957; Mackie 1990) and is part of the infralittoral etage described by Glemarec. This community is also characterised by the sipunculid *Thysanocardia procera* and the polychaetes *Nephtys incisa*, *Phoronis* sp. and *Pholoe* sp., with cirratulids also common in some areas. Other taxa such as *Nephtys hombergii*, *Echinocardium cordatum*, *Nucula nitidosa*, *Callianassa subterranea* and *Eudorella truncatula* may also occur in offshore examples of this biotope (e.g. Konitzer *et al.* 1992).

Similar Biotopes

Taxa	Frequency	Typical Abundance	% Contribution to similarity	Abundance (no.^{2})

SS.SSa.CMuSa.AalbNuc : In sandier sediments AfilMysAnit may grade into AalbNuc.

SS.SSa.IMuSa.FfabMag : In shallower sandy sediments AfilMysAnit may grade into FfabMag

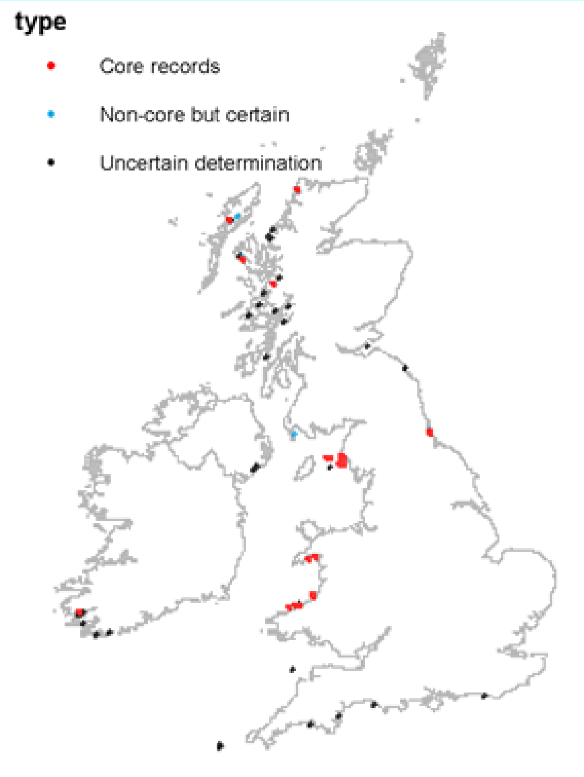
SS.SMu.CSaMu.AfilNten : AfilNten may be distinguished from AfilMysAnit by the abundance of the characterizing species *Nuculoma tenuis* in AfilNten and by the importance of other characterising species such as *Thysanocardia procera* and *Nephtys incise* in AfilMysAnit. AfilNten is also generally found in deeper water.

SS.SMu.CSaMu.ThyNten : ThyNten may be distinguished from AfilMysAnit by the abundance of the characterising species *Thyasira flexuosa* and by the decreased abundance of *Amphiura filiformis* in ThyNten. ThyNten is generally found in deeper waters.

<u>Characterising Species</u>

Tubularia indivisa	●●	R	2	
Sagartiogeton undatus	●●	R	2	
Nemertea	●●●	P	1	47
Thysanocardia procera	●●●●	P	4	129
Phascolion strombus strombus	●●	R	2	
Polychaeta	●●●	A	14	
Aphrodita aculeata	●●	R	2	
Pholoe inornata	●●●●	F	3	157
Nephtys hombergii	●●	F	1	
Nephtys incisa	●●●●	P	5	97
Levinsenia gracilis	●●●	P	2	83
Cirratulidae	●●●	S	4	600
Chaetozone setosa	●●	F	1	
Tharyx	●●●	C	2	240

Tharyx	●●	F	1	
Diplocirrus glaucus	●●●	P	2	107
Pectinariidae	●●●	O	6	
Lagis koreni	●●●	P	1	62
Melinna palmata	●●●	P	3	85
Lanice conchilega	●●●	R	5	
Pariambus typicus	●●●	C	2	260
Pagurus bernhardus	●●●●	O	11	
Turritella communis	●●●	R	5	
Mysella bidentata	●●●●●	A	22	1635
Abra nitida	●●●●	S	11	838
Corbula gibba	●●	P	1	49
Phoronis	●●●●	A	2	121
Ophiuroidea	●●●	A	7	252
Amphiura chiajei	●●●	C	12	
Amphiura filiformis	●●●●●	S	19	760
Amphiura filiformis	●●●	A	12	
Ophiura ophiura	●●●●	R	6	



Distribution of habitat SS.SMu.CSaMu.AfilMysAnit *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud, based on records on the JNCC marine database. Red dots represent records on which the biotope is based. Blue dots show orther certain records, black dots show records tentatively assigned to this biotope.

A predictive biotope map produced by the HABMAP project is illustrates in Figure 1.2.42. This biotope should only really occur on muddy sand and sandy muds, not on coarse sands and sediments. The predictions made to the North West of Anglesey are unlikely to be correct, as are those in offshore areas in the middle of the Irish Sea. Patches could occur in St. George's Channel, though predictions in the Outer Bristol Channel are dubious, as are those off Hells Mouth and Strumble Head.

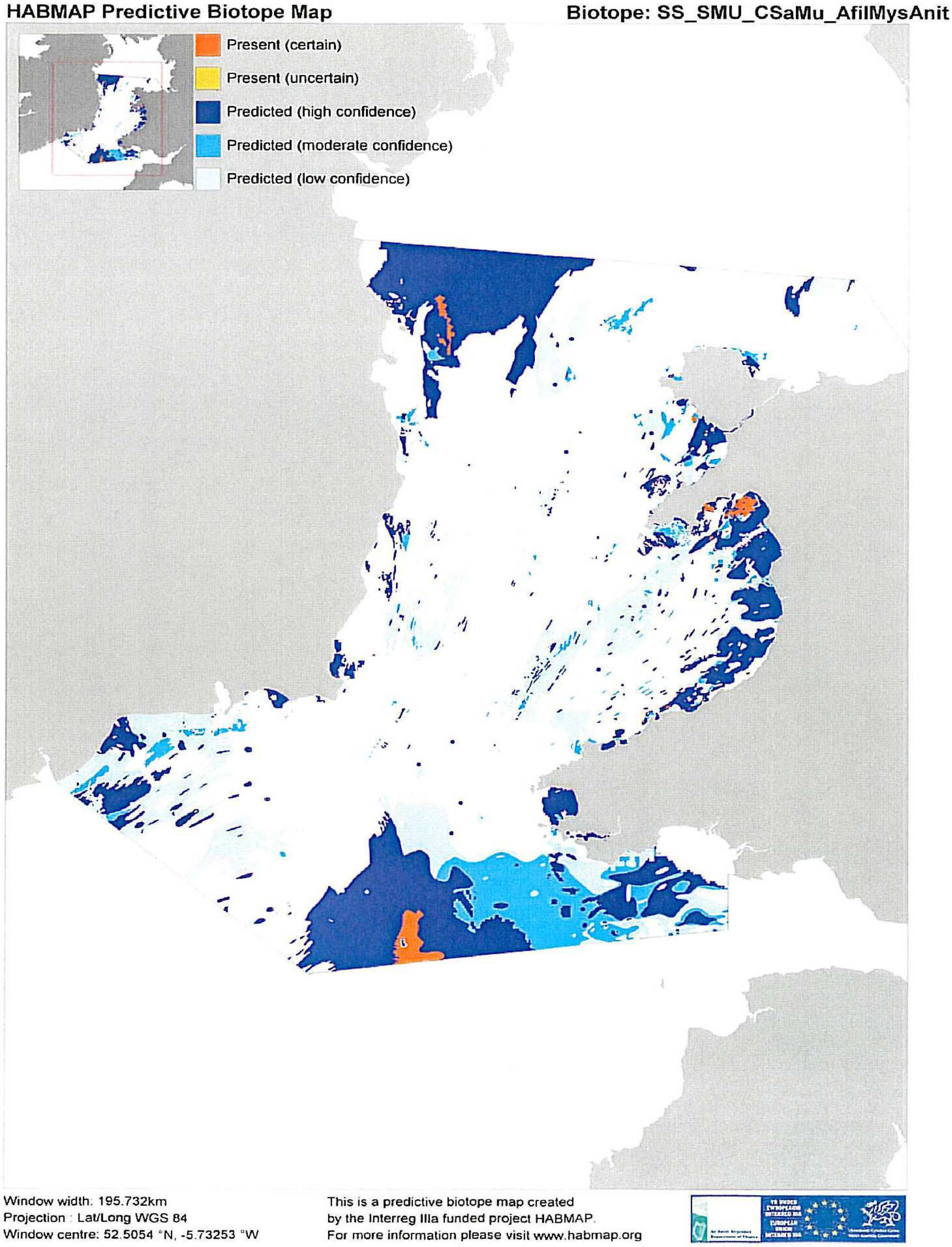


Figure 1.2.42: Predictive Habitat map for SS.SMu.CSa.AfilMysAnit biotope from HABMAP project (2007).

1.2.2.3 Muddy Sediment

Muddy sediments (labelled 'shallow as 'Infralittoral Sandy Mud/Fine Mud', Circalittoral Sandy Mud/Fine Mud', 'Deep Circalittoral Mud' and 'Deepsea Mud' in Figure X) occur throughout the NWW RAC particulary in the north of the Irish Sea, in two large areas separated by the central belt of gravelly sediments, in the Atlantic Basins, Rockall Trough and southern Celtic Sea. The main concentration in the Irish Sea is in the basinal area between the Isle of Man and Northern Ireland, where the sediments have a very high mud content. Other areas of muddy sediments also occur in St. George's Channel and smaller areas can be found locally in coastal areas off rivers and estuaries and in small bathymetric depressions. This type of habitat (EUNIS A5.37) can be found in the western Irish Sea where the seabed is supplied with a regular supply of organic material from the highly productive Western Irish Sea front. Holme & Rees (1986) reported dense stands of filter-feeding benthos beneath this front with densities of the polychaete worm *Ampharete falcata* reaching approximately 3000/m² and the bivalve *Parvicardium ovale* at approximately 27000/m².

EUNIS habitat **code and names** A5.37 Deep circalittoral mud

Description

In mud and cohesive sandy mud in the offshore circalittoral zone, typically below 50-70 m, a variety of faunal communities may develop, depending upon the level of silt/clay and organic matter in the sediment. Communities are typically dominated by polychaetes but often with high numbers of bivalves such as *Thyasira* spp., echinoderms and foraminifera.

Source Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004)

Legal instruments

Legal instrument	Legally designated habitat	Code
Council of Europe Bern Convention Res. No. 4 1996	Sublittoral soft seabeds	11.22

Descriptive or diagnostic parameters

Parameter	**Value(s)**

Altitude zones (terrestrial and marine):	Offshore circalittoral
Depth zones (for marine habitats):	50 - 100m
Exposure characteristics:	Weak tidal stream; Very weak or no tidal stream
Substrate types:	Muddy sand
Salinity levels:	Fully saline

SS.Smu.Omu.AfalPova

***Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy sediment near margins of deep stratified seas (source JNCC)**

Habitat (physical) description

Salinity	Full (30-35 ppt)
Tidal Streams	Weak (>1 kn)
Substratum	Cohesive sandy mud
Zone	Circalittoral
Depth Band	50-100m
EUNIS code	A5.371

Biotope description

Dense stands of *Ampharete falcata* tubes which protrude from muddy sediments, appearing as a turf or meadow in localised areas. These areas seem to occur on a crucial point on a depositional gradient between areas of tide-swept mobile sands and quiescent stratifying muds. Dense populations of the small bivalve *Parvicardium ovale* occur in the superficial sediment. Other infauna in this diverse biotope includes *Lumbrineris scopa*, *Levinsenia* sp., *Prionospio steenstrupi*, *Diplocirrus glaucus* and *Praxillella affinis* although a wide variety of other infaunal species may also be found. Both the brittlestars *Amphiura filiformis* and *Amphiura chiajei* may be present together with *Nephrops norvegicus* in higher abundance than the BlyrAchi or AfilEcor biotopes. Substantial populations of mobile epifauna such as *Pandalus* *montagui* and smaller fish also occur, together with those that can cling to the tubes, such as *Macropodia* spp. A similar turf of worm tubes formed by the maldanid polychaete *Melinna cristata* has been recorded from Northumberland (Buchanan 1963). Nephrops trawling may severely damage this biotope and it is possible that such activity has destroyed examples of this biotope in the Irish Sea (E.I.S. Rees pers. comm. 2002).

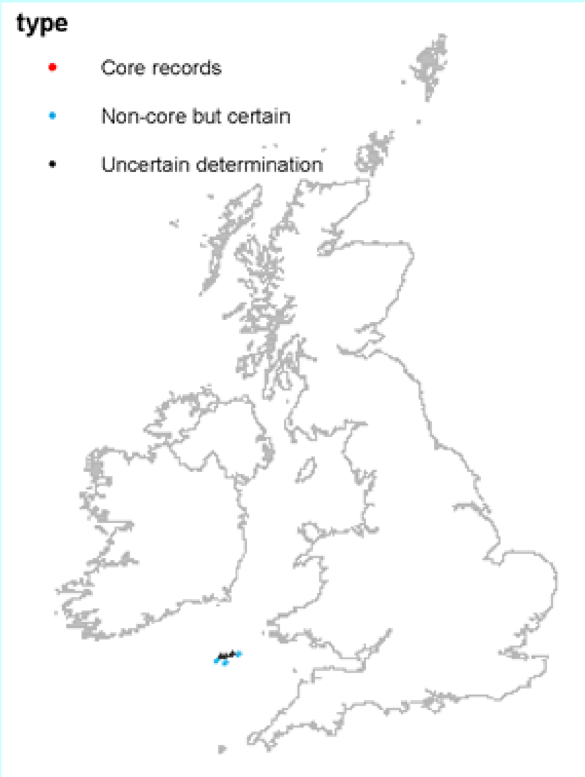
Similar Biotopes

SS.Smu.CsaMu.AfilNten : This biotope is closely linked to SMU.AfilNten, which also may support *A. falcata* in some areas of the Irish Sea.

Charactering Species

Taxa	Typical Abundance
Scalibregma inflatum	A
Amphictene auricoma	C
Lagis koreni	A
Ampharete falcata	S
Pandalus montagui	-
Crangon crangon	-
Nephrops norvegicus	-
Macropodia linaresi	-
Goneplax rhomboides	C
Nuculoma tenuis	C
Mysella bidentata	C
Parvicardium ovale	S
Abra nitida	A

Amphiura chiajei	S
Amphiura filiformis	A
Brissopsis lyrifera	A
Agonus cataphractus	-
Liparis liparis	-



Distribution of habitat SS.SMu.OMu.AfalPova *Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy sediment near margins of deep stratified seas, based on records on the JNCC marine database. Red dots represent records on which the biotope is based. Blue dots show orther certain records, black dots show records tentatively assigned to this biotope.

1.2.2.4 Deep-Sea habitats

The JNCC biotope resource (www.jncc.gov.uk/marine/biotopes/hierarchy.aspx) does not describe biotopes in the deep sea. Within the NWW area deep sea EUNIS habitats include Deep mixed sediments (A5.45), Deep-sea rock and artificial hard substrata (A6.1), Deep-sea mixed sediment (A.2), Deep-sea san/muddy sand (A6.3/A6.4), Deep sea mud (A6.5), Deep-sea coarse sediment (421/423/523). Table 1.2.5 below lists the deep sea fauna that can be found at different depth ranges and includes the substrate each species is typically associated with.

Upper slope communities

From the shelf break at approximately 200m down to approximately 700m the composition of the benthic fauna depends on whether coral banks are developed (Gage, 1986). The coral banks are composed mainly of cold water reef building corals *Lophelia pertusa* and *Madrepora oculata*. Rogers (1999) recorded *Lophelia pertusa* at scattered localities on the slope west of Scotland and at more frequent positions on the Rockall Plateau. On the sparse sandy deposits where coral is not developed, the epibenthis fauna is rather sparse but prominent among it are the echinoderm species *Cidaris cidaris*, *Spatangus raschi* and *Stichopus tremulus* along with several others (Table 1.2.5).

Mid-slope communities (700-1,400m)

At around the 700m contour on the slope, as the bottom sediment becomes predominantly a pelagic ooze, the benthic fauna becomes richer. Among the most characteristic species of this zone, which extends down to approximately 1,300m, is the sea urchin *Echinus acutua norvegicus*. Enormous populations of this species occur in a ribbon-like distribution around the continental margin of Europe down to approximately 1,400m. Other characteristic species include several decapod crustaceans and echinoderms (Table 1.2.5), including the brittle star *Ophiocten gracilis*, which also occurs in enormous numbers. Other species found at this level, such as sea stars, solitary corals and pycnogonids have a bathymetric range that extends to greater depths, while others have been recorded from shallower as well as deeper depths (IOSEA3).

Lower Slope communities (1,400-2,000m)

From approximately 1,400m, the sediment changes little down to the base of the slope at approximately 2,00-2,500m, consisting of a mixture of pelagic ooze and turbidite. The fauna is dominated by echinoderms with a few characteristic species such as Echinus alexandri, Psilaster patagiatus and Plinthaster dentatus (Table 1.2.5). Other species are found within this depth range a well as a depths of approximately 2,500m and beyond (IOSEA3).

Bottom communities (2,000-2,500m)

The floor of the northern part of the Rockall Trough slopes gently from about 2,000m in the north to about 3,000m in the south and in general the epibenthic fauna is similar within this range. Near the base of the continental slope, the current bottom energy increases and growths of the tree-like gorgonian *Acanella arbuscula* are found which provide a perch for other fauna such as the brittlestar *Ophiacantha bidentata* to feed in the current. Other species present include those that occur on the lower slope but also mainly echinoderm species characteristic of the upper abyssal zone (Table 1.2.5).

Table 1.2.5: Main megabenthic animal groupings expected in deep sea zones within the NWW (source: IOSEA3).

Main megafaunal groups expected	***300 - 700 m; 8 - 11°C; 35.35 - 35.45S; muddy sand with varying amounts of gravel, pebbles, cobbles and boulders; exposed rock, particularly in steep-sided canyons***	***700 - 1,300 m; 6 - 8°C; 35.15 - 35.30S; calcareous mud; occasional pebbles or ice-rafted dropstones; exposed rock, particularly in steep-sided canyons; carbonate mounds***	***1,300 - 1,900 m; 3 -5°C; 34.9 - 35.0S; calcareous pelagic ooze; occasional ice-rafted dropstones; exposed rock***	***1,900 - 2,300 m; 2.5 - 3.0°C; 34.9 - 34.95S; calcareous pelagic ooze; occasional ice-rafted dropstones; exposed rock***	***2,300 - 2,800 m; 2 - 2.5°C; c. 34.9S; calcareous pelagic ooze; occasional ice-rafted dropstones; exposed rock***
Porifera (sponges)		*Pheronema carpenteri* (mud or muddy sand, but moderately fast currents, sometimes associated with corals) *Aphrocallistes bocagei* (on hard surfaces, including corals) *Thenea muricata* (mud or muddy sand) *Plakortis simplex* (hard substrates, including corals)			
Cnidaria (sea pens, sea anemones, corals)	*Kophobelemnon stelliferum* (mud or muddy sand) *Pennatula aculeata* (mud or muddy sand) *Actinauge richardi* (on stones in mud) *Bolocera tuediae* (on stones in mud) *Flabellum macandrewii* (mud and sand) *Caryophyllia smithii* (mud and muddy sand) *Stenocyathus vermiformis* (fixed to stones, rock or shells, or free in mud and sand) *Dendrophyllia cornigera* (hard substrates including rocks, stones and other corals)	*Umbellula lindahli* (on mud) *Actinoscyphia saginata* (on rock and associated with corals) *Actinauge richardi* (on stones in mud) *Bolocera tuediae* (mud) *Actinostola callosa* (on mud) *Phelliactis hertwigi* (on stones in mud) *Chondrophellia aff coronata* (mud) *Fungiacyathus fragilis* (mud) *Caryophyllia seguenzae* (on stone or shell in mud) *Flabellum alabastrum* (mud) *Flabellum macandrewi* (mud) *Stephanocyathus moseleyanus* (mud) *Lophelia pertusa* (L) (on stones or coral debris in mud) *Madrepora oculata* (on stones or coral debris in mud) *Desmophyllium cristagalli* (on rocks and corals) *Cirrhipathes spiralis* (on rocks and corals) *Callogorgia verticillata* (usually assoc with hard substrates such as scleractinians or stones) *Epizoanthus paguriphilus* (on pagurids, specifically *Parapagurus pillosimanus*)	*Umbellula lindahli* (mud) *Umbellula thomsonii* (mud) *Anthoptilum grandiflorum* (mud) *Sicyonis gossei* (on mud) *Actinoscyphia aurelia* (mud) *Actinoscyphia saginata* (on rock) *Phelliactis hertwigi* (on stones in mud) *Coralliomorphus ingens* (mud) *Chondrophellia aff coronata* (mud) *Caryophyllia ambrosia* (on mud) *Stephanocyathus nobilis* (on mud) *Flabellum alabastrum* (on mud) *Paramuricea biscaya* (Stones and rock; probably west side of Trough only)	*Umbellula lindahli* (soft) *Umbellula thomsonii* (soft) *Phelliactis robusta* (on stones in mud) *Actinoscyphia aurelia* (soft mud) *Actinoscyphia saginata* (on rock) *Desmophyllum cristagalli* (on vertical rock surfaces; also known as dense extinct populations) *Caryophyllia ambrosia* (soft) *Stephanocyathus nobilis* (on mud) *Flabellum alabastrum* (mud) *Solenosmilia variabilis* (vertical rock surfaces) *Bathypathes patula* (on rock) *Antipathes glaberrima* (on rock) *Antipathes punctata* (on rock) *Leiopathes grimaldii* (on rock) *Anthomastus sp.* (on rock or stones) *Acanella arbuscula* (on mud) *Iridogorgia sp.*	*Umbellula lindahli* (mud) *Bathypathes patula* (on rock) *Antipathes punctata* (on rock) *Anthomastus sp.* (on rock or stones) *Chrysogorgia agassizii* (on rock) *Iridogorgia sp* (on rock)

Main megafaunal groups expected	***300-700 m; 8-11°C; 35.35-35.45S; muddy sand with varying amounts of gravel, pebbles, cobbles and boulders; exposed rock, particularly in steep-sided canyons***	***700-1,300 m; 6-8°C; 35.15-35.30S; Calcareous mud; Occasional pebbles or ice-rafted dropstones; exposed rock, particularly in steep-sided canyons; Carbonate mounds***	***1,300-1,900 m; 3-5°C; 34.9-35.0S; calcareous pelagic ooze; occasional ice-rafted dropstones; exposed rock***	***1,900-2,300 m; 2.5-3.0°C; 34.9-34.95S; calcareous pelagic ooze; occasional ice-rafted dropstones; exposed rock***	***2,300-2,800 m; 2-2.5°C; c. 34.9S; calcareous pelagic ooze; occasional ice-rafted dropstones; exposed rock***
Echinodermata (sea cucumbers, sea urchins, star fish, brittlestars, feather stars, sea lilies)	*Stichopus tremulus* (sand and muddy sand) *Laetmogone violacea* (mud and muddy sand) *Psolus squamatus* (stones and boulders, suspension feeder) *Cidaris cidaris* (sand/muddy sand) *Spatangus raschi* Lovén (sand) *Echinus acutus* (sand and mud) *Stichastrella rosea* (sand and muddy sand) *Pseudarchaster parelii* (Düben and Koren) (mud to sand and stones) *Pontaster tenuispinus* (mud, muddy sand, shell) *Luidia sarsi* (sand and muddy sand) *Luidia ciliaris* (fine gravel and stones) *Astropecten irregularis* (sand) *Ophiactis abyssicola* (mud, sand and rock, assoc with gorgonians, Sponges (eg *Pheronema*) and scleractinians) *Ophiocten gracilis* (mud) *Ophiomyces grandis* (mud) *Gorgonocephalus caputmedusa* (often on rocks, suspension feeder) *Rhizocrinus lofotensis* (mud) *Porania pulvillus pulvillus* *Stichastrella rosea* *Areaosoma fenestratum*	*Bathyplotes natans* (mud, muddy sand) *Laetmogone violacea* (mud, muddy sand) *Stichopus tremulus* (sand and muddy sand) *Ypsilothuria talismani talismani* (deposit feeder in mud) *Psolus pourtalesii* (suspension feeder, in fast currents often on hard substrates) *Calveriosoma hystrix* (mud) *Phormosoma placenta* (muddy sand to soft mud) *Echinus acutus* (sand and mud) *Gracilechinus elegans* (mud) *Cidaris cidaris* (sand and mud) *Pontaster tenuispinus* (mud, muddy sand and shell) *Stichastrella rosea* (sand and muddy sand) *Plutonaster bifrons* (mud) *Plinthaster ?dentatus* (mud) *Zoroaster fulgens* (mud) *Pseudarchaster parelii* (soft mud to sand and pebbles) *Bathybiaster vexillifer* (soft mud) *Brisingella coronata* (suspension feeder, probably on mud, stones or rock) *Psilaster □efertiti* (mud) *Gorgonocephalus caputmedusae* (often associated with sponges) *Ophiactis abyssicola* (often associated with the sponge *Pheronema carpenteri*) *Ophiocten gracilis* (mud) *Ophiomusium lymani* (mud)	*Benthogone rosea* (mud) *Echinus alexandri* (soft ooze) *Hygrosoma petersii* (soft mud) *Sperosoma grimaldii* (soft mud) *Phormosoma placenta* (soft mud) *Psilaster patagiatus* (soft mud) *Psilaster □efertiti* (soft mud) *Stichastrella rosea* (sand and muddy sand) *Plinthaster dentatus* (mud) *Bathybiaster vexillifer* (soft mud) *Zoroaster fulgens* (mud) *Pseudarchaster parelii* (mud to sand and pebbles) *Pontaster tenuispinus* (soft mud to sand with shell) *Plutonaster bifrons* (soft mud) *Brisingella coronata* (suspension feeder, probably on mud or rock) *Freyella elegans* (mud) *Ophiactis abyssicola* (suspension feeder; with gorgonians and scleractinians) *Ophiomusium lymani* (mud) *Ophiacantha bidentata* (suspension feeder; associated with gorgonians and scleractinians)	*Ypsilothuria bitentaculata □efertiti* (deposit feeder, in mud) *Myriotrochus bathybius* (mud) *Benthogone rosea* (mud) *Molpadia blakei* (infaunal sediment feeder, mud) *Peniagone azorica* (in water column, generally within 100 m or so of soft mud bottom) *Phormosoma placenta* (mud) *Spherosoma □efertit* (mud) *Hygrosoma petersii* (soft mud) *Echinus alexandri* (soft ooze) *Echinus affinis* (soft ooze) *Echinosigra phiale* (soft ooze) *Porcellanaster ceruleus* (soft mud) *Pseudarchaster parelii* (soft mud, sand, pebbles) *Bathybiaster vexillifer* (soft mud) *Plutonaster bifrons* (soft mud) *Zoroaster fulgens* (mud) *Psilaster patagiatus* (soft mud) *Psilaster □efertiti* (soft mud) *Paragonaster subtilis* (soft mud) *Benthopecten simplex* (soft mud) *Pectinaster filholi* (mud; probably east side of Trough only) *Plinthaster dentatus* (mud) *Hymenaster membranaceus* (mud) *Brisinga endecacnemos* (mainly rock) *Brisingella coronata* (suspension feeder, probably on mud or rock)	*Myriotrochus bathybius* (mud) *Ypsilothuria bitentaculata* (deposit feeder, on mud) *Molpadia blakei* (infaunal sediment feeder, mud) *Peniagone azorica* (pelagic, usually within 100 m or so of soft mud sediment) *Cherbonniera utriculus* (deposit feeder, mud) *Psychropotes depressa* (soft mud) *Phormosoma placenta* (soft mud) *Spherosoma grimaldii* (soft mud) *Hygrosoma petersii* (□efe mud) *Pourtalesia miranda* (□efe mud) *Echinus affinis* (soft ooze) *Echinosigra phiale* (soft ooze) *Hymenaster membranaceus* (mud) *Dytaster grandis* (omnivorous scavenger; soft ooze) *Zoroaster fulgens* (mud) *Plutonaster bifrons* (soft mud) *Psilaster □efertiti* (soft mud) *Psilaster patagiatus* (soft mud)

Main megafaunal groups expected	***300-700 m; 8-11°C; 35.35-35.45S; muddy sand with varying amounts of gravel, pebbles, cobbles and boulders; exposed rock, particularly in steep-sided canyons***	***700-1,300 m; 6-8°C; 35.15-35.30S; Calcareous mud; Occasional pebbles or ice-rafted dropstones; exposed rock, particularly in steep-sided canyons; Carbonate mounds***	***1,300-1,900 m; 3-5°C; 34.9-35.0S; calcareous pelagic ooze; occasional ice-rafted dropstones; exposed rock***	***1,900-2,300 m; 2.5-3.0°C; 34.9-34.95S; calcareous pelagic ooze; occasional ice-rafted dropstones; exposed rock***	***2,300-2,800 m; 2-2.5°C; c. 34.9S; calcareous pelagic ooze; occasional ice-rafted dropstones; exposed rock***
Crustacea (barnacles, crabs and shrimp)	*Bathylasma hirsutum* (on stones in fast currents) *Dichelopandalus bonnieri* (mud and sandy mud) *Pontophilus echinulatus* (mud and sandy mud) *Pontophilus norvegicus* (mud and sandy mud) *Pontophilus spinosus* (mud and sandy mud) *Nephrops norvegicus* (on mud) *Nephropsis atlantica* (on mud) *Polycheles typhlops* (mud) *Munida sarsi* (on mud, muddy sand or with stones) *Munida tenuimana* *Geryon trispinosus* (on mud or muddy sand) *Chaecon affinis* *Goneplax rhomboides* (on mud or muddy sand) *Bathynectes maravigna* (mud, sand or stones) *Macropipus tuberculatus* (Roux) (mud, sand or stones) *Atelecyclus rotundatus* (muddy sand) *Acanthephyra purpurea* *Pasiphaea multidentata* *Pasiphaea sivado* *Pasiphaea tarda* *Gnathophausia zoea* *Paramola cuvieri* *Polycheles typhlops* *Sergia robusta* *Polybius henslowii* *Anapagurus laevis*	*Anapagurus laevis* (mud) *Pagurus carneus* (mud) *Munida tenuimana* (mud or with stones and corals) *Pontophilus norvegicus* (mud and muddy sand) *Nephropsis atlantica* (mud) *Polycheles typhlops* (mud) Polycheles sculptus *Stereomastis nana* (mud) *Stereomastis sculpta* (mud) *Rochinia carpenteri* (mud, sand or hard substrates) *Dorhynchus thomsoni* (in assoc with *Pheronema*) *Paromola cuvieri* (mud, sand or hard substrates) *Parapagurus pilosimanus*(in assoc with *Epizooanthus paguriphilus*) *Acanthephyra purpurea* *Pasiphaea multidentata* *Pasiphaea sivado* *Pasiphaea tarda* *Parapasiphaea sulcatifrons* *Sergia robusta* *Geryon trispinosus* *Gnathophausia zoea*	*Glyphocrangon longirostris* (mud) *Nematocarcinus exilis* (mud) *Nematocarcinus ensifer* *Nephropsis atlantica* (mud) *Polycheles granulatus* (mud) *Stereomastis grimaldii* (mud) *Stereomastis sculpte* (mud) *Munidopsis curvirostra* (mud) *Neolithodes grimaldii* (mud) *Rochinia carpenteri* (mud, sand or hard substrates) *Ephyrina hoskynii* *Pasiphaea tarda* *Sergia robusta* *Polycheles nanus* *Polycheles sculptus* *Gnathophausia zoea* *Sabinea hystrix*	*Glyphocrangon longirostris* (mud) *Glyphocrangon sculpta* (mud) *Polycheles validus* (mud) *Stereomastis grimaldii* (mud) *Stereomastis nana* (mud) *Munidopsis rostrata* (mud) *Neolithodes grimaldii* (mud)	*Glyphocrangon sculpta* *Polycheles validus* (mud) *Stereomastis grimaldii* (mud) *Munidopsis rostrata* (mud) *Neolithodes grimaldii* (mud)
Brachiopoda (lamp shells)	*Dallina septigera* (on hard substrates in fast) *Macandrevia cranium* (Müller) (on hard substrates in fast , as above)				

1.2.2.5 Special and Protected Habitats

The MEFEPO Study Area encompasses three protection zones. These zones can be seen in Figure 1.2.43.

Under the Whale Fisheries Act 1937 the hunting of all whale species, including dolphins and porpoises, is totally banned within the fisheries limits out to 200 miles from the coast. The Whale Fisheries Act also prohibited the hunting by Irish registered ships of certain whales, including right whales and female whales accompanied by calves, outside of the fisheries limits. In 1991, Ireland declared its waters a whale and dolphin sanctuary (Berrow, 2001), the first European sanctuary within the fishery limits of an entire country. In addition, the Wildlife (Amendment) Act 1976 and 2000 list species of whales, dolphins, porpoises and seals as protected wild animals. It is an offence to kill or injure a wild animal. Any person who wilfully interferes with or destroys the breeding place or resting place of a wild animal is also guilty of an offence. All of the whale and dolphin sanctuary is located within the MEFEPO Study Area.

Western European Waters were designated as a Particularly Sensitive Sea Area (PSSA) in 2004 (IMO, 2006). MARPOL 73/78 defines certain sea areas as ‘special areas’ in which, for technical reasons relating to their oceanographical and ecological condition and to their sea traffic, the adoption of special mandatory methods for the prevention of sea pollution is required. Under the Convention, these special areas are provided with a higher level of protection than other areas of the sea. PSSAs are areas that require special protection through action by the IMO because of their significance for recognised ecological, socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities.

When an area is approved as a particularly sensitive sea area specific measures can be used to control the maritime activities in that area. Measures may include routeing and strict application of MARPOL discharge and equipment requirements for ships such as oil tankers. All of the MEFEPO Study Area lies within the PSSA boundary, except the western, northern and southern areas.

The Irish Conservation Box was established as part of the Common Fisheries Policy review in 2003 and replaces the former “Irish Box” (Source: Coastal Marine Resource Centre, MIDA).

Fishing by non-Irish registered vessels is restricted in this area. All of the Irish Conservation Box lies within the MEFEPO Study Area.

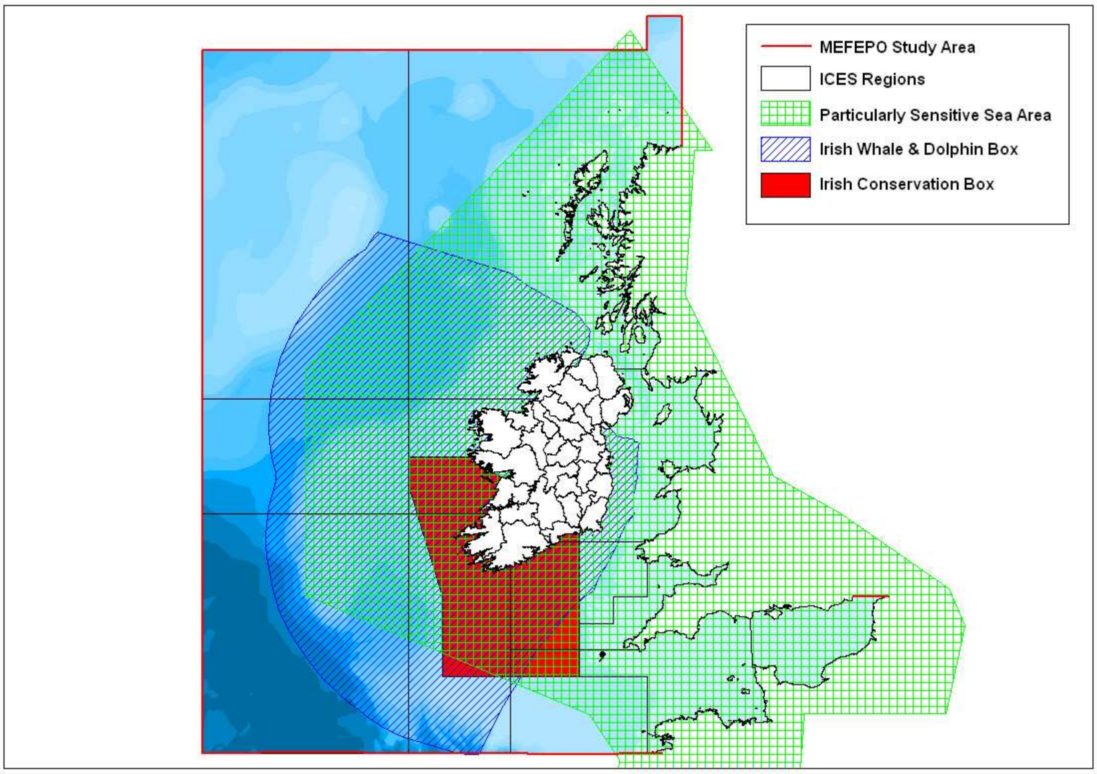


Figure 1.2.43: Conservation zones within MEFEPO Study Area.

Figure 1.2.44 shows the locations of candidate Special Areas of Conservation (cSAC) within the MEFEPO Study Area. This data was compiled from NPWS, JNCC and L'Agence des aires marines protégées. Most of these cSAC's are associated with coastal structures and some extend offshore, e.g. Pen Llyn a'r Sarnau (Site Code: UK0013117) designated for the following Annex I Habitats: sandbanks, estuaries, coastal lagoons, large shallow inlets and bays and reefs and Cardigan Bay (Site Code: UK0012712) designated for sea caves, sandbanks and reefs, all Annex I Habitats. A number are not connected to the coast e.g. Wicklow Reefs (Site code: 002274), Long Bank (Site Code: 002161) and Belgica Mound province (Site Code: 002327). Wicklow reefs are of high conservation value as they are the only documented example in Ireland of a biogenic *Sabellaria alveolata* subtidal reef, which are listed in Annex I of the EU Habitats Directive. The Long Bank is protected because it is a submerged sandbank a habitat listed on Annex I of the EU Habitats Directive. The Belgica Mound Province is protected because it is a biogenic reef, with *Madrepora oculata* and *Lophelia pertusa* being the main reef forming coral species.

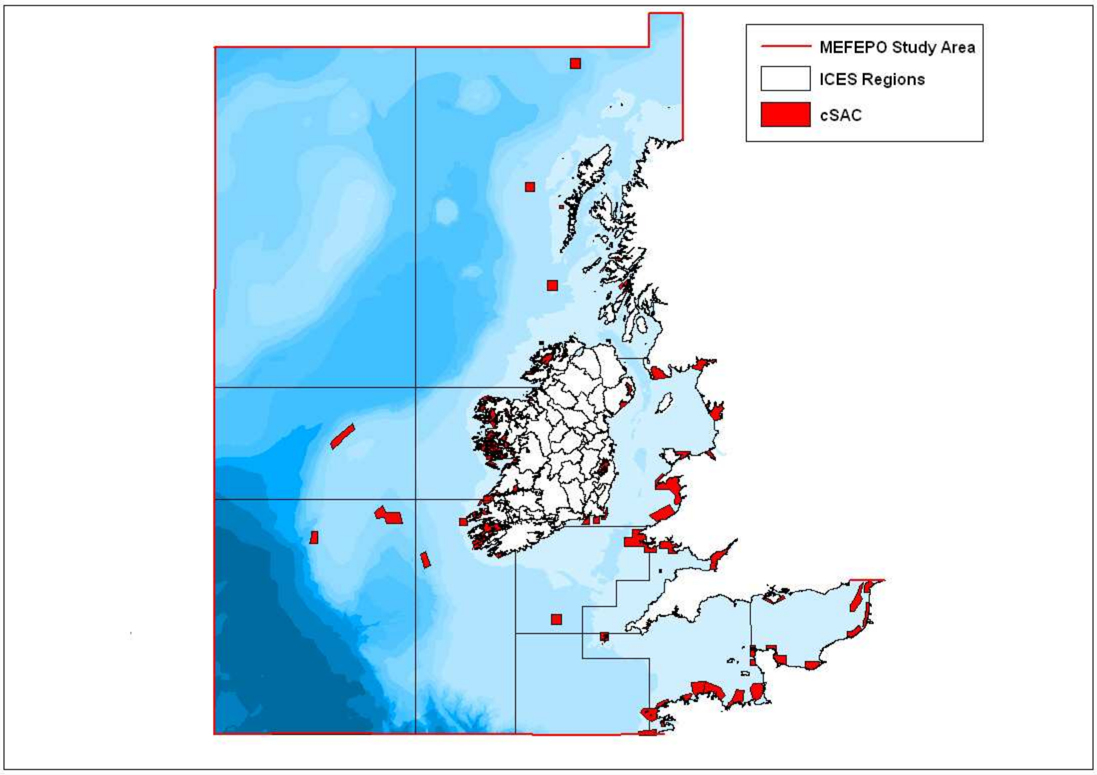


Figure 1.2.44: cSAC's within the MEFEPO Study Area (Source: NPWS, JNCC & L'Agence des aires marines protégées).

Figure 1.2.45 shows the locations of Special Protection Areas and Ramsar Sites within the MEFEPO Study Area. This data was compiled from NPWS, JNCC, L'Agence des aires marines protégées and ramsar.org. Table 1.2.6 shows a list of all marine species identified in the Habitats Directive which may be found in the MEFEPO Study Area.

Table 1.2.6: Marine species identified in the Habitats Directive which may be found in the MEFEPO Study Area.

	Common Name	**Latin Name**
Annex II (Animal and plant species whose conservation requires the designation of SACs)	Grey Seal	*Halichoerus grypus*
	Harbour Seal	*Phoca vitulina*
	Harbour porpoise	*Phocoena phocoena*
	Bottlenose dolphin	*Tursiops truncatus*
	Loggerhead turtle (occasional vagrant)	*Caretta caretta*
	Green turtle (very rare)	*Chelonia mydas*
	Sea lamprey	*Petromyzon marinus*
	Shad	*Alosa* spp
	Sturgeon	*Acipenser sturio*
	Otter	*Lutra lutra*
Annex IV (animal and plant species in need of strict protection)	Whales and dolphins (all species)	Cetacea
	Loggerhead turtle	*Caretta caretta*
	Green turtle (very rare)	*Chelonia mydas*
	Kemp's ridley turtle (less frequent)	*Lepidochelys kempii*
	Hawksbill turtle	*Eretmochelys imbricata*
	Leatherback turtle	*Dermochelys coriacea*
	Sturgeon	*Acipenser sturio*

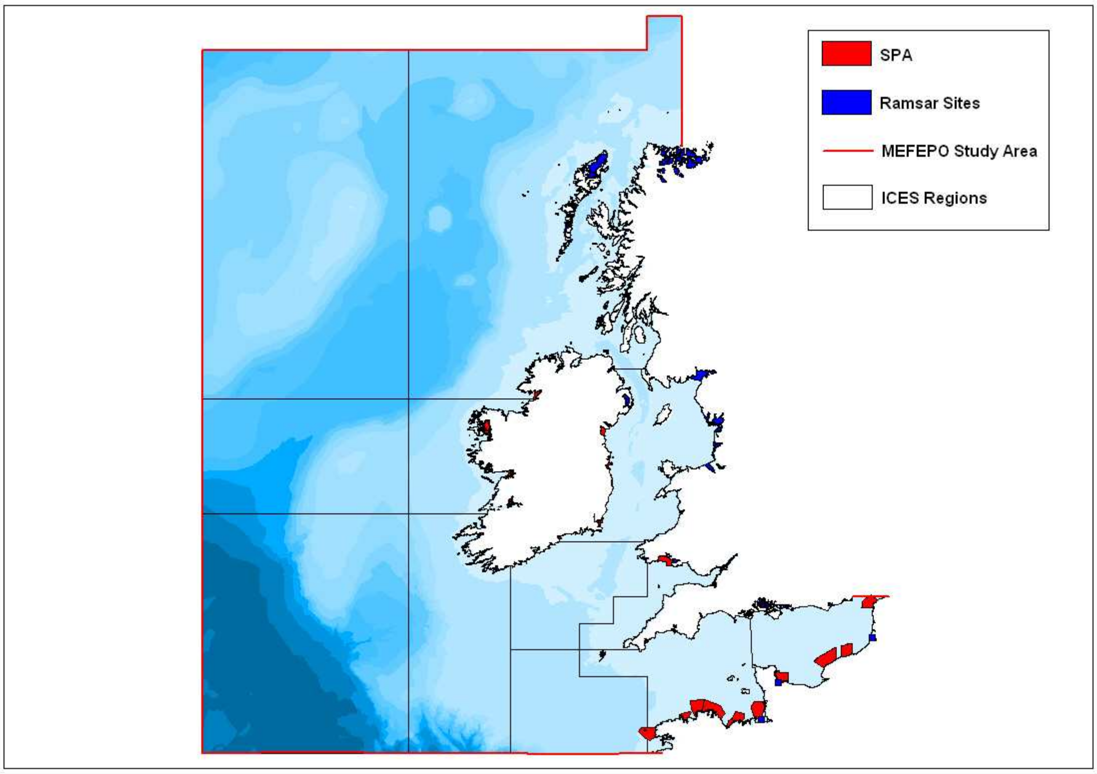


Figure 1.2.45: SPA and Ramsar Sites within the MEFEPO Study Area (Source: NPWS, JNCC, L'Agence des aires marines protégées & ramsar.org)

In addition to these conservation sites in the MEFEPO Study Area, there are a number of habitats listed by OSPAR as being threatened or in decline in OSPAR Regions II, III and V (See Figure 1.2 for MEFEPO Study Area coverage of the OSPAR Regions). Figure 1.2.46 and 22 show the locations of these listed habitats within the MEFEPO Study Area (Source: http://data.nbn.org.uk/hosted/ospar/ospar/html). Additional data on the distribution of maerl beds in Irish waters (excluding Northern Ireland) has been taken from De Grave *et al.* (2000). Table 1.2.7 shows the habitats and the OSPAR regions they occur in. Geographical data was not available for Carbonate Mounds and *Ostrea edulis* beds and therefore these are not mapped in Figures 31 and 32. In addition, any habitat listed in Table 3 that is not located within the MEFEPO Study Area is not mapped.

Table 1.2.7: OSPAR habitats within the MEFEPO Study Area.

Habitat	**OSPAR Region where the habitat occurs**	**OSPAR regions where the habitats are under threat and/or in decline**
Carbonate mounds	**V**	**V**
Coral gardens	**II, III, V**	**All where it occurs**
Deep-sea sponge aggregrations	**III, V**	**All where it occurs**
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	**II, III**	**All where it occurs**
Intertidal mudflats	**II, III**	**All where it occurs**
Littoral chalk communities	**II**	**All where it occurs**
Lophelia pertusa reefs	**All**	**All where it occurs**
Maerl beds	**All**	**III**
Modiolus modiolus beds	**All**	**All where it occurs**
Oceanic ridges with hydrothermal vents/fields	**V**	**V**
Ostrea edulis beds	**II, III**	**All where it occurs**
Sabellaria spinulosa reefs	**All**	**II, III**
Seamounts	**V**	**All where it occurs**
Seapen and burrowing megafauna communities	**II, III**	**II, III**
Zostera beds	**II, III**	**All where it occurs**

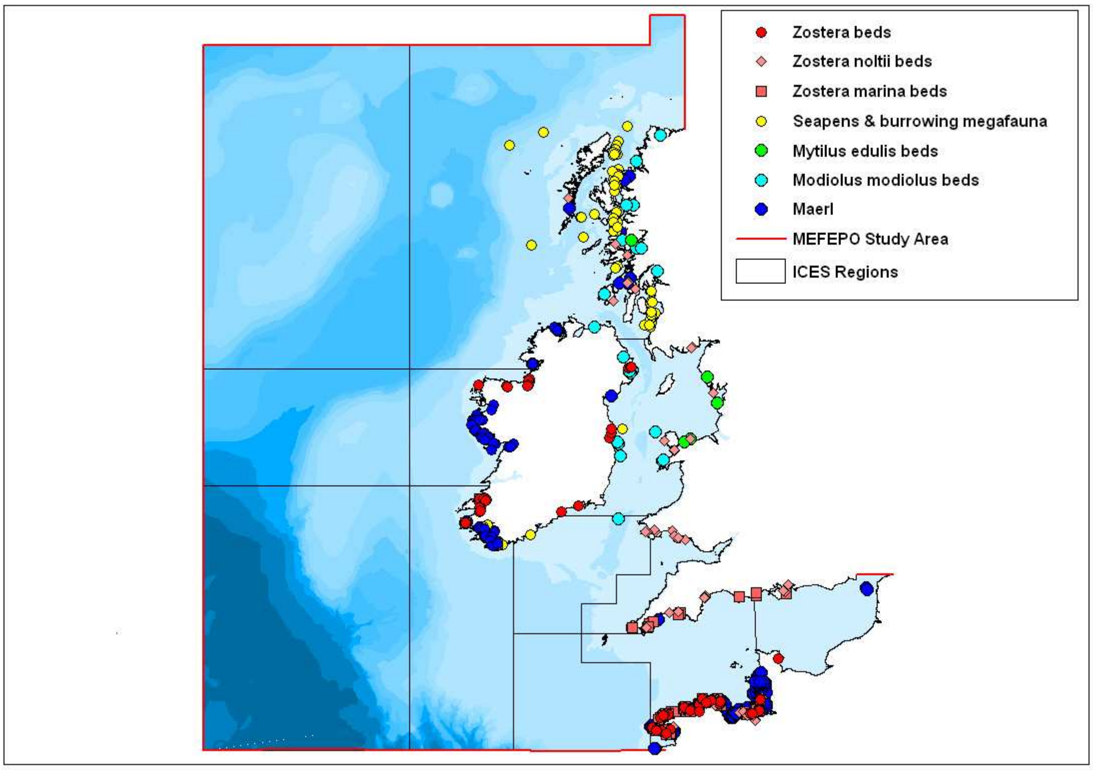


Figure 1.2.46: OSPAR listed habitats within the MEFEPO Study Area (Source: http://data.nbn.org.uk; De Grave *et al.,* 2000).

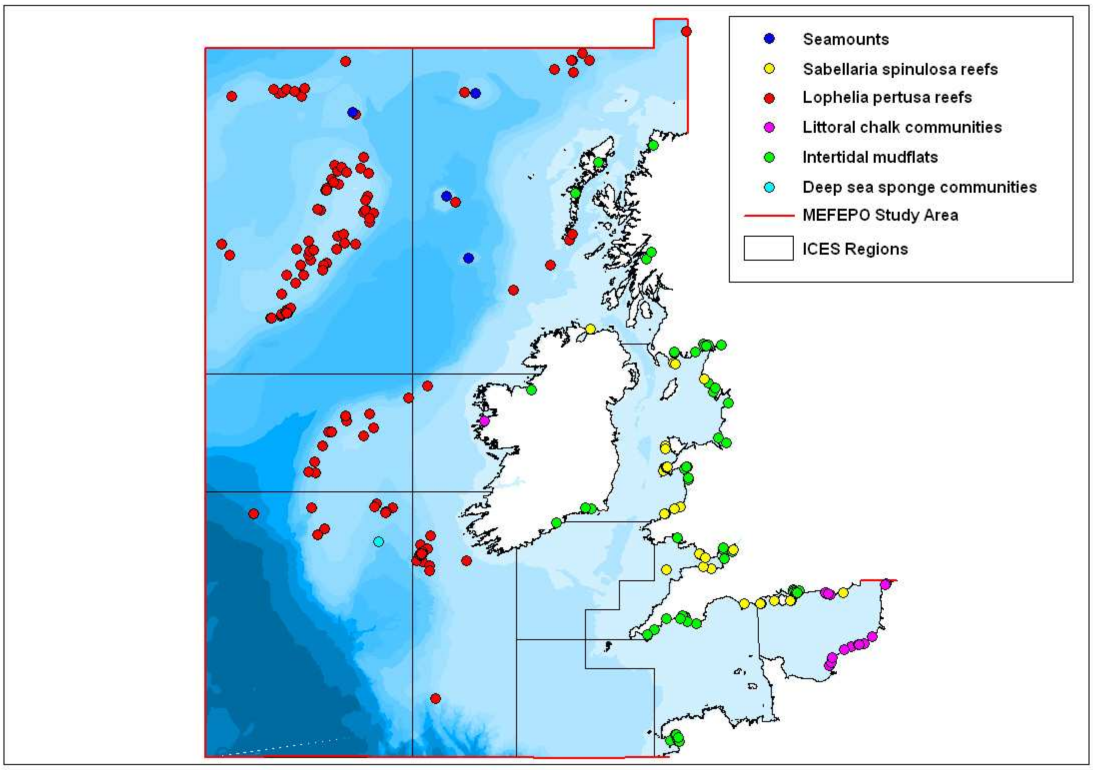


Figure 1.2.47: OSPAR listed habitats within the MEFEPO Study Area (Source: http://data.nbn.org.uk).

In addition, the OSPAR List of Threatened and/or Declining Species lists the following species (See Table 1.2.8) found within OSPAR Regions II, III and V.

Table 1.2.8: Species identified by OSPAR which may be found in the MEFEPO Study Area.

Group	**Common Name**	**Latin Name**	**OSPAR Regions where they occur**	**OSPAR Regions where they are in threat and/or in decline**
Invertebrates	Ocean quahog	*Arctica islandica*	**II, III**	**II**
	Azorean barnacle	*Megabalanus azoricus*	**V**	**All where it occurs**
	Dog whelk	*Nucella lapillus*	**II, III, V**	**II, III**
	Flat oyster	*Ostrea edulis*	**II, III**	**II**
	Azorean limpet	*Patella ulyssiponensis aspera*	**V**	**All where it occurs**
Birds	Little shearwater	*Puffinus assimilis baroli* (auct. incert.)	**V**	**All where it occurs**
	Balearic shearwater	*Puffinus mauretanicus*	**II, III, V**	**All where it occurs**
	Black-legged kittiwake	*Rissa tridactyla*	**II, III, V**	**II**
	Roseate tern	*Sterna dougallii*	**II, III, V**	**All where it occurs**
Fish	Sturgeon*	*Acipenser sturio*	**II**	**All where it occurs**
	Allis shad*	*Alosa alosa*	**II, III**	**All where it occurs**
	European eel*	*Anguilla anguilla*	**II, III**	**All where it occurs**
	Portuguese dogfish*	*Centroscymnus coelolepis*	**All**	**All where it occurs**

	Gulper shark*	*Centrophorus granulosus*	**V**	**All where it occurs**
	Leafscale gulper shark*	*Centrophorus squamosus*	**All**	**All where it occurs**
	Basking shark*	*Cetorhinus maximus*	**All**	**All where it occurs**
Group	**Common Name**	**Latin Name**	**OSPAR Regions where they occur**	**OSPAR Regions where they are in threat and/or in decline**
Fish	Houting	*Coregonus kavaretus oxyrinchus*	**II**	**All where it occurs**
	Common skate*	*Dipterus (Raja) batis*	**All**	**All where it occurs**
	Spotted ray*	*Raja montagui*	**II, III, V**	**All where it occurs**
	Cod*	*Gadus morhua*	**All**	**II, III**
	Long-snouted seahorse	*Hippocampus guttulatus*	**II, III, V**	**All where it occurs**
	Short-snouted seahorse	*Hippocampus hippocampus*	**II, III, V**	**All where it occurs**
	Orange roughy*	*Hoplostethus atlanticus*	**V**	**All where it occurs**
	Porbeagle*	*Lamna nasus*	**All**	**All where it occurs**
	Sea lamprey	*Petromyzon marinus*	**II, III**	**All where it occurs**
	Thornback skate/ray*	*Raja clavata*	**II, III, V**	**II**
	White skate*	*Rostroraja alba*	**II, III**	**All where it occurs**
	Atlantic salmon*	*Salmo salar*	**II, III**	**All where it occurs**

	Northeast Atlantic spurdog*	*Squalus acanthias*	**All**	**All where it occurs**
	Angel shark*	*Squatina aquatina*	**II, III**	**All where it occurs**
	Bluefin tuna	*Thunnus thynnus*	**V**	**All where it occurs**
Group	**Common Name**	**Latin Name**	**OSPAR Regions where they occur**	**OSPAR Regions where they are in threat and/or in decline**
Marine turtles	Loggerhead turtle	*Caretta caretta*	**V**	**All where it occurs**
	Leatherback turtle	*Dermochelys coriacea*	**All**	**All where it occurs**
Marine mammals	Blue whale	*Balaenoptera musculus*	**All**	**All where it occurs**
	Northern right whale	*Eubalaena glacialis*	**All**	**All where it occurs**
	Harbour porpoise	*Phocoena phocoena*	**All**	**II, III**

* Fish species affected by fishing

There are a number of OSPAR Marine Protected Areas (MPA's) located within the MEFEPO Study Area (See Figure 1.2.48). Ireland does not at present have any designated MPA's. The UK MPA's correspond to their SAC sites. The French MPA's were accessed through the OSPAR MPA Database (http://www.ospar.org/content/content.asp?menu=00180302000011_000000_000000).

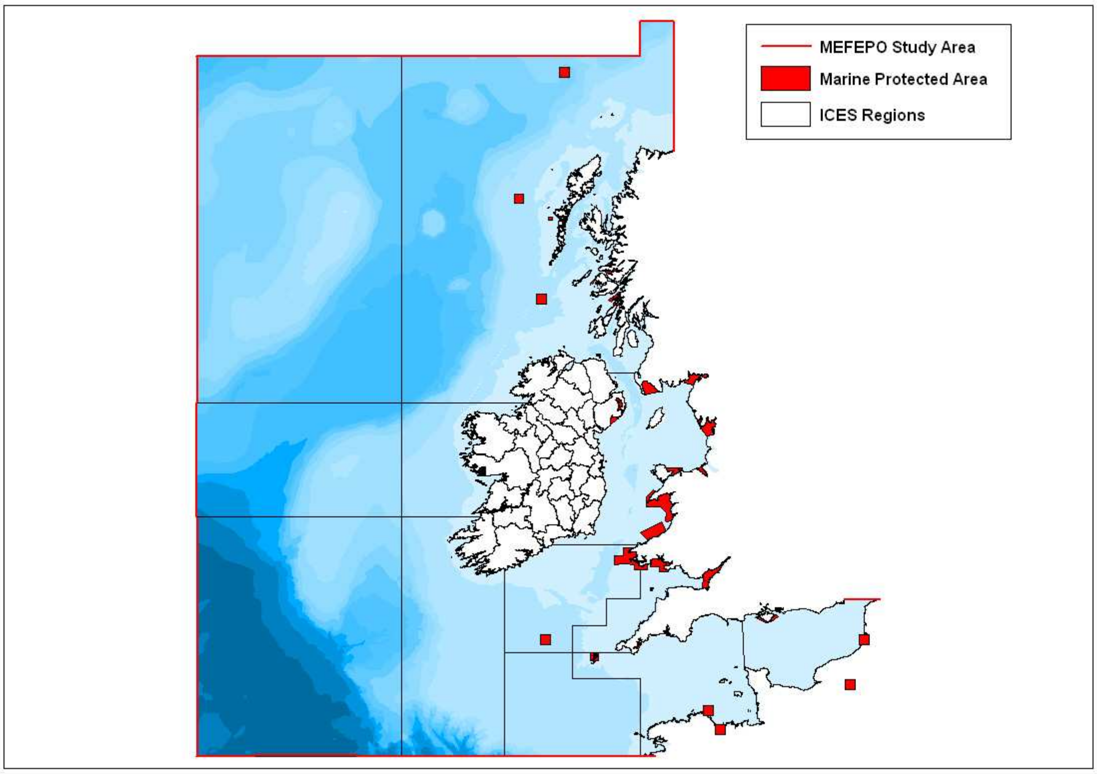


Figure 1.2.48: OSPAR Marine Protected Areas within the MEFEPO Study Area (Source: JNCC & OSPAR MPA Database).

1.2.3 Biological features

This section draws from the ICES Working Group on Regional Ecosystem Descriptions (WGRED 2008; 2007), the OSPAR Quality Status Report of 2000 and various ICES Reports and publications.

For the purposes of the technical Report, North Western Waters are divided into four distinct areas. These areas facilitate the fisheries case studies (Mackerel, Nephrops, Scallop, mixed trawl for hake monk and megrim) and correspond with the areas used by WGRED. The areas are:

(1) Celtic Seas Area (including the Irish Sea)

(2) English Channel

(2) Pelagic Waters to the west of Ireland and Scotland

(4) Deep waters off the west of Ireland and Scotland

NOTE

In general this region has attracted less attention than areas such as the North Sea. It is probably not that data do not exist, but that they have not been correlated and integrated. For example, the ICES Annual Ocean Climate Status Summary does not address this area as a whole. The CPR programme samples within the area, but detailed breakdown of these data has not been carried out. There is also no single assessment working group responsible for the fisheries in the region. These are covered by nine different groups, including both northern and southern shelf demersal WGs. This makes the integration of data by eco-region more complex. There is currently no multi-species working group for this region, and hence there has been no coordinated effort towards exploring predator-prey relationships and inter-dependencies among commercial species (WGRED 2008).

1.2.3.1 Celtic Seas Area

From WGRED 2008

1.2.3.1.1 Phytoplankton and Zoolplankton

For most of the Celtic Seas ecoregion productivity is reasonably strong on the shelf but drops rapidly west of the shelf break. Based on CPR greenness records for this area the spring bloom occurs around April and collapses by October, although in recent years has continued into December. CPR data also suggest that there has been a steady increase in phytoplankton colour index across the whole area over at least the last 20 years. Phytoplankton productivity and taxonomic composition in the Celtic Sea has been shown to depend on water column structure. Diatoms dominate well mixed areas with high nutrient content and display high rates of productivity, while dinoflagellates and microflagellates are found in stratified waters exhibiting lower rates of productivity (Raine *et al*., 2002). Certain oceanographic conditions can lead to the formation of toxic algal blooms around Irish Coasts with highest occurrence of them noted along the southwest of Ireland. Large harmful algal blooms recorded in 2005 were associated with the dinoflagellate *Karenia mikimotoi* and caused mortalities to benthic and pelagic marine organisms at a scale that has not previously been observed (Silke *et al.*, 2006).

As is true of the adjacent North Sea, the overall abundance of zooplankton in this region has declined in recent years. CPR areas C5, D5 and E5 all show substantial drops in *Calanus* abundance and these are now below the long term mean. *Calanus finmarchicus* is known to overwinter in the Faroe-Shetland channel and the abundance of these is known to have been reduced in recent years. This species distribution in deep waters further south is unknown. More detailed information should be available from the CPR programme but this is not available at present.

Zooplankton monitoring data are available from one station (“L4”) in the English Channel. This station is influenced by seasonally stratified waters and is maintained by Plymouth Marine Laboratory (ICES, 2005). Whether or not changes in the zooplankton community evident at this site are representative of changes and trends in the wider “Celtic Seas” remains uncertain, further analyses of CPR data or additional information from static sampling stations (e.g. Nash and Geffen, 2004) are urgently needed to clarify the situation.

The ten most abundant zooplankton taxa at “L4” have been ranked according to their annual mean proportion of the total zooplankton (Table 1.2.9). In 2005, major changes in the zooplankton composition were reported. Not only has the rank order of the top ten species changed, but new groups, Echinoderm larvae, Noctiluca scintillans, Siphonophores, and C. helgolandicus appear in the dominant species for the first time, contributing 4.6% to 3% of the total zooplankton abundance respectively. In addition, Ps. elongatus, which was the most abundant species during the period 1988–2004 when it contributed nearly 12% of the total zooplankton abundance, represented only 2.3% of the zooplankton community in 2005. Ps. elongatus abundance in 2005 is the lowest abundance observed over the whole time-series (53 ind m−3). Peaks of high zooplankton abundance and chlorophyll a concentration are regularly observed in spring and late summer/beginning of autumn, the latter resulting from intense summer dinoflagellate blooms in some years. Zooplankton at L4 shows two decreasing trends from 1988 to 1995 and from 2001 to 2005. This is mainly the result of relatively low abundances of the spring species Paracalanus, Pseudocalanus, and A. clausi. Small copepods like Oncaea, Oithona, and Corycaeus contribute greatly to the total zooplankton population.

Table 1.2.9: Benthos, larger invertebrates and biogenic habitats.

RANK	TAXA	% TOTAL ZOOPLANKTON 1988–2004	% TOTAL ZOOPLA NKTON 2005	YEARLY AVERAG E 1998–2004 (N/M3)	2005 AVERAGE (N/M3)
1	*Pseudocalanus*	11.74	2.32	380	54
2	*Oithona*	11.30	6.23	366	144
3	*Oncaea*	11.11	7.69	360	178
4	*Paracalanus*	9.53	4.23	309	98
5	*Temora*	9.19	8.52	298	198
6	Cirripeda nauplii	8.69	7.93	281	184
7	*Acartia clausi*	6.18	2.74	200	64
9	*Appendicularia*	2.59	1.22	84	28
10	*Corycaeus*	2.25	5.72	73	133
Total		78.43	48.90	2540.62	1133.30
N/m3		3239.60		2320.40	

Ellis *et al.* (2000) provided a review of benthic community structure in the Irish Sea and described six distinct assemblages. Plaice and dab dominated on fine substrates in inshore waters, whereas sea urchins and sun-stars dominated on the coarser substrates further offshore. Thickback sole *Microchirus variegates* and hermit crabs were typical of the transitional zone, while Norway-lobster and Witch (*Glyptocephalus cynoglossus*) dominated on the muddy sediments in the central Irish Sea. Beds of

Alcyonium digitatum (Dead man's finger) occurred on coarse substrates throughout the study area, whereas common spider crabs were only dominant in the Bristol Channel (*Maja* assemblage). The common starfish (*Asterias rubens*) was an important component of all assemblages and the distribution of these assemblages was primarily correlated with depth, temperature and substrate type. Kaiser *et al.* (2004) added a distinct sandbank type habitat off the Welsh coast, typified by low species diversity and shared indicator species such as the weever fish *Echiichthys vipera*, the shrimp *Philocheras trispinosus* and the hermit crab *Pagurus bernhardus*.

Over 340 species of invertebrate and fish were captured in a survey of the epibenthos in ICES area VIIf-h (Ellis *et al.* 2002), the most ubiquitous species being the hermit crab *Pagurus prideaux* and the spotted dragonet *Callionymus maculatus,* both of which are major prey items for commercial fish (Pinnegar *et al*., 2003). Two epibenthic assemblages predominate in the Celtic Sea. The first is dominated by the anemone *Actinauge richardi* (41.8% of faunal biomass) and occurs along the shelf edge and slope in waters 132–350m deep. The second assemblage is more widely distributed on the continental shelf (depth range: 66–232 m) and *P. prideaux* dominates along with other mobile invertebrates (shrimps and echinoderms), although there are some spatial differences in assemblage structure and relative abundance.

Rees *et al*. (1999) provided a comparison of benthic biodiversity in the North Sea, English Channel, Celtic and Irish Seas. Similar infaunal assemblages were encountered on both the eastern and western UK coasts in comparable environmental conditions. Grab stations in the easternmost part of the English Channel, southern North Sea, and within the Bristol Channel, supported a very sparse infauna communities associated with sandy sediments. Highest diversities were generally encountered off the NE and SW English coast. Densities were also relatively high in coastal waters off Morecambe Bay, NW England.

Heath (2005) used the abundance of benthic invertebrate larvae in CPR (continuous-plankton-recorder) data, to establish trends in benthic production for the 'Celtic Seas' ecoregion. Based on these data the author reported an increasing long-term trend in benthic production (by 0.8 g C m2y) between 1973 and 1999.

Biogenic reefs of horse mussels *Modiolus modiolus*, maerl and Serpulid worms occur in specific locations (Irish Sea, West coast of Scotland). The latter support benthos of conservation interest such as sea fans and structurally complex bryozoans. Offshore areas on the shelf slope support reefs of deep water corals such as *Lophelia pertusa.*

1.2.3.1.2 Fish

In the northern part of this ecoregion, (Irish Sea, West of Ireland and western Scotland) there are important commercial fisheries for cod, haddock and whiting and a number of flatfish species. Hake *Merluccius merlucius* and angler fish *Lophius* spp.are also fished across the whole area. The Rockall plateau is subject to an important haddock *Melanogrammus aeglefinus* and small-scale *Nephrops* fishery. Commercial fisheries for, cod *Gadus morhua*, plaice *Pleuronectes platessa* and sole *Solea solea* are conducted in the Irish Sea. The whole area is characterised as a spawning area for a number of key wide-ranging, migratory species, notably mackerel *Scomber scombrus*, horse mackerel *Trachurus trachurus* and blue whiting *Micromesistius potassou*. These species are also commercially exploited within the area. Key pelagic species on the continental shelf are herring *Clupea harengus*, considered as consisting of a number of different stocks, as well as sardine *Sardina pilchardus* in the southern part of the area, and sprat *Sprattus sprattus*, particularly in the Celtic Sea. The area accommodates considerable stocks of argentines (two species) and also large numbers of small mesopelagic myctophids along the shelf break.

The shelf slope (500–1800m) comprises a distinct species assemblage including roundnose grenadier *Coryphaenoides rupestris*, black scabbard fish *Aphanopus carbo*, blue ling *Molva macrophthalma* and orange roughy *Hoplostethus atlanticus* as well as deep sea squalids (sharks) and macrouridae. Stock assessments have been most often unreliable for these species so far. However, strong evidence exist that some have been severely depleted by the deep water fisheries carried out in this area. All these fish are characterised as being long lived, slow growing and having a low fecundity, making them very vulnerable to overfishing.

More than 170 species of marine fish have been recorded from within the Irish Sea, (Ellis *et al*., 2002). Trawl surveys in this region (Parker-Humphreys, 2004) have revealed that dab *Limanda limanda*, plaice, solenette *Buglossidium luteum* and common dragonet *Callionymus lyra* are the most abundant species, along with large numbers of poor-cod, whiting and sole. Dab, solenette and scaldfish (*Arnoglossus laterna*), all non-commercial species, are thought to have increased in recent years, whereas hake, dragonets and pogge *Agonus cataphractus* have become less abundant. Red gurnards *Aspitrigla cuculus* are also thought to have increased in recent years.

The Celtic Sea groundfish community consists of over a hundred species and the most abundant 25 make up 99 percent of the total estimated biomass and around 93 percent of total estimated numbers (Trenkel and Rochet, 2003). Population and community analyses have shown that fishing has impacted a number of commercial species, primarily because individuals of too small a size have been caught and discarded in the past (Trenkel and Rochet, 2003, Rochet *et al*., 2002).The size structure of the fish community has changed significantly over time, and a decrease in the relative abundance of larger fish has been accompanied by an increase in smaller fish (4–25g) (Blanchard *et al*., 2005; Trenkel *et al*., 2004). Temporal analyses of the effects of fishing and climate variation suggest that fishing has had a stronger effect on size-structure than changes in temperature. A marked decline in mean trophic level of the fish community over time has been documented (Pinnegar *et al.*, 2003) and this has resulted from a reduction in the abundance of large piscivorous fishes such as cod and hake, and an increase in smaller pelagic species which feed at a lower trophic level. Since 1990 the non-exploited species *Capros aper* has become particularly abundant in French and UK survey catches. This phenomenon has been reported as occurring elsewhere in the North Atlantic including the Bay of Biscay (Farina *et al*., 1997) and offshore seamounts (Fock *et al.*, 2002).

Limited information is available for the west coasts of Scotland and Ireland, however Scottish groundfish surveys between 1997 and 2000 revealed declines in most commercial fish stocks, including haddock, whiting, norway pout, herring and hake. Similarly, Irish groundfish surveys revealed a downward trend in the biomass and abundance of cod, whiting and hake between 1993 and 2000, in particular in the latter part of the time-series. Megrim were somewhat more abundant in recent years particularly along the coasts of southern Ireland and the Celtic Sea shelf edge (Mahé 2001).

1.2.3.1.3 Demersal elasmobranchs

The Celtic Seas eco-region covers west of Scotland (VIa), Rockall (VIb), Irish Sea (VIIa), Bristol Channel (VIIf), the western English Channel (VIIe), and the Celtic Sea and west of Ireland (VIIb-c, g-k), although the south-western sector of ICES Division VIIk is contained in the oceanic northeast Atlantic eco-region. This eco-region broadly equates with the area covered by the North-western waters RAC. Whereas some demersal elasmobranchs, such as spurdog *Squalus acanthias* and lesser-spotted dogfish *Scyliorhinus canicula,* are widespread throughout this region, there are some important regional differences in the distributions of other species. Other than spurdog and tope, the main species of shark taken in demersal fisheries in this eco-region are lesser-spotted dogfish, smooth-hounds *Mustelus* spp. and greater-spotted dogfish *Scyliorhinus stellaris*. Sixteen species of skate and ray are recorded in the area, the most abundant skates being thornback ray *Raja clavata*, cuckoo ray *Leucoraja. naevus*, blonde ray *R. brachyura*, spotted ray *R. montagui,* undulate ray *R. undulata*, common skate *Dipturus batis*, shagreen ray *L. fullonica* and smalleyed ray, *R. microocellata*. Other batoids (stingray *Dasyatis pastinaca*, marbled electric ray *Torpedo marmorata* and electric ray *T. nobiliana*) may be observed in this eco-region, although they are more common in more southerly waters. These are generally discarded if caught in commercial fisheries and are not considered in this report.

Landings of rays appear as a series off peaks and troughs, with lows of approximately 14 000 t in the mid-1970s and 1990s, and highs of just over 20 000 t in the early and late 1980s and late 1990s. While landings have fluctuated considerably over the time series, they have been in a constant decline since 2003, and the 2006 landings of approximately 10 000 t are the lowest in the time series. This decline in landings is thought to be mainly due to a combination of increased regulation and changes in consumption (ICES, 2007).

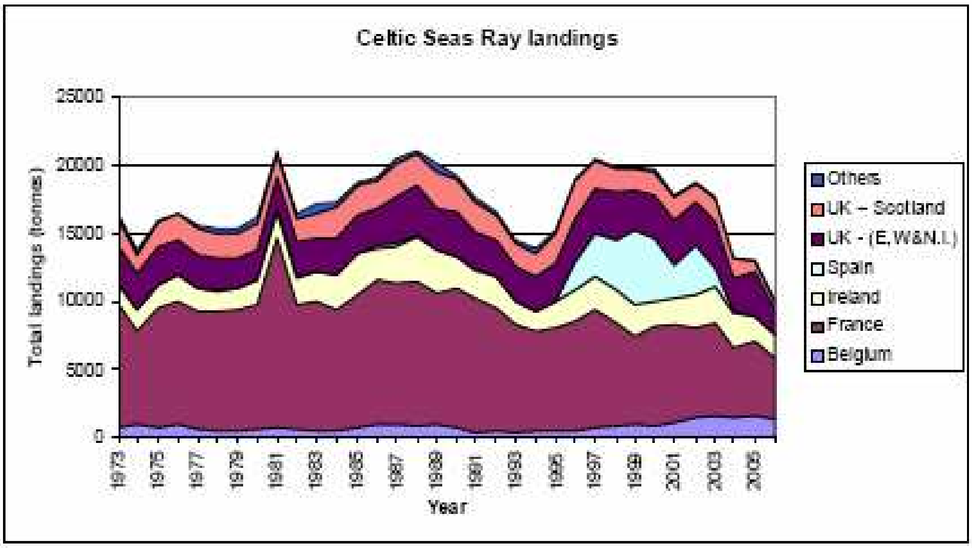


Figure 1.2.49: Demersal elasmobranchs in the Celtic Seas. Total landings (tonnes) of Rajidae by nation in the Celtic Seas from 1973–2006 (Source: ICES).

1.2.3.1.4 Trophic web

For the Celtic and Irish Sea, two sources of fish stomach data have recently been collated and these are described by Pinnegar *et al.* (2003).UK researchers collected stomachs for 66 species during annual groundfish surveys from 1986 to 1994. French researchers (du Buit and co-workers) sampled stomachs of seven species aboard commercial fishing vessels, throughout the years 1977 to 1992 (in all seasons). The main predator species in the Celtic Sea (hake, megrim, monkfish, whiting, cod, saithe) are generalist feeders which exhibit size-dependent, temporal and spatial prey-switching behaviour (Pinnegar *et al.*, 2003, Trenkel *et al.*, 2005). Consequently, utilisation of a conventional multispecies assessment model such as MSVPA in such a system would be unlikely to yield useful insights. Overall, higher prey densities in the environment coincide with higher occurrences of particular prey species in predator stomachs (Trenkel *et al.*, 2005). Blue whiting was found more often in predator stomachs over the shelf edge during the summer months while mackerel and Triopterus spp were relatively more prevalent in stomachs sampled on the continental shelf during the winter half-year. Little is known concerning trophic interactions among fish species west of Ireland and northwest Scotland (although see du Buit, 1989; 1991a, b). No major studies of forage fish have been conducted in the eco-region. Sand eel Ammodytes spp., sprat and Norway pout Trisopterus esmarki are known to be present, but their role and importance in the ecosystem remains unclear.

For cod in the Irish Sea, the decapod *Nephrops* norvegicus is known to be an important prey item (Armstrong, 1982). Consequently, Bennett and Lawler (1994) attempted to model cod-*Nephrops* in a simple multispecies model. Whiting, Norway-pout and *Nephrops* are known to be important for monkfish in the Irish Sea (Crozier, 1985). In north-west of Scotland there have been additional studies focusing on inshore demersal assemblages (e.g. Gibson and Ezzi, 1987).

According to Heath (2005) fish taken from the shelf edge areas of the Celtic Seas tend overall to be less planktivorous and from a higher trophic level than those in the North and Baltic Seas (Heath, 2005). The secondary production required per unit of landed fish from the southern part of the Celtic Seas is suggested to be twice that for North Sea fish. In the Celtic Seas benthos production has been suggested to be a 'bottom-up' driver for fisheries production, which seems to be independent of variability in plankton production. As this situation is very different to the situation in the North Sea (see NS section), climate change and fishing pressures might be expected to influence these regional fisheries in very different ways. Overall, there appear to be strong spatial patterns in the fish food web structure and function, which should be important considerations in the establishment of regional management plans for fisheries (Heath, 2005).

Heath (2005) argues that, because the blue-whiting fishery is conducted mainly off the continental shelf, there is no rationale for a foodweb connection between the bulk of the blue whiting catch and the other landed species from the Celtic Sea and west of Scotland. However, Pinnegar *et al.* (2003) and Trenkel *et al.* (2005) have both highlighted the importance of this species as a prey for fish on the shelf-edge, notably for hake and megrim.

1.2.3.1.5 Vulnerable species

Skates are arguably the most vulnerable of exploited marine fishes because of their large size, slow growth rate, late maturity and low fecundity. Dulvy *et al.* (2000) discussed the disappearance of skate species (*Dipturus oxyrhinchus, Rostooraja alba* and *D. batis*) in the Irish Sea, and the widespread decline in the abundance of smaller species. In 2006 the Working

Group on Fish Ecology (WGFE) evaluated the status of rarer elasmobanchs throughout the 'Celtic Seas' ecoregion. The Celtic Sea was highlighted as a particularly important area for common skate (*D. batis*), electric ray (*Torpedo nobiliana*), and shagreen ray (*Leucoraja fullonica*) whereas the English Channel is an important area for undulate ray (*Raja undulata*) and stingray (*Dasyatis pastinaca*) (ICES, 2006c).

The blackspot (red) seabream (*Pagellus bogaraveo*) was previously an important target species of English fisheries in the 1930s (Desbrosses, 1932), catches in the Celtic seas declined well before the cited collapse of the fishery in region G (see this chapter for a longer account on this species). The species can be considered as commercially extinct in the Celtic seas.

The red lobster (*Palinurus elephas*) was exploited by pot fisheries prior to the late 1970s, and current catches of this species can be considered as residual.

As mentioned above, several species of deep water fish are considered as being severely depleted and meriting protection (see Section 1.2.3.4).

1.2.3.1.6 Mammals and large elasmobranches

Basking shark (*Cetorhinus maximus*), are seen throughout the Celtic Sea, Irish Sea and Northern Shelf region, from April through to October but the stock seems to be severely depleted. Basking shark is protected within British territorial waters. Blue shark (*Prionace glauca*) are found in the summer in the southern part of the area. They are subject to a variety of fisheries, both recreational and directed (longlines and gillnet) as well as bycatch in offshore tuna fisheries. Porbeagle (*Lamna nasus*) and tope (*Galeorhinus galeus*) are also targeted in both recreational and commercial fishing.

Six species of cetacean are regularly observed in this Advisory Region (Reid *et al*., 2003). Minke whale *Balaenoptera acutorostrata* is found throughout the region, particularly off western Scotland and Ireland. SCAN surveys and observer programmes on ships of oppurtunities have recorded that bottlenosed dolphin *Tursiops truncatus* occur in large numbers off western and southwest Ireland and in smaller numbers throughout the region. Common dolphin *Delphinus delphis* are widely distributed in shelf waters, but especially in the Celtic Sea and adjacent areas,

White-beaked dolphin and White-sided dolphin (*Lagenorhynchus albirostris* and *L. acutus*) occur over much shelf area, but are less common in the southwest. Harbour porpoise *Phocoena phocoena* is the smallest but by far the most numerous of the cetaceans found in the Celtic Seas ecoregion, particularly south-west Ireland, and west of Scotland (Hammond *et al*., 2002, Wall *et al*., 2004). Santos *et al*. (2004) has suggested that whiting and sandeels are the most important prey for porpoises around the coasts of Scotland, comprising around 80% of the diet.

Grey seals (*Halichoerus grypus*) are common in many parts of the area, with population estimates ranging from approximately 50 000 to 110 000 animals (SCOS, 2005). The majority of individuals are found in the Hebrides and in Orkney although some 5000–7000 are thought to exist in the Irish and Celtic Seas (Kiely *et al*., 2000). Studies of grey seal diet in the western Irish Sea reveal that the predominant prey species (Norway pout, bib, poor cod, whiting, plaice) are not the principle target species for commercial fisheries in this region (Kiely *et al.*, 2000). However, a recent study (Hammond and Harris, 2006) of seal diets off western Scotland revealed that grey seals may be an important predator for cod, herring and sandeels in this area. Common seals (*Phoca vitulina*) are also widespread in the northern part of the ecoregion with around 15 000 animals estimated (SCOS, 2005). Smaller numbers are seen in Ireland (c. 4000) and very few further south.

In 2002, the ICES Working Group on Seabird Ecology reported seabird population estimates within all ICES areas. For ICES Area VIa west of Scotland a total of 1.2 million pairs of breeding seabirds were reported. Auks, predominantly the common guillemot (*Uria aalge*), razorbill (*Alca torda*) and the Atlantic puffin (*Fratercula arctica*) accounted for 51% of the total, while petrels (including fulmar, *Fulmarus glacialis*; storm petrel, *Hydrobates pelagicus;* and Manx shearwater, (*Puffinus puffinus*) accounted for 29%, Northern gannet accounted for 10%, and gulls (particularly kittiwake and herring gull) 9%(ICES, 2002). In the Irish Sea, Bristol Channel and English Channel (ICES areas VIIa,d,e,f) gulls predominate (47%, 66%, 90%, 68% respectively), in particular black-headed, lesser black-backed and herring gulls as well as guillemots. Petrels (fulmar and storm-petrel) dominate in the west of Ireland and Celtic Sea region (area VIIb,g,j 48%, 60% and 79% respectively) but there also large breeding colonies of kittiwake, guillemot and gannet. Climate change is likely to impact significantly on seabird populations. The breeding success of some seabird populations in the Celtic Sea has already been linked to climatic fluctuations in the North Atlantic, such as the North Atlantic Oscillation (NAO). Projected consequences of global warming, such as sea level rises, increased storminess and rises in sea/air temperatures are also likely to have a direct impact on seabird populations.

Porpoise

The harbour porpoise is the most commonly encountered and widely distributed cetacean species in the North Sea but there are few sightings south of 47°N. Overall abundance of harbour porpoises in the North Sea and adjacent areas has not changed between the two SCANS surveys (1994 and 2005). Harbour porpoise numbers in the whole area were estimated to be 386 000 (Coefficient of variation, CV=0.20). Porpoise density was lowest in strata along the outer shelf to the west of Britain and Ireland and off the Atlantic coasts of France, Spain and Portugal (<0.1 animals/km2). It was highest in the south central North Sea and coastal waters of northwest Denmark (~0.6 animals/km2). Elsewhere there was relatively little variation in porpoise density. Harbour porpoise distribution, however, has undergone a southward shift with a two-fold increase in the number of porpoises in the southern North Sea strata while porpoise numbers in the northern North Sea strata have halved (Figure 1.2.50 and Figure 1.2.51). The reasons for this southward shift of harbour porpoise distribution are unknown; however, a change in distribution and availability of prey species is considered the most likely explanation, although other explanations are possible.

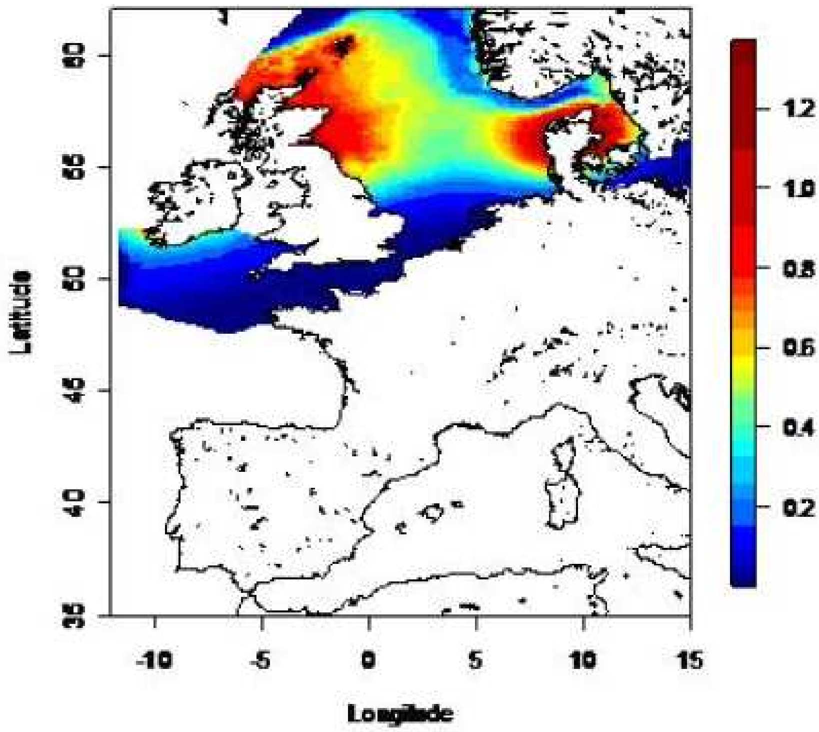


Figure 1.2.50: Density surface of harbour porpoise abundance from the SCANS I survey in 1994 (animals.km−2). Note the main concentrations off East Scotland and north-east England and around Denmark. Surveys were not conducted in the Irish Sea and west of Scotland.

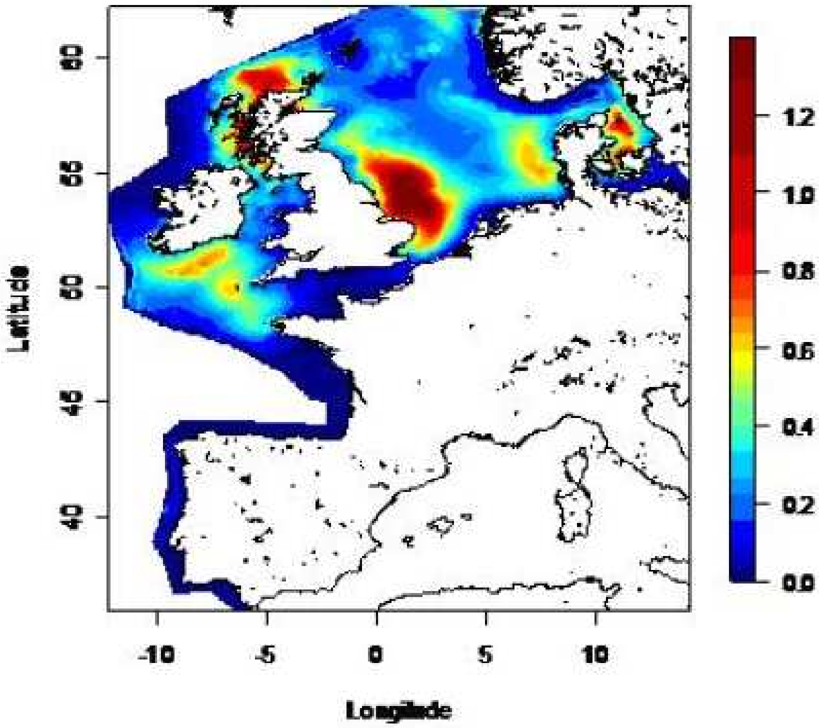


Figure 1.2.51: Density surface of harbour porpoise abundance from the SCANS II survey in 2005 (animals.km-2). Note that the main concentration in the North Sea is now off East England and North Scotland, also the increased densities on Celtic Shelf. The concentration to the west of Denmark is further offshore.

Evidence of increased numbers of porpoises in the southern North Sea has continued to accumulate (Figure 1.2.51). From sightings during two aerial observation flights (modified pollution control flights) performed by MUMM (Management Unit of Mathematical Models for the North Sea, in Brussels) it was (roughly) estimated that the average density of porpoises in Belgian waters in March and April 2004 was between 0.2 to 0.6 per square km, or 650 to 2100 animals (Haelters and Jacques, 2006). Numbers of porpoises in Belgian waters in summer and autumn are much lower. Long-term passive acoustic monitoring has been conducted in the German Baltic Sea from August 2002 to December 2005 with porpoise detectors (T-PODs). Results show seasonal as well as geographical variation in harbour porpoise presence (and therefore abundance), with decreasing detections from west to east and more porpoises in the summer months than in winter (Verfuß *et al.*, 2007). 2006 data show similar results (Verfuß, pers. comm.).

1.2.3.1.7 Seabirds

See Section 1.2.3.5.5 Seabirds

1.2.3.2 English Channel

From WGRED 2008

1.2.3.2.1 Phytoplankton and Zoolplankton

Phytoplankton

Among the identified microalgae in the Eastern Channel are diatoms (genus Nitzschia, Thalassiosira, Rhizosolenia, Chaetoceros, Skeletonema and Gyrodinium, Gymnodinium, Ceratium for dinoflagelates). For the areas of the Seine and Somme estuaries, diverse marine, brackish and fresh water population of diatoms are mixing some being planktonic and others benthic. In the Channel, some toxic and harmful species form blooms with direct effect on marine animals (eg: Dictyocha speculum, Prorocentrum minimum and P. micans, Gymnodinium cf nagasakiense) and human consumption (Dinophysis and Alexandrium) (Belin and Martin-Jézéquel, 1997). The spatial distribution of the primary production may vary largely seasonally but is often concentrated along the coasts (Figure 1.2.52).

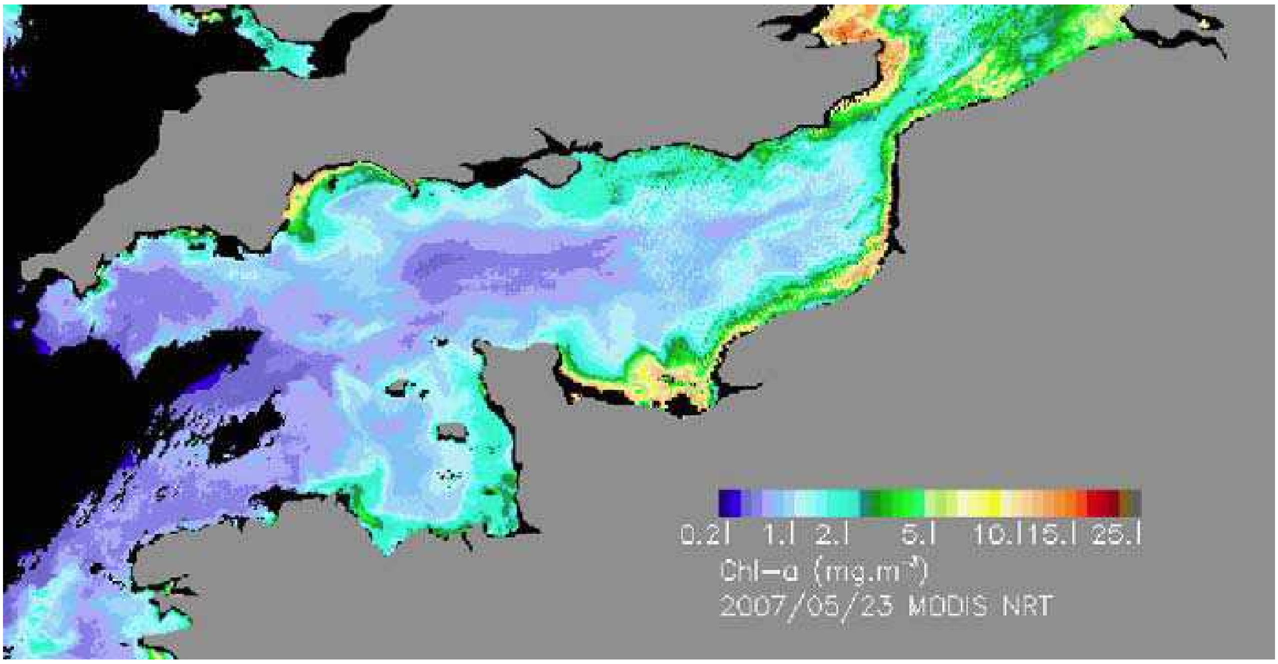


Figure 1.2.52: Chlorophyll a concentration in May 2007 from satellite images (calculated after Gohin *et al*., 2002, source http://www.ifremer.fr/cersat/facilities/browse/del/roses/browse.htm**).**

Zooplankton

In the Eastern Channel, the stability of the hydrological structure orientated along the coast gives rise to a specific coastal ecosystem slowly drifting northward with a characteristic coastal and offshore assemblage of plankton. These two ecosytems are separated by a relatively narrow front (Brylinski and Lagadeuc, 1990).

The most represented groups are the copepods, *Sagitta setosa* (chaetognathe), cladocera and jellyfish as well as numerous benthic invertebrate larvae (Cirripedia, Annelidae and Echinodermae). In the western Channel, the zooplankton is subject to the influence of Atlantic water mainly in areas deeper than 50 m. Fauna is more diversified than in the eastern part of the Channel and an offshore (central western channel) assemblage may be distinguished from a coastal assemblage (<30 m) (Le Fèvre-Lehoërff *et al.*, 1997).

1.2.3.2.2 Benthic habitats

Large tidal currents and the associated increased seabed stresses give rise to coarse seabed sediment conditions with associated characteristic sessile epifauna. In inlets and bays, where the tidal stresses are weaker fine sediments accumulate giving rise to dominant infauna communities (Castel *et al.*, 1997). Along this gradient, associated benthic assemblages often follow the same repartition (Cabioch, 1968; Gentil, 1976; Retière, 1979) (Figure 1.2.53).

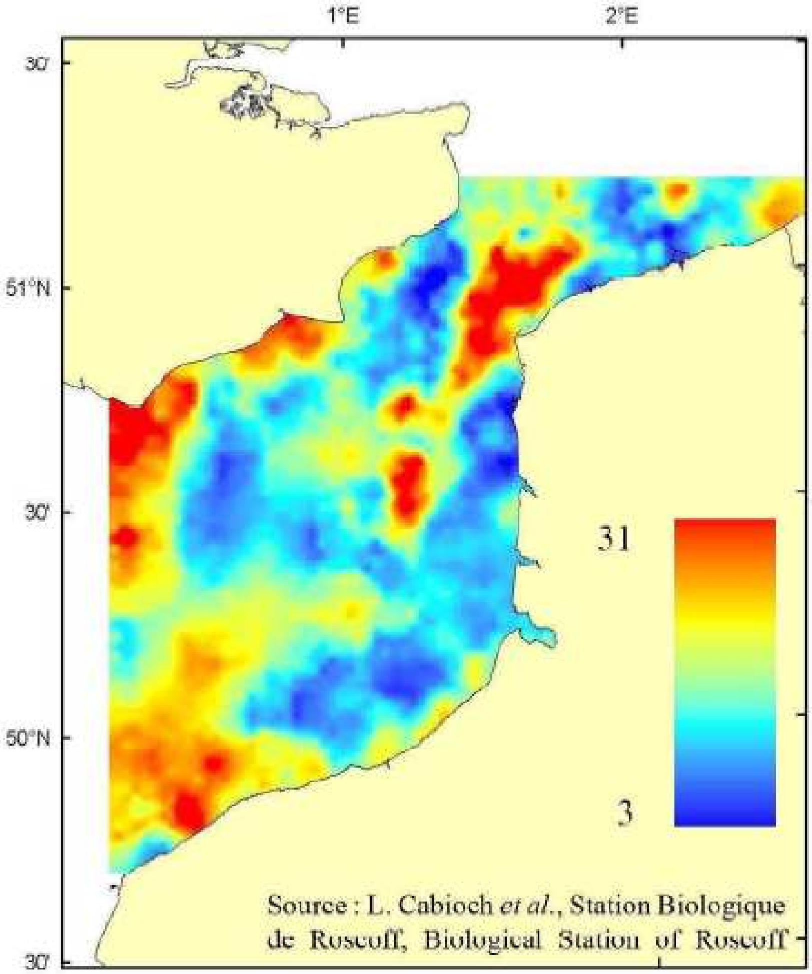


Figure 1.2.53: Macrobenthic community distribution in the Eastern English Channel (modified by Carpentier *et al.*, 2005 after Sanvicente Anorve, 2002).

In the western Channel, due to its particular tidal conditions, intertidal and subtidal zones characterised by a large variety of habitats occur. This translates into very large faunistic and floristic species richness.

1.2.3.2.3 Fish communities

Most European commercial species are present in the Channel. Of the 100 (or so) species that contribute to the catches, about 40 species constitute 90% of the landed biomass. It is unusual to have so many species contributing to the bulk of the commercial landings, This is possibly due to the relative shallowness and large variety of habitats in the area, but also it may be related to the structure of the local fishery which supports a large number of small coastal vessels exploiting diversified resources to meet a varied demand in consumption with less reliance on large pelagic fisheries as experienced elsewhere. Large life history traits (benthic, demersal, pelagic) and taxonomic diversity may be noted as flat fish (sole, plaice,…), gadoids (cod, whiting, hake…), elasmobranches (skates, sharks, dogfish), crustaceans (crabs, spider crab, lobster), cephalopods (squids and cuttlefish), shellfish (scallops, whelk) and algae may all be found in the area (Guitton *et al.*, 2003). Some species are considered as resident as particularly attached to some Channel biotopes (scallops, whelk, algae), others are seasonal, following their migration (mackerel) or reproductive cycle (herring, seabass, cuttlefish). Most are species with a larger geographic distribution that may be found indiscriminately in the Channel or in adjacent areas. (sole, whiting,…), some displaying some Atlantic preference (hake, squids, anglerfish) or rather some North Sea attachment (Cod, herring). Numerous spawning and nursery grounds as well as migratory routes of many species occur in the Channel.

Populations are distributed along the main ecological gradients resulting in a combination of cold and temperate water species, the Channel being the thermal partition limit for some of them (southern limit for cod and whiting, and northern limit for hake and anglerfish).

The spatial distribution of some species has been recently described over the last two decades in the Eastern English Channel (Carpentier *et al*., 2005, http://charm.canterbury.ac.uk/). This distribution was strongly structured by the local abiotic environment most of which have remained stable over this period. Studies of the fish, cephalopod and macro-invertebrate assemblages in this area have identified four distinct community types that are determined by environmental factors such as depth, salinity, water temperature, seabed shear stress, and sediment type (Figure 1.2.54). From 1997 to 2004, some 25% of overall community structure variance could be related to the available environmental descriptors and 20% to persistent factors such as depth, seabed shear stress, sediment, and macro-invertebrate community type. The different communities differ in their species diversity and are highest in areas of soft sediment and wide variation in temperature and salinity (Vaz *et al*., 2007).

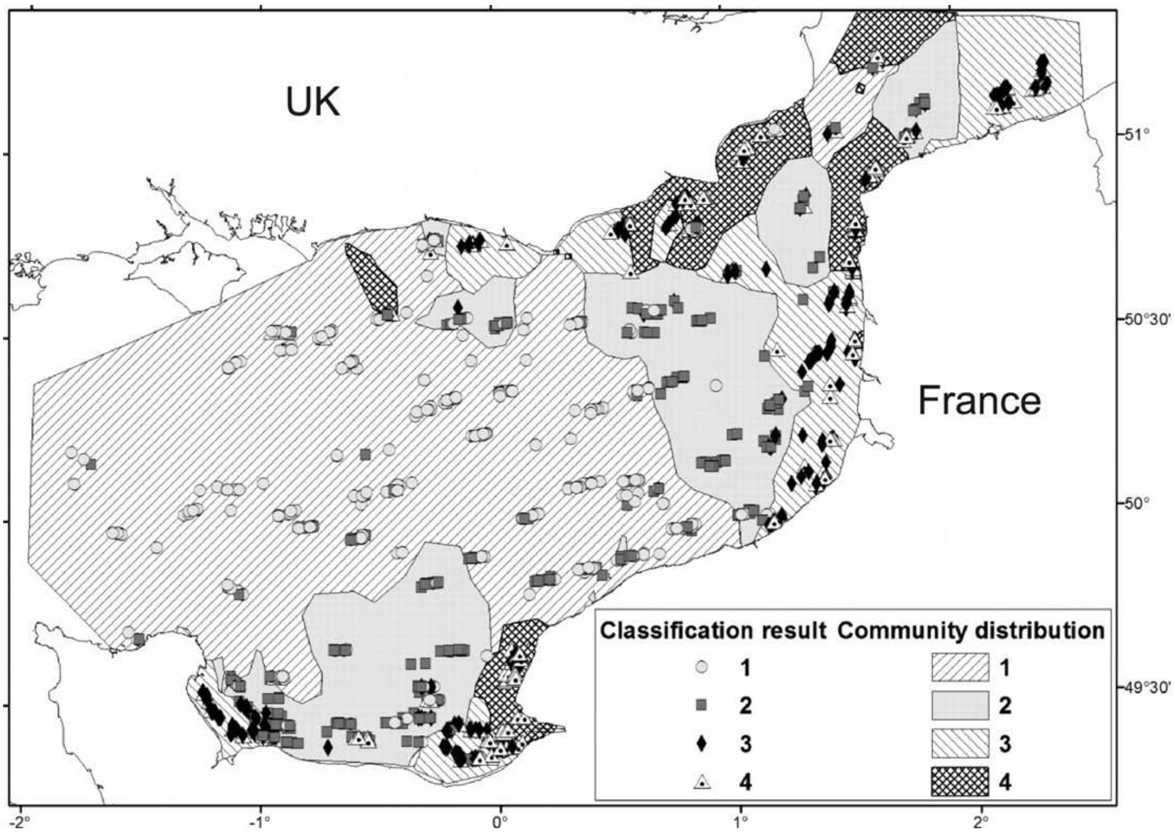


Figure 1.2.54: Spatial distribution of fish sub-communities in the Eastern Channel from 1988 to 2004. Gradation from open sea community to coastal and estuarine communities is shown (Vaz *et al*., 2007).

Rochet *et al.* (2005) assessed two estuarine communities (Seine and Somme estuaries) identified as nursery areas for commercially important stocks exploited elsewhere in mixed fisheries. In both estuaries, no significant evolution trends were found. They also concluded that overall the fish stock populations of the Eastern Channel were not deteriorating.

This result was also supported by recent studies showing that although the Eastern Channel fish communities displayed significant inter-annual variation in both structure and composition over the last two decades, the different communities, and their spatial distribution, are persistent over time reflecting the relative stability of environmental conditions in the area (Vaz *et al.*, 2007). Overall, however, species diversity over the entire region appears to have increased over the last two decades, (Vaz *et al.*, 2007). The figures produces in this paper were updated by the authors and are presented below.

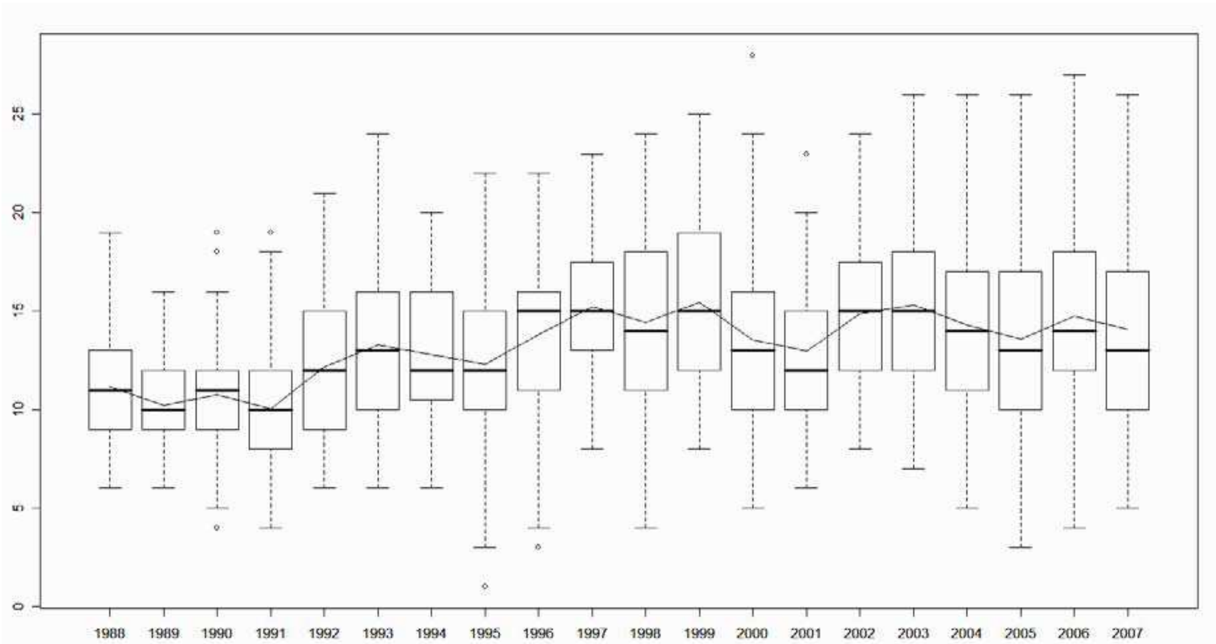


Figure 1.2.55: Species richness per haul (the line represents the average) The species richness evolution from 1988 to 2007 is significant (p<0.001).

The community appears to be slowly shifting towards species assemblages dominated by flatfish, whiting, sprat and dragonet (Figure 3.10.16). These species are characteristic of species rich coastal assemblages well adapted to changing temperature and salinity conditions. This pattern is correlated to an overall increase in species richness at the level of the haul translating an increase in the species co-existence (Figure 1.2.55). This may be induced by higher spatial heterogeneity and more variable conditions.

1.2.3.2.4 OTHER ISSUES - KNOWLEDGE GAPS

Primary and secondary production data in the Channel originate mainly from very coastal areas. These data are too restricted temporally and spatially to be extrapolated to the whole region (Lacroix *et al*., 2007). Also primary production and large functional group of phytoplankton have been modeled with success in the Channel (Menesguen *et al*., 2007), these models still require field data or satellite imagery to be better calibrated. Secondary production patterns are still not well described.

The sediment and benthic invertebrates distribution are over 30 years old and these data certainly need updating. A better understanding of the overall effect of aggregate extraction activities over the whole system (sediment dynamic, coastline erosion, benthic invertebrates, and fish) is also required to anticipate possible adverse effect of mineral resources exploitation in the Channel.

There are gaps in the knowledge of fish distribution and abundance evolution in the Western Channel. CEFAS historic and future surveys may enable to close these gaps in the future.

Synthetic information of seabirds and marine mammals are available but often aggregated to adjacent regions. These need to be added to account for upper trophic levels.

Major significant ecological events and trends

Hawkins *et al.* (2003) reviewed the changes in marine life abundance recorded in the Western Channel off Plymouth and related them to environmental change and human activity. They have shown that, from the 1920s to the 1950s, there was a period of warming of the sea, with increases in abundance of species of fish, plankton and intertidal organisms that are typically common in warmer waters to the south of Britain. This period was followed by a cooler period where northern cold-water species became more abundant but over-exploitation prevented them to return to abundance levels close to those observed at the beginning of the century. Since the 1980s regional sea-surface temperature has warmed again and abundances of warm-water species are increasing.

Some warm-water species, in particular red mullet and common squid, exhibited a strong evolution in their abundance over the last few years. The following figures are indices computed by IFREMER from the Channel Ground Fish Survey observed abundance in October in the Eastern Channel onboard the Ifremer RV “Gwen Drez”. These indices include all age classes and may translate strong recruitment (Figure 1.2.56 and Figure 1.2.57). In both cases, a new fishery is developing.

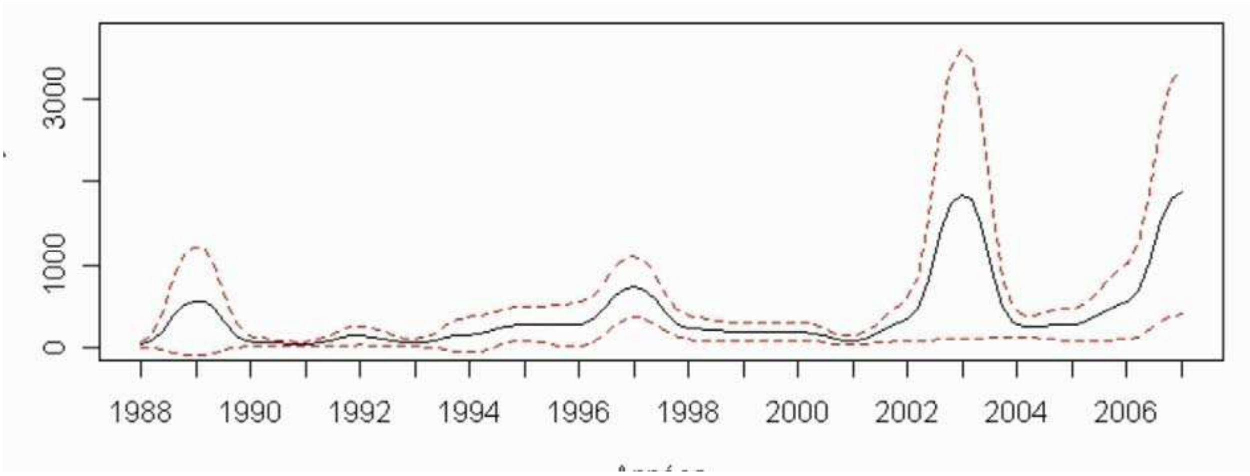


Figure 1.2.56: Red Mullet (Mullus surmulletus) average density (nb/km²) with 95% confidence interval.

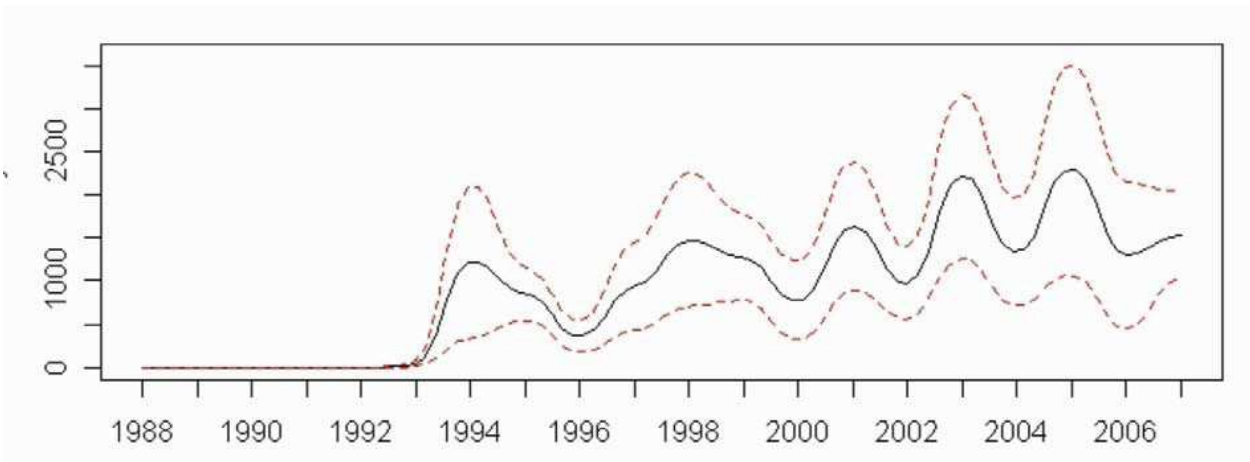


Figure 1.2.57: Common squids (*Loligo vulgaris*) average density (nb/km²) with 95% confidence interval.

1.2.3.3 Pelagic

From WGRED 2008

1.2.3.3.1 Plankton

The ICES Report on Zooplankton Monitoring Results in the ICES Area (ICES, 2006b) provides an overview of recent changes in North Atlantic plankton and the ICES PGNAPES reports on zooplankton biomass in wider feeding areas for migratory stocks in the Norwegian Sea (ICES, 2007b). The Ecological Status report from SAHFOS (Edwards et al., 2006), provides standard time series of geographic and seasonal information on changes in phytoplankton and zooplankton back to 1946, with analysis of biogeographic shifts, changes in phenology and biodiversity and regime shifts, which are related to changes in fish populations.

Phytoplankton abundance in the NE Atlantic increased in cooler regions (north of 55oN) and decreased in warmer regions (south of 50oN). The effects propagate up through herbivores to carnivores in the plankton food web (bottom-up control), because of tight trophic coupling. Similar effects may be expected for other mid-latitude pelagic ecosystems, because the proposed mechanisms are general and the results for the NE Atlantic are consistent and based on very large scale, long-term ampling (Richardson and Schoeman, 2004).Indicators of the zooplanktonic community have been developed over recent years (Beaugrand, 2005). Broad scale changes have occurred (Figure 1.2.58) showing that over the last decade there has been a progressive increase in the presence of warm-water/sub-tropical species into the more temperate areas of the northeast Atlantic, with 2004 continuing with this trend.

In the Norwegian Sea the total zooplankton biomass in May was the lowest on record since 1997. In the area west of 2°W (cold water mass) the biomass equalled the mean for the time series while it in the eastern region (warm Atlantic water) was low, as was the case in 2006 (ICES, 2007b).

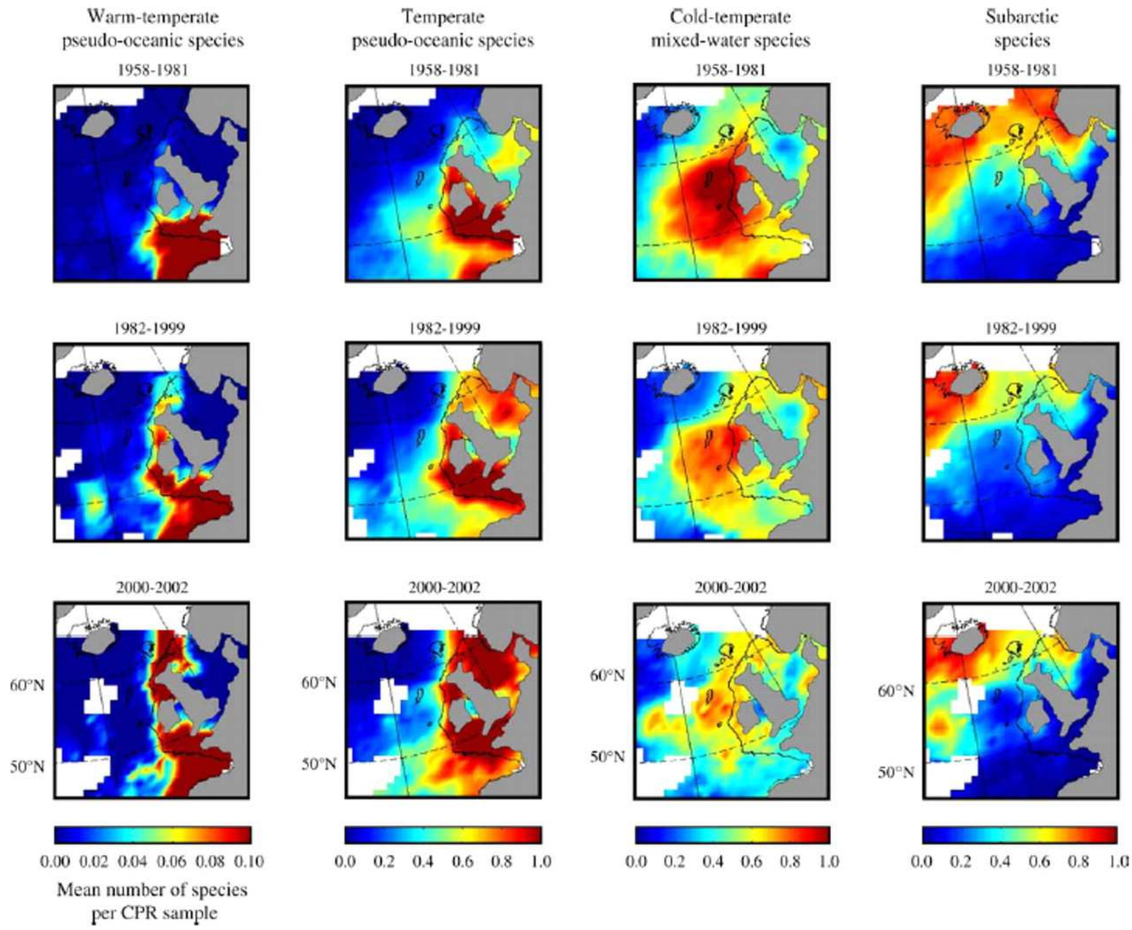


Figure 1.2.58: Long-term changes in the mean number of species per assemblage based on three periods: 1958–1981, 1982–1999 and 2000–2002 (source: Beaugrand *et al*., 2005).

1.2.3.3.2 Pelagic fish species

Blue whiting is distributed in European waters from the western Mediterranean Sea to the Barents Sea, around the Canary Islands and the Azores, in the North Sea, west of the British Isles, around the Faroes, east and south of Iceland, and westwards beyond Cape Farewell. The main spawning area extends from southwest of Ireland, over the Porcupine Bank and further north along the slope to north of the Hebrides. Spawning also takes place in the Rockall Bank area, in the Bay of Biscay and off the Iberian coast, and on a minor scale off the Norwegian coast, in Faroese waters and off the southern coast of Iceland (Monstad, 2004).

Spawning occurs at 300–500 m depth from January to June, earlier in the south than in the north. Mature fish migrate to the spawning grounds west of the British Isles during the winter months. In spring-early summer, the post-spawning migration brings the adults back to the feedings areas. Exact migration patterns are not well known. Traditionally, the Norwegian Sea is considered as the main feeding area; also south of Iceland and along the continental shelf edge from Bay of Biscay to and into the Barents Sea. The northern stock component feeding in the Norwegian Sea disperses over large areas on the warm side of the polar front area. High concentrations may appear along hydrographic fronts (ICES, 2005ca).

From the spawning grounds west of the British Isles the hatched larvae drift northwards, towards the Norwegian Sea and Iceland, or southwards, towards the Bay of Biscay. The direction of drift depends on the spawning area; hydrographic modelling suggests that the separation line between northern and southern drift varies from year to year but is usually at the northern parts of the Porcupine Bank (Skogen *et al*., 1999). By February the year after spawning, blue whiting probably originating from the main spawning area are found in surveys in the Barents Sea (Heino *et al*., 2003). A part of the northward-drifting larvae enter the North Sea and fishery there by the fourth quarter of the year. The main nursery areas are in the Atlantic water in the Norwegian Sea, south of Iceland, southwest Barents Sea, and Bay of Biscay. Also the deeper parts of shelf areas around the Faroes and the British Isles function as nursery area.

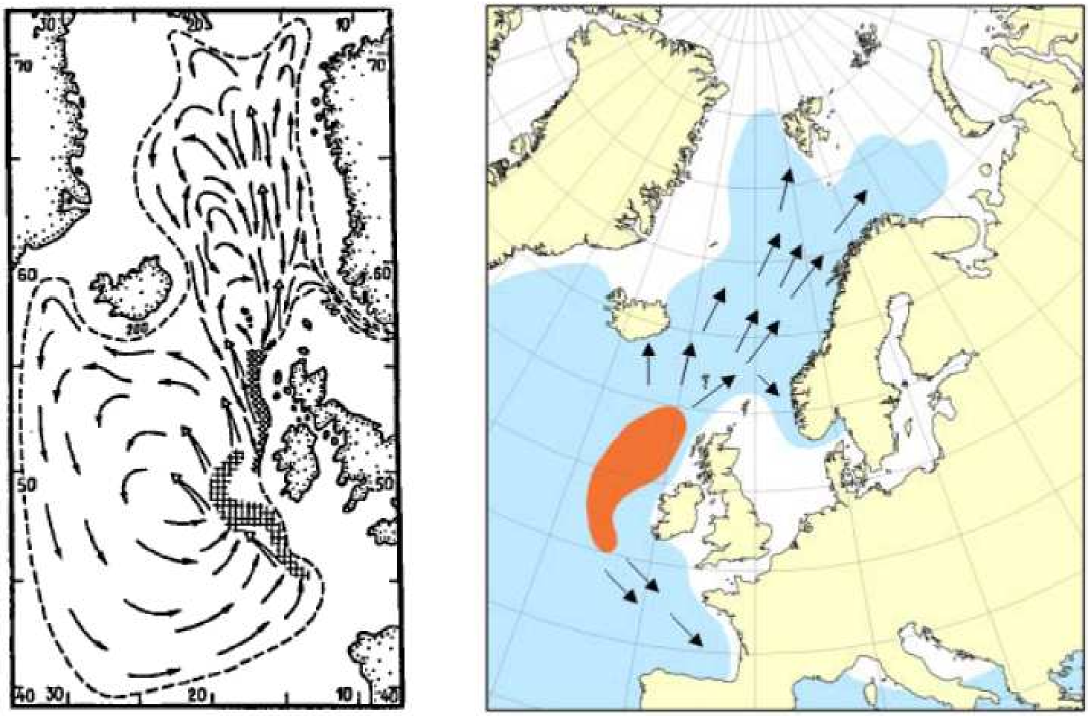


Figure 1.2.59: Migration of blue whiting. The left panel shows the migration pattern of adult blue whiting as suggested by Isaev *et al*. (1992). Hatched area shows the main spawning grounds. The current understanding does not fully support the pattern suggested for the component spawning around the Porcupine Bank by not accounting for the Bay of Biscay component. The migrations in the west are also virtually unknown. The right panel shows the current understanding on the drift patterns of blue whiting larvae (source: ICES, 2005c).

The overall distribution of the **North East Atlantic mackerel** stock ranges between the Iberian Peninsula and the Norwegian Sea and changes with life history stage and migration patterns. NEA Mackerel is divided into three spawning components depending on location of their spawning grounds. Spawning of the North Sea component is concentrated in the western and central part of the North Sea in June. The southern component spawns along the coast of the Iberian peninsula between January to May, while the western component spawns along the European shelf between the Bay of Biscay and the west of Scotland. Timing of spawning is between March and July with peak spawning usually occurring in April to May. Spawning on the shelf is concentrated along the 200 m contour line whereby mackerel are migrating northwards and progressively releasing their eggs. This latitudinal propagation of spawning appears to follow the increase of sea surface temperatures in the spring. Geographical changes in the centre of spawning along the western shelf have been observed over the last decades with peak spawning shifting west and northwards (Reid, 2001, Beare and Reid, 2002). Mackerel larvae are found close to the spawning grounds along the shelf edge but can drift and be retained onto the shelf and the Porcupine Bank. Transport and IBM models have shown that location of spawning and ambient circulation patterns influences larval survival (Bartsch et al., 2004).

Nursery areas are generally on the shelf adjacent to coast lines. From south to north, juvenile mackerel have shown to aggregate in close to the Spanish/Portuguese border; Biscay (between 45 and 48oN); Celtic Sea/Cornwall; west and north of Ireland; West of the Hebrides and North edge of North Sea.

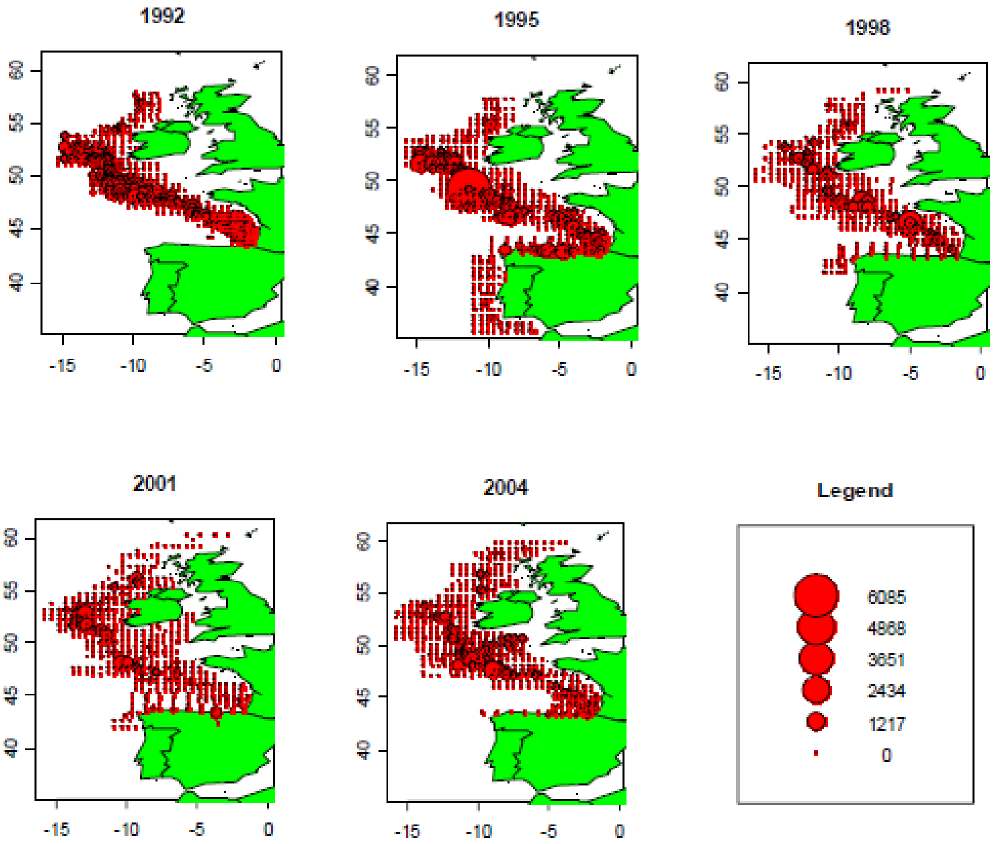


Figure 1.2.60: North East Atlantic mackerel, average distribution of stage 1 mackerel eggs, by year from the ICES international egg surveys (source: ICES 2005c).

After spawning, mackerel migrate to the Norwegian Sea in July and August to their feeding grounds. Overwintering occurs in the northern North Sea before the prespawning migration recommences southwards towards the western shelf in January.

Data from a coordinated ecosystem survey in the Norwegian Sea in July-August 2007 showed a significant increase in the western and northern distribution area of adult mackerel. Furthermore, juvenile mackerel from the 2006 year class where present for the first time in relatively large quantities up to 66°N and constituted about 10% of the sampled specimen (ICES, 2007c).

The ICES WGMHSA has put forward a hypothesis that an overall northerly shift in the distribution of NEA mackerel has taken place in 2005–2007. There is also a westerly shift in the northern part of the spawning and feeding areas. If such a large-scale change in distribution and migration pattern really has occurred it is assumed this may have substantial consequences for future abundance, spawning, growth and recruitment of the NEA mackerel stock.

The reasons for the observed changes in distribution are likely to be found in recent changes in the hydrographic conditions in the spawning area. It is well-known that there have been large changes in the size and distribution of blue whiting stock since the mid 1990s, especially in the western distribution area (ICES 2007/ACFM:29). Mackerel uses more or less the same areas to spawn, thus it is likely that these large-scale changes in the environment would also affect mackerel. Changes in the oceanic environment in the Porcupine/Rockall/Hatton areas have been shown to be linked toe the strength of the so-called subpolar gyre (Hátún *et al*., 2005). In recent years the area has been dominated by the more warm and saline Eastern North Atlantic Water (origination from the south), thus giving favorable conditions for spawning over a relatively wide area (Hátún *et al*., 2007). However, it remains to be shown whether there is a causal relationship between hydrographic conditions and recruitment of mackerel.

The **western horse mackerel** stock is distributed along the Bay of Biscay, south and west off the British Isles, in the western Channel, the northern North Sea, the Norwegian Sea and the western part of Skagerrak. Like NEA mackerel, western horse mackerel are closely connected to the shelf contour, and shows distinct areas for spawning, feeding and over-wintering. Spawning occurs along the shelf edge from the Bay of Biscay to the west of Ireland between April and July with peak spawning around June.

Migration might be mainly driven by water temperature. In autumn, at a temperature falling below ca. 10°C, T. trachurus retreat from the feeding areas in the southern Norwegian and the North Sea and migrate to the over-wintering areas further south. These are situated in the English Channel (Lockwood & Johnson, 1977, Macer, 1974 and 1977) and along the continental slope (Macer, 1977) in the Bay of Biscay and Celtic Sea (Eaton, 1983, Figure 3.12.7). In winter they form dense schools in deeper water. In spring the fish become far more dispersed (Polonsky, 1965) and migrate northward again with increasing water temperature (e.g. Chuksin and Nazarov, 1989).

The **Southern Horse mackerel** (*Trachurus Trachurus*) stock (ICES, 2007c; Abaunza *et al*., 2004) is distributed within the West Iberian Atlantic with relative stability along the year. This might be explained by the coincidental location of spawning and feeding grounds. Old adults after spawning migrate northward for feeding. Spawning takes place during the winter predominantly along the shelf break (Farinha and Borges, 1994), well adjusted to the seasonal upwelling timing of the West Iberian system (Santos, *et al*., 2001). In the Autumn, when the peak of recruitment takes place (Borges and Gordo, 1991) the juveniles are more abundant in the northwest region (Borges, 1991; Murta and Borges, 1994). Ontogenic migrations of horse mackerel along the Iberian region inferred from autumn surveys indicated juveniles and adults moving along the area but not undertaking long migrations outside northwest Iberia region (Murta *et al*., 2008).

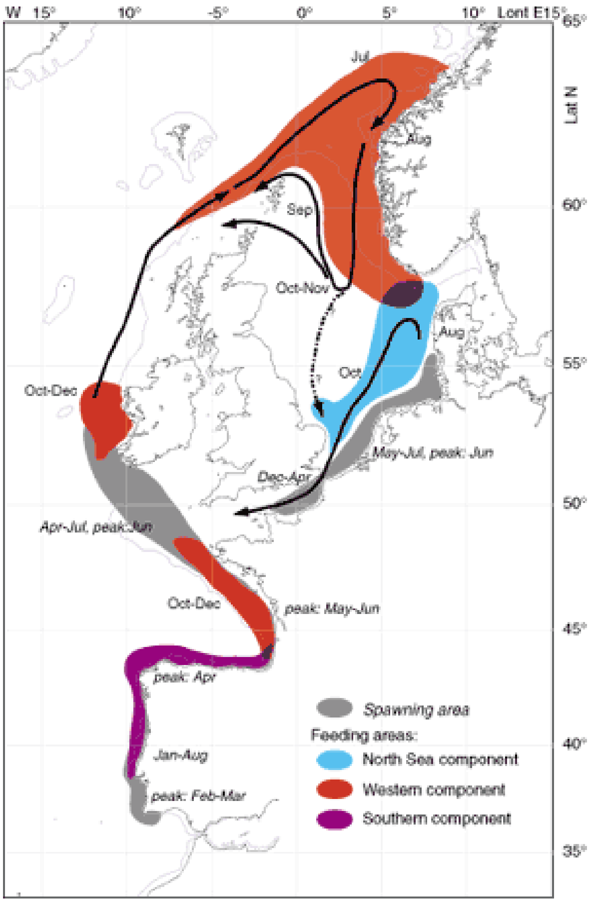


Figure 1.2.61: Schematic outline of assumed migration routes, spawning, feeding and over-wintering areas for the three Horse Mackerel stocks. Depth line drawn is the 200 m contour. (source: www.HOMSIR.com and based on ICES, 1998 and Eaton, 1983).

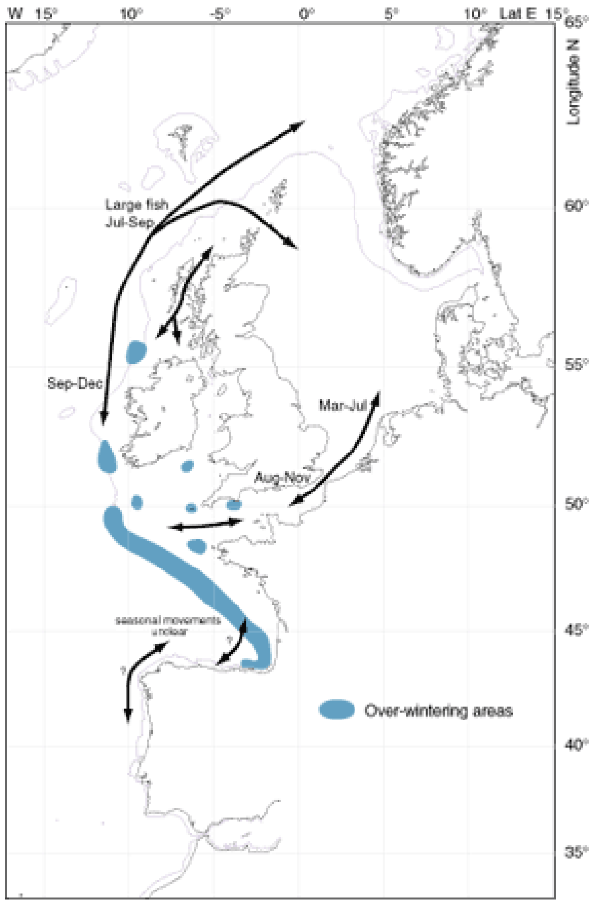


Figure 1.2.62: Schematic outline of over-wintering areas and assumed migration routes, Depth line drawn is the 200 m contour (source: www.homsir.com and based on Eaton, 1983).

Feeding and school behaviour

The **Blue Whiting** occurs in loose layers or schools that show diurnal migrations; juveniles can occur in the surface waters during night. It feeds by snapping prey. The prey species are crustaceans (large copepods, amphipods, krill), small cephalopods, small fish and fish larvae (Bailey, 1982; Monstad, 2004).

During summer feeding, **NEA Mackerel** cohabit with Norwegian Spring spawners in the Norwegian Sea, whereby their main feeding period is a month later than Herring. During feeding, mackerel occur in small schools near the surface where they feed predominately on Calanus, but also on other crustaceans, fish larvae and small adult fish. Recent feeding studies in June /July in the Norwegian Sea showed that Calanus finmarchicus was their principal prey item accounting for 53 to 98% of total stomach content by weight (Prokopchuk and Sentyabov, 2006). Mackerel remains as small high schools until aggregation in the overwintering area in the northern North Sea, in October, when it starts to form very large schools in 200 m+ water at the western edge of the Norwegian Deeps.

Parts of the **Western horse mackerel** stock move to the southern Norwegian and the North Sea for feeding in July-August. Other parts feed in areas west of Ireland or at the Bay of Biscay continental slopes. Several investigations indicate that *T. trachurus* is a filter feeder, mainly ingesting zooplankton (e.g. Ben Salem, 1988). In the **English Channel** adult horse mackerel were found to forage to nearly 70% on crustaceans and only to 17% on fish, with monthly varying proportions (Macer, 1977). Recent work of Olaso *et al*., 1999) for the **Bay of Biscay** on the diet composition in the southern Bay of Biscay showed seasonal differences: preying on crustaceans dominated during spring, while in autumn T. trachurus >30 cm began to prey on fishes (blue whiting, gobiids, anchovy), which represented 45% of the food volume in this size-range.

Potential environmental influences

Environmental influences on the fisheries Increasing temperature and changes in zooplankton communities are likely to have an impact on the life histories of many species, but particularly on the migratory pelagic species; mackerel, horse mackerel and blue whiting.

Mackerel and **horse mackerel** migrations are closely associated with the slope current, and mackerel migration is known to be modulated by temperature (Reid *et al*., 2001). Continued warming of the slope current is likely to affect the timing and the spatial extent of this migration. The southwards migration of Mackerel from wintering in the Norwegian Sea/North Sea to the spawning grounds west of Ireland, for example, commences when the temperature falls below a certain threshold (ca. 9°C). Thus during warmer oceanographic conditions migration is only initiated once this threshold is reached and southwards movement can be delayed (Reid, *et al.*, 2001). The postspawning migration northwards to the Norwegian Sea has undergone changes in the last few decades with an earlier migration occurring in recent years (Reid *et al*., 2006).

Eggs and larvae of **Blue Whiting** may be influenced by hydrographic conditions during the spawning season which affect the relative amounts of eggs and larvae drifting to northern and southern nursery areas; a certain spawning area may seed northern areas in one year, southern areas in another (Skogen *et al*., 1999). There is a positive effect of the large inflow of warm Atlantic water to the Barents Sea (as indicated by a positive salinity anomaly on the Fugløya-Bear Island section) on abundance of blue whiting in the Barents Sea one year later (Heino *et al*., 2003).

The strength of year classes as 0-group in the North Sea is only weakly coupled to the strength of year classes in the main Atlantic stock. This suggests either local recruitment or variation in transportation of larvae into the North Sea. Increased inflow of Atlantic water into the Norwegian Sea through Faroe-Shetland Channel (as indicated by a positive temperature anomaly, e.g. Hátún *et al*., 2005) coincides with increased recruitment, although earlier warm periods have not witnessed a similar increase in recruitment.

For **Norwegian Spring Spawning** Herring the inflow of Atlantic water into the Norwegian Sea and Barents Sea (NAO-index) seems to influence the condition and hence fecundity of adult fish as well as the survival of larvae (Toresen and Østvedt , 2000, Fiksen and Slotte, 2002, Sætre *et al.*, 2002). There is very good correlation between environmental changes locally at spawning grounds and nursery areas and the large-scale variations in Atlantic water inflow. The survival of larva is also influenced by changes in currents; some years retention areas may be stronger. It has been demonstrated that the tendency of retention may increase larval survival, i.e., the larvae stay for a longer period in warmer water, drifting slower towards the north (Sætre *et al.*, 2002). The environmental conditions also affect the condition of the fish, which again may cause reduced fecundity (Oskarson *et al.*, 2002). The strong year classes have occurred in periods of good condition and high temperatures.

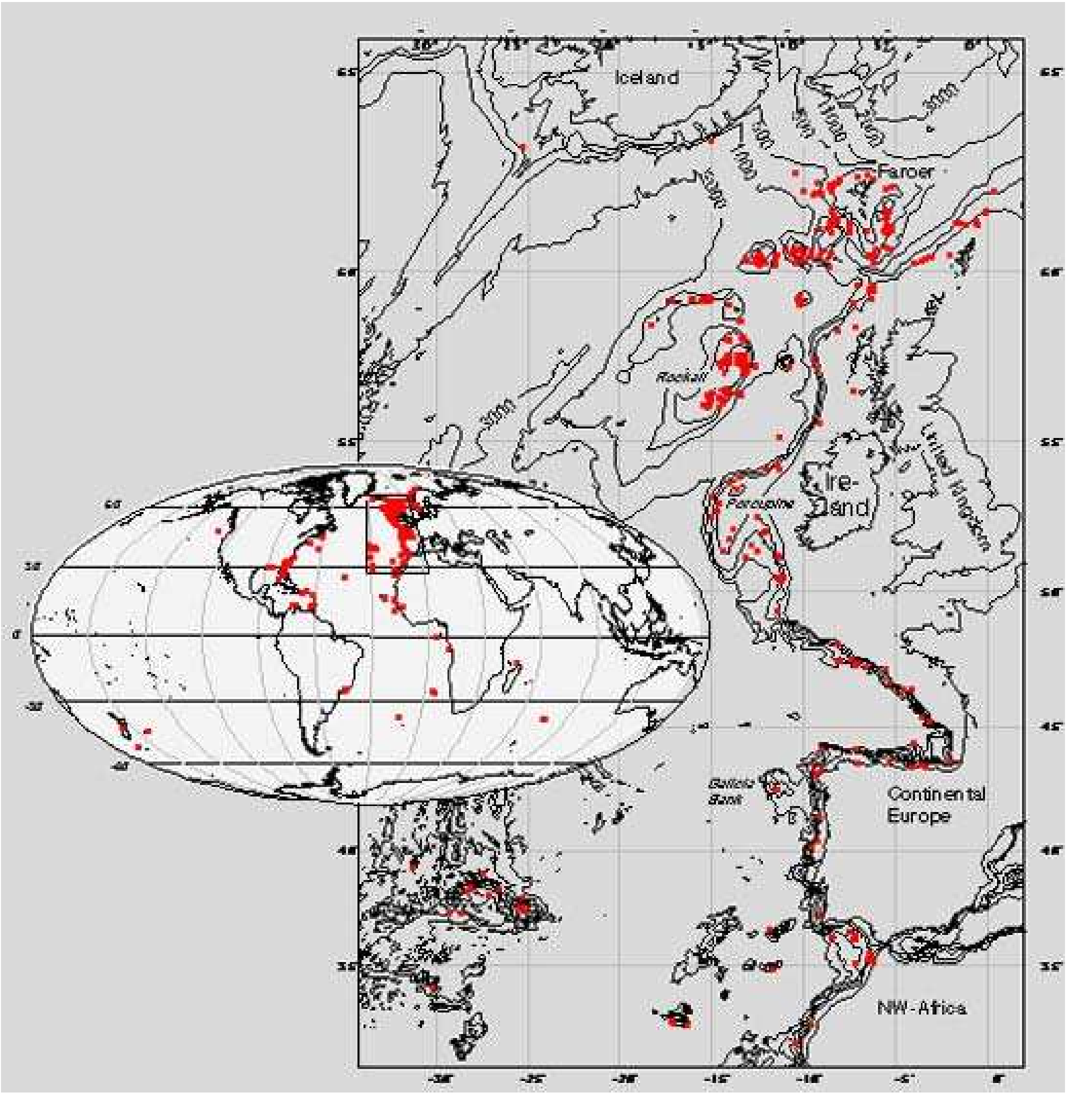
1.2.3.4 Deep Water

From WGRED 2008

1.2.3.4.1 Benthos, larger invertebrates (cephalopods, crustaceans, etc.), biogenic habitat taxa

For a description of the benthos and associated fauna by depth range see Table 1.2.5 in the Deep-Sea habitats section on page 107. There is little commercial exploitation of large invertebrates in this region. Deep-water trawling is known to have a small bycatch of cephalopods, the landings are often reported as miscellaneous cephalopods. The crab *Chaceon affinis* occurs at slope depths over the advisory region and is a bycatch of deep-water trawling and netting and a target of pot and net fisheries.

Biogenic habitat occur along the slope, the most well-known of these being formed by the scleractinian *Lophelia pertusa* a colonial coral, which locally forms large bioherms or reefs, along the slope, on the offshore banks (Rockall and Hatton), on the mid-Atlantic Ridge and on seamounts



(

Figure 1.2.63) (Freiwald, 1998; Rogers, 1999). Many areas remain to be surveyed for *Lophelia pertusa*. Some of these reefs are large, for instance, to the south and west of Ireland several reefs have built mounds of 150 to 200 m height and about 1 km wide are known. The bases of these mounds are comprised of dead coral rubble with some infill; live corals grow on top of the mounds.

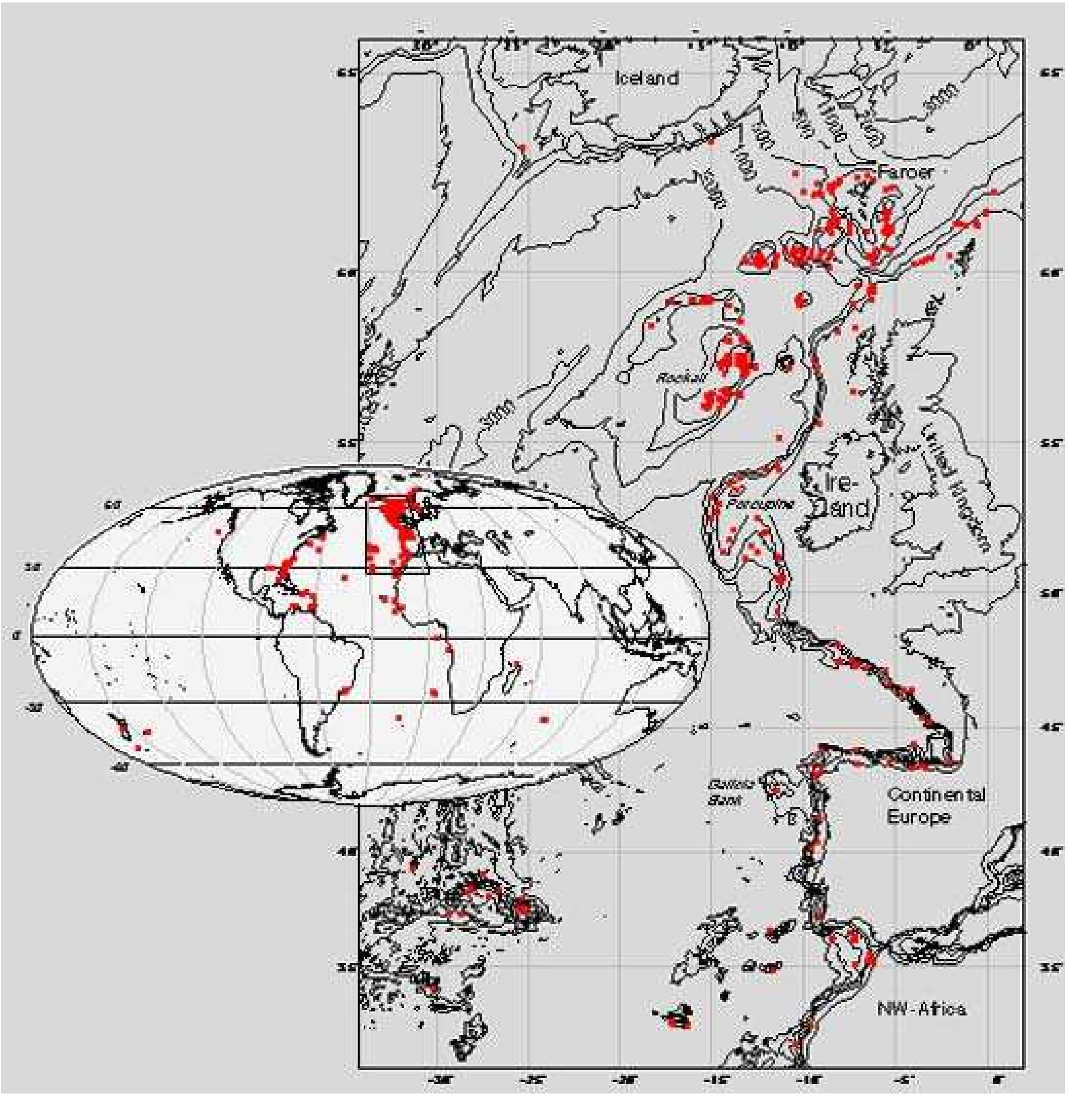


Figure 1.2.63: Distribution of deepwater Lophelia reefs in the North East Atlantic and wider (Freiwald, 1998).

A dense and diverse fauna is associated with *Lophelia* reefs. This includes fixed (e.g. anthipatarians, gorgonians) and mobile invertebrates (e.g. echinoderms, crustaceans). The species richness of fauna associated with coral reefs is up to three time higher than on surrounding sedimentary seabed (Mortensen *et al.*, 1995). Several species of deepwater fish occur on corals, some are more abundant around corals but possible functional links between fish and coral have proved difficult to demonstrate (Husebo *et al*., 2002).

1.2.3.4.2 Fish community

Large pelagic fish (tunas, swordfish, some sharks) are not considered in this section.

In the advisory region the two major small pelagic species are blue whiting *Micromesistius poutassou* and greater argentine *Argentina silus*. Both occur mainly over the slope and at the shelf edge. Blue whiting is a major prey of some deepwater (e.g. black scabbard fish *Aphanopus carbo*) and shelf (e.g. hake *Merluccius merluccius*) fish.

The mesopelagic zone (200–1000 m) has a high diversity of small fish species with striking morphological characters and adaptations such as large mouths, light organs and specialised eyes. The most abundant families are Myctophidae and Gonostomatidae (with *Cyclothone*, the most common vertebrate genus on earth), these may form up to 50% of a sample catch. The most diverse (number of genus and species) families are Myctophidae and Stomiidae. Many, if not all, mesopelagic fish migrate to feed on pelagic prey in upper water layers during the night. They return to the depths during daytime probably in order to avoid epipelagic predators. This is another mechanism by which nutrients reach deeper water layers.

A similar, but less abundant, fauna is found in the bathypelagic zone (1000-3000m). Bathylagidae is the most common family; other common families are Platytroctidae and Searsidae.

The demersal deep water fish community includes several larger species. Species composition primarily depends on depth and most deepwater species have large areas of distribution, some being found in both hemispheres and in the Atlantic, Pacific and Indian Oceans (e.g. orange roughy, Alphonsinos., several deep water squalid sharks and smaller non-commercial species such as *Halagyreus johnsonii*).

In this deep water region, dominant commercial species at 200–2000m include species such as ling, tusk, roundnose grenadier, orange roughy and deep-water sharks and chimaeriforms (Table 1.2.10) and other species such as redfish, monkfish and Greenland halibut that are dealt with elsewhere. Amongst sharks, *Centroscymnus coelolepis* and *Centrophorus squamosus,* the two main commercial species (1 to 1.5 m long) are seriously depleted. The status of a number of smaller or less common species (*Centroscymnus crepidater*, *Deania calcea*, *Dalatias licha*, *Scymnodon ringens*, *Etmopterus* spp. *Galeus* spp. *Apristurus* spp.) is less clear. Chimaeriforms occur at least down to 3000 m but are more abundant on the upper slope, 400–800m (Lorance *et al*., 2000). All deep-water shark species and most larger deepwater demersal fish are assumed highly vulnerable to over-exploitation, having a low reproductive capacity. For example, the maximum sustainable exploitation rate of orange roughy is estimated between 1 and 2% of the unexploited biomass (Koslow *et al*., 2000). Most stocks of the larger species are overexploited. Orange roughy, which forms dense aggregations (Koslow *et al*., 2000; McClatchie *et al*., 2000; Lorance *et al*., 2002) was depleted in the early 1990s in some ICES areas, in particular off west Scotland and Ireland (Lorance and Dupouy, 2001; ICES, 2004). The blue ling, exploited on the upper slope, was depleted by the 1980s. The status of chimaeriform populations is unknown. Most of these species are discarded but there is some directed fishing for *Chimaera monstrosa* on the upper slope.

Table 1.2.10: Broad distributional description of some important deep water fish in the North Atlantic.

SPECIES	LATITUDINAL DISTRIBUTION	DEPTH DISTRIBUTION (M)	OTHER INFORMATION
Blue ling *Molva dypterygi*	79°N–48°N	150–1000m	Found mostly from 350–500 m depth on muddy bottoms
Ling *Molva molva*	75°N–35°N	100–1000m	Occurs mainly on rocky bottoms in fairly deep-water, usually 100–400 m
Tusk *Brosme brosme*	83°N–37°N	18–1000m	Far from the shore, near the bottom, mostly 150–450 m
Roundnose grenadier *Coryphaenoides rupestris*	67°N–20°N	400–2200 m	Bentho-to bathypelagic in about 400–1200 m depth. Large schools at 800–1000 m
Orange roughy *Hoplostethus atlanticus*	65°N–56°S	180–1809 m	Inhabits deep, cold waters over steep slopes, ocean ridges and sea-mounts.
Black scabbardfish *Aphanopus carbo*	69°N–27°N	200–1800 m	Occurs on slopes from 200m off the British Isles to 1800m off Madeira

Black dogfish *Centroscyllium fabricii*	68°N–51°S	180–1600 m	Found on the outermost continent. shelves and upper slopes, mostly below 275 m
Portuguese dogfish *Centroscymnus coelolepis*	64°N–48°S	150–3700 m	Commonly found on continental slopes and abyssal plains.
Leaf-scale gulper shark *Centrophorus squamosus*	69°N–54°S	145–2400 m	Found on or near the bottom of continental slopes.

Many demersal slope species are not commercial because they do not reach sufficient size while the alepocephalid are large but have a low palatability due to the high proportion of water in their flesh. At 1000 m–1500 m *Alepocephalus bairdii* is the dominant species by biomass to the west of the British Isles (Gordon, 1986; Gordon and Bergstad, 1992) so that it makes the bulk of fisheries discards (Allain *et al*., 2003).

1.2.3.4.3 Seabirds

The only breeding birds in the advisory region are on the Azores where, the main species are Cory's shearwater, *Calonectris diomedea* (189 000 pairs), common tern, *Sterna hirundo* (4000), yellow-legged gull, *Larus cachinnans* (3000), little shearwater, *Puffinus assimilis* (1200), Madeiran storm-petrel, *Oceanodroma castro* (1000), roseate tern, *Sterna dougalii* (700) and Manx shearwater, *Puffinus puffinus* (180). These deep offshore waters are visited by migrant birds breeding elsewhere outside their breeding seasons; most are Procellariformes and include northern fulmar *Fulmarus glacialis*, from colonies around the North Atlantic and sooty *Puffinus griseus* and great *P. gravis* shearwaters from the South Atlantic.

1.2.3.4.4 Mammals

The most common among the approximately 30 marine mammal species that occur in the advisory region are common dolphin *Delphinus dephis*, striped dolphin *Stenella coeruleoalba*, long-finned pilot whale *Globicephala melas*, Risso's dolphin *Grampus griseus*, fin whale *Balaenoptera physalus* and sperm whale *Physeter macrocephalus*. Those abundance estimates that exist for these species have wide confidence intervals.

See section 1.2.3.5.4 Marine mammals and reptiles

1.2.3.4.5 The major environmental impacts on ecosystem dynamics

The deep sea environment is considered to be less variable than surface systems. Moreover, due to the long life span of exploited species, variations in annual recruitment have a relatively minor effect on the standing biomass so short-term variability in the environment is unlikely to have great effects on stocks. The North Atlantic Oscillation may influence the composition of the deep sea fauna over time. It has been suggested that an outburst of sea cucumbers and brittle stars on the abyssal plain of the North Atlantic might be linked to the extremes of NAO seen in these years. It is not known how global warming might change the deep seas in the longer term.

1.2.3.5 Overall (Macroalgae, Plankton, Mammals, Reptiles and Fish)

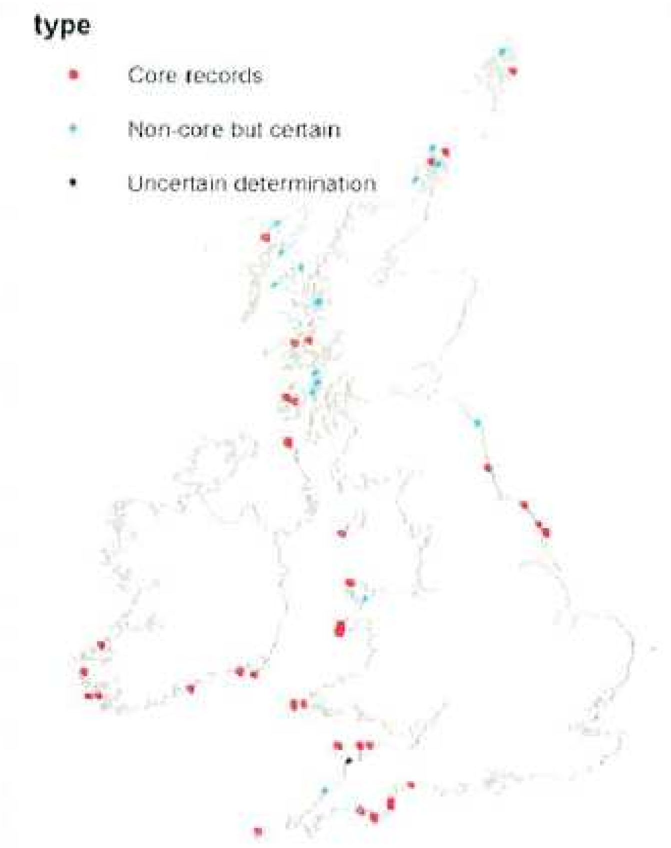
1.2.3.5.1 Macroalgae

The species composition and distribution of various macroalgal species in the NWW area is described in details on the JNCC Marine Habitats Classification website (www.jncc.gov.uk/marine/biotopes/hierarchy.aspx) such as:

IR.MIR.KR.LhypT.Ft

Laminaria hyperborea forest, foliose red seaweeds and a diverse fauna on tide-swept upper infralittoral rock.

Salinity:	Full (30-35 ppt)
Wave exposure:	Extremely exposed, Very exposed, Exposed, Moderately exposed
Tidal streams	Strong (3-6 kn), Moderately strong (1-3 kn)
Substratum:	Bedrock; boulders
Zone:	Infralittoral - upper
Depth Band:	0-5 m, 5-10 m, 10-20 m



Distribution of habitat IR.MIR.KR.LhypT.Ft *Laminaria hyperborea* forest, foliose red seaweeds and a diverse fauna on tide-swept upper infralittoral rock, based on records on the JNCC marine database. Red dots represent records on which the biotope is based. Blue dots show orther certain records, black dots show records tentatively assigned to this biotope.

Biotope description

Exposed to moderately exposed, tide swept bedrock and boulders, with dense Laminaria hyperborea forest, characterised by a rich under-story and stipe flora of foliose seaweeds. The kelp stipes support epiphytes such as *Callophyllis laciniata*, *Corallina officinalis*, *Cryptopleura ramosa*, *Mambranoptera alata* and *Phycodrys rubens*.

At some sites, instead of being covered by red seaweeds, the kelp stipes are heavily encrusted by the ascidians *Botryllus schlosseri* and in the south-west Distomus variolosus. Epilithic seaweeds (*Dilsea carnosa*, *Hypoglossum hypoglossoides*, *Delesseria sanguinea*, *Plocamium cartilagineum*, *Brongniartella byssoides*, and *Dictyota dichotoma*) and crustose seaweeds commonly occur beneath the kelp. The kelp fronds are often covered with growth of the hydroid *Obelia geniculata* or the bryozoan *Membranipora membranacea*. Although these species are also found in most kelp forests, in this biotope they are particularly dense. On the rock surface, a rich fauna comprising of the sponges *Pachymatisma johnstonia*, *Halichondria panicea*, *Esperiopsis fucorum* and *Dysidea fragilis*, anthozoans such as *Urticina felina*, *Alcyonium digitatum* and *Caryophilia smithii*, the barnacle *Balanus crenatus*, colonial ascidians such as *Clavelina lepadiformis*, and the gastropods *Calliostoma zizyphium* and *Gibbula cineraria*, occur. Also found on the rock is the echinoderm *Asterias rubens* and the crab *Cancer pagurus*. This biotope occurs below Alaria esculenta (Ala) at exposed sites or L. digitata (Ldig.Ldig) at moderately exposed locations. With increasing depth the kelp density diminishes to become tide-swept kelp park (LhypT.Pk).

Similar biotopes

IR.HIR.KFaR.LhypFa: On very exposed coasts subject to weaker tidal currents. The fauna turf is characterised by a higher abundance of anthizoans such as *Corynactis viridis* and *Sargartia elegans*, but topshells such as *C. zizyphinum* and *Gibulla cineraria* are also common. Red seaweeds are present but less dense than LhypT.Ft.

IR.MIR.KR.LhypT.Pk: Found in similar tide-swept conditions, often forming a zone below the kelp forest (LhypT.Ft) in deeper water where the kelp is less dense and more upper circalittoral species occurs.

IR.MIR.KR.Lhyp.Ft: Found in areas with similar wave exposure but not subject to accelerated tidal currents and lacks therefore a prominent filter feeder community. The large variety of sponges such as *H. panicea* and *Esperiopsis fucorum*, the bryozoans *A. diaphanum* and *Flustra foliacea* and the barnacle *Balanus balanus* are not found in great abundance in the kelp forest.

IR.MIR.KR.LhypTX.Ft: Found in similar tide swept conditions, but on mixed substrata.

Characterising Species

Taxa	Frequency	Typical Abundance	% Contribution to similarity
Pachymatisma johnstonia	●●●	O	2
Halichondria panicea	●●	O	1
Esperiopsis fucorum	●●	O	1
Dysidea fragilis	●●	O	2
Obelia geniculata	●●●	F	1
Alcyonium digitatum	●●●	O	2
Urticina felina	●●●	O	1
Caryophyllia smithii	●●	O	1
Balanus crenatus	●●	O	1
Cancer pagurus	●●●	P	1
Membranipora membranacea	●●●	P	2
Asterias rubens	●●●●	P	3
Clavelina lepadiformis	●●●	O	2
Botryllus schlosseri	●●●	O	3
Corallinaceae	●●●●	F	3
Corallina officinalis	●●	O	1
Dilsea carnosa	●●●	O	2
Callophyllis laciniata	●●●	O	2
Plocamium cartilagineum	●●●●	F	6
Cryptopleura ramosa	●●●●	F	3
Delesseria sanguinea	●●●●	F	4
Hypoglossum hypoglossoides	●●	F	1
Membranoptera alata	●●●	O	1
Phycodrys rubens	●●●●	F	3
Brongniartella byssoides	●●●	O	2
Dictyota dichotoma	●●●	F	2
Laminaria hyperborea	●●●●●	A	10

1.2.3.5.2 Planktonic habitat

Much of the information on the phytoplankton and zooplankton communities within the NWW RAC, including species composition, geographical and seasonal variability has been gathered by the Sir Alister Hardy Foundation for Oceanic Science (SAHFOS) in their CPR (Continuous Plankton Recorder) surveys. Databases at SAHFOS date back to 1958 and are essential in mapping plankton trends in the North East Atlantic. SAHFOS has been contacted for consultancy quote for an assessment of (1958 – present):

- the phytoplankton and zooplankton community composition (presence in more than 1% of samples),
- phytoplankton colour index,
- regional variation,
- abundance of calanoids, euphausiids, meroplankton and megaplankton.

For the purposes of this report the plankton of the Irish Sea and Celtic Sea will be broadly discussed and a list of relevant publications for the NWW RAC will be provided.

1.2.3.5.2.1 IRISH SEA

Marine plankton consist of microscopic organisms that are found floating in the water column and all taxa have limited mobility. Phytoplankton (comprising diatoms, dinoflagellates and smaller flagellates) are the primary producers in the marine environment, deriving energy from sunlight and they form the primary source of nutrition for the marine food web. Nanoplankton include all organisms in the size range of 2-20µm. This group contains organisms belonging to the pymnesiophytes (coccolithophores), prasinophytes, choanoflagellates and cyanobacteria amongst others. Zooplankton includes a wide range of animal species including the eggs and larvae of fish and benthic species. The largest zooplankton taxa are jellyfish and the most numerous are the copepods; microscopic crustaceans which tend to be herbivores, feeding on the phytoplankton and in turn providing food for organisms higher up in the food chain such as fish larvae and juvenile fish. Some species of zooplankton are only temporary members of the plankton (meroplanktonic species) while others spend their entire life cycle within the plankton (holoplanktonic species). Zooplankton are typically common where algal production and biomass are greater and the seasonal cycles of many zooplankton are clearly linked to those of primary production (Tett, 1992).

Much of the information on the phytoplankton and zooplankton communities within the Irish Sea, including species composition, geographical and seasonal variability has been gathered by the Sir Alister Hardy Foundation for Oceanic Science (SAHFOS) in their CPR (Continuous Plankton Recorder) surveys. As gaps exist in the extent of the Irish Sea CPR surveys data from other sources have been gathered during the UK SEA6 survey (Kennington & Rowlands, 2006). These include data sets held by the Port Erin Marine Laboratory (PEML).

Phytoplankton

In the plankton community a 'bloom' of phytoplankton occurs every spring, often followed by a smaller peak in the autumn. Phytoplankton (diatom) blooms are normally initiated by the establishment of a thermal stratification in spring, as a result of increased light and temperature. Dinoflagellate communities are associated with post spring bloom conditions, when surface waters are limited by the amount of phosphorus and nitrogen left after the initial diatom bloom (Williams and Lindley, 1980).

In a recent study of the phytoplankton spatial distribution and seasonal cycles in the North East Atlantic, McQuatters-Gollop *et al.* (2007) analysed diatom and dinoflagellate abundance during the period 1958–2003 using CPR data. They demonstrated the dissimilar bloom patterns of the two phytoplankton groups, with the diatom spring bloom peaking in May before gradually declining through mid-summer and then weakly blooming again in late summer. Dinoflagellates bloom most intensely during the late summer, peaking in autumn, before progressively declining throughout autumn.

However, due to the great diversity with respect to hydrology (including depth and tidal mixing), nutrient chemistry and ecology within the Irish Sea, the timing of the phytoplankton production season differs from that in off shelf waters and the wider North Atlantic.

The factors that initiate the spring bloom are vertical mixing and stratification of the water column, along with the length of photoperiod. During the winter months, in periods of low light, phytoplankton growth is inhibited. In this period, the nitrogen, phosphorus and silicate and ammonia nutrients increase in concentrations, as little or no primary production is taking place to utilise them. When the water becomes stratified in the spring, advantageous diatom species increase rapidly in abundance, hence the term 'bloom'. As the spring progresses to summer, surface waters warm and a more permanent thermocline develops. Colder, nutrient-rich waters sink away from the photic zone; primary production slows and tends to be largely confined to deeper layers in the pycnocline. Silicate (essential for diatom growth, being incorporated into their 'test') eventually becomes limited and other groups, such as flagellates, bloom, followed later by the dinoflagellates. The resulting phytoplankton community is one that can cope with reduced nutrient levels. With the onset of autumn, and the increase in wind strength, the sea becomes mixed once again. This secondary bloom is limited in size by the amount of phosphorus and nitrogen left after the initial diatom bloom. As the light levels diminish in the latter part of the year, primary production once again decreases. The water then becomes mixed and this aids the distribution of nutrients throughout the water column. (Kennington & Rowlands, 2006).

Water Column Landscapes

Based on the classification of water features, distinct water bodies have similar characteristics with regard to hydrology, nutrient chemistry and phytoplankton composition.

<u>Estuarine waters</u> include such areas as Morecambe Bay, Solway Firth and southeast Liverpool Bay. This water body type is characterised by low salinity (≤ 30ppt), non-thermally stratified conditions with high winter nutrient concentrations. The phytoplankton growth season is the longest of all Irish Sea water body types lasting 6 to 7 months. Diatoms are abundant throughout the growth season. Dinoflagellates peak initially in early summer with highest abundances occurring during late summer. Nanoflagellate abundances can be high with peak abundances generally occurring after silicate has been depleted from the water column (see section on Nutrients). The area around Liverpool bay is regularly an area of *Phaeocystis* bloom formation.

<u>Coastal or Region of Freshwater Influence (ROFI</u>) These waters are found in the proximity of near-shore transitions from mixed or more persistently stratified waters (e.g. the salinity front in Liverpool Bay and the tidal mixing fronts associated with the coastal zone). These waters have salinities between 30 and 33 and moderately high winter nutrient concentrations, owing to their proximity to Estuarine waters. Although these waters are generally well mixed, haline stratification can still occur during periods of high river run-off. The phytoplankton growth season lasts for 5 to 6 months, with diatom abundance showing a distinctive spring peak. The

dinoflagellates also show an initial increase in abundance during the spring but become more abundant during late summer (Kennington & Rowlands, 2006).

Shelf waters. These waters are characterised by high salinity (>34 but <35) and moderate winter nutrient conditions. Waters in this typology are generally well mixed, although a weak thermocline can develop during extended times of fine weather. This water body type has a reasonably short production season of between 3 to 4 months and includes a distinctive peak in all algal groups during the spring.

Frontal ROFI. This water body type refers to waters that stratify regularly, although stratification is usually weak or intermittent. Such waters are found in the central eastern Irish Sea and around the gyre in the western Irish Sea which develops during the summer. Waters of this type have moderately high salinity levels (>33) and moderate winter nutrient concentrations. The phytoplankton season is similar to that of Shelf waters, although all algal groups are generally more abundant.

Stratified ROFI with high salinity. This water body type represents waters that are thermally stratified during the summer months, a good example of which are waters within the western Irish Sea gyre. Salinities in this typology are high, owing to the reduced influence of freshwater run-off. This typology also has moderate concentrations of winter nutrient salts. The phytoplankton season in this zone varies considerably.

In regions where there are frontal zones of mixing water bodies there is evidence of a higher than normal productivity. These areas include a permanent salinity front in the Liverpool bay area which is permanent throughout the year and seasonal fronts which result from the stratification of the water column in late spring and persist throughout the summer. These seasonal fronts are illustrated in Figure 1.2.64, and include the frontal zone around the stratified gyre in the western Irish Sea. Liverpool Bay has the highest phytoplankton biomass and zooplankton abundance within the Irish Sea (Golding *et al.*, 2004).

Zooplankton

Zooplankton are the animal constituent of the plankton, some are herbivores, feeding upon phytoplankton, while others are carnivorous, feeding upon other members of the zooplankton.

Some members of the zooplankton community, particularly copepods (small crustacea), are of importance to higher trophic levels (i.e. food for fish larvae).

1.2.3.5.2.2 CELTIC SEA

The development of fronts and the physical partitioning of the sea into seasonally stratified, permanently mixed and frontal regimes are crucial in determining the environment for primary production. In stratifying regions during the spring, the development of a thermocline and increasing light levels leads to the rapid growth of phytoplankton. The timing of the spring bloom plays an important role in the growth of zooplankton communities and in the recruitment of fish larvae (Sharples, 2008 and references therein). Shelf fronts have long been associated with enhanced levels of phytoplankton biomass due to the replenishment of nutrients from below the thermocline.

The turbulence caused by the Irish shelf front introduces nutrients from deeper waters to the surface where they promote the growth of phytoplankton especially diatoms in the spring but also dinoflagellates where there is stratification. At the edge of the shelf break of the south west of Ireland, enhanced planktonic production occurs in a ~100km broad band of cold water during the summer. This band of water is 1-2 ° colder than adjacent neritic and oceanic water in the Celtic Sea and Atlantic and has higher inorganic nitrate levels and chlorophyll a concentrations due to physical processes occurring at the edge – namely the slopes, ridges and canyons which cause enhanced mixing, particularly due to internal tides and upwelling. This leads to nutrient renewal and phytoplankton growth along the shelf edge. These internal tides are formed when tidal flow across the steep continental slope induces vertical displacements and associated pressure fields. In North Western European shelf waters, spring tidal currents are typically twice those occurring during neap tides. This spring-neap variability has been shown to play a part in the timing of the spring bloom, possibly by briefly interrupting the development of spring stratification Sharples, 2008 and references therein). At the Celtic sea shelf edge, large tidal currents (>0.5 m s^{-1}) cause large internal tides (vertical displacements up to 150m) (Huthnance *et al*. 2001).

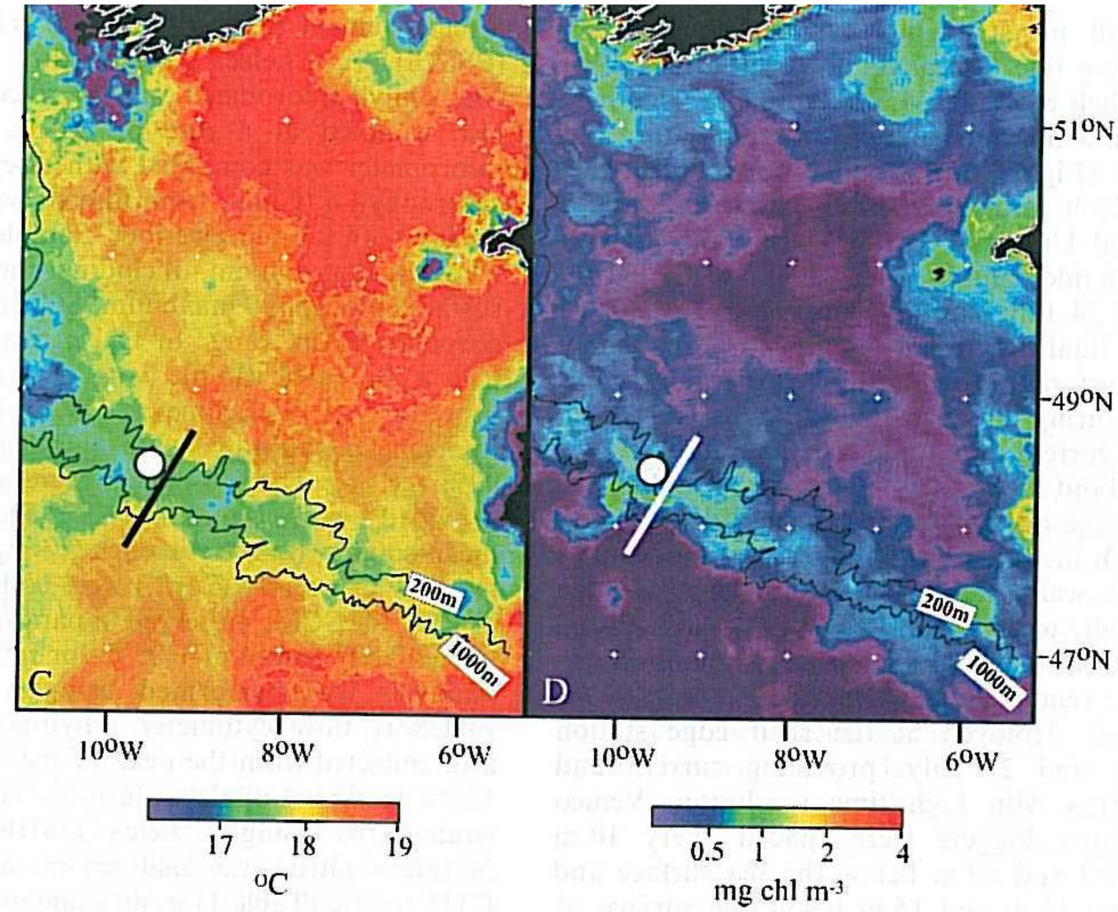


Figure 1.2.64: Sea surface temperature (C) and sea surface chlorophyll (D) within the Celtic Sea indicating area of cold water along the Irish shelf front and the higher chlorophyll production due to nutrient renewal in the area (from Sharples *et al.*, 2007).

The Celtic Sea and shelf edge are known to be important spawning grounds for commercial species such as mackerel (*Scomber scombrus*), hake (*Merluccius merluccius*) and megrim (*Lepidorhombus whiffiagonus*). Large spawning shoals of mackerel travel northwards from the Bay of Biscay each year and are usually associated with the high productivity areas close to the shelf break. Circulation patterns tend to carry the larval stages towards and onto the shelf where first feeding larvae may find good feeding conditions (Acevedo *et al.,* 2002).

Most fish larvae feed primarily on zooplankton and so changes in their food quantity and quality as well as seasonal timing will affect their survival and bottom up control is thought to be a significant factor in determining year-class strength (Pitois & Fox, 2006). Copepods are considered to be the major trophic link between phytoplankton primary production and fish larvae, given that the different herbivorous copepod stages are the main feeding resource for most pelagic fish larvae (Gonzales-Quiros *et al*., 2003).

Pitois & Fox (2006) examined the long-term changes in zooplankton on the northwest European shelf based on data collected by the Continuous Plankton Recorder (CPR). This long-term (70 years) dataset has been essential in examining how climate change might affect primary and secondary production. This in turn can impact ecosystem functioning, by cascading up the food web to higher trophic levels including fish. During the period 1958-2003 the Celtic Sea area experienced a decline in total zooplankton biomass and in general, the waters of the northwest European shelf have experienced a northward spread of temperate species (e.g. the copepods *Centropages typicus, Para-Pseudocalanus* spp., *Calanus helgolandicus, Pseudocalanus elongatus* and the cladocerans *Podon* spp. and *Evadne* spp.) and a decline in boreal species (e.g. the copepods *Calanus finmarchicus* and *Euchaeta norvegica*) (Pitois & Fox, 2006). Boreal copepod species with an affinity for cold water tend to be larger than temperate species and it has been suggested that the larger species might provide more suitable prey for pre-recruit stages of fish such as cod (Sundby, 2000; Beaugrand *et al.,* 2003). Any changes in the zooplankton communities due to increased temperature and hydrographic changes can radically change the food environment for fish larvae.

Relevant Plankton publications

Acevedo *et al.,* 2002. The community structure of larval fish populations in an area of the Celtic Sea in 1998. *Journal of the Marine Biological Association of the United Kingdom,* 82, 641–648.

Acevedo & Fives, 2001. The distribution and abundance of the larval stages of the Myctophid *benthosoma glaciale* (Reinhardt) in the Celtic Sea and West coast of Ireland in 1998. *Biology and Environment: Proc. RIA,* 101B, 245–249.

Arkhipov & Mamedov, 2007. Ichthyoplankton of Rockall-Hutton Seamounts. *Journal of Ichthyology,* 47, 511–519.

Alvarez *et al.,* 2004. Distribution and abundance of European hake *Merluccius merluccius* (L), eggs and larvae in the North East Atlantic waters in 1995 and 1998 in relation to hydrographic conditions. *Journal of Plankton Research*, **26**, 811-826.

Barnes *et al.,* 2009. Distribution of plankton and hydrography in relation to Great Sole, Cockburn and Little Sole Banks. *Journal of the Marine Biological Association of the United Kingdom*, 89(1), 11–18.

Bartsch, 2005. The influence of spatio-temporal egg production variability on the modelled survival of the early life history stages of mackerel (*Scomber scombrus*) in the eastern North Atlantic. *ICES Journal of Marine Science,* 62, 1049–1060.

Batten *et al.,* 1999. Mesoplankton biomass in the Celtic Sea: a first approach to comparing and combining CPR and LHPR data. *Journal of the Marine Biological Association of the United Kingdom*, 79, 179–181.

Beaugrans *et al.,* 2002. Diversity of calanoid copepods in the North Atlantic and adjacent seas: species associations and biogeography. *Marine Ecology Progress Series*, 232, 179–195.

Bresnan *et al.,* 2009. Seasonal and interannual variation in the phytoplankton community in the north east of Scotland. *Journal of Sea Research,* 61, 17–25.

Brown, J. Hill, A.E., Fernand, L., Bennett, D.B. & J.H. Nichols. 1995. A physical retention mechanism for *Nephrops norvegicus* larvae. ICES, C.M. 1995/K:31 Ref.C.

Corton & Lindley, 2003. The usae of CPR data in fisheries research. *Progress in Oceanography,* 58, 285–300.

Cusack *et al.,* 2004. Occurrence of species of *Pseudo-nitzschia* Peragallo in Irish waters. *Biology and Environment: Proc. RIA,* 104B, 55–74.

Doyle *et al.,* 2006. The broad-scale distribution of five jellyfish species across a temperate coastal environment. *Hydrobiologia*, 579:29–39.

Gibbons & Richardson, 2009. Patterns of jellyfish abundance in the north Atlantic. *Hydrobiologia,* 616, 51–65.

Gonzales-Quiros *et al*., 2003. Ichthyoplankton distribution and plankton production related to the shelf break front at the Aviles Canyon. *ICES Journal of Marine Science,* **60,** 198-210.

Gowan *et al.,* 1998. Plankton distributions in relation to physical oceanographic features on the southern Malin Shelf, August, 1996. *ICES Journal of Marine Science,* 55, 1095–1111.

Grioche & Koubbi, 1997. A preliminary study of the influence of a coastal frontal structure on ichthyoplankton assemblages in the English Channel. *ICES Journal of Marine Science,* 54, 93–104.

Heath, 2005. Regional variability in the trophic requirements of shelf sea fisheries in the Northeast Atlantic, 1973–2000. *ICES journal of Marine Sciences*, 62, 1233–1244.

Heath, 2007. The consumption of zooplankton by early stages of fish in the North sea. *ICES journal of Marine Sciences*, 64, 1650–1663.

Heath *et al.,* 2000. Winter distribution of *Calanus finmarchicus* in the North east Atlantic. *ICES journal of Marine Sciences*, 57, 1628–1635.

Heath *et al.,* 2004. Comparative ecology of over-wintering *Calanus finmarchicus* in the northern North Atlantic, and implications for life-cycle patterns. *ICES journal of Marine Sciences,* 61: 698–708.

Horstmann and Fives, 1994. Ichthyoplankton distribution and abundance in the Celtic Sea. *ICES Journal of Marine Science,* 51, 447–460*.*

Lee *et al.,* 2005. Small scale spatio-temporal variability in the ichthyoplankton and zooplankton distribution in relation to a tidal-mixing front in the Irish Sea. *ICES Journal of Marine Science,* 62, 1021–1036.

Lindley & Daykin. 2005. Variations in the distributions of *Centropages chierchae* and *Temora stylifera* (Copepoda: Calanoida) in the north-eastern Atlantic Ocean and western European shelf waters. *ICES journal of Marine Sciences*, 62, 869–877.

McQuatters-Gollop *et al.,* 2007. Spatial patterns of diatom and dinoflagellate seasonal cycles in the NE Atlantic Ocean. *Marine Ecology Progress Series*, 339, 301–306.

Mahe *et al.,* 2007. Ontogenetic and spatial variation in the diet of hake (*Merluccius merluccius*) in the Bay of Biscay and the Celtic Sea. *ICES Journal of Marine Science,* 64, 1210–1219.

Pitois, S.G. & Fox, C.J. 2006. Long term changes in zooplankton biomass concentration and mean size over the Northwest European shelf inferred from Continuous Plankton recorder data. *ICES Journal of Marine Science,* **63,** 785-798.

Pybus, 2007. Pre-bloom phytoplankton in the surface waters of the Celtic Sea and some adjacent waters. *Biology and Environment: Proc. RIA,* 107B, 43–53.

Sharples, 2008. Potential impacts of the spring-neap tidal cycle on shelf sea primary production. *Journal of Plankton Research,* 30, 183–197.

Sims *et al.,* 2003. Seasonal movements and behaviour of basking sharks from archival tagging: no evidence of winter hibernation. *Marine Ecology Progress Series,* 248, 187–196.

Sundby, S. 2000. Recruitment of Atlantic cod stocks in relation to temperature and advection of copepod populations. *Sarsia*, **85**, 277-298.

Trenkel *et al.,* 2003. Does diet in Celtic Sea fisheries reflect prey availability. *Journal of Fish Biology*, 23(1), 197–212.

Vanhoutte-Brunier *et al.,* 2008. Modelling the *Karenia mikimotoi* bloom that occurred in the western English Channel during summer 2003. *Ecological Modelling,* 210, 351–376.

1.2.3.5.3 Fish

Mackerel spawning

Mackerel (*Scomber scombrus*) spawn along the European shelf-edge from the Iberian Peninsula to the west of Scotland (Figure 1.2.65). Spawning starts in January/February in the south, and moves progressively north following the seasonal warming, ending around July to the west of Scotland (Lockwood et al., 1981). Prior to this winter mackerel migrate to the sea bottom and stop feeding and only resume after they have spawned. Spawning is concentrated along the shelf break but larvae progressively drift eastwards onto the shelf (Klopmann *et al.* 2001). The diet of mackerel is varied and consists of planktonic prey, crustaceans (especially copepods and euphausids) and fish. The first feeding larvae of mackerel (~3.5mm long) are phytovores and feed on phytoplankton. At ~ 4.5mm the larvae feed primarily on the nauplii of copepods such as *Acartia* spp., *Temora spp.* and *Pseudocalanus* spp. Copepodites of *Acartia* spp. and *Temora spp.* form the bulk of the diet of larvae > 5mm and those mackerel larvae ≥ 6.5mm eat other fish larvae and are often cannibalistic eating larvae in the 3.4 –4.5mm size range (Peterson & Ausubel, 1984).

The CEFAS database of fish stomach records (www.cefas.co.uk/dapstom) lists the stomach contents of numerous commercially important fish within the Celtic Sea area. For mackerel with a length of 20cm, for example, calanoid copepods (22.89 %) are listed as the largest identifiable component in stomachs followed by phytoplankton (15.66%) and other marine crustacean (10.84%).

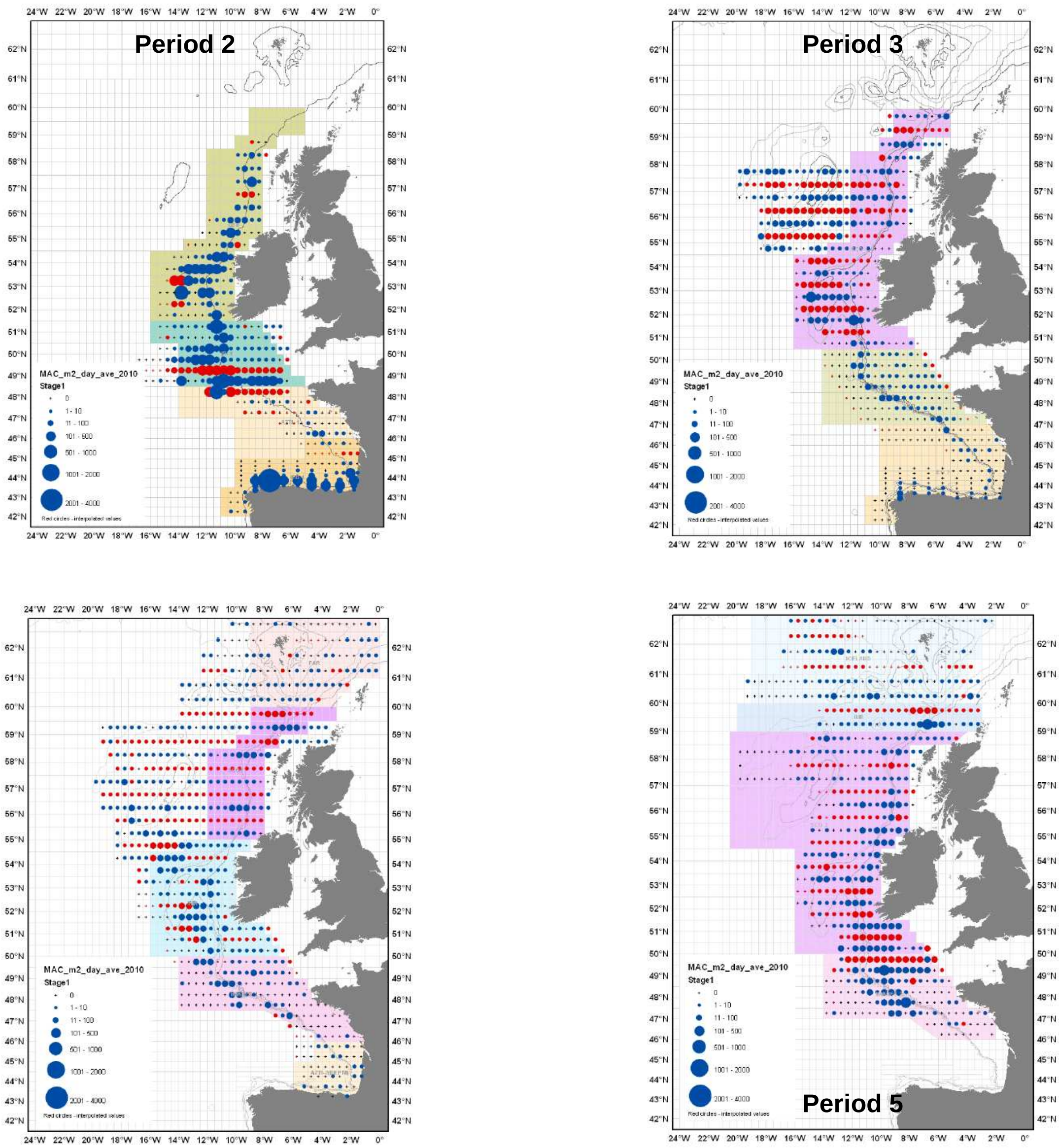
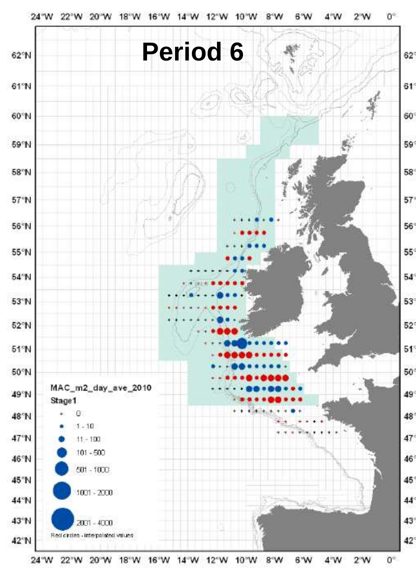


Figure 1.2.65: Maps showing the distribution of stage one mackerel eggs by period (approximately monthly) from the ICES international egg survey. Spawning starts in period 2 (March), expands northwards through periods 3-5 and ends off the south west of Ireland in period 6 (July) (Source: ICES WGMEGS 2011).



Megrim spawning

The spawning period of megrim (*Lepidorhombus whiffiagonus*) is short. Spawning occurs in deep water off the west of Ireland and off Iceland. Mature males can be found from December to March and mature females from January to March but spawning peaks in March. In southern areas megrim spawn from January to April. These fish general live on soft bottom habitats (100-500m) but their larvae can be found in the plankton from July to August. When larvae reach a length of 19 mm, they assume a benthic life.

Hake spawning

Hake (*Merluccius merluccius*) eggs and larvae can be found concentrated around the shelf break, although at the Celtic Sea shelf break, this spawning area extends onto shallower waters (Alvarez *et al.,* 2004). In their investigation in to the distribution and abundance of hake eggs and larvae in North East Atlantic waters, Alvarez *et al.* (2004) found that the incidence of hake eggs (and thus spawning) was intense during the first quarter of the year (late winter and early spring). The Celtic Sea is the principle spawning area for European hake with peak spawning taking place from March to June here (Figure 1.2.66). Hake eggs and larvae tend to be most abundant between just below the base of the mixed layer in the water column. CPR only 10m deep, hake larvae found 50-100m deep.

Hake are nectobenthic and usually found between 70 and 400m deep. They live close to the seabed during the day and ascend through the water column during the night. During late summer and early autumn hake larvae enter their demersal phase (at approximately 6-10cm long) and the Celtic Sea shelf is an important nursery area.

These nursery grounds are located in the northern part of the Celtic Sea with the maximum abundance of juveniles found between 81-120m. However, as the main spawning area is located well offshore, mainly over the shelf break, the eggs and larvae must be transported towards the coast the shelf into the nursery areas (Alvarez *et al.,* 2004). During the early life history stages of hake, final fate of the vulnerable larvae is dependant on oceanographic conditions. At the Celtic Sea shelf break, large internal tides propagate currents both off-slope towards the ocean and on-shelf towards the Celtic Sea nursery grounds. Larvae advected off-shore are removed from the population.

Bozzano *et al.* (2005) found that juvenile hake move into the midwater at night to feed in response to similar behaviour by their prey. Hake are piscivorous predators of many commercial species and as such they are at the top of the food web. The composition of their diet changes with the increase in size of the predator. Mahe *et al.* (2007) investigated the spatial variation in the diet are various hake size classes in the Bay of Biscay and Celtic Sea. Crustaceans (mainly euphausiids such as *Euphausia krohni*) dominated the diet of 0-group hake (length <20cm). A piscivorous diet commenced at ~11cm but only became significant in hake >20cm. As hake grow, fish take up a larger proportion of their diet with blue whiting, horse mackerel, anchovy, pilchard and small hake (cannibalism) becoming particularly important prey items.

Figure 1.2.66: Distribution and abundance of hake eggs/m² for 1998 (Alvarez et al., 2000).

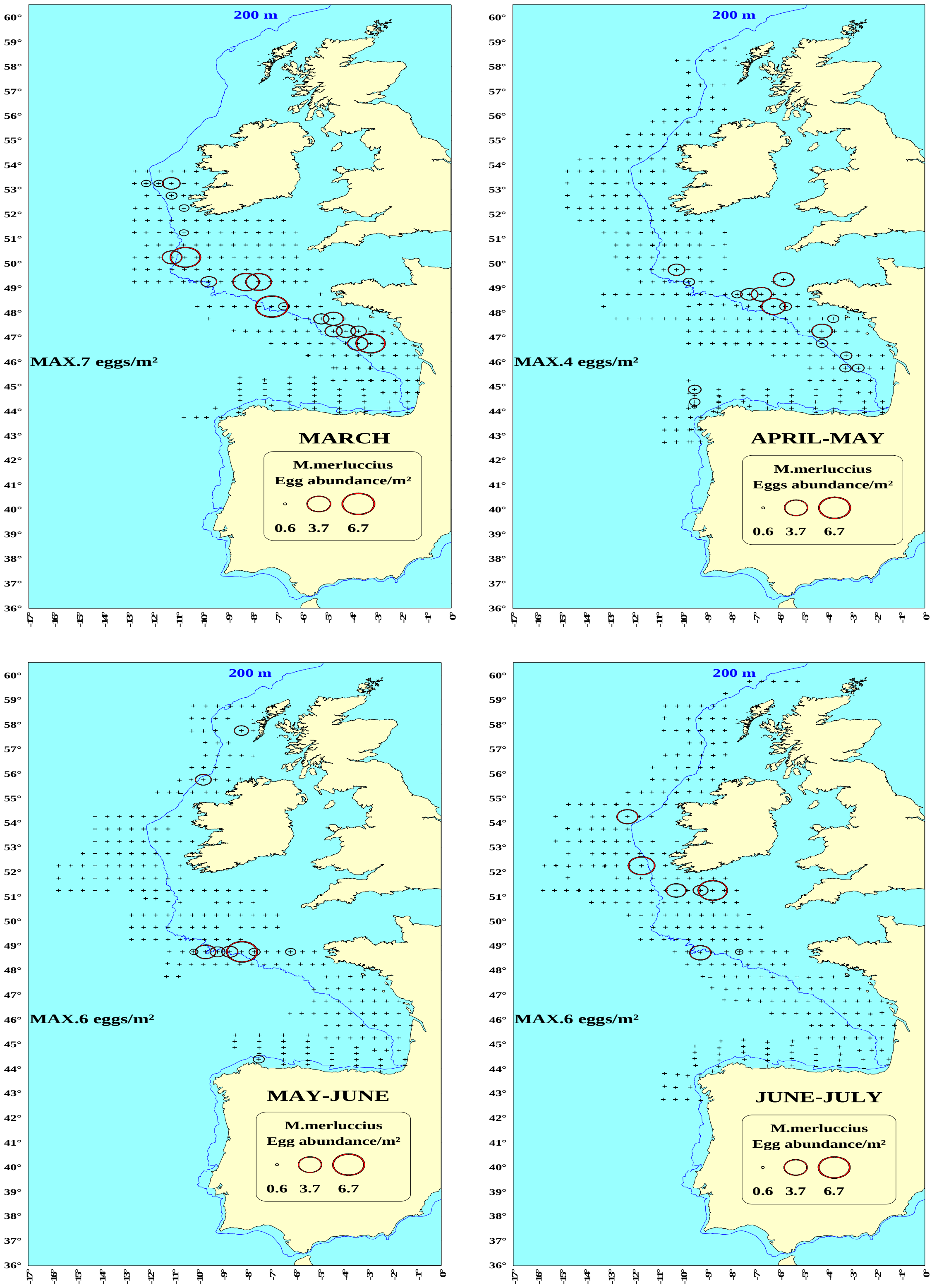
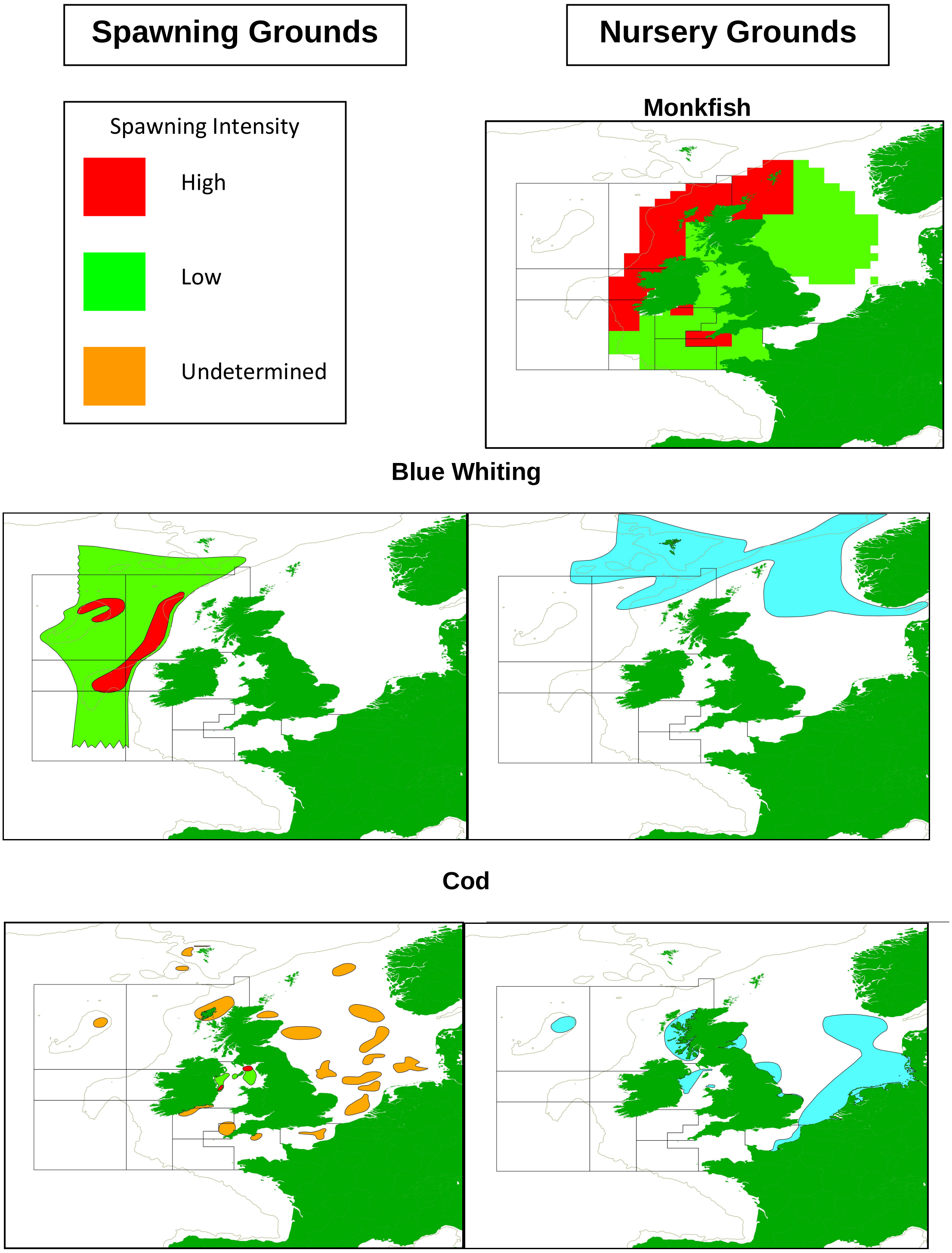
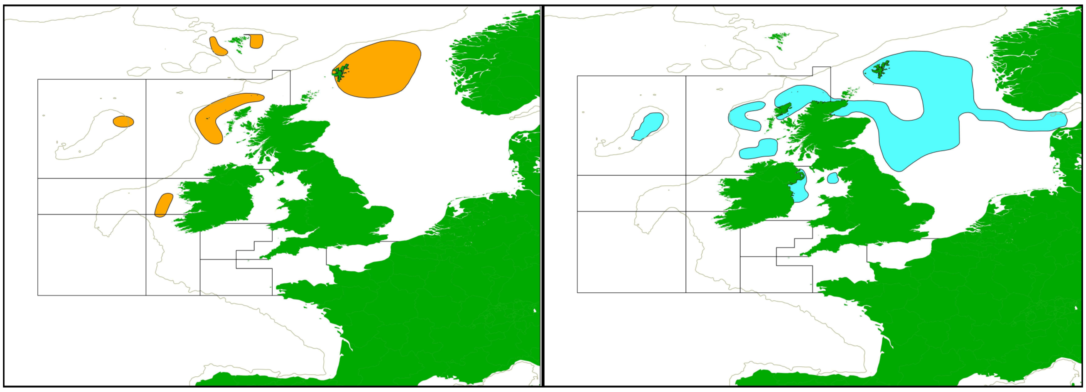


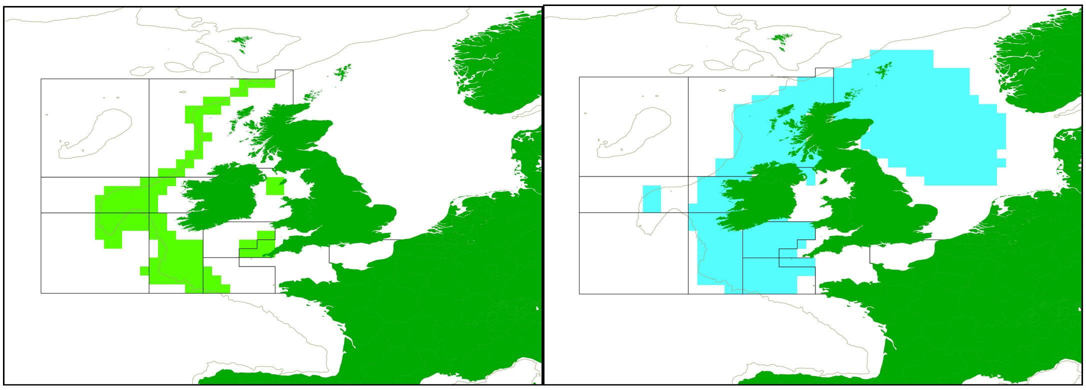
Figure 1.2.67: Maps of important spawning and nursery grounds for many commercially caught species of fish in and around the NWW. Included in each diagram are the 500m depth contour and the ICES divisions that make up the NWW.



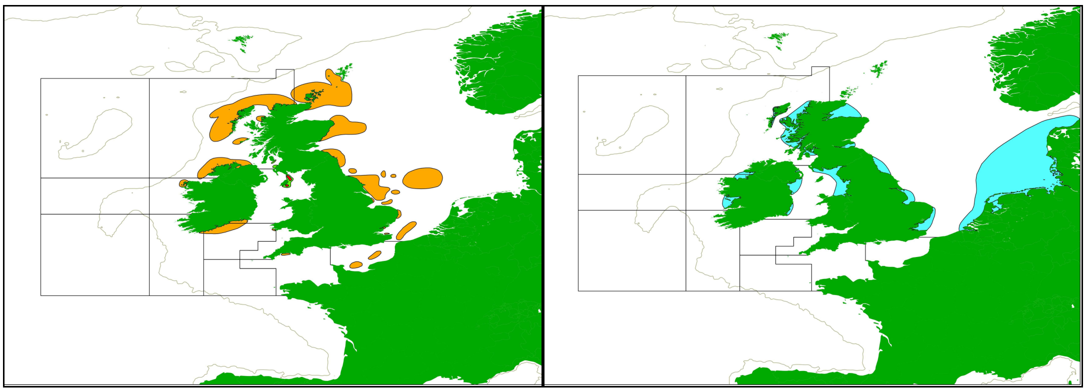
Haddock



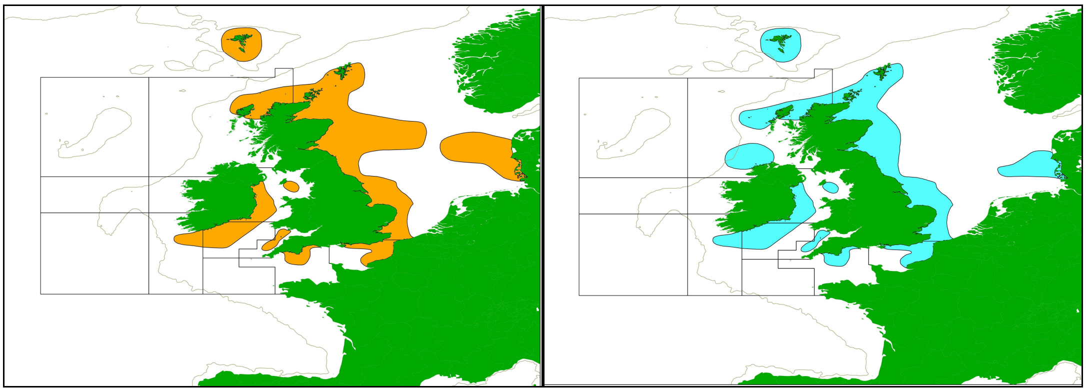
Hake



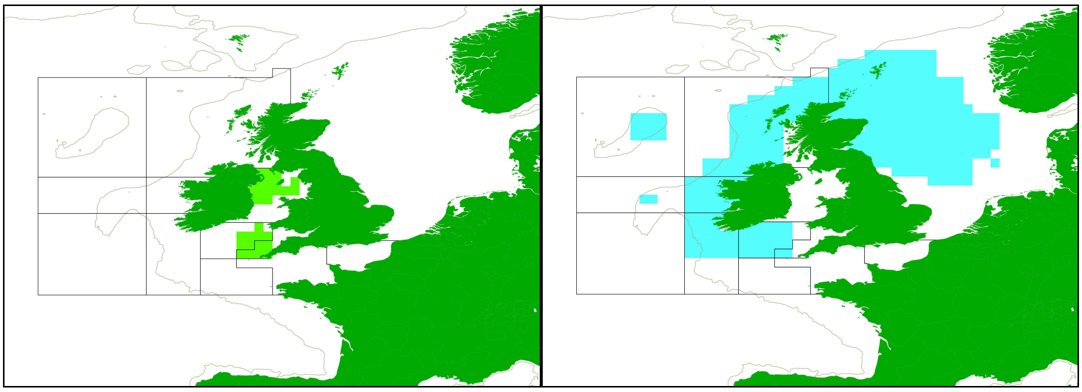
Herring



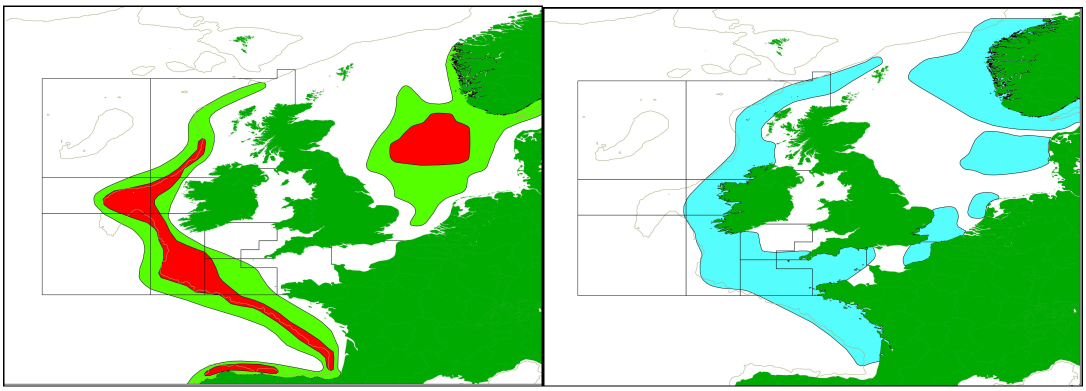
Lemon Sole



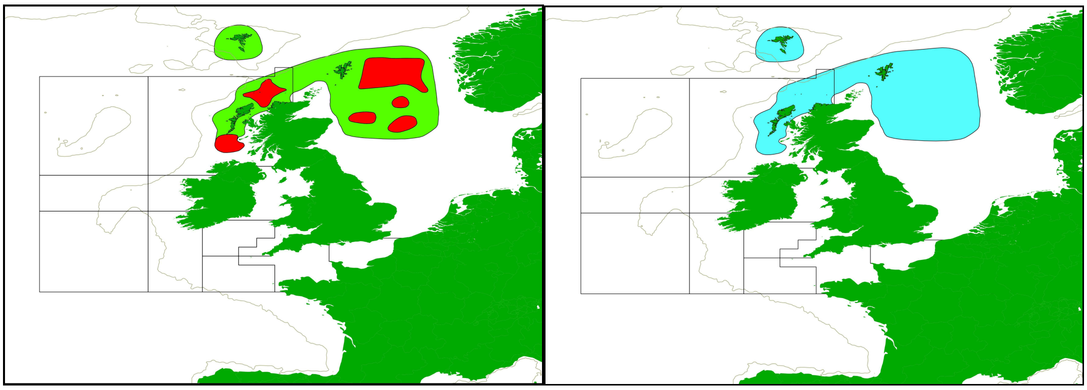
Ling



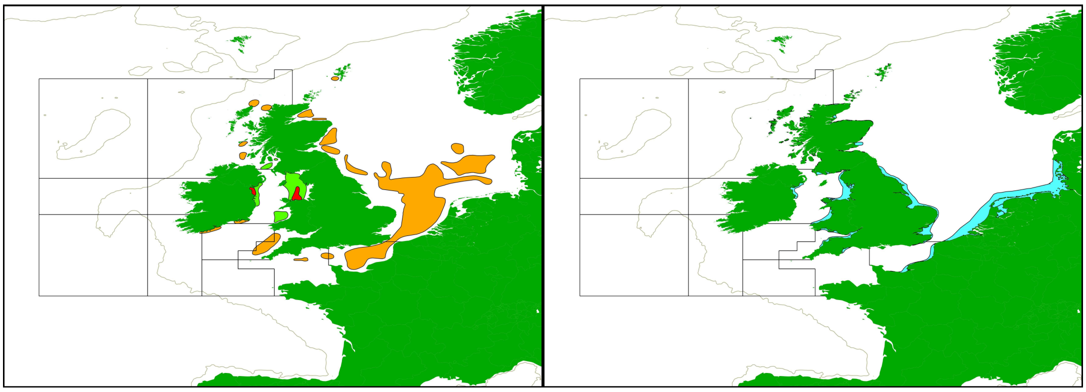
Mackerel



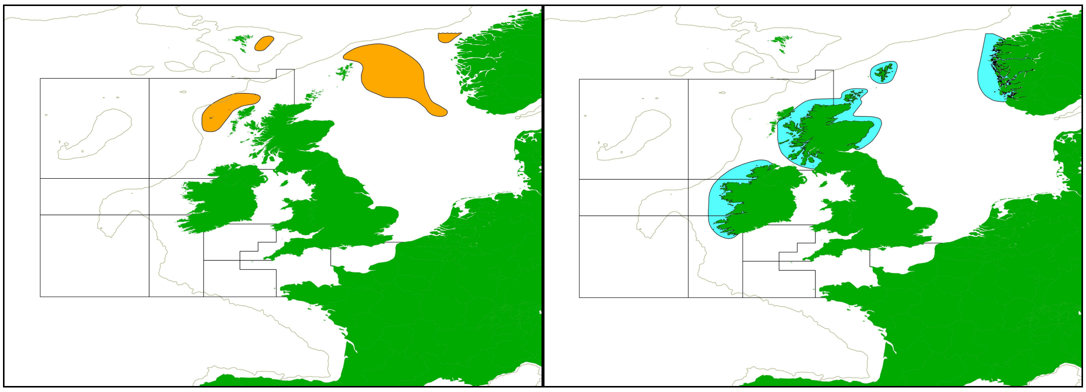
Norway Pout



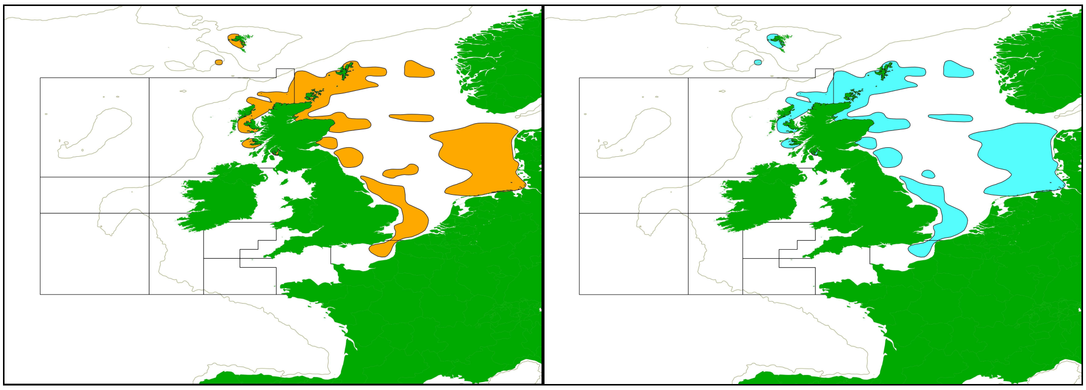
Plaice



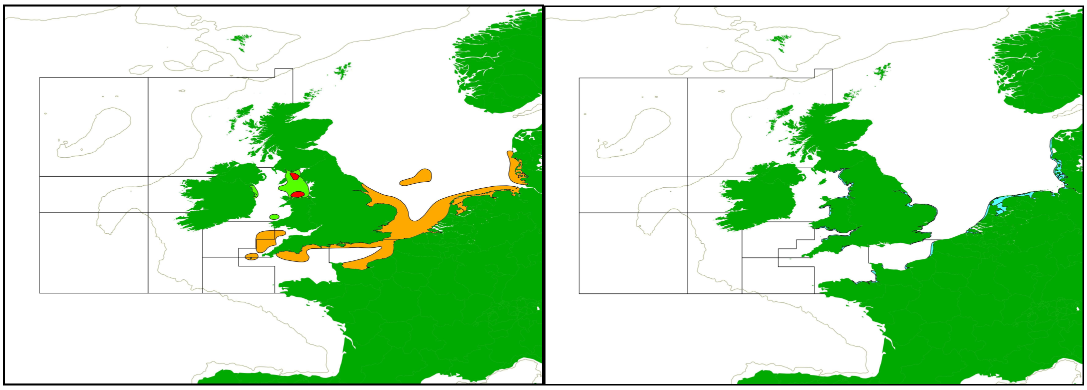
Saithe



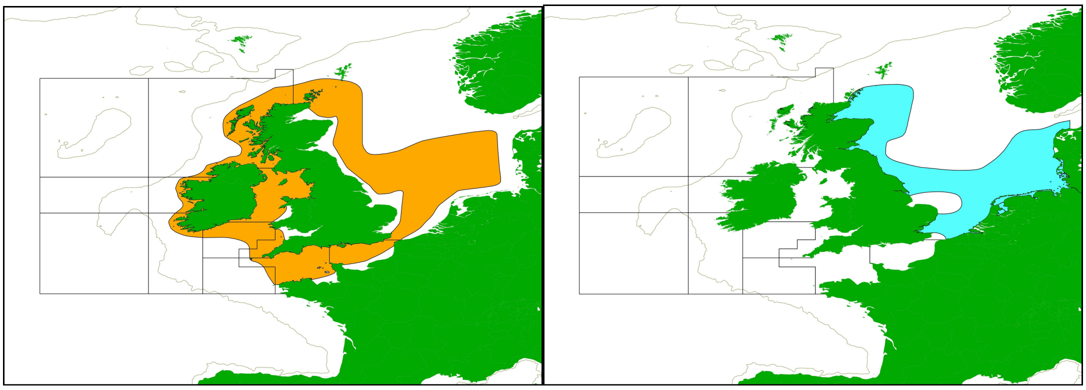
Sandeel



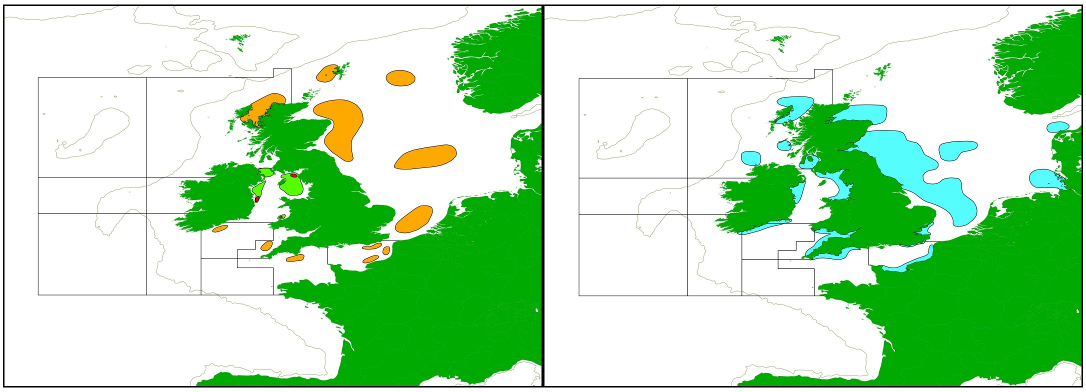
Sole



Sprat

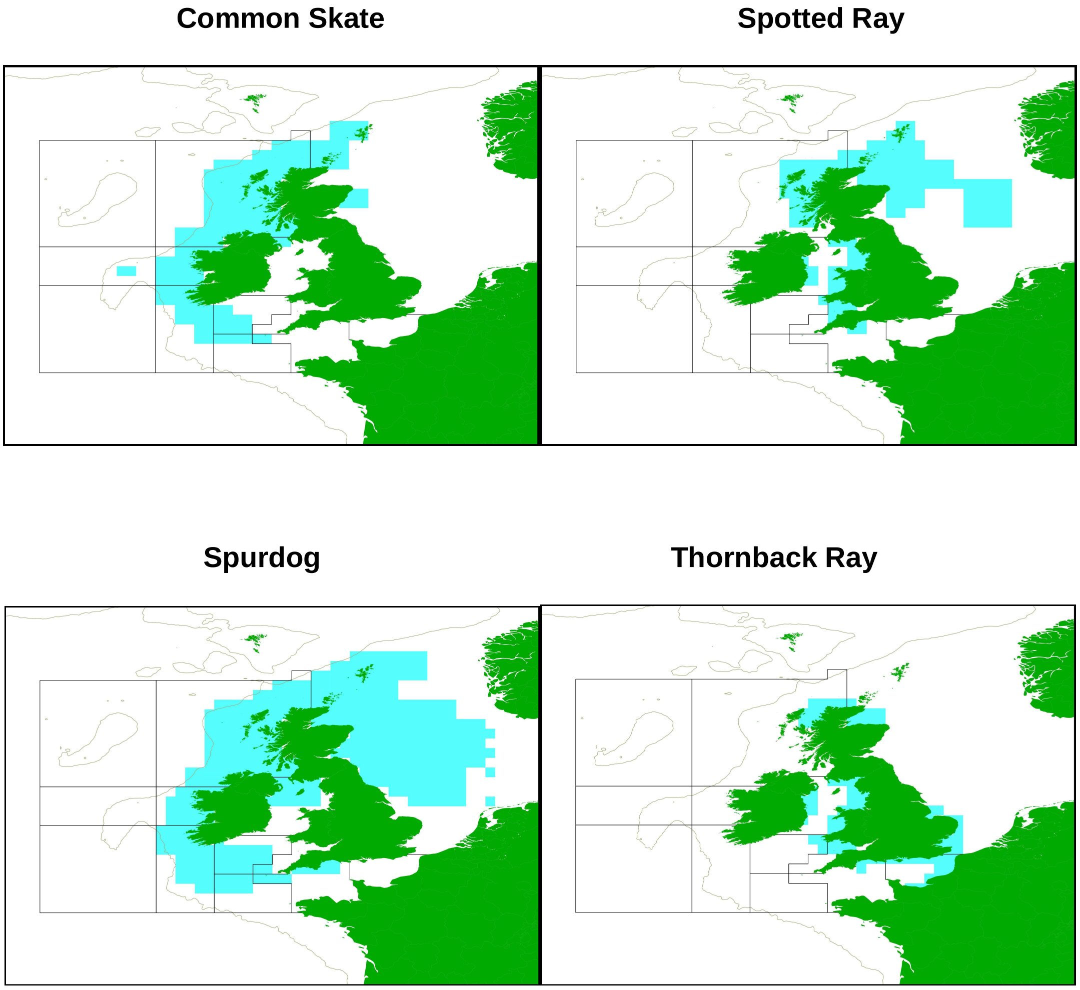


Whiting

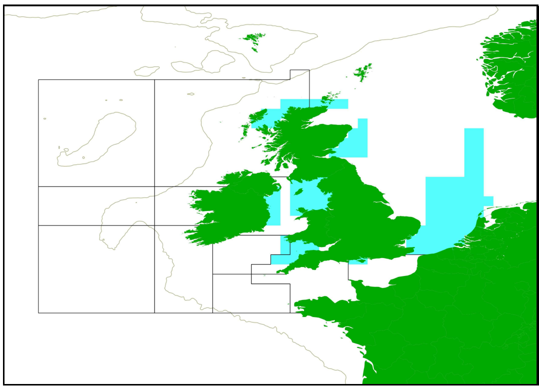


(GIS Source: CEFAS 2010)

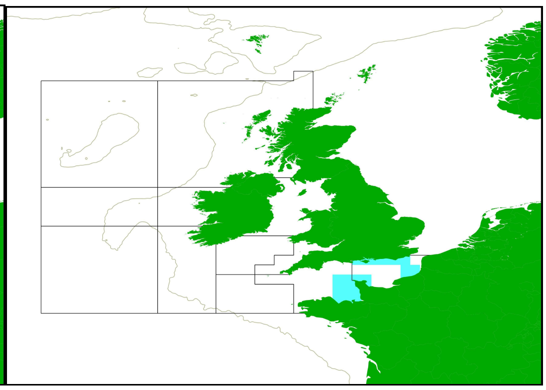
Figure 1.2.68: Maps depicting the nursery areas of some sharks, skates and rays commonly caught in NWW. The 500m depth contour and NWW boundary are included in each.



Tope Shark



Undulate Ray



(GIS Source: CEFAS)

1.2.3.5.4 Marine mammals and reptiles

1.2.3.5.4.1 Cetaceans

Data on marine mammals was sourced from Reid *et al* (2003) Cetacean Atlas, Mackey *et al* (2004) SEA678 Cetacean Report and Irish Whale & Dolphin Group sightings. Figure 1.2.69 – Figure 1.2.71 below show the toothed whales recorded from the MEFEPO Study Area from 2003 to present. Figure 1.2.72 below shows the baleen whales recorded from the MEFEPO Study Area from 2003 to present.

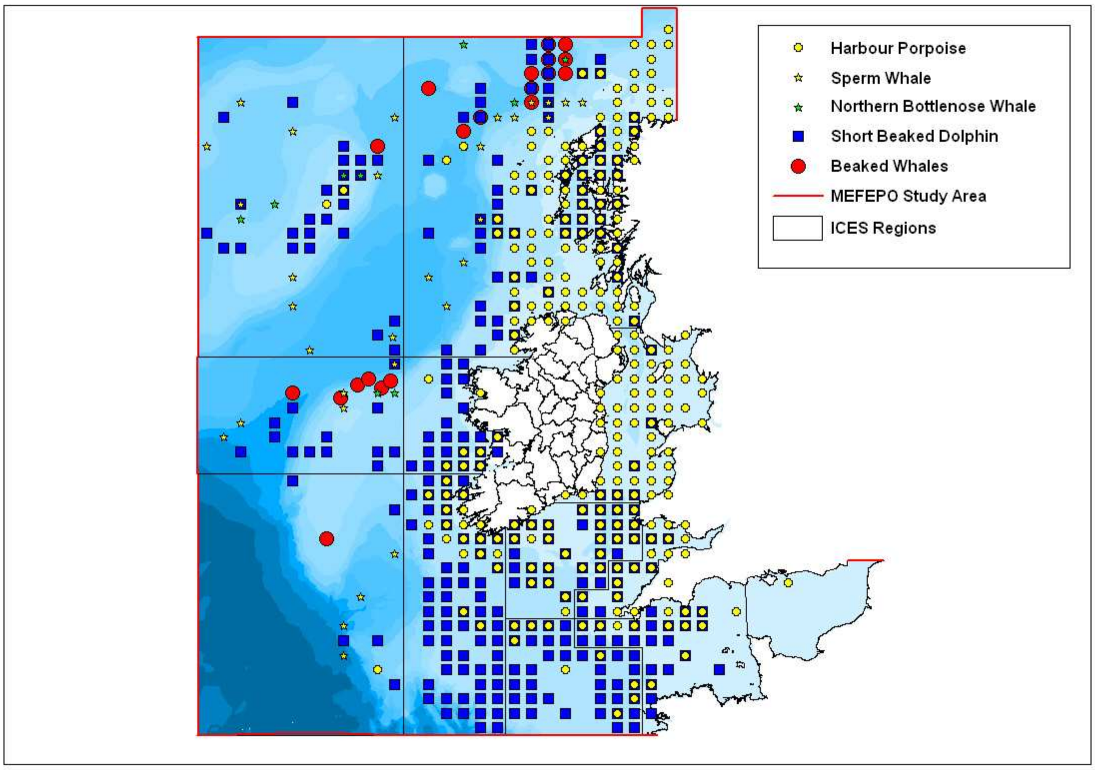


Figure 1.2.69: Harbour Porpoises, Sperm Whales, Northern Bottlenose Whales, Short Beaked Dolphins and Beaked Whales recorded from the MEFEPO Study Area from 2003 to 2009 (Source: Reid *et al*, 2003; Mackey *et al*, 2004; IWDG 2003-2009).

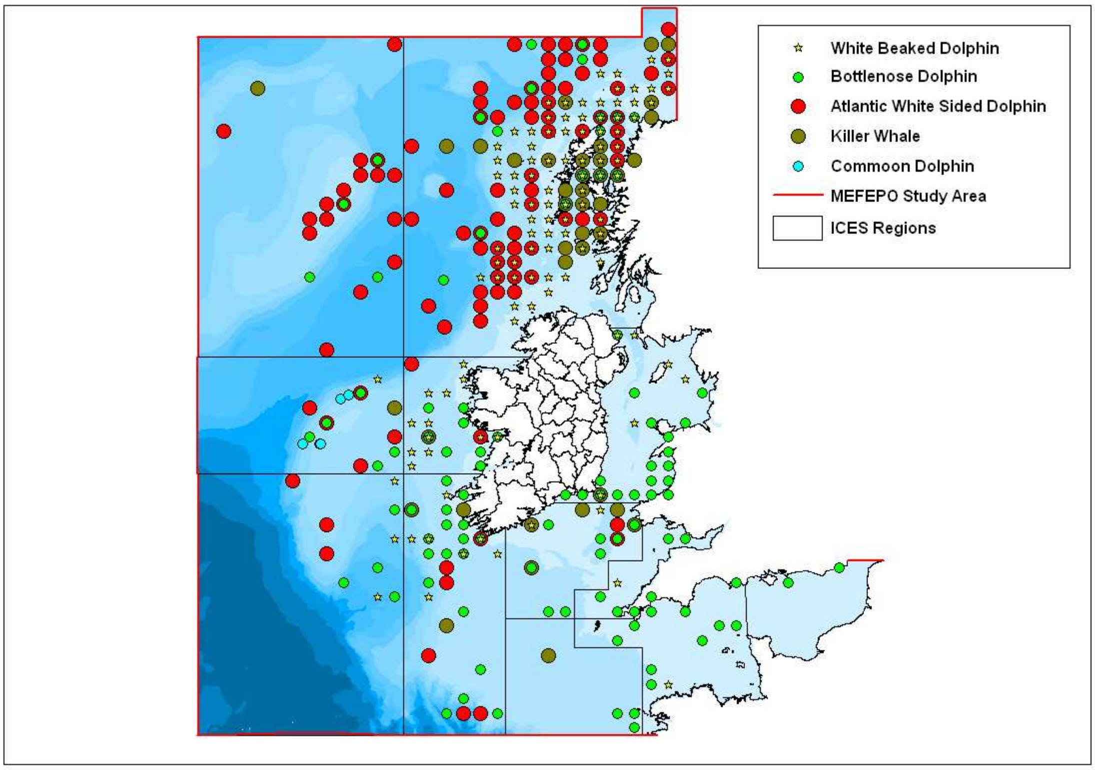


Figure 1.2.70: White Beaked Dolphins, Bottlenise Dolphins, Atlantic White Sided Dolphins, Killer Whales and Common Dolphins recorded from the MEFEPO Study Area from 2003 to 2009 (Source: Reid *et al*, 2003; Mackey *et al,* 2004; IWDG 2003-2009).

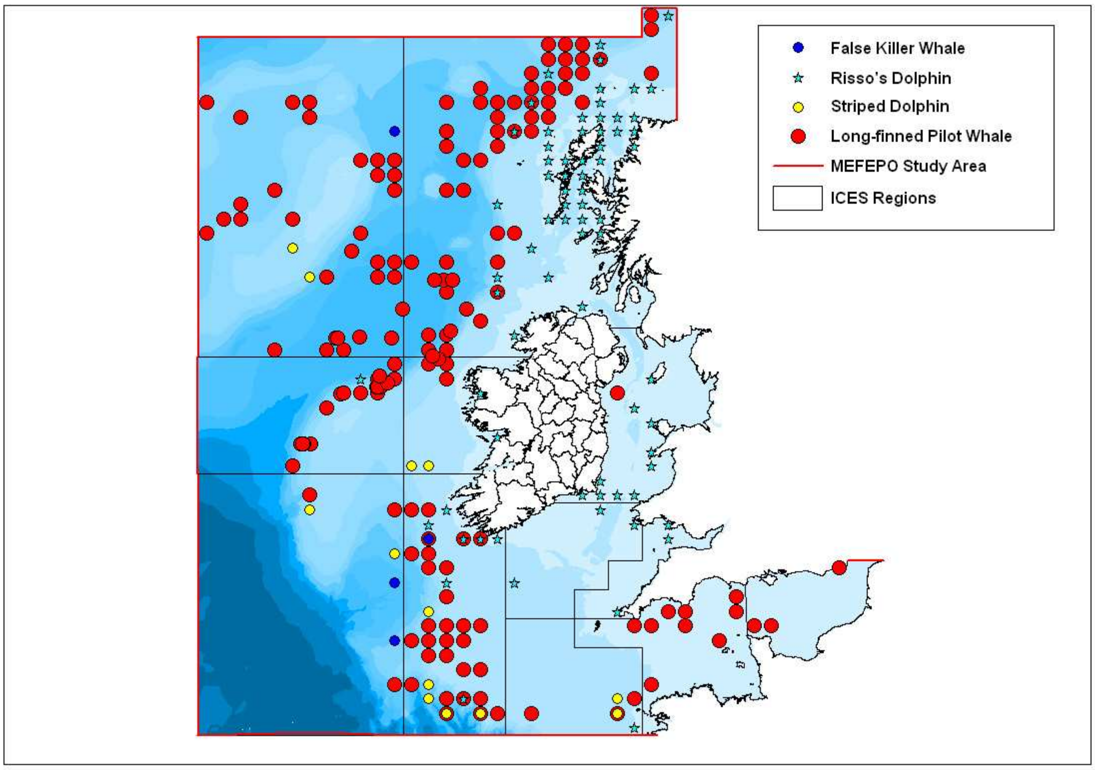


Figure 1.2.71: False Killer Whales, Risso's Dolphins, Striped Dolphins and Long-Finned Pilot Whales recorded from the MEFEPO Study Area from 2003 to 2009 (Source: Reid *et al*, 2003; Mackey *et al*, 2004; IWDG 2003-2009).

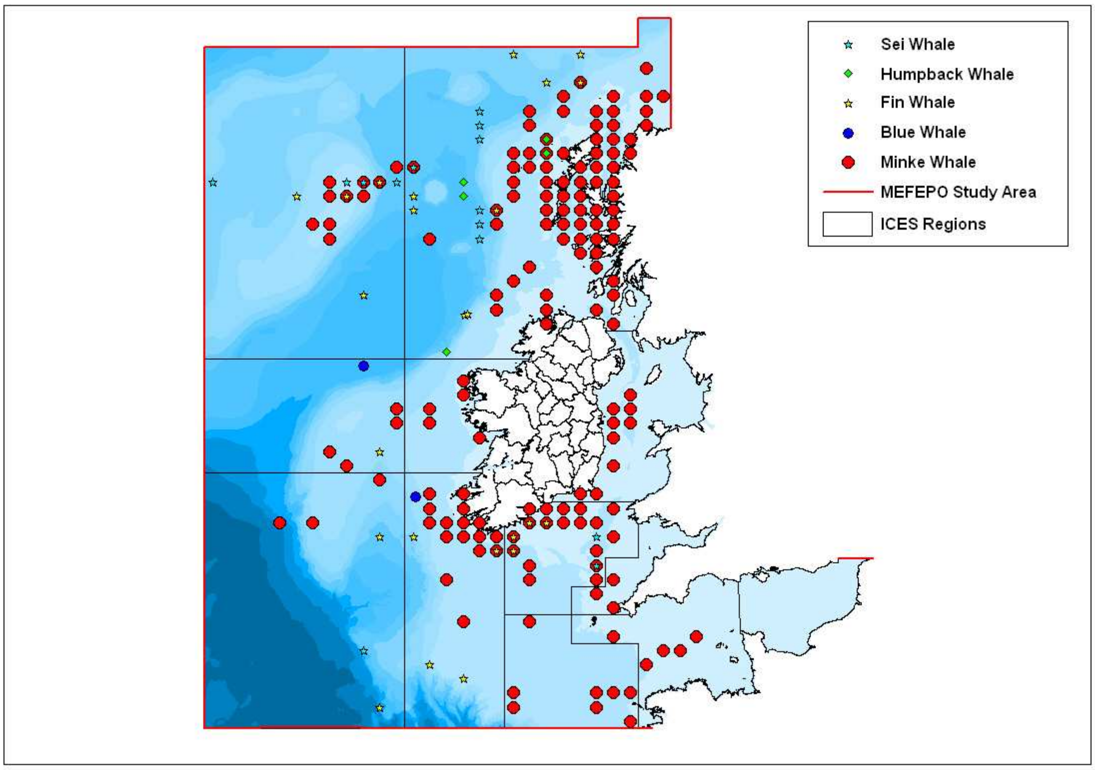


Figure 1.2.72: Baleen whales recorded from the MEFEPO Study Area from 2003 to 2009 (Source: Reid *et al*, 2003; Mackey *et al*, 2004; IWDG 2003-2009).

1.2.3.5.5 Seabirds

The seas and coastline of the NWW area are important for birds year round, with many areas being of international or national importance for the individual species or assemblages they support. The coastal and offshore waters of the NWW area provide local breeding and non-breeding seabirds, in addition to pelagic and passage migrants, with a rich source of nutrition, particularly near coastal upwelling and frontal systems (e.g. along the Irish Shelf front and north of the Porcupine Seabight).

Furthermore, the exposed and inaccessible west coasts of Ireland and Scotland provide perfect breeding habitats for many seabird species. NWW are important fishing grounds and nursery and spawning areas for fish and invertebrate species. As a result, the NWW area is an important area for seabirds. Off the west of Ireland and Scotland, petrels, shearwaters, skuas, gannets, gulls and auks dominate. The majority of these birds breed in colonies located on the southwest coast of Ireland while others overwinter in Irish waters. Some species such as shearwaters and skuas are passage migrants that use the area as a migratory corridor.

The Mackey and Giménez (2004) report summarises seabird data generated by all parties for the NWW. The most common species encountered in NWW were the Northern Fulmar, Manx Shearwater, Northern Gannet, Common Guillemot and the Black Legged Kittiwake.

Mackey, M. & Giménez, D.P. 2004. SEA 678 Data Report for Offshore Seabird Populations. A report for the DTI.

Available http://www.offshore-sea.org.uk/consultations/SEA678/SEA678_Seabirds.pdf

Indicators of Ecosystem Health

Bird abundance can provide good indicators of the state of the ecosystem due to the wide range of habitats which they exploit and their high position in the food chain. Changes in the abundance of their prey at lower trophic levels can have major impacts on bird populations. The decline in breeding success at many seabird colonies has been related to low food availability (e.g. sandeel availability in the North Sea). Changes in the levels of discarded fish from commercial fishing vessels can also alter the availability of food for many species which scavenge.

The **Northern Fulmar** () is a common resident along British and Irish coastlines, whose breeding range has expanded rapidly in the northeast Atlantic during the last century. This highly pelagic seabird was the most frequently recorded and the most widespread species, where it was recorded throughout most of the study area during all seasons.

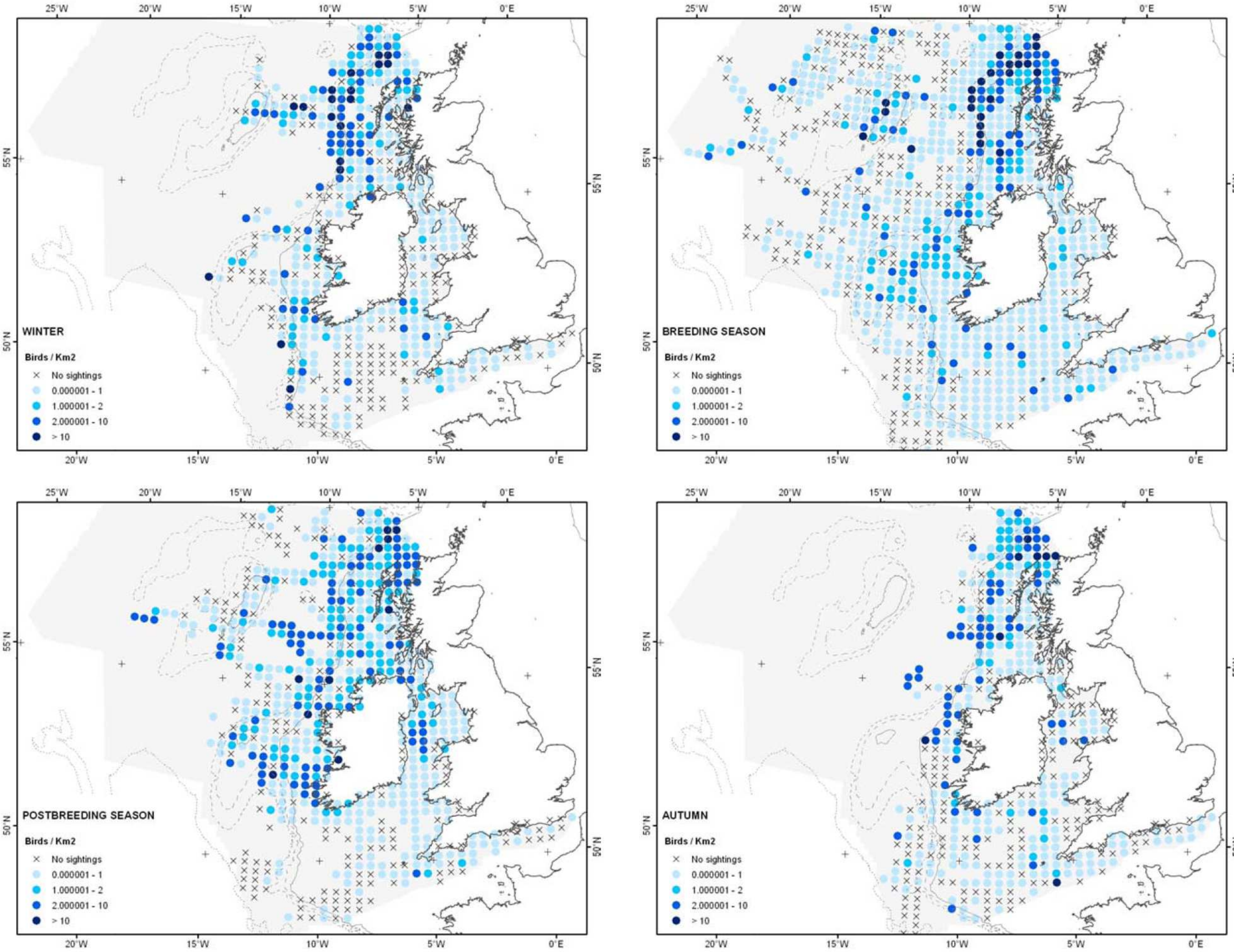


Figure 1.2.73: Seasonal distribution and density of the Northern Fulmar within NWW, 1980-2003 (Source: Mackey & Giménez 2004).

The **Manx Shearwater** (

Figure 1.2.74) is a common local breeder and passage migrant that are regularly recorded between March and October (IRBC, 1998). The breeding distribution of this long distance migrant is largely restricted to northwestern Europe, where the largest concentrations are located along the west coasts of Britain and
Ireland.

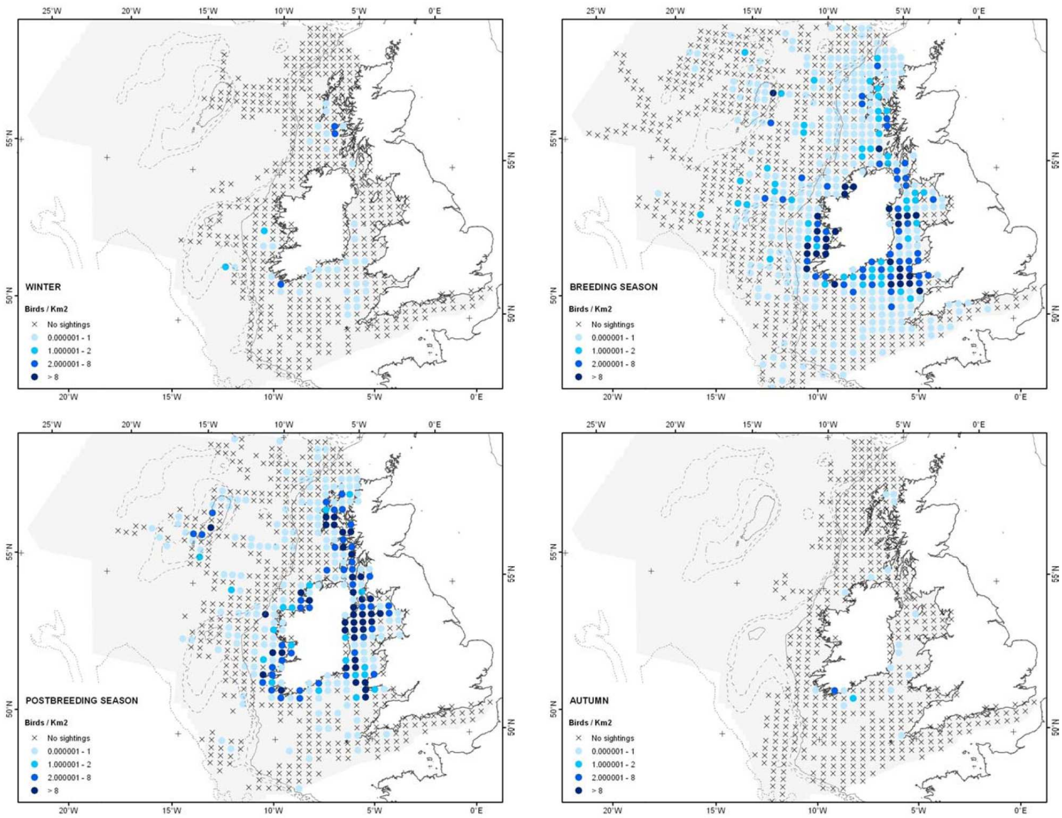


Figure 1.2.74: Seasonal distribution and density of the Manx Shearwater within NWW, 1980-2003 (Source: Mackey & Giménez 2004).

The **Northern Gannet** (Figure 1.2.75) is the largest of Europe's seabirds. This prominent species, widely known for its spectacular diving behaviour, breeds on both mainland cliffs and remote islands off Scotland and Ireland. British and Irish colonies support approximately 67.5% of the world's growing breeding population.

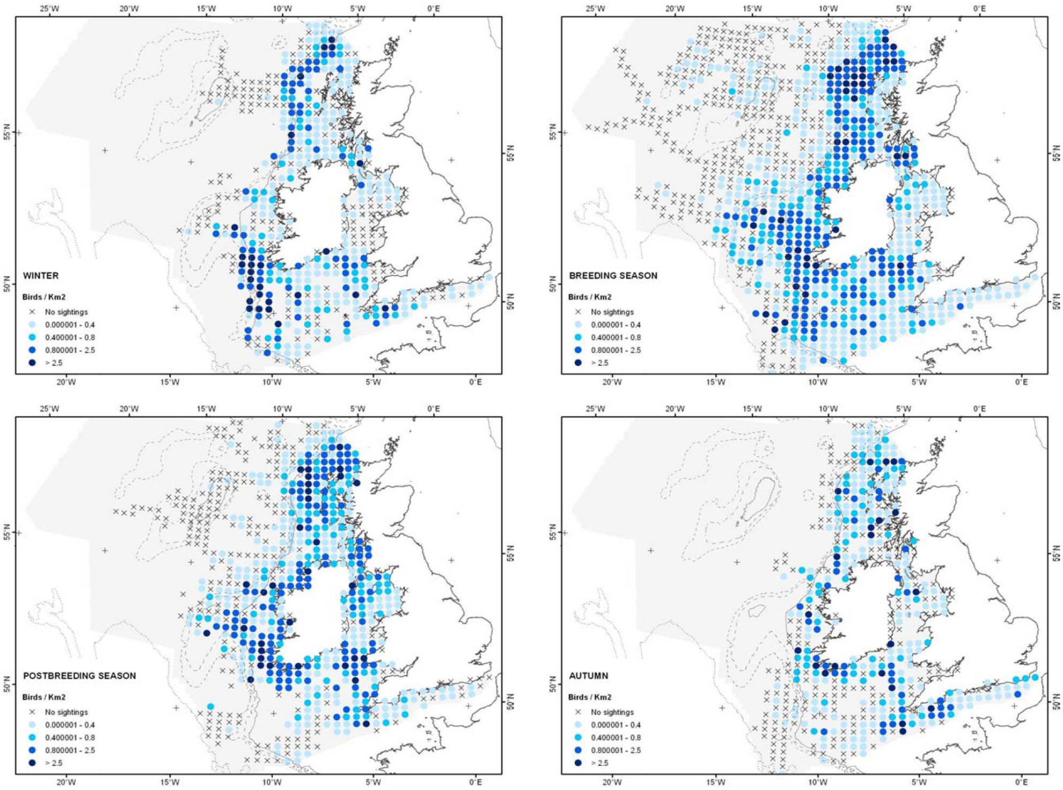


Figure 1.2.75: Seasonal distribution and density of the Northern Gannett within NWW, 1980-2003 (Source: Mackey & Giménez 2004).

The **Black-legged Kittiwake** (Figure 1.2.76) is a small, cliff-nesting gull species that breeds along much of the British and Irish coastlines. It is the most pelagic of the local gull species especially during the winter when birds disperse to the Bay of Biscay, the North Sea and westward to the northern Atlantic.

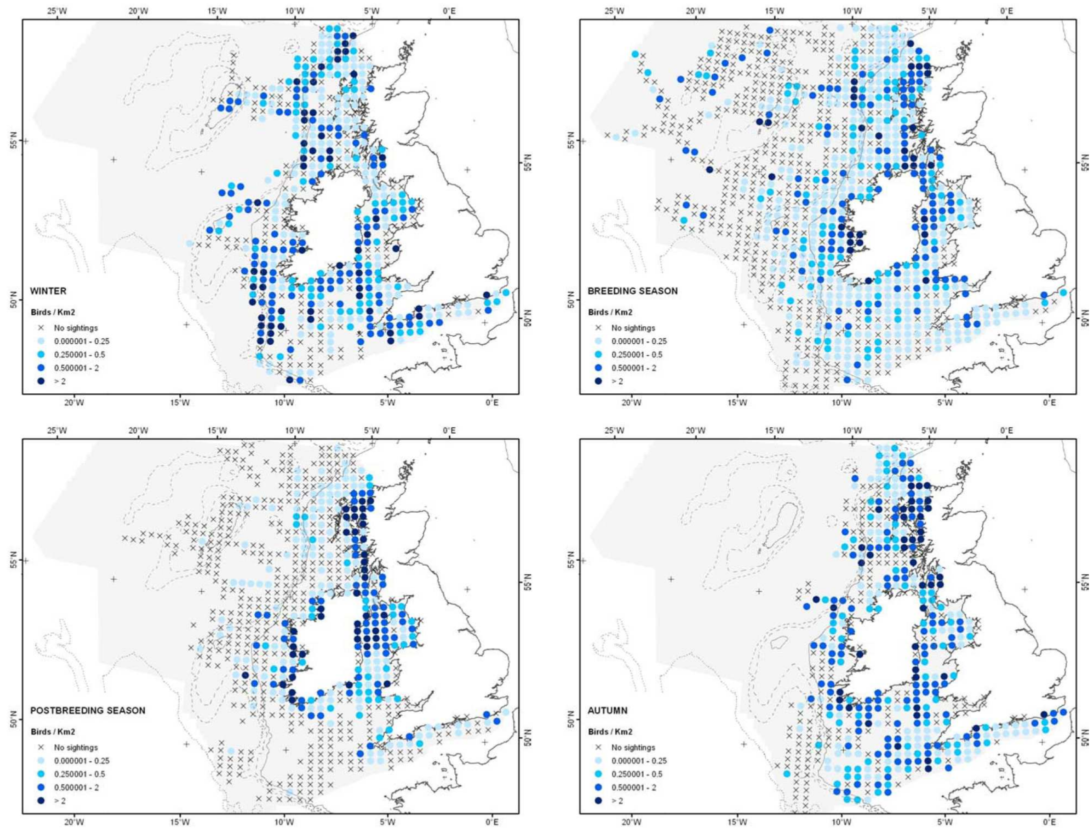


Figure 1.2.76: Seasonal distribution and density of the Black Legged Kittiwake within NWW, 1980-2003 (Source: Mackey & Giménez 2004).

The **Common Guillemot** (Figure 1.2.77) is the largest of the four auk species that breed in Britain and Ireland. The most widespread of all auk species, its population size has continued to fluctuate in response to a combination of human-related and natural events. The main stronghold of the local breeding population is located in Shetland, Orkney and Scotland.

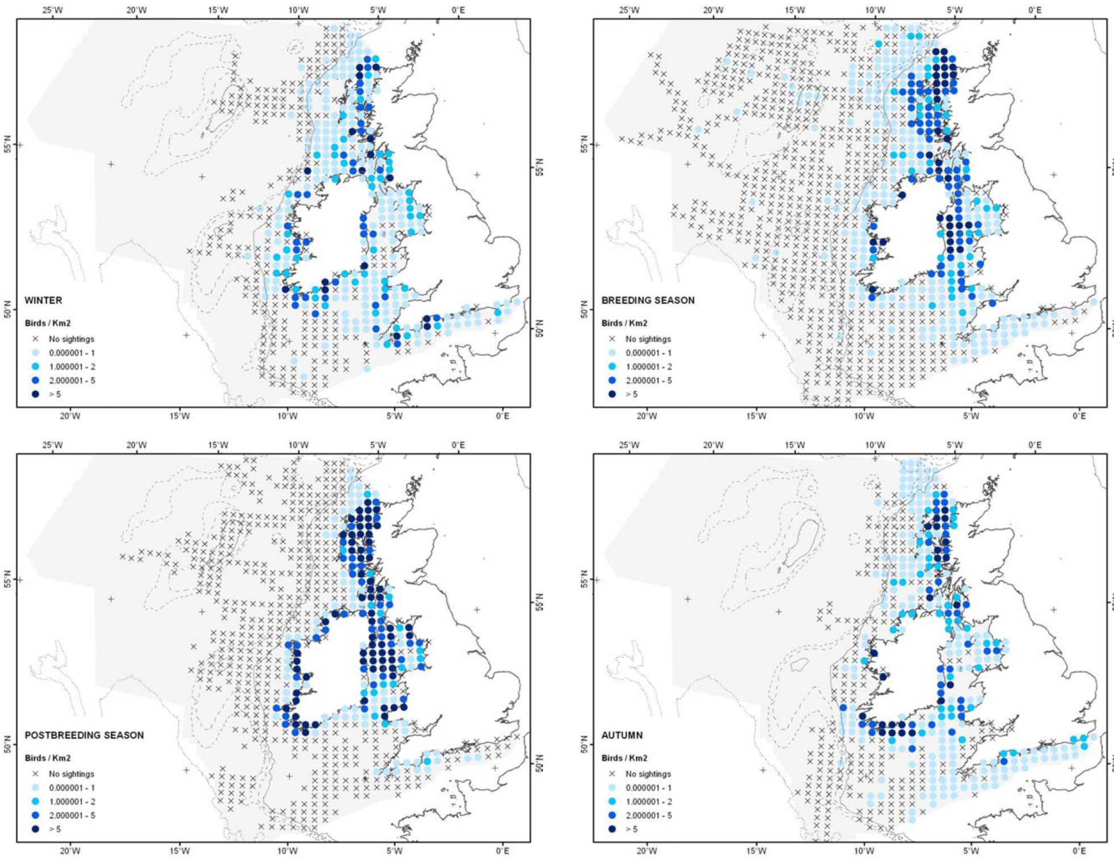


Figure 1.2.77: Seasonal distribution and density of the Common Guillemott within NWW, 1980-2003 (Source: Mackey & Giménez 2004).

Table 1.2.11: Total Number of the commonly encountered seabird species recorded during ship based surveys in NWW July 1980 to August 2003 (Source: Mackey & Giménez 2004).

Common Name	Latin Name	Uncorrected Total
Northern Fulmar	*Fulmarus glacialis*	357,661
Great Shearwater	*Puffinus gravis*	5,654
Sooty Shearwater	*Puffinus griseus*	2,730
Manx Shearwater	*Puffinus puffinus*	187,354
European Storm-petrel	*Hydrobates pelagicus*	23,460
Leach's Storm-petrel	*Oceanodroma leucorhoa*	1,232
Northern Gannet	*Morus bassanus*	196,334
Great Cormorant	*Phalacrocorax carbo*	1,812
European Shag	*Phalacrocorax aristotelis*	7,046
Pomarine Skua	*Stercorarius pomarinus*	557
Arctic Skua	*Stercorarius parasiticus*	833
Long-tailed Skua	*Stercorarius longicaudus*	380
Great Skua	*Stercorarius skua*	3,785
Black-headed Gull	*Larus ridibundus*	11,561
Mew Gull	*Larus canus*	8,764
Lesser Black-backed Gull	*Larus fuscus*	36,721
Herring Gull	*Larus argentatus*	56,019
Great Blacked-backed Gull	*Larus marinus*	24,360
Black-legged Kittiwake	*Rissa tridactyla*	126,324
Common Tern	*Sterna hirundo*	1,747
Arctic Tern	*Sterna paradisaea*	1,233
Common Guillemot	*Uria aalge*	136,934
Razorbill	*Alca torda*	34,015
Black Guillemot	*Cepphus grylle*	1,132
Atlantic Puffin	*Fratercula arctica*	28,504

1.2.3.5.6 Protected species

See section 1.2.2.5 Special and Protected Habitats

1.2.3.5.7 Non-indigenous species

Non-indigenous or alien species are of primary concern to many regulating authorities and are seen as one of the top four anthropogenic threats to the worlds' oceans. Intentional and accidental species introductions have resulted in their establishment outside their natural range with potentially disastrous consequences for native species. The primary introduction vectors of non-indigenous species are believed to be unintentional transport by ships, in ballast waters (*Styela clava*) and hull foulings (*Elminus medestus*) and intentional importations of aquaculture target species as well as their accidental release from aquaculture sites (*Crassostrea gigas*) (Gollasch, 2006).

Overviews on introduced species exist for the NWW study area and include British Isles (Eno, 1996; Eno *et al*., 1997) and Ireland (Stokes *et al*., 2006; Minchin and Eno, 2002; Minchin, 2007a and 2007b). Detailed descriptions on the spread of some particularly invasive species in the NWW region include the tunicates *Styela clava* (Davis *et* al., 2007) and the invasive algae *Sargassum muticum* (Haries *et al*., 2007) and *Heterosiphonia japonica* (Sjotun *et al*., 2008).

Figure 1.2.78 and Figure 1.2.79 illustrate a range of non-indigenous species established within the NWW. The list of species illustrated in not exhaustive, as exact locations for many of the species were not available. The journal Aquatic Invasions is particularly useful in describing the spread and extent of these species. Other usefull sources include www.invasivespecies Ireland.com and DAISE (Delivering Alien Invasive Species Inventories for Europe (www.daisie.ceh.ac.uk).

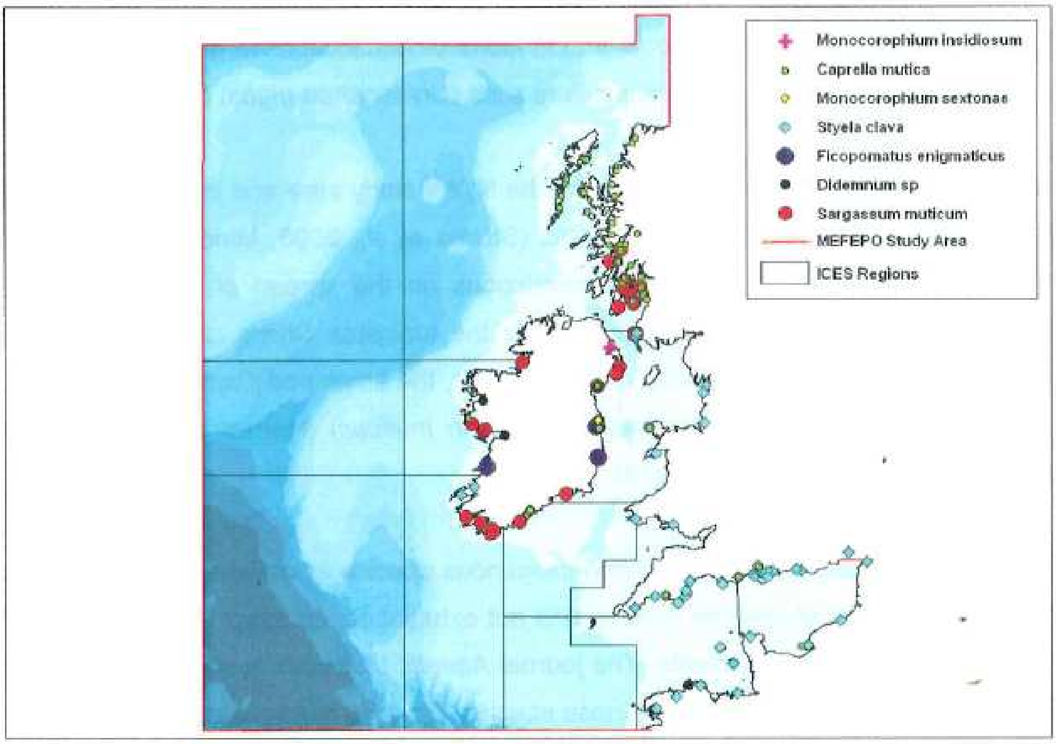


Figure 1.2.78: Distribution of non-indigenous species within NWW (source: Minchin, 2007; Minchin and Sides, 2006; Irish Seaweed Centre; Harries et al., 2007; Davies et al., 2007; Cook et al., 2007; Woods Hole Science Centre, woodshole.er.usgs.gov/projectpages/stellwagen/didemnum).

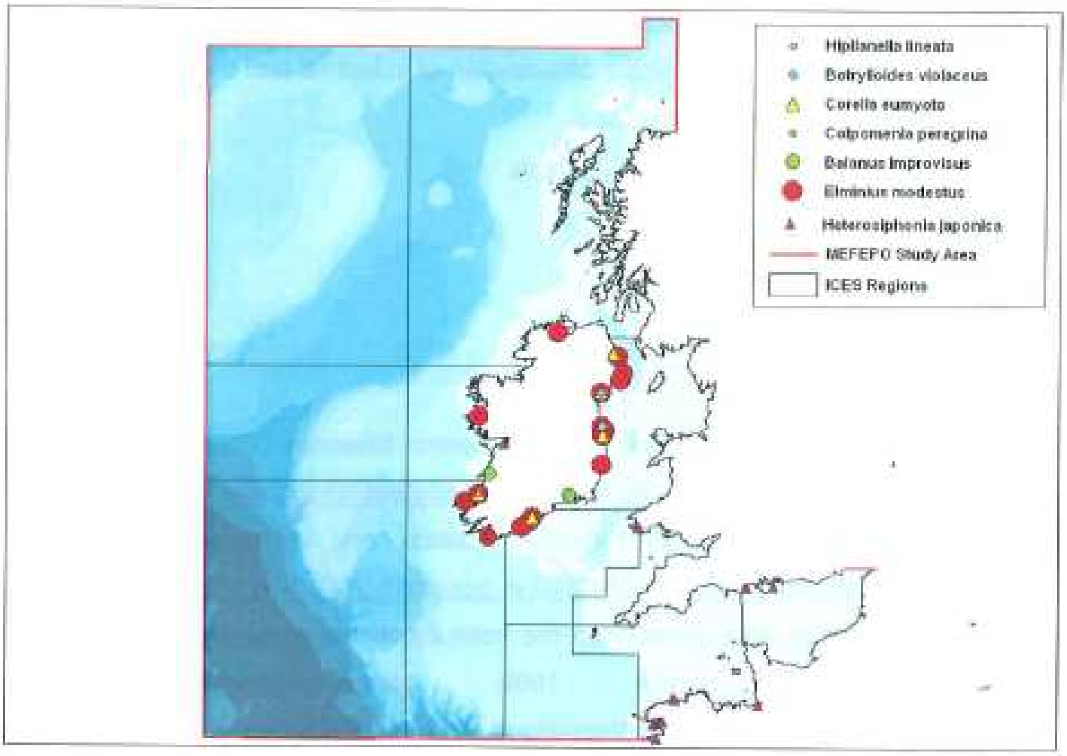


Figure 1.2.79: Distribution of non-indigenous species within the NWW study area (source: Minchin, 2007; Sjotun *et al*., 2008).

1.2.4 Other Features

Chemistry

Marine Inputs

There are three main entry routes for contaminants and nutrients to enter the marine environment: direct, riverine and atmospheric.

Direct discharges of effluents and coastal waters can be divided broadly into three categories:

Urban wastewater containing both industrial and domestic waste

Domestic sewage discharges

Direct discharges of industrial effluents

Inputs can be divided into trace, organic contaminants (in particular persistent organic pollutants, POPs), oil, radionuclides and nutrients.

Combined discharges of domestic and industrial effluents from municipal outfalls currently dominate inputs of organic material to esturine and coastal waters. Figure 1.2.80 shows the locations of municipal outfalls around the coast of Ireland, England and Wales. Irish data was sourced from Boelens et al., 1999 (originally from O'Leary et al. 1997) and updated where relevant to 2005 status from EPA data (Smith et al. 2007) Only Irish locations with a population equivalent = 2000 were mapped. English and Welsh data was sourced from CEFAS (2000) using CEFAS 1999 data.

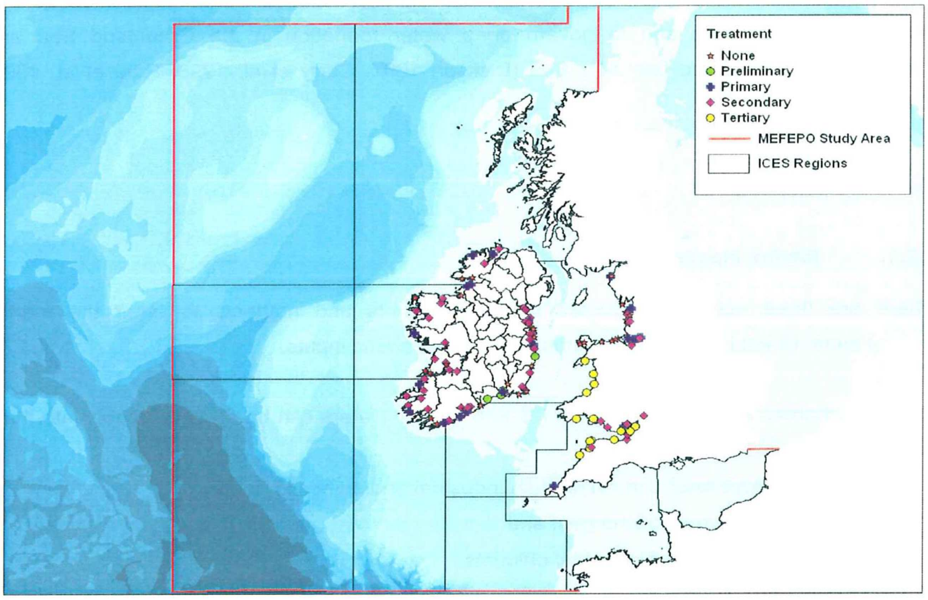


Figure 1.2.80: Locations of municipal outfall sites along the coast of Ireland, England and Wales (source: Boelens et al., 1999; CEFAS, 2000)

In addition to direct inputs, riverine inputs also contribute discharges to the marine environment. In 1988, the Paris Convention initiated a programme to study riverine inputs. The objective of this programme was to quantify river-borne loads of selected priority contaminants at the freshwater limits of rivers discharging to marine areas. The following substances were listed for mandatory reporting: mercury, cadmium, copper, lead, zine, hexchlorocyclohexane (lidane), ortho-phosphorous, total phosphorous, nitrate, total nitrogen and suspended solids. This data is reported to OSPAR. Table 1.2.11 below shows direct discharges and riverine inputs into the Celtic Seas (Region III) from 1990 to 2002 (OSPAR Commission, 2005). Figure 1.2.81 shows the total inputs of nitrogen and phosphorous to the Celtic Seas in the same period. Generally, direct discharges were the smaller, and progressively diminishing, component of overall inputs for each substance. For four of the assessed 15 determined load types acceptable downward trends were detected.

	Direct Discharges					Riverine inputs and Flows				
Year	Tot-N kt/a	Po4-P kt/a	Cd t/a	Hg t/a	Pb t/a	Tot-N kt/a	Po4-P kt/a	Cd t/a	Hg t/a	Pb t/a
1990	45	12.0	26.9	3.2	72	243	12.9	20.2	8.0	400
1991	41	12.8	15.8	1.8	38	269	10.0	25.1	7.7	264
1992	53	12.2	12.4	1.8	57	243	11.3	17.7	7.6	234
1993	45	7.0	9.3	1.0	100	267	14.2	16.0	8.4	223
1994	48	9.5	6.7	0.7	83	281	16.4	18.0	7.1	257
1995	43	8.4	6.3	0.5	72	254	13.8	13.9	7.4	200
1996	38	8.6	7.1	0.5	64	286	14.3	11.4	6.5	223
1997	40	9.7	5.6	0.4	64	281	14.8	8.9	6.6	234
1998	46	10.1	3.5	0.5	75	298	19.8	10.4	6.7	320
1999	38	8.2	4.5	0.5	60	126	12.8	8.8	2.2	290
2000	38	7.6	2.5	0.5	48	132	12.7	14.0	2.1	240
2001	35	7.3	2.0	0.4	34	105	10.9	9.3	1.0	241
2002	32	5.9	2.9	0.4	28	220	10.4	13.1	1.3	300

Table 1.2.12: Basic data on inputs to the Celtic Seas from 1990 to 2001 (source: OSPAR Commission, 2005).

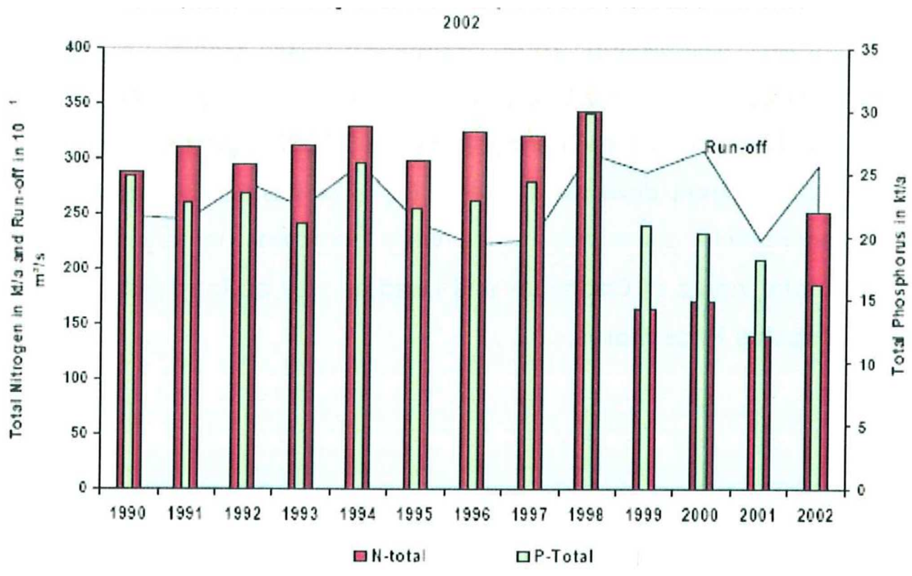


Figure 1.2.81: Total inputs of total nitrogen and total phosphorous to the Celtic Seas from 1990 to 2002 (source: OSPAR Commission, 2005).

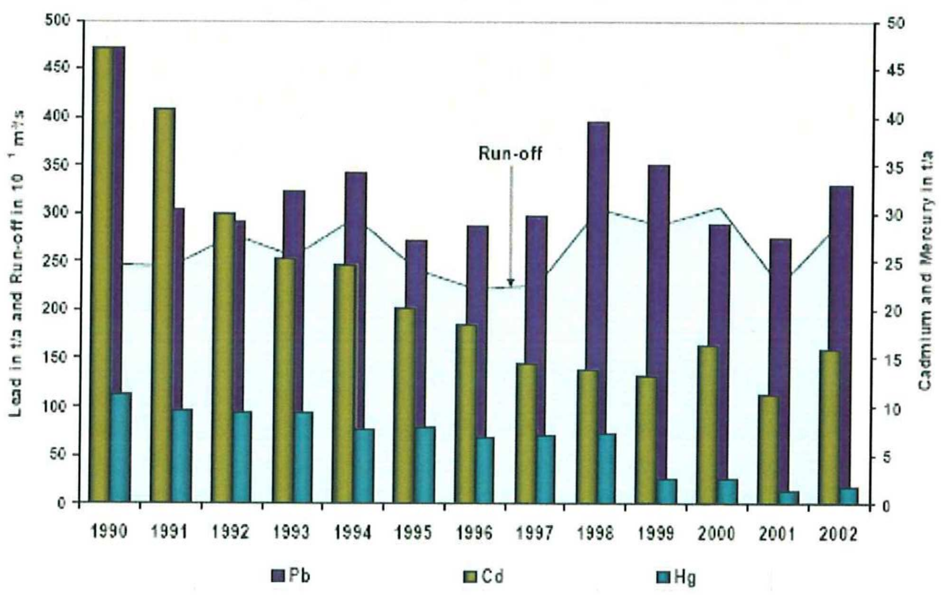


Figure 1.2.82: Cadmium, mercury and lead total inputs to the Celtic Seas from 1990 to 2002 (source: OSPAR Commission, 2005).

Table 1.2.13 below shows direct dischrges and riverine inputs into the Channel (Region III) from 1990 to 2002. Figure 1.2.83 shows the total inputs of nitrogen and phosphorous to the channel in the same period. Figure 1.2.83 shows the input of other contaminants. Apart from nitrogen, direct discharges showed significant downward trends. For 8 of the 15 determinant-load types that were assessed, acceptable downward trends were detected, namely for direct discharges, riverine loads and total inputs of Cadmium and lead as well as for direct discharges and total loads of ortho-phosphate.

	Direct Discharges					Riverine inputs and Flows				
Year	Tot-N kt/a	Po4-P kt/a	Cd t/a	Hg t/a	Pb t/a	Tot-N kt/a	Po4-P kt/a	Cd t/a	Hg t/a	Pb t/a
1990	10.5	2.56	2.71	0.15	20.5	12	0.94	2.7	0.13	27.3
1991	11.6	2.48	1.80	0.10	17.1	22	1.07	4.5	0.10	26.4
1992	10.6	1.71	0.09	0.01	9.5	21	1.31	2.1	0.06	34.3
1993	10.4	2.04	0.09	0.00	5.7	25	1.07	0.8	0.11	21.5
1994	9.2	1.47	0.07	0.00	4.8	29	1.17	1.0	0.12	52.2
1995	9.7	1.74	0.06		6.3	28	1.23	0.8	0.07	13.2
1996	9.4	1.70	0.06	0.01	6.5	22	0.95	0.4	0.03	8.3
1997	9.7	1.79	0.47	0.00	4.5	25	1.06	0.6	0.06	7.5
1998	8.1	1.58	0.09		2.7	28	1.19	0.6	0.04	18.5
1999	8.6	1.73	0.29	0.00	5.9	25	1.10	0.7	0.04	20.7
2000	8.3	1.70	0.12	0.00	4.9	23	1.07	0.8	0.06	21.5
2001	11.1	1.68	0.11	0.02	6.3	29	1.27	0.5	0.11	22.0
2002	9.2	1.30	0.03	0.01	2.7	35	1.20	0.8	0.19	24.0

Table 1.2.13: Basic data on inputs to the channel from 1990 to 2002 (source: OSPAR Commission, 2005)

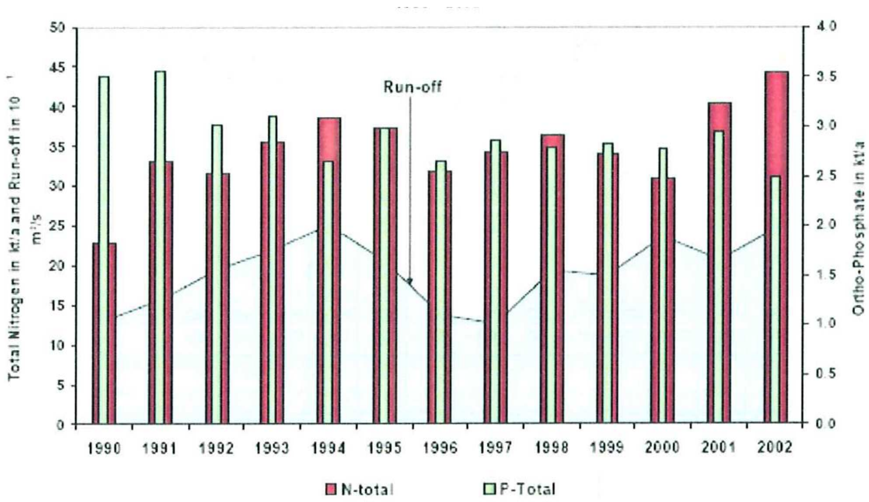


Figure 1.2.83: Total inputs of total nitrogen and total phosphorous to the Channel from 1990 to 2002 (source: OSPAR Commission, 2005).

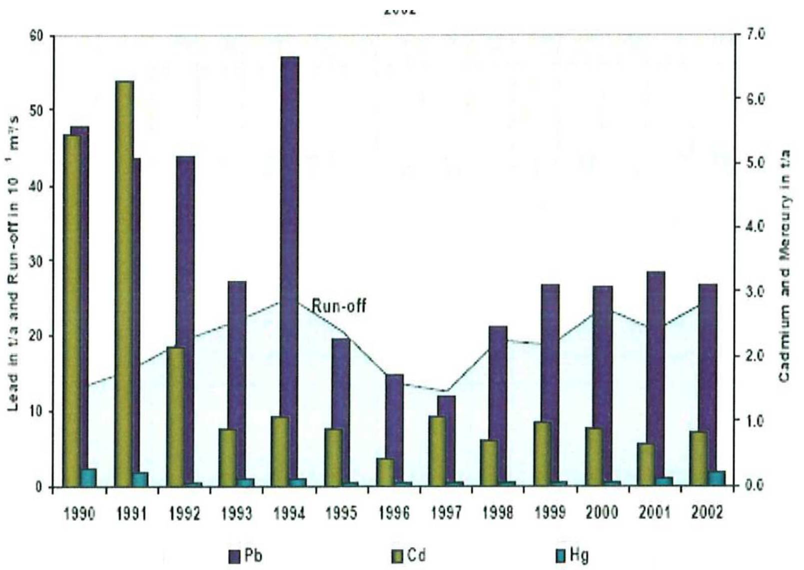


Figure 1.2.84: Cadmium, mercury and lead total inputs to the Channel from 1990 to 2002 (source: OSPAR Commission, 2005).

Table 1.2.14shows an estimate of total annual direct discharges to the Atlantic Region (Region V) in 1993/1995 (O'Leary et al., 1997). Table 1.2.15 shows estimates of sewage and industrial discharges to the Atlantic Region (Region V) submitted to OSPAR in 1990 (INPUT, 1998b).

Table 1.2.14: Estimates of total annual direct discharges to the Atlantic region (Region V) in 1993/1995. (source: Boelens et al., 1999).

	BOD (ktonnes/y)	COD (ktonnes/y)	Total N (ktonnes/y)	Total P (ktonnes/y)	SPM (ktonnes/y)
Atlantic (municipal)	6.1	13.3	1.2	0.3	7.1

Table 1.2.15: Estimates of sewage and industrial discharges to the Atlantic region (Region V) in 1993/1995 submitted to OSPAR: 1999 data (INPUT, 1998) (source: Boelens et al., 1999).

	Total N (ktonnes/y)		Total P (ktonnes/y)		SPM (ktonnes/y)	
Atlantic	0.4	0.3	0.1	0.1	2.6	1.7

Table 1.2.16: Input estimates for metals from municipal sources to the Atlantic Region (Region V) (1994-1996). Data extrapolated from Ringsend STP discharge loads and corrected for treatment patterns in the regions (source: Boelens et al., 1999).

	Hg (kg/y)	Cd (kg/y)	Cu (tonnes/y)	Pb (tonnes/y)	Zn (tonnes/y)	Cr (tonnes/yr)	Ni (tonnes/yr)	Fe (tonnes/y)
Atlantic	3	8	1.0	0.6	4.1	0.2	0.6	13.7

Table 1.2.17: Estimates of sewage and industrial discharges of metals to the Atlantic region (Region Vsubmitted to OSPAR: 1999 data (INPUT, 1998).

	Cd (kg/y)		Cu (tonnes/y)		Pb (tonnes/y)		Zn (tonnes/y)	
Atlantic	1	5	0.3	0.5	0.2	0.2	3.1	4.6

Table 1.2.18: Estimated annual loads of oxidised nitrogen (nitrate and nitrite) , ammonia-N, total nitrogen, soluble reactive phosphorous (SRP), total phosphorous, cadmium, lead, zinc and copper between 1986-96 (flow-weighted mean annual concentrations multiplied by annual mass flow) for the principal rivers discharging to the Atlantic (source: Boelens et al., 1999).

	1990	1991	1992	1993	1994	1995	1996
Oxidised Nitrogen (ktonnes)	22.08	23.00	14.86	14.68	16.43	14.83	24.02
Ammonia-N (ktonnes)	0.52	0.44	0.34	0.63	0.67	0.86	0.54
Total Nitrogen (ktonnes)	35.86	30.56	27.45	27.79	32.96	27.29	35.9
SRP (tonnes)	540	491	611	639	789	771	500
Total Phosphorus (tonnes)	1153	993	1057	1078	1461	1300	1240
Copper (tonnes)	33.6	n/a	59.7	36.2	67.6	62.5	19.3
Zinc (tonnes)	235.8	n/a	498.0	165.4	183.4	418.5	138.4

	1990	1991	1992	1993	1994	1995	1996
Lead (tonnes)	26.5	n/a	23.4	4.5	14.5	16.9	7.6
Cadmium (tonnes)	1.14	n/a	0.45	0.37	0.54	0.46	0.77

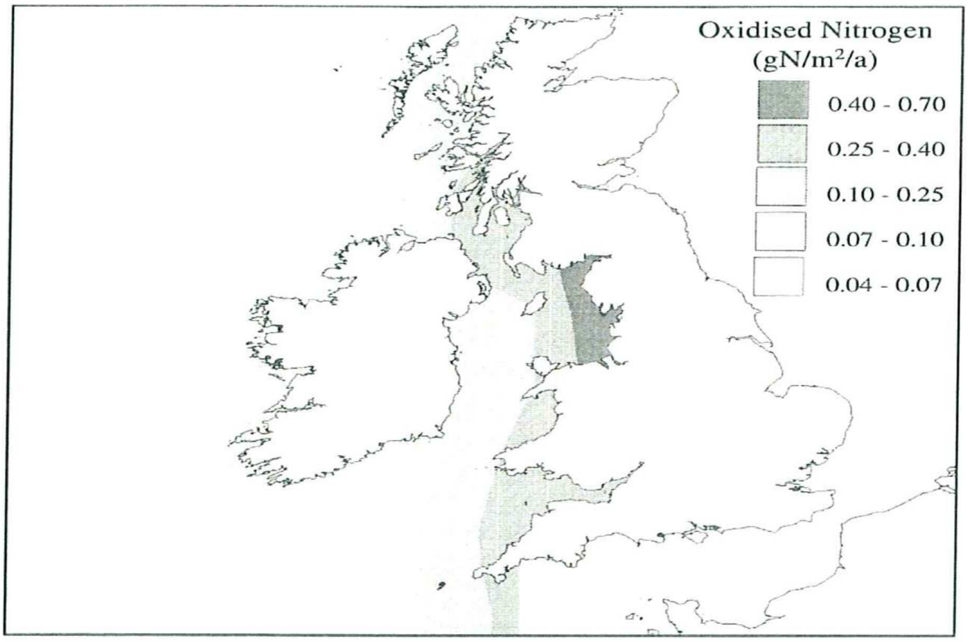


Figure 1.2.85: Total deposition of oxidized nitrogen in Irish waters for 1990 (Sanders and Styve, 1992) (source: Boelens et al., 1999)

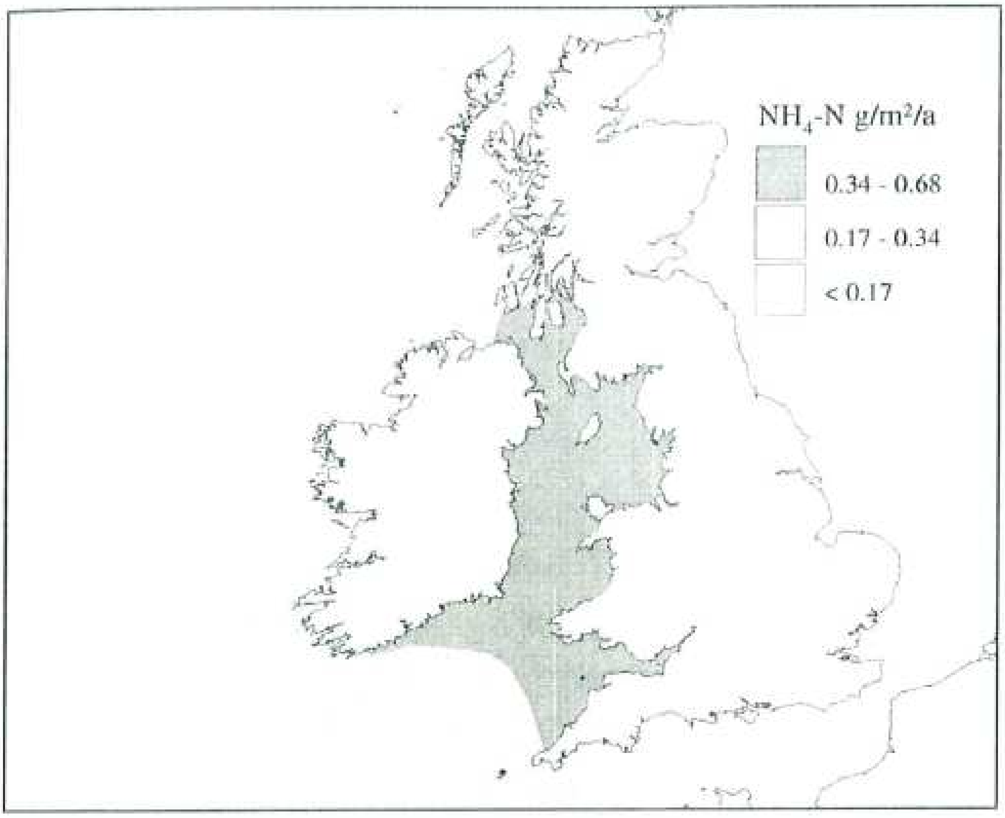


Figure 1.2.86: Total deposition of ammonium in Irish waters for 1990 (Asman and Jaarsveld, 1992) (source: Boelens et al., 1999).

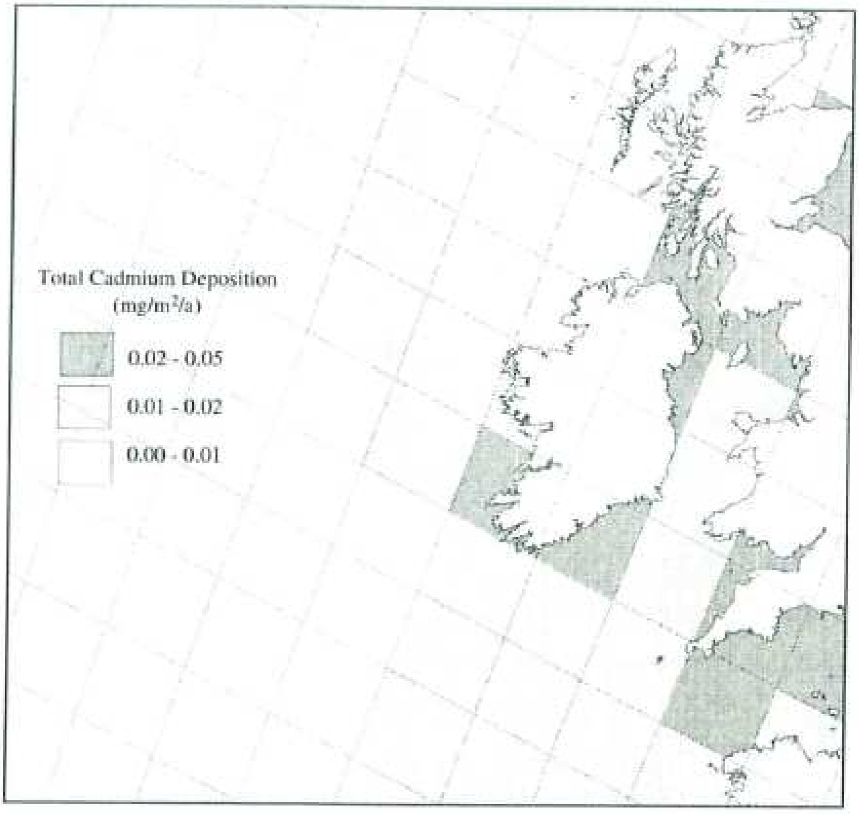


Figure 1.2.87: Depositional pattern for total cadmium in Irish waters for 1985 (source: Bartnicke, 1996; from Boelens et al., 1999).

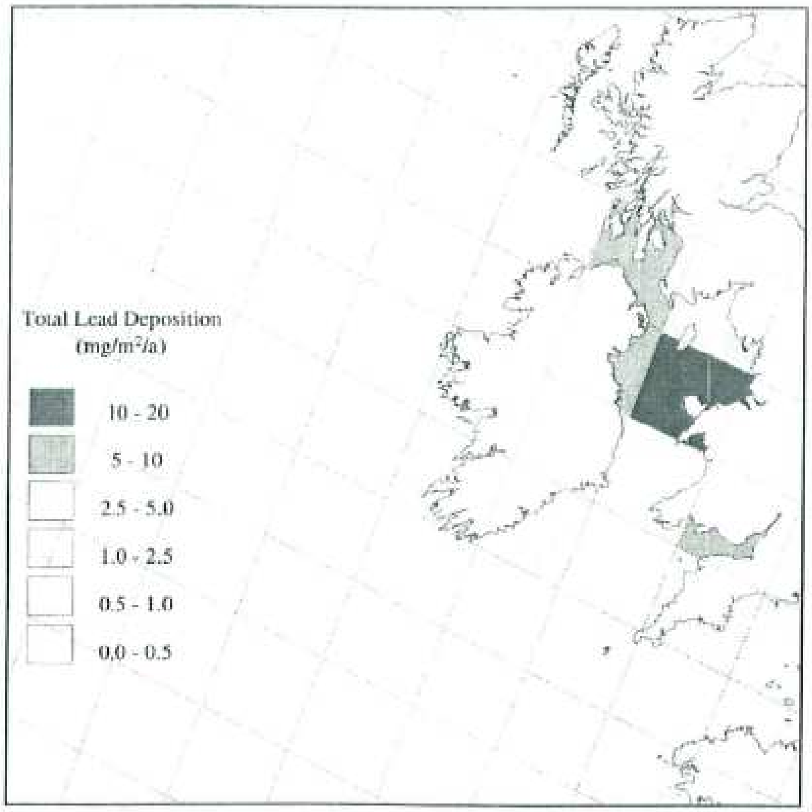


Figure 1.2.88: Depositional pattern for total lead in Irish waters for 1985 (source: Bartnicke, 1996; from Boelens et al., 1999).

In addition to direct, riverine and atmospheric inputs of contaminants into the marine environment there are other ways in which contaminants can enter:

Dumping

Petroleum hydrocarbons

Radionuclide inputs

Mariculture

The disposal of dredge spoil at sea is an activity that requires a license from releant Government Departments. Fine sediment form industrial harbours may contain relatively high concentrations of metals and/or organics which may be of concern when disposed of at sea. Similarly, sewage and chemical sludges may contain high concentrations of contaminants, which may also have environmental implications.

Figure 1.3.8 shows the locations of disposal sites and munitions sites within the NWW.

1.3 Human Activities

Figure 1.3.1 shows the population size for all major cities along the coastline of the MEFEPO study area. Glasgow, Scotland has the largest population and Etaples, France has the smallest. Population data for Irish cities came from the Central Statistics Office and is based on 2006 census results (http://www.cso.ie/statistics/popofeachprovcountycity2006.htm). UK data came from the Office for National Statistics and is based on 2006 data (http://www.statistics.gov.uk/downloads/theme_population/KPVS33_2006/FINAL_KPVS2006-web.pdf). French data came from the Institut national d'etudes démographiques and is based on 1999 data (http://www.statistiques-locales.insee.fr/carto/ESL_CT_cartethematique.asp?lang=FR&nivgeo=COM).

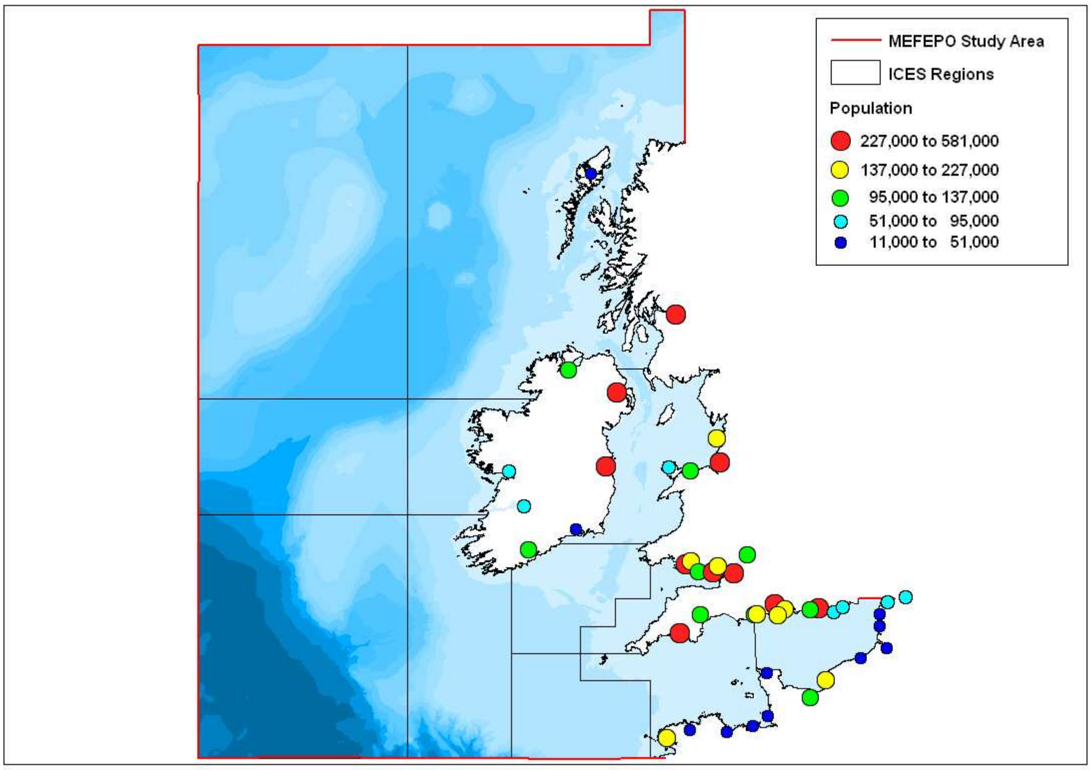


Figure 1.3.1: Population size for all major cities along the coast of the MEFEPO study area (Source: CSO, Office for National Statistics, INED).

1.3.1 What they are and where they occur

1.3.1.1 Ports

1.3.1.1.1 Fishing & Commercial Ports

Major Irish fishing ports were considered to be the ports that landings data was available for from the Sea Fisheries Protection Authority 2007. UK major fishing ports were those with landings data available from UK Sea Fisheries for 2007. No French landings data is available at present, therefore major ports were identified from an internet search. Commercial ports were those identified as such on www.ports.org.uk, on MIDA and from local knowledge. Figure 1.3.2 shows the fishing and commercial ports in the MEFEPO study area.

1.3.1.1.2 Ferry Ports and Routes

Ferry ports were those identified from www.ports.org.uk and those identified by ferry companies and google maps. Figure 1.3.3 shows the ferry ports in the MEFEPO study area.

1.3.1.1.3 Leisure Ports

Leisure ports were those identified as such from www.port.org.uk and from local knowledge. Figure 1.3.4 shows the leisure ports in the MEFEOP study area.

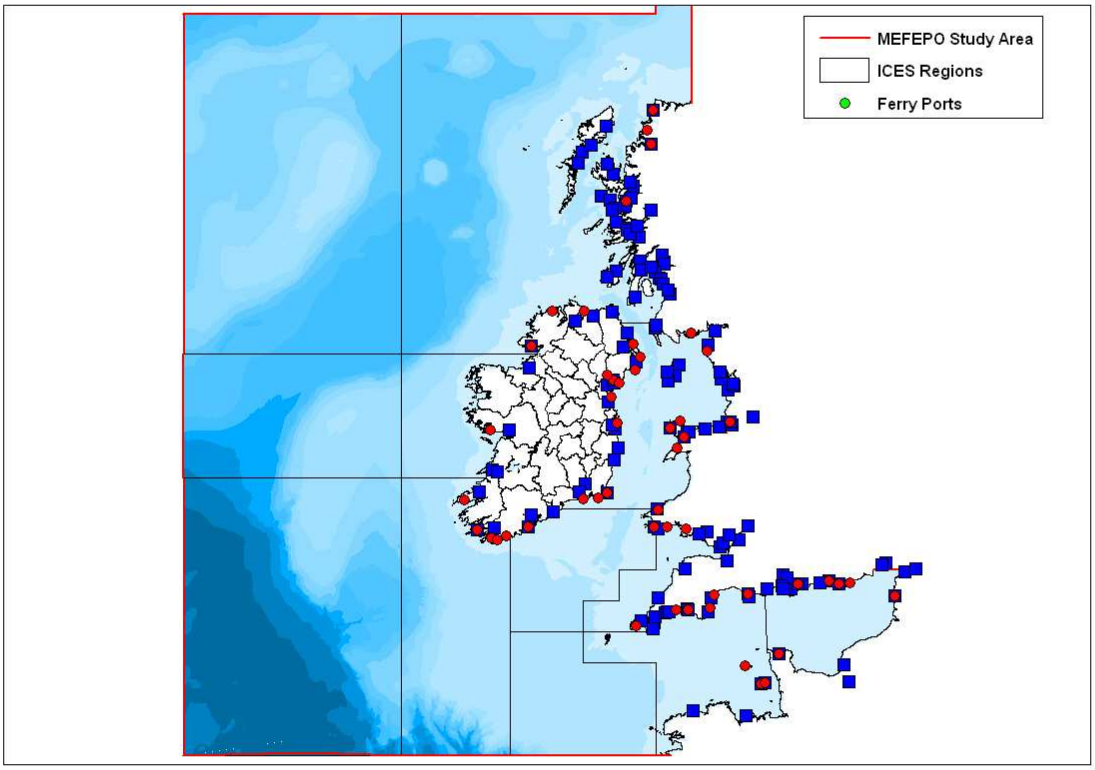


Figure 1.3.2: Commercial and fishing ports in the MEFEPO study area (Source: ports.org.uk, MIDA, SFPA, UK Sea Fisheries).

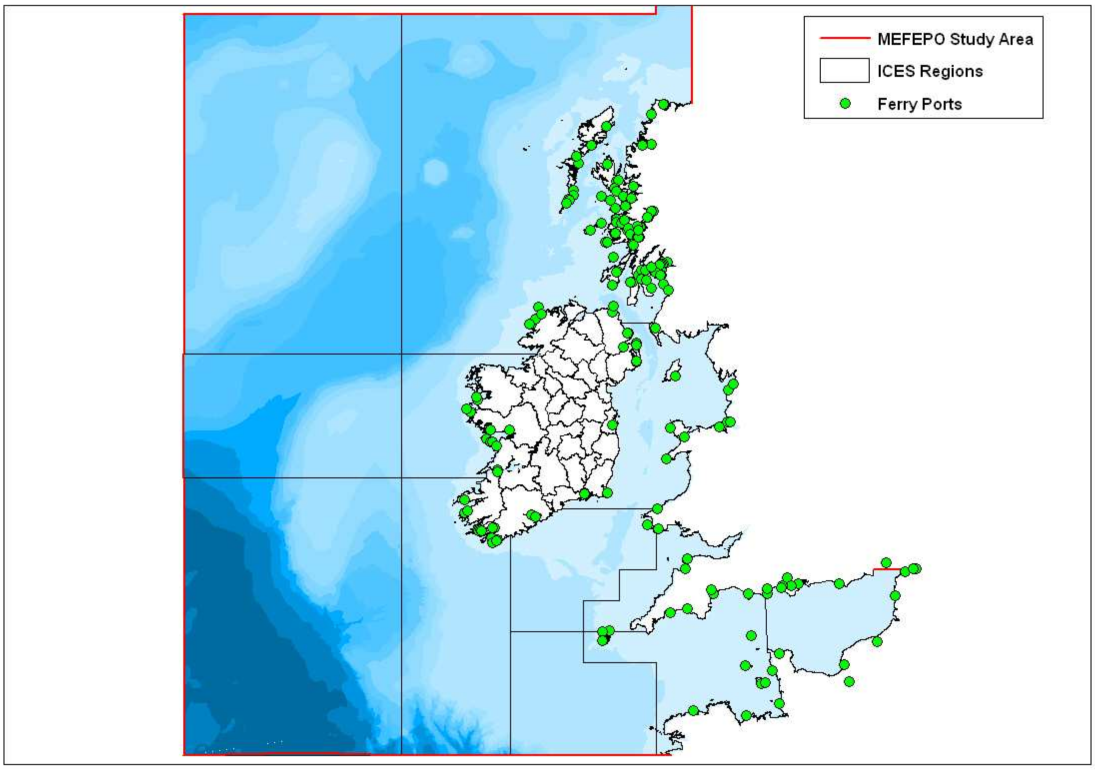


Figure 1.3.3: Ferry ports in the MEFEPO study area (Source: ports.org.uk and google maps).

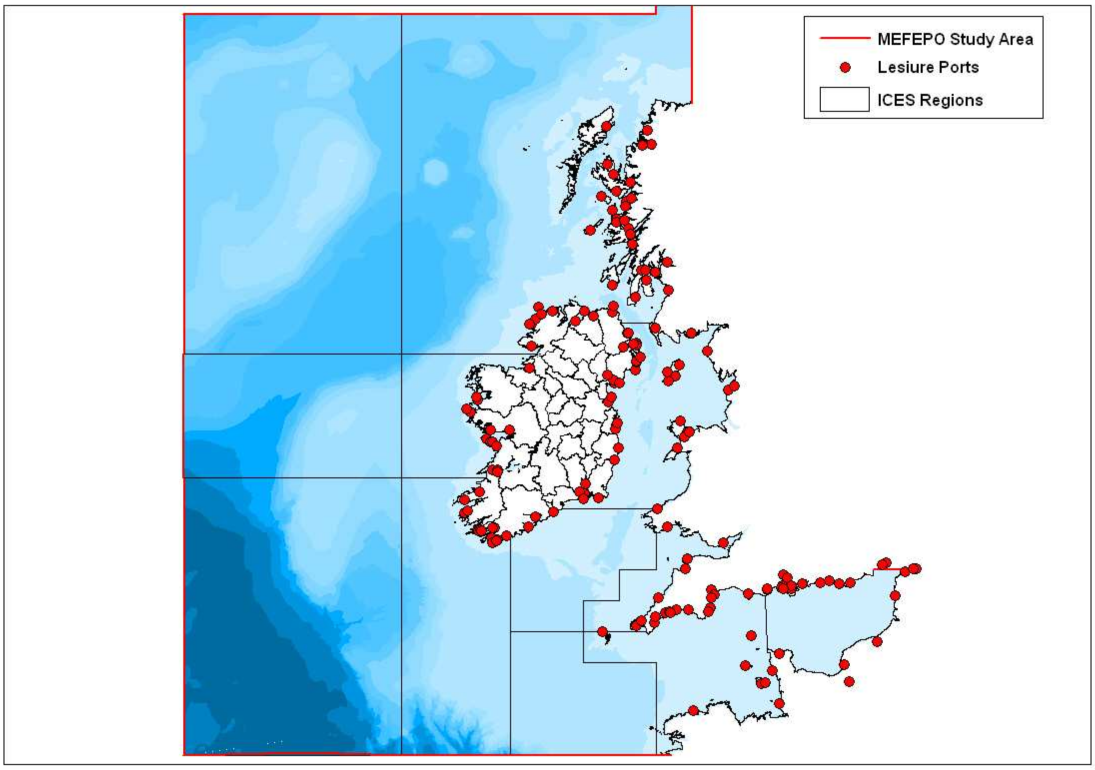


Figure 1.3.4: Leisure ports in the MEFEPO study area (Source: ports.org.uk).

1.3.1.2 Shipping

Figure 1.3.5 shows the traffic separation zones and deep water shipping routes in the MEFEPO Study Area. This information was sourced from Admiralty charts, OSPAR Region III QSR, UK SEA 7, SEA6 and SEA 8.

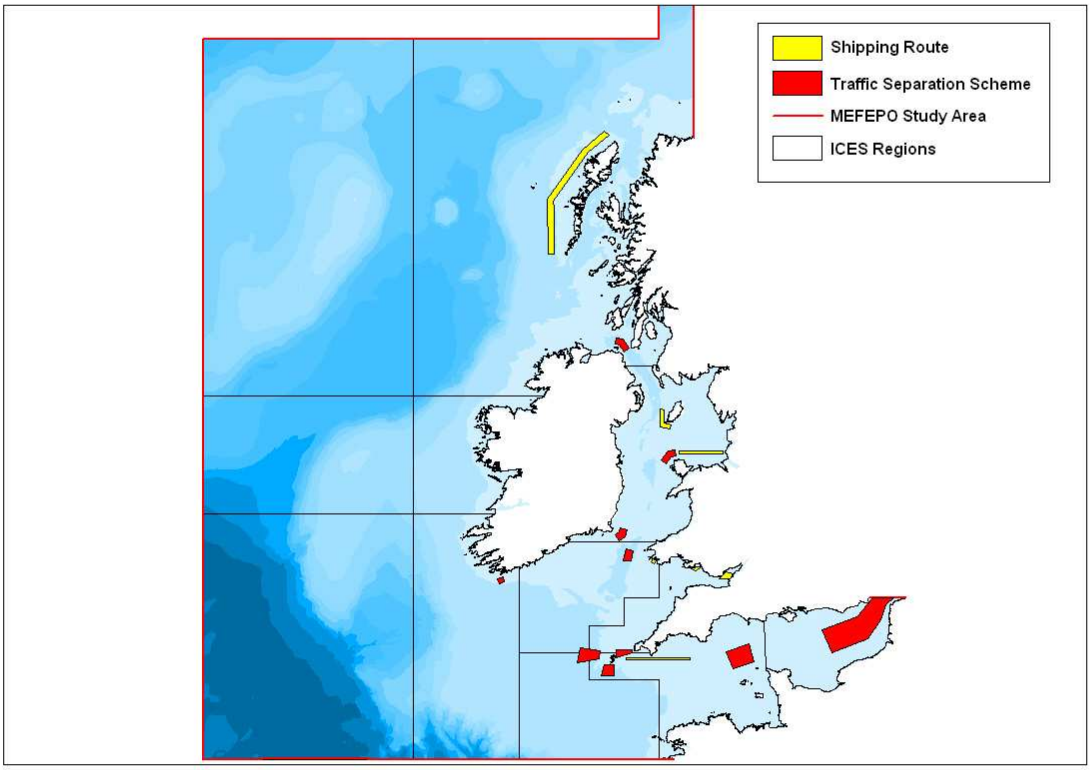


Figure 1.3.5 Traffic separation schemes and shipping routes within the NWW Study Area (Source: OSPAR QSR Region III, UK SEA 6,7 and Admiralty Charts).

1.3.1.3 Marine Environmental High Risk Areas (MEHRA)

Marine Environmental High Risk Area's were established following the Braer tanker oil spill disaster off the Shetland Islands in January 1993. In February 2006, 32 locations around the UK coast were identified as MEHRAs. The primary purpose is to inform mariners of areas of high environmental sensitivity where there is a realistic risk of pollution from shipping. There are 16 MEHRAs within the MEFEPO Study Area (See Figure 1.3.6). These sites were taken from UK SEA 6, SEA 7 and SEA 8. Table 1.3.1 gives the location names of these 16 sites.

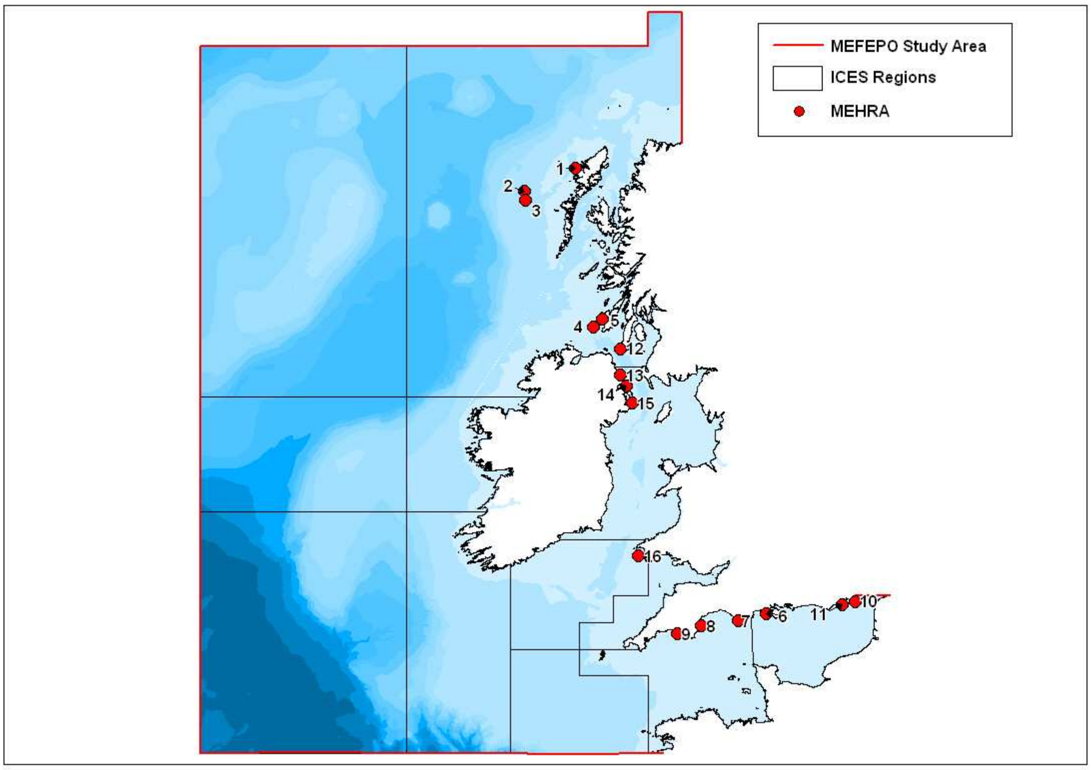


Figure 1.3.6: MEHRA locations within the MEFEPO Study Area.

Table 1.3.1: MEHRA locations names.

Number	Location Name	Number	Location Name
1	Gallan Head, Isle of Lewis	9	Plymouth, Devon
2	North St. Kilda	10	Dundeness, Kent
3	South St. Kilda	11	Hastings, East Sussex
4	West Islay 1	12	SE point of Kintyre
5	West Islay 2	13	Larne
6	Western Solent, Hampshire	14	Bangor
7	Portland. Dorset	15	Keareny Point
8	Berry Head, Devon	16	Skomer & Skokholm Point

1.3.1.4 Aggregate Extraction

Figure 1.3.7 shows the aggregate extraction sites within the MEFEPO Study Area (Source: SEA6 and SEA8). Within the NWW RAC the only maerl extraction site is located off the south west coast of Ireland near Castletownbere, Co. Cork (De Grave *et al.,* 2000). The remaining aggregate extraction sites illustrated are for sand and gravel extraction. There are no dredging licence sites off the Scottish Coast (UK SEA 7)

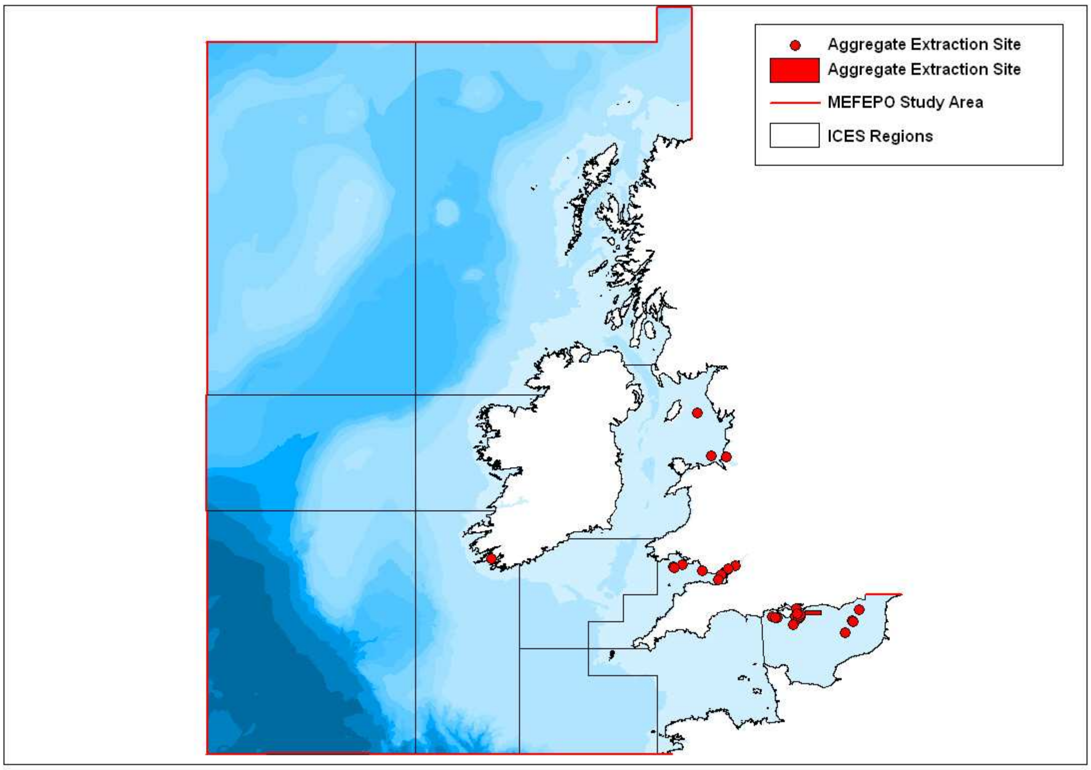


Figure 1.3.7: Aggregate extraction sites within the MEFEPO Study Area (Source: SEA8, SEA6).

1.3.1.5 Disposal Sites

Figure 1.3.8 shows disposal sites and munitions disposal sites within the MEFEPO Study Area. The sources for this data were the OSPAR QSR 2000 Region V, UK SEA7 and the OSPAR Report "Draft Annual OSPAR Report on Dumping of Wastes at Sea in 2007. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic Meeting of the Biodiversity Committee (BDC) Stockholm: 23-27 February 2009 (OSPAR, 2009). The locations given on the map below are rough estimations based on the maps provided in the above sources. The coordinates should not be taken as exact.

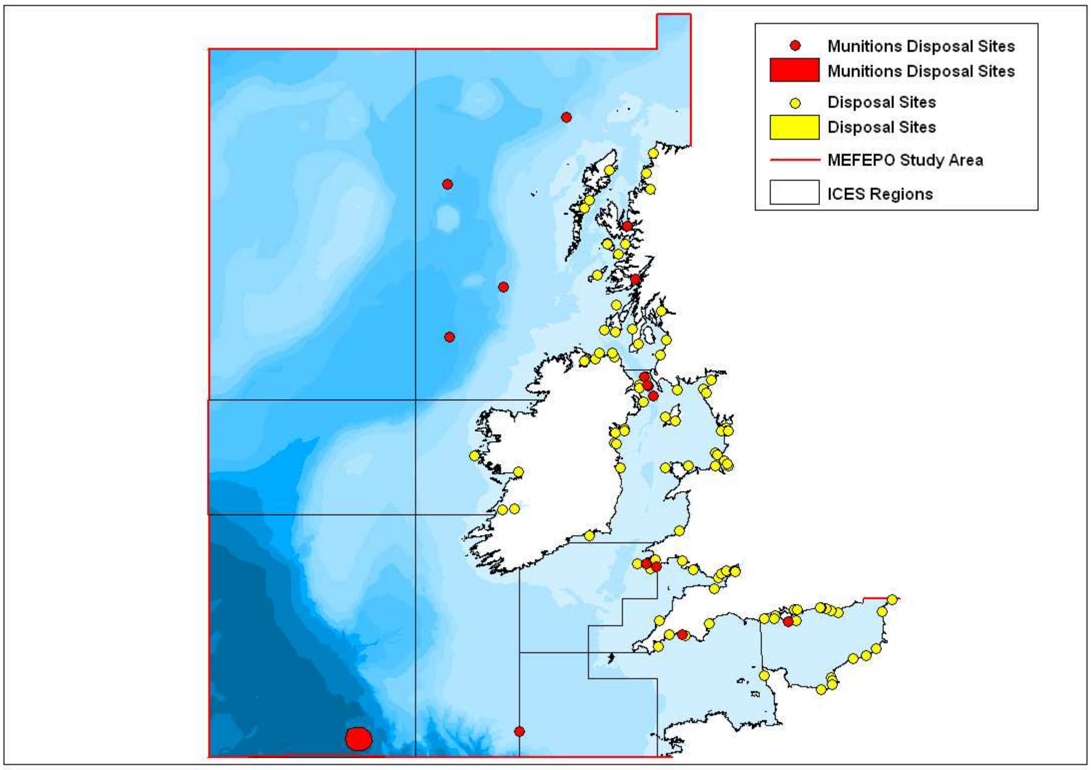


Figure 1.3.8: Disposal sites within the MEFEPO Study Area (OSPAR Region V QSR, 2000; UK SEA7; OSPAR 2009, Boelens *et al*., 1999).

1.3.1.6 Military Restrictions

Figure 43 shows the military restrictions within the MEFEPO Study Area. This data was sourced from the UK SEA7, SEA6, SEA8, IOSEA2, IOSEA3 and Admiralty Charts where available. The locations shown on the map below are based on maps in the above mentioned sources and the boundaries of which should not be taken as exact.

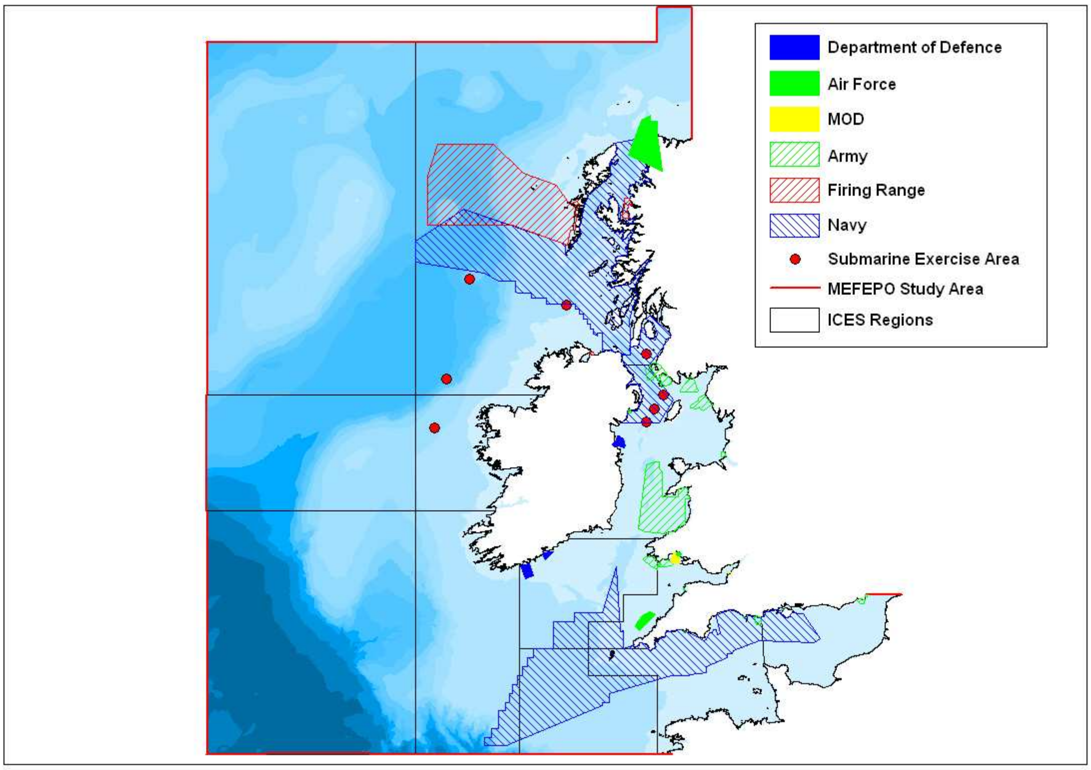


Figure 1.3.9: Military restrictions within the MEFEPO Study Area (Source: UK SEA6, SEA7, SEA8, IOSEA2, IOSEA3, Admiralty Charts).

1.3.1.7 Undersea Cables & Pipelines

Data for the locations of undersea cables and pipelines came from Admiralty charts, Kingfisher Information Service, UK (accessed through the Marine Information Digital Atlas (MIDA)) and from Bundesamt fűr Naturschutz. They are illustrated in Figure 1.3.10.

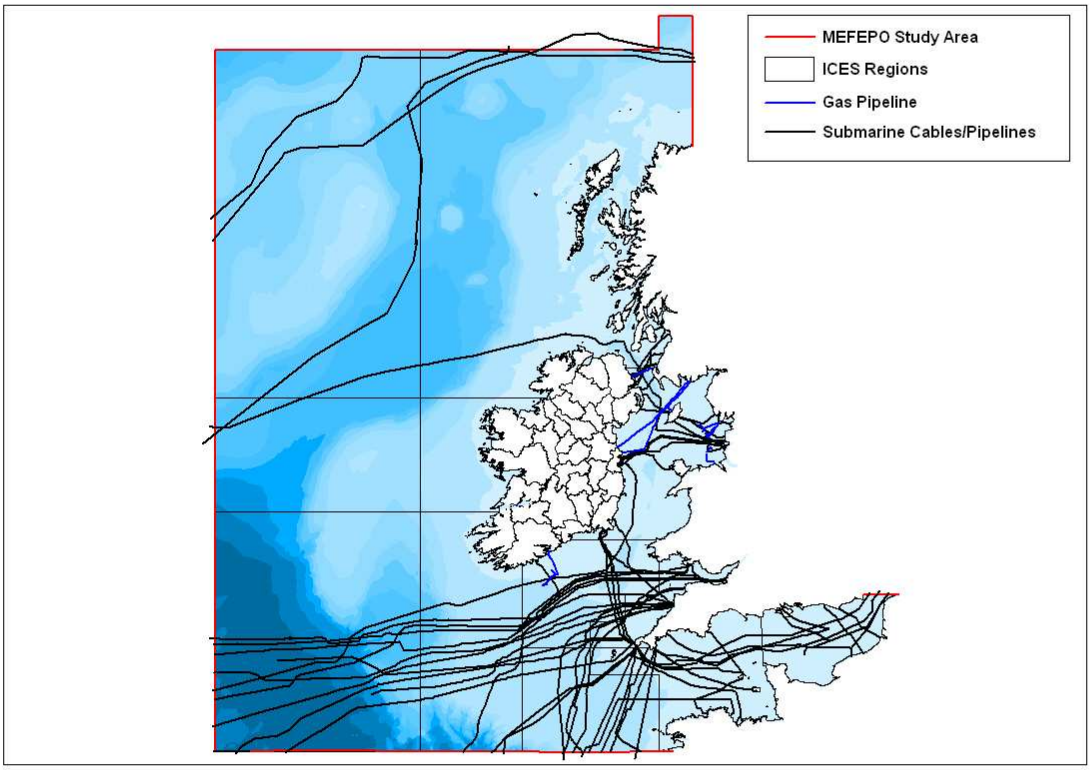


Figure 1.3.10: Submarine cables and pipelines (Source: Admiralty charts, Kingfisher Information Service, Bundesamt fűr Naturschutz).

1.3.1.8 Oil & Gas

Figure 1.3.11 shows oil and gas activity within the MEFEPO Study Area. Irish licences from PAD and UK licences and wells from BERR (https://www.og.berr.gov.uk/information/maps_offshore.htm). Irish data extends to 2006, UK data extends to 2009.

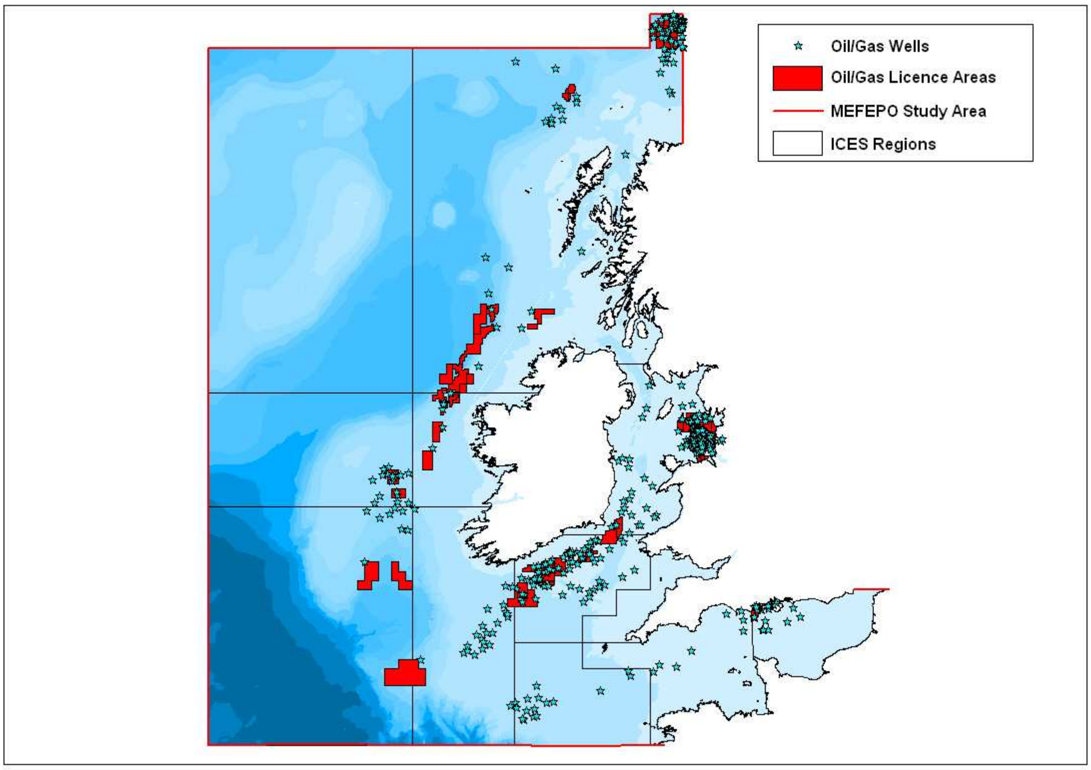


Figure 1.3.11: Oil and gas activity within the MEFEPO Study Area (Source: PAD, BERR)

1.3.1.9 Renewable Energy

Data on wind farm locations was taken from the British Wind Energy Association (www.bwea.com) and from an unpublished OSPAR report on the Working Group on the Environmental Impact of Human Activities (http://www.ospar.org/v_meetings/browse_downloads.asp?menu=00050500000000_000024_000001). Tidal and wave development sites were identified from Admiralty Charts and development companies. Figure 1.3.12 shows the locations of these renewable energy sites. There is 1 operational wind farm off the Irish coast, with 1 approved and 2 applications submitted. There are 3 operational wind farms off the UK coast, 1 under construction and 6 approved. There is a tidal energy site in Strangford Lough, Northern Ireland and in La Rance, France. There is a renewable energy development site located in Galway Bay, Ireland, which is currently being used to test wave energy devices and there are 2 further development sites off the coast of France, which will be used to test tidal energy devices. There is a wave energy site off Islay Island, Scotland.

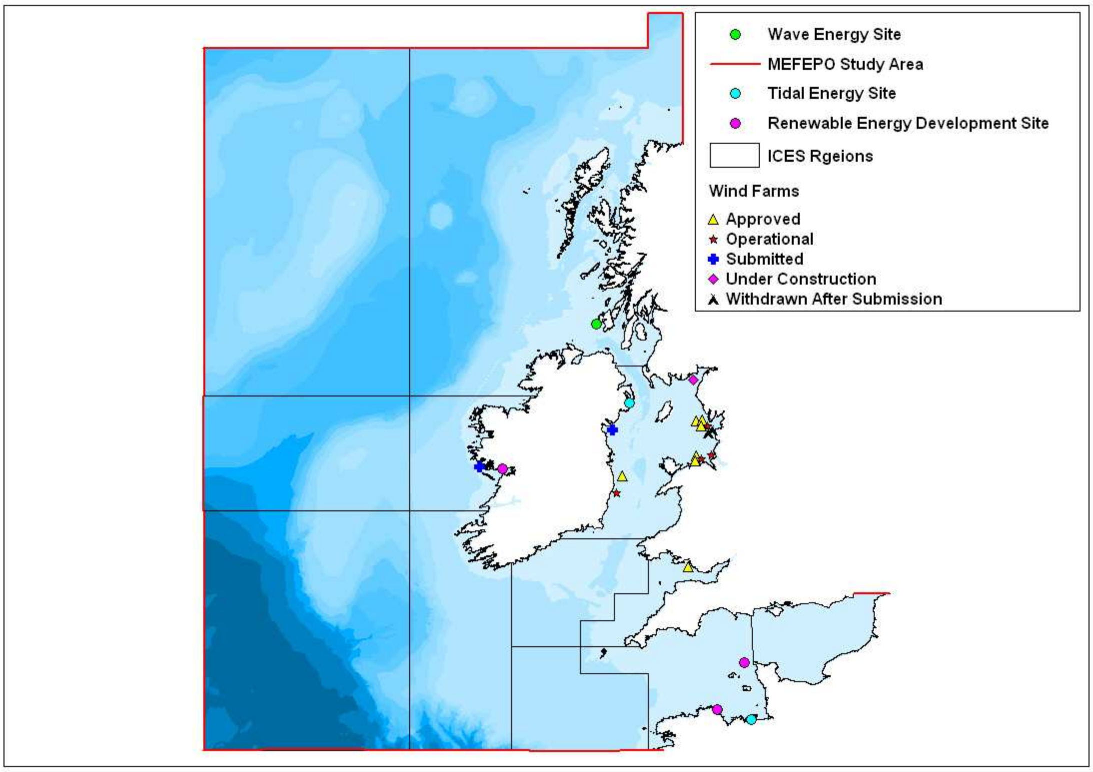


Figure 1.3.12: Renewable energy sites within the MEFEPO study area (Source: BWEA, OSPAR).

1.3.1.10 Power Stations

The power stations located within the MEFEPO Study Area can be seen in Figure 1.3.13. The UK SEA6 and SEA8 and the Eirgrid Network Distribution Map were used to located power stations along the English, Welsh and Irish coasts. Scottish stations were located from http://en.wikipedia.org/wiki/List_of_power_stations_in_Scotland and French power stations were located from http://en.wikipedia.org/wiki/Category:Power_stations_in_France.

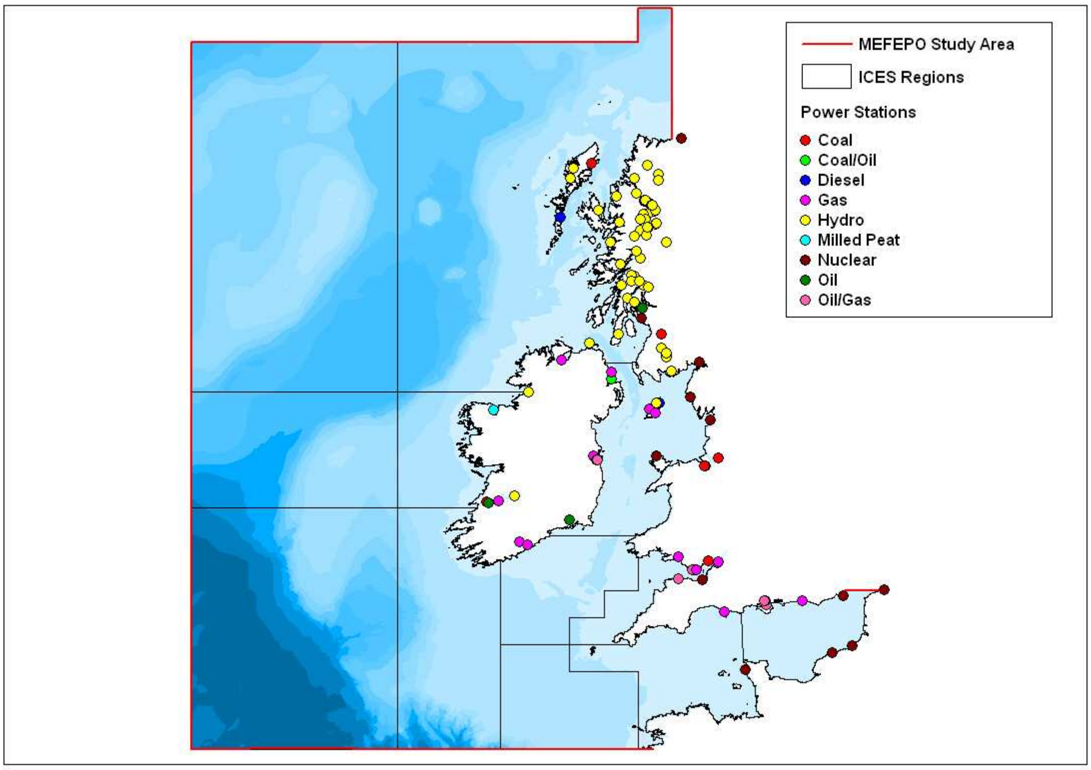


Figure 1.3.13: Power stations located within the MEFEPO Study Area (Source: Eirgrid, UK SEA6, UK SEA8, http://en.wikipedia.org/wiki/Category:Power_stations_in_France, http://en.wikipedia.org/wiki/List_of_power_stations_in_Scotland).

1.3.1.11 Recreational

Figure 1.3.14 shows bathing water quality in 2007 for all coastal locations within the MEFEPO Study Area. Irish data was sourced from the EPA 2007 bathing water quality report (EPA, 2008) and the UK and French data was sourced from the EUROPA website http://ec.europa.eu/environment/water/water-bathing/report_2008.html.

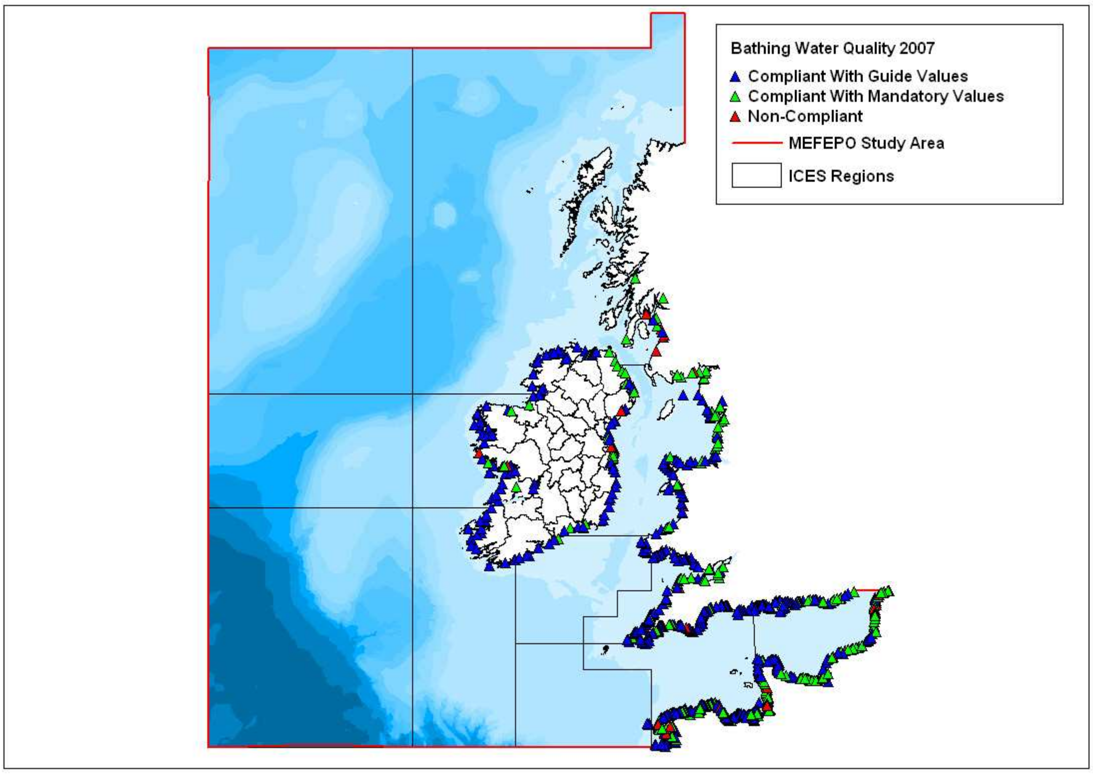


Figure 1.3.14: Bathing water quality in 2007 within the MEFEPO Study Area (Source: EPA, EUROPA).

There are 79 blue flag beaches and/or marinas along the coast of ICES Region VIIa (See Figure 1.3.15). Figure 1.3.16 illustrates the numerous surf spots within the NWW area.

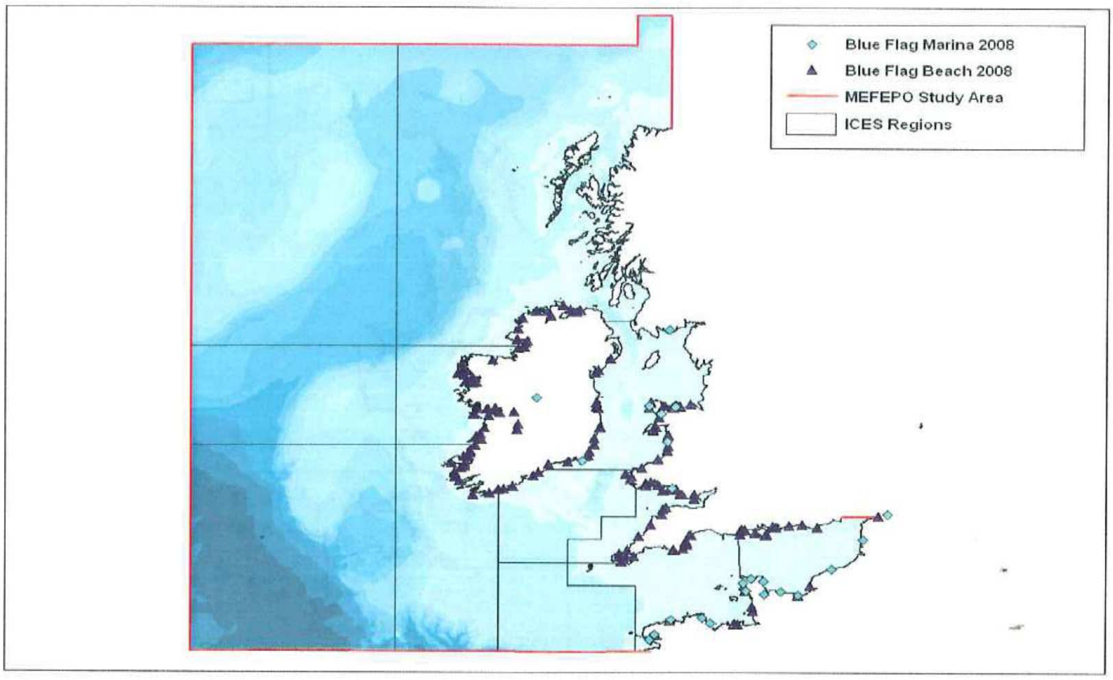


Figure 1.3.15 Blue flag beaches and Blue flag marinas in the NWW area (source: www.blueflag.org).

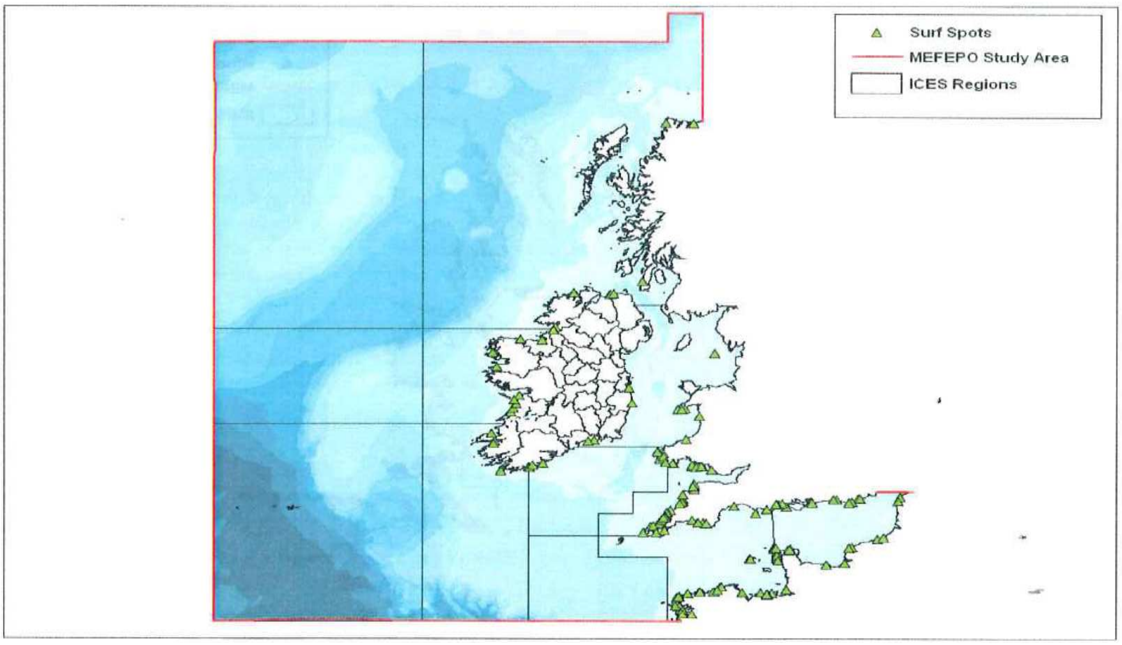


Figure 1.3.16 Surf spots within the NWW study area (source: www.wannasurf.com).

1.3.1.12 Fisheries

1.3.1.12.1 Shellfish

Figure 1.3.17 to 18 below show the shellfish fishing grounds around the Irish coast. There are lobster grounds all around the Irish coastline, brown crab all around the south and southwest coasts, and along the west and northwest coasts up as far as the Hebrides. There are velvet crab grounds along the south and east coasts and along the Galway coastline. Spider crab grounds are located along the south coast of Ireland and along the Galway and Kerry coasts.

Scallop grounds are located in the Irish, in Morecambe Bay, in Cardigan Bay, off the southeast coast of Ireland, in the Celtic Sea, along the northern, western and southern coasts of Ireland and in the northwestern part of the MEFEPO area. Shrimp grounds are located along the northwestern, western and southwestern coasts of Ireland and whelk fisheries are located off the southeastern and eastern coasts of Ireland and off the north coast of Donegal.

There are Crassostrea gigas oysters located along the Donegal and Galway coastlines. Cockles are found along the northwestern, western, eastern and southeastern coastlines. Clams are found along the west coast and queen scallops are located along the west and north coasts.

Mussel beds are located along the Donegal coast. Native flat oysters are located along the west and north coasts and razors are located along the west and east coasts.

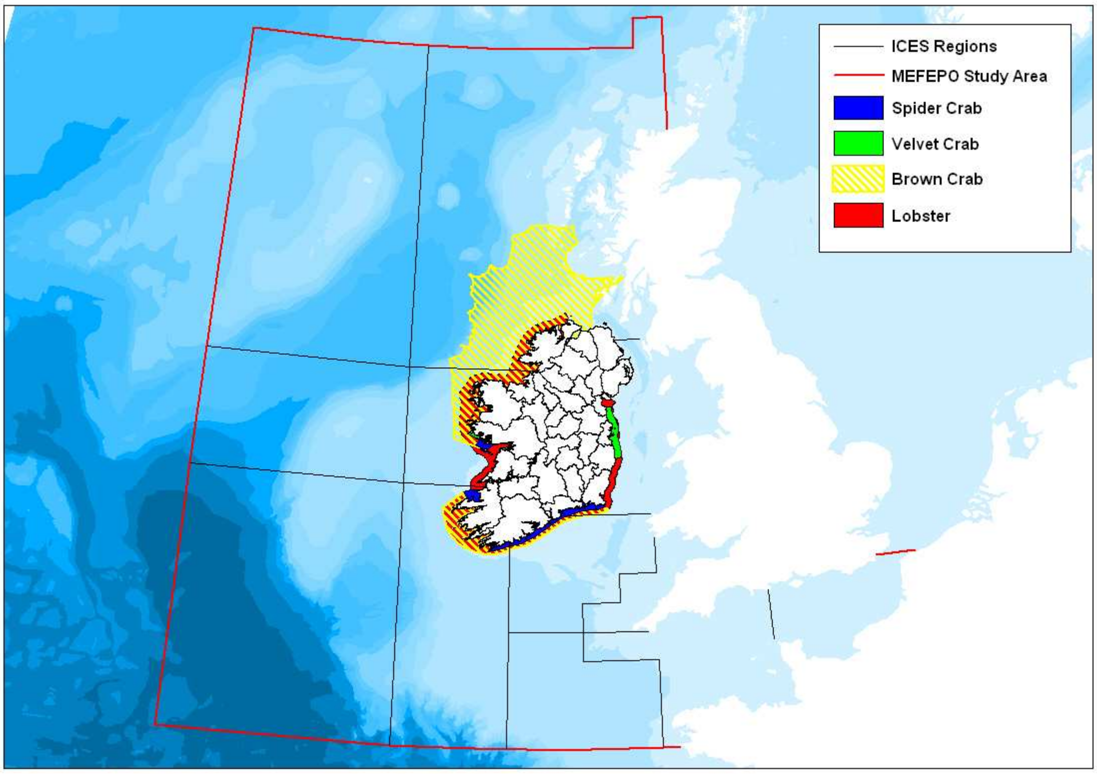


Figure 1.3.17: Velvet crab, spider crab, brown crab and lobster fishing grounds (Source: BIM)

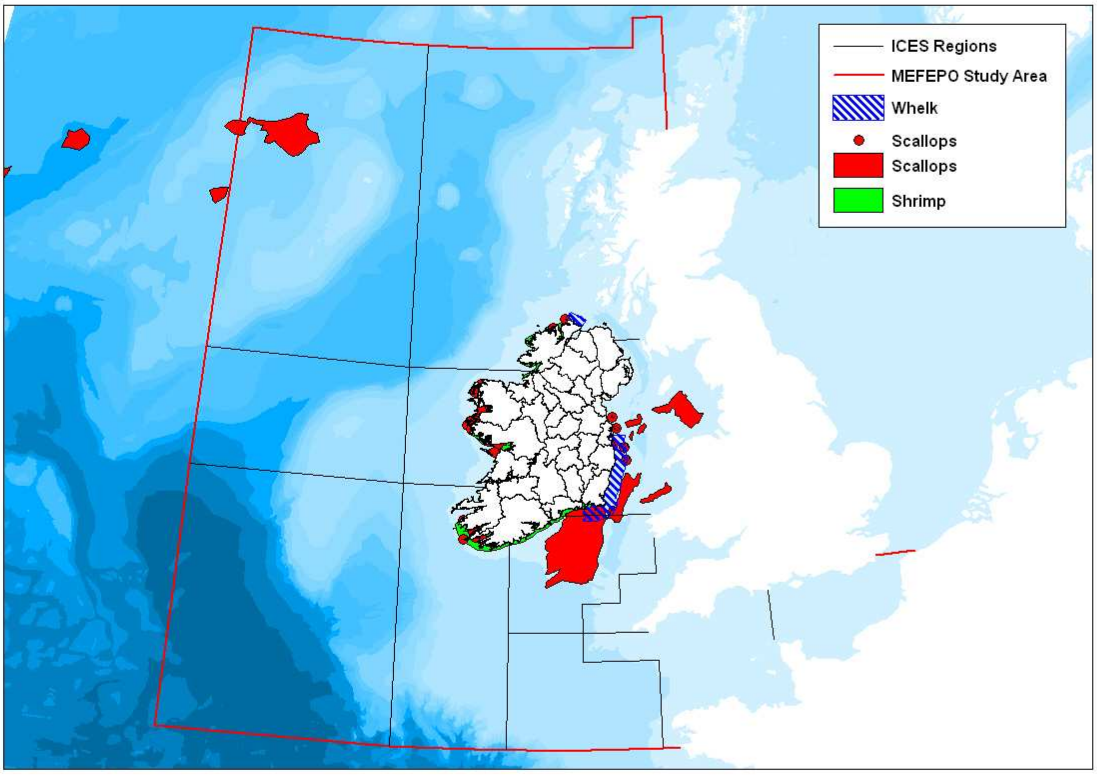


Figure 1.3.18: Scallop, whelk and shrimp fishing grounds(Source: BIM).

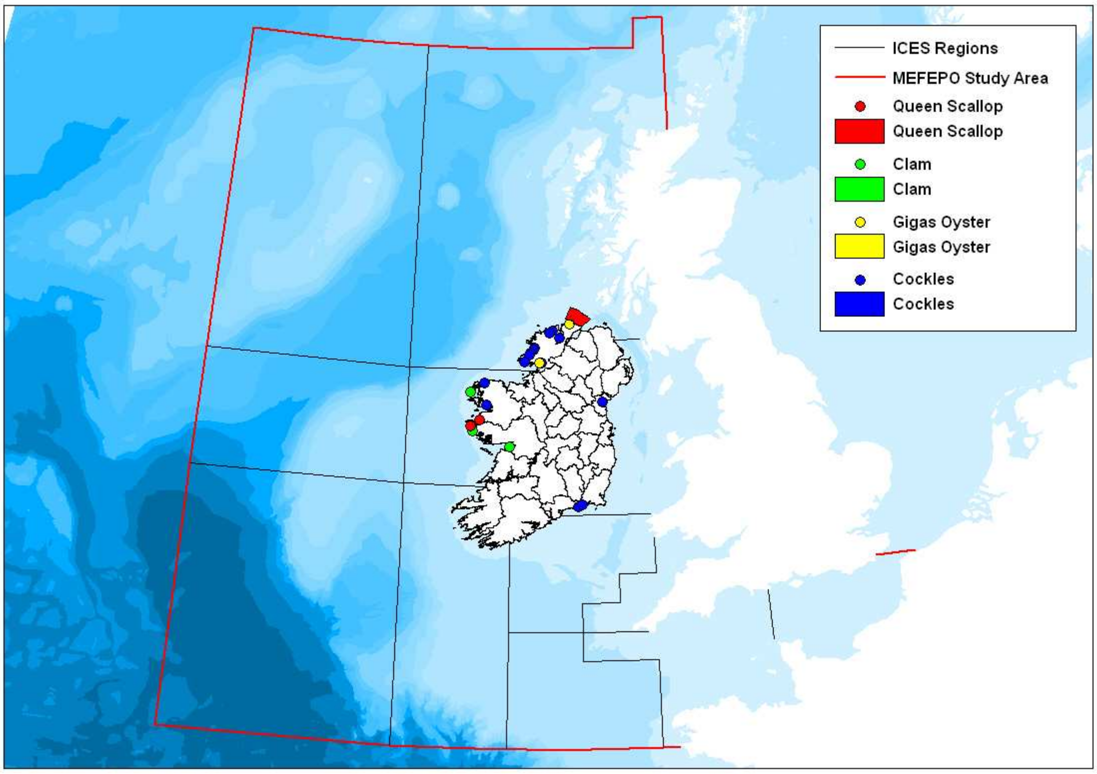


Figure 1.3.19: ***Gigas*** **oysters, clams, cockles and queen scallop locations (Source: BIM).**

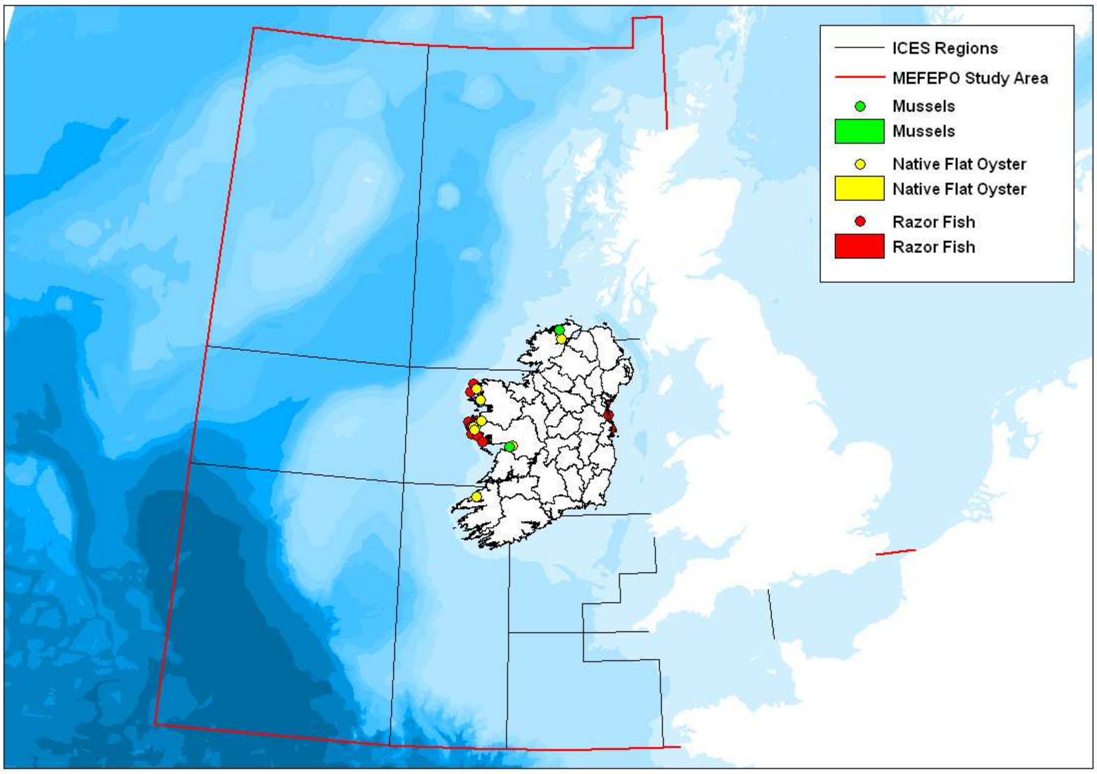


Figure 1.3.20: Native flat oysters, mussels and razor locations (Source: BIM).

1.3.1.12.2 Finfish

Fishery effects on benthos and fish communities in the Celtic Sea

The distribution of fishing activity in the Irish exclusive economic zone (EEZ) by boats over 15m in length is shown in Figure 1.3.21. The impact of fishing activities on shelf fish communities is unclear, although there are numbers of severely depleted stocks e.g. cod, whiting and plaice and hake. Furthermore, the level of discarding in some fisheries can be significant. Analysis of discarding levels of the demersal fleet around Ireland has shown that a significant proportion of the catch is discarded (Borges, 2005). Discarding levels differ between the different fleets but have shown to be up to two thirds of the total catch. In this study Whiting, haddock, megrim and dogfish are the main species discarded by otter trawler, while the Scottish seiners discard mostly whiting, haddock and grey gurnard and beam trawls mostly dab and plaice. The majority of these discard species consist of immature fish and discarding appears to be increasing in recent years. Cetacean bycatch in fisheries has been acknowledged to be a threat to the conservation of cetaceans in this eco-region (CEC, 2002a; Ross and Isaacs, 2004). As in other areas this mainly affects small cetaceans; i.e. dolphins, porpoises and the smaller toothed whales. Species caught in the region are primarily the harbour porpoise, common dolphin, striped dolphin, Atlantic white-sided dolphin, white-beaked dolphin, bottlenose dolphin and long-finned pilot whale (CEC, 2002a). However, other larger cetaceans, such as the minke whale, can also be affected.

An extensive review of the bycatch of cetaceans in pelagic trawls was carried out for Greenpeace in 2004 (Ross and Isaacs, 2004). This report considered published and anecdotal information. In the Celtic Seas the report identified a small number of fisheries where cetacean bycatch could be documented. These were:

Bass fishing in the western channel
Mackerel and horse mackerel trawling SW of Ireland
Gill netting for hake in the Celtic Sea

In the last two cases, the number of animals caught was low, however, it is probably higher in the bass fishery and has attracted considerable public attention. The report identified that many countries had initiated cetacean bycatch monitoring programmes, and had generally found little or no evidence that serious bycatch had occurred.

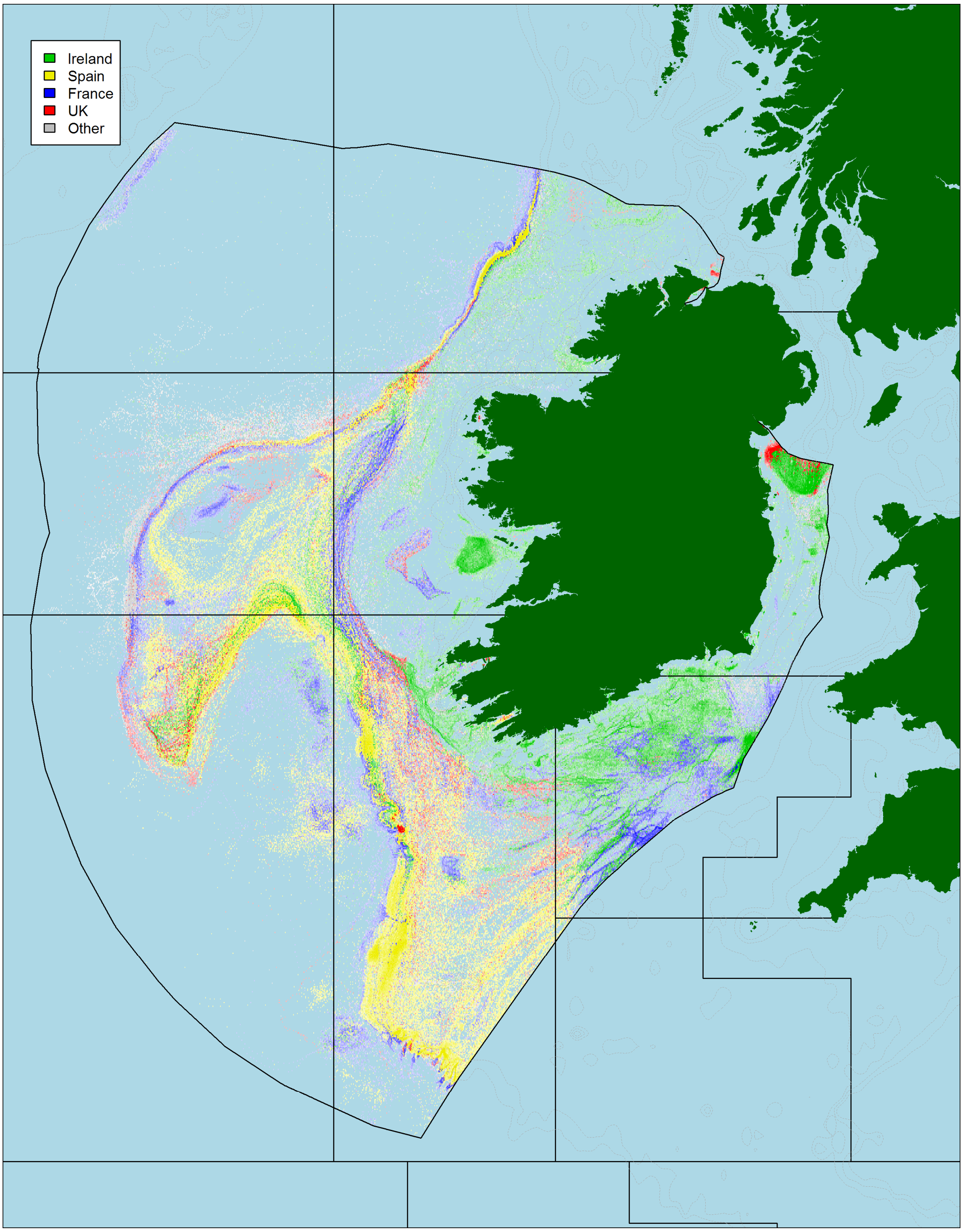


Figure 1.3.21: The distribution of fishing activity in the Irish exclusive economic zone (EEZ) by boats over 15m in length (Source: Marine Institute).

The major fishery effects on the deep-sea ecosystem

Modern fishing fleets are capable of causing a very significant reduction in demersal deep water fish biomass in just a few years; a consequence of this has been the collapse of several fisheries (Koslow *et al*., 2000). Along the MAR, roundnose grenadiers were depleted by fisheries in the 1970s (Merrett and Haedrich, 1997).

Populations of large fish that aggregate on oceanic bathymetric features such as seamounts are particularly sensitive to overfishing, due to low productivity and high catchability. On the southern part of the MAR and adjacent seamounts, populations of alphonsinos were depleted also in the 1970s. More recently, longline fisheries appear to have depleted seamounts populations of "giant" redfish on seamounts of the northern MAR (Hareide and Garnes, 2001).

These depletions of dominant species lead to major changes in demersal deep sea fish communities due to the loss of their larger predators and corresponding ecological functions. In addition to catching target species, deepwater fisheries bycatch unwanted species that are either too small or unpalatable. Discarding rates are often high (in the order of 50%) and the bulk of the discarded catch is made of smoothheads (Alepocephalidae) because of their high abundance (Allain *et al*., 2003).

Deep-water trawling damages deep sea benthic communities. Over recent years attention has focussed on the impact of trawling on *Lophelia* reefs. Measures to reduce these impacts and to protect some areas have been taken.

Passive gears may also have effects. At least under some conditions (long soak time, hundreds of km of net, deployment over coral reefs) deep-water set nets can also have an impact, both on the fish community due to ghost fishing and targeting vulnerable species such as sharks (Hareide *et al*., 2005). As a consequence, deepwater netting was banned in ICES divisions VIa, b, VIIb, c, j, k and part of sub-area XII in 2006. Long-line fishing can have effects through breaking off branches of coral and overturning large sponges. Long-lines can also have a relatively high bycatch of seabirds.

COMMENTS

Over the last 15 to 20 years, the deep-water ecosystem has been significantly impacted by fishing as fisheries have extended into deeper waters, driven partly by the overexploitation of shelf stocks. Deepwater stocks typically have a low productivity and therefore sustainable levels of exploitation are much smaller than those of shelf stocks. Many stocks have therefore been over-exploited and depleted within a few years of a fishery opening.

Towed fishing gears have severe impacts on benthic communities; this is a major problem on structurally complex habitats, including biogenic reefs, which have long recovery times. Static netting can also be undesirable as it can generate (i) habitat disturbance, (ii) ghost fishing by dumped and lost nets and (iii) overfishing if too much net is deployed. Therefore deep water trawling should be restricted primarily to sedimentary bottoms and where possible fisheries should shift to long-lining and closely managed netting (away of coral areas). This switch has occurred in some southern hemisphere fisheries (e.g. the fishery for Patagonian toothfis, *Disostichus eleginoides* around South Georgia and South Shetland Islands).

There are some large gaps in the knowledge of exploited stock structure and biomass. For EU fleets, this may improve with the revision of the EU Data Collection Regulation (Council Regulation (EC) 1543/2000) and the improved on-board observer programme (Council Regulation (EC) 2347/2002). Better reporting of catches and effort data is necessary especially in international waters (NEAFC regulatory area). VMS (Vessel Monitoring System) data for all fleets should be made available to National Research Institutions.

1.3.1.12.3 Restrictions

Figure 1.3.22 shows some of the fishing restrictions in place within the MEFEPO study area. Figure 1.3.23 illustrates the details of the hake and cod recovery boxes.

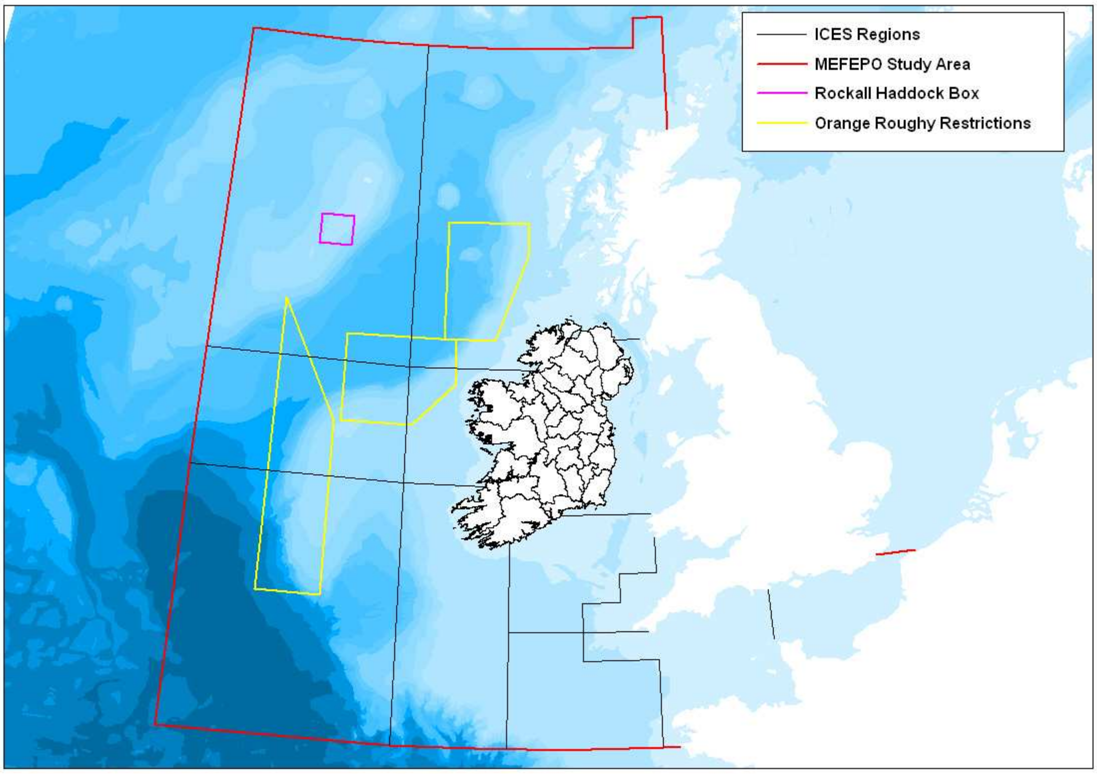


Figure 1.3.22: Fisheries restrictions within the MEFEPO Study Area.

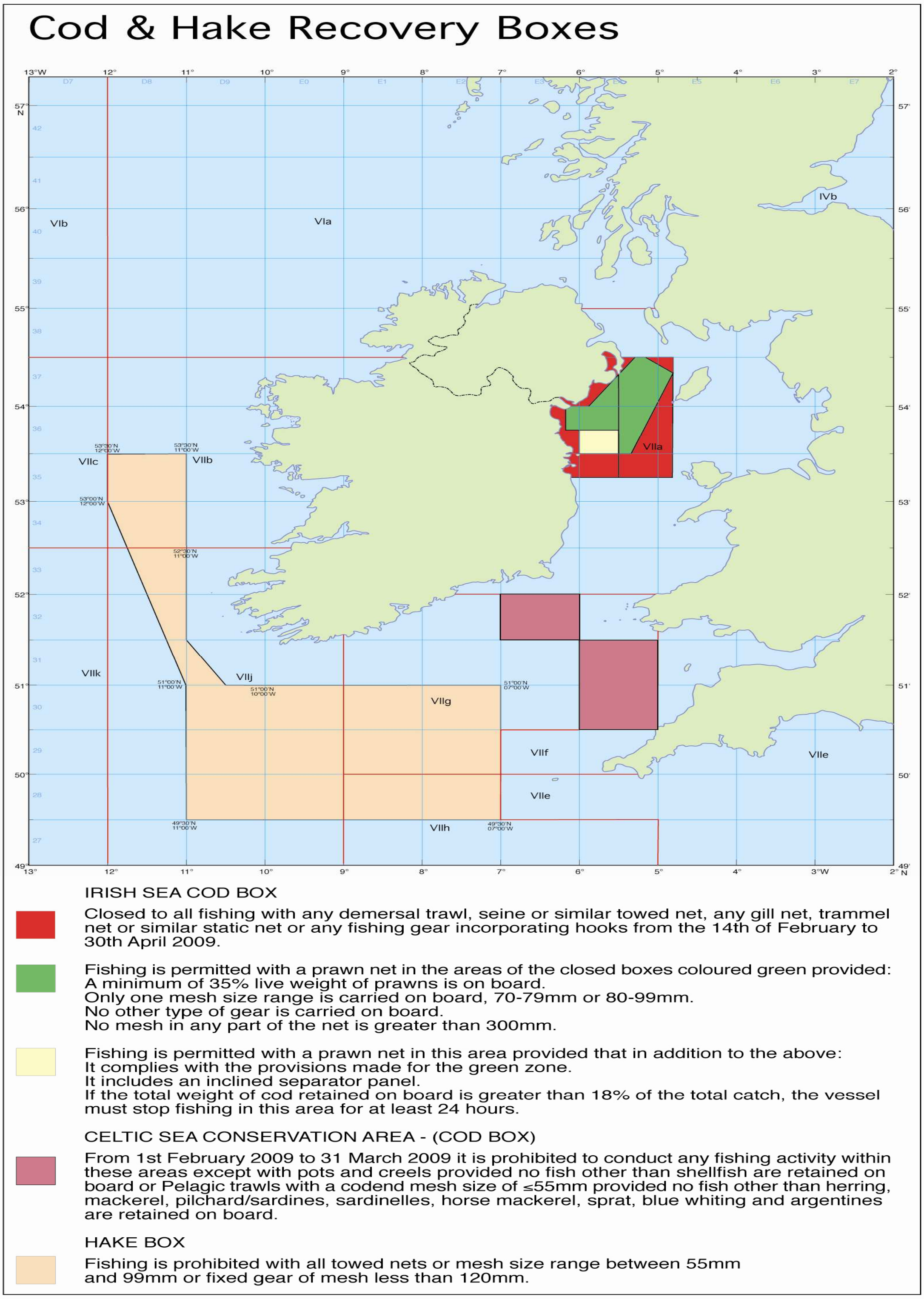


Figure 1.3.23: Restrictions on hake fishing in the area of the BSA. Note the hake box is a subset of the BSA and was an integral part of the hake recovery plan (source: Lordan, C. and Gerritsen, H.

2009. Working Document on the Assessment of the "Irish Box" in the context of the Western Waters Regime. Working paper prepared for ICES Advisory Committee)

1.3.1.12.4 Aquaculture

Three species dominate mariculture in the NWW countries: Atlantic salmon, Blue mussel and Pacific cupped oyster (Figure 1.3.24). The last quarter of a century has seen a huge increase in salmon farming in the area, from almost nothing in the early 1980s to the largest share of the total 2009 production.

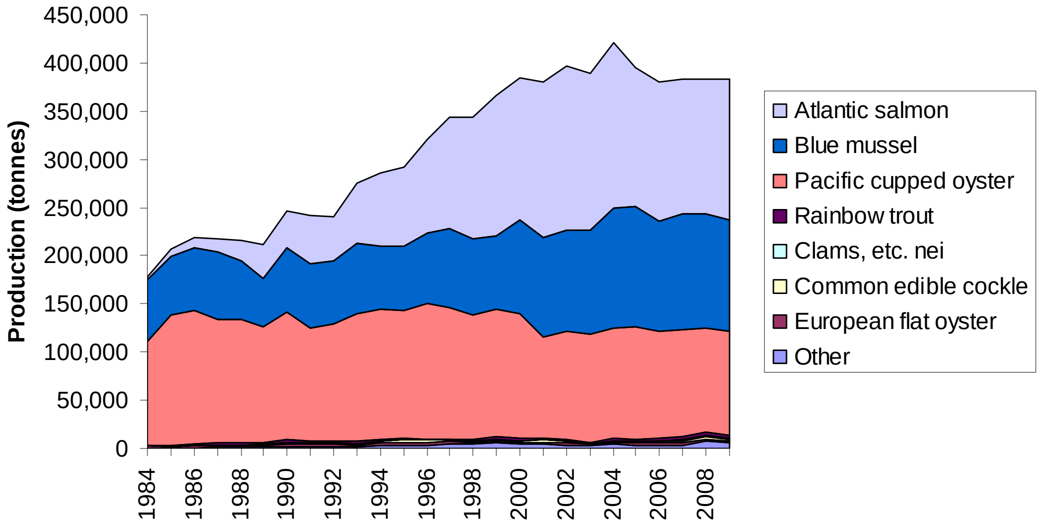


Figure 1.3.24: Annual production of the top 7 species farmed in the Channel Islands, the Isle of Man, France, Ireland and the United Kingdom (Source: FAO FishStat). Note: As data is aggregated by country, this graph includes some areas that are outside NWW.

Effects of mariculture on populations of wild fish

While the farming of fish in coastal cages may have advantages over wild capture fisheries, such as reducing the pressure on seafloor integrity from trawling, it is not without its risks.

Escaped Fish: Large numbers of escaped fish have the potential to significantly dilute the genetic diversity in local wild populations, particularly if the wild stock is already in a poor condition. Farmed fish are selected for fast growth, good feed conversion and disease resistance. These traits may not be ideal for the conditions encountered by hybrids of wild and farmed fish.

Parasites: Densely populated fish farms have ideal conditions for the proliferation of parasites, such as fish lice. These can be transmitted to passing wild fish unless effective management in place. The use of preventative chemical treatments, in turn, brings its own concerns.

Pathogens: Similar to parasites but with less research evidence behind it.

Fish Feed: A significant proportion of the feed used in finfish farms is made from meal and oil derived from wild captured, small pelagic fish. Although this proportion is dropping, the overall amount used is growing due to the expansion of the mariculture sector. These meal fish may be sourced locally or as far away as the Peruvian anchoveta. In European waters they include: sandeel, blue whiting, sprat, pout and capelin. These types of schooling fish are prone to large annual fluctuations in the populations and sometimes dip below reference limits.

In a risk analysis, ICES identified the impact of producing fish feed as the greatest risk posed by farmed fish (salmon and cod) to wild fish populations. Parasites and pathogens were considered a low risk and reproductive competition by escapees was moderate (ICES advice 2010).

Figure 1.3.25 shows the locations of Ireland and Scotland's aquaculture licences. Data was obtained from BIM and FRS. Data for UK sites is not available from CEFAS until the summer of 2009. English sites on the map are from UK SEA6 and SEA8. French aquaculture sites are from an OFIMER document "Les chiffres clés de la filiére pêche et aquaculture en France Edition 2008.

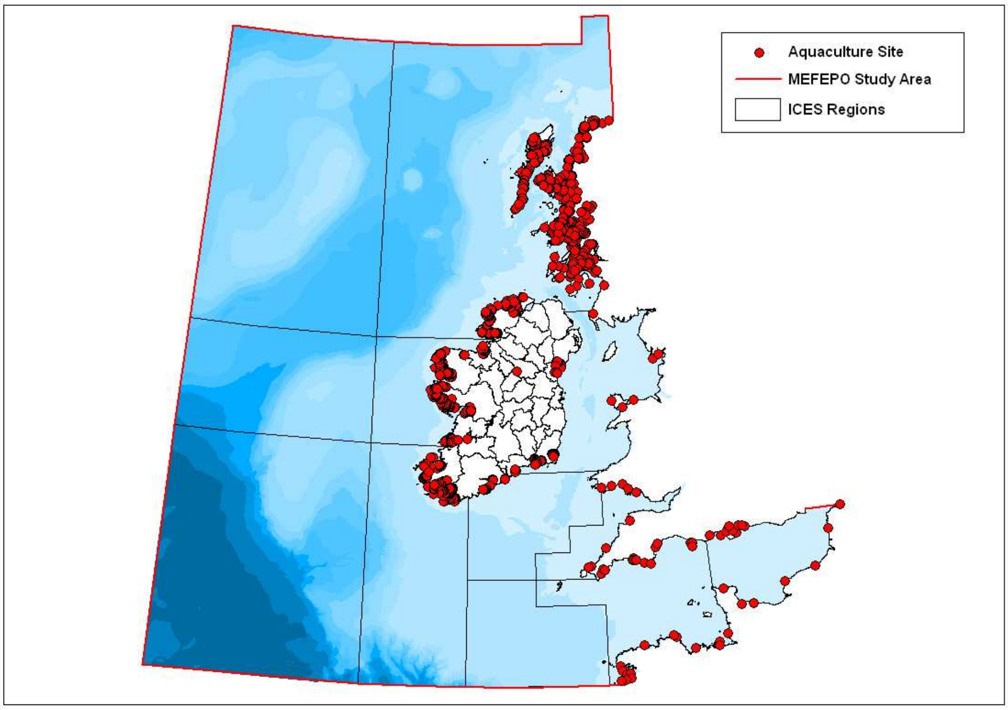
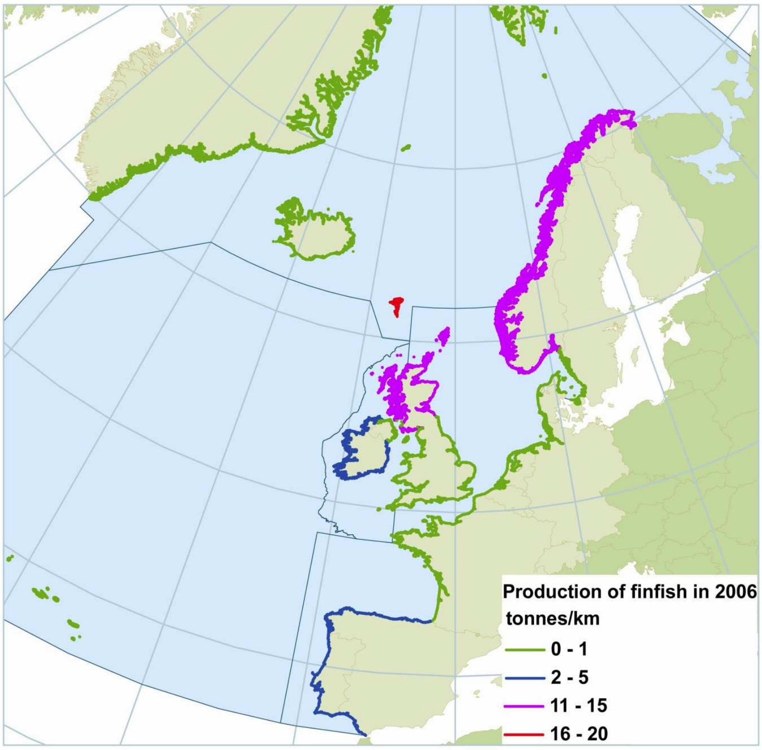


Figure 1.3.25: Aquaculture licence sites within the MEFEPO Study Area (Source: BIM, FRS, UK SEA6, UKSEA7, OFIMER, 2008).

Figure 1.3.26 below shows that the main fish farming country in NWW is Scotland and the main shellfish country is France.



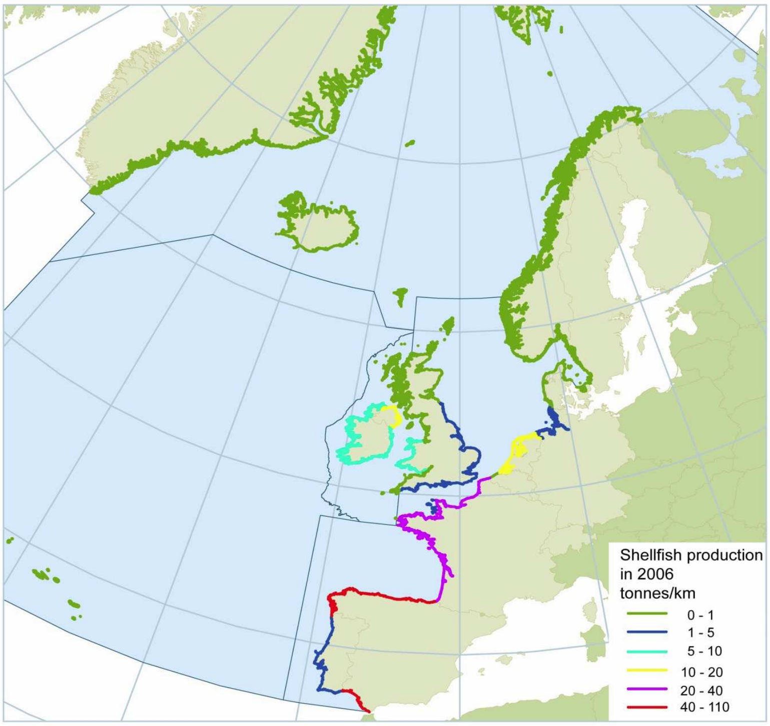


Figure 1.3.26: Production of Finfish and Shellfish per Km of Coastline in 2006 (Source: OSPAR, 2009).

1.3.2 How the human activities are likely to develop (future scenarios)[1]

Luc van Hoof[2]

Introduction: human activities and the marine ecosystem

The development of the impact of human activities on the ecosystem is closely related to the specific activities being undertaken within the confines of the ecosystem, next to spill over of more further away terrestrial activities. Trends in these human activities are influenced by a multitude of factors including developments of demand and supply, population development, developments of consumer preferences, developments of markets, regulation, technology, political environment.

The most important activities out at sea and in the coastal zone are fisheries and aquaculture, international shipping, oil and gas extraction, energy production (wind farming) and tourism. These activities both impact on the ecosystem goods and services as well as on each other. Below we will analyse some of the most important trends. We will start with an analysis of demand and supply of fish and fish products after which we will present trends in fisheries and aquaculture, marine tourism, off shore wind farming, off shore oil- and gas extraction and marine transport

1.3.2.1 Trends and Developments

1.3.2.1.1 World demand for fish and fish products

In 2004, about 75 percent (105.6 million tonnes) of estimated world fish production was used for direct human consumption. The remaining 25 percent was destined for other products, in particular the manufacture of fishmeal and oil. In 2004, the bulk of the fishery products used for other purposes than direct human consumption came from natural stocks of small pelagics.

---

[1] The information and analysis below mainly builds on the FP6 funded project FEUFAR: The Future of European Fisheries and Aquaculture Research which ran from January 2007 until September 2008. All project reports can be accessed at www.feufar.eu

[2] Corresponding author; Institute for Marine Resources and Ecosystem Studies, PO Box 68, 1970 AB, IJmuiden, The Netherlands. Email: Luc.vanhoof@wur.nl; Tel:+31610961991; Fax+31317487326

Most of these fishery products were used as raw material for the production of animal feed and other products. Ninety percent of world fish production (excluding China) destined for non-direct human consumption was reduced to fishmeal/oil; the remaining 10 percent was largely utilized as direct feed in aquaculture and for fur animals (and the remaining for marine ingredients).

Global *per capita* fish consumption has risen from 9.0 kg in 1961 to an estimated 16.5 kg in 2003, but China has been responsible for most of this increase (though official values for China may be overestimated). If China is excluded, the *per capita* fish supply has been stable at about 14.2 kg since the mid-1980s.

During the 1990s, world *per capita* fish supply, excluding China, was relatively stable at 13.2−13.8 kg. This can be attributed manly to faster population growth than food fish supply during the 1990s (1.6% p.a. compared with 1.1%, respectively). Since the early 2000s, there has been an inversion of this trend, with the rate of food fish supply increasing faster than that of the human population (2.4% p.a. compared with 1.1%). Preliminary estimates for 2004 indicate a slight increase in global *per* capita fish supply, to about 16.6 kg.

In terms of food security, the contribution of fish is crucial in some densely populated countries where total protein intake levels may be low. For instance, fish contributes to, or exceeds, 50 percent of total animal protein intake in some small island developing states, as well as in Bangladesh, Equatorial Guinea, the Gambia, Guinea, Indonesia, Myanmar, Senegal, Sierra Leone and Sri Lanka. These countries are located in sub-Saharan Africa or Asia.

The EU population will increase more slowly than elsewhere in the world. Both the trend towards urbanisation and the percentage of people living in coastal areas will increase in future, inducing greater consumption of seafood. Moreover, the age distribution of the European population will change, older people becoming increasingly prevalent, with a preference for healthy food (fish rather than meat) but also smaller quantities than younger people.

Hence the main future trends in global demand for fish and fish products is for one determined by a growing population: an overall increase in demand for fish. With changing income and following food preferences a substitution effect in demand from terrestrial animal protein to marine animal protein will occur. And in addition, especially in the western world a trend towards ‘healthy’ food in which fish plays an increasing role.

1.3.2.1.2 Consumer preferences

Over time the preferences of consumers chance. Some major trends in Europe over the past decades have been increased consumer awareness of the link between food stuffs and diet and health aspects. This is both reflected by an increase in consumption of fish and fish products (as fish emulates a healthy image based on fish being a ‘natural’ product and the health aspects of omega 3 fatty acids) as in the development of functional foods and neutraceuticals. Functional food or medicinal food is any fresh or processed food claimed to have a health-promoting and/or disease-preventing property beyond the basic nutritional function of supplying nutrients. *Nutraceuticals*, rerfers to food, or parts of food, that provide medical or health benefits, including the prevention and treatment of disease. The general category includes processed food made from functional food ingredients, or fortified with health-promoting additives, like "vitamin-enriched" products, and also, fresh foods (e g vegetables) that have specific claims attached. Fermented foods with live cultures are often also considered to be functional foods with probiotic benefits.

Another major trend has been attention for tracking and tracing schemes and labelling schemes. The consumer desires that product origin and quality are assured. In addition, through labelling, certain product attributes such as production method (ecolabelling of sustainability) are guaranteed.

New household patterns, with more families where both parents are working outside the house and with more single-person households, develop a trend towards products that require less time and effort in preparation. Products ready-to-eat, ready-to-cook and complete meal solutions are examples of this trend. As a result consumer demand will shift away from utilising raw ingredients towards fish and fish products being part of a composite product. This of course has an effect on the demand for raw products: away from f.e. fish being sold as fresh and whole, towards fish being an ingredient into a process of product preparation.

In contrast, and for example linked to the slow-food movement. discriminating consumers want to have the best of raw material available for their week-end meals, when they have time for enjoying, and experimenting with, more advanced cooking. Slow food is a relevant trend in this setting; another is the self-realisation through cooking. As people in developed countries move up the Maslow hierarchy of needs, food consumption turns from a necessity, through fulfilling of social needs to a means of self-actualisation.

1.3.2.1.3 Supply of fish and fish products

The demand for fish and fish products shows an upward trend. Between the 1950s and 2004, fish production from fisheries and aquaculture increased from 20 million tonnes to some 140 million tonnes. At this moment production from fisheries is stable. Growth is realised in aquaculture production. The growth over the past 20 years is mainly due to increased production in China, especially aquaculture production.

European production of fish product shows a steady decline. Hence in order to meet European demand there is a need to import fish products from outside the EU. Also the demand for continued exploitation of European fish resources will remain, next of course to demand for increased aquaculture production.

1.3.2.1.4 International fish trade

Over the past 20 years, flows of fish around the world have increased. In part this can be attributed to an increase in fish consumption in Western Europe and America which has been met by increased fish production and trade elsewhere (also by an increase in fish products from aquaculture). Also, due to an increase in *per capita* income, China, for example, has risen rapidly as a fish importer, using fish for the purposes of direct human consumption.

In addition, world trade flows in fish have increased as progressively more raw fish is exported for processing, after which the final consumer product or half-product is re-exported. Between 1980 and 2001 global export and re-export has increased by some 400%.

The EU is increasingly dependent on imports of fish and fishery products to meet its needs. In 2005, the EU-25 imported in excess of €14 billion worth of fish and fishery products, with exports amounting to €2.5 billion. As a result, the EU's trade deficit in fish and fishery products continued to widen and reached a new record of €11.7 billion. Most imports go to Spain (20%), followed by the United Kingdom (13%) and Denmark (11%). Overall, 55% of imports came from 10 countries, with Norway accounting for the largest share (17%) followed by Iceland (8%) and China (6%). The most significant imported products in value terms were fish fillets (€3.3 billion), crustaceans (€2.4 billion), and fresh or chilled fish excluding fillets (€2 billion). The main export items were frozen fish (€879 million), prepared and preserved fish (€307 million) and fresh or chilled fish excluding fillets (€305 million). Japan was the most important export market, with a value of €292 million.

1.3.2.1.5 Trends in fishing fleets

Fishing fleets are of varying size, structure and use different gears. As technology is forever advancing, fleet size and capacity are ever-changing parameters. The number of fishing vessels and/or the gross tonnage can provide just a rough indication on the fishing capacity of a given fleet.

The majority (81%) of EU fishing vessels have a length of less than 12 metres and only 4% are larger than 24 metres in length. Only in Belgium and the Netherlands are the smaller vessels not in the majority. In the remaining Member States vessels of less than 12 metres in length make up of over two thirds of the fleet; in Finland and Greece even over 90% of the total. The median age of EU fishing vessels in 2002 was 22.3 years. The median age was greatest in Denmark and Spain (25.0 years each) closely followed by Italy (24.8 years), Portugal (24.7 years) and Ireland (24.4 years). The youngest fleets were found in Belgium (median age 16.7 years), followed by France (17.2 years) and Finland (17.5 years).

Engine power and tonnage are the main factors determining the fishing capacity of a fleet and hence provides a proxy for the pressure on the fish stocks. Excess power is considered to be one of the major factors of over capacity resulting in overfishing. Despite the drop in fishing fleet capacity experienced by the EU fleet in the past 15 years the chronic overcapacity persists, undermining conservation measures. The Multi-Annual Guidance Programmes (MAGPs) have been proven inadequate and in the reformed CFP (January 2003) have been replaced by a simpler entry/exit regime. Advances in technology and design mean that newer vessels exert more fishing pressure than older vessels of equivalent tonnage and power; hence despite the drop of fleet capacity, fish resources remain seriously depleted and unsustainably managed.

Over the 1989-2004 period the EU fishing fleet capacity followed a downward trend, with reductions of 23 % in power, 15 % in tonnage and 23 % in numbers. Similarly the NMS (New Member States) fleet decreased by 80 % in tonnage and 5 % in number. However, the EFTA fleet (Iceland and Norway) increased in terms of tonnage (by 34%) and power (by 33%) despite the drop in numbers by 52% over the same period. During the 2000-2005 period the fleet was in constant decline.

As fishing fleets expanded through the late 1980s and as fish-finding and harvesting technologies became more efficient, the world's fishers have systematically gone after their catch at greater depths and in more remote waters. In Europe, recent examples of expansion/development of new profitable fisheries with high capitalization and technology include French and Spanish tuna seiners, German pelagic trawlers, and Norwegian combination vessels equipped for pelagic trawling and purse seining.

An important part of the European fishing fleet depends on access to non-EU fish resources, either in waters under the jurisdiction of third countries, with which the EU has signed Fisheries Agreements, or in international waters. Competition for decreasing resources is fiercer every day, making it increasingly difficult for the EU to conclude bilateral fisheries agreements which would grant its fleets access to the surplus fish resources in third country waters. Moreover, the EU distant water fishing fleets are becoming less and less competitive vis-à-vis the fleets of new emerging fishing nations which are operating at lower costs.

1.3.2.1.6 Trends in aquaculture

In Europe the main techniques used to produce farmed fish are: extensive aquaculture, land based ponds, land based recirculation systems and cages. A significant increase in total European aquaculture production has been observed in the past 10 years. In general, significant improvements in the efficiency of feed and nutrient utilisation as well as environmental management have served to partially mitigate the associated increase in environmental pressure. The increase in both production and pressure on the environment has not been uniform across countries or production systems. Only the mariculture sector has experienced a significant increase, while brackish water production has increased at a much slower rate and the levels of freshwater production have declined.

Europe's fish farms fall into two distinct groups: the fish farms in western Europe grow high-value species such as salmon and rainbow trout, frequently for export, whereas lower-value species such as carp are cultivated in central and eastern Europe, mainly for local consumption.

Extensive aquaculture is still used in Europe but production with this technique is decreasing. Still extensive fish farming can be found in Italy mainly for mullet production, in Spain for seabream and seabass, in Portugal for sole. The extensive production is relatively low-tech with low energy input. A rather eco-friendly practice, however with low yields. Integrated aquaculture systems, with the production of algae and animals of different trophic levels is tested (Hussenot, 2004). Land based ponds without recirculation systems are also used in Europe but no consistent technological improvements have been made over the last years.

In Europe, different fish species are produced in *recirculation systems*, such as turbot, seabass, African catfish and European eel. Recirculation systems involve a lot of specific equipments, including mechanical filters, UV reactors, biofilters, CO_2 stripping and oxygenation systems. Recirculation systems are based on water treatment by bacteria, transforming particulate organic matter in dissolved carbon and nitrogen. Recirculation systems represent a way for better fish management, improved controls, less diseases, but also a reduction of environmental impact, by reduced emission of phosphorus, nitrogen and organic matter.

A large part of farmed fish in Europe is being produced in *cages*. Salmon, cod and halibut in northern Europe and seabass and seabream in southern Europe. Fish are reared in open sea net cages since the sixties, which allow a supply of good quality water. First cages were made of wood, then of polyethylene. Feed was distributed by hand at the beginning. Large farms with hinged steel cages, including feeding system with feed blowers and appetite controlled feeding are now used.

The circumference of a single cage increased from 70 m to 160 m diameter, the capacity from 20 tons to 1000 tons in one net cage, and several thousand tons per location. Production developed from 1 employee for every 600 tonnes produced to today 1 employee per 1000 tonnes. Production cost decreased from about 5 euros/kg in 1999 to 2 euros/kg in 2004. Feeding costs make up 40 to 50% of the production costs, slaughtering and transportation 15%, equipment 5 to 10%, finance, insurance and administration 10%, salaries only 5 to 10%.

R&D is currently conducted to improve cage technology. The floating fish farm will be improved to withstand sea (strength, flexibility), to be operational (cost efficient), to ensure fish welfare (oxygen clean water) and to prevent environmental impacts (escape of fish, visual pollution). Research is especially geared at offshore fish farming, and submersible systems. The number of sheltered in shore locations for fish cages is rather limited next to arising conflicts in the costal zone with other uses and users and visual pollution. Offshore development could allow increasing productivity, fish welfare and possibly increase the quality of the product. Up to now, there is no clear technological trend for offshore systems, and focus is more on cage design than on operational aspects. Development is driven by private companies.

1.3.2.1.7 Recreational Fisheries

Recreational fishing appears to be a growing activity within many European Member States (Pawson *et al*., 2007), and concerns have been raised about its influence on commercial fish stocks. Correspondingly, there is a growing body of regulation at the national level governing marine recreational fishing, albeit exerting far less control than is evident for recreational fishing within inland waters.

Total expenditure on recreational fishing across Europe is believed to exceed €25 billion a year (Dillon, 2004). By comparison, the 1998 value of commercial landings in the 15 EU member states was estimated at €20 billion (Pawson *et al*., 2007). In its report on the problems encountered by inshore fishers (A6-0141/2006), the European Parliament's Committee on Fisheries noted that there is increasing tension between inshore fishers, who fish for a livelihood, and recreational fisheries that are competing in the same physical space of the same coastal areas for the same fish, and suggest that this issue needs to be addressed.

Recreational fishing is an important leisure activity in all the Scandinavian countries. It is estimated that almost 25% of recreational fishers in Europe are Nordic, and their expenditure in connection with this hobby is considerable (Pawson *et al*., 2007).

In several of the existing scenario exercises for the marine environment, recreational fisheries have been considered (notably Pope, 1989; MEA, 2005; Pinnegar *et al*., 2006). The future importance of recreational fisheries will be dependent upon the prevailing socio-political climate and the emphasis that society places on leisure versus environmental protection, animal welfare or food production.

Several authors have anticipated that Europeans will enjoy greater leisure time in the future and therefore that we might expect an expansion of sport fisheries. Others have anticipated a situation whereby recreational fishers will be governed by the same rules as commercial fishers, i.e. their access to sites and fish resources will be greatly restricted.

1.3.2.1.8 Activities in Coastal Areas

In the EU, most of the fishing communities have been getting smaller with time as quotas and fleets have become progressively reduced and jobs in fishing and associated industries have become scarcer. Fishing has traditionally been associated with many coastal communities dependant on the fishing industry for their very existence. In some areas of the European coast, there are not many opportunities for employment other than fishing. Certainly in the past 20 years, few new job opportunities have been created at the coast, although some enterprising ex-fishers and fishing industry support workers have found ways of making a living in for example tourism.

Small-scale or in certain cases even large-scale aquaculture has developed and in some cases outstripped the income from wild fisheries in certain areas suitable for such activity, generally those that are less exposed to the elements but where local conditions (e.g. plankton productivity for shellfish; flushing capacity for both finfish and shellfish culture) are suitable for it. Also, some processing plants of large national and multinational companies have retained or even expanded their presence in coastal communities, processing vegetables and meats on lines previously devoted only to fish or shellfish, and/or bringing in fish and shellfish from other landing areas to supplement their processing activities as local supplies of marine produce were interrupted or halted. In some areas too, immigration from new EU states has produced a coastal workforce more willing to handle the menial tasks of fish and shellfish processing and farming than long-resident locals, many of whom have moved elsewhere to seek work which they find more acceptable, changing the cultural make-up of some coastal communities and sometimes causing the coastal population to burgeon.

The coastline of many European countries has long been a favoured holiday and tourist destination, particularly in summer, so jobs have also been created in that sector to support tourist expectations, perhaps seasonally, but often lucratively within the accommodation, entertainment and catering industries. Ports have historically been crucial to the economies and the populations/consumers of European states and of the region as a whole, with shipping and small-boat recreation in many areas being highly visible.

As a result of an increase of activities both in the coastal zone as out on sea ,competition between sectors is rising. There is managed competition for space in European waters between those wishing to erect coastal or offshore windfarms and the fishing fraternity. Some oil and/or gas extraction facilities or their pipelines ashore cause yet further competition, and many energy plants (e.g. power stations, nuclear or otherwise) are sited next to the sea. With burgeoning populations and traditional fishing now no longer able to meet the demand for fish and shellfish, intensive aquaculture is also now taking over large expanses of suitable coastline, affecting onshore space availability and subtidal habitat and space, further adding to the pressure on coasts. Further, the need to dispose of waste, through rivers or directly into the sea, has increased with the human population explosion and increasing industrialization, though regulations governing such discharges and minimizing impacts on the environment and potentially on human health have to a large extent and in most coastal European countries kept pace with man's need for a healthy coastal environment.

1.3.2.1.9 Trends in marine tourism

The marine tourism industry has developed over the centuries from one, which consists of 'getaway' islands for the elite of the Roman empire, to the discovery of seaside tourism in Western Europe between 1750 and 1840, to the mass and special interest tourism of the late twentieth century. Globally leisure time is growing for key groups, particularly the more wealthy. In Europe, pressure on leisure time will lead to more but shorter trips. The growing group of an aging population but still of good health signifies a trend towards increased demand for leisure activities, with an emphasis on cultural aspects, specially designed programmes (for the older traveller).

It is expected that for marine tourism there will be both growth in mass tourism as in more special interest tourism. As for the marine ecosystem, this will be articulated in developments in the cruise industry, recreational fisheries at sea, but especially in the use of the coastal zone as recreational area.

However, tourism as well as for example international shipping presented below, are activities for which the development is closely related to general economic trends. In a downward economical development (such as the current world wide economic crisis) tourism is a sector which is rapidly affected. Hence a long term upward trend in demand for leisure activities can in the short run be adjusted downwards as a result of economic developments.

1.3.2.1.10 Trends in off shore wind farming

With a total of 1,080 MW by the end of 2007, offshore accounted for 1.9 per cent of installed EU capacity and 3.5 per cent of the electricity production from wind power in the EU. Development has been slower than previously anticipated.

Since 2003, the only country to consistently activate at least one offshore project per year has been the UK, when the 60 MW North Hoyle wind farm was commissioned. Denmark, Europe's earliest offshore pioneer, has not added any new projects since the 17 MW Ronland wind plant was commissioned in 2004, while Germany's first offshore wind turbine, a N90/2500, was installed in March 2006 in Rostock international port. The Netherlands, Sweden and Ireland are the only other European markets with operational offshore projects.

Overall, the European wind market is expected to grow at a rate of over 9 GW annually through 2010, which translates into annual investments pushing of €11 billion. Europe remains the leading market for wind energy and new installations represented 43 of the global total. European companies supplied 66 of the world's turbines in 2007. According to EWEA's reference scenario, the EU-27 could see 80 GW of installed capacity in 2010; 180 GW by 2020; and 300 GW by 2030.

The Global Wind Energy Council (GWEC) predicts the global market for wind turbines will grow by over 155 from 94 GW in 2007 to reach 240 GW of total installed capacity by 2012. Depending on the increase in electricity demand, wind power could cover 11.5 to 12.7 of global electricity demand in 2020, according to GWEC, and as much as 20.2 to 24.9 in 2030.

The EU has set a binding target of 20% of its energy supply to come from wind and other renewable resources by 2020. To meet this target, more than one-third of European electricity demand will need to come from renewables. Wind power is expected to deliver 12 to 14 of the total EU electricity demand in 2020. The EU needs to increase by an average of 9.5 GW per year between 2008 and 2020 to supply 12-14 of EUs electricity. In 2007, wind energy capacity in the EU increased by 8.5 GW.

1.3.2.1.11 Trends in off-shore oil and gas extraction

Over the past five years we have witnessed growth of the deepwater oil and gas industry. The global industry continues to face a combination of declining shallow water production, falling reserves in place and poor shallow water prospectivity. Deepwater offered a new exploration and production frontier and has seen projects which have been developed through stable oil prices.

The next couple of years are expected to see a plateau of activity levels as constraints within the market are realised. This has been expected even before banking crisis and oil price decline as capacity constraints within the supply chain and rapid inflation has caused operators to prioritise the most profitable projects. Now with limited access to financing and a lower price outlook there are questions regarding the viability of future projects. Especially the smaller projects in Europe and in South East Asia are most at risk and could see potential delays and cancellations.

Although required for investment over the long term has to be completed on the expectations of lower oil price scenarios, the future for the subsea industry is still expected to be very strong with a variety of water depths, project sizes and locations expected over the next five years.

1.3.2.1.12 Trends in marine transport

Around 90% of global merchandise is transported by sea, in which high quality European shipping is on the frontline in trades from and to Europe, in intra-European and in global cross-trades. In the mid 2000s the growth in world trade is now more marked, in relation to the growth in global gross national product, than is usually the case. This is primarily due to China's increasing integration into the global economy. Positive signals from the WTO negotiations make it likely that the process of global economic integration will continue at a good pace. Since the greater part of exports now travel by sea, this helps boost the demand for shipping services.

According to WTO data world seaborne trade amounted to 5.9 billion tons of loaded goods in 2002, up by 0.8 per cent from the previous year. The general picture of world shipping developments was very favourable during 2003 and the first 8 months of 2004. Oil tanker demand and revenues were volatile. While starting high, they dipped in the second quarter, recovered strongly and after a quieter summer shot up again. Bulk carriers enjoyed a more steady development, from last quarter 2003 to early 2004 showing almost unrecalled strong demand and rates. Developments in the container market showed a similar positive picture with an unexpectedly high demand for capacity, notwithstanding substantial phasing in of large new buildings, resulting in high charter rates.

Freight rates increased to adjust to capacity demand and increased costs, but invariably lag behind, and much of the trade is subject to longer-term contract rates. The total international seaborne trade volume in 2003 increased by 4,4% to about 5840 million tonnes, with a 5,9% increase in tonne-miles and a definite improvement compared to 2002.

There is, of course, an underlying and growing world market, stimulated by growing consumer demand and globalization of production. As main generators these can be considered responsible for the strong growth in the world economy and the international and regional trades in Asia.

International shipping is an activity highly influenced by general economic trends in world trade and developments in the oil market; the latter both in terms of input prices (hence costs) as for demand in oil tanker shipping capacity. In the short run, with a shrinking world economy, demand for shipping will decrease. In the long run the long term trend of increased world trade and hence demand for transport is likely to continue.

Sources:

- "World Intellectual Property Organization" http://www.wipo.int/patentscope/en/
- Basiron, M.N. (1998) Marine Tourism Industry - trends and prospects
- Belk, R. W., T. Devinney, et al. (2005). "Consumer ethics across cultures." Consumption, Markets and Culture 12(2): 275-289.
- Blancheton JP, 2004. Recirculation systems towards closed systems. Diversification in Aquaculture, European Fisheries and Aquaculture Research organisations (EFARO), Budapest February 2004. EC MUTFISHARE Concerted Action.
- Caswell, J. A. (1998). "How labelling of safety and process attributes affects markets for food." Agricultural and Resource Economics Review(October): 151-158.
- Caswell, J. A. and D. I. Padberg (1992). "Toward a more comprehensive theory of Food labels." American Agricultural economics association 74(2): 460-468.
- Delgado, C.L.,, N. Wada, M.W.Rosegrant, S. Meijer, M. Ahmed N. Wada, M.W.Rosegrant, S. Meijer, M. Ahmed Outlook for fish to 2020 Meeting Global Demand,; IFPRI – Woldfish center, October 2003.
- Dillon, B. 2004. A bioeconomic review of recreational angling for Bass (Dicentrachus labrax). Scarborough Centre for Coastal Studies, University of Hull.
- European Commission – Eurostat (http://epp.eurostat.ec.europa.eu)
- European Environment Agency (http://themes.eea.europa.eu/)
- FAO (2005a). Ethical issues in fisheries. Rome, FAO.
- FAO, (2005b). Discards in the World's Marine Fisheries: An Update. FAO Fisheries Technical paper 470.
- FAO, (2007) The state of World Fisheries and Aquaculture 2006 , FAO, Rome 2007
- Franz, N. (2005). Overview of Organic Markets. Rome, Globefish: 102.
- Fredheim A, 2004. Offshore fish farming construction- Diversification in Aquaculture, European Fisheries and Aquaculture Research organisations (EFARO), Budapest February 2004. EC MUTFISHARE Concerted Action.
- Harper, G. and Makatouni (2002). "Consumer perception of organic food production and animal welfare." British Foos Journal 104(3-5): 287-299.
- Honkanen, P., B. Verplanken, et al. (2006). "Ethical values and motives driving organic food choice." Journal of Consumer Behaviour(5): 420-430.
- Hussenot J, 2004. Extensive aquaculture systems. Diversification in Aquaculture, European Fisheries and Aquaculture Research organisations (EFARO), Budapest February 2004. EC MUTFISHARE Concerted Action.

- Jennings, S., K.J. Warr, S.P.R. Greenstreet, and A.J.R. Cotter, Spatial and temporal patterns in North Sea fishing effort. In: M.J. Kaiser, and S.B. de Groot (Eds) Effects of fishing on non-target species and habitats. Oxford: Blackwell Science (2000) pp. 3–14.
- Larcombe, P., Morris, D. J., and O'Brien, C. M. (2008). In recognition of inevitable uncertainties: from fisheries management to managing marine resources. In Advances in Marine Science: 50 years on from Beverton and Holt. Ed. by A. Payne, J. Cotter and T. Potter. Blackwell, Oxford
- MEA (2005) Ecosystems & Human Well Being: Scenarios Volume 2. Findings of the Scenarios Working Group of the Millennium Ecosystems Assessment, Carpenter S.R., Pingali P.L., Bennett E.M., Zurek M.B. (eds.). Island Press, Washington, 560pp.
- Nicholls, R. J. (2007). The threat to coastal populations and ecosystems. In Climate change impacts, adaptation and vulnerability. A meeting to present and discuss the results of the Intergovernmental Panel on Climate Change Working Group II, Fourth Assessment, 18/19 September 2007. WMO/UNEP. Available at http://www.rgs.org/NR/rdonlyres/E6426EAE-9895-481B-B97C-CEBA01467AE5/0/IPCCRNicholls18Sept2007.pdf
- Nierentz, J. Overview of Production and Trade – the Role of Aquaculture Fish Supply, FAO GLOBEFISH. Global Trade Conference, May 2007, China.;
- Oliver, R. L. and R. S. Winer (1987). "A framework for the formation and structure of consumer expectations: Review and propositions." Journal of Economic Psychology(8): 469-499.
- Pawson MG, Tingley D, Padda G, & Glenn H (2007) EU contract FISH/2004/011 on "Sport Fisheries" (or Marine Recreational Fisheries) in the EU. Final Report, Centre for Environment, Fisheries & Aquaculture Science (Cefas), Lowestoft UK. 211pp.
- Pinnegar, J.K., Viner, D., Hadley, D., Dye, S., Harris, M., Berkout, F., and Simpson, M. (2006) Alternative future scenarios for marine ecosystems: technical report. Cefas Lowestoft, 109pp.
- Pope, J. (1989) Fisheries research and management for the North Sea; the next hundred years. Dana, 8: 33-43.
- The Fifth Edition of the Global Perspectives Subsea Market Update, Infield Energy Analysts, p analysis of the global subsea sector; 2004 through to 2013.
- Toften, K. (2007). Nye krav til miljøvennlig og etisk sjømat: Trusler eller muligheter for norsk sjømatnæring? Tromsø, Fiskeriforskning: 10.
- van Hoof, L. Project coordinator (editor), Payne, A. (editor). Iversen, A., Evrard, M., Pinnegar, J., Tserpes, G., Antoine, L., Cahu, C., Lamblin, V. (2008). The Future of Fisheries and Aquaculture: Trends and Developments, Project Report FEUFAR, available at www.feufar.eu

1.4 Socio-economic 'environment'

1.4.1 Management Tools

The management tools used to control the fishery activity can be divided into three groups:

Input management

These are measures aiming at controlling the input used in a fishery. One can restrict (control) the input used in a fishery in different dimensions; area restrictions, time restrictions, entrance restrictions, gear restrictions, bycatch reduction devices. The most applied measures belonging to this group are gear restrictions such as mesh size, vessel size, engine capacity. Also time and entrance restrictions have long traditions within specific fisheries, whereas area restrictions have become more relevant at least in EU-fisheries only the last xx years.

Output management:

These are measures aiming at controlling the output resulting from a fishery. The most prominent examples are TAC (total allowable catch), IQ (individual quotas), bycatch regulations, and minimum landing size.

Economic incentives

These are measures with which a manager tries to direct the behaviour of the fishers in specific directions. The most prominent examples are tradeable quotas, taxes, subsidies

Table 1.4.1 gives an overview of the management applied by some selected EEA member states.

Table 1.4.1 Management tools and their dispersion in selected EEA member states

	Portugal	*Spain*	*France*	*Netherlands*	*UK*	*Ireland*	*Denmark*	*Norway*
Input manage								
Area restr		X	X			X		X
Time restr		X	X			X		X
Entrance		X	X			X		X

restr								
Gear restr		X	X			X		X
Bycatch red dev		X	X			X		
Output manage								
TAC		X	X			X		X
IQ		X						X
Bycatch reg		X?	X			X		X
Min landing size		X	X			X		
Economic incentives								
Tradable IQ		X						X
Taxes/fees			X					X
Trad effort quotas		X						
Subsidies		X (CFP)	X			X		X (indir.)

As can be seen, most countries combine a wide selection of management measures. As long as the fishery activity serve multiple aims and is subdued to several considerations, having access to a selection of measures increase the possibility for reaching efficient management solutions. Hence, the widespread use of different management measures may reflect that authorities try to reach efficient (not to say optimal) management regimes.

The problem connected to pick selective measures for each specified aim or consideration is that the simultaneous use of two or more measures may lead to a low-power incentive scheme, which is the case when one measure revokes the effects of another measure. Also, with several regulations and measures the enforcement becomes a comprehensive task. If this implies that enforcement becomes less strict, the agents in the fishery sector may find it profitable to cheat as the probability for being caught is low.

1.4.2 Socio-Economic considerations

The most basic socio-economic variables are production, as measured in nominal terms, and employment. Production is often measured as sales value. The disadvantage with this measure is that it encompasses input produced elsewhere in the economy and thus not a part of the values generated by the specific sector activity, e.g. fishing or fish processing. As an alternative, value added may be used, as this variable expresses the contribution to the value of the product (e.g. fish) made by labour and capital. Gross value added is the (sales) value of the product when all input except for labour and capital (profits and capital depreciation) is deducted. Gross value added is the basic measure in the national accounts, and an international standard for how to calculate this variable secures comparability between countries.

Employment may also be measured in different ways. In most statistics it is measured as number of persons being (legally) employed or self-employed. However, as this may hide the fact that many of these persons work only part-time, it does not necessarily give a good picture of the total labour (measured in e.g. working hours) generated in the economy. An alternative measure is thus full time employment (FTE), which translates the work the persons employed in a specific sector, e.g. fisheries, carry out into full time jobs. This translation is especially important in a sector like the fisheries, as, due to input restrictions and other regulations, many of the persons employed in the sector do not work full time.

Below we present value added and employment, measured as FTE, in the fishery sector and in the economy as a total for selected EURpean fishing nations (the partners in the MEFEPO-project). To get an impression of the relative importance of this sector to the national economy, we have measured value added and employment in the fishery sector relative to the total value added and employment in the economy.

Admittedly, the fisheries' relative share of total employment underestimates this sector's real importance for employment. The reason is that total employment in the economy is measured as number of employed persons and thus does not correct for part time working, whereas the fisheries employment is measured in full time equivalents.

Table 1.4.2 Gross domestic product (GDP) and value added in the fisheries in selected EEA countries, current prices, 2006

	Gross value added in the economy (GDP), mln EUR	Gross value added in the fisheries, mln EUR	Gross value added in the fisheries in % of GDP
Denmark	218,341	261	0.1
France	1807,462	672	0.03
Ireland	177,268	126	0.07
Netherlands	539,929	149	0.02
Norway	268,363	875*	0.3
Portugal	155,446	124*	0.08
Spain	982,303	412*	0.04
UK	1938,979	354	0.02

* estimated, assumed to account for 60% of value of landings

Source: Preparation of Annual Economic Report (SGECA 08-02), Eurostat: National accounts

Table 1.4.3 Total employment and employment in the fisheries and in fish processing in selected EEA countries

	Total employment, (1000 persons) 2006	Full time equivalent employment in the fisheries 2006	FTE employment in the fisheries in % of total employment, 2006	Employment in fish processing (# of persons) 2003	Employment in the fisheries and in fish processing in % of total employment
Denmark	2,805	2,667	0.1	8,948	0.4
France	25,173	13,462	0.05	21,676	0.14
Ireland	2,039	3,994	0.2	3,439	0.4

Netherlands	8,206	1,893	0.02	6,382	0.1
Norway	2,353	8,600	0.365	11,380	0.88
Portugal, incl Azores and Madeira	5,159	18,124	0.35	6,300	0.47
Spain (2004)	19,748	44,212	0.22	27,000	0.42
UK	28,931	7,973	0.03	18180	0.09

Source: Preparation of Annual Economic Report (SGECA 08-02), Employment in the fisheries sector: current situation (FISH/2004/4), Eurostat: Persons: income, employment and social conditions

The value added in the fishery sector as showed in Table 1.4.2 only encompasses catching the fish. No processing or transportation is included in these figures. Having this in mind, it is obvious that the fisheries do not constitute a substantial part of the national economy in any of the selected countries. Typically, it contributes to below 0.1% of total GDP. The exceptions are Denmark and Norway, where it contributes to 0.1 and 0.3 per sent of total GDP. On average the direct fishing activities counts for 0.0825% of GDP.

Of total landings value (the production measured by first hand sales prices) the gross value added constitutes about 60% for the countries presented.

Employment in the fishing sector as percentage of total employment in the economy is below 0.5%, varying between 0.02% and 0.365% between the countries and with an average equal to 0.17%. Due to different measures for employment these shares are underestimates, but still can not hide the fact that the direct fishery related employment mean very little to the total national employment in all the selected countries. Including processing does not change the picture substantially, as it only increases the relative shares up to a maximum of 0.88%.

Comparing Table 1.4.2 and 3 shows that in most countries the fisheries' share of total gross value added (GDP) corresponds to its share of employment. This implies that the (labour) productivity in the fishery sector is on the same level as in the economy as a whole (average labour productivity). Exceptions are Ireland, Portugal and Spain, where the fisheries' share of total employment is higher than the share of GDP. This implies that the (labour) productivity in the fisheries is lower compared to the average labour productivity in the economy. The fact that the fisheries' share of employment is an underestimate strengthens the argument that labour productivity in the fisheries is lower compared to the average labour productivity in the economy also in the other countries listed in tables 1.4.2 and 3.

EU as a whole is a large net importer of fish, with a net import in 2006 amounting to 13,680 mln EUR[3]. Measured in nominal values Norway, Denmark, Ireland and Netherlands were net exporters of fish products (Denmark, however, was a net importer when measured in tonnes), whereas the other countries were net importers of fish products. Table 1.4.4 shows that fish products constitute a more significant share of total exports compared to their share of GDP[4]. Though aquaculture is included in the export data, it is still likely that this conclusion holds also for harvested products as the export share at average equals 1.17% compared to the GDP share with an average of 0.08%. As can be seen from table 1.4.4, for all countries the export share of fish products exceed their share of GDP. This indicates that fish products may be more important for the foreign trade of the member states (plus Norway) than for the national production (gross value added as expressed by GDP).

Table 1.4.4 Total exports and exports of fish products for selected EEA countries, current prices, 2006

	Total exports, mln EUR	Exports of fish products, mln EUR	Export value of fish products in % of total export value
Denmark	113,484	3,082	2.7
France	484,545	1,360	0.3
Ireland	141,663	359	0.25
Netherlands	394,396	2,344	0.6
Norway	124,573	4,403	3.5

[3] For the 25 EU-member states total imports of fish products in 2006 amounted to EUR 17,195 mln, whereas total exports amounted to EUR 3,516 mln.
[4] The shares are not completely comparable as the figures for export include aquaculture whereas the figures for value added only encompass harvested products. However, in all countries aquaculture products constitute a minor share of total production of fish products when measured in tonnes.

Portugal	48,204	436	0.9
Spain	259,172	2,275	0.88
UK	552,101	1,405	0.25

Source: Eurostat: National accounts

How to evaluate the contribution of the fishing activities to the national economy depends on what we compare with. As fishing is a primary production sector for obvious reasons we compare with agriculture.

Table 1.4.5 Gross value added in the agricultural sector, farm labour force and productivity in the agricultural sector and the fishing sector, 2006

	Gross value added in the agricultural sector in % of GDP,	Total farm labour force in % of total employment	Productivity (gross value added per employee) in the agricultural sector, EUR per worker	Productivity (gross value added per employee) in the fishing sector, EUR per worker
Denmark	1.0	2.0	41,100	97,860
France	1.3	3.4	27,065	49,920
Ireland	1.0	7.5	12,150	31,545
Netherlands	1.6	2.1	48,570	78,710
Norway	0.3	2.5	14,120	101,745
Portugal	1.6	7.7	6,135	6,840
Spain	2.1	5.0	20,670	9,320
UK	0.4	1.2	23,235	44,400

Source: Eurostat: Yearbook 2008

Table 1.4.5 shows that the agricultural sector clearly contributes more significantly to the national economy, in terms of gross value added and employment, compared to the fishing sector. On the other hand, when it comes to labour productivity the fishing sector far surpasses the agricultural sector. This means that the contribution per worker to GDP is higher in the fishing sector compared to the agricultural sector. Taking into consideration the subsidisation of the sectors, this conclusion is strengthened.

Though official statistics show that nominally the fishing sector (catching the fish) is of limited importance to the national economy in most EU-countries with a substantial fishing sector, it is a premature conclusion that the fishery activities are not important to these nations. The fishery sector generates substantial economic activity in other sectors, and this activity may exceed the value added generated in the sector itself. Due to difficulties in providing data we are not able to quantify indirect and induced effects of the fishery sector[5]. However, the narratives connected to the cases presented in the matrix in section 2 will give some (qualitative) information about such effects.

Also, in all countries listed in the tables there are regions where the fisheries constitute an important sector of the economy and where a substantial part of the population works in the fisheries or fisheries related activities. This is shown in Table 1.4.6. The table presents 17 communities located on the coast of the North Sea, and which used to have a high share of the employment in traditional fisheries and related industries. As can be seen, these shares are considerably above those employment shares which were presented on the national level.

Table 1.4.6 Fisheries dependent communities around the North Sea. Population, share of total employment in the fishery sector, other fishery relevant characteristics

Community (country)	*Population (2003)*	*Employment in fisheries and fisheries related sectors in % of total employment (2003)*	*Other characteristics (2003)*
Peterhead (UK)	17,500	28%	£7 m to promote P as Europes premier whitefish port, mainly public contributions
Shetland (UK)	23,000	22%	The municipal authorities uses income from oil and gas to provide grants and loans to

[5] To quantify such effects estimations executed by comprehensive input-output models for the regional or national economy have to be used.

			fishers
Heroy (Norway)	8,350	21%	Municipality active in strengthening businesses that serve the fisheries
Austevoll (Norway)	4,500	17%	Improved facilities in three fishing harbours, municipal investments
Hanstholm(Denmark)	5,860	17%	
Stellendam	11,000	n.a.	Improved facilities in fishing harbours, municipal investments
Urk (Netherlands)	15,700	15%	The future lies in processing and aquaculture
Den Helder (Netherlands)	59,440	n.a.	Fisheries culture to promote the tourist industry
Froya (Norway)	4,200	n.a.	Aquaculture largest industry and trad fisheries as a clear second
Thyboron-Hatboore (Denmark)	4,875	15%	
Holmsland (Denmark)	5,300	14%	Tourism taken over as the largest industry
Karmoy (Norway)	37,200	n.a.	Oil and gas industry expanding at the expence of the traditional fisheries
North Shields (UK)	9,500	10%	Fisheries culture to promote the tourist industry
Ijmuiden (Netherlands)	14,800	n.a.	Invest more in heavy-industry at the expence of the fisheries
Lowestoft (UK)	55,280	10%	More emphasis on new industries, such as tourism
Scheveningen (Netherlands)	23,000	n.a.	More emphasis on new industries, such as tourism
Ulfborg-Vemb (Denmark)	7,000	5%	The fisheries are no longer a major industry in the local economy

Source: EFEP (European Fisheries Ecosystem Plan): Annex 1 Second Stakeholder Consultation

An interesting, but not unexpected, characteristic is the tendency to a positive correlation between the share of the employment in the fisheries and fisheries related sectors and the efforts from the municipal government to maintain fisheries as a main industry in the community. As an example, in all communities with employment shares above 15% in the fisheries and fisheries related sectors there are investments in infrastructure to support the fisheries. These investments are mainly financed through municipal, state and EU-contributions.

When discussing the fisheries and their socio-economic importance it is necessary to make a balance between the insignificance of the sector in a national context and the big importance it has in some local communities.

The local importance of fisheries activities will be closer described in the narratives presented in connection with the matrix in section 2 of this report.

1.4.3 The Institutional Governance Setup of Fisheries Management

1.4.3.1 Introduction to the EU Institutional Setup for Fisheries Management

Providing a schematic overview of the institutional setup underlying the governance system of the Common Fisheries Policy (CFP) of the European Union (EU) is difficult. It runs the risk of either creating the illusion of a simple system or may further confuse what is already a complex system. Figure 1.4.1 is an attempt to provide a schematic overview of the system. . The model includes the main actors in CFP governance and streams between them of knowledge, legal processes and policy/management interventions.[6]

[6] A number of publications from the last 10 years have dealt in depth with the knowledge, legal and policy/management systems related to the CFP. For an overview of the knowledge system underlying the CFP see Hegland (2006) and for a more in-depth analysis Wilson (Forthcoming); for legal aspects of the CFP see Berg (1999) and Long and Curran (2000); and for the management and policy issues, see for instance Sissenwine and Symes (2007), Lequesne (2004), Raakjær (2008), Gezelius and Raakjær (2008).

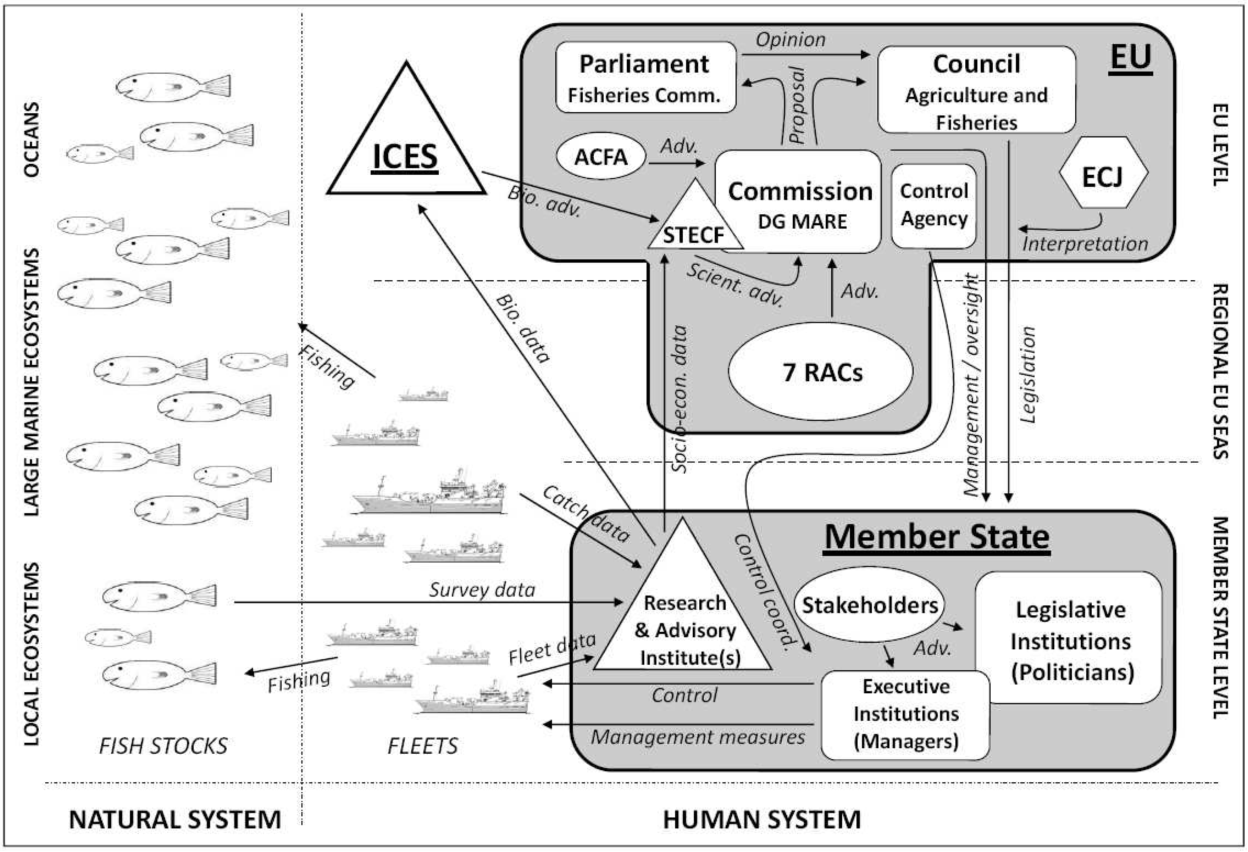


Figure 1.4.1: The Institutional Setup for Fisheries Management in the EU[7]
The scientific bodies are depicted as triangles, legal bodies as hexagons, stakeholder bodies as eclipses, and policy/management bodies as 'soft' rectangles.

Although the model in Figure 1.4.1 includes a multiplicity of actors and interactions, the model remains a simplified picture of the actual setting in which CFP governance unfolds. Other streams of interactions, as well as actors could have been added. The main institutional actors of the system are the EU and the member states. However, neither the EU nor the member states are unitary bodies, as it is evident from the model.

The human governance system can be understood as operating on several political levels. In this model, three levels have been included: EU supranational/intergovernmental level, EU regional seas level and EU member state level. However, above the EU level there is a global international level, on which the EU has signed a number of treaties, conventions and declarations dealing with fisheries policy and management among other issues. At the other end of the spectrum, there may be regional and/or local level governance considerations beneath

[7] Vessel illustrations from www.fiskerforum.dk.

the national level. Whilst this may not be particularly relevant for countries such as Denmark where fisheries management is highly centralised (Hegland and Raakjær 2008), in countries such as Spain it is necessary to consider regional/local level governance issues when discussing fisheries policy and management.

The policy levels described above have counterparts to different ecological scales in marine systems. One such scale could start at a fjord or a bay, and move up to oceans and ultimately the global marine ecosystem. In between these levels, we have a relatively well-defined category of *large marine ecosystems* (LME)[8], of which the North Sea is one example. The ecologically defined scales of the natural system are not, however, necessarily reflected by corresponding levels of policy-making/management in the governance system.

1.4.3.2 History and Performance of the Common Fisheries Policy

The CFP is the fisheries policy framework of the EU. In its present, comprehensive form, it covers measures relating to markets, conservation, sector structures, external relations and control. It was first established in 1983 (Council 1983). Conservation of living aquatic resources (a main pillar under the CFP) is, as one of only a handful of policy areas, under the exclusive competence[9] of the EU. In this area it governs primarily by means of regulations that are binding and directly applicable at member state level. As such these legislative acts do not need to be transposed into national legislation. However, although the EU has exclusive competence, it is up to the member states to implement and operationalise the policy. This imbalance has made it extremely difficult to provide a level playing field for the industry across the EU.

The first acts relating to markets and fisheries sector structures were adopted as early as 1970 (Council 1970, 1970a). Since 1983, the policy has undergone reforms in 1992/93 (Council 1992) and 2002/03 (Council 2002). The next major reform is scheduled for 2012/13. Over the years the primary focus of the CFP has, alongside the general development in fisheries management worldwide, increasingly gone from being that of ensuring efficient fishing fleets and well functioning markets for fish products, towards conserving the resource base, which the sector

---

[8] The concept of a large marine ecosystem was pioneered by the National Oceanic and Atmospheric Administration, United States Department of Commerce, and a large marine ecosystem/LME is defined as an area *"of the ocean characterized by distinct bathymetry, hydrology, productivity and trophic interactions."* Information from http://www.publicaffairs.noaa.gov/worldsummit/lme.html (accessed 25 January 2009).

[9] Exclusive competence on behalf of the EU *"means that the member states cannot adopt their own legislation within the area* […] *unless that power has explicitly been given back to them"* (Hegland and Raakjær 2008: 164).

ultimately stands and falls by (Gezelius et al. 2008). In practice, EU subsidies over the years have contributed to making the fleet more efficient, so, paradoxically, the success of the CFP in the area of developing an efficient fleet has contributed to its failure in relation to conserve fish stocks, as overcapacity is consistently mentioned as one of the fundamental reasons for the conservation failure. As a consequence, the focus of the policy has in part gone from that of developing the sector to that of conserving the stocks.

Although it has been argued that the mere adoption and maintenance of an EU fisheries policy under the prevailing circumstances must be considered an institutional success (Holden 1994; Nielsen and Holm 2006), the output that the CFP has delivered *vis-à-vis* indisputable core objectives of fisheries management has been far from impressive. At present the situation is according to Sissenwine and Symes (2007) characterised by:

- a significant overcapacity in the EU member states' fleets compared to available resources;
- a poor profitability in large parts of the catch industry;
- overexploited stocks above what comparable regimes worldwide have been able to deliver;
- a lack of legitimacy of the management framework among industry stakeholders and conservationist non-governmental organisations (NGOs) alike;
- a continuation of environmentally destructive practices of fishing; and
- uneven and generally poor implementation and enforcement of conservationist fisheries legislation.

Consequently, although the CFP may possibly be considered an institutional success story, it is, we and many others would argue, a failure in terms of performance in nearly any other aspect. Paradoxically, the fact that the CFP can be regarded as an institutional success may in itself stand as an obstacle to decisive policy reforms since it is recognised that the fundamental political compromises that the CFP rests on, were long and hard in the making. One such compromise is the principle of *relative stability*, which stands as one of the fundamental features of the CFP. The relative stability, which was agreed in 1983, based on historical fishing patterns, outlines the fixed allocation keys to be used, after deciding on total allowable catches (TAC)[10] for individual fish stocks in specific sea areas, to distribute the fishing opportunities into national quotas to the member states (Hegland and Raakjær 2008a). This allocation key ensures relative stability in relation to fishing opportunities between member states, but it is at the

[10] The overall TACs are ultimately set by the relevant ministers in the Council of the European Union acting on a proposal from the Commission; the decision is in short based on a combination of scientific advice on the state of the stocks and socio-economic considerations.

same time a complicating factor in terms of reforming the CFP, as any proposal that directly or indirectly potentially impinges on the relative stability is *per se* highly contentious among the member states.

Although the magnitude of the failure cannot exclusively be blamed on the internal properties of the policy regime, which arguably in the EU is operating within a particularly complicated context of 'mixed and multi-everything'[11], there seems as of today to be a broad agreement on the fact that the policy regime seen in isolation has functioned far from optimally (e.g. Raakjær 2008; Sissenwine and Symes 2007; Gezelius and Raakjær 2008; Commission 2008; European Court of Auditors 2007).

In the following sections we will, with reference to Figure 1.4.1, briefly introduce the institutions and actors at the different levels as well as present their roles in the governance system. We will start at EU level and move downwards.

1.4.3.3 EU level Institutions and Actors

The formulation, adoption and implementation of EU fisheries legislation is, as it is evident from Figure 1.4.1, a process involving a multiplicity of actors and institutions operating on various levels in the political system. The standard procedure of EU fisheries policy-making involves that a unit within the Directorate General for Maritime Affairs and Fisheries (DG MARE) (which is the relevant directorate-general within the Commission of the European Communities (Commission)), drafts the envisioned piece of legislation. In this process, DG MARE incorporates to varying extents, depending on the nature of the proposal, input from stakeholders and/or scientific bodies. Once the draft proposal has been agreed according to the internal procedures of the Commission, it is forwarded to the European Parliament (EP, Parliament), which under the consultation procedure[12] that covers fisheries issues, has the right to be heard on fisheries matters. Once adopted according to the internal rules of the Parliament, the resolution, usually in the form of suggestions for amendments, is forwarded to the Council of the European Union (Council). The Council receives the proposal from the Commission at the same time as the Parliament, and it is technically the Council that consults the Parliament. The Council is, however, not obliged to implement the Parliament's amendments. In the Council, the relevant

[11] The CFP have to stretch across more than 20 member states with very diverse fishing fleets; the fleets of the member states apply a multiplicity of fishing practices and gears; many of the important fisheries inside the EU are mixed fisheries (i.e. fisheries where multiple species are caught at the same time), a feature that is known to be a challenge for any fisheries management system as the fishermen are not able to control the composition of fish species in the catch.

[12] It should be mentioned that the Lisbon Treaty, which is currently under negotiation/adoption in the EU, entails that fisheries policy issues will in the future be dealt with under the co-decision procedure, which gives the EP considerably more power in the area.

ministers in the Agriculture and Fisheries Council discuss the proposal and vote on it. Once adopted (possibly in a revised form), it is passed on to the member states for implementation. Should disputes on the interpretation of EU fisheries legislation arise, it is ultimately up to the Court of Justice of the European Communities (ECJ) to make a ruling. (Hegland 2004, Hegland and Raakjær 2008a)

In the following sections, we provide a brief overview of each of the institutions of relevance at EU level in the governance system as presented in Figure 1.4.1.

1.4.3.3.1 Commission

The Commission serves as the EU bureaucracy in the area of fisheries policy as in most other policy areas. However, compared to a traditional, national bureaucracy, the Commission has a considerable degree of authority and political power *vis-à-vis* the main decision-making body of the Council (see section 1.4.3.3.3). The Commission fulfils a number of other functions in the EU system, but in the following we will focus on the role of the Commission as the developer and proposer of legislation. However, as indicated in Figure 1.4.1, other important tasks of the Commission in the area of fisheries include carrying out direct management (e.g. by filling out Council legislation with more detailed or technical legislation) and overseeing that the member states fulfil their obligations, and if they are not take action possibly by referring disputes to the Court of Justice of the European Communities (see section 1.4.3.3.5).

It is the Commission that drafts and proposes new legislation in the area of the CFP. Furthermore, the Commission is also an active player in the negotiations with the Council, although without the right to vote. This means that it is not possible to draw a clear line between the political system and the bureaucracy/administration in the EU to the same degree as in national systems (Hegland and Raakjær 2008a).

In practice, a Commission proposal, communication, paper etc. relating to fisheries is drafted in the relevant office under the relevant Directorate under the Directorate General for Maritime Affairs and Fisheries (DG MARE).[13] In drafting the proposal DG MARE takes to a varying extent, depending on the nature of the proposal, information from other relevant Directorate Generals, various committees, institutions and organisations into consideration. If scientific expertise is

[13] There is as of February 2009 six Directorates under DG MARE: Directorate A: Policy development and co-ordination; Directorate B: International affairs and markets; Directorate C: Atlantic outermost regions and Arctic; Directorate D: Mediterranean and Black Sea; Dirctorate E: Baltic Sea, North Sea and landlocked member states; Directorate F: resources (DG MARE administartion). Information from DG MARE's website: http://ec.europa.eu/dgs/fisheries/organi/oganig_en.pdf (accessed 18 February 2009).

needed to draft the proposal, DG MARE is particularly dependent on information from other sources, as there is limited in-house scientific capacity (Commission 2003). The International Council for the Exploration of the Sea (ICES) (see section 1.4.3.3.6) and the Scientific, Technical and Economic Committee for Fisheries (STECF) (see section 1.4.3.3.1.1) are of particular importance in these instances. The Regional Advisory Councils (RACs) (see section 1.4.3.4.1) are now also consulted on a routine basis on most of the substantial initiatives from DG MARE.

Once DG MARE has received the information it has deemed necessary from the various sources, the responsible Directorate finishes drafting the proposal and passes it upwards through the Commission hierarchy. Ultimately, the proposal is dealt with in the College of Commissioners, which consists of 27 Commissioners, each appointed by a member state. However, the Commissioners are supposed to act on behalf of the EU and not on behalf of a member state, something which cannot, however, always be taken for granted in general or in fisheries in particular (see Hegland 2006: 223, footnote 2 for an illustrative example). The Commissioners can then accept the proposal (in that case it is passed on to the European Parliament and the Council), reject it, refer it back for re-drafting or decide not to take any decision whatsoever. The Commissioners decide by simple majority voting and individual votes as well as results of votes are confidential (Hegland 2006).

The Council and the Commission are, partly as a consequence of the blurred situation in relation to the lines between the political system and the bureaucracy/administration in the EU, engaged in a continuous negotiation over what the responsibilities of the two institutions should be. It is in the Commission's interest to frame issues as being administrative in nature (to gain control over them), and it is in the interest of the Council to frame issues as being political in nature (to keep control over them). Hegland and Raakjær (2008) describe the debate during the negotiations leading up to the 2002 reform on who should be in charge of setting the TAC once a multi-annual management plan for a specific species had been adopted by the Council as an example of a dispute of this kind. The Commission proposed that the question of the TAC for subsequent years should, by default, be dealt with by the Commission itself and only be referred to the Council if a Management Committee set up under the Commission and consisting of member states' representatives could not support it. This proposal was rejected by an almost united Council taking the stance that the setting of TACs is a politically issue even if subject to a multi-annual management plan.

Following Hegland (2004), the Commission is broadly perceived as being in favour of increased integration within the various policy areas. Consequently, increased integration can be said to be the institutional preference of the Commission bureaucracy. In the area of fisheries, increased integration has often been equated with stronger central powers on behalf of the Commission, as illustrated by the work of Holden (1994), a long-time high ranking Commission civil servant in the directorate general dealing with fisheries. Furthermore, according to Lequesne (2000), Commission officials view themselves as guardians of expertise, especially biological expertise, as opposed to governments, which are vulnerable to lobbying efforts from the industry.

1.4.3.3.1.1 Scientific, Technical and Economic Committee for Fisheries

The Scientific, Technical and Economic Committee for Fisheries (STECF) is the independent committee, appointed by the Commission that advises the Commission / DG MARE on matters where scientific knowledge is vital. The committee consists primarily of scientists with a background in marine biology or ecology, fisheries science, nature conservation, population dynamics, statistics, fishing gear technology, aquaculture, or the economics of fisheries and aquaculture (Commission 2005). STECF forms internal sub-groups, which can include experts from outside the STECF (Commission 2003)

STECF and its sub-groups draw to a large extent on the same (limited) pool of expertise as the International Council for the Exploration of the Sea (see section 1.4.3.3.6), which according to the Commission (2003) has led to repetitive work on behalf of some of the STECF members, as one of the main tasks of the STECF is to review scientific advice emanating from ICES. Notably, besides reviewing advice and advising the Commission on its use, STECF contributes with economic calculations on potential effects of the predominantly biological conclusions on selected fleets. This work is carried out in the Subgroup on Economic Assessment and constitutes the sole source of systematic economic advice to DG MARE; a task of the STECF, which is considered increasingly important. (Commission 2003, Hegland 2006)

According to Hegland (2006: 226) the wide overlap between the experts within ICES and the STECF should not conceal the fact that experts when working in STECF in some instances can come to different conclusions or recommendations than when working within the context of ICES:

> *”STECF tends to be able to provide advice on issues, and in a manner, which ICES is not - even on issues within its area of expertise. Part of the reason for this is that the same scientists accept different approaches, depending on whether they are working within or outside the ICES system. Within STECF the scientists are free to act more as consultants responding to whatever is required from the customer, DG Fisheries [now DG MARE], without having to consider, to the extent that ICES does, if the requests are reasonable or if answers can be misused.”*

Besides this institutional reason, it should also be mentioned that the issues are discussed by another group of scientists and the conclusions may reflect that the balance between scientists of differing opinions and perspectives has changed.

1.4.3.3.1.2 Advisory Committee on Fisheries and Aquaculture

The Advisory Committee on Fisheries and Aquaculture (ACFA) is a consultative body set up in 1971 by the Commission to provide stakeholder input from European-level stakeholder groups and umbrella-organisations on fisheries matters (as opposed to the RACs, see section 1.4.3.4.1). The mandate of the committee is to issue opinions and resolutions on fisheries issues and proposals emanating from the Commission.

ACFA was reorganised in 1999 and 2004 and is currently organised with four working groups under it. The plenary committee consists of representatives of private ship-owners, cooperative ship-owners, employed fishermen, producer organisations, stock-breeders of fish, mollusc/shellfish stock-breeders, processors, traders, consumers, environmentalists, and development organisations. ACFA is numerically dominated by representatives of the fishing industry. ACFA's four working groups are: 1) Access to fisheries resources and management of fishing activities, 2) Aquaculture: fish, shellfish and molluscs, 3) Markets and Trade Policy and, finally, 4) General questions: economics and sector analysis. (Commission 1999, 2004, Hegland 2006)

According to Lequesne (2000), the actual impact of ACFA on Commission proposals has over the years been limited. Consequently, he argues, *"*[t]*he core raison d'être of the Consultative Committee* [ACFA] *has been an exercise in mutual legitimization"* (Lequesne 2000: 353).

1.4.3.3.2 European Parliament

As described in section 1.4.3.3, the European Parliament (EP, Parliament), which consists of democratically elected parliamentarians from the 27 member states, has the right to be heard in relation to fisheries issues. The consultation procedure dictates that the Parliament has little decisive power in the area of fisheries, and as such the power of the Parliament lies mostly in the pressure it can exert by it being a democratically elected body and as such representing the voice of the EU citizens.

Most of the work towards fisheries resolutions is carried out in the standing Committee on Fisheries, which, after having discussed the issues based on a report drafted by one of its members, adopts a proposal for a resolution by a simple majority. This proposal for a resolution is subsequently dealt with by the Parliament in plenary, where each proposed amendment has to gather a majority of present parliamentarians. When the Parliament has arrived at a compromise in the form of an adopted resolution, this is forwarded to the Council, which is, as mentioned in section 1.4.3.3.3, not obliged to implement the Parliament's opinion under the consultation procedure. Although the Parliament is technically consulted by the Council and not by the Commission, the latter can choose to amend its proposal in light of the Parliament's opinion before the negotiations in the Council but, again, there is no obligation to do so. (Hegland 2004, 2006)

Given its status in the consultative procedure, the power of the Parliament is, as mentioned above, limited. Nonetheless, stakeholders such as environmental non-governmental organisation (NGOs) and industry organisations alike, which have traditionally felt deprived of fair access to the EU fisheries policy-making process, have used the Parliament as a route for lobbying particularly the Commission through parliamentarians (Lequesne 2000). Anyway, it seems reasonable to expect that this kind of indirect lobbying has become less appealing to NGOs given the formalised role these groups now have through the RACs (see section 1.4.3.4.1). Notably, the Lisbon Treaty, which is currently under negotiation/adoption in the EU system, suggests that fisheries policy issues will in the future be dealt with under the co-decision procedure, which gives the EP considerably more power in this area.

1.4.3.3.3 Council of the European Union

In the Council of the European Union (Council), the member states are each represented by their minister responsible for fisheries issues. These ministers meet in the Agriculture and Fisheries Council, which acts as the primary decision-making body in relation to the CFP.

Fisheries policy issues in the Council are subject to qualified majority voting (QMV), which means that no single member state is in a position to block a proposal coming from the Commission. The member states hold different numbers votes in the Council; the largest member states have most votes but the smaller member states have more votes than the size of their populations would strictly suggest.[14] The total number of votes in the Council is 345, and a qualified majority is reached when there is 255 votes (73.9%) in favour, on the condition that 1) the votes in favour are cast by simple majority of member states (in some cases other than fisheries 2/3 of the member states) and 2) that the votes in favour represent at least 62% of the total population of the EU (this provision is only relevant is a few cases of alignment within the Council and it is only invoked on specific request from a member state). In practice abstentions under the QMV procedure count as negative votes and a blocking minority is thus constituted by

[14] 29 votes: France, Germany, Italy, and United Kingdom; 27 votes: Spain and Poland; 14 votes: Romania; 13 votes: Netherlands; 12 votes: Belgium, Czech Republic, Greece, Hungary, and Portugal; 10 votes: Austria, Bulgaria, and Sweden; 7 votes: Denmark, Finland, Ireland, Lithuania, and Slovakia; 4 votes: Cyprus, Estonia, Latvia, Luxembourg, and Slovenia; and 3 votes: Malta.

91 votes or abstentions (or a simple majority of member states or votes representing more than 38 percent of the EU population).[15]

The question of how often a member state finds itself in the favourable position to decide if a proposal is adopted or not depends, consequently, on its size (number of votes and size of population), and on the prevailing coalition patterns within the Council. Coalition building was particularly evident in connection with the 2002 reform where three different positions could be observed in the Council:

> *"The Commission, which does not have the right to vote, but nevertheless plays an important role in Council negotiations and the decision-making process in general, proposed a radical reform, which bore the marks of a conservationist world view. One position was assumed by a network of member states, which informally referred to themselves as the 'Friends of Fish' (FoF), composed of Germany, the UK, Sweden, the Netherlands, and Belgium - and to a lesser extent Finland, which had opposing views to the rest of the network on especially the question of structural aid. FoF were in favour of a comprehensive reform, but were less radical than the Commission in terms of conservationist focus. The network's nickname was chosen in response to the opposing group of member states who referred to themselves as 'Amis de la Pêche' (AdlP), or in English 'Friends of Fishing'. AdlP was composed of France, Spain, Ireland, Portugal, Italy and Greece and had been formed around December 2001 in response to the Green Paper and what they saw as an overly conservationist approach from the Commission. These member states, which to a large extent argued from a social / community perspective, engaged in an unprecedented level of coordination of strategies, meetings at high levels, publication of joint conclusions and counterproposals, etc."* (Hegland and Raakjær 2008: 153, drawing on Hegland 2004)

In practice, it is only a limited number of fisheries issues that actually reach the level of ministers. The Council is a hierarchical structure where proposals are initially scrutinised by member states' civil servants in one of the two working groups dealing with fisheries issues: the External Fisheries Working Group/Working Party on External Fisheries Policy deals with relations with third countries, and the Internal Fisheries Working Group/Working Party on Internal Fisheries Policy deals with conservation, markets and structures. The least contentious issues can be negotiated at this level where also the Commission can choose to amend its proposal if it encounters too much opposition and the Commission is not adamant about holding on to a specific position. Questions of a more contentious nature are passed on upwards to the higher ranking civil servants in the Permanent Representatives Committee (Coreper). Only the most

---

[15] The information on the voting rules from the EU's website: http://europa.eu/institutions/inst/council/index_en.htm (accessed 18 February 2009).

politically sensitive issues are discussed in substance and subsequently decided on by the ministers in the Council; the Agriculture and Fisheries Council meets approximately once a month in Brussels or Luxembourg. One of the issues, which are normally dealt with by the ministers themselves, is the yearly setting of TACs, which traditionally has taken place at a marathon meeting in Brussels in the second half of December (Hegland 2006). This is however, rapidly changing due to advice now being delivered earlier from ICES.

Although there is, as described above, a voting arrangement in the Council, networking and informal contacts and communication remain extremely important in Council negotiation processes on fisheries issues. The informal communication serves multiple purposes, e.g. leaking one's own and getting other countries' positions in order to explore possible compromises or gaining a better understanding of other member states' underlying motives (Hegland 2004).

1.4.3.3.4 Community Fisheries Control Agency

The recent establishment[16] of the independent Community Fisheries Control Agency (CFCA) is an integral element in the progressive implementation of the 2002/03 reform of the fisheries policy framework, and the objective of the CFCA is to strengthen the uniformity and effectiveness of enforcement across the EU territory. This should be done by assisting with the organisation of operational cooperation and coordination of monitoring and enforcement activities among member states (Council 2005).

The powers of the CFCA are highly limited and it is specifically stated in its legal foundation that the agency does not have the power to impose additional obligations on the member states besides those outlined in the basic regulation of the CFP. Neither does the agency have any powers to sanction member states (Council 2005). With its staff of 49 as of 2008 (Community Fisheries Control Agency Undated), the agency is amongst the seven smallest EU level agencies out of the 30 examined in Egeberg, Martens and Trondal (Undated). In practice the main task of the CFCA is to adopt 'joint deployment plans' (for specific stocks in specific sea areas) with the aim of coordinating the use of the different member states' human and material resources related to control and inspection as well as solving issues related to how and when control and enforcement activities of one member state may take place in waters under the sovereignty and jurisdiction of another member state, among other things. The relevant RACs should be involved in developing the plan (Council 2005, Community Fisheries Control Agency Undated a).

1.4.3.3.5 Court of Justice of the European Communities

The Court of Justice of the European Communities (ECJ, Court) is the legal body mandated to rule in disputes on the interpretation of EU law (including fisheries legislation) and thereby settle disputes between citizens and member states, between member states and EU

[16] Operational from 2007 in Brussels and physically set up in Vigo, Spain, in 2008.

institutions, as well as between EU institutions or between member states etc. In principle, the Court is a neutral actor in the governance system. However, as briefly mentioned in Hegland (2004), the Court has in some instances been accused of having engaged in 'judicial activism' to favour increased integration.

1.4.3.3.6 International Council for the Exploration of the Sea[17]

The International Council for the Exploration of the Sea (ICES) is an international scientific organisation covering the North East Atlantic and is the predominant source of scientific input to the decision-making process relating to the CFP. The science is almost exclusively biological, and mainly in the form of stock assessments, which are essentially statistical interpretation of sampling programmes. However, it is important to note that ICES is not an EU institution and that ICES delivers advice to a range of clients besides the EU. Nevertheless, the EU is its largest client. ICES has 20 member states[18] and six affiliate states.[19] The basic units of ICES are individual marine scientists, primarily fisheries scientists, drawn from national scientific institutes or universities. The ICES network of scientists consists of approximately 1600 persons.

ICES' advice is based on data provided by national scientific institutes in either the shape of fisheries-independent data (e.g. from trawl surveys carried out by research vessels) or fisheries-dependent data (e.g. catch statistics from commercial vessels). Within the ICES system, the data from the various sources are analysed in a large system of working and study groups and turned into scientific advice for ICES clients'. Their clients include governments and international organisations with marine management responsibilities of which the EU is the single largest. Within the ICES system, it is the practice that the Advisory Committee formally formulates, adopts and submits advice to the clients.

The national institutes are funded by their national governments to attend meetings, but universities must procure their own funding. In respect to specifically EU member states, an increasing amount of work is funded by the Commission. The budget of ICES, with its staff of 47, does not cover more than coordination activities and ICES is as such mainly a secretariat bringing together scientists without the means to actually pay them. ICES is consequently highly dependent on the national institutes and universities having sufficient funding. That the EU is ICES' largest client means among other things that ICES is particularly responsive to the requirements and political signals coming from there (Hegland 2006).

---

[17] This section builds in part on information from the ICES website: http://www.ices.dk/ (accessed 16 February 2009).

[18] The ICES member states are Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Russia, Spain, Sweden, the United Kingdom, and the United States of America.

[19] Australia, Chile, Greece, New Zealand, Peru, and South Africa

1.4.3.4 Institutions and Actors at Regional EU Seas Level

There are relatively few institutions situated at regional levels (Figure 1.4.1). Common to all the regions discussed in MEFEPO are the presence of a Regional Advisory Council (RAC). MEFEPO is using this regional management unit for its research. Besides the RACs, there are a few additional institutions of particular relevance for individual regions. Both RACs and other regionally relevant institutions will be dealt with below. Initially we will discuss the RAC set-up from a generic point of view before introducing the specific RACs of the region in question. Given the strong link between the RACs and the MEFEPO project, we will go slightly more in detail with the RACs and other regional institutions than with other institutions.

1.4.3.4.1 Regional Advisory Councils

Seven Regional Advisory Councils (RACs) were set up under the CFP following the 2002 reform. These are stakeholder fora consisting predominantly of representatives of the fisheries sector, defined as *"the catching sub-sector, including shipowners, small-scale fishermen, employed fishermen, producer organisations as well as, amongst others, processors, traders and other market organisations and women's networks"* (Council 2004: art. 1), which according to the legal foundation should have 2/3 of the seats. The remaining 1/3 is to be filled with representatives of other interest groups, including *"amongst others, environmental organisations and groups, aquaculture producers, consumers and recreational or sport fishermen"* (Council 2004: art. 1). Other than the members, a number of people can be involved either as experts or active observers. These include Commission representatives, member state representatives, scientists, representatives from third countries etc. The RACs are primarily meant to function as advisory bodies towards the Commission but member states can also draw on the RACs for resolutions. The RACs are also mandated to issue resolutions on their own initiative (Council 2002). The Commission (or the member state authorities) is not obliged to follow a recommendation from a RAC and, therefore, in practice the advantage of following a recommendation from the RAC will always be weighed against other preferences of those receiving the recommendation. A critical discussion of the lack of formal powers of the RACs can be found in Gray and Hatchard (2003).

The RACs are either organised along specific sea areas roughly corresponding to large marine ecosystems / regional seas (five RACs[20]) or specific types of fisheries (two RACs[21]) (Council 2004). It is noteworthy that the introduction of RACs introduced a new political level in EU fisheries management which meant there was, for the first time, a close one-to-one match between a level of management in the governance system and a biological, ecological scale in the natural system (see Figure 1.4.1). Each RAC consists of a General Assembly (GA) and an Executive Committee (ExCom). The membership of particularly the GA is rather fluent from year to year, particularly for RACs with many smaller organisations in the GA. However, in practice most of

---

[20] Baltic Sea RAC, North Sea RAC, South Western Waters RAC, North Western Waters RAC and Mediterranean RAC.

[21] Pelagic RAC and Distant Waters RAC.

the work on the resolutions is done in a number of specific working groups set up under each RAC. It is the ExCom that adopts recommendations, as far as possible, by consensus. However, if it is not possible to arrive at a compromise that is acceptable to all, then decisions can be taken by a majority vote but dissenting opinions should then be recorded in the resolution (Council 2004). However, it is clear that generally consensus resolutions have considerably more political clout in the decision-making process than resolutions including dissenting opinions; particularly if a broad selection of RAC members both from the sector and other interests has been active in the process of drafting the resolution.

Based on a study of the process of developing a long-term management plan for horse mackerel within the Pelagic RAC, Hegland and Wilson (2008) identified a number of challenges the Pelagic RAC faced in its work on the plan. In particular, as a general challenge to the RACs, the issue of the limited access to funding emerged. This is particularly a challenge for the conservation organisations, which have to cover the meetings of most or all of the RACs because they are dealing with cross-cutting issues. On top of this, the limited access to funding complicates a number of initiatives that the RACs could potentially engage in because they have difficulties for instance paying travel costs for invited experts. However, at the same time, the horse mackerel process also evidenced a considerable capacity of the Pelagic RAC to overcome these challenges.

1.4.3.4.1.1 North Western Waters RAC[22]

The North Western Waters RAC (NWW RAC) became operational in 2005 and covers ICES areas Vb (EC waters), VI and VII. Table 1.4.7 beneath outlines the membership of the NWW RAC in relation to both the GA and the ExCom.

Table 1.4.7: Membership of the NWW RAC as of February 2009[23]

Organisation	Country	Sector	GA	ExCom
AIPCE-CEP	EU	Fisheries Sector	X	X
Anglo-North Irish FPO Ltd (ANIFPO)	UK	Fisheries Sector	X	
ARPESCO	Spain	Fisheries Sector	X	
Assciacion Nacional de Armadores de pesca en El Gran Sol (ANASOL)	Spain	Fisheries Sector	X	X

[22] This section builds for the most on information from the NWW RAC's website: http://www.nwwrac.org/ (accessed 12 February 2009).
[23] Based on information from the NWW RAC secretariat.

Association Nationale des Organisations de Producteurs (ANOP)	France	Fisheries Sector	X	X
CAPSUD OP	France	Fisheries Sector	X	
Comité National des Pêches Maritimes et des élevages Marins (CNPMEM)	France	Fisheries Sector	X	X
Comité Régional des Pêches Maritimes et des élevages Marins de Basse Normandie	France	Fisheries Sector	X	
Comité Régional des Pêches Maritimes et des élevages Marins de Bretagne	France	Fisheries Sector	X	
Comité Régional des Pêches Maritimes et des élevages Marins de Haute-Normandie	France	Fisheries Sector	X	
Comité Régional des Pêches Maritimes et des élevages Marins du Nord/Pas de Calais/Picardie	France	Fisheries Sector	X	
Confédération Française des Travailleurs Chrétiens / Syndicat Prof. Des Marins	France	Fisheries Sector	X	X
Coopératives Maritimes Etaploises & Armement Cooperatif Artisanal du Nord	France	Fisheries Sector	X	
Copeport Maree OPBN	France	Fisheries Sector	X	
Cornish Fish Producers Organisation Ltd	UK	Fisheries Sector	X	
European Anglers Alliance	EU	Other Interest Group	X	X
European Association of Fishing Ports and Auctions (EAFPA)	EU	Fisheries Sector	X	X
European Bureau for Conservation and Development (EBCD)	EU	Other Interest Group	X	X
Fédération Internationale de la Pêche Sportive en Mer (FIPS-M)	EU	Other Interest Group	X	
FEDOPA	France		X	
Fleetwood Fish Producers Organisation PO	UK	Fisheries Sector	X	
France Pêche Durable et Responsible	France	Fisheries Sector	X	
From Bretagne	France	Fisheries Sector	X	
FROM Nord	France	Fisheries Sector	X	

Irish Fish Producers Organisation (IFPO)	Ireland	Fisheries Sector	X	
Irish Fishermens Organisation	Ireland	Fisheries Sector	X	
Irish Seal Sanctuary	Ireland	Fisheries Sector	X	X
Irish South and East Fishermens Organisation	Ireland	Fisheries Sector	X	
Irish South and West Fishermens Organisation	Ireland	Fisheries Sector	X	X
Killybegs Fishermens Organisation	Ireland	Fisheries Sector	X	X
Lonja de La Coruna S.A.	Spain	Fisheries Sector	X	
Mallaig and North West Fisheries Association	UK	Fisheries Sector	X	
Manx Fish Producers Organisation	UK	Fisheries Sector	X	
Mna na Mara	Ireland	Other Interest Group	X	X
National Federation of Fishermen's Organisations (UK)	UK	Fisheries Sector	X	X
North East Scotland Fishermen's Organisation Ltd (NESFO)	UK	Fisheries Sector	X	
O Malley Fisheries	Ireland	Fisheries Sector	X	
OPP13	Spain	Fisheries Sector	X	
Organisation des Pêcheries de l'Ouest Bretagne	France	Fisheries Sector	X	
Organización de Productores de Pesca (OPPAO)	Spain	Fisheries Sector	X	X
Organizacion de Productores Pesqueros de Lugo	Spain	Fisheries Sector	X	
Orkney Fisheries Association & Orkney Fish Producers Organisation Ltd	UK	Fisheries Sector	X	
Pescagalicia-Arpega Obarco	Spain	Fisheries Sector	X	
Puerto de Celeiro	Spain	Fisheries Sector	X	
Rederscentrale	Belgium	Fisheries Sector	X	X
Royal Society for the Protection of Birds, representing Birdlife International	EU	Other Interest Group	X	X
Scallop Association	UK	Fisheries Sector	X	
Scottish Fishermen's Federation	UK	Fisheries Sector	X	X

SOCOSAMA	France	Fisheries Sector	X	
South West Fish Producers Organisation Ltd	UK	Fisheries Sector	X	
Stichting van de Nederlandse Visserij(Dutch Fisheries Organisation)	Netherlands	Fisheries Sector	X	X
Stichting van de Nederlandse Visserij(Dutch Fisheries Organisation)	Netherlands	Fisheries Sector	X	X
Stichting voor Duurzame Visserij Ontwikkeling (SDVO)	Belgium	Fisheries Sector	X	X
Union des armateurs de la pêche en France (UAPF)	France	Fisheries Sector	X	
Welsh Federation of Fishermen's Associations	UK	Fisheries Sector	X	
West of Scotland Fish Producers Organisation Ltd	UK	Fisheries Sector	X	
World Wildlife Fund (WWF)	EU	Other Interest Group	X	X

The North Western Waters RAC (NWW RAC) has, due to the large spatial area that it covers, has set up four geographically defined working groups: Working Group 1 deals with the West of Scotland, Working Group 2 deals with the West of Ireland and Celtic Sea, Working group 3 deals with the English Channel, and Working Group 4 deals with the Irish Sea.

1.4.3.4.1.2 Pelagic RAC[24]

The Pelagic RAC became operational in 2005 and deals with issues related to four pelagic species in all EU waters: blue whiting, horse mackerel, mackerel and herring, and the Pelagic RAC is consequently also relevant for the North Western Waters.

The Pelagic RAC is according to Hegland and Wilson (2008) among the most active of the RACs and has during its short life *"developed a great deal of institutional momentum"* (Hegland and Wilson 2008: 6). Table 1.4.8 beneath outlines the membership of the Pelagic RAC in relation to both the GA and the ExCom.

Table 1.4.8: Membership of the Pelagic RAC as of February 2009[25]

[24] This section builds for the most on information from the Pelagic RAC's website: http://www.pelagic-rac.org/ (accessed 12 February 2009).
[25] Based on information from the Pelagic RAC's website and information from its secretariat.

Organisation	**Country**	**Representing**	**GA**	**ExCom**
Association Nationale des Organisations de Producteurs (ANOP)	France	Industry	X	
Comité National des Pêches Maritimes et des Elevages Marins (CNPMEM)	France	Industry	X	
Confederación Española de Pesca (Cepesca)	Spain	Industry	X	X
Coopóratives Maritimes Etaploises - Organisation de Producteurs (CME - OP)	Spain	Industry	X	
Danmarks Fiskemel- og Fiskeolieindustri	Denmark	Industry	X	
Danmarks Fiskeriforening	Denmark	Industry	X	
Danmarks Pelagiske Producentorganisation	Denmark	Industry	X	X
Danske Fiskeres Producent Organisation (Danish PO)	Denmark	Industry	X	
EU Fishmeal Association	International	Industry	X	X
European Association of Fishing Ports and Auctions (EAFPA)	International	Industry	X	X
European Anglers Alliance	International	Other interests	X	X
European Bureau for Conservation and Development (EBCD)	International	Other interests	X	X
European Transport Workers' Federation (ETF)	International	Industry	X	X
Federación de Cofradias de Pescadores de Bizkaia	Spain	Industry	X	
Federación de Cofradias de Pescadores de Guipuzcoa	Spain	Industry	X	
Federation Internationale de la Pêche Sportive en Mer (FIPS-M)	France	Industry	X	
Federation of National Organisations of Importers and Exporters of Fish (AIPCE-CEP)	International	Industry	X	X
Fonds Régional d'organisation du marché du poisson (FROM Nord)	France	Industry	X	
Herring Buyers Association Limited	International	Industry	X	

Irish Fish P.O.	Ireland	Industry	X	
Irish South & West Fish Producers Organisation Ltd.	Ireland	Industry	X	
Killybegs Fisherman's Organisation Ltd.	Ireland	Industry	X	X
National Federation of Fishermen's Organisations	UK	Industry	X	
North Atlantic Producers Organisation	Poland	Industry	X	X
Organizacion de Productores de Pesqueros de Lugo	Spain	Industry	X	
Pescagalicia-Arpega-Obarco	Spain	Industry	X	
Dutch pelagic freezer-trawler association (RVZ)	Netherlands	Industry	X	X
Scottish Fishermen's Federation	UK	Industry	X	
Scottish Fishermen's Organisation Ltd	UK	Industry	X	
Scottish Pelagic Fishermen's Association (SPFA) Ltd	UK	Industry	X	X
Seas at Risk	Internationa l	Other interests	X	X
Seefrostvertrieb GmbH	Germany	Industry	X	X
Shetland Fish Producers' Organisation	UK	Industry	X	
Shetland Fishermen's Association	UK	Industry	X	
Skagen Fiskernes Producent Organisation	Denmark	Industry	X	
Swedish Fishermen's Federation	Sweden	Industry	X	X
Union des Armateurs à la Peche de France (UAPF)	France	Industry	X	X
University of Copenhagen	Internationa l	Industry	X	
WWF European Policy Office	Internationa l	Other interests	X	X

The Pelagic RAC has set up two working groups: Working Group I dealing with herring and mackerel and Working Group II dealing with blue whiting and horse mackerel.

1.4.3.5 The Member State Level

Aside from Norway in the North Sea, the European countries of relevance in the MEFEPO regions are all EU member states. This means, as described earlier, that they are subject to the CFP framework. In the following sections we will initially provide a generic understanding of the role and responsibilities of the member states in the EU governance system. Subsequently, we will, based on features of selected EU member states, provide a brief account of convergence and divergence between national governance systems. Although there are significant similarities between the member states, there are also differences between them, e.g. in terms of how centralised or decentralised the national governance system is, or the extent to which user groups and other interest groups are involved in the national governance system.

1.4.3.5.1 The Role of the EU Member States in the CFP Governance System

Although the conservation of resources is a fundamental pillar of the CFP, and under the exclusive competence of the EU, this does not mean that member states are powerless to protect marine resources. Importantly, as described in section 1.4.3.3.3, the member states occupy a central role in the decision-making process through their membership of the Council. Though the Commission is also a powerful actor at the EU level (section 1.4.3.3.1**)**, it is ultimately the member states themselves that adopted the legislation of the CFP.

Moreover, it is the member states that are tasked with implementing CFP legislation nationally, although most of the legislation under the CFP is adopted in the shape of regulations that are directly binding on the member states. The power of implementation does allow the member states to take national considerations into account. As discussed in Gezelius et al. (2008), the Commission is only to a limited degree able to control and sanction member states that take these national considerations too far and engage in implementation practices that are problematic as seen from central EU perspective. This is particularly the case when unsustainable implementation practices are not outright against the rules but rather against the spirit of the rules.

In terms of the setup for governance it is particularly important to note that it is the member states themselves that are primarily responsible for control and enforcement in their own waters. The basic regulation (Council 2002) and more detailed legislation (e.g. Council 1993) provide details on how control and enforcement activities should take place but much is left to the discretion of the member states. Examples of other important areas where the member states have responsibilities for fisheries management decisions include allocation of fishing opportunities and adjustment of capacity. The issue of allocation of fishing opportunities deals with the question of how to allocate the national quotas within the national fleet. The member states vary significantly on this point but there is an increasing tendency to use market based approaches such as individual transferable quotas (ITQs). The issue of adjustment of capacity deals with the question of how to determine which vessels that are taken out of the fleet to allow for the entry of new vessels. Originally the EU set targets for capacity reduction, a practice that has now been abandoned in favour of a simpler exit/entry scheme where new additions to the national fleet presuppose that existing capacity is withdrawn from the fleet.

How the national institutional setup for fisheries management looks like in practice differs from member state to member state; something we will look more at in the following section. However, in Figure 1.4.1 we have outlined the basic elements of any national system: 1) Political institutions to legislate in the areas where the member states themselves are in charge, e.g. allocation of fishing rights. 2) Managerial institutions tasked with executing the decisions of the political system including the EU. 3) Stakeholders, often predominantly from industry but increasingly from conservationist NGOs, offering advice both to managers and politicians either through formal or informal channels. 4) National research and advisory institutes that monitor the state of fish stocks (as well as carry out other research activities related to fish and fisheries) and feed data and experts into ICES and STECF. Besides the institutions depicted in the figure, there is also a national legal system. And as mentioned earlier, if the state has delegated responsibilities to regional governments then the picture gets more complicated, see section beneath.

1.4.3.5.2 Variations of National Governance Approaches in Selected EU Member States[26]

The current fisheries governance landscape in Europe is diverse regarding the dominant forms of institutional design. Much of this variation is attributable to the varying political traditions across member states.

In Denmark the national governance system is largely influenced by the political environment in Scandinavia where ‘negotiation economies’ prevail (Hoel et al. 1997; Hersoug 2005; Christensen et al. 2007, and Hegland and Raakjær 2008), applying a centralised consultation of user-groups and stakeholders in the decision-making process. This tradition is rooted in the co-operative movement, which took off more than a century ago. Policy-making in Denmark fits the tradition of corporatist management, involving industry and user-groups in the decision-making through various types of advisory bodies. The system can be characterised as ‘centrally directed consultation’.

France has a tradition of territorial management and this has created a strong focus on the state. In general, decision-making arrangements are dominated by political and institutional traditions with a sector-based corporatist structure. The state undertakes a systematic consultation process at the national level and decision-making power is delegated to the regional levels as well. In parallel to the rather structured official system (with a relatively clear

[26] This section draws intensively on Hoof et al. (2005).

division of responsibilities) there is a system based on informal agreements between the different groups, the administration and political bodies (such as the state and territorial communities).

The political philosophy in the Netherlands is based on ‘subsidiarity’ and ‘sovereignty’ having the implication that the government is willing to devolve responsibility to industry. In an organisational sense this is exemplified by corporatist institutions for inclusion of sector interest, including fisheries in the Dutch economy (since 1950). Here social organisations and their elite act as interest groups. Those interest groups take far-reaching decisions in consultative bodies without consulting the parliament (Hoefnagel 2002). Recently corporatist institutions have been weakened in terms of policy making and created a vacuum for policy mediation between government and sector interests. In Dutch fisheries co-management arrangements have largely filled this vacuum, but these are not yet properly institutionalised.

The Spanish system of organising the state into autonomous communities, which are delegated legislation authority to implement basic state legislation, has led to a high level of regional self-governance. This has resulted in a rather complex and complicated administrative framework, because new authorities and structures are constantly emerging. In the Spanish fisheries management model a tension exists between the different aims that are reflected by the present division of responsibilities between the various authorities and the move towards greater involvement of the fisheries sector in the decision-making process. However, the institutional set-up for participation has be accused for an imbalanced representation having an over-representation of the fishing industry in state and autonomous communities’ consultative bodies providing limited space for other stakeholder groups. Furthermore, there is an overlap in resource management powers and responsibilities between the state and the autonomous communities and boundaries are not clearly defined, seemingly resulting in management objectives not being achieved.

The United Kingdom has applied an approach in which local institutional traditions are followed with a relative high degree of regionalisation of policy-making procedures. The UK institutional setting is very old with some remnants of the feudal era still in place. There is no written constitution and a rather powerful executive. Both the executive and civil service do not routinely consult before deciding policies, and citizens do not participate in decision-making, and the civil service does not yet have a culture of sharing information with citizens. Quango's (quasi autonomous government organisations) play an important role in day-to-day management. Accountability of these is considered to be rather low. Regional decentralisation and devolution is currently being introduced, manifested by the Scottish Parliament and Scottish Assembly, Welsh Assembly and Northern Ireland Assembly. Fisheries management has to a large extent been devolved. The fishing industry is divided in numerous organisations tied to a region or a specific fleet segment. The environmental organisations are immensely popular, with large membership that provides funding for lobbying, media campaigns and research in the areas of fisheries. The executive manages fisheries without duty to consult or negotiate with the industry. Lobbyism is well known, and the industry participation is very fragmented (Symes 1996).

1.4.3.6 Characteristics of the Common Fisheries Policy Governance System

The CFP can in many ways be argued to take the form of a classical intergovernmentalist, state-centric command-and-control, top-down management system, where member states' ministers in the Council exercise strong control over the fisheries management measures, which are developed and adopted[27] on the background of proposals from the Commission. The member states are responsible for the implementation of the rules and for monitoring compliance in relation to fishing activities taking place in waters under their jurisdiction, and they report back to the Commission, which is among other issues tasked with *"making sure that CFP rules are effectively implemented and that Member States set up and apply appropriate systems and rules to manage, control and enforce the limitations on fishing possibilities and fishing effort required by the CFP"* (DG MARE 2008).

Though situated at the top of the top-down structure together with the Council, the Commission has very weak powers in relation to direct control and monitoring of fishing activities compared to the member states. Gezelius et al. (2008) analyse with outset in the principal-agent approach the relationship between the EU (in that analysis treated as principal) and the member states (in that analysis treated as multiple agents) and document how the EU, represented by the Commission, is on crucial points in a weak position *vis-à-vis* the member states. One of the key findings of the analysis is the apparent inability of the EU to sanction member states whose implementation practices conflict with the intention of the rules or the with overall political goals *but are not directly against the rules* (in principal-agent terminology this can be referred to as *non-criminal agency drift*).[28] Usually non-criminal agency drift can be moderated by amending the framework that the agents operate under to change the incentive structure or make rules less open to interpretation. However, this has often not been possible under the CFP, which to a wide extent rests on sticky historical compromises. Moreover, the member states in the Council tend to be aligned in semi-permanent groups, each able to produce a blocking minority (Hegland 2004 and Raakjær 2008). Another key finding relates to the fact that the Commission largely relies on the member states themselves in the process of monitoring and overseeing

[27] If necessary by means of qualified majority vote (QMV).

[28] One example could be that for the most fundamental conservation measures under the CFP, the TACs and quotas, there are few incentives for the member states to catch their quotas in a conservationist manner, i.e. reduce discards (fish thrown back dead or dying in the sea because they are too small or the vessel does not have a quota for them), at least if the stocks in question are shared with other member states. Whereas the benefits of being able to fish even with high discard rates are reaped by the individual member state, the negative impact of the non-conservationist behaviour is shared among all the member states, who will receive lower quotas in the following year. This is a typical example of the "tragedy of the commons" dynamic (Hardin 1968). The EU has so far been unsuccessful in putting an incentive structure in place to eliminate this problem (Gezelius et al 2008).

their management efforts (although conservation NGOs can and do function as watchdogs). The Commission does not have the institutional capacity or legal mandate to genuinely monitor the member states and the member states in the Council are traditionally reluctant to transfer 'police-like' authorities to the Commission. Consequently, Gezelius et al. (2008: 217) conclude that *"it is hard to escape the fact that what seems to characterise the CFP from a principal-agent perspective seems to be strong incentives for the agents to drift away from conservation and weak powers on behalf of the principal to prevent this".*

At the other end of the top-down process, Lequesne (2004) argues that although administrations of sub-national regions in some member states do have management tasks *vis-à-vis* fisheries there is little evidence that these administrations interact directly with supranational EU institutions with loss of central state control over the fisheries policy agenda as a result. Moreover, the fishermen as recipients of the management measures are weakly represented in the upstream policy formulation processes. The fishermen do not have any direct say in fisheries management at EU level. Though the Commission is in its preparatory work supported by input from various sources, incl. stakeholder fora (see Figure 1.4.1); it is not obliged to include stakeholder input in its proposals. Moreover, the pan-European organisation that organises the fishermen's organisations from the largest fishing nations in EU, Europêche, is weak due to limited institutional capacity and strong disagreements among its member organisations, and consequently its impact is limited. Instead the fishermen's organisations prefer to lobby their national administrations individually, which reinforces the member states' governments as central hubs in the process.

1.4.3.7 Selected Reforms of the Current EU Fisheries Governance System

1.4.3.7.1 Providing a Level Playing Field for the Industry across EU[29]

The CFP framework has for a long time been widely criticised for not being able to ensure efficient and uniform control and enforcement of its legislation. In response, the Commission is currently taking action to overhaul the control and enforcement system of the CFP as a core priority. The reformed framework is projected to enter into force from 2010.

1.4.3.7.2 Describing the Problem

Two reports published in 2007 summed up the shortcomings of the current system for control and enforcement. The European Court of Auditors (2007) provided an external analysis of the enforcement system of large fisheries nations in the EU: Denmark, Spain, France, the Netherlands, Italy and the United Kingdom (England and Wales). The report tested the national enforcement systems in terms of: 1) their ability to provide complete and reliable data, 2) the application of effective inspections and 3) the application of an effective penalty system. On

---

[29] [29] This section and subsections build for the most on information from the Commission's websites on the reform of the control and enforcement system: http://ec.europa.eu/fisheries/cfp/control_enforcement/reform_control_en.htm (accessed 20 February 2009).

these points the report drew devastating conclusions with implication for the entire framework of the CFP:

> *"The incompleteness and unreliability of catch data prevent the TAC and quota system, which is a cornerstone in the management of Community fisheries resources, from functioning properly. The regulatory framework and the procedures in force guarantee neither the exhaustiveness of data collection, nor the detection of inconsistencies during validation. Nor is the Commission in an overall position to identify errors and anomalies in the data forwarded by Member States, and, to take all the timely decisions required to protect the resource."* (European Court of Auditors 2007: 49)

> *"The inspection systems do not prevent infringements and do not ensure that they are effectively detected. The absence of general standards has resulted in the existence of divergent national systems that neither ensure adequate inspection pressure nor optimise inspection activities. Furthermore, it actually limits the scope and effect of the Commission's work of evaluating national arrangements, and as a consequence limits the latter's capacity to form an opinion as to the overall effectiveness of the national systems."* (European Court of Auditors 2007: 49f)

> *"The procedures for dealing with infringements found do not support the assertion that every infringement is followed up and even less that it is subject to penalty. Even when penalties are imposed, taken as a whole they prove to have very little deterrent effect. With regard to infringements of Community legislation by a Member State, the only instrument of proven effectiveness available to the Commission is an action before the Court of Justice for failure to fulfil an obligation. This however has certain features which limit its use and make it an insufficiently responsive instrument."* (European Court of Auditors 2007: 50)

Although this was not an aim of the report, it nonetheless also indicated that there is a wide variation across the six selected member states in terms of how well the national systems of control and enforcement delivers in terms of the points above. There has been little attention to this fact, likely because the variation across member states on this point is a highly contentious issue. However, Hegland and Raakjær (2008a) made a simple count of critical comments (thus without discussing the severity of them) directed towards specific member states and found that Denmark and the Netherlands each received three remarks; Spain, Italy and the UK more than ten and France almost 20. However, although with some variation across member states, the picture that the report painted was that of a system generally not functioning properly.

The report, entitled *Report from the Commission to the Council and the European Parliament on the monitoring of the Member States' implementation of the Common Fisheries Policy*, was presented to the Council and the Parliament by the Commission (2007) itself and was, although positive developments were duly noted, not much more positive in its conclusions, which included among other things in the 'negative-department' that:

> *"many inspectors are not fully qualified for the work required"*, "[t]*he recording of inspection activity is patchy and not harmonised in a way that would enable results to be compared between Member States"*, "[p]*ort inspections are too often poorly organised, some of the basic catch registration documents are still not collected in many Member States"*, "[a] *better use of well defined risk-based strategies could increase the efficiency of the control resources"*, and "[i]*nfringing the rules of the CFP is a risk some individual fishermen may be prepared to take given the low chance of detection of infringements or the application of any dissuasive sanctions."* (Commission 2007: 7-9)

According to the report, the above shortcomings have resulted in lack of compliance with key rules of the CFP in a number of fisheries. Importantly, compliance with TACs and quotas continues to be a problem, which is especially problematic in a situation where drastic reductions in fishing mortality are called for in relation to a number of stocks. Moreover, mis-reporting of (or failure to report altogether) landings undermines the management of TACs and quotas by forcing scientists to work with estimations of actual catches in cases where official figures are not considered reliable. Furthermore, the report noted that control of fishing effort often seemed to be organised in a way that caused the least effect on actual fishing activity, that satellite tracking systems had not effectively been used to monitor fishing effort and that significant amounts of undersized fish continued to be landed. (Commission 2007)

Notably, the inability under the CFP of the member states to ensure - in practice by means of Commission oversight and actions - that other member states enforce regulation strictly on their own fishermen creates a 'Tragedy of the Commons' situation where no member state views it as being in its best interest to enforce strictly *vis-à-vis* own fishermen (Raakjær Nielsen 1992). On its website on reform of the control and enforcement system the Commission sums up the motivations behind taking action now in these words:

"The control system is now caught in a kind of vicious circle. Inadequate control undermines the reliability of the basic data on which scientific advice is formed. Fisheries policy decisions based on this scientific advice lead to unsustainable catch levels, which impact on the stocks even more. EU and Member State inspectors are currently unlikely to discover fraudulent practices. When they do, the penalties imposed are often much lower than the potential profits to be made from overfishing. When the Commission detects a serious problem in the performance of national control systems, a lack of legal tools hampers its ability to react quickly and effectively. At the same time, new technologies offer a potential that is not used to the full."[30]

1.4.3.7.3 Control Reform

In its preparations for a reform of the control and enforcement system of the CFP, the Commission considered various general options. As a result, impact assessments of four possible strategies were carried out: The *first option* considered was to continue within the current policy framework. This option had two sub-options: one where there was no policy change (basically a continuation of *status quo*, and another where focus was put on adopting a number of implementation regulations containing technical rules to fully implement the current control regulation. The *second option* involved a recasting of the control regulation and the addition of a Code of Conduct. The *third option* included the introduction of a reform package through a new regulatory instrument in the form of a binding regulation. The *fourth and final option* considered was to centralise control at EU level with significantly increased powers for the Commission and to the newly established Community Fisheries Control Agency (CFCA) as a result. However, no real impact assessment of the forth option was carried out as this approach was at an early stage deemed as being not feasible both technically (because of it requiring a reallocation of tasks exceeding what the Treaties provide for, as well as it being extremely costly at EU level) and politically (because the member states would be unlikely to accept giving up this much power) (Commission 2008b, 2008c).

As for the remaining three options, both sub-options under option one were found not to be able to bring about the desired change in the system. The 'activist' sub-option two might in fact further add to the complexity of the legal framework, which had been identified as one of the major shortcomings of the current set-up. Option two - recasting of control regulation and Code of Conduct - was found to be able to improve the situation in some member states but not to the required degree and it would not bring about a level playing field. Consequently, the impact assessment suggested that option three would be the best choice under the prevailing circumstances, and this is the strategy that the Commission has followed:

[30] Cited from http://ec.europa.eu/fisheries/cfp/control_enforcement/why_reform_en.htm (accessed 20 February 2009).

> *"A complete reform of the current fisheries control regime based on a binding Regulation as considered under option 3 would not only consolidate and simplify the existing legislation, currently spread over a number of different regulations. It would also allow us to develop a new, harmonised approach to inspection and control covering all aspects from 'net to plate', to develop a common culture of compliance and to ensure the effective application of CFP rules. The outcome would be a truly global and integrated control system able to restore the confidence of stakeholders in the CFP."* (Commission 2008c: 5)

According to the Commission, the proposed reform along the lines of the third option, currently embodied by the Commission's proposal (Commission 2008a), aims in general terms to: simplify the legal framework within the area; broaden the scope for control by including previously neglected fields and other areas where a need for control has emerged; establish a level playing field for control by harmonising inspection procedures and penalty systems; rationalise the approach to control and inspection by targeting on where the risk of infringements is highest; and reducing the administrative burden partly by using modern technologies; and, finally, ensure more effective application of CFP rules by increasing the focus on controlling and verifying the member states' implementation of the rules and giving the Commission and the Community Fisheries Control Agency (CFCA) new tools to react stronger and quicker when infringements are detected.

Under the new framework the mandate of the CFCA and its Community inspectors will be broadened. The CFCA will under the new framework as proposed by the Commission be in a position to carry out on-the-spot checks on the territory of member states, to set up emergency units with special powers and responsibilities when situations that pose a serious threat to the CFP arise. Furthermore the CFCA will be the responsible institution for coordination and exchange of data between other institutions and agencies of the EU (Commission 2008a, 2008d).

1.4.3.8 Making the Decision-Making Process more Participatory

The CFP has been criticised for being *"the most top-down command and control fisheries management regime in the developed world"* (Hegland and Wilson 2008:5). Only very recently the EU has taken steps towards a more participatory approach where a wide range of stakeholders are systematically invited to give advisory input to the decision-making process and where regional considerations are made when taking decisions. A continuation of this effort towards increased regionalisation and stakeholder involvement is likely to be an important part of the upcoming 2012 reform.

1.4.3.8.1 Describing the Problem

Stakeholders have traditionally had little direct say in the decision-making process relating to the CFP. Before the 2002 reform the primary source of direct input from stakeholders to the process was the Advisory Committee for Fisheries and Aquaculture (ACFA), which has seemingly exerted little real influence (section 1.4.3.3.1.2**)**. Most influential stakeholder input was consequently brought to the decision-making process in 'processed' form, indirectly by the member states' governments, which to varying extent engaged formally and informally with national interests groups in the domestic arena. It has been argued that this lack of direct, systematic and formal inclusion of stakeholders' input at EU level has contributed to the failure of the CFP[31] in at least two ways.

Firstly, the lack of inclusion of particularly industry stakeholders has been considered to have in part *contributed to the situation of widespread non-compliance with the CFP regulations*, which came to be in wide circles regarded as irrational, arbitrary decisions from a distant bureaucratic centre - the Commission - out of touch with the realities of the day-to-day situation of the sector. Although it is ultimately the member states themselves that adopt CFP legislation on the background of Commission proposals, the member states have to some extent found it convenient not to take co-responsibility for unpopular decisions and instead to some extent support this somewhat biased picture of the Commission and the CFP. Hence, most member states have consistently used the annual setting of TACs as an opportunity to bring 'victories' over the Commission home from Brussels - notably victories that have involved semi-systematic setting of TACs above the scientific advice. For some member states the picture has been the same in relation to the continued practice of allowing financial support to modernise old and build new vessels. From a political perspective, the practices of inflated TACs and financial support to increase fishing capacity are - while in themselves highly problematic - likely the most significant explanations of why the CFP has continuously failed to effectively address the issue of fleet overcapacity, which increasingly is identified as the most fundamental reason to the failure of the CFP to conserve fish stocks.

Secondly, it was considered a problem for the technical quality of regulations that input from stakeholders was not directly fed into the process of developing legislation at EU level. Stakeholders, in particular from the industry, have insight in how technical legislation works in practice - and in many instances also on how it could be made more effective and more difficult to circumvent.[32] The failure to include it and give the industry a feeling of partial ownership over

---

[31] However, it is worth mentioning that user and stakeholder consultation/representation in the CFP decision-making process is not new. Corporatist models have been widespread for decades in the various member states. At the EU level users and stakeholders have been consulted through the ACFA since the early 1970s. This is a clear indication that it is not without its challenges to develop structures for effective stakeholder involvement in relation to the CFP.

[32] This is supported by Raakjær (2008) who argue that it is critical to gain support from the fishers for imposed regulations in order to ensure compliance and to introduce more flexibility in the implementation of regulations. Dialogue with fishers is a precondition for this to happen. At the same time, however, users

the rules presents the risk that this knowledge is not employed to improve legislation and make it more robust but rather to evade legislation with negative impact on its effectiveness.

That stakeholders did not feel sufficiently included was confirmed by the consultations in advance of the 2002 reform of the CFP, which showed that stakeholders felt excluded from influencing several important aspects of the CFP, for example in the provision of scientific advice (see section 1.4.3.9 beneath) and technical legislation from the Commission. Particularly industry stakeholders felt that their experience based knowledge was not taken into account, neither by managers or politicians nor by scientists.

Besides the failure to include stakeholders, the CFP has also been accused of being too centralised and lacking a consideration of the different situations in different marine areas of the EU. Besides the fact that the Mediterranean has for various reasons never been included fully in the CFP, the CFP framework has been largely applied as a 'one-size-fits-all' management system covering all EU waters; although there is, as an example, little resemblance between the fisheries taking place in the Baltic Sea and the fisheries taking place off the coast of Portugal. There has, at least in part due to the presence of a 'one-size-fits-all' approach, been considerable reluctance in the Council to experiment with regional distinct solutions due to a fear of these solutions subsequently being applied to regions, where they are not welcomed. In part as a consequence of a one-size-fits-all and exclusive competence of the EU, EU regulations include moreover an array of micro-management regulations as the example beneath illustrates:

"It is prohibited to carry on board or deploy any beam trawl of mesh size equal to or greater than 80 mm unless the entire upper half of the anterior part of such a net consists of a panel of netting material of which no individual mesh is of mesh size less than 180 mm attached:

- *directly to the headline, or*
- *to no more than three rows of netting material of any mesh size attached directly to the headline.*

The panel of netting shall extend towards the posterior of the net for at least the number of meshes determined by:

- *(i) dividing the length in metres of the beam of the net by 12;*
- *(ii) multiplying the result obtained in (i) by 5 400 and*

---

and stakeholders have vested interest in the process and there are several examples where industry representatives have advocate for regulations that protect the interests of fishermen at the expense of conservation concerns and society at large. As well as conservation NGO's have argued for more severe restrictions on fishing that can be justified by conservation concerns. This is a clear indication of the difficulties to separate technical and political decisions in practice.

- *(iii) dividing the result obtained in (ii) by the mesh size in millimetres of the smallest mesh in the panel and*
- *(iv) ignoring any decimal or other fractions in the result obtained in (iii)."*

(Commission of the European Communities 2001: Art 5.3)

1.4.3.8.2 Regionalisation and Greater Involvement of Stakeholders

However, as described in section 1.4.3.4.1, following the 2002 reform a number of Regional Advisory Councils (RACs) have been set up to provide input from stakeholders on issues applying to specific fisheries or specific sea areas. The RACs constitute so far the most important response to the critique arguing that (particularly sub-EU level) stakeholders have not to a sufficient degree been included in the decision-making process at EU level, and that earlier and more consequent inclusion of these stakeholders could potentially lead to both better decisions, due to their expertise from the field, and a higher degree of compliance, due to a feeling of ownership over the rules on behalf of especially industry stakeholders (Hegland 2006).

RACs were, as discussed, proposed by the Commission as purely advisory bodies as a tentative step toward more stakeholder participation in developing EU fisheries policy; the idea being that the stakeholders on a RAC will seek a consensus about fisheries management and policy issues and thereby allow DG MARE to weigh the political advantages of following the RAC's consensus against any differences between the consensus and other preferences of DG MARE (Hegland and Wilson 2008). A description of the RACs' composition and mandate has been provided in section 1.4.3.4.1.

To what extent the role of the RACs and the RAC regions will be rethought in connection with the 2012 reform remains uncertain. However, it deserves mentioning that Sissenwine and Symes (2007) in their review of the CFP award special attention to the concept of regionalisation as an option in relation to future management under the CFP. Moreover, in the first official document from the Commission on the 2012 CFP reform, entitled *Reflections on further reform of the Common Fisheries Policy,* a move to greater use of *"regional management solutions"* (Commission 2008: 8) (possibly later than 2012) is also mentioned as a major, longer term reform possibility. However, the Commission does not in this paper specifically address the role of RACs in this respect.

According to Raakjær (2008) regionalisation of the CFP is not a new idea and is in line with the thinking that led to the creation of RACs as part of the 2002 reform. The move to ecosystem approaches in fisheries management is another factor that can support regionalisation of the CFP.

However, turning again to the way stakeholders are increasingly, directly involved in CFP decision-making, besides the increased focus on including stakeholders through the RACs, the Commission is also increasingly inviting stakeholder contributions to proposed initiatives by means of open consultations announced on its website. However, the extent to which these open and broad consultations actually have any impact on Commission policy is uncertain. As the example in Table 1.4.9 beneath shows, the open consultations attract contributions from a wide variety of stakeholders.

Table 1.4.9: Contributions received: open consultation on control reform (consultation closed 5 May 2008)[33]

Type of actor	Name of contributor
Advisory body	Baltic Sea RAC
	Long Distance RAC
	Advisory Committee on Fisheries and of Aquaculture (ACFA)
	North Western Waters RAC
Industry	Productschap Vis
	European Association of Fishing Ports & Auctions
	Deutscher Fischerei-Verband e. V.
	Asociación Nacional de Fabricantes de Conservas de Pescados y Mariscos
	Stowarzyszenia Armatorów Rybackich
	Comité National des Pêches Maritimes et des Elevages Marins
	CNES, CLS, DCNS, Thales (Alenia Space, Airborne Systems, Maritime Safety & Security)
	Association Nationale des Organisations de Producteurs (ANOP) et de l'Union des Armateurs à la Pêche de France (UAPF)
	Docapesca Portos e Lotas SA, Delegação do Sotavento Algarvio
	European Association of Fish Producers Organisations / Association Européenne des

[33] From http://ec.europa.eu/fisheries/cfp/governance/consultations/consultation_280208_contributions_en.htm (accessed 23 February 2009).

	Organisations de Producteurs dans le secteur de la pêche
	Europêche/COGECA
	SHOAL: Shetland Oceans Alliance
	WWF
	Coalition for Fair Fisheries Arrangements
NGOs	Conference of Peripheral and Maritime Regions of Europe
	The Pew Charitable Trust's EU Marine Programme
	Birdlife International
Mixed membership associations	FishPopTrace Consortium
Public authorities	UK Statutory nature conservation agencies
	Prof. Corrado Piccinetti
Individuals	Johnny Woodlock,, http://ec.europa.eu/fisheries/cfp/governance/consultations/contributions111207/33_ligue_roc_fr.pdfSea Fisheries Advisory Group, Irish Seal Sanctuary

Generally, in terms of the involvement of industry stakeholders, the Commission document on the 2012 reform emphasises strongly the need to move past the present decoupling of rights and responsibilities so that it becomes increasingly up to those exploiting the common resource to document that this is happening in the way society has prescribed:

> *"Very little can be achieved if a reform does not include elements which will motivate the industry to support the objectives of the policy and take responsibility for effective implementation. Industry incentives need to be turned around from the present set-up, where it pays to be irresponsible, to a situation where fishermen would be made responsible and accountable for sustainable use of a public resource."* (Commission 2008: 8)

"Results-based management, where the industry is made responsible for outcomes rather than means, would be a move in this direction. Results-based management will also relieve both the industry and the legislators of part of the burden of detailed management of technical issues, to which the industry tends to adapt with solutions that are economically ineffective and sometimes even counterproductive i.e. in relation to safety at sea and energy efficiency. Results-based management can be linked to a reversal of the burden of proof whereby it is up to the industry to demonstrate that it operates responsibly in order to get access. This would lead to simplification and reverse the present incentives where it pays to withhold information or even to provide false information." (Commission 2008: 8)

Thus, the Commission suggests that it would in principle be possible to relieve the industry of much detailed management in return for the industry itself being responsible for documenting that its actions do not result in unwanted outcomes.

Although the 2002 reform of the CFP to some extent responded to the lack of stakeholder input into the CFP decision-making process, the CFP is still far from being a policy-framework characterised by stakeholder participation. Although stakeholders are increasingly consulted through RACs or in other ways, there is still little or no role for them in terms of actually taking decisions or having responsibility for management functions.

1.4.3.9 Restructuring the Scientific Advice System relating to the CFP

The system that feeds scientific advice to the CFP decision-making process has in later years been criticised on a number of points. In the following sections we will go through some of the main issues and subsequently take a brief look at what has happened in response to the demand for reform and restructuring.

1.4.3.9.1 Describing the Problem

One of the major issues in relation to the scientific advice system for EU fisheries management has been the imbalance between the status and amount of biological advice compared to advice based on other forms of science. As also indicated by Figure 1.4.1, which is the simplified picture of the institutional set-up, it is biological institutions that dominate that picture. STECF does include particularly economic expertise and there are also in most member states institutions or individuals that carry out economic or socio-economic analyses within the area of fisheries management. However, socio-economic or economic information is not systematically fed in to the CFP decision-making system, as is the case with biological information from ICES. If at all socio-economic aspects are being considered it is not at all socio (the whole development of the community and knock on effects in the long run are hardly taking on board when evaluating ex ante a proposed management measure) and if economic analysis is included it is mere addition of cost and earning data in a short term perspective than a long term societal cost benefit analysis.

In the few cases, where socio-economic aspects are being considered they do not address important social issues, such as community development, and the knock on effects in the long run are hardly considered when evaluating ex ante a proposed management measure. Economic analyses are often of a bio-economic nature or merely an addition of cost and earning data in a short term perspective. In general, the availability of comparable and quality checked data are considered higher concerning biological issues than economic or socio-economic.

Another issue has been the inability or lack of interest from the biological advice system to include fishermen's experience-based knowledge in their analysis, or at least give fishermen better access to observing how the biological advice system works. This critique mirrors the one raised in relation to the limited inclusion of stakeholders in the overall CFP decision-making process, see above. The lack of transparency and openness of the biological advice system has, according to the critics, contributed to the lack of legitimacy of the scientific process and the CFP as a whole. The CFP is a very science dependent policy framework and it has not been conducive for the general support of it that scientific processes, which are fundamental for CFP outcomes have been taking place behind closed doors. This system appears to many outsiders to be a black box, where catch data, sometimes of questionable quality, is inserted in one end and TACs come out in the other end.

A third issue relates to the timing of the scientific advice. A particular problem in relation to this has been that the advice from ICES has not been available until very late in the year. This has meant that there has been very little time to agree on the TACs, which have to be in place by 1 January. As a result of this, TACs have traditionally been set for most stocks at a marathon meeting of the ministers on the Agriculture and Fisheries Council in the end of December. Taking decisions in this compressed way is problematic and it complicates feeding in and considering input from other sources, e.g. stakeholders. Additionally, the fishing industry have for a long time been calling for the TACs to be set earlier so that they would know their fishing opportunities for the coming year more in advance.

1.4.3.9.2 Reforms of the Scientific Advice System

The scientific advice system has in later years been undergoing a number of changes. In response to the lack of comparable data the Data Collection Regulation (DCR) is progressively being implemented and amended to facilitate the change from single stock management to fisheries or fleet-based management and the eco-system approach to fisheries management. Although primarily concerned with biological data, the regulation also calls for the collection of a range of economic and socio-economic data to provide a better basis for carrying out impact assessments of new legislation and better monitoring of the performance of the EU fleet. This must be considered as a step towards making comparable data on other than biological issues available and thus conducive for a strengthening of the possibility to get advice originating from other relevant scientific disciplines than biology.

In response to the perception of ICES as a black box, ICES has now opened its meetings to include stakeholders as observers and in some cases participants. The establishment of RACs has also had impact on the science system and strengthened the role of stakeholders in that process. ICES now have a range of stakeholder institutions that it can interact with, which was not the case before. Moreover, ICES has reorganised its internal committee structure to facilitate the kind of integrated advice that will be needed for implementing EAFM.

In response to the timing issue ICES has streamlined its processes to make the advice available earlier - often referred to as 'frontloading the advice'. This has, however, not been a straightforward process as the advice is dependent on an institutionalised rhythm of data gathering that is not easily changed (Wilson Forthcoming). Nevertheless, as from 2008 advice will come earlier and thereby allow more time to hear stakeholders and eventually also allow the industry to know its fishing opportunities earlier.

1.5 References

References for section 1.2

Acevedo, S., Dwane, O. and Fives, J.M. (2002) The community structure of larval fish populations in an area of the Celtic Sea in 1998. *Journal of Marine Biological Association U.K*: 82, 641-648.

Akhmetzhanov, A. M., Kenyon, N. H., Ivanov, M. K., Wheeler, A. J., Shashkin, P. V. & van Weering, T. C. E., 2003. Giant carbonate mounds and current-swept seafloors on the slopes of the southern Rockall Trough. In J. Mienert, P. Weaver (Eds) European Margin Sediment Dynamics: Side - Scan Sonar and Seismic Images. Springer-Verlag, p. 203-209.

Aldridge, J.N. 1997. Hydrodynamic model predictions of tidal asymmetry and the observed sediment transport paths on Morecambe Bay. *Estuar. Coast. Shelf Sci.* **44:** 39-56.

Aldridge, J.N. & A.M. Davies. 1993. A high-resolution three-dimensional tidal model of the eastern Irish Sea. *J. Phys. Oceanogr.* **23:** 207-224.

Alvarez *et al.,* 2004. Distribution and abundance of European hake *Merluccius merluccius* (L), eggs and larvae in the North East Atlantic waters in 1995 and 1998 in relation to hydrographic conditions. *Journal of Plankton Research*, **26**, 811-826.

Boelens, R.G.V., Maloney, D.M., Parsons, A.P. & A.R. Walsh. 1999. Ireland's Marine and Coastal Areas and Adjacent Seas: An Environmental Assessment. Marine Institute.

Bowden, F.F. 1980. Physical and dynamical oceanography of the Irish Sea. In: The northwest European shelf seas: the seabed and the sea in motion. II Physical and chemical oceanography and physical resources. F.T. Banner, W.B. Collins and K.S. Massie (eds). Elsevier, Amsterdam, Oxford and New York, pp. 391-413.

Brown, J. 1991. The final voyage of the 'Rapaiti'; An estimate of sea-surface drift velocity in relation to the surface wind in the North East Atlantic. *Mar. Poll. Bull.* **22:** 37-40.

Brown, J. & E.M. Gmitrowicz. 1995. Observations of the transverse structure and dynamics of the low frequency flow through the North Channel of the Irish Sea. *Cont. Shelf Res.* **15:** 1133-1156.

Brown, J. Hill, A.E., Fernand, L., Bennett, D.B. & J.H. Nichols. 1995. A physical retention mechanism for *Nephrops norvegicus* larvae. ICES, C.M. 1995/K:31 Ref.C.

Brown, J., Carrillo, L., Fernend, L., Horsburgh, K.J., Hill, A.E., Young, E.F. Medler, K.J. 2003. Observations of the physical structure ans seasonal jet-like circulation of the Celtic Sea and St. george's Channel of the Irish Sea. *Continental Shelf research.* 23 533-561.

Bozzano *et al.* 2005. Vertical distribution and feeding patterns of the juvenile European hake *Merluccius merluccius* in the NW Mediterranean. *Fisheries Research*, **73,** 29-36.

CEFAS. 2000. Quality Status Report of the Marine and Coastal Areas of the Irish Sea and Bristol Channel. Centre for Environment, Fisheries and Aquaculture Science. pp. 258.

Connor, D.W., Gilliland, P.M. Golding, N. Robinson, P., Todd, D. & E. Verling. 2006. UKSeaMap: the mapping of seabed and water column features of UK Seas, ISBN 86107 590 1.

Curry, R. Dickson, R. & Yasahayaev, I. 2003. A Change in the freshwater balance of the North Atlantic ocean over the3 last four decades, *Nature,* 426, 826–829.

De Grave, S., Fazakerley, H., Kelly, L., Guiry, M.D., Ryan, M. & Walshe, J. 2000. A Study of Selected Maërl Beds in Irish Waters and their Potential for Sustainable Extraction Marine Resource Series 10. Marine Institute, Dublin, 44pp.

De Mol, B. 2002. Development of coral banks in Porcupine Seabight (SW Ireland). A multidisciplinary approach. PhD Thesis. Faculty of Sciences, Department of Geology and Soli Science. Ghent, University of Ghent, 363pp.

De Mol, B., Kozachenko, M., Wheeler, A., Alvares, H., Henriet, J.P. & Olu-Le-Roy, K. 2007. Thèrese Mound: a case study of coral bank development in the Belgica Mound province, Porcupine Seabight. *International journal of Earth Sciences,* 96(1), 103–120.

De Santo, E.M. & Jones, P.S. 2007. The Darwin Mounds: from undiscovered coral to the development of an offshore marine protected area regime. In: George, R.Y. & Cairns, S.D. (eds.) *Conservation and adaptive management of seamount and deep sea coral ecosystems.* Rosenstiel School of Marine and Atmospheric Science, University of Miami.

Dickie-Collas, M. Brown, J., Fernand, L. Hill, A.E., Horsburgh, K.J. & R.W. Garvine. 1997. Does the western Irish Sea gyre influence the distribution of pelagic juvenile fish?. *J. Fish Biol.* **51(A):** 206-229.

Dietrich, D.E., Tseng, Y., Medina, R., Piacsek, S.A., Liste, M., Olabarrieta, M., Bowman, M.J. and Mehra, A. 2008 Mediterranean overflow water (MOW) simulation using a coupled multiple grid Mediterranean Sea/North Atlantic Ocean model. *Journal of Geophysical Research*. 113, 14pp.

Dower, J., Freeland, H & Juniper, K. 1992. A strong biological response to oceanic flow past Cobb Seamount. *Deep-Sea Research*. 39, 1139-1145.

EPA. 2008. The quality of bathing water in Ireland. A report for the year 2007. Environmental Protection Agency.

ERT (Scotland) Ltd. & Aquafact International Services Ltd. 2007. Second Strategic Environmental Assessment for Oil and Gas Activity in Ireland's Offshore Atlantic Waters: IOSEA2 Porcupine

Basin. Environmental Baseline Annex. Commissioned by Department of Communications Energy and National Resources.

Flather, R.A. 1987. Estimates of extreme conditions of tide and surge using a numerical model of the northwestern European Continental Shelf sea. *Cont. Shelf Res.* **24:** 69-93.

Games, K.P. 2001. Evidence of shallow gas above the Connemara oil accumulation, Block 26/28, Porcupine Basin. In: Shannon P.M., Haughton, P.D.W. & Corcoran, D.V., (eds), *The Petroleum Exploration of Ireland's Offshore Basins.*geological Society, London, Special Publications, 188, 361–373.

Garcia, X., Monteys, X., Evans, R. & Kelleher, B. 2007. Geohazard identification and early reconnaissance for hydrocarbon potential using marine electromagnetic and high frequency acoustic methods. *Geophysical Research Abstracts,* 9,

Golding, N., Vincent, M.A. & Connor, D.W. 2004. Irish Sea Pilot - Report on the development of a Marine Landscape classification for the Irish Sea. Joint Nature Conservation Committee, Peterborough.

Gonzales-Quiros *et al*., 2003. Ichthyoplankton distribution and plankton production related to the shelf break front at the Aviles Canyon. *ICES Journal of Marine Science,* **60,** 198-210.

Gubbay, S., Baker, C.M. & Bett, B.J. 2002. The Darwin mounds and the Dogger Bank, case studies of the management of two Special Areas of Conservation in the offshore environment. WWF-UK, Surrey. 72pp.

Gubbay, S. 2003 *Seamounts of the North East Atlantic*. WWF/OASIS, Bremen, 38 pp.

Hartley Anderson, 2005. Deep Water Environment to the West of Ireland. Report to the Irish Shelf Petroleum Studies Group. Project ISO3/21. Draft Report, December 2005.

Hill, A.E., Durazo, R. & D.A. Smeed. 1994. Observations of a cyclonic gyre in the western Irish Sea. *Cont. Shelf Res.* **14:** 479-490.

Hill, A.E. 1996. Spin-down and the dynamics of barocline gyres in shallow seas. *J. Mar. Res.* **54:** 1-17.

Hill, A.E., Brown, J. & L. Fernand. 1996. The western Irish Sea gyre: a retention mechanism for the Norway Lobster (*Nephrops norvegicus*)?. *Oceanologica Acta,* **19:** 357-368.

Hill, A.E., Brown, J. & L. Fernand. 1997. The summer gyre in the western Irish Sea: shelf sea paradigms and management implications. *Est. Shelf Coast. Sci.* **44:** 83-99.

Holmes, R., Hitchen, K. & Ottemoller, L. 2006. Strategic Environmental Assessment Area 7: hydrocarbon prospectivity, earthquakes, continental shelves and Rockall trough surficial and sea-bed geology and sea bed processes. *British Geological Survey Commissioned report,* CR/06/063.

Holt, R., Fisher, E. & C. Graham. 1990. Coastal classification and description. In: The Irish Sea – An Environmental Review. Part One: Nature Conservation. pp. 5-38.

Howarth, M.J. 1984. Currents in the eastern Irish Sea. *Oceanogr. Mar. Biol. Ann. Rev.* **22:** 11-53.

Howarth, M.J., Harrison, A.J., Knight, P.J. & R.J.J. Player. 1995. Measurements of net flow through a channel. In: proc 'IEEE Fifth Working Conference on Current Measurement', Edited by Anderson, S.P., Appell, G.F. & Williams, A.J. pp. 121-126.

Huthnance *et al*. 2001. Physical structures, advection and mixing at Goban Spur. *Deep-Sea Research II*, **48,** 2979-3021.

Huvenne, V.A.I., de Mol, B. & Henriet J.P. 2003. A 3D seismic study of the morphology and spatial distribution of buried coral Banks in the Porcupine Basin, SW of Ireland. *Marine Geology*. 198, 5–25.

Huvenne, V.A.I., Bailey, W.R., Shannon, P.M., Naeth, J., di Primio, R., Henriet, J.P., Horsfiels, B., Wheeler, A. & Olu-Le-Roy, K. 2007. The Magellan mound province in the Porcupine Basin. *International Journal of Earth Sciences*. 96(1), 85–101.

James, I.D., 1992. Tidal currents at two deep sea moorings near the shelf edge. *Deep Sea research.* 29, 1099-1111.

Jefferies, D.F., Steele, A.K. & A. Preston. 1982. Further studies on the distribution of ^{137}Cs in British coastal waters – I. Irish Sea. *Deep-Sea Res.* **29:** 713-738.

JNCC, 2008. Offshore Special Areas of Conservation: Darwin Mounds. SAC selection assessment. Version 4.0. 1st July 2008.
http://www.jncc.gov.uk/PDF/DarwinMounds_SelectionAssessment_4.0.pdf

Kelly-Geereyn, B.A., Hydes, D.J., Jégou, A.M., Lazure, P., Fernand, L.C., Puillat, I., & Garcia Soto, C. 2006. Low salinity intrusions in the western English Channel. *Continental Shelf Research,* 26, 1241–1257.

Kenyon, N.H., Akhmetzhanov, A.M., Wheeler, A.J., van Weering, T.C.E., de Haas, H. & Ivanov, M.K., 2003. Giant carbonate mud mounds in the southern Rockall Trough. *Marine Geology*, 195, 5-30.

Kenyon, N.H., Ivanov, M.K. & Akhmetzhanov, A.M., Eds., 1998. Cold water carbonate mounds and sediment transport on the Northeast Atlantic Margin. IOC Technical Series. Paris, UNESCO, 178pp.

Lee, A.J. & J.W. Ramster. 1981. Atlas of the seas around the British Isles. (Eds). Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research. 98pp.

Leonard, K.S., McCubbin, D. Brown, J. Bonfield, R. & T. Brooks. 1997. Distribution of Technetium-99 in UK coastal waters. *Mar. Poll. Bull.* **34:** 628-636.Levitus, S. & Boyer, T. 1994. World Ocean Atlas 1994, vol. 4, Temperature, 150pp., NOAA Atlas NESDIS 4.

Lockwood et al., 1981. The estimation of mackerel (*Scomber scombrus* L.) spawning stock size by plankton survey. *Journal of Plankton Research*, **3**, 213-222.

MacAodha, P., Brown, C. & Johnson, A. 2005. Methane Hydrate resource Assessment Offshore Western Ireland. Department of Earth and Ocean Sciences, Nui Galway, Technical report to the Irish Petroleum Infrastructure Programme, Project IS05/02.

Mahe *et al.* 2007. Ontogentic and spatial variation in the diet of hake (*Merluccius merluccius*) in the Bay of Biscay and the Celtic Sea. ICES Journal of Marine Science p 1-10.

Masson, D., Bett, B.J., Billett, D.S.M., Jacobs, C.L., Wheeler, A.J., & Wynn, R.B. 2003. The origin of deep-water, coral-topped mounds in the northern Rockall Trough, Northeast Atlantic. *Marine Geology* 194, 159-180.

Mienis, F., van Weering, T., de Haas, H. de Stiger, H., Huvenne, V. & Wheeler, A. 2006. Carbonate mound development at the SW Rockall Trough margin based on high resolution TOBI and seismic recording. *Marine Geology*. 233, 1–19.

Murray Roberts, J., Wheeler, A. & Freiwald, A. 2006. Reefs of the Deep: The biology and geology of cold-water coral ecosystems. *Science*, 312, 543-547.

New, A.L. & Smythe-Wright, D. 2001. Aspects of the circulation in the Rockall Trough. *Continental Shelf Research,* 21, 777–810.

OSPAR, 2000a. Quality Status Report 2000. Region V – Wider Atlantic. OSPAR Commission, London. 110pp.

OSPAR, 2000b. Quality Status Report 2000. Region III – Celtic Seas. OSPAR Commission, London. 116pp.

OSPAR. 2009. Draft Annual OSPAR Report on Dumping of Wastes at Sea in 2007. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic Meeting of the Biodiversity Committee (BDC) Stockholm: 23-27 February 2009.

Paillet, J.,& Arhan, M., 1996. Shallow pycnoclines and node water subduction in the North East Atlantic. *J. Phys. Oceanogr.*, 26, 96–114.

Pingree, RD & LeCann, B. 1989. Celtic and Armorican slope and shelf residual currents. *Prog. Oceanogr.,* 23, 303-338.

Pitois, S.G. & Fox, C.J. 2006. Long term changes in zooplankton biomass concentration and mean size over the Northwest European shelf inferred from Continuous Plankton recorder data. *ICES Journal of Marine Science,* **63,** 785-798.

Prandle, D. 1984. A modelling study of the mixing of Cs in the seas of the European continental shelf. *Phil. Trans. Roy. Soc. Lond.* **A310:** 407-436.

Robinson, I.S. 1979. The tidal dynamics of the Irish and Celtic Seas. *Geophysical Journal of the Royal Astronomical Society* **56:** *159-197.*

Roberts, J.M., Henry, L.A., Long, D., & Hartley, J.P. 2008. Cold water coral reef frameworks, megafaunal communities and evidence for coral carbonate mounds on the Hatton Bank, north east Atlantic. *Facies,* 54. 297–316.

Robinson K., Ramsay K., Wilson J., Mackie A., Wheeler A., O' Beirn F., Lindenbaum C., Van Landeghem K., McBreen F., Mitchell N. 2007. HABMAP: Habitat Mapping for conservation and management of the southern Irish Sea. Report to the Welsh European Funding Office. CCW Science Report Number 810. Countryside Council for Wales, Bangor. 233 pp plus appendices.

Sager, G. 1963. Atlas der Elemente der Gexeitenstrome fur die Nordsee, den Kanal und die Irische Sea. Deutsche Akadamie der Wissenschaften zu Berlin. Institute fur Meereskunde, Rostock, Germany. Pp. 45.

Sharples, J., Tweddle, J., Green JAM, Palmer, M., Kim, YN., Hickman, AE., Holligan, PM, Moore, CM, Rippeth, TP, Simpson, JH. And Krivtsov, V. 2007. Spring-neap modulation of internal tide mixing and vertical nitrate fluxes at a shelf edge in summer. *Limnology and Oceanography*,. 52, (5), 1735-1747.

Sharples, J., 2008. Potential impacts of the spring-neap tidal cycle on shelf sea primary production. *Journal of Plankton Research*, 30 (2), 183-197.

Sundby, S. 2000. Recruitment of Atlantic cod stocks in relation to temperature and advection of copepod populations. *Sarsia*, **85**, 277-298.

van Weering, T.C.E., De Haas, H., Akhmetzanov, A.M. & Kenyon, N.H., 2003a. Giant carbonate mounds along the Porcupine and SW Rockall Trough Margins. In J. Mienert, P. Weaver (Eds) European Margin Sediment Dynamics: Side - Scan Sonar and Seismic Images. Springer-Verlag, p.211-216.

Van Weering, T.C.E., De Haas, H., De Stiger, H.C., Lykke-Andersen, H., Kouvaev, I., 2003b. Structure and development of giant carbonate mounds at the SW and SE Rockall trough margins, NE Atlantic Ocean. *Marine Geology*., 198, 67–81.

Vincent, M.A., Atkins, S.M, Lumb, Golding, N., Lieberknecht, L.M., & Webster, M., 2004. Marine nature conservation and sustainable development – the Irish SeaPilot. Report to Defra by the Joint Nature Conservation Committee.

Wheeler, A.J., Kozachenko, M., Beyer, A., Foubert, A., Huvenne, V.A.I., Klages, M., Masson, D.G., Olu-Le-Roy, K. & Thiede, J. 2005a. Sedimentary processes and carbonate mounds in the Belgica mound province, Porcupine Seabight, NE Atlantic. In: A. Freiwald & J.M. Roberts (eds). *Cold-water corals and Ecosystems,* Springer-Verlag, Berlin. 533–564.

Wheeler, A.J., Beck, T., Thiede, J., Klages, M., Grehan, A. Monteys, F.X. & Polarstern ARK XIX/3a Shipboard Party 2005b. Deep-water cold-water coral carbonate mounds on the Porcupine Bank, Irish margin: preliminary results from Polarstern ARK-XIX/3a ROV cruise. In: A. Freiwald & J.M. Roberts (eds). *Cold-water corals and Ecosystems,* Springer-Verlag, Berlin, p.323-333.

Wheeler, A.J., Beyer, A., Freiwald, A., de Haas, H., Huvenne, V.A.I., Kozachenko, M., Olu-Le-Roy, K. & Opderbenke, J. 2007. Morphology and environment of cold water coral carbonate mounds on the NW European margin. *International Journal of Earth Sciences.* 96, 37–56.

Wheeler, A.J., Kozachenko, M., Masson, D.G. & Huvenne, V.A.I. 2008. Influence of benthic sediment transport on cold-water coral bank morphology and growth: the example of the Darwin Mounds, north-east Atlantic. *Sedimentology*, 55, 1875-1887(13).

White, M. & Bowyer, P. 2007. The shelf-edge current north west of Ireland. *Ann. Geophysicae*. 15 1076-1083.

White, M. & Mohn, C. 2004. Seamounts: a review of physical processes and their influence on the seamount ecosystem. OASIS report, University Hamburg, 40 pp.

Wilson, T.R.S. 1974. Ceasium-137 as a water movement tracer in St. George’s Channel. *Nature* 248**:** 125-127.

WWF. 2001. implementation of the EU Habitats Directive Offshore: Natura 2000 sites for reefs and submerged sandbanks. Volume II Northeast Atlantic and North Sea.

References for Section 1.4

Berg, A. (1999): *Implementing and enforcing European fisheries law.* Boston: Kluwer Law International.

Christensen, A.S., J. Raakjær and T. Olesen (2007): The voices of Danish fishermen in resource management - An examination of the system of negotiated economy. In: Ocean & Coastal Management, vol. 50: 551-563.

Commission of the European Communities (1999): *Commission Decision of 14 July 1999 renewing the Advisory Committee on Fisheries and Aquaculture.* In: *Official Journal of the European Communities.* L 187, 20.7.1999: 70-73.

Commission of the European Communities (2001): *Commission Regulation (EC) No 2056/2001 of 19 October 2001 establishing additional technical measures for the recovery of the stocks of cod in the North Sea and to the west of Scotland.* In: *Official Journal of the European Communities.* L 277, 20.10.2001: 13–16.

Commission of the European Communities (2003): *Communication from the Commission, Improving scientific and technical advice for Community fisheries management.* In: *Official Journal of the European Communities*. C 47, 27.2.2003: 5-16.

Commission of the European Communities (2004): *Commission Decision of 16 December 2004 amending Commission Decision 1999/478/EC of renewing the Advisory Committee on Fisheries and Aquaculture.* In: *Official Journal of the European Communities*. L 370, 17.12.2004: 91.

Commission of the European Communities (2005): *Commission Decision of 26 August 2005 establishing a Scientific, Technical and Economic Committee for Fisheries.* In: *Official Journal of the European Communities*. L 325, 31.8.2005: 18-22.

Commission of the European Communities (2007): *Report from the Commission to the Council and the European Parliament on the monitoring of the Member States' implementation of the Common Fisheries Policy 2003-2005.* COM (2007) 167 final. Brussels: Commission of the European Communities. 10.4.2007.

Commission of the European Communities (2008): *Subject: Reflections on further reform of the Common Fisheries Policy*. Commission Working Document.

Commission of the European Communities (2008a): *Proposal for a Council Regulation establishing a Community control system for ensuring compliance with the rules of the Common Fisheries Policy.* COM (2008) 721 final. Brussels: Commission of the European Communities. 14.11.2008.

Commission of the European Communities (2008b): *Commission staff working document accompanying the Proposal for a Council Regulation establishing a Community control system for ensuring compliance with the rules of the Common Fisheries Policy - Impact Assessment.* SEC (2008) 2760. Brussels: Commission of the European Communities. 14.11.2008.

Commission of the European Communities (2008c): *Commission staff working document accompanying the Proposal for a Council Regulation establishing a Community control system for ensuring compliance with the rules of the Common Fisheries Policy - Summary of the Impact Assessment.* SEC (2008) 2761.

Commission of the European Communities (2008d): *Communication from the Commission to the European Parliament and the Council on the proposal for a Council Regulation establishing a Community control system for ensuring compliance with the rules of the Common Fisheries Policy.* COM (2008) 718 final. Brussels: Commission of the European Communities. 14.11.2008.

Community Fisheries Control Agency (Undated): *Community Fisheries Control Agency: Organisational Structure.* From: http://cfca.europa.eu/pdf/organisational_structure_vigo.pdf (accessed 6 January 2009).

Community Fisheries Control Agency (Undated a): *Community Fisheries Control Agency: Joint deployment plans.* From: http://cfca.europa.eu/pdf/jdps_vigo.pdf (accessed 6 January 2009).

Council of the European Communities (1970): *Council Regulation (EEC) No 2141/70 of the Council of 20 October 1970 laying down a common structural policy for the fishing industry.* In: *Official Journal of the European Communities*. L 236, 27.10.1970.

Council of the European Communities (1970a): *Council Regulation (EEC) No 2142/70 of the Council of 20 October 1970 on the common organisation of the market in fishery products.* In: *Official Journal of the European Communities*. L 236, 27.10.1970.

Council of the European Communities (1983): *Council Regulation (EEC) No 170/83 of 25 January 1983 establishing a Community system for the conservation and management of fishery resources.* In: *Official Journal of the European Communities.* L 024, 27.01.1983, pp. 1-13.

Council of the European Communities (1992): *Council Regulation (EEC) No 3760/92 of 20 December 1992 establishing a Community system for fisheries and aquaculture.* In: *Official Journal of the European Communities*. L 389, 31.12.1992: 1-14.

Council of the European Communities (1993): *Council Regulation (EEC) No 2847/93 of 12 October 1993 establishing a control system applicable to the common fisheries policy.* In: *Official Journal of the European Communities*. L 261, 20.10.1993: 1-16.

Council of the European Union (2002): *Council Regulation (EC) No 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy*. In: *Official Journal of the European Communities*. L 358/59, 31.12.2002: 61-80.

Council of the European Union (2004): *Council Decision (EC) of 19 July 2004 establishing Regional Advisory Councils under the Common Fisheries Policy (2004/585/EC)*. In: *Official Journal of the European Communities*. L 256, 3.8.2004: 17-22.

Council of the European Union (2005): *Council Regulation (EC) No 768/2005 of 26 April 2005 establishing a Community Fisheries Control Agency and amending Regulation (EEC) No 2847/93 establishing a control system applicable to the common fisheries policy.* In: *Official Journal of the European Communities*. L 128, 21.5.2005: 1-14.

DG MARE (2008): *The mission of the Directorate General for Fisheries and Maritime Affairs.* Accessed 24.11.2008: http://ec.europa.eu/dgs/fisheries/missn_en.htm.

Egeberg, M., M. Martens and J. Trondal (Undated): *Building Executive power at the European Level: Some preliminary Findings on the Role of EU-Level Agencies.* Department of Political Science and ARENA Centre for European Studies, University of Oslo.

European Court of Auditors (2007): *Special Report No 7/2007 (pursuant to Article 248(4) second paragraph, EC) on the control, inspection and sanction systems relating to the rules on conservation of Community fisheries resources.*

Gezelius, S.S. (2008): *Implementation of Resource Conservation Policies in the Norwegian*

Fisheries: A Historical Outline. In: S.S. Gezelius and J. Raakjær (Eds.): *Making Fisheries Management Work*. *Implementation of Policies for Sustainable Fishing.* Dordrecht: Springer: 41-98.

Gezelius S.S. and J. Raakjær (Eds.) (2008): *Making Fisheries Management Work*. *Implementation of Policies for Sustainable Fishing.* Dordrecht: Springer.

Gezelius, S.S. et al. (2008): *The Politics of Implementation in Resource Conservation: Comparing the EU/Denmark and Norway.* In: S.S. Gezelius and J. Raakjær (Eds.): *Making Fisheries Management Work*. *Implementation of Policies for Sustainable Fishing.* Dordrecht: Springer: 208-229.

Gray, T. and J. Hatchard (2003): *The 2002 reform of the Common Fisheries Policy's system of governance - rhetoric or reality?* In: *Marine Policy*. Vol. 27(6): 545-554.

Hardin, G. (1968): *The Tragedy of the Commons*. In: *Science.* Vol. 162(3859): 1243-1248.

Hegland, T.J. (2004): *The Common Fisheries Policy - caught between fish and fishermen?* Master thesis. Aalborg: Department of International Affairs, Aalborg University. Unpublished. Available from: http://vbn.aau.dk/fbspretrieve/16716264/The_common_Fisheries_Policy.pdf.

Hegland, T.J. (2006): *Fisheries Policy-Making: Production and Use of Knowledge.* In: L. Motos and D.C. Wilson (Eds.): *The Knowledge Base for Fisheries Management.* Oxford and Amsterdam: Elsevier: 219-237.

Hegland, T.J. and D.C. Wilson (2008): *Participatory Modelling: developing a Long-Term Management Plan for Western Horse Mackerel within the Pelagic RAC.* Deliverable no. 7b to the EU 6th Framework Programme, Project no. 013639, SAFMAMS.

Hegland, T.J. and J. Raakjær (2008): *Implementation Politics: The case of Denmark under the Common Fisheries Policy.* In: S.S. Gezelius and J. Raakjær (Eds.): *Making Fisheries Management Work*. *Implementation of Policies for Sustainable Fishing.* Dordrecht: Springer: 161-205.

Hegland, T.J. and J. Raakjær (2008a): *Recovery Plans and the Balancing of Fishing Capacity and Fishing Possibilities: Path Dependence in the Common Fisheries Policy.* In: S.S. Gezelius and J. Raakjær (Eds.): *Making Fisheries Management Work*. *Implementation of Policies for Sustainable Fishing.* Dordrecht: Springer: 131-159.

Hersoug, B. (2005): *Closing the commons. Norwegian fisheries from open access to private property*. Delft: Eburon Academic Publisher.

Hoefnagel, E. (2002): Corporatist Origin of the Dutch Co-Management System. In: Fisheries in the Global Economy. 2002 IIFET conference proceedings. New Zealand.

Hoel, A.H., S. Jentoft and K. Mikaelsen (1997): User-group participation in Norwegian fisheries management. In: Meyer et al. (Eds.): Fisheries Utilization and Policy: Proceedings of the World Fisheries Congress. 2. Vol. New Delhi: Oxford & IBH publishing Co.

Holden, M. (1994): *The Common Fisheries Policy. Origin, valuation and future.* Fishing News Books. Oxford: Blackwell Science.

Hoof, L. van, E. Hoefnagel, J.W. van der Schans, J. Raakjær Nielsen, A.S. Christensen, S. Sverdrup-Jensen, A. Delaney, S. Jentoft, K. Mikaelsen, G.R. Karlsen, C. Bodiguel, J. Catanzano, J.L. Suarez de Vivero, I.M. Alba, S.F. Domínguez and D. Rommel (2005): *Sharing responsibilities in fisheries management*. Part 1 and 2. The Hague: LEI.

Lequesne, C. (2000): *The Common Fisheries Policy. Letting the Little Ones Go?* In H. Wallace and W. Wallace (Eds.): *Policy-Making in the European Union.* 4th ed. Oxford and New York: Oxford University Press: 345-372.

Lequesne, C. (2004): *The politics of fisheries in the European Union.* Manchester and New York: Manchester University Press.

Long, R.J. and P.A. Curran (2000): *Enforcing the Common Fisheries Policy.* Fishing News Books. Oxford: Blackwell Science.

Nielsen, K.N. and P. Holm (2008): *The TAC Machine: On the Institutionalization of Sustainable Fisheries Resource Management in the Northeast Atlantic.* Unpublished manuscript. Tromsø: Norwegian College of Fishery Science.

Raakjær, J. (2008): *A Fisheries Management System in Crisis - the EU common Fisheries Policy.* Senior doctoral thesis. Department of Development and Planning. Aalborg: Innovative Fisheries Management - an Aalborg University Research Centre.

Raakjær Nielsen, J. (1992): *Fiskerisektorens strukturproblemer i en socio-økonomisk belysning. PhD thesis.* Aalborg: Institut for Produktion, Aalborg Universitetscenter.

Sissenwine, M. and D. Symes (2007): *Reflections on the Common Fisheries Policy.* Report to the General Directorate for Fisheries and Maritime Affairs of the European Commission. July 2007.

Symes, D.G. (coordinator) (1996): *Devolved and regional management systems for fisheries.* Final report for the EU funded research project, No AIR – 2CT93 – 1392: DG XIV SSMA. Compiled by School of Geography and Earth Resources, University of Hull and CEMARE, University of Portsmouth.

Wilson, D.C. (Forthcoming): *The Paradoxes of Transparency: Scientific Institutions and the Ecosystem Approach to Fisheries Management in Europe.* Amsterdam: University of Amsterdam Press.

References for Section 1.2.3 Biological features

(1) CELTIC SEAS AREA

Armstrong, M.J. (1982). The predator-prey relationships of Irish Sea poor-cod (*Trisopterus minutus* L.), pouing (*Trisopterus luscus* L.), and cod (*Gadus morhua* L.). *Journal du Conseil International pour l'Exploration de la Mer,* 40, 135–152.

Beare, D., Burns, F., Greig, A., Jones E.G., Peach, K., Kienzle, M., McKenzie E. and Reid, D.G. (2004). Long-term increases in prevalence of North Sea fishes having southern biogeographic affinities. *Marine Ecology Progress Series*, 284: 269–278.

Bennett, D.B. & Lawler, A.R. (1994) Irish Sea cod and *Nephrops* interactions-can the model be validated? ICES CM 1994/K34.

Blanchard, J.L., Dulvy N.K., Ellis, J.E., Jennings S. , Pinnegar, J.K. , Tidd, A. & Kell, L.T. (2005) Do climate and fishing influence size-based indicators of Celtic Sea fish community structure? *ICES Journal of Marine Science,* 62: 405–411.

Borges, L., Rogan, E., and R. Officer (2005). Discarding by the demersal fishery in the waters around Ireland. *Fisheries Research* 76: 1–13.

CEC. 2002a. *Incidental catches of small cetaceans*. Report of the meeting of the subgroup on fishery and the environment (SGFEN) of the Scientific, Technical and Economic Committee for Fisheries (STECF), Brussels December 2001. SEC (2002) 376. Commission of the European Communities, Brussels.

Crozier, WW. (1985). Observations on the food and feeding of the angler-fish, Lophius piscatorius L., in the northern Irish Sea. *Journal of Fish Biology*. 27: 655–665.

Desbrosses, P. (1932) La dorade commune (*Pagellus centrodontus* Delaroche) et sa pêche. *Rev. Trav. Inst. Pêches Marit.,* 5:167–222.

Du Buit, M.H. (1989) Quantitative analysis of the diet of cod (*Gadus morhua L.*) off the coast of Scotland. Annales de l'Institut océanographique, Paris. Nouvelle serie 65: 147–158.

Du Buit, M.H., (1991a) Food and feeding of saithe (*Pollachius virens* L.) off Scotland. *Fisheries Research.* 12: 307–323.

Du Buit, M.H., (1991ba) Food of whiting (Merlangius merlangus L., 1758) off Scotland. *Cybium,* 15: 211–220.

Dulvy, N.K., Metcalfe, J.D., Glanville, J., Pawso n, M.G. , Reynolds J.D., (2000) Fishery Stability, Local Extinctions, and Shifts in Community Structure in Skates. Conservation Biology, 14, 1: 283–293.

Ellis, J.R., Rogers S. I., Freeman, S. M. (2000) Demersal assemblages in the Irish Sea, St George's Channel and Bristol Channel. *Estuarine, Coastal and Shelf Science,* 51: 299–315.

Ellis, J.R., Lancaster, J.E., Cadman, P.S. & Rogers, S.I. (2002). The marine fauna of the Celtic Sea. In: J.D.Nunn (ed), *Marine Biodiversity in Ireland and adjacent waters. Proceeding of the E.C.S.A. Conference,* pp 45–65. Ulster Museum, Belfast.

Ellis, J.R., Armstrong, M.J., Rogers, S.I., Service, M. (2002). The distribution, structure and diversity of fish assemblages in the Irish Sea. In: J.D.Nunn (ed), Marine Biodiversity in Ireland and adjacent waters. Proceeding of the E.C.S.A. Conference, pp.93–114. Ulster Museum, Belfast.

Farina, A.C., Freire, J., Gonzalez-Gurriaran, E. (1997) Demersal fish assemblages in the Galician continental shelf and upper slope (NW Spain): Spatial structure and long-term changes. *Estuarine, Coastal and Shelf Science*, 44, 435–454.

Fernand, L., Nolan, G.D., Raine, R., Chambers, C.E., Dye, S.R., White, M., Brown, J. (2006) The Irish coastal current: a seasonal jet-like circulation. *Coastal Shelf Research,* 26: 1775–1793.

Fock, H., Uiblein, F., Köster, F., von Westernhagen, H. (2002) Biodiversity and species-environment relationships of the demersal fish assemblage at the Great Meteor Seamount (subtropical NE Atlantic), sampled by different trawls. *Marine Biology,* 141: 185–199. ICES WGRED Report 2008 65.

FRS (2005). Scottish Ocean Climate Status Report 2002–2003. Fisheries Research Services, Aberdeen.

Genner, M.J., Sims, D.W., Wearmouth, V.J., Southall, E.J., Southward, A.J., Henderson, P.A., Hawkins, S.J. (2004) Regional climate warming drives long-term community changes of British marine fish. *Proceedings of the Royal Society of London series B – Biological Sciences* 271**:** 655–661.

Gibson, R.N. and I.A. Ezzi, (1987) Feeding relationships of a demersal fish assemblage on the west coast of Scotland. *Journal of Fish Biology,* 31:55–69.

Greve, W., Lange, U., Reiners, F., and Nast, J. (2001). Predicting the seasonality of North Sea zooplankton. In: Burning Issues of North Sea Ecology, Proceedings of the 14th International Senckenberg Conference North Sea 2000, pp. 263–268. Ed. By I. Kröncke, M. Tu¨rkay, and J. Sündermann. *Senckenbergiana Maritima* 31 (2).

Harris, M.P., Beare, D., Toresen, R., Nøttestad, L., Kloppmann, M., Dörner, H., Peach, K., Rushton, D.R.A., Foster-Smith, J., Wanlass, S. (in press) A major increase in snake pipefish (*Entelurus aequoreus*) in northern European seas since 2003: potential implications for seabird breeding success. *Marine Biology.*

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jørgensen, Heim-lich, S., Hiby, A.R., Leopold, M.F., Øien, N. 2002. Abundance of harbour porpoise other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology*, 39: 361–376.

Hammond, P.S. & Harris, R.N. (2006) Grey seal diet composition and prey consumption off western Scotland and Shetland. Final Report to Scottish Executive, Environment and Rural Affairs Department and Scottish Natural Heritage.

Heath, M.R., (2005) Regional variability in the trophic requirements of shelf sea fisheries in the northeast Atlantic, 1973-2000. *ICES Journal of Marine Scienc*e, 62: 1233–1244.

Houghton, J.D.R., Doyle, T.K., Davenport, J., Hays, G.C. (2006). The ocean sunfish *Mola mola*: insights into distribution, abundance and behaviour in the Irish and Celtic Seas. *Journal of the Marine Biological Association of the United Kingdom*, 86: 1237–1243.

ICES (2002) Report of the Working Group on Sea-bird Ecology (WGSE). ICES CM 2002

ICES (2006) Zooplankton monitoring results in the ICES area: summary status report 2004/2005 ICES Co-operative Research Report, Number 281, 38pp.

ICES (2006) ICES Report on Ocean Climate 2005. ICES Co-operative Research Report, Number 280. 49pp.

ICES (2006b) Report of the Working Group on the Assessment of Northern Shelf Demersal Stocks (WGNSDS). ICES ACFM:30.

ICES (2006c) Report of the Working Group on Fish Ecology (WGFE). ICES CM 2006/LRC:06.

ICES (2007). Report of the Working Group on Elasmobranch Fishes (WGEF). ICES CM 2007/ACFM:27.

Joyce, A.E., (2006). The coastal temperature network and ferry route programme: long-term temperature and salinity observations. Sci. Ser. Data Rep., Cefas Lowestoft, 43: 129pp.

Kaiser, M.J., Bergmann, M., Hinz, H., Galanidi, M., Shucksmith, R., Rees, E.I.S., Darbyshire, T., Ramsay, K. (2004) Demersal fish and epifauna associated with sandbank habitats. *Estuarine, Coastal and Shelf Science* 60: 445–456.

Kirby R.R., Johns, D.G., Lindley, J.A. (2006) Fathers in hot water: rising sea temperatures and a Northeastern Atlantic pipefish baby boom. *Biology Letters*, 2, 597–600.

Kloppmann, M.H.F. & Ulleweit, J. (in press) Off-shelf distribution of pelagic snake pipefish, Entelurus aequoreus (Linnaeus, 1758), west of the British Isles. *Marine Biology.* 66 | ICES WGRED Report 2008.

Kiely, O., Ligard, D., MvKibben, M., Connolly, N., Baines, M. (2000) Grey seals: status and monitoring in the Irish and Celtic Seas. Maritime Ireland/Wales INTERREG Report Number 3. The Marine Institute, Dublin. 76pp.

Lordan, C. (2001) The distribution and abundance of cephalopod species caught during demersal trawl surveys west of Ireland and in the Celtic Sea. *Irish Fisheries Investigations* no. 8, 26 pp. 2001.)B.

Mahé, J.-C. ed. 2001. International Program of Standardised Trawl Surveys (IPROST). Study EC-DGXIV No. 98–0587. Ifremer-Marine Laboratory-Marine Institute. 122 pp.

Nash, R.D.M & Geffen, A.J. (2004) Seasonal and interannual variation in abundance of *Calanus finmarchicus* (Gunnerus) and *Calanus helgolandicus* (Claus) in inshore waters (west coast of the Isle of Man) in the central Irish Sea. *Journal of Plankton Research* 26:265–273.

Nolan, G.D. and Lyons, K. (2006) Ocean climate variability on the western Irish Shelf, an emerging time series ICES CM 2006/C:28.

OSPAR (2000) Quality Status Report 2000. OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic, London.

Pinnegar J.K., Jennings, S., O'Brien, C.M. & Polunin N.V.C. (2002) Long-term changes in the trophic level of the Celtic Sea fish community and fish market price distribution. *Journal of Applied Ecology,* 39: 377–390.

Pinnegar, J.K., Trenkel, V.M., Tidd, A.N., Dawson, W.A. and Du Buit, M.H. (2003). Does diet in Celtic Sea fishes reflect prey availability? *Journal of Fish Biology,,* 63 (Supplement A): 197–212.

Quero, J. C., M. H. D. Buit, and J. J. Vayne. (1998). Les observations de poissons tropicaux et le rechauffement des eaux de l'Atlantique europeen. *Oceanologica Acta* 21:345–351.

Raine, R; White, M; Dodge, JD, (2002) The summer distribution of net plankton dinoflagellates and their relation to water movements in the NE Atlantic Ocean, west of Ireland, *Journal of Plankton Research.* 24: (11) 1131–1147.

Rees, H. L., Pendle, M. A., Waldock, R., Linpenny, D. S. & Boyd, S. E. (1999) A comparison of benthic biodiversity in the North Sea, English Channel and Celtic Seas. *ICES Journal of Marine Science* 56: 228–246.

Reid, D. G., Walsh, M., and. Turrell, W. R (2001a) Hydrography and mackerel distribution on the shelf edge west of the Norwegian deeps. *Fisheries Research* 50: 141–150.

Reid, J.B., Evans, P.G.H., Northridge, S.P. (2003) Atlas of Cetacean distribution in north-west European waters. Joint Nature Conservancy Committee, Peterborough, UK.

Rochet M.-J., Péronnet I., Trenkel V.M., 2002. An analysis of discards from the French trawler fleet in the Celtic sea. *ICES Journal of Marine Science* 59: 538–552.

Santos, M.B., Pierce, G.J., Learmonth, J.A., Reid, R.J., Ross, H.M., Patterson, I.A.P., Reid, D.G. Beare, D. 2004. Variability in the diet of harbour porpoises (*Phocoena phocoena*) in Scottish waters 1992–2003. *Marine Mammal Science,* 20: 1–27.

SCOS (2005) Scientific Advice on matters related to the management of seal populations: 2005. Special Committee on Seals (SCOS). smub.st.and.ac.uk/CurrentResearch.htm/ SCOS%2005_v2f.pdf.

Silke J., O Beirn F., Cronin M (2005). Karenia Mikimotoi: An Exceptional Dinoflagellate Bloom in Western Irish Waters-Summer 2005 Marine Environment and Health Series, No 21, 2005**.**

Southward AJ, Boalch GT, Maddock L (1988) Fluctuations in the herring and pilchard fisheries of Devon and Cornwall linked to change in climate since the 16th Century. *Journal of the Marine Biological Association of the United Kingdom* 68:423–445. ICES WGRED Report 2008 67Stebbing, A.R.D., Turk, S.M.T, Wheeler, A. and Clarke, K.R. (2002) Immigration of southern fish species to south-west England linked to warming of the North Atlantic (1960–2001). *Journal of the Marine Biological Association of the United Kingdom,* 82: 177–180.

Trenkel, V.M., Pinnegar, J.K., Dawson, W.A., Du Buit, M.H. and Tidd, A.N., (2005) Spatial and temporal predation patterns in the Celtic Sea. *Marine Ecology-Progress Series,* 299: 257–268.

Trenkel, V.M., Pinnegar, J.K., Rochet, M.-J. & Rackham, B. (2004) The effect of different survey designs on population and community indicators for the Celtic sea groundfish community. *ICES Journal of Marine Science.* 61: 351–362.

Trenkel, V. M. and Rochet, M.-J. 2003. Performance of indicators derived from abundance estimates for detecting the impact of fishing on a fish community. *Canadian Journal of Fisheries and Aquatic Sciences,* 60: 67–85.

Wall D., O'Brien J., Meade J.and Allen B. M.(2004)Summer distribution and relative abundance of cetaceans off the west coast of Ireland. *Biology & Environment: Proceedings of the Royal Irish Academy,* Volume 106B, Number 2, 135–142.

Young, E.F., Brown, J., Aldridge, J.N., Horsburgh, J.K., Fernand, L., (2004) Development and application of a three-dimensional baroclinic model to the study of the seasonal circulation in the Celtic Sea. *Continental Shelf Research,* 24: 13–36.

(2) ENGLISH CHANNEL

Aldridge, J. N., and Davies, A. M. 1993. A high-resolution threedimensional hydrodynamic tidal model of the eastern Irish Sea. Journal of Physical Oceanography, 23: 207–224.

Belin C. & Martin-Jézéquel V., 1997. Le phytoplancton. In : Dauvin J.C., (édit.) 1997. Les biocénoses marines et littorales françaises des côtes Atlantique, Manche et Mer du Nord, synthèse, menaces et perspectives. Laboratoire de Biologie des Invertébrés Marins et Malacologie, MNHN, Paris, 376 pp.

Brylinski J.-M. & Lagadeuc Y. 1990. L?interface eaux côtières/eaux du large dans le Pas-de-Calais (côte française) : une zone frontale. Comptes rendus de l?Académie des sciences. Série deux, Mécanique, physique, chimie, sciences de l?univers, sciences de la terre, vol. 311, no5, pp. 535–540.

Cabioch L., 1968. Contribution à la connaissance des peuplements benthiques de la Manche occidentale. *Cah. Biol. Mar.,* 9 (5), 493–720.

Carpentier, A., Vaz, S., Martin, C.S., Coppin, F., Dauvin, J.-C., Desroy, N., Dewarumez, J.-M., Eastwood, P.D., Ernande, B., Harrop, S., Kemp, Z., Koubbi, P., Leader-Williams, N., Lefèbvre, A., Lemoine, M., Meaden, G.J., Ryan, N. & Walkey, M. (2005) Eastern Channel Habitat Atlas for Marine Resource Management (CHARM). INTERREG IIIa. Ifremer, Brest.

Castel J., Dauvin J.C. & Glémarec M., 1997. Les conditions générales en Atlantique, Manche et Mer du Nord. In : Dauvin J.C., (édit.) 1997. Les biocénoses marines et littorales françaises des côtes Atlantique, Manche et Mer du Nord, synthèse, menaces et perspectives. Laboratoire de Biologie des Invertébrés Marins et Malacologie, MNHN, Paris, 376 pp.

Dauvin J.C., (édit.) 1997. Les biocénoses marines et littorales françaises des côtes Atlantique, Manche et Mer du Nord, synthèse, menaces et perspectives. Laboratoire de Biologie des Invertébrés Marins et Malacologie, MNHN, Paris, 376 pp.

Faugere, Y.,P. Le Borgne et H. Roquet, 2001 Realisation d�une climatologie mondiale de la temperature de surface de la mer a echelle fine,, La Meteorologie, 35, 24–35.

Froidefond J.M., Lavender S., Labordes P., Herbland A., and V. Lafon, 2002. Références SeaWiFs data interpretation in a coastal area in the Bay of Biscay. International Journal of Remote Sensing, Vol. 23 , 5, pp 881–904.

Frontier S. & Pichot-Viale D., 1995. Ecosystèmes. Structure, fonctionnement, évolution. Paris : Masson.

Gentil F., 1976. Distribution des peuplements benthiques en baie de Seine. *Thèse 3ème cycle, Université Paris VI*, 70 pp.

Gohin F., Druon J.N., and L. lampert, 2002. A five channel chlorophyll algorithm applied to SeaWiFS data processed by SeaDAS in coastal waters, International Journal of Remote Sensing, Vol. 23 , 8, pp 1639–1661.

Guitton J., Dintheer C., Dunn M.R., Morizur Y. & Tétard A., 2003. Atlas des pêcheries de la Manche. Ed. Ifremer, 216 pp.

Hawkins S.J.1; Southward A.J.; Genner M.J., 2003. Detection of environmental change in a marine ecosystem-evidence from the western English Channel. The Science of the Total Environment, 310, 1, 245–256(12).

Lacroix G, Ruddick K, Park Y, Gypens N, Lancelot C (2007) Validation of the 3D biogeochemical model MIRO&CO with field nutrient and phytoplankton data and MERIS-derived surface chlorophyll a images. Journal of Marine Systems 64:66

Larsonneur, C., Bouysse, P. & Auffret, J.-P. (1982) The superficial sediments of the English Channel and its western approaches. Sedimentology, 29, 851– 864.

Leblond, Daurès, Berthou, Bermell, Merrien, Demaneche, 2003. The 2003 French fishing fleets North Sea-Channel-Atlantic.

(https://www.ifremer.fr/isih/affichagePageStatique.do?page=produits/rapports_syntheses/documents_synthese.htm).

Le Fèvre-Lehoërff G., Brylinski J.M. and Castel J., 1997. Le zooplancton. In: Dauvin J.C., (édit.) 1997. Les biocénoses marines et littorales françaises des côtes Atlantique, Manche et Mer du Nord, synthèse, menaces et perspectives. Laboratoire de Biologie des Invertébrés Marins et Malacologie, MNHN, Paris, 376 pp.

Ménesguen, A., Cugier, P., Loyer, S., Vanhoutte-Brunier, A., Hoch, T., Guillaud, J-F., Gohin F. (2007). Two-or three-layered box-models versus fine 3D models for coastal ecological modelling? A comparative study in the English Channel (Western Europe). Journal of Marine Systems Vol. 64, 4 Pages 47–65.

Pingree, R.D., 1980. Physical Oceanography of The Celtic Sea and English Channel. In: The Northwest European Shelf Seas: The Sea Bed And The Sea In Motion. Physical and Chemical.

Retière C., 1979. Contribution à l'étude des peuplements benthiques du golfe normano-breton. Thèse Doctorat Etat, Sci. Nat., Université Rennes, 370 pp.

Rochet, M-J., Trenkel, V. M., Bellail, R., Coppin, F., Le Pape, O., Mahé, J-C., Morin, J. *et al*., 2005. Combining indicator trends to assess ongoing changes in exploited fish communities: diagnostic of communities of the coasts of France. ICES Journal of Marine Science, 62: 1647–1664.

Salomon, J. C. and Breton, A. M., 1991. Courants résiduels de marée dans la manche. Oceanolography Acta vol sp no. 11, 47–53.

Salomon, J. C. and Breton, A. M., 1993. An atlas of long-term currents in the Channel. Oceanologica acta, Vol. 16, no. 5-6, pp. 439–448.

Sanvicente-Anorve L, Lepretre A, Davoult, D, 2002. Diversity of benthic macrofauna in the eastern English Channel: comparison among and within communities. Biodiversity and Conservation 11: 265–282.

Vaz, S., Carpentier, A. & Coppin, F. (2007) Eastern English Channel fish assemblages: measuring the structuring effect of habitats on distinct subcommunities. ICES Journal of Marine Science, 64, 271–287.

Woehrling D, Lefebvre Alain, Le Fevre-Lehoerff G, Delesmont R, 2005, Seasonal and longer term trends in sea temperature along the French North Sea coast, 1975 to 2002. Journal of the Marine Biological Association of the UK (2005), 85: 39-48

(3) PELAGIC WATERS

Abaunza, P., Murta, A., Mattiucci, S., Cimmaruta, R., Nascetti, G., Magoulas, A.,Sanjuan, A., Comesaña, S., MacKenzie, K., Molloy, J., Santos, A. T, Iversen, S. Dahle, G., Gordo, L., Stransky C. Zimmermman, C., Santamaria, M.T., Ramos, P., Quinta, R., Pinto, A.L., Ruggi, A., Campbell, N., 2004. Stock discrimination of horse mackerel (*Trachurus trachurus* L.) in the Northeast Atlantic and Mediterranean Sea: Integrating the results from different stock identification approaches. ICES CM 2004/EE:19.

Bailey, R.S. 1982. The population biology of blue whiting in the North Atlantic. Advances in Marine Biology 19, 257–355.

Bartsch, J., Reid, D.and S. H. Coombs (2004) Simulation of mackerel (*Scomber scombrus*) recruitment with an individual-based model and comparison with field data Fish. Oceanogr. 13:6, 380–391.

Beaugrand, G. 2005. Monitoring pelagic ecosystems from plankton indicators. ICES Journal of Marine Science 62: 333–338.

Beare, D. J., and Reid, D. G. 2002. Investigating spatio-temporal change in spawning activity by Atlantic mackerel between 1977and 1998 using generalized additive models. ICES Journal of Marine Science, 59: 711–724.

Ben Salem, M., 1988. Regime alimentaire de Trachurus trachurus (Linnaeus, 1758 et de T. mediterraneus (Steindachner, 1868), (poissons, teleosteens, Carangidae) de la province atlantico-mediterraneenne. Cybium. Paris. Vol. 12, no. 3, pp. 247–253. 1988.

Bower, A.S., B. Le Cann, T. Rossby, W. Zenk, J. Gould, K. Speer, P. Richardson.

Borges, M.F., 1991. Biannual cohorts parameters and migration effects of horse mackerel (*Trachurus trachurus* L.) in Western Iberian waters, using length frequency analysis. ICES CM 1991/H:52.

Borges, M.F., Gordo, L.S.,1991. Spatial distribution by season and some biological parameters of horse mackerel (*Trachurus trachurus* L.) in the Portuguese continental waters (Division IXa). ICES CM 1991/H:54.

M. D. Prater, H-M. Zhang, 2002. Directly measured mid-depth circulation in the northeastern North Atlantic Ocean. Nature, Vol. 419, 603–606.

Chuksin, Yu.V. and Nazarov, N.A. 1989 Peculiarities of distribution and behaviour of horse mackerel in the NE Atlantic. ICES. C.M. 1989/H:7.

Eaton, D.T. 1989. Spawning stock biomass of scad (Trachurus trachurus L.) to the west of the British Isles, as indicated by egg surveys. J. Cons. int. Explor. Mer., 45.

Edwards, M.; Johns,D.G; Licandro,P; John,A.W.G. & Stevens,D.P. 2006. Ecological Status Report: results from the CPR survey 2004/2005. SAHFOS Technical Report, 3:1–8. ISSN 1744–0750.

Farinha, A., Borges, M.F., 1994.. Daily egg production of Horse mackerel (*Trachurus trachurus* L) in Portuguese area (Div. IXa).ICES C.M. 1994/H:19.

Fiksen, Ø. and Slotte, A. 2002. Stock-environment recruitment models for Norwegian spring spawning herring. Canadian Journal of Fisheries and Aquatic Science 59: 211–217.

Fratantoni, D. M., 2001. North Atlantic surface circulation during the 1990s observed with satellite-tracked drifters. Journal of Geophysical Research, Vol. 106, No. C10, pp. 22067–22094.

Furevik, T., 2001. Annual and interannual variability of Atlantic water temperatures in the Norwegian and Barents seas: 1980 – 1996, Deep Sea Res., Part I, 48, 383–404.

Hátún, H., Sandø, A. B., Drange, H., and Bentsen, M. 2005. Seasonal to decadal temperature variations in the Faroe-Shetland inflow waters.

Hátún, H., Jacobsen, K. A., and Sandø, A. B. 2007. Environmental influence on the spawning distribution and migration pattern of northern blue whiting (Micromesistius poutassou). ICES CM 2007/B:06. 10 pp.

Harvey, J. and M. Arhan, 1988. The water masses of the Central North Atlantic in 1983-84. Journal of Physical Oceanography, Vol. 18, No. 12, pp. 1855–1875.

Heino, M., Søiland H., Dahl M., Alvarez J., Tangen Ø., Shnar V., Malyshko A., Krasnoborod'ko O., Ratushnyy S., Mullins E., Johnston G., Power G., Kristiansen J., Goddijn L., Jacobsen J.A., Smith L., Joensen M.M. Ybema S., Bol R., Bakker K., Tjoe-Awie P., Pedersen P. 2006. International blue whiting spawning stock survey Spring 2006. 21 pp. Annex 2. to ICES, 2006. Report of the planning group on northeast atlantic pelagic ecosystem surveys (pgnapes). ICES CM 2006/RMC:08 Ref. LRC, ACFM, ACE, 95pp.

Heino, M., Engelhard, G. H., and Godø, O. R. 2003. Variations in the distribution of blue whiting in the Barents Sea: climatic influences or year class effects? ICES CM 2003/Q:03.

Holst , J.C. and Slotte, A. 1998. Effects of juvenile nursery on geographic spawning distribution in Norwegian spring-spawning herring (*Clupea harengus* L.). ICES Journal of Marine Science [ICES J. Mar. Sci.]. Vol. 55, no. 6, pp. 987–996.

Holst, J.C., Røttingen, I. and Melle, W. 2004. The herring. In: Skjoldal, H.R. (ed.) The Norwegian Sea Ecosystem. Tapir Academic Press, Trondheim, Norway. ISBN 82–519–1841–3.

Huse G, Railsback SF, Fernö A (2002) Modelling changes in migration pattern of herring: collective behaviour and numerical domination. J Fish Biol 60:571–582.

ICES (1998) Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy. ICES C.M. 1998/ACFM:6.

ICES 2004. Report of the Study Group on Regional Scale Ecology of Small Pelagics (SGRESP). Nantes, France 23–26 February 2004. ICES CM 2004/G:06.

ICES 2005a. Report of the Study Group on Regional Scale Ecology of Small Pelagics (SGRESP). Plymouth, UK 28 February - 2 March 2005. ICES CM 2005/G:06.

ICES. 2007a. ICES Report on Ocean Climate 2006. ICES Cooperative Research Report No.289. 59 pp.

ICES 2007b. Report of the of the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES). ICES CM 2007/RMC:07. 94 pp.

ICES 2007c. Report of the working group on the assessment of makerel, horse makerel, sardine and anchovy (WGHMSA). ICES 2007/ACFM:31.

ICES. 2006a. Report of the Northern Pelagic and Blue Whiting Fisheries Working Group(WGNPBW), 24-30 August 2006, ICES Headquarters. ICES CM 2006 /ACFM:34.294 pp.

ICES. 2006b. Zooplankton monitoring results in the ICES area, summary status report 2005/2005. ICES Cooperative Research Report, No. 281, 43 pp.

ICES. 2006d. Report of the working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 27-31 March 2006, Vigo, Spain. ICES CM 2006/LRC:09, Ref. RMC. 75 pp.

Lockwood, S.J. and Johnson, P.O. (1977) Horse Mackerel. Laboratory Leaflet, MAFF Direct. Fish.Res. Lowestoft, number 38., 18pp.

Macer, C.T. (1974) The reproductive biology of the horse mackerel *Trachurus trachurus* (L.) in the North Sea and English Channel. J. Fish Biol., 6: 415–438.

Macer, C.T. (1977) Some aspects of the biology of the horse mackerel *(Trachurus trachurus* L.) in waters around Britain. J. Fish Biol., 10: 51–62.

Misund, O. A., Vilhjálmsson, H., Jakupsstovu, S. H. I., Røttingen, I., Belikov, S., Asthorsson, O., Blindheim, J., Jónsson, J., Krysov, A., Malmberg, S. A. and Sveinbjørnsson, S. (1998). Distribution, migration and abundance of Norwegian spring spawning herring in relation to the temperature and zooplankton biomass in the Norwegian Sea as recorded by coordinated surveys in spring and summer 1996. Sarsia 83: 117–127.

Monstad, T. 2004. Blue whiting. *In*: Skjoldal, H. R., Editor. The Norwegian Sea ecosystem. Trondheim: Tapir Academic Press. pp. 263–288.

Murta, A.G., Borges M.F., 1994. Factors affecting the abundance distribution of horse mackerel *Trachurus trachurus* (Linnaeus,1758) in Portuguese waters. ICES CM 1994/H:20.

Murta, A.G., Abaunza, P., Cardador, F., Sanchez, F. 2008. Ontogenic migrations of horse mackerel along Iberian coast. Fisheries Research 89 (2008) 186–195.

Olaso, I; Cendrero, O; Abaunza, P1999. The diet of the horse mackerel, Trachurus trachurus (Linnaeus 1758), in the Cantabrian Sea (north of Spain) Journal of Applied Ichthyology [J. Appl. Ichthyol./Z. Angew. Ichthyol.]. Vol. 15, no. 6, pp. 193–198.

Oskarsson, G. J., Kjesbu, O. S., and Slotte, A. 2002. Predictions of realised fecundity and spawning time in Norwegian spring spawning herring (*Clupea harengus* L.). Journal of Sea Research 48: 59–79.

Pollard, R.T., F.F. Read and N.P. Holliday, 2004. Water masses and circulation pathways through the Iceland Basin during Vivaldi 1996. Journal of Geophysical Research, Vol. 109, C04004, doi:10.1029/2003JC002067.

Polonski, A.S. 1965 The horse mackerel of the Eastern Atlantic and its fishery. Rybnoe Khozyaistvo 41 (6), 8–10 and (7), 13–15, transl. by Fish. Lab. Lowestoft, no. N.S.85, Lowestoft, England.

Prokopchuk, I., and Sentyabov, E. 2006. Diets of herring, mackerel, and blue whiting in the Norwegian Sea in relation to Calanus finmarchicus distribution and temperature conditions. ICES Journal of Marine Science, 63: 117–127.

Reid, D. G. 2001. SEFOS e shelf edge fisheries and oceanography studies: an overview. Fisheries Research, 50: 1–15.

Reid, D. G., Walsh, M., and. Turrell, W. R 2001 Hydrography and mackerel distribution on the shelf edge west of the Norwegian deeps. Fisheries Research 50: 141–150.

Reid D. G., Eltink, A. Kelly C. J., and M. Clark (2006) Long term changes in the pattern of the prespawning migration of the western mackerel (*Scomber scombrus*) since 1975, using commercial vessel data. ICES CM 2006/B:14.

Richardson, A.J. and Schoeman D.S. 2004. Climate impact on plankton ecosystems in the northeast Atlantic. Science 305:1609–1612.

Rossby, T., 1999. On gyre interaction. Deep-Sea Research II, Vol. 46, No. 1-2, pp. 139–164.

Santos, A.M.P., Borges, M.F., Groom, S., 2001. Sardine and horse mackerel recruitment and upwelling off Portugal. *ICES Journal of Marine Science*. Vol 58, No 3, 589–596.

Skogen, M. D., Monstad, T., and Svendsen, E. 1999. A possible separation between a northern and a southern stock of the northeast Atlantic blue whiting. Fisheries Research 41, 119–131.

Slotte, A.1999a. Differential utilisation of energy during wintering and spawning migration in Norwegian spring spawning herring (*Clupea harengus* L.). Journal of Fish Biology 54: 338–355.

Slotte, A. 1999b. Effects of fish length and condition on spawning migration in Norwegian spring spawning herring (Clupea harengus L.). Sarsia 84: 111–127.

Slotte, A. 2000. Factors influencing location and time of spawning in Norwegian spring-spawning herring: an evaluation of different hypotheses. In: Funk, F. *et al.* (eds.). Herring. Expectations for a New Millennium. pp. 255-278. Lowell Wakefield Fisheries Symposium Series [Lowell Wakefield Fish. Symp. Ser.]. no. 18.

Slotte, A. and Fiksen, Ø. 2000. State-dependent spawning migration in Norwegian spring spawning herring (*Clupea harengus* L.). Journal of Fish Biology 56: 138–162.

Sætre, R., Toresen, R., and Anker-Nilssen, T. 2002. Factors affecting the recruitment variability of the Norwegian spring-spawning herring (*Clupea harengus* L.). ICES Journal of Marine Science 59: 725–736.

Toresen, R., and Østvedt, O. J. 2000. Variation in abundance of Norwegian spring spawning herring (*Clupea harengus*, Clupeidae) throughout the 20th century and the influence of climatic fluctuations. Fish and Fish. 1: 231–256.

(4) DEEP WATERS

Allain V., Biseau A. and Kergoat B. 2003. Preliminary estimates of French deepwater fishery discards in the Northeast Atlantic Ocean. Fishery Research, 60: 185–192.

Freiwald, A. and Wilson, B.J., 1998. Taphonomy of modern deep, cold-temperate water corals reefs. Historical Biology, 13: 37–52.

Gage J.D. and Tyler P.A. 1991. Deep-sea biology. A natural history of organisms at the deep-sea floor. Cambridge University Press, Cambridge, pp. 263–273.

Genin, A., Dayton, P.K., Lonsdale, P.F. and Spiess, F.N. 1986. Corals on seamount peaks provide evidence of current acceleration over deep-sea topography. Nature, 332: 59–61.

Gordon J.D.M. 1979. Lifestyle and phenology in deep sea Anacanthine Teleosts. Symposia of the Zoological Society of London, 44: 327–359.

Gordon, J.D.M. 1986. The fish populations of the Rockall Trough. Proceedings of the Royal Society of Edinburgh, Series B, 88: 191–204.

Gordon J.D.M. and Bergstad O.A. 1992. Species composition of demersal fish in the Rockall Trough, north-eastern Atlantic, as determined by different trawls. Journal of the Marine Biological Association of the United Kingdom, 72: 213–230.

Gordon J.D.M. and Duncan J.A.R. 1985. The ecology of deep-sea benthic and benthopelagic fish on the slopes of the Rockall Trough, northeastern Atlantic. Progress in Oceanography, 15: 37–69.

Gordon, J.D.M., Merrett, N.R. and Haedrich, R.L. 1995. Environmental and biological aspects of slope-dwelling fishes of the north Atlantic. Pp 1–26 in: Hopper A.G. (eds) Deep-water fisheries of the North Atlantic oceanic slope. Kluwer Academic, London. ICES WGRED Report 2008.

Hareide N.-R. and Garnes G. 2001. The distribution and abundance of deep water fish along the Mid-Atlantic ridge from 43°N to 61°N. Fisheries Research. 51: 297–310.

Hareide, N.-R., Garnes, G., Rihan, D., Mulligan, M., Tyndall, P., Clark, M., Connolly, P.L., Misund, R., Mcmullen, P., Furevik, D., Humborstad, O.B., Høydal, K. and Blasdale, T. 2005. A preliminary investigation on shelf edge and deepwater fixed net fisheries to the west and north of Great Britain, Ireland, around Rockall and Hatton Bank. 47 pp. Available at: http://www.bim.ie.

Husebo, A., Nottestad, L., Fossa, J.H., Furevik, D.M. and Jorgensen, S.B. 2002. Distribution and abundance of fish in deep-sea coral habitats. Hydrobiologia, 471: 91–99.

ICES, 2004. Report of the working group on biology and assessment of deep-sea fisheries resources. International Council for the Exploration of the Sea, Copenhagen. ICES CM 2004/ACFM:15 Ref. G. ICES CM 2003/ACFM: 25. 308 pp.

ICES, 2007. The Annual ICES Ocean Climate Status Summary 2006. ICES Cooperative Research Report, No. 289. 59 pp.

ICES, 2005b. Report of the working group on marine mammal ecology. ACE: 05, 137pp.

Joubin, M.L. 1922. Les coraux de mer profonde nuisibles aux chalutiers [Deepsea coral harmful to trawlers]. Office Scientifique et Technique des Peches Maritimes, Notes et Memoires, 18: 5–16.

Koslow, J.A. 1997. Seamounts and the ecology of deep-sea fisheries. American Scientist, 85: 168–176.

Koslow, J.A., Boehlert, G., Gordon, J.D.M., Haedrich, R.L., Lorance, P. and Parin, N. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. ICES Journal of Marine Science, 57: 548–557.

Lorance, P., Latrouite, D. and Seret, B. 2000. Observations of chondrichthyan fishes (sharks, rays and chimaeras) in the Bay of Biscay (North-eastern Atlantic) from submersibles. Proc. 3rd European Elasmobranch Association Meeting, Boulogne-sur-Mer, 27–29 May 1999: 29–45.

Lorance, P. and Dupouy, H. 2001. CPUE abundance indices of the main target species of the French deep-water fishery in ICES Sub-areas V-VII. Fisheries Research, 51: 137–149.

Lorance P., Uiblein F. and Latrouite D. 2002. Habitat, behaviour and colour patterns of orange roughy *Hoplostethus atlanticus* (Pisces: Trachichthyidae) in the Bay of Biscay. Journal of the Marine Biological Association of the United Kingdom, 82: 321–331.

McClatchie, S., Thorne, R.E., Grimes, P. and Hanchet, S. 2000. Ground truth and target identification for fisheries acoustics. Fisheries Research, 47: 173–191.

Merrett, N.R. and Haedrich, R.L. 1997. Deep-sea demersal fish and fisheries. Chapman & Hall, London, 282 p.

Mortensen, P.B., Hovland, M., Brattegard, T. and Farestveit, R. 1995. Deep water bioherms of the scleractinian coral *Lophelia pertusa* (L.) at 64 degree N on the Norwegian shelf: structure and associated megafauna. Sarsia, 80: 145–158.

Rogers, A.D. 1999. The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. International Review of Hydrobiology, 84: 315–406.

2 Interaction between the ecosystem and fisheries case studies

2.1 Description of the fisheries case studies

It is impossible to deal with all types of fisheries and gear types within the scope of this project. Therefore case studies are selected that include a mixture of gear types and trophic levels across the regions. In the NWW RAC region, four fisheries are selected (Table 2.1.1) for their socio-economic importance and impact they have on the NWW ecosystem. The fisheries are discussed separately and the rationality behind their selection will be commented on.

Table 2.1.1: The four case studies selected for the North Sea RAC region and their targeted species

Case study	Target species
North East Atlantic Mackerel	*Scomber scombrus*
Dublin Bay Prawn (Area VI & VII)	*Nephrops norvegicus*
Northern Hake	*Merluccius merluccius*
Scallop	*Pecten maximus*

Mackerel is mainly exploited in a directed fishery for human consumption. Mackerel catches in 2007 are estimated to be about 600,000 t. This stock is in a good state and the Total Allowable Catch (TAC) for 2009 was increased by over 30 % compared with 2008.

Nephrops are limited to a muddy habitat and the distribution of suitable sediment defines the species distribution. Most stocks in the NWW area appear to be stable in terms of abundance and size composition. In 2007, 16, 333 t were landed from VI and 15,395 t from VII.

Hake is widely distributed over the northeast Atlantic shelf, from Norway to Mauritania, with a larger density from the west of Ireland to the south of Spain. This species has been a very important resource for many demersal fisheries of the NWW region. It is landed as targeted or incidental catch by a wide variety of gears (bottom trawls, nets, and longlines). In 2007, 44,392 t of hake were landed by all fleets.

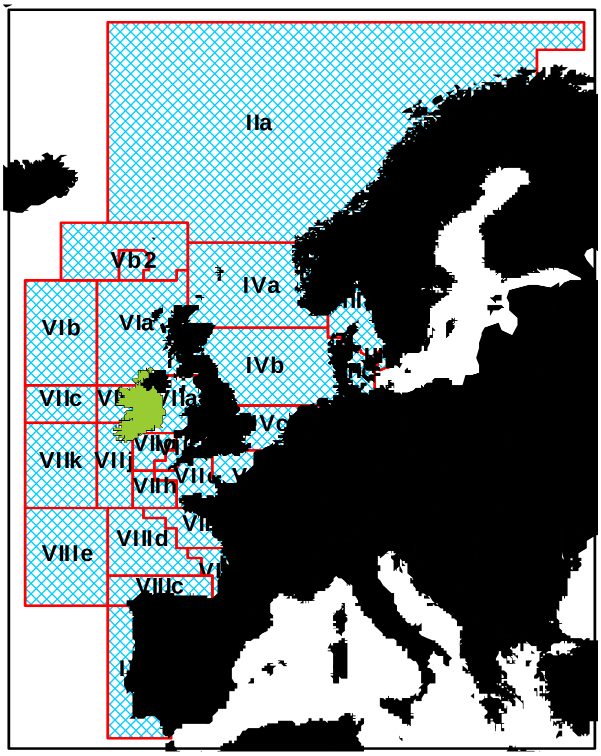
The scallop is an important commercially exploited species of bi-valve in northern Europe, extending from Norway south to Spain. It attains a large body size, is a high value species and is also the subject of extensive and intensive aquaculture in northern Europe. In 2007, 56,189 t of scallop were landed from NWW.

2.1.1 North East Atlantic Mackerel

Pelagic trawls target pelagic species that usually swim in shoals. These shoals are located with the use of echo-sounding equipment which provides information on the location, size and position of a shoal in the water column. This technique makes this fishery very efficient in targeting fish and the use of echo-sounding equipment should result in low by-catch. However, shoals may consist of mixed species (most notable of herring and mackerel), which could result in non-target species being discarded (ICES, 2008a). A less frequent, but more rigorous way of discarding is referred to as slippage (Borges et al., 2008). This occurs when large amounts of catch are released from the cooling tanks (tank slippage) or straight from the net (net slippage).

The pelagic trawl is a cone-shaped net which is towed behind the ship just below the water surface or further down the water column, depending on the target species. The trawling depth for mackerel is 50-200 metres. Trawl doors are used to keep the mouth of the net open during trawling. The hydrodynamic forces playing on the boards push the net outwards. Alternatively, the horizontal opening of the net is maintained by towing the net with two ships (pair trawling). Floats on the headline and weights on the ground line often maintain the vertical opening of the net. The net sounders give information on the position of the gear relative to the seafloor in addition to the vertical opening of the net mouth. In order to catch a shoal, the net has to be put in such a position that the net opening cuts of the densest part of the shoal. The duration of a haul can vary enormously. When the net is hauled in, pumps are used to transfer the catch from the cod-end to the ship, where it is stored in cooling tanks until it can be processed. The duration of each fishing trip depends mainly on the catch rate and storage capacity of the ship. The vessels usually return when all cooling tanks are full.

Catches of mackerel in 2007 and 2008 were considerably in excess of the ICES' advice. The absence of effective international agreements on the exploitation of the stock (between all nations involved in the fishery) is a cause of concern and prevents control of the exploitation rate of the stock. According to the short-term forecast, the total estimated catch in 2009 resulted in an estimated fishing mortality which is above that stipulated in the management plan. The 2010 TAC advice implies catches between 527 000 t and 572 000 t and this should apply to all areas fished (Figure 1.1.1). The SSB is expected to remain stable in 2011 for a catch in this range.



Red Boxes-TAC/Management Areas

Blue Shading– Assessment Area

Figure 1.1.1: Management and assessment area for North East Atlantic Mackerel

The spawning stock biomass (SSB) has increased from a low of 1.8 million t in 2002 to around 2.5 million t in 2008, a level similar to that seen in the 1990s. The current estimated stock level and recent stock development is shown in Figure 1.1.2.Available information indicates that the distribution of the spawning area and feeding areas of mackerel have expanded in recent years. Mackerel has been commercially fished in areas where it was previously not fished, particularly in the Icelandic EEZ. An evaluation of unaccounted mortality in the mackerel fishery (Simmonds, 2007) suggested that both biomass and removals were significantly greater than those estimated using the standard assessment model. These analyses also suggested that the historic estimates of fishing mortality provided by the standard assessment are not affected by unaccounted mortality. These conclusions need further investigation. The results from the stock assessment provide the best estimates of biomass for mackerel in the Northeast Atlantic.

Mackerel is mainly exploited in a directed fishery for human consumption. This fishery tends to target bigger fish and there is evidence that this causes discarding of smaller, less marketable fish. In June 2009, an agreement was concluded between contracting parties to the Coastal States on mackerel banning high-grading, discarding, and slipping from pelagic fisheries targeting mackerel, horse mackerel, and herring beginning in January 2010.

Prior to the late 1960s, spawning biomass of North Sea mackerel was estimated to be above 3 million tonnes. Due to over-exploitation, recruitment has failed since 1969 leading to a marked decline in the stock size. The measures advised by ICES have been aimed at protecting the North Sea spawning component and promoting stock recovery. The North Sea spawning component has increased since 1999, but continued protection is needed as the abundance remains low. The closure of the mackerel fishery in Divisions IVb,c and IIIa throughout the whole year is designed to protect the North Sea component in this area, and also protect juvenile Western mackerel which are numerous, particularly in Division IVb,c during the second half of the year. Unfortunately, the closure has resulted in increased discards of mackerel in the non-directed fisheries (especially horse mackerel fisheries) in these areas as vessels are currently permitted to take only 10% of their catch as mackerel by-catch. As estimates of mackerel by-catch are not available, the reported landings of mackerel in Divisions IIIa and IVb,c from 1997 onwards underestimate catches because they do not include discarded by-catch.

The advised fishery closure of Division IVa during the first half of the year is based on the perception that the Western mackerel enter the North Sea in July/August, and stay there until December before migrating back to their spawning areas. Updated observations in the late 1990s suggest that this return migration actually begins in mid- to late February. This is believed to result in large-scale misreporting from the northern part of the North Sea (Division IVa) to Division VIa. As a consequence, ICES recommended that the closure for Division IVa be extended to the 15th of February1. This was adopted for the 1999/2000 fishing season onwards. However, misreporting from Division IVa to VIa continues to occur.

In recent years significant catches have been taken in Icelandic waters, an area where almost no catches have been previously reported. In 2008 and 2009, catches in this area constituted approximately 18% of the total catch. In the southern part of the distribution area, Atlantic mackerel (*Scomber scombrus*) can be caught together with Spanish mackerel (*Scomber colias*).

In recent years, catches of Spanish mackerel have increased. The catch in 2005 was the highest since 1982. Catches of both species are landed separately. ICES advice applies to Atlantic mackerel only.

Survey data and catch information suggest distributional changes of both juveniles and adult mackerel. This indicates an expansion of mackerel further west and less north compared to previous years, illustrating the inter-annual dynamics of a fast moving species. The distribution pattern coincided with considerably warmer surface waters in 2009 than in earlier years in both the western part of the Norwegian Sea and in the northern part of the Icelandic zone. Together with temperature, feeding opportunities seem to affect the distribution of the mackerel stock.

ICES currently uses the term “Mackerel in Northeast Atlantic” to define the mackerel present in the area extending from ICES Division IXa in the south to Division IIa in the north, including mackerel in the North Sea and Division IIIa (Figure 1.1.1). The spawning areas of mackerel are widely spread, and only the stock in the North Sea is sufficiently distinct to be clearly identified as a separate spawning component. Tagging experiments have demonstrated that after spawning, fish from Southern and Western areas migrate to feed in the Norwegian Sea and the North Sea during the second half of the year. In the North Sea they mix with the North Sea component. Since it is currently impossible to allocate catches to the stocks previously considered by ICES, for practical reasons all mackerel in the Northeast Atlantic are considered to comprise a single stock (i.e. the mackerel in the Northeast Atlantic stock). Catches cannot be allocated specifically to spawning area components on biological grounds but by convention, catches from the Southern and Western components are separated according to the areas in which these are taken. To keep track of the development of spawning biomass in the different spawning areas, mackerel in the Northeast Atlantic stock are divided into three area components: the Western Spawning Component, the North Sea Spawning Component**,** and the Southern Spawning Component:

Mackerel are distributed and fished in ICES Subareas and Divisions IIa, IIIa, IV, V, VI, VII, VIII, and IXa. Spawning Areas are found in areas VI, VII, VIIIa,b,d,e. VIIIc, IXa. IV, IIIa. The Western Component is defined as mackerel spawning in the western area (ICES Divisions and Subareas VI, VII and VIII a,b,d,e). This component currently accounts for 76% of the entire Northeast Atlantic stock. Similarly, the Southern Component is defined as mackerel spawning in the southern area (ICES Divisions VIIIc and IXa). Although the North Sea component has been at an extremely low level since the early 1970s, ICES considers that the North Sea Component still exists as a discrete unit. This component spawns in the North Sea and Skagerrak (ICES Subarea

IV and Division IIIaN). Current knowledge of the state of the spawning components is summarised below.

The catches of this Western component were low in the 1960s, but increased to more than 800 000 t in 1993. The main catches are taken in directed fisheries by purse-seiners and mid-water trawlers. Large catches of the western component are taken in the northern North Sea and in the Norwegian Sea. The 1996 catch was reduced by about 200 000 t compared with 1995, because of a reduction in the TAC. The catches since 1998 have been stable. The SSB of the Western Component declined in the 1970s from above 3.0 million t to 2.2 million tonnes in 1994, but increased to 2.7 million tonnes in 1999. A separate assessment for this stock component is no longer required, as a recent extension of the time-series of mackerel in the Northeast Atlantic data now allows the estimation of the mean recruitment from 1972 onwards. Estimates of the spawning-stock biomass, derived from egg surveys, indicate a decrease of 14% between 1998 and 2001 and a 6% decrease from 2001 to the 2004 survey. The results from 2007 indicated a 5% increased from 2004 to 2007.

Very large catches of the North Sea component were taken in the 1960s in the purse-seine fishery, reaching a maximum of about 1 million t in 1967. The component subsequently collapsed and catches declined to less than 100 000 t in the late 1970s. Catches during the last five years are assumed to be about 10 000 t. The 2002 and 2005 triennial egg surveys in the North Sea both indicate similar egg production, but in 2008 egg production decreased by about 40%.

Southern Mackerel is a target species for the hand line fleet during the spawning season in Division VIIIc, during which about one-third of the total catches are taken. Mackerel are also taken as a by-catch in other fleets. The highest catches (87%) from the Southern Component are taken in the first half of the year, mainly from Division VIIIc, and consist of adult fish. In the second half of the year catches consist of juveniles and are mainly taken in Division IXa. Catches from the Southern Component increased from about 20 000 t in the early 1990s to 44 000 t in 1998, and were close to 50 000 t in 2002. Estimates of the spawning-stock biomass, derived from egg surveys, are highly variable, and give average estimates of around 16-20% of the combined mackerel in the Northeast Atlantic stock (1995–2007).

This assessment is based on catch numbers-at-age for the period 1972–2008 and triennial egg survey estimates of SSB from 1992 to 2007. In the past, estimates of total mortality have been similar to those obtained from tag-recapture studies. Some sampling for discards has been carried out since 2000 and a formal requirement was initiated in the EU in 2002. Estimating proportions of catch discarded and slipped is problematic in pelagic fisheries due to high variability in discard and slipping practices. In some fleets no sampling for discards is carried out. Recently, information on these practices has been improving; discards from sampled fleets (Scotland, the Netherlands, and Germany) in 2008 amounted to 27 000 t.

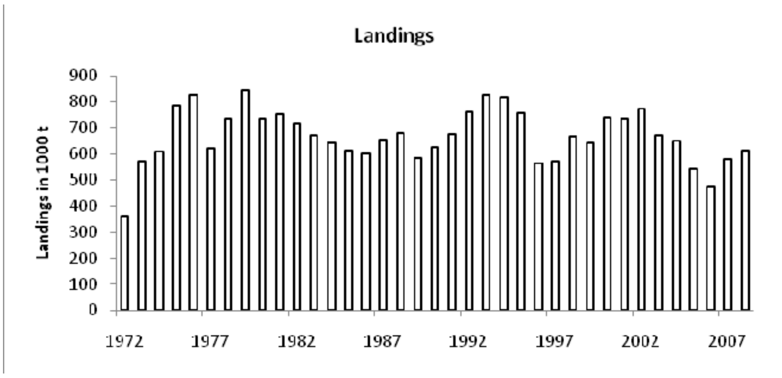
Recruit surveys provide information on the distribution of young mackerel, but are subject to high variability and have not proved useful in estimating year-class strength.

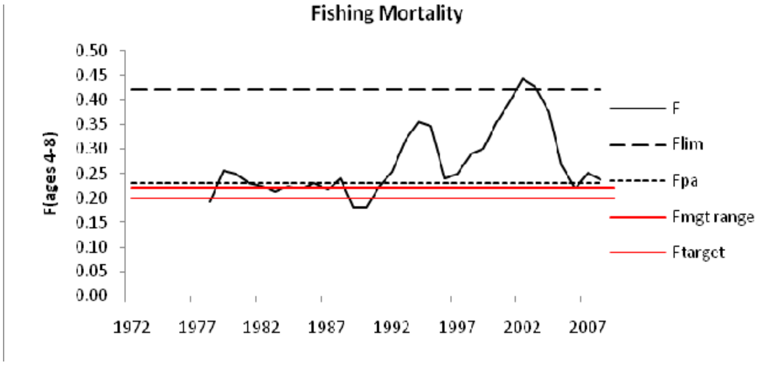
The fishing industry has informed ICES that in all the EU fishing fleets targeting mackerel, large quantities of juvenile and adult mackerel continue to be seen on the fishing grounds, as reported last year. This is not confined to one area or to one member state’s fleet. In addition, the abundance of mackerel in the entire distribution area is creating major problems with unwanted by-catches for some fleets not targeting mackerel. Furthermore, the industry has observed that the distribution seems to have changed in a westerly direction, giving more catches of larger fish in the earlier part of the season than usual. Stakeholders are actively seeking mechanisms that would allow inclusion of fishing industry information into the assessment process and are involved in a number of pilot projects in this regard.

Due to the shortage of fishery-independent data, the absence of age-disaggregated information for the spawning-stock index and the uncertainty in the magnitude of catches, SSB estimates are uncertain, but fishing mortality and the trend in SSB are better estimated.

The estimated catch for 2009 used in the forecast is uncertain due to additional catches in excess of the TAC that cannot be quantified precisely at present. Some information on the level of discards is available and was included in the assessment, but the number of fleets sampled is not sufficient to capture the full scale of discarding.

The perception of the stock based on the assessment results is very similar to last year's assessment. The basis of the advice this year is the precautionary management plan given above. Norway, Faroe Islands, and the EU agreed to the plan in 2008, but it has not been agreed to by all of the participants in the fishery. Previous advice was based on a management plan agreed by Norway, Faroe Islands, and the EU in 1999.


Landings
Landings in 1000 t
900
800
700
600
500
400
300
200
100
0
1972
1977
1982
1987
1992
1997
2002
2007


Fishing Mortality
F(ages 4-8)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1972
1977
1982
1987
1992
1997
2002
2007
F
Flim
Fpa
Fmgt range
Ftarget


Recruitment (age 0)
Recruitment in billions
9
8
7
6
5
4
3
2
1
0
1972
1977
1982
1987
1992
1997
2002
2007

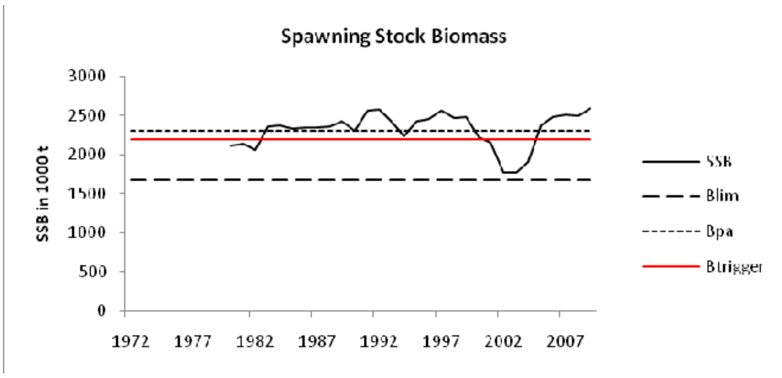

Spawning Stock Biomass
SSB in 1000 t
3000
2500
2000
1500
1000
500
0
1972
1977
1982
1987
1992
1997
2002
2007
SSB
Blim
Bpa
Btrigger

Figure 1.1.2: Summary of stock assessment: landings, fishing mortality, recruitment, and SSB for Mackerel in the Northeast Atlantic (Combined Southern, Western, and North Sea spawning components).

2.1.2 Dublin Bay Prawn (Nephrops) Area VI

Nephrops are limited to a muddy habitat and the distribution of suitable sediment defines the species distribution and the stocks are therefore assessed as three separate Functional Units (FU) as identified in Figure 1.1.3.

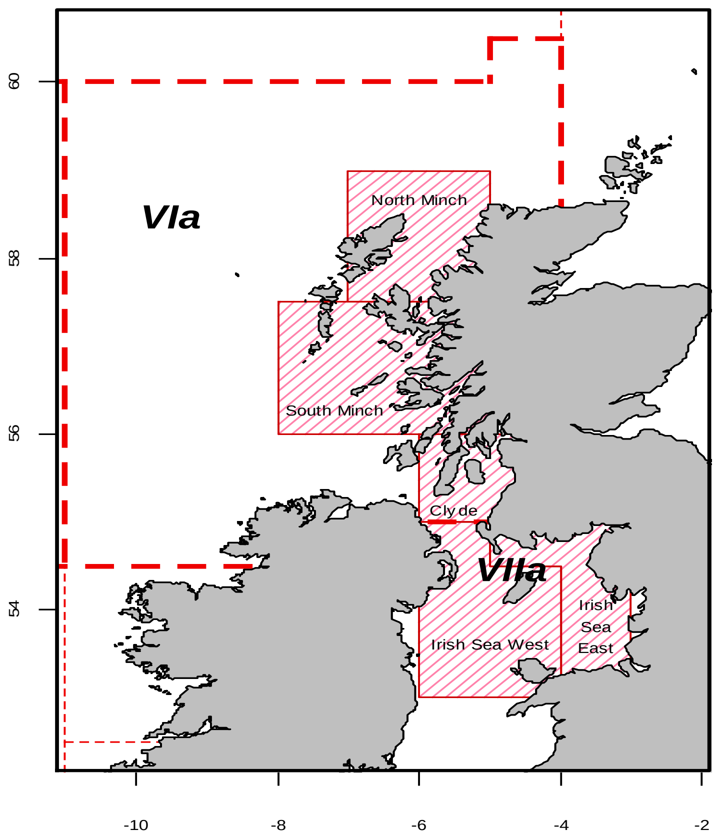


Figure 1.1.3: *Nephrops* Functional Units in Division VIa.

The overriding management consideration for these stocks is that management should be at the Functional Unit rather than the ICES Subarea/Division level. Management at the Functional Unit level should provide the controls to ensure that catch opportunities and effort are compatible and in line with the scale of the resources in each of the stocks defined by the Functional Units. Current management of *Nephrops* in Subarea VI (both in terms of TACs and effort) does not provide adequate safeguards to ensure that local effort is sufficiently limited to avoid depletion of resources in Functional Units. In the current situation vessels are free to move between grounds, allowing effort to develop on some grounds in a largely uncontrolled way and this has historically resulted in inappropriate harvest rates from some parts.

There are no precautionary reference points defined for *Nephrops*. This year ICES advises that F should be in the range of $F_{0.1}$ to F_{max} to maximize long-term average yield without unduly risking low SSB. Where the advice suggests a large change in landings, a constraint on the year-to-year change in catches as is typical of management plans and as implied by "Communication on Fishing Opportunities for 2010 [COM (2009) 224]" might be considered.

The by-catches of cod in the *Nephrops* fisheries have been fairly small (less than 1.5% in weight or numbers/Nephrops catch, DEFRA, 2009). However, it is important that emerging cod year classes should not be subject to mortality as by-catch. The capture of juvenile fish or other species such as haddock is also a problem in some of the Functional Units and discarding of these is a problem in some years. This problem can be addressed with the use of more selective gear and efforts are already being made in Scotland through the Conservation Credits Scheme, requiring vessels targeting *Nephrops* to use gear with larger square meshed panels (110 mm). Subject to evaluation of the effectiveness of these measures, further action may be required to reduce by-catch. Surveys in the area do not take account of some smaller areas containing *Nephrops* populations. These areas are not well surveyed and do not have adequate sediment distribution to define abundance adequately. In particular landings are made from the sea loch areas which are not covered by the Underwater TV (UWTV) survey. The sea lochs support an unknown part of the creel fishery. As such the surveys should be considered underestimates of the overall biomass. There are also *Nephrops* catches in "other rectangles" in Division VIa, e.g. from offshore areas adjacent to Stanton Bank where Irish fishers frequently operate from the shelf edge. To provide some guidance on appropriate future landings for these areas, the use of average landings of 250 t could be considered. There are no Functional Units in ICES Division VIb, but occasional small landings are made.

Impacts of fisheries on the ecosystem

Trawling for *Nephrops* results in by-catch and discards of other species, including cod, haddock, and whiting. 80 mm is the predominant mesh size used in *Nephrops* fisheries and the resulting discarding of fish can be high. Initiatives are in place to reduce the discard problem with respect to small fish (see Regulations and their effects below). The high mud content and soft nature of *Nephrops* grounds means that trawling readily marks the seabed, trawl marks remaining visible for some time. Burrowing fauna can be seen re-emerging from freshly trawled grounds, implying that there is some resilience to trawling.

Regulations and their effects

The implementation of the "Buyers and Sellers" legislation in the UK in 2006 considerably tightened up the levels of reporting for *Nephrops*, and the landings figures since then are considered to be more reliable. Recent increases in landings and lpue may result from the increase in reporting levels and do not necessarily reflect changes to the stock. Recently introduced effort allocation schemes (kW*days) have reduced opportunities for directed whitefish fishing. This may increase the effort aimed at *Nephrops* fisheries as it has done in similar schemes in the North Sea. A ban on the use of multi-trawl gears (3 or more trawls) for all Scottish boats was introduced from April 2008, limiting the expansion of effective effort.

The development of a Conservation Credits Scheme in Scotland requires all trawlers to implement more selective gears in 2009, including the use of 110 mm square mesh panels in 80 mm gear. This measure should reduce catches (and discards) of small fish, including whiting, haddock, and juvenile cod.

Scientific basis

Data and methods

Assessments of the *Nephrops* Functional Units of Division VIa utilized a number of approaches including UWTV surveys, length composition information, and basic fishery data such as landings and effort. Owing to uncertainties in the accuracy of historic landings and to inaccurate effort figures in some fisheries, increasing attention is paid to survey information and size composition data as an indicator of stock status.

There have been important developments in the methodology to assess the status of *Nephrops* stocks. The use of UWTV surveys has enabled the development of fishery-independent indicators of abundance. STECF (2005) had suggested that a combination of an absolute abundance estimate from an UWTV survey and a harvest rate based on F0.1 from a combined sex–length cohort analysis (LCA) and the mean weight and selection pattern from the commercial fishery could be used to calculate appropriate landings. This approach has been further developed and evaluated at ICES workshops in 2007 and 2009 (ICES, 2007, ICES 2009b). The 2009 workshop addressed concerns raised regarding factors which could potentially bias the UWTV survey results. Major sources of bias were quantified for each survey and an overall bias correction factor derived which, when applied to the estimates of abundance from the UWTV survey, allows them to be treated as absolute abundance levels.

In particular the workshop concluded that the UWTV surveys detect the burrows of *Nephrops* considerably smaller than the sizes of those taken by the fishery. Therefore the abundance estimates used to calculate the Harvest Ratios presented in the 2009 advice include a component of the stock that is too small to be exploited by the fishery. This has resulted in calculated Harvest Ratios appearing to have decreased in the current advice compared to previous estimates of Harvest Ratios. In essence, this is a scaling issue, not a change in exploitation rate. The previous Harvest Ratios corresponding to fishing at F0.1 were in the range of 15-20% whereas the revised values are in the range of 8-10%.

Uncertainties in assessment and forecast

ICES groups WKNephTV (ICES 2007), WKNephBid (ICES 2008), SGNepS (ICES 2009a) have worked to reduce uncertainty and increase precision in the interpretation of survey data. Ultimately there still remains a degree of subjectivity in the production of UWTV indices.

There is a gap of 18 months between the survey and the start of the year for which the assessment is used to set management levels. It is assumed that the stock is in equilibrium during this period (i.e. recruitment and growth balance mortality) although this is rarely the case. The effect of this assumption on realised harvest rates has not been investigated. The calculations of Harvest Ratio and F0.1 are all based on yield-per-recruit analyses from length cohort analyses. These analyses utilise average length frequency data taken over a 3 year period and therefore assume that the stocks is in equilibrium. However, it is unlikely that the *Nephrops* stocks to which the approach has been applied are actually in equilibrium due to variable recruitment. F0.1 estimates may vary in time due to changes in selection pattern.

Stock monitoring continues, and enhanced work on observer trips on-board commercial vessels should furnish additional data which will be beneficial in developing assessment approaches further. Vessel Monitoring data from satellite (VMS) are being successfully used to match survey and fishery areas for vessel >15m. The UWTV survey results reported here do not cover the sea loch areas adjacent to the main FU fishing grounds and should therefore be considered underestimates of the overall biomass. The sea lochs support an unknown part of the creel fishery. This creel fishery is mainly smaller vessels without VMS. In the provision of catch options based on the absolute survey estimates additional uncertainties related to mean weight

in the landings and the discard rates also arise. A three year average (2005-2007) discard rates have been used in the calculation of catch options. The discard rates for stocks in Division VIa has been quite variable in the past and all three stocks show a large decline in discards in 2007 coincident with a drop in survey abundance. Prior to the implementation of 'Buyers and Sellers' legislation in 2006 reporting rates are considered to have been low and hence the estimated Harvest Ratios prior to 2006 are also likely to have been underestimated. The reliability of fishery statistics is improving but the transition period is accompanied in some cases by large changes in landings which produce significant changes in the LPUE and CPUE series that cannot be completely attributed to changes in stock. Until a sufficient time series of reliable data has built up, use of fishery catch and effort data in the assessment process should be avoided.

2.1.3 Dublin Bay Prawn (Nephrops) Area VII

As in Division VI *Nephrops* stocks assessed as separate Functional Units (FU) as shown in Figure 1.1.4. There are also some smaller catches from areas outside these Functional Units.

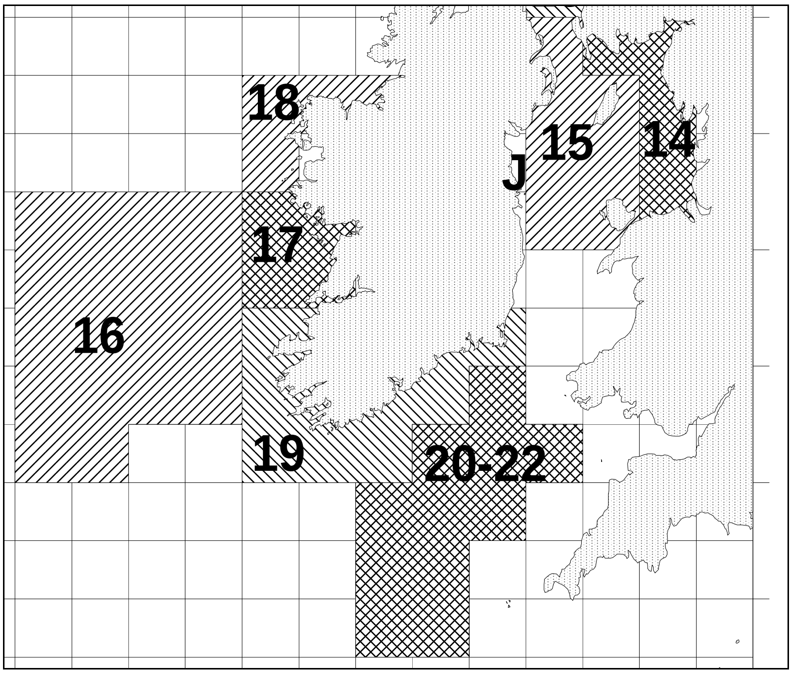


Figure 1.1.4: ***Nephrops*** **Functional Units in Subarea VII (around Ireland). The TAC for Sub-Area VII applies to the area bounded by the red line. The FUs within the TAC area are shaded.**

Current management of *Nephrops* in Subarea VII (both in terms of TACs and effort) does not provide adequate safeguards to ensure that local effort is sufficiently limited to avoid depletion of resources in separate Functional Units. The current situation allows for catches to be taken anywhere in the ICES Division and this could imply inappropriate harvest rates from some parts. More importantly, vessels are free to move between grounds, allowing effort to develop on some grounds in a largely uncontrolled way. This appears to have been a particular problem in the Porcupine Bank where a large increase in effort has occurred over the past five years and the stock has declined substantially.

There are no precautionary reference points defined for *Nephrops*. This year ICES has provided advice on a range of catch options including a long-term exploitation rate for *Nephrops* and advises that F should be in the range of $F_{0.1}$ to F_{max} to maximize long-term average yield without unduly risking SSB.

Where the new advice suggests a large change in landings, a constraint on the year-to-year change in catches as is typical of management plans and as implied by the Communication on Fishing Opportunities for 2010 [COM (2009) 224] might be considered. Some combinations of F and trend in SSB are included for completeness, even though not all of these combinations have been applied to Celtic Sea *Nephrops*.

Landings from the northwest coast of Ireland NW (FU 18) have previously been treated as a separate Functional Unit although landings have been negligible in recent years and there is no major *Nephrops* fishery in that area. ICES only reports landings statistics for that area. There are also *Nephrops* catches in “other rectangles” in Subarea VII. Landings from these “other rectangles” have been up to 800 t in the past, but since 2003 landings have been around 200 t. To provide some guidance on appropriate future landings for these areas, the use of landings of 200 t could be considered.

Landings in recent years have been well below the TAC due to low uptake by France and Spain, whereas the UK and Irish landings are close to the quota.

Impacts of fisheries on the ecosystem

Trawling for *Nephrops* results in by-catch and discards of other commercial species, including cod, haddock, whiting, hake, monkfish and megrim.

80 mm is the predominant mesh size used in *Nephrops* fisheries and the resulting discarding of small *Nephrops* and fish can be high.

The high mud content and soft nature of *Nephrops* grounds means that trawling readily marks the seabed, trawl marks remaining visible for some time. Despite the high intensity of fishing (some areas are impacted >7 times/year) burrowing fauna can be seen re-emerging from freshly trawled grounds, implying that there is some resilience to trawling.

Factors affecting the fisheries and the stock

Regulations and their effects

Landings by some fleets prior to 2007 are thought to have been underreported. The implementation of the 'Buyers and Sellers' legislation in the UK in 2006 and 'sales notes' in Ireland in 2007, coupled with the increased TAC in 2007, is thought to have improved the reliability of reported landings data. The transition has been accompanied by a large change in reported landings and a significant recent increase in landings per unit effort (LPUE) for some countries that cannot completely be attributed to changes in the stock.

Scientific basis

Data and methods

Assessments of the *Nephrops* stocks around Ireland utilised a number of approaches. The fishery-independent data include Underwater TV surveys (Western Irish Sea and Aran Ground) and trawl surveys (Western Irish Sea, Porcupine Bank, and Celtic Sea). There is some information on the length structure and sex ratio of either landings or catches in most areas. There are also landings and effort data from *Nephrops*-directed fleets. These are mainly not corrected for changes in fishing power or efficiency. Owing to uncertainties in the accuracy of historic landings in some fisheries, increasing attention is paid to survey information and size composition in the catch data as an indicator of stock status.

There have been important developments in the methodology to assess the status of *Nephrops* stocks. The use of Underwater TV (UWTV) surveys has enabled the development of fishery-independent indicators of abundance. STECF (2005) had suggested that a combination of an absolute abundance estimate from an UWTV survey and a harvest rate based on F0.1 from a combined sex–length cohort analysis (LCA) and the mean weight and selection pattern from the commercial fishery could be used to calculate appropriate landings. This approach has been further developed and evaluated at ICES workshops in 2007 and 2009 (ICES, 2007, ICES 2009b). The 2009 workshop addressed concerns raised regarding factors which could potentially bias the UWTV survey results. Major sources of bias were quantified for each survey and an overall bias correction factor derived which, when applied to the estimates of abundance from the UWTV survey allows them to be treated as absolute abundance levels. In particular the workshop concluded that the UWTV surveys detect burrows of *Nephrops* considerably smaller than the sizes of those taken by the fishery. Therefore the abundance estimates used to calculate the Harvest Ratios presented in the 2009 advice include a component of the stock that is too small to be exploited by the fishery. This has resulted in calculated Harvest Ratios appearing to have decreased in the current advice compared to previous estimates of Harvest Ratios. In essence, this is a scaling issue, not a change in exploitation rate. The previous harvest rates corresponding to fishing at F0.1 were in the range of 15-20% whereas the revised values are in the range of 8-12%.

Uncertainties in assessment and forecast

The UWTV assessment provides an adequate basis for predicting catches. ICES groups WKNephTV (ICES 2007), WKNephBid (ICES 2008), SGNepS (ICES 2009a) have worked to reduce uncertainty and increase precision in the interpretation of survey data. Ultimately there still remains a degree of subjectivity in the production of UWTV abundance estimates.

In the provision of catch options based on the absolute survey estimates additional uncertainties related to mean weight in the landings and the discard rates also arise. The procedure outlined in WKNEPH 2009 is to use a multi-annual average to dampen variability. For FU 15 and FU17 only 2008 sampling data could be used due to problems with sampling in previous years. The variability in mean weight and discarding is a key uncertainty in the derivation of catch options. Stock monitoring continues, and enhanced work on observer trips on-board commercial vessels should furnish additional data which will be beneficial in developing assessment approaches further and characterising the uncertainty in these key parameters.

There is a gap of 18 months between the survey and the start of the year for which the assessment is used to set management levels. It is assumed that the stock is in equilibrium during this period (i.e. recruitment and growth balance mortality) although this is rarely the case. The effect of this assumption on realised harvest rates has not been investigated. The calculations of harvest ratio and reference points $F_{0.1}$ and F_{max} are all based on yield-per-recruit analyses. In addition, important assumptions are made on growth, natural mortality and discard rates in the derivation of reference points.

Trends in LPUE data that are subject to uncertainties associated with changes in fishing practices.

2.1.4 Northern Hake

European hake is widely distributed over the northeast Atlantic shelf, from Norway to Mauritania, with a larger density from the west of Ireland to the south of Spain and in the Mediterranean and Black sea. This species has been a very important resource for many demersal fisheries of the NWW region and is landed as targeted or incidental catch by a wide variety of gears such as bottom trawls, nets, and long-lines.

The hake fishery includes a diverse community of species including megrim, anglerfish, *Nephrops*, sole, seabass, ling, blue ling, greater forkbeard, tusk, whiting, blue whiting, *Trachurus spp*, conger, pout, cephalopods (octopus, *Loligidae*, *Ommastrephidae*, and cuttlefish), and rays. The relative importance of these species in the hake fishery varies between years depending on gears, sea areas, and biological conditions.

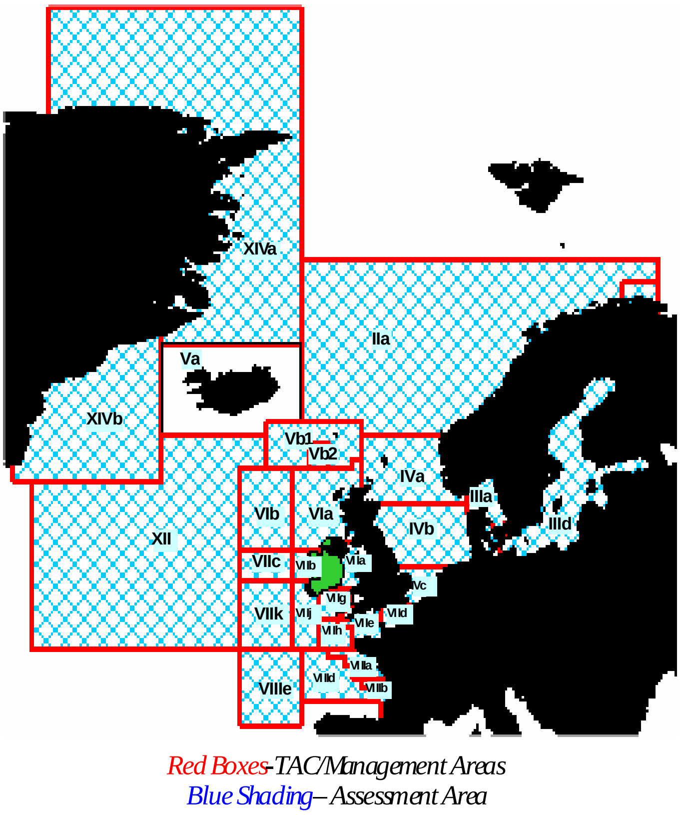


Figure 1.1.5: Management and assessment area for Northern Hake Stock

Based on the most recent estimates of SSB (in 2009) and fishing mortality (in 2008) ICES classifies the stock as being at full reproductive capacity and being harvested sustainably. SSB is estimated to be just above B_{pa} in 2009, and F has been around F_{pa} since 2001. Recruitment has been relatively stable over the last decade.

Management considerations

ICES advice for 2010 coincides with the maximum landings implied by the existing recovery plan (ICES, 2009). Discards of juvenile hake can be substantial in some areas and fleets. The spawning biomass and the long-term yield can be substantially improved by reducing mortality of small fish. This could be achieved by measures that reduce unwanted by-catch through shifting the selection pattern towards larger fish.

The northern hake SSB for 2009 is estimated to be above the recovery plan target (140 000 t). Article 3 of the recovery plan prescribes that a management plan should be implemented when the target is reached in two consecutive years. ICES considers that SSB has been approximately 140 000 t in the last two years.

Stable fishing mortalities since 2001 at about F_{pa} (0.25) and the above average 2006 year class have contributed to the recent increase in SSB.

Impacts of fisheries on the ecosystems

Hake is caught in a variety of fisheries which use a range of gears. Many of these are mixed fisheries. The impact of the fisheries on the ecosystem has not been assessed.

Factors affecting the fisheries and the stock

Regulations and their effects

A number of regulations have been introduced in recent years, to promote the recovery of the stock. The most important of these are listed below:

The minimum mesh size for trawls in the Bay of Biscay was increased from 55 mm ("*Nephrops* fishery")/65 mm ("otter trawlers") to 70 mm in 2000. The minimum landing size for hake is 27 cm.

Two areas where a 100 mm minimum mesh size is required for all otter-trawlers, regardless of the amount of hake caught were introduced in 2002 (EC Reg. 494/2002), one in Subarea VII (SW of Ireland) and the other in Subarea VIII (Bay of Biscay).

Measures to limit fishing effort in a 'biologically sensitive area' in Subareas VIIb, VIIj, VIIg and VIIh were introduced in 2003 (EC Reg. 1954/2003).

The hake recovery plan (EC Reg. No. 811/2004) came into operation in 2004.

These regulations and others have contributed to stabilise the fishing mortality since 2001. The effect of these measures cannot be precisely quantified.

Changes in fishing technology and fishing patterns

Since the introduction of the high opening trawls in the mid-1990s, no significant changes in fishing technology have been introduced.

In the French *Nephrops* fishery in the Bay of Biscay, the use of a squared mesh panel to reduce discarding of undersized hake has been enforced since 2006.

Scientific basis

Data and methods

Up until 2009 the stock assessment for hake was age-based using ‘Extended Survivors Analysis’ (XSA) and was performed using four commercial CPUE series and four surveys for tuning. Tagging of hake provided initial evidence of substantial growth underestimation (de Pontual et al. 2006) and a subsequent ICES workshop (ICES, 2010a) confirmed that the previous internationally agreed ageing method was neither accurate nor precise and provides overestimation of age. A replacement ageing method with sufficient precision and accuracy was not available and consequently a new stock assessment was required. The assessment method for the northern hake stock was evaluated by the ICES Benchmark Workshop (ICES, 2010b) and the use of the Stock Synthesis assessment model was accepted as an alternative (Methot, 2005).

The assessment for northern hake in 2010 is a length-based approach using the Stock Synthesis assessment model. This approach allows direct use of the quarterly length composition data and explicit modeling of a retention process that partitions total catch into discarded and retained portions.

The underlying population can be partitioned in time to include as many seasons within a year as required. This is important where temporal aspects of biology (like growth in the case of Hake), or fishing activity dictate finer than annual-level representation, however all the basic input data must then be partitioned to the level of the underlying dynamics.

Recruitment is based on a Beverton-Holt and annual deviations can be estimated for any portion of the modeled time period.

Growth is described through a von Bertalanffy growth curve with the distribution of lengths for a given age assumed to be normally distributed. The coefficient of variation of these distributions is structured to include two parameters which can be estimated or fixed, defining the spread of lengths at a young and old age with a linear interpolation between. In addition to growth, the relationships between weight and length, fecundity and length as well as maturity at length are all generalized to allow parameters to be estimated or fixed, temporally invariant or not. All model parameters can vary over time either as a function of annual deviations about a mean level, user defined ‘blocks’ of years in which the parameters differ or a combination of the two.

All model expectations for comparison with data are generated as observations from a ‘fleet’, either a fishery or a survey/index of abundance. Each fleet has unique characteristics defining relative selectivity across age or size, and can be structured to remove catch or collect observations at a particular time of the year or season. All fleets may be considered completely independent, or parameters may be shared among fleets where appropriate via ‘mirroring’.

A suite of selectivity curves including logistic-based shapes of up to eight parameters, power functions and nonparametric forms can be explored through relatively simple modification of the input files.

Kinds of data that model expectations can be fit to include: absolute or relative abundance, length-frequency distributions, age frequency distributions (either total or conditional by length), length at age, body weight, and proportion discard. Each of these can be from the retained, discarded or total removals by a specific fleet. Each source has an error distribution (either normal, lognormal or multinomial) associated with it, described by either an input sample size or standard deviation.

The overall fishery prosecuting the northern stock of hake has been categorised into 7 “fleets”, 4 of which use trawl gears, whereas the remaining three use gillnet, longline and a combination of several gears. For each fleet, estimates of landings in weight and length frequency distributions are available. For some fleet only, discards in weight and length frequency distribution are used.

The 2010 stock assessment for northern hake using the length based model in Stock Synthesis will take place during May in Bilbao, Spain.

Information from the fishing industry

The fishing industry and scientists have, at national level, discussed information that can be used in the assessments. However, national industries have not provided any additional quantitative information for use in the assessment.

2.1.5 Scallops

The scallop (*Pecten maximus*) is an important commercially exploited species of bivalve mollusc in northern Europe, extending from Norway south to Spain. It is most abundant on gravel, sand/shell or stony substrates at depths of 15-75 meters. It attains a large body size, is a high value species and is also the subject of extensive and intensive aquaculture in northern Europe.

The fishing gear used by the Irish scallop fleet is a toothed spring loaded dredge of approximately 0.8m wide, with a bag that is constructed of 75mm internal diameter metal rings. The length and shape of the teeth, which penetrate the seabed, vary in size and design between vessels. These dredges are held in series on two beams, which are fished on each side of the vessel (Tully et al., 2008).

In NWW, the fishery for scallops occurs mainly in inshore waters off the south east coast of Ireland, in the south Irish Sea and in the western approaches to the UK and France. There are also important fisheries around the Isle of Man and off the west coast of Scotland. In these areas, fleets from the UK, Ireland and France exploit stocks both within and outside of national 12nm territorial limits. These fisheries are very economically important to local coastal communities.

Scallops stocks do not come under the remit of the Common Fisheries Policy (CFP) and ICES does not provide assessment or advice for the management of the fisheries. Management of the scallop fisheries in NWW is nationally based. In 2007 an estimated 56,189 t of scallop were landed from the NWW area.

Life Cycle of Scallop

The life cycle of scallop is divided into two distinct phases; a pelagic larval phase and juvenile and adult benthic phases. Fertilisation of gametes is external and success is related to the proximity of male and female spawners and to the population density of scallops on the seabed. The larval phase lasts from 18-42 days depending on temperature. The larvae seek suitable substrate on which to settle and once settled, scallops are mainly sedentary. Growth may be related to temperature and food supply and is relatively fast. In Irish waters scallops attain a size of approximately 25mm shell height in the first year after settlement and 40mm at 2 years. Significant spawning does not occur until the third or fourth year but this pattern is spatially variable. Annual growth rings are deposited, which allows age to be estimated, although in some areas the annual pattern of ring formation is unclear. Recruitment to the fishery occurs mainly at 4 years. Scallops may live for 10-15 years (Tully *et al*., 2008).

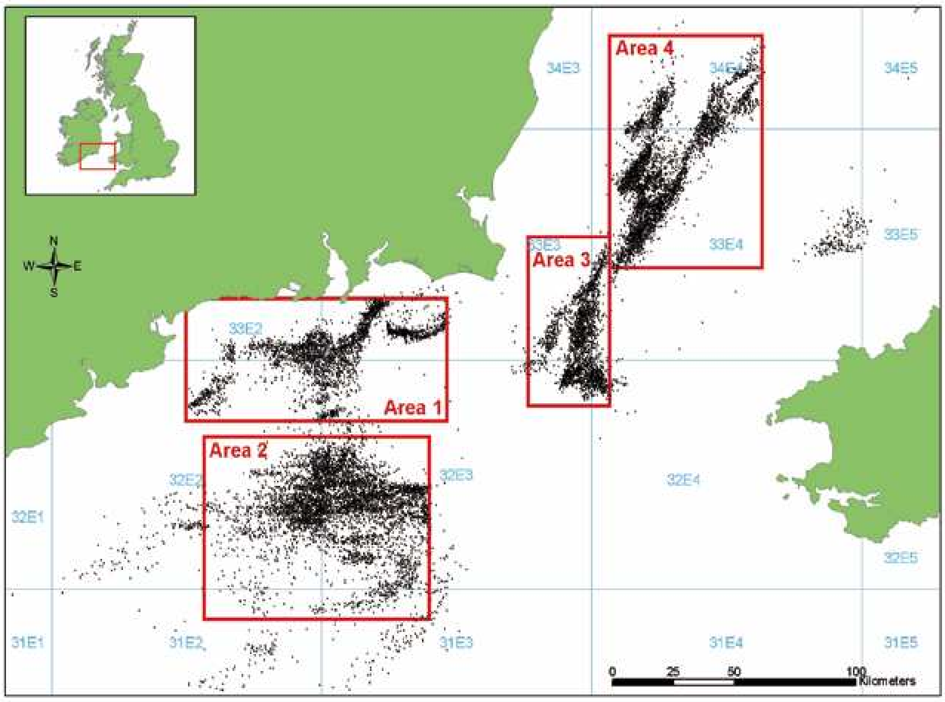


Figure 1.1.6: Distribution of fishing by the Irish scallop fleet off the south east coast 2000-2004. Data were derived from vessel monitoring system (VMS) (Source Tully et al. 2008)

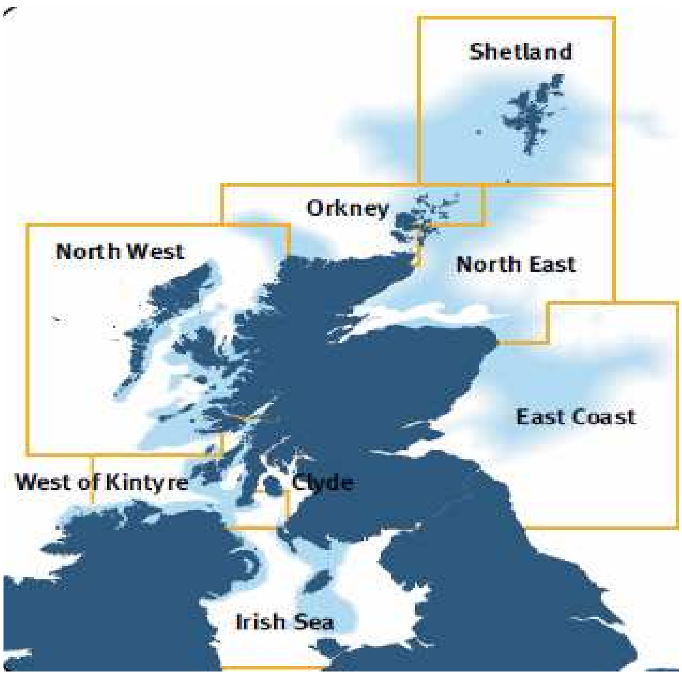


Figure 1.1.7: The eight management areas for scallops defined by Marine Scotland. The shaded areas represent sediment types where scallops are likelty to occur (Source: Marine Laboratory, Aberdeen)

Benefits of Closed Areas

A study was carried out over a 14 year period (1989 to 2003) on the impacts of closed areas on the scallop fishery in the Isle of Man. Scallop densities were very low in the areas when the closed area was set up. However, they increased at an accelerated rate over time within the closed area. Scallop densities also increased on the adjacent fishing ground, but not to the same extent. There was also a shift towards much older and larger scallops in the closed area as a result of reduced total mortality. The patterns of scallop density, age and size structure resulted in the exploitable biomass (adductor muscle and gonad) of scallops being nearly 11 times higher in the closed area than in the fished area by 2003. This is significant for fisheries management because the build up of high densities of large individual scallops enhanced local reproductive potential and therefore the likelihood of export of larvae to the surrounding fishing grounds. Fisheries for relatively sedentary and long-lived species such as scallops appear to be particularly suitable for this type of management (Beukers-Stewart, *et al*. 2005).

In Ireland, France and the UK different assessment methods and management measures are applied to scallop fisheries. Some fisheries in France are quota controlled and are assessed by age based analytical methods or by annual survey corrected for dredge efficiencies. In Scotland age based virtual population analysis is used together with survey data.

The biology of scallop poses real difficulties for assessment and management. There is usually significant spatial variability in biological characteristics, commercial catch rates, abundance and recruitment within a given stock. The boundaries between stocks and the interconnection between scallop ‘populations’ via larval dispersal are also generally unknown. As a result, the interpretation of commercial catch and effort data, survey data and forecasting the impacts of management measures, such as minimum landings sizes, effort or catch limitation, can be difficult.

2.2 Description of the 'social and ecological component by pressure matrix'

A powerful way of providing data for management decision making is to combine the information from natural and socio-economic systems, rather than having two separate information sets and avenues (MEFEPO project meeting, October 2008). This allows for the simultaneous comparison of the effects of human activities on ecological components as well as socio-economic components and is what we tried to achieve with the development of the matrix.

2.2.1 Socio-economic variables in the matrix

2.2.1.1 Background

This working paper provides a set of variables that can characterise the socio-economic impacts of specific fishing activities in the three selected EU regions in the MEFEPO project.

When choosing the variables, the following criteria have been used as guidance:

- It must be possible to justify the selection of variables from a professional (economic, social science) point of view
- The selection of variables should be supported by references (peer-reviewed literature, expert opinion, etc)
- There should be reliable and easily accessible data sources for operationalising the variables
- There should be comparable data on the variables in the three selected EU regions

Based on these criteria we have chosen a set of variables, describing the socio-economic impacts of selected EU fisheries. These are presented below. Ideally all the selected variables should fully live up to these criteria, but we recognise that this may not be the case in reality.

2.2.1.2 Socio-economic variables

The variables selected can be divided into three groups (numbers in brackets refer to the variables listed in appendix 3):

(i) Catches measured in physical terms (1-6)
(ii) The economic value of the catches (7-13)
(iii) Employment and productivity (14-21)

Catch is the basic fishery statistics variable and describes the output of the fishery activity in physical terms. Combined with unit price of each species caught, data on catches gives the economic value of the catches, i.e. how society values the harvested resource. This is an expression of the fishery's income generation and a basic economic variable. Whereas catch and price describes income, employment also contributes to determining the cost of the fishery activity. Combined with catches measured in physical units it also expresses the productivity in the specific fisheries.

These three main groups of data are also among the core variables presented in the EU report "Employment in the fisheries sector: current situation" (European Commission, FISH 2004/4), and in the Annual Economic Report (AER).

How the variables are operationalised will differ between the three groups:

Catches measured in physical terms

The ICES database on catches contains catches distributed on country, catch area and species. By the use of the software system FishPLus anybody can extract catch data for the period 1973-2007, and one is free to decide the aggregation level for the variables fishing area, country, and species.

For single species fisheries it is easy to get data on total catches (all countries) of the selected species in the selected sea areas. For multispecies fisheries we correspondingly can get total catches (all countries) of all the species in the fishery in the selected sea areas.

It might be the case that two or more fisheries in one sea overlap with respect to which species they include. Measuring actual catch in tonnes for each case, such an overlap does not necessarily constitute a problem. However, if we want to assess the relative importance of the fisheries in the sea under consideration there is a problem with such overlapping cases. Hence, when selecting fisheries they should be defined in a way that ensures that they are mutually exclusive (do not include any common species). For later use, we will for multispecies fisheries construct an index consisting of the share of each species in the total catch. Such an index will most likely vary over time.

In addition to data on catches, the ICES statistical office also provides data on TACs for the current year (2008), at the same disaggregated level.

The economic value of catches

The AER provides data on fish prices both on EU and on member state level.

For most fisheries several countries take part in the fishery. Data on prices per species measured in Euro/kg are given in AER, and these reflect the fact that the price of the same species can vary between countries. One possibility is to apply the price achieved in the country which has the dominating catch of the specific species, but this may be confusing and also give a biased estimate in cases where more than one country has a substantial catch of the species. As an alternative we have chosen to construct price indices. This must be done at two levels.

1) Single species fisheries: The price index consists of the first hand price, measured in Euro/kg, for the species in each country taking part in that fishery. A weighted average of these prices, where the country's share of the total catch in that fishery in each of the three selected sea areas is used as weight.

2) Multi species fisheries: First a price index for single species fisheries is constructed as above. Next, a weighted average of the price indices over all species encompassed is calculated, where the weights are the relative share of each species in the total catch of that fishery.

Finally, we make a price index for all species in each of the regional seas. This is a weighted average of the first hand price of each species in the countries that most actively take part in the fishery, where the relative proportion of each species in the total catch are the weights.

First hand prices measured in Euro/kg for all important species harvested in the European waters are given in the AER. However, the most up to date numbers here are for the year 2006.

Employment and productivity

To get an idea of the significance of the fisheries for society, employment is a crucial indicator. Fishery based employment encompasses both the fishers (fleet) and processing labour (land plants).

There is no annually updated statistical report or database providing these employment data on species and fishing area level, as demanded for the use in the matrix. Data are not readily available for processing labour, but do exist for the fleet data but require manipulation. Hence, we suggest the division of the employment indicator into two components; fleet and land plants.

Fleet

AER provides data on employment on a member state (MS) level, and they are also distributed on gear- and vessel types within each country. However, they are not distributed on fishing area or species, which are the two categories prevalent in the matrix. Thus, we have to process the existing employment data into catch-area and species specific employment data.

The employment indicator for the fleet is constructed as follows:

In the AER there are data on employment and catch for the most important fleet segments in each country. In the matrix the cases are specified as species. Through the use of expert knowledge about which gear and vessel type catch the case species, we pin down 1-3 main gear and vessel types for each case in the countries most important for the catch in this case. Then we calculate a productivity indicator for each gear and vessel type. This is also done for the most active countries participating in the fishery. Next, a weighted average is made of the productivity indicators above, and where the weights are the relative share caught by the nation-gear/vessel types in the fishery under consideration. This provides a case-specific productivity indicator.

As long as we do not expect significant changes in the productivity, annual employment for each case (fishery) can be found by multiplying the total catch in the respective fishery (defined as species and catch area) with the productivity indicator.

Land plants

Data on the land based fishery activities are scarce. There is a report, prepared on behalf of and financed by the European Commission, called "Employment in the fisheries sector: current situation" (FISH/2004/4). This report presents highly disaggregated data on the employment within the fisheries, encompassing fleet, land plants and aquaculture. The data are presented on NUTS-2 level (geography) and NACE-3 level (industrial sector). Data on such disaggregated levels are hardly publicly available. These reports are not updated, as the most recent numbers are from 2004, and the data most relevant for our purpose is from 2002-2003.

However, as this is the only easily accessible source we have for data on land based fishery activity, we will use these data as an indication of the size of land-based fishery related employment. As an example, for the North Sea countries (fishing in the North Sea), land-based employment exceeds fleet employment by more than two times (35000 vs 15000). This indicates the importance of land-based fishery employment.

On the other hand, it is important to be aware that this employment cannot, in its whole, be connected to the fisheries in the adjacent seas. Many MS import raw materials to the fish processing industry, which means that industrial employment is based on fishing activities in other seas. Also, fishing activity in one sea, e.g. the North Sea, may lay the foundation for industrial activity in an adjacent sea, e.g. the Northwestern Waters or Southwestern Waters. The land based fishery employment obviously must be a function of access to raw materials. Due to economic and political circumstances, the amount of fish imported for processing may vary significantly over time, and this will thus also be the case for land based fishery employment. Also, as the numbers in the mentioned report are quite old, there may have been increases in productivity, which would imply that for the same size of catch/raw material the land based fishery employment will be lower.

2.2.1.3 Background variables and variable correlations

Fuel is the single most important economic input in most fisheries, disregarding capital and labour. Hence, changes in fuel price have severe consequences for the profitability of fisheries. This variable (fuel costs or fuel consumption) is included in the AER and there is often a special section in the report treating fuel prices and how they affect the profitability of the fisheries. Hence, it is a relevant variable to include in the matrix.

However, fuel consumption is a variable that is highly correlated with other decision variables in the fishery, and may vary significantly over time. This may cause some problems with the calculation and presentation of this variable, as explained below.

The socio-economic variables presented in the matrix are usually not given for fisheries, but rather for countries, and divided on species and gear type within a country. Thus, when presenting these variables on fishery level they are composed from average country specific indicators, which make them less exact compared to data, which are taken directly from databases. Only data on catches is available to take directly from an existing database (ICES), and thus need no further computing. Catches is therefore used as a basic variable, which also contribute in the composition of the two other variable groups (value of catches and employment).

This problem implies that when choosing variables for the matrix they should be as de-composed as possible, i.e. not derived from other variables (than catches) and with as little dependency on other variables as possible.

The value of catches and employment are two such variables. The value of the catches, which is the gross income to the fishers or shipping companies, is supposed to cover all costs, including fuel costs, crew costs, and maintenance of gear and vessel. Assuming that all fishers are profit maximising, the relative input-output price (price on a specific input relative to the price in the market for the species under consideration) will be decisive for the composition of the input. Hence, there will be interdependencies between the price of a species, the value of the landings, and the use of specific input, such as fuel and crew. When not knowing the exact nature of such interdependencies, we have little control over the variables "deeper down" in the chain. Hence, it has been a guideline through the work of developing the socio-economic variables to choose variables which are as independent as possible, i.e. variables high up in the chain.

In this respect, fuel consumption is a “dependent” variable, and one must be aware of the interdependencies between this and other economic variables. Also, fuel consumption stemming for the fishery activities does not impact society directly, in the way employment does, for example. As such, it cannot be regarded as a good representative for describing socio-economic conditions.

Matrix variables and background variables

Many of the socio-economic variables for the matrix, described above, have to be constructed. During the construction process, underlying and preliminary variables are developed. Some of these variables may be of interest in themselves. Hence, when developing and operationalising the matrix variables, we also have underlying tables with so-called background variables. The background variables are variables, necessary to calculate and estimate the matrix variables. In appendix 3 there is a list of each of the single socio-economic variables to be developed in order to complete the socio-economic part of the matrix. It is indicated whether the variable is a background (underlying) variable or a matrix-variable.

2.2.2 Biological variables in the matrix

The biological variables in the matrix were assessed in terms of whether the specific pressure (rows) exerted by the case-study fishery had an effect on the ecological components (columns). The list of ecological components was taken from the Marine Strategy Framework Directive (MSFD; Annex III) and the pressures from the MSFD (Annex III) and OSPAR. Such effects will exist on a continuum from no effect through to a catastrophic effect (i.e. extirpation of a species). For the purpose of informing managers, the interaction strength was mapped onto a three point scale. A three point scale was used as this requires assessment of the impact against only two break points and so is able to cope with high levels of data uncertainty. The first breakpoint separates situations where there is no interaction from situations where there is an impact. The second breakpoint seeks to capture the shift from the situation where there is an impact but on its own it is not ‘ecologically significant’ from situations where the scale of the impact results in a significant ecological effect. The latter are likely to warrant some form of management action, either a direct response or a monitoring scheme, while the former need to be considered in relation to their possible interaction with other pressure components. Given the lack of a formal definition/test of ‘ecological significance’ this was assessed by means of expert judgement from the scientific team within the project and using expertise and experience gained with OSPAR and ICES working groups. Where scientific evidence was available from experimental studies, meta-analyses or field comparisons this was used to inform this judgement. Expert scientific judgement was used where information was not available. The information base used to make the assessments is detailed below.

- Where there was no interaction the cell was left blank.
- Where there was an interaction of the pressure component and the ecological component the cell was light blue.
- Where the interaction was deemed ecologically significant the cell was coloured dark blue.

2.2.3 Reading the SECPM

For each fishery the SECPM provides an overview of the interactions between the fishery and various component of the fishery system, ecological and socio-economic. In developing management procedures for a fishery the first area of concern should be those areas where cells are shaded deep blue. These are areas where interactions are significant and might need addressing in the management plan. Some of these interactions will be positive other negative e.g. positive employment potential but negative environmental effects through high fuel consumption.

Cells shaded light blue indicate areas where the review needs to consider possible interactions and cumulative effects. The mechanisms for dealing with such multiple pressures on ecological components is in its infancy and linking these to socio-economic interactions remains a challenge (Hegmann et al., 1999; James et al., 2003; Halpern et al., 2007; Foden et al., 2008; ICES, 2008e).

2.3 Social and ecological component by pressure matrix

	Ecological components												Fishery	*Socio-economic components*		
	habitats				plants		invertebrates		vertebrates			other groups	North East Atlantic Mackerel			
Impact Type (MSD & OSPAR)	seafloor	watercolumn	protected habitats	special cases	Phyto plankton	Macro algae	Zoo plankton	benthos	fish	mammals & reptiles	seabirds	non-indigenous & invasive		Catches measured in physical terms	Economic value of the catches	Employment and productivity
Barrier to species movement																
Community structure or species dynamics changes																
Death or injury by collision																
Introduction [spread] of non-indigenous species & translocations																
Introduction of microbial pathogens																
Removal of non-target species																
Removal of target species																
Heavy metal contamination																
Hydrocarbon contamination																
Radionucleotide contamination																
Synthetic compound contamination																

Changes in species or community distribution, size/extent or condition																
De-oxygenation																
Input of nitrogen & phosphorus																
Electromagnetic changes																
Litter																
Noise and visual disturbance																
Noise disturbance																
Visual disturbance																
Habitat structure changes																
Siltation (turbidity) changes																

Table 2.3.1: Social and ecological component pressure matrix for North East Atlantic Mackerel

	Ecological components												*Fishery*	*Socio-economic components*		
	habitats				plants		invertebrates		vertebrates			other groups	**Dublin Bay Prawn**			
Impact Type (MSD & OSPAR)	seafloor	watercolumn	protected habitats	special cases	Phyto plankton	Macro algae	Zoo plankton	benthos	fish	mammals & reptiles	seabirds	non-indigenous & invasive		Catches measured in physical terms	Economic value of the catches	Employment and productivity
Barrier to species movement																
Community structure or species dynamics changes																

Death or injury by collision																
Introduction [spread] of non-indigenous species & translocations																
Introduction of microbial pathogens																
Removal of non-target species																
Removal of target species																
Heavy metal contamination																
Hydrocarbon contamination																
Radionucleotide contamination																
Synthetic compound contamination																
Changes in species or community distribution, size/extent or condition																
De-oxygenation																
Input of nitrogen & phosphorus																
Electromagnetic changes																
Litter																
Noise and visual disturbance																
Noise disturbance																

Visual disturbance																
Habitat structure changes																
Siltation (turbidity) changes																

Table 2.3.2: Social and ecological component pressure matrix for Dublin Bay Prawn

	Ecological components												*Fishery*	*Socio-economic components*		
	habitats				plants		invertebrates		vertebrates			other groups	Northern Hake			
Impact Type (MSD & OSPAR)	seafloor	watercolumn	protected habitats	special cases	Phyto plankton	Macro algae	Zoo plankton	benthos	fish	mammals & reptiles	seabirds	non-indigenous & invasive		Catches measured in physical terms	Economic value of the catches	Employment and productivity
Barrier to species movement																
Community structure or species dynamics changes																
Death or injury by collision																
Introduction [spread] of non-indigenous species & translocations																
Introduction of microbial pathogens																
Removal of non-target species																
Removal of target species																

Heavy metal contamination																
Hydrocarbon contamination																
Radionucleotide contamination																
Synthetic compound contamination																
Changes in species or community distribution, size/extent or condition																
De-oxygenation																
Input of nitrogen & phosphorus																
Electromagnetic changes																
Litter																
Noise and visual disturbance																
Noise disturbance																
Visual disturbance																
Habitat structure changes																
Siltation (turbidity) changes																

Table 2.3.3: Social and ecological component pressure matrix for Northern Hake

	Ecological components												*Fishery*	*Socio-economic components*		
	habitats				plants		invertebrates		vertebrates			other groups				
Impact Type (MSD & OSPAR)	seafloor	watercolumn	protected habitats	special cases	Phyto plankton	Macro algae	Zoo plankton	benthos	fish	mammals & reptiles	seabirds	non-indigenous & invasive		Catches measured in physical terms	Economic value of the catches	Employment and productivity
Barrier to species movement													Scallops			
Community structure or species dynamics changes																
Death or injury by collision																
Introduction [spread] of non-indigenous species & translocations																
Introduction of microbial pathogens																
Removal of non-target species																
Removal of target species																
Heavy metal contamination																
Hydrocarbon contamination																
Radionucleotide contamination																
Synthetic compound contamination																
Changes in species or community distribution, size/extent or condition																

De-oxygenation																
Input of nitrogen & phosphorus																
Electromagnetic changes																
Litter																
Noise and visual disturbance																
Noise disturbance																
Visual disturbance																
Habitat structure changes																
Siltation (turbidity) changes																

Table 2.3.4: Social and ecological component pressure matrix for Scallops

2.4 Ecological matrix elements supporting evidence

2.4.1 North East Atlantic Mackerel

2.4.1.1 Habitats

Mackerel fisheries such operate in pelagic habitats and they are unlikely to have direct negative affects on either pelagic or benthic habitats.

2.4.1.2 Plants

Mackerel fisheries are unlikely to affect plants except possibly phytoplankton indirectly through the food web.

2.4.1.3 Invertebrates

2.4.1.3.1 Zooplankton

Mackerel in the North East Atlantic have seasonal changes in the composition of their diet. In spring juvenile mackerel consume euphausiids, crustacean larvae and other zooplankton. The adult diet at this time consists almost entirely (90%) of euphausiids. In addition, during this period mackerel are cannibalistic, feeding on their own planktonic eggs. In autumn, the juveniles consume hyperiid amphipods and other, mainly gelatinous zooplankton, whereas the adults move away from zooplankton and feed almost entirely (90%) on blue whiting (Olaso et al., 2005).

2.4.1.3.2 Benthos

2.4.1.3.2.1 Removal of target species

Typically the gears used in pelagic fisheries do not make contact with the seafloor and so do not directly affect the benthos. However large discards or slippage of the catch may cause considerable localised harm to the benthos in terms of organic enrichment and disturbance to the benthic community (ICES, 2006).

2.4.1.4 Vertebrates

2.4.1.4.1 Fish

2.4.1.4.1.1 Community structure or species dynamic changes

Mackerel is an integral and important part of the pelagic ecosystem in the North Atlantic (Overholtz *et al*., 1991a, b). There are seasonal and spatial variations in feeding patterns although the adult diet generally consists of pelagic crustaceans and small fish, including herring, sprat, sand eel and Norway pout. Mackerel stop feeding almost completely during winter. Euphausids and copepods represent major food items in the north, and fish are the most important prey in the south, especially for larger individuals (Mehl and Westgård, 1983). Diurnal patterns have also been reported, feeding activity being greatest during the afternoon and until sunset (Dahl and Kirkegaard, 1986). Juvenile and adult mackerel are an important food source for demersal fish and is an important food resource for larger pelagic predators, including sharks and marine mammals, and are also preyed upon by a variety of sea birds. (Lockwood, 1988). Mackerel is therefore considered as the key pelagic species in the North Atlantic.

Considerable changes in the size composition and trophic structure within pelagic fish have been documented. The cause of these changes is less certain, but fishing of the larger piscivorous individuals seems likely to have resulted in the observed changes in abundance and size structure (Heath, 2005).

Mackerel form schools and fishers may exploit this behaviour as entire schools of pelagic fish can be enclosed by seine nets. The consequences of this may be further compounded by additional fish behaviours. As the abundance of fish declines, shoaling fish often reduce their range, e.g. herring (Winters and Wheeler, 1985), which may result in pelagic fish maintaining the same average school size (Ulltang, 1980) despite a decrease in abundance in real terms. This aggregative behaviour means the density of the schools will remain relatively constant and fishers can maintain a constant catch per unit effort (CPUE) until the stock collapses. Fish behaviour may affect their susceptibility to fishing gears.

2.4.1.4.1.2 Death by injury or collision

Animals may be injured by different parts of the gear, or may find certain parts of the fishing process more stressful than others. Fishes tend to be injured by pressure changes during hauling, crushing and the abrasive action of other species' spines or scales. Besides the caught fish that are discarded, a proportion of the fish slip through the cod end (Millar and Fryer, 1999). The mortality of these individual is presumably lower than of those hauled and discarded later, but may still be significant. Fish disturbed by fishing are most likely to be stressed and more susceptible for predation by seals and birds (Chopin and Arimoto, 1995).

2.4.1.4.1.3 Removal of non-target species

As mackerel is a schooling species it is thought to be a relatively clean fishery with considerably less by-catch of non-target fish species compared to the mixed bottom trawl fisheries. However, pelagic shoals may consist of mixed species (most notably of herring and mackerel), which can result in non-target species being caught and landed or discarded (van Helmond and van Overzee, 2007). The status of some of the non-target species are discussed below:

Herring (*Clupea harengus*)

Herring in the NE Atlantic is assessed within ICES by HAWG. The picture of herring stocks around Ireland is varied. The Celtic Sea stock (Division VIIaS, VIIg-h, VIIj-k) has rebuilt since the low levels seen in the early party of this decade, and is now subject to an industry-led rebuilding plan. Herring to the north west of Ireland (Divisions VIa South & VIIb,c) is however, depleted and needs to be rebuilt.

Western Horse mackerel (*Trachurus trachurus*)

Western horse mackerel is assessed within ICES by WGWIDE. The current management plan provides for a TAC of 180 000 t for the period 2008–2010 which is expected to maintain SSB above B_{lim} with a high probability. The key problem with the management of this stock is that the TAC for the Western stock is allocated to ICES division VIId (Eastern Channel), but catches from this area are of North Sea horse mackerel. To ensure precautionary management of this stock the TAC should apply to all areas where western horse mackerel is caught (EU, Norwegian, and Faroese waters).

Blue whiting (*Micromesistius poutassou*)

Blue whiting combined stock (Subareas I-IX, XII, and XIV) is assessed within ICES by the Working Group on Northern Pelagic and Blue Whiting Fisheries (WGNPBW). Based on the most recent estimates of fishing mortality and SSB, ICES classifies the stock as having fully reproductive capacity, but being harvested at increased risk. SSB increased to a historical high in 2003, but has decreased since then and is expected to be just above B_{pa} (2,250,000t) in 2009. The estimated fishing mortality is well above F_{pa} (0.32). Recruitment of the 2005 and 2006 year classes are estimated to be in the very low end of the historical time-series (ICES, 2008g).

Discarded species

Theoretically, the use of echo-sounding equipment in pelagic fisheries should result in low by-catch. However, as stated above shoals may consist of mixed species (most notable of herring and mackerel), which could result in non-target species being discarded (ICES, 2008a). A less frequent, but more rigorous way of discarding is referred to as slippage (Borges et al., 2008). A catch (or a proportion of it) can be pumped directly from the chilling tanks out to sea, or the codend of the net may be opened although the net is still in the water (Borges et al., 2008). This occurs when catch volumes are too small, or the average size of fish is too small, or the fish have poor quality (ICES, 2008a) and can result in relatively large amounts of catch being discarded

A study by Pierce et al. (2002) monitored the by-catch composition and discarding practices onboard pelagic vessels in the Scottish fisheries for mackerel, herring, “maatjes” herring (herring caught just before their first spawning) and argentines (*Argentina silus*). The “maatjes” herring fishery had a discard rate of around 11%. In addition, STECF (2008) presented discard rates from Germany and the Netherlands of herring for the period 2004-2006. Germany found a discard percentage of 4% and the Netherlands of 3%. However, these rates were estimated for the pelagic fishery (in areas II, IV, V VI, VII, VIII). Unfortunately data for the herring fishery specifically were not presented.

2.4.1.4.1.4 Removal of target species

See Section 2.1.1.

2.4.1.4.1.5 Noise and visual disturbance

Noise and visual disturbance caused by pelagic fisheries can result in an avoidance reaction and stress which can make fish more susceptible to predation and possibly pathogens.

2.4.1.4.2 Mammals and reptiles

Occasional by-catch of pilot whale (*Globicephala melaena*), other small cetaceans and seals occur in pelagic trawl fleet (ICES, 2006; Couperus, 2008), although however these incidents are considered to be limited. In general marine mammals are opportunistic feeders capable of switching diets to reflect local abundance and are therefore robust to the effects of prey removal by the mackerel fishery. It is considered that the mackerel fleet has no significant impact at the population level (ICES, 2006).

2.4.1.4.3 Seabirds

Lipid rich pelagic fish such as mackerel provide an important prey source for many seabirds (ICES, 1996), consequently the fishery acts as a competitor with seabirds. However, few seabirds are entirely dependent upon a particular species and show prey switching behaviour. Nevertheless, the reproductive failure of Norwegian puffins (*Fratercula arctica*) was associated with the collapse of the herring fishery (Barrett et al., 1987). In general pelagic fisheries tend to produce low levels of discards and are not thought to cause notable food subsidy for seabirds (ICES, 2006).

2.4.1.5 Other groups

2.4.1.5.1 Non-indigenous and invasive species

There is no evidence of any effect of the mackerel fishery on non-indigenous or invasive species.

2.4.2 Dublin Bay Prawn

2.4.2.1 Habitats

2.4.2.1.1 Seafloor

Prawns are primarily fished using bottom otter trawls and the direct effect of such fishing gear on the benthic habitat is related to physical disturbance by contact with the seafloor. These effects include marking of the seabed, removal of large physical features, reduction in structural biota and a reduction in complexity of habitat structure (leading to increased homogeneity) (ICES, 2002;ICES, 2003).

Krost et al. (1990) estimated that otter boards could penetrate up to 15cm into soft mud, and to prevent them penetrating too far into the sediment sometimes the doors may be fitted with metal shoes (Jennings and Kaiser, 1998). Laboratory experiments established that a single door could create a 2cm deep furrow in a sandy substrate and form an adjacent berm of displaced frontal spoil along the trailing edge of the trawl door (Gilkinson et al., 1998). The width of the tracks created by the otter boards may range between 0.5m–0.6m. These tracks were visible for up to one year after trawling the sandy sea floor of the Grand Banks of Newfoundland (Schwinghamer et al., 1998), and up to 18 months on muddy substrates in the Irish Sea (Ball et al., 2000), suggesting that the long-term damage to benthic habitats is dependent partly upon the substrate type. Tickler chains are used to disturb fauna and disrupt the surface of the sea bed, but their numbers are usually limited on otter trawls as they reduce the width of the mouth of the net (Rijnsdorp and Leeuwen, 1996). All the components of the otter trawl that make contact with the seabed are capable of impacting the habitat. This may be the case especially in areas with complex biogenic structures, as (Collie et al., 2000b).

Despite the high intensity of fishing (some grounds in Subarea VII are impacted >7 times/year) burrowing fauna, such as prawns, have been observed re-emerging from freshly trawled grounds, implying that there is some resilience to trawling.

The impact of discarded catch on the benthos can provide food for scavengers which leads to shortcuts in trophic relationships and may enhance secondary production (Groenewold and Fonds, 2000). However, if discarding is excessive it can lead to the development of anaerobic conditions and reduction in biodiversity (Hill and Wassenberg, 1990).

Ocean sediments also act as a sink for many persistent organic pollutants, usually lipophilic pollutants like DDT, PCB and PAH (Schiff, 2000). Bottom trawling mixes these pollutants into the plankton ecology where they can move back up the food chain and into our food supply (see section 2.4.2.4.1.6 and 2.4.2.4.1.7).

2.4.2.1.2 Water column habitats

Bottom trawling in muddy areas will cause sediments to be re-suspended which increases turbidity in the water column. Pelanques *et al*. (2001) showed that trawling activity led to a threefold increase in turbidity that lasted up to five days after the disturbance. Increased turbidity decreases the amount of light reaching the seafloor and reduces primary productivity in this area. In contrast primary production can increase in the water column as phosphorus is often found in high concentration in soft shallow sediments (Ruttenberg, 2003) and re-suspension can cause algal blooms some of which may be harmful. Such blooms can also introduce oxygen demand in the water column, and result in oxygen deficient dead zones (Giannakourou *et al*., 2005; Weaver and Dallas, 2007). Bottom trawling introduces more suspended solids into the water column than any other human activity and sediment plumes from trawling activity can be seen on satellite imagery (Palanques, 2001).

2.4.2.1.3 Protected habitats

Habitats may be protected to prevent damage to fisheries resources or for more general conservation purposes such as protection of a coral reef or the habitat of a marine mammal. The former type of protected habitat is considered here.

The *Nephrops* fishery in NWW overlaps in certain areas with other demersal fisheries. Collapses in the cod (*Gadus morhua*) stock have been attributed to overfishing, and in February 2000 the European Commission established a closed area in the Irish Sea as part of a general recovery plan. The recovery plan was further revised and implemented between 2001 and 2005. However, the plan has not provided the expected benefit, and the stock is still thought to be below the safe limit (Kelly *et al*., 2006). Consequently, in 2008, a new long-term plan (LTMP) for cod stocks (EC Reg.1342/2008) was agreed for a number of EU cod stocks including those in Subareas VIa and VIIa. The plan aims to reduce fishing mortality to a target levels by regulating TAC and national effort allocations across a range of gear types including those for *Nephops*. Article 11 makes provision for a group of vessels to be exempt from effort controls provided that they can demonstrate that they constantly catch less than 1.5% cod. At present the only successful application for exclusion from the

LTMP effort restrictions under Article 11 has been a fishery that uses "Swedish grids". These grids essentially eliminate the majority of round fish (cod, haddock and whiting) from the catch while maintaining catch rates of *Nephrops*. In NWW the most likely fisheries that could be exempted under article 11 include directed *Nephrops* fisheries using the "Swedish grid" or other highly selective trawls.

2.4.2.2 Plants

2.4.2.2.1 Phytoplankton

As discussed in Section 2.4.2.1.2 the re-suspension of fine sediments due to trawling activity may increase primary productivity if it adds phosphorus to areas where this nutrient is limiting. Conversely, the increased turbidity reduces the penetration of light and can decrease primary productivity.

2.4.2.2.2 Macroalgae

Macroalgae can be negatively affected by prawn trawls if they are attached to hard substrates (e.g. rocks and cobbles) which can be turned over by the fishing activity. However, this habitat is not common on prawn grounds. Furthermore, as this type of substrate is likely to damage fishing gears or the catch, these areas are likely to be avoided.

2.4.2.3 Invertebrates

2.4.2.3.1 Zooplankton

Prawn trawls are unlikely to directly affect zooplankton although there may be indirect effects through the food chain or by the release of nutrients from the disturbance to the surface of the sediment but these effects are likely to be minor.

Changes in the abundance of fish and benthos, from the direct and indirect effects of fishing, will alter the total amount and spatial distribution of larvae produced.

In many regions, the seasonal input of mero-planktonic larvae (including *Nephrops* larvae) comprises a major part of the total zooplankton community and this can influence system dynamics through their consumption of phytoplankton and micro-zooplankton. Similarly, there are occasions when large, gelatinous, plankton are caught in, or macerated by, passing through nets. The EcoJel project (www.jellyfish.ie) aims to assess the opportunities and detrimental impacts of jellyfish in the Irish Sea as there are concerns that the abundance of jellyfish is increasing globally as a result of climate change and degradation of marine ecosystems under the pressure of human activities.

2.4.2.3.2 Benthos

The effects of fishing on benthic populations and communities are discussed in this section. In section 2.3 the cells of the matrix were coloured to depict the level of impact. For most impact themes it is impossible to disentangle the effects of a specific fishery from the overall changes in the ecosystem. The overall changes relevant for a specific cell will be discussed in this section and will be referred to in the other case studies, along with an attempt to determine how this specific fishery would contribute to the overall change.

2.4.2.3.2.1 Barrier to species movement

The prawn trawl operates on the seafloor and therefore directly affects habitat structures (see section 2.4.2.1.1) and indirectly affects the movement of benthic species.

2.4.2.3.2.2 Community structure or species dynamic changes

Benthic invertebrates suffer mortality by being caught in the fishing gear but also by being in the towpath of the gear. Interpretation of the actual mortality resulting from the fishing event is problematic as there is often a time lag between the fishing event and the subsequent assessment of the invertebrate benthic community. This time lag allows for the factors such as immigration, emigration and predation to come into effect. Thus, the longer the period between the fishing event and the sampling event, the greater the likelihood that the community level response to fishing is measured, rather than the absolute fishing mortality. It is also difficult to quantify the mortality on the benthic invertebrates in the towpath of the gear as assessment cannot exclude predation mortality. In addition there is the influence of the disturbance history on the level of mortality sustained by populations. Areas that have not been trawled recently will experience the highest levels of mortality whereas in areas of high fishing activity the fishing-induced mortality will decrease with every subsequent fishing event.

Not all species of benthic invertebrates are likely to be affected equally by trawling activity. Smaller, more mobile species with hard bodies that live deeper in the sediment are less likely to be affected. Clearly selective mortality is likely to lead to reduced abundance of large species with low intrinsic rates of increase, and dominance of smaller species with higher intrinsic rates of increase. However, determining which taxa are particularly vulnerable to fishing activity is not as clear. This may be because a taxon will be vulnerable in one respect, for example having soft body parts with little armour, but will have this offset by another characteristic such as its' location within the sediment. For example, it is widely believed that thin-shelled molluscs and some echinoderms, such as delicate sea urchins and heart urchins, are at greater risk to serious physical damage than thick-shelled molluscs or robust crustaceans (Rumohr and Krost, 1991; Collie et al., 2000b). However, where these species have high intrinsic population growth rates due to high fecundity and/or low age at maturity, high levels of mortality experienced could be offset by high levels of juvenile recruitment (e.g. for brittle stars see (Bergman, 2000)) meaning that population size is not noticeably affected. There is certainly evidence that benthic invertebrate communities respond to fishing disturbance (Robinson and Frid, 2008) but predicting the outcome at the community level is not easy.

Other potential fishery affects are changes to the size distribution of benthic invertebrates and shifts in the dominant groups. Unfortunately the evidence to determine whether or not this is a result of fishing activity is not available for NWW. The increase of moribund material in the towpath of the gear has been described in the Irish Sea but the implications of this for benthic invertebrates at the population level and at the scale of the NWW area are unknown (Ball et al., 2000).

2.4.2.3.2.3 Death by injury or collision

The majority of the invertebrates that are killed by demersal trawling die as a result of contact with the fishing gear as it passes over the seafloor and not as a result of being caught in the net itself (Robinson, 2003). This 'towpath mortality' is not recorded in the catch data as the dead/dying animals remain on the seafloor. This process is much more important to invertebrates than it is to demersal fish due to the largely sessile nature of benthic invertebrates. This 'unobserved mortality' is difficult to quantify and it is only in recent years that real progress has been made in bringing together the results of a number of different studies (Collie et al., 2000a; Collie et al., 2000b; Kaiser et al., 2000; Kaiser et al., 2006). Determining actual mortality is even more difficult because of uncertainty regarding survival rates after encountering the fishing gear. However, if an animal is badly damaged it is likely that it will be vulnerable to predation or disease as a result of its injuries and thus will face secondary mortality as a consequence of fishing (Hill et al., 1996).

2.4.2.3.2.4 Removal of non-target species

A large proportion of the catch in the *Nephrops* fishery in NWW is made up of non-target, invertebrate, by-catch species, some of which are marketable. For the proportion that is marketable, there should be a record of mortality in the landings data, in the same way that there is for the target stocks. However, a large proportion of the by-catch is not marketable and is discarded at sea. In almost all cases, epifauna, followed by shallow burying infauna, are most likely to be part of the invertebrate by-catch. Unfortunately, due to the lack of market value, quantification of non-target invertebrate by-catch is rare on commercial vessels and data are only available from dedicated research. Bergmann et al. (2002) investigated the discarded by-catch from *Nephrops* trawlers operating in the Clyde Sea on the West Coast of Scotland (ICES Subarea VI). The quantity and composition of the by-catch differed within the study area with invertebrates making up 60% of discards in the north and only 15% in the south. In both northern and southern regions various species of crustaceans and echinoderms accounted for the majority (83% and 73% respectively) of the by-catch. These differences were considered to be a reflection of differing bathymetries, hydrographic conditions and ground types in each area.

2.4.2.3.2.5 Removal of target species

See Section 2.1.2 and 2.1.3.

2.4.2.4 Vertebrates

2.4.2.4.1 Fish

The case study fisheries in this technical report all directly affect fish through their removal. Also, indirect effects may impact fish species through ecological cascades starting with a direct effect of fishing on other ecological components. In these instances the indirect effects on fish are discussed by referring to previous sections for direct effects on the other ecological components.

According to WGECO 2007 (ICES, 2007b) fish populations are severely affected by fishing. Acute pressure was defined as a relatively short but intense and instantaneous interaction, and causing mortality or destruction to a high proportion of the component or populations included. Fishing mainly affects ecosystem components by two pathways "physical disturbance" and "selective extraction of species", which may therefore be considered the main pathways determining the impact of fishing on the ecosystem. Most of the other pathways are a consequence of the fact that certain types of gear (e.g. bottom trawl) re-suspend the sediment, thereby affecting turbidity and light regime. This, in turn, may result in increased levels of contaminants or nutrients (and hence lower levels of oxygen), or a change in suspended sediment which may result in substratum loss and/or smothering.

2.4.2.4.1.1 Barrier to species movement

The prawn trawl operates on the seafloor and therefore directly affects habitat structures (see section 2.4.2.1.1) and indirectly affects species movement. The trawled habitat becomes homogenised, and may result in larger distances between suitable patches for survival (Auster and Langton, 1999) (Johnson, 2002). Thus prawn trawling activity could lead to barriers for the movement of stocks and mixing of populations.

2.4.2.4.1.2 Community structure or species dynamic changes

Recorded landings vastly underestimate the total number of fish removed from the NWW ecosystem, as discards and unobserved mortality are not included. In the past, it was believed that marine organisms could not be harvested to extinction (Lamarck, 1809; Huxley, 1883). More recent studies suggest that although fishing may cause temporary disappearance of local stocks, it is unlikely that fecund species in marine systems will become extinct (Beverton, 1990). However, it is possible that the main loss of species, and changes in species diversity, occurred before scientific records began. It is also possible that species richness and distribution in NWW may have increased in recent years due to the effects of climate change. No evidence is available for NWW but in the North Sea Hiddink and Hofstede (2007) claim that species richness and distributional range has increased from 1985-2006 due to increasing water temperatures.

In the Celtic Sea population and community analyses have shown that fishing has affected a number of commercial species, primarily because individuals of too small a size have been caught and discarded in the past (Trenkel and Rochet, 2003; Rochet et al., 2002). The size structure of the fish community has changed significantly over time, and a decrease in the relative abundance of larger fish has been accompanied by an increase in smaller fish (4-25g)

(Blanchard et al., 2005; Trenkel et al., 2004). Temporal analyses of the effects of fishing and climate variation suggest that fishing has had a stronger effect on size-structure than changes in temperature. A marked decline in mean trophic level of the fish community over time has been documented (Pinnegar et al., 2003), resulting in a reduction in the abundance of large piscivorous fishes such as cod and hake, and an increase in smaller pelagic species which feed at a lower trophic level. Models have shown that under predicted temperature changes the cod stocks in the Celtic and Irish Seas are expected to disappear by the year 2100 (Drinkwater, 2005). However, growth rates for many of the cod stocks are predicted to increase, leading to an overall increase in the total production of Atlantic cod in the North Atlantic. Increased ocean temperatures have also led to observed changes in the species composition of NWW fish communities. Since 1990 the previously unexploited Boarfish (*Capros aper*) has become particularly abundant in NWW and an industrial fishery (for fish meal) developed in 2006 in the Celtic Sea and West of Ireland. This phenomenon has been reported as occurring elsewhere in the North Atlantic, including the Bay of Biscay (Farina et al., 1997) and offshore seamounts (Fock et al., 2002).

2.4.2.4.1.3 Species life history changes

Selective fishing mortality on larger fish can result in changes in growth rates and sexual maturation within species. Slower growth and earlier maturity would be beneficial under high fishing pressure. These changes could be compensatory (phenotypic plasticity), however evidence is accumulating that heavy exploitation of fish stocks causes them to undergo genetic change. The consequences of genetic change are important in the medium- and long-term as some of the traits under selection (e.g. growth and sexual maturation) are related to the productivity of fisheries. By ignoring genetic change, we run the risk of reducing productivity in ways that are not readily reversed in the future. Phenotypic changes, on the other hand, could be reversed in the short-term (Law, 2002).

2.4.2.4.1.4 Death by injury or collision

Fish species that possess swim bladders, such as Gadoids, tend to be easily injured by pressure changes during hauling. Crushing and the abrasive action of other species' spines or scales also result in injury and death to species that encounter the fishing gear. In addition to the caught fish and subsequently discarded, a proportion of the fish slip through the cod end mesh (Millar and Fryer, 1999). Experiments in the North Sea have shown that the mortality of these fish species is lower than of those hauled and discarded later but may still be significant (Van Beek et al., 1990; Kaiser and Spencer, 1995). Fish disturbed by trawling activity are likely to be stressed and more susceptible for predation (Chopin and Arimoto, 1995). Seals and birds swimming behind trawls predating on fish and benthos affected by the trawls have been observed.

2.4.2.4.1.5 Removal of non-target species

The by-catch of cod (*Gadus morhua*) in the *Nephrops* fishery has become an important issue since the collapse of the stock and the introduction of the long term management plan (see Section 2.4.2.1.3 for details).

Stratoudakis et al., (2001) investigated the fish by-catch and discarding from *Nephrops* trawlers in the Firth of Clyde on the west coast of Scotland (ICES Subarea VIa) using data from 106 commercial fishing trips, sampled between 1982 and 1998. They found that a large proportion of the bycaught fish in the Clyde was discarded. These discarded fish consisting mainly of small demersal species (mean length about 19 cm), particularly young whiting (*Merlangius merlangus*). Fish landings and discards biomass per unit effort both decreased over the study period. However, the decline in landings per unit effort was greater than that in discards per unit effort, corresponding to an increase in the discard rate over time. At the time of publication about 70 % of the fish by-catch was discarded. The mean length of discarded fish was positively related to mesh size.

Whiting dominated the fish discarded in the Clyde *Nephrops* fishery. It was discarded in all sampled hauls, and comprised almost 40 % of the discarded fish biomass. Poor cod (*Trisopterus minutus*), long rough dab (*Hippoglossoides platessoides*), hake (*Merluccius merluccius*) and Norway pout (*Trisopterus esmarkii*) were discarded in at least 80 % of hauls. Among these species, only whiting and hake have commercial importance, with both species mostly discarded at lengths well below their minimum landing size.

<u>State of Whiting (*Merlangius merlangus*) stocks in NWW:</u>

The Whiting stock in the Irish Sea has decreased substantially to very low levels in recent years. High discarding, low landings and poor sampling has lead to uncertain catch data in recent years. ICES advises that the catches of whiting should be the lowest possible (ICES CM 2009/ACOM:09). Furthermore, urgent management action is required to rebuild the whiting stock in this area and the cornerstone of any rebuilding of whiting stocks should be measures that significantly reduce or eliminate the discarding in the *Nephrops* fishery. This could be achieved by the strengthening of existing technical conservation measures such as a reduction in trawl twine thickness, increasing size of the existing square mesh panel as well as changes in panel position (Briggs, 1992). The spawning stock of whiting in the area west of Scotland (ICES Subarea VIa) is at estimated to be at the lowest observed level and total mortality at the highest level. ICES recommends that whiting catches from this stock in 2010 should be reduced to the lowest possible level. In the western English Channel and the Celtic Sea the state of the whiting stock is not presicely known. The current estimates of fishing mortality and SSB are uncertain, but SSB shows a decreasing trend while recruitment has been low in recent years although the 2007 year class is above average, and the 2008 year class may be very strong. In order to reverse the trend in SSB, ICES considers that fishing mortality should be reduced. However, ICES cannot quantify the required reduction in fishing mortality. There is no ICES advice for West of Ireland Whiting Stock (ICES Divisions VIIb,c) and catches should be no more than the recent average (2005 to 2007) of around 156 t in order to avoid an expansion of the fishery until there is more information to facilitate an adequate assessment.

State of Hake (*Merluccius merluccius*) stocks in NWW:

See Section 2.1.4 for status of northern hake stock.

2.4.2.4.1.6 Heavy metal contamination / Hydrocarbon contamination / Radio-nucleotide contamination

Trawls resuspend the sediment, which may result in increased levels of contaminants that have previously been stabilised in the sediment (ICES, 2006; ICES, 2007b). The ecological effects of contaminants are often very difficult to assess, however some evidence has been found for the effect of contaminates on fish species.

Exposure to heavy metals can effect respiration and other physiological and neurological processes. Heavy metal uptake in organisms from water tends to be proportional to the concentration in the water although accumulation within organisms also occurs, which can result in less than proportional increases in tissue concentration compared with the increase in metal concentration in the food, this is similar for Dioxins and PCBs. This bio-accumulation can occur through the food chain resulting in high concentrations in predatory species (INEXFISH, 2006).

Polycyclic Aromatic Hydrocarbons (PAHs), which can also accumulate in species, have been found to have a deleterious effect on the vitellogenesis of fish from natural populations as well as in laboratory experiments (Johnson et al., 2002; Myers et al., 2003). PAHs and chlorinated hydrocarbons seem to be the cause of the occurrence of liver tumours in North Sea flatfish (OSPAR, 2000).

The main global contribution to marine radioactivity is still from fallout from nuclear tests in the atmosphere, particularly during the 1950s and 1960s. However, in the NWW area there is also radioactive contamination from the Sellafield reprocessing plant and to a lesser extent the explosion at Chernobyl in 1986 (Povinec et al., 1996). Radioactivity has been determined to have a harmful effect on a modelled population of plaice due to direct effects on individual fertility, fecundity, morbidity and mortality. Small radiation-induced, reductions in egg production and embryonic survival, and increases in age dependant mortality, could aggregate to produce significant effects at the population level. However, it needs to be stated that assessing the effects of radiation with this method requires caution due to the simplistic nature of the model (Woodhead, 2003).

Natural and synthetic hormones can disrupt the hormone system. There is ample evidence in male flounder (*Platichthys flesus*) for elevated concentrations of vitellogenin, which is an indicator of oestrogenic endocrine disruption (Vethaak et al., 2002). Evidence of endocrine disruption in open waters such as the NWW is less common but it exists for flounder in UK coastal waters (Allen et al., 1999), and male cod in the North Sea (Scott et al., 2006).

Concentrations of these contaminates do not have to be lethal or have a negative effect themselves, as indirectly they have the potential to make fish species more susceptible for pathogens.

2.4.2.4.1.7 Input of nitrogen and phosphorous

Trawling activity resuspends the sediment and may result in increased levels of nitrogen and phosphorus that have previously been stabilised in the sediment (ICES, 2006; ICES, 2007b).

The marine environment is nutrient limited. Resuspension of nutrient-rich sediments can increase primary production which may have both positive and negative effects on the marine environment. An increase in the amount of organic matter sinking to the sea floor, as a result of increased primary production, will provide additional energy input to the benthos which can enhance secondary production. This enhanced secondary production can in turn enhance the food availability to fish species and increase the carrying capacity of the system, which may provide benefits for overall production.

However, large increases in organic input can lead to the mortality of benthic fauna as the oxygen requirements of the bacteria degrading the organic matter may deplete oxygen from the bottom waters (Brockmann et al., 1988), and cause anoxia. In NWW the periods of anoxia may be relatively short because of rapid restoration of the oxygen content by tidal movement, although anoxic and methanogenic sediments can persist in coastal areas near towns and cities (Jones et al., 1986).

2.4.2.4.1.8 Noise and visual disturbance

Noise and visual disturbance caused by prawn trawlers can result in avoidance reactions and stress in fish. This can increase susceptibility to predation and pathogens. Visual disturbance by resuspension of sediments could lead to difficulties during foraging of visual hunters.

2.4.2.4.1.9 Habitat structure changes

The effect of prawn trawlers on habitat structure is discussed in section 2.4.2.1. The habitat available for fish species depending on these structures becomes smaller or could fully disappear, with consequences as discussed under barriers to species movement (Section 2.4.2.4.1.1).

2.4.2.4.2 Marine mammals and reptiles

Fisheries can have direct or indirect interactions with marine mammal populations. Direct mortality can be caused by fishing gear, while and indirect trophic effects result in changes to the food web that support the mammals.

The Marine Institute in Ireland has been running a discard observer program since 2002. During that period 4349 fishing operations using otter trawls have been observed and no cetacean or pinnipeds have been recorded as by-catch. While this figure includes non *Nephrops* directed fishing effort it is clear that if by-catch incidents of marine mammals occur they are very rare events and are unlikely have any effect at the population level.

The indirect trophic effects of fishing on marine mammals could be adverse due to prey depletion if, or positive if the fishery is catching species that compete for prey. There are two resident cetacean and two resident pinniped species in NWW. The two resident cetacean species are harbour porpoise (*Phocoena phocoena*) and the bottlenose dolphin (*Tursiops truncatus*) while the resident pinniped species are the harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*).

Harbour porpoise are known to eat over 30 species of fish, cephalopods and benthic invertebrates although their diet is predominantly made up of gadoids (e.g. whiting), sandeel and clupeids (e.g. herring) (Santos and Pierce, 2003, Santos et al., 2004). The literature on porpoise diets in the northeast Atlantic suggests that there has been a longterm shift from predation on clupeid fish (mainly herring *Clupea harengus*) to predation on sandeels and gadoid fish. This shift is possibly related to the decline in herring stocks since the mid-1960s and such a shift could have adverse health consequences. Stomach content analysis of stranded bottlenose dolphins from the east coast of Scotland showed that cod (*Gadus morhua*), saithe (*Pollachius virens*) and whiting (*Merlangius merlangus*) were found to be the main prey eaten although several other fish species were also found, including salmon (*Salmo salar*) and haddock (*Melanogrammus aeglefinus*), and also cephalopods (Santos et al., 2001). Feeding studies of bottlenose dolphin from around the world have found that they are generally opportunistic feeders.

Harbour seals in the have been found to predate on a range of fish, cephalopods and (Thompson et al., 1996; Tollit and Thompson, 1996; Brown and Pierce, 1998; Hall et al., 1998). The fish component of harbour seal diet, which is the major component of their diet, consists of gadoids, sandeel and pelagics (e.g. herring, mackerel). Grey seal have a similar diet to harbour seal, although on occasion they have been found to include a significant proportion of flatfish (Prime and Hammond, 1990) or sculpins (Hammond et al., 1994). As with the cetaceans the seal have an opportunistic diet that generally reflects the local survey abundance of fish in the size range in which they feed.

The diet of the cetacean and pinniped species in NWW includes species that are directly targeted by the prawn trawl fleet, and species that are the prey items of targeted species. Therefore the prawn trawl fleet could simultaneously cause negative and positive indirect impacts on marine mammals. However their wide ranging opportunistic diets suggest that cetaceans and pinniped species will be reasonably robust to alterations in prey abundance. The prawn trawl fleet in NWW is not considered to have a significant effect on marine mammal populations.

The main marine reptile species recorded from NWW are marine turtles. Five species of marine turtle have been recorded in UK and Irish waters. However, only one species, the Leatherback turtle (*Dermochelys coriacea*), is reported annually and is considered a regular and normal member of NWW marine fauna. Loggerhead turtles (*Caretta caretta*) and Kemp's ridley turtles (*Lepidochelys kempii*) occur less frequently, with most specimens thought to have been carried north from their usual habitats by adverse currents. Records of two other vagrant species, the Hawksbill turtle *Eretmochelys imbricata* and the Green turtle *Chelonia mydas* are very rare. Turtles are protected under the EU Habitats Directive (EU Council Directive 92/43/EEC). There is no known direct interactions between the prawn trawl fleet in NWW and marine reptiles although the indirect trophic interactions described above for cetaceans and pinnipeds would also apply to sea turtles.

2.4.2.4.3 Seabirds

Fishing can affect seabird populations negatively, through direct mortality and prey reductions, and positively by feeding subsidy from discarding of whole organisms and offal. There is no evidence that prawn trawling causes any direct mortality on seabirds in NWW.

The indirect effects of fishing activity have been investigated more thoroughly in the North Sea than in NWW although Furness et al. (1992) studied the use of fishery waste by gulls on the west coast of Scotland and the Irish Sea. Boats trawling for prawns discard large quantities offish, generally 5-25 cm in length, that are predominantly flatfish, whiting (*Merlangius merlangus*), Norway pout, or poor cod (*Trisopterus minutus*) (Watson 1981). The discarding rate (mass of fish) was about twice the mass of *Nephrops* caught for boats in the Clyde and in the Hebrides (Furness et al., 1988). In the Irish Sea, most discards come from prawn trawlers and so are primarily small fish. In north-west Scotland roughly similar amounts of discards come from the whitefish fleet and the prawn fleet. Competition between various species of birds for offal and discards was found to be intense with Fulmars (*Fulmarus glacialis*) taking the most offal. Gannets mainly exploit discards in spring, when they cause a reduced feeding success in, and partially displace, Herring Gulls from feeding at boats. Lesser Black-backs show a greater tendency than Herring Gulls to feed at boats rather than at refuse tips. Numbers foraging at boats in the Clyde, west Scotland, in summer are large in relation to breeding numbers for Lesser and Great Black-backed Gulls. Faecal pellets also indicate that discards are important for adult gulls of these species in summer. Discards can be an important part of Herring Gull chick diets but are rather less important for adults. Technical conservation measures, such as changes to minimum mesh size, to reduce discarding and a trend to use offal rather than discharge it may have pronounced effects on scavenging seabird populations.

2.4.2.5 Other groups

2.4.2.5.1 Non-indigenous and invasive species

There is no evidence of any effect of the prawn trawl fishery on non-indigenous or invasive species.

2.4.3 Northern Hake

European hake (*Merluccius merluccius*) is widely distributed over the northeast Atlantic shelf, from Norway to Mauritania, with a larger density from the west of Ireland to the south of Spain and in the Mediterranean and Black sea. Hake spawn from February through to July along the shelf edge, the main areas extending from the north of the Bay of Biscay to the south and west of Ireland. After a pelagic life, 0-group hake migrate to the bottom at depths of more than 200 m, then move to shallower water with a muddy seabed (75–120 m) by September. There are two major nursery areas: in the Bay of Biscay and off southern Ireland. The Northern European hake stock is located in ICES Division IIIa, Subareas IV, VI and VII and Divisions VIIIa,b,d and is exploited over this range by a variety of fishing methods such as trawling, gill nets and baited long lines (see section 2.1.4 for information on stock status). Hake is preyed upon by sharks and other fishes. Cannibalism on juveniles by adults is also quoted. Adults feed on fish (mainly on blue whiting and other gadoids, sardine, anchovy, and other small pelagic fish); juvenile hake prey mainly upon planktonic crustaceans (above all euphausids, copepods, and amphipods). Ecological factors or environmental conditions affecting hake population dynamics are not taken into account at present in the assessment or in the management.

2.4.3.1 Habitats

2.4.3.1.1 Seafloor

The impact of the hake fishery on the seafloor depends on the fishing methods used to catch it. Otter trawls targeting hake will have a similar impact as those used to catch *Nephrops* (see sections 2.4.2.1.1, 2.4.2.4.1.6 and 2.4.2.4.1.7). Gillnets are large, rectangular mesh nets that are anchored by weights on the bottom of the net to the sea floor whereas long lines consist of a main line, with baited hooks attached at intervals by means of branch lines called "snoods". To date there have been no peer-reviewed studies based on actual observations of the effects of bottom set gillnets or long lines on benthic organisms, in contrast to a multitude of comparable studies of the effects of trawl gear (Sharp et al., 2009). This is largely due to the inherent difficulty of achieving independent observations of a bottom set long line or gill net. Tethered cameras (Constable et al., 2007) show some promise however the cameras themselves will influence the movement of the line during setting and subsequent retrieval. Truly independent observation will likely require the use of towed cameras (i.e. on a line other than the long line itself) or Remotely Operated Vehicles (ROVs). However, because the impact of gillnets and long lines occur primarily during gear retrieval or from unforeseen events, such as lost gear, directly observing impacts as they occur will remain a challenge. Unlike heavy trawl gears that may leave a visible track

(Hall-Spencer et al., 2002), the impact footprint of a bottom long line or gillnet is likely to be difficult to discern after the fact. The need to make decisions in such a data poor setting favours the use of impact assessment approaches to address the benthic affects of bottom gillnets and long lines. Nevertheless, if these fixed gears operate correctly they are unlikely to have any serious impact on the structural integrity of the seafloor.

2.4.3.1.2 Water column habitats

Otter trawling for hake is likely to have similar impacts on the water column as otter trawling for *Nephrops* relating to the resuspension of sediments and nutrients (see section 2.4.2.1.2). Bottom set gillnets and long lines are unlikely to have any direct impact on the habitats of the water column.

2.4.3.1.3 Protected habitats

The Marine Institute in Ireland, working closely with the Government and Industry, compiled information on the distribution and abundance of eggs and larvae, juvenile and adult fish in the waters around Ireland and presented these data to the EU Commission. This presentation was powerful evidence of the biological importance of this area. In 2003 the EU Commission established a “Biologically Sensitive Area (BSA)” off the south west of Ireland (Figure 2.4.1). In the same year the EU also established a specific fishing effort regime inside and outside the BSA for demersal fishing vessels as well as scallop and crab fisheries (i.e. different fishing effort regulations apply inside and outside of the box).

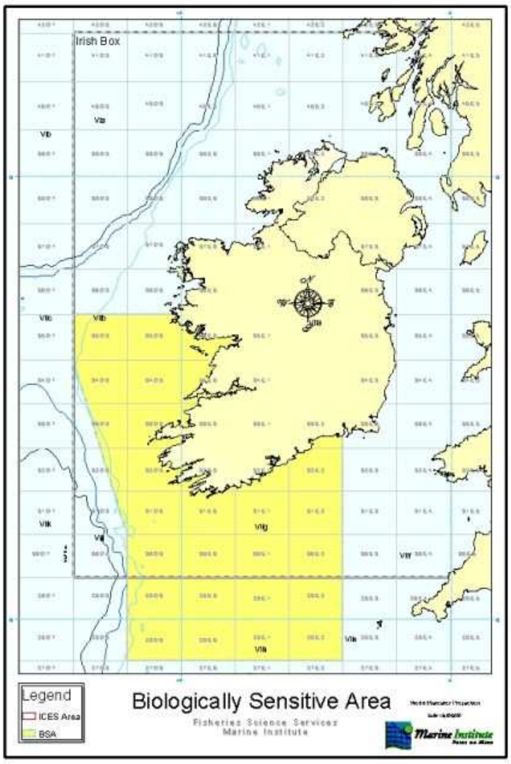


Figure 2.4.1: Biologically Sensitive Area (in yellow) off the south west of Ireland

The BSA plays a major role in the rebuilding of fish stocks in the waters around Ireland, particularly the hake stock which has a high juvenile concentration in this area. Inside the BSA fishing is prohibited with towed gears between 55–99 mm and static gears <120 mm within much of the BSA (towed gears of 80–99 mm and static gears <120 mm are commonly used to target hake in ICES Area VII outside the box). The objectives of the BSA and associated effort constraints were not defined at the outset making an evaluation of whether these met their objectives impossible. The BSA is linked to the hake recovery plan and recent assessments have indicated that the hake SSB has increased above B_{pa} (ICES, 2009). The degree to which the BSA contributed to this SSB increase (or not) is unclear. The BSA does correspond well to a known nursery area of juvenile hake west and southwest of Ireland. The BSA is also adjacent or overlapping somewhat with the main hake spawning area in ICES Area VII. The BSA also overlaps with spawning and nursery areas for several other important demersal stocks and pelagic stocks. Based on the overlap and the impact of the associated management measures (i.e. demersal effort limit and increased mesh size for towed and fixed gear), the main stocks that may have benefited from the presence of the BSA are megrim and anglerfish. The spatial distribution of fishing effort by country and gear from Vessel Monitoring System (VMS) indicates that Ireland is the most important fisher in the BSA followed by France and Spain. There are several inconsistencies in the effort statistics for the BSA as reported to the EC and as estimated directly using VMS data. This lack of consistency and transparency prevents any definitive conclusions on whether the BSA actually limits fishing effort for member states. For example Spain reports effort levels close to their limit but VMS estimates of effort are significantly below reported levels. Other countries reported and VMS estimated effort levels for demersal gears are well below their limits in most cases.

As stated above, it is not possible to draw conclusions on the utility of the BSA. The current effort control regime appears not to be limiting fishing effort for most countries. The precautionary approach would be to retain the measures associated with BSA since removal may result in some undesired changes in fishing patterns. However, if the BSA is retained its objectives need to be clearly defined and effort baselines need to be transparently calculated, routinely reported and properly enforced. Given the complex area of the BSA an improved VMS based effort reporting system with integrated vessel, gear, logbook and fishing track information would be the optimum way of doing this. The increased mesh size within the BSA may have benefited the hake and megrim stock both of which have significant nursery area overlap with the area of increased mesh size.

2.4.3.2 Plants

2.4.3.2.1 Phytoplankton

As discussed in Section 2.4.2.1.2 the re-suspension of fine sediments due to trawling activity may increase primary productivity if it adds phosphorus to areas where this nutrient is limiting. Conversely, the increased turbidity reduces the penetration of light and can reduce primary productivity near the seabed. The use of gillnets and long lines to target hake has no known impact on phytoplankton productivity.

2.4.3.2.2 Macroalgae

Macroalgae may be affected by hake trawling if they are attached to hard substrates (e.g. rocks and cobbles) although this habitat is not common on hake fishing grounds. Furthermore, as this type of substrate is likely to damage fishing gears or the catch, these areas are likely to be avoided. There is no known impact of long lines on macroalgae and gillnets are set too deep (~200m) for macroalgal growth.

2.4.3.3 Invertebrates

2.4.3.3.1 Zooplankton

Trawling for hake is unlikely to directly affect zooplankton. Indirectly there may be an effect through the food chain or from the release of nutrients from the disturbance to the surface of the sediment but this is likely to be minor. There is no known impact of long lines or gillnets on zooplankton.

2.4.3.3.2 Benthos

2.4.3.3.2.1 Community structure or species dynamic changes

The impact of trawling for hake on the benthic community is likely to be similar to trawling for *Nephrops* although there will be some differences related to the variation in the ground type and associated fauna. Gillnets and long lines are not known to have any impact on the benthic community structure.

2.4.3.3.2.2 Death by injury or collision

Long lines do not target benthic species. Gill nets can entangle mobile epifauna, such as crab and lobsters, which may be damaged or killed during removal from the net. The impact of trawling on the benthos by injury or collision was considered in section 2.4.2.3.2.3.

2.4.3.4 Vertebrates

2.4.3.4.1 Fish

2.4.3.4.1.1 Barrier to species movement

The hake trawl operates on the seafloor and therefore directly affects habitat structures (see section 2.4.2.1.1) and indirectly affects species movement. The trawled habitat becomes homogenised, and may result in larger distances between suitable patches for survival (Auster and Langton, 1999; Johnson, 2002). Thus trawling activity could lead to barriers for the movement of stocks and mixing of populations. There is no known impact of long lines on species movement. In contrast, gillnets are fixed on the seafloor and depend on the movement of species in order to catch fish. Depending on the density of the gear, and spatial manner of deployment, gillnets can represent a serious barrier to species movement.

2.4.3.4.1.2 Community structure or species dynamic changes

The mortality caused by the otter trawl is higher for larger roundfish species, while for pelagic and small specimens the impact is less. Gill nets and longlines are size selective but not species selective. These effects will lead to changes in the size composition of the community. Selective mortality of larger fish can result in changes in growth rates and sexual maturation within a species. See section 2.4.2.4.1.2 for discussion on unaccounted mortality (discards) and impact of climate change on species dynamics.

2.4.3.4.1.3 Species life history changes

See section 2.4.2.4.1.3.

2.4.3.4.1.4 Death by injury or collision

Fish may be temporarily restrained by gill nets and long lines and subsequently escape. Such individuals will more than likely be injured or stressed by this process and be more susceptible to predation and disease. However, no evidence could be found to quantify the scale of this effect. The death by injuries caused by trawling was considered in section 2.4.1.4.1.2.

2.4.3.4.1.5 Removal of non-target species

The hake fishery includes a diverse community of species including megrim, anglerfish, *Nephrops*, sole, seabass, ling, blue ling, greater forkbeard, tusk, whiting, blue whiting, horse mackerel, conger eel, pout, cephalopods (octopus, *Loligidae*, *Ommastrephidae*, and cuttlefish), and rays. The relative importance of these species in the hake fishery varies between years depending on gears, sea areas, and biological conditions.

2.4.3.4.1.6 Removal of target species

See section 2.1.4 for stock status.

2.4.3.4.1.7 Heavy metal contamination / Hydrocarbon contamination / Radio-nucleotide contamination

See section 2.4.2.4.1.6.

2.4.3.4.1.8 Input of nitrogen and phosphorous

The input of nitrogen and phosphorous from re-suspension of sediments by trawling activity is covered in section 2.4.2.4.1.7. There is no known impact from gill net and long line fishing activity on the input of nitrogen and phosphorous.

2.4.3.4.1.9 Noise and visual disturbance

The noise and visual disturbance from trawling is covered in section 2.4.2.4.1.8. Gill net and long line activity do not introduce any serious noise or visual disturbance to the marine environment.

2.4.3.4.1.10 Habitat structure changes

The impact of trawling on the structure of the habitat was covered in section 2.4.2.1.

2.4.3.4.2 Mammals and reptiles

A programme to assess the cetacean by-catch in the Irish and UK set gillnet fisheries in the Celtic Sea was conducted from August 1992 to March 1994 using volunteer observers. Observers were present for the hauling of over 2500 km of net which resulted in the by-catch of 43 harbour porpoises and four common dolphins, with one of each released alive. The by-catch rate was 7.7 porpoises per 10,000 km hours of net immersion. A negative relationship was found between porpoise by-catch and tidal speed but no other relationships were found with operational or environmental variables. Spatial and temporal stratification of the by-catch rate and effort data had a small effect on estimated total by-catch, which was therefore estimated from pooled data. The estimated total annual by-catch of 2,200 porpoises (95% C.I. 900–3500) was 6.2% of the estimated number of porpoises in the Celtic Sea and there is serious cause for concern about the ability of the population to which they belong to sustain this level of by-catch.

Since 2006, European regulations (812/2004 and S.I 274 of 2007) have made it mandatory to use acoustic pingers in bottom gillnet fisheries in a number of EU waters, including areas off the south and southwest coasts of Ireland. The aim is to reduce by-catch, particularly of harbour porpoises in these fisheries. Although a number of devices are commercially available, fishermen raised concerns about the effectiveness and the practicality of using them in a working environment. The Irish Sea Fisheries Board, Bord Iascaigh Mhara (BIM), carried out a number of trials on Irish gillnet vessels for hake in 2005 and 2006 using four different types of pingers, and compared notes with agencies from Sweden, Denmark, France and the UK. They looked at spacing, reliability, and effective range. This work showed that in the Irish fishery, porpoise by-catch is very low, and that pingers can be used to successfully deter them away from the gillnets. However, there is a need for manufacturers to develop pingers with much greater durability to reduce the cost implications of deployment.

Trawling for hake is likely to have a similar impact on marine mammals and reptiles as trawling for *Nephrops* (See section 2.4.2.4.2). There is no known direct interactions between the hake fishing fleet in NWW and marine reptiles although the indirect trophic interactions described in section 2.4.2.4.2 would also apply to sea turtles.

2.4.3.4.3 Seabirds

The impact of long line fishing on seabirds in the north-east Atlantic was investigated in a joint project between the UK's Royal Society for the Protection of Birds (RSPB), Norwegian Ornithological Society (NOF), BirdLife International, and the UK's Joint Nature Conservation Committee (JNCC). In this study (Dunn and Steel, 2001) on-board observers recorded the by-catch of seabirds taken by Norwegian offshore long line fishing vessels in the Norwegian Sea in 1997 and 1998. By extrapolating the catch rates to the known fishing effort, it was estimated that the Norwegian fleet takes a significant by-catch of northern fulmar, *Fulmarus glacialis*. The total Norwegian long lining fleet (including the inshore fleet of smaller vessels) was estimated to take approximately 20,000 northern fulmars annually. While northern fulmars are caught in significant numbers by long lining, the estimated annual mortality was not thought to be threatened given that the north-east Atlantic breeding population of northern fulmars is around 2-4 million pairs, and the overall population much higher when non-breeding adults and immature individuals are included. The fieldwork included an evaluation of the mitigating measures used by the Norwegian fleet, including an underwater setting tube and streamer lines. The application of such technical devices and procedures could reduce incidental mortality of seabirds in European long line fisheries.

Alternatively, fishing can have a positive affect on seabird populations by providing feeding subsidy from discarding of whole organisms and offal (see section 2.4.2.4.3).

2.4.3.5 Other groups

2.4.3.5.1 Non-indigenous and invasive species

There is no evidence of any effect of the hake fishing fleet on non-indigenous or invasive species.

2.4.4 Scallops

2.4.4.1 Habitats

2.4.4.1.1 Seafloor

Seabed mapping surveys, using MULTIBEAM acoustic methods were undertaken on the Irish RV Celtic Voyager in 2002-2004, to characterise and describe the distribution of the main sediment types in the Celtic Sea that may be suitable for scallop settlement and habitation (Tully et al., 2006). The acoustic images, together with ground validation data, in the form of sediment samples and digital images of the seabed showed that the seabed structure varies on a variety of spatial scales. Broadscale regional distribution of sand and gravel can be recognized in additional to smaller scale features including rock outcrops and, particularly, sand dunes 200-300m in length and 50-100m wide. These dunes are composed of medium coarse sand and are aligned in a northwest to southeast direction in accordance with prevailing currents. Large areas of gravel also occur throughout the area. The relative proportion of each substrate varies throughout the area, resulting in a mosaic pattern which has implications for the distribution of scallops, the catch rates in the fishery and for the interpretation of catch and effort data. Surveys in 2001-2005 showed that catch rates were 4-5 times higher on gravel patches. However, within areas where gravel predominates the ground is mixed with varying proportions of sand. Commercial fishing effort in these areas, therefore, involves dredging over varying amounts of sand for little benefit to catch and considerable cost to the seabed habitat.

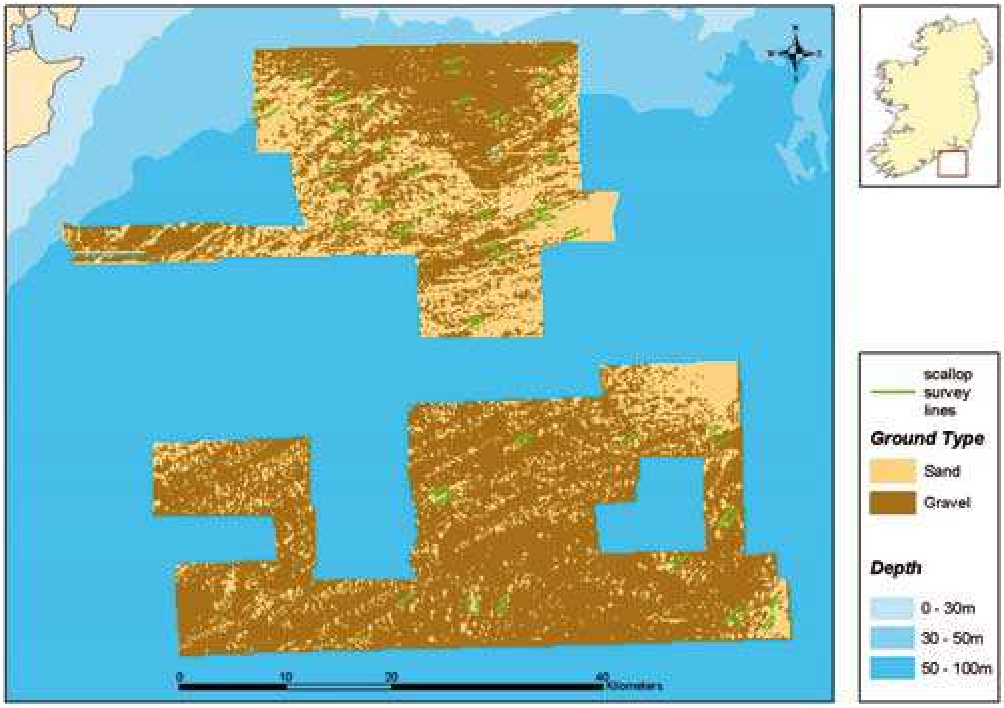


Figure 2.4.2: Acoustic backscatter map of the seabed off the south east coast showing the main acoustic classes defined here as sand and gravel. Scallop survey positions in 2002-2004 are shown by the green lines (Tully et al., 2006).

As noted in section 2.1.5 the spring loaded dredges used by the scallop fleet are designed to penetrate the seabed in order to remove the scallops and this has a number of effects on the seabed habitat (www.ukmarinesac.org.uk/activities/fisheries/f4.htm). Tracks are created on the seabed, fine sediments are lifted into suspension and large rocks can be overturned (Caddy, 1973, Sea Fish Industry Authority. 1993, Bullimore, 1985, ICES, 1992). A mound of sediment may be carried in front of the toothed bar and deposited around the sides in distinct ridges, most obviously in the case of the spring-loaded dredges (Riemann and Hoffmann, 1991). There are reports of the top 100 mm of sediment being disturbed by scallop dredging which has the effect of smoothing out the surface with pits and depressions being filled in and mounds removed (Currie D.R. & Parry G.D. 1996). These physical changes as well as the track marks may still be present months later depending on the conditions at the site. Where there is little current movement the tracks may be visible for a several months and even a relatively minor fishery may have a significant cumulative effect on bottom micro topography (Caddy, 1973). Heavy chain dredges can mix surface organic material into subsurface layers (Mayer *et al.*, 1991). This removes the organic material from the surface metazoan-microbial aerobic chain to an anaerobic system. If the subsurface layers are already anoxic, further problems can occur. Churning up the soft bottom can create anaerobic turbid conditions which are, for example, capable of killing scallop (*Platinopecten* sp.) larvae (Yamamoto, 1960).

In contrast, Eleftheriou and Robertson (2003) carried out an experimental dredging operation in a small sandy bay in Scotland with the aim of quantitatively assessing the effects of scallop dredging on both the benthic fauna and the physical environment. An area within the 10m depth contour was selected and 1.2m scallop dredge was operated at frequencies of 2, 4, 12 and 25 dredges, carried out over a period of nine days. The effects on the bottom topography, the physical characteristics of the sediment and the fauna were investigated by grab and core sampling, and direct observations were carried out by a diving team. Observed changes in bottom topography were not translated into changes in the disposition of the sediments, their grade distribution and the organic carbon and chlorophyll content, all of which showed no effects.

2.4.4.1.2 Water column habitats

Dredging for scallop is likely to produce sediment clouds similarly to otter trawling (section 2.4.2.1.2) although the larger sediment size found on scallop grounds would reduce its temporal and spatial extent. Two other issues related to the re-suspension of sediments are the smothering of settled scallop larvae and the potential for increased feeding by adult scallop. Galtsoff (1964), in Jones (1992), showed that as little as a 1 mm layer of silt over a settlement surface could prevent spat settlement in *Ostrea virginica* and Stevens (1987) claimed that high levels of turbidity inhibited settlement of *Pecten novaezelandiae* veliger larvae, depressed growth rates of adults, and caused inefficient metabolism of glycogen stores through enforced anaerobic respiration.

2.4.4.1.3 Protected habitats

The scallop fishery in NWW overlaps with habitats that are protected for various reasons such as the cod stock in the Irish Sea (Section 2.4.2.1.3) and the Biologically Sensitive Area in the Celtic Sea (Section 2.4.3.1.3). In addition there are areas around the Isle of Man that are protected specifically for the scallop stock. These regulations are spatially based with fishing for scallops in the 3-12 mile area restricted to between 05:00-21:00 GMT, and the maximum width of scallop dredges must not exceeding 1219 cm (40 ft), with no more than 8 dredges per side. In the 0-3 mile area fishing for scallops is not allowed after 18:00 hours GMT or before 06:00 hours GMT on any day. The total width of scallop dredges must not exceed 762 cm (25 ft). There are further restrictions on the number of teeth and spacing per bar, the belly rings and the mesh size. In addition to these spatial and technical regulations, there is a closed season between 1st June and 31st October and minimum size rules also apply.

A comparative analysis between a fished area and a closed area off the Isle of Man by Beuker-Stewart et al. (2005) revealed that after 15 years the catch rates of legal sized scallops were 7 times higher in the protected area than outside. Experimental dredging of 2 plots within the closed area confirmed that fishing drove these differences in population dynamics and structure. These patterns of scallop density, age and size structure resulted in the exploitable biomass (adductor muscle and gonad) of scallops were nearly 11 times higher in the closed area than in the fished area by 2003, and the reproductive biomass was 12.5 times higher. This is significant for fisheries management because the build up of high densities of large *P. maximus* individuals enhanced local reproductive potential and therefore the likelihood of export of larvae to the surrounding fishing grounds.

2.4.4.2 Plants

2.4.4.2.1 Phytoplankton

Scallops are filter feeders and consume phytoplankton as a large part of their diet. Aquaculture studies have shown that the production and viability of scallop eggs and embryos depends on the presence of essential fatty acids in the microalgae diets (Utting and Millican, 1998). Therefore, the scallop stock is directly dependent on the availability and composition of the phytoplankton in the water column.

Amnesic shellfish poisoning (ASP) is a human illness caused by consumption of the marine biotoxin called domoic acid. This toxin is produced naturally by marine diatoms belonging to the genus *Pseudonitzschia* and, when accumulated in high concentrations by shellfish, such as scallops, can then be passed on to humans via consumption of contaminated shellfish. Levels of domoic acid in scallops from the Celtic Sea in 2003 were found to exceed the legal limit of 20 mg.per kg (for combined tissues) in the majority of stations (Tully et al., 2006). However, levels were below the legal limit in the majority of stations where water temperatures at the bottom were less than 12ºC in August. Although the observed pattern does not explain the mechanisms which give rise to high levels of ASP they show that, for this area, low levels of the toxin are associated with low seabed temperatures and to some degree low current speeds both of which are negatively correlated with the growth rate and feeding rate of scallops.

As discussed in Section 2.4.2.1.2 the re-suspension of fine sediments due to trawling activity may increase primary productivity if it adds phosphorus to areas where this nutrient is limiting. Conversely, the increased turbidity reduces the penetration of light and can reduce primary productivity near the seabed.

2.4.4.2.2 Macroalgae

Maerl beds are mixed sediments built by a surface layer of slow-growing, unattached coralline algae that are of international conservation significance as they facilitate the creation of areas of high biodiversity. During dredging maerl is killed through burial and crushing, which in turn limits opportunities for habitat recovery. A comparison of a previously un-fished maerl bed with a commercially fished ground in the Clyde Sea area, off the coast of Scotland, showed that counts of live maerl remained high on the control plot, while scallop dredging led to a >70% reduction with no sign of recovery over the subsequent four years (Spencer and Moore, 2000).

Large attached macroalgae, such as kelps, can also be torn up, or turned over, by the action of the passing dredge although they are faster growing than maerl and recover more quickly.

2.4.4.3 Invertebrates

2.4.4.3.1 Zooplankton

Scallops are filter feeders and consume zooplankton as part of their diet. However, the contribution of zooplankton to the overall diet of *P. maximus* in the wild is not known and in commercial aquaculture operations they are rearing exclusively on phytoplankton culture (Utting and Millican, 1998).

Dredging for scallop may indirectly affect zooplankton levels through the food chain or by the release of nutrients from the disturbance to the surface of the sediment but this is likely to be minor.

2.4.4.3.2 Benthos

2.4.4.3.2.1 Community structure or species dynamic changes

From http://www.ukmarinesac.org.uk/activities/fisheries/f1_5_3.htm:

On gravel substrates around the Isle of Man, the structure of the benthic community has been shown to be related to the intensity of commercial dredging effort (Bradshaw *et al.*, 2001). Effects may differ from those in areas of soft sediment due to the extreme patchiness of animal distribution, greater abundance of epifauna and the combined effect of the toothed gear and stones caught in the dredges. Impacts may also be apparent in lightly dredged areas, including the loss of a number of species including some potentially fragile tube-dwellers (Fonseca *et al.*, 2004).

There are very few studies which compare the fauna of dredged and un-dredged areas and therefore give clues about possible long term effects of dredging which may be different from short or medium term effects. One example is a study off the Isle of Man (Bradshaw *et al.*, 2001) which showed differences in the epifaunal communities including greater species numbers in the area closed to fishing even under conditions of considerable seasonal variation. A higher density of shallow burrowing and epi-benthic species (particularly those noted for their vulnerability to dredging such as the bryozoan, *Cellaria fistulosa*, and the common sea urchin, *Echinus esculentus*) were recorded at the un-dredged sites. Long-lived and slow recruiting epifauna such as sponges and ascidians were also likely to be particularly vulnerable. There was no evidence of longer-lived benthic species being more prevalent at the un-dredged sites. It was suggested that this could be due to the relatively short time period since effective closure of the area to dredging which gives another indication of the time scales required for these species to become re-established in dredged areas.

2.4.4.3.2.2 Death by injury or collision

From http://www.ukmarinesac.org.uk/activities/fisheries/f1_5_3.htm:

Jenkins et al. (2001) assessed the impact of scallop dredging on benthic megafauna by directly observing the damage caused to the by-catch and to organisms that encounter the dredges but are not caught. Experimental dredging was undertaken on a scallop fishing ground in the north Irish Sea, off the Isle of Man. Divers were deployed immediately after dredges had passed, to record levels of damage to megafauna left in the dredge tracks. The level of damage in the by-catch and on the seabed was found to be the same in most species although some common species did show differences. The edible crab (*Cancer pagurus*) was more severely damaged when not captured, while the starfish (*Asterias rubens*) and whelk (*Neptunea antique*) received greater damage within the by-catch. Capture efficiency for the megafauna was low, ranging from 2 to 25% among species. The results of this study indicate that the majority of damage to large benthic invertebrates during scallop dredging occurs unobserved on the seabed, rather than in the by-catch. The fate of these damage individuals was investigated by Veale et al. (2000) using a time-lapse video system which was positioned in an area closed to fishing, adjacent to the most heavily fished scallop (*Pecten maximus*) ground in the Irish Sea. A variety of undamaged and damaged by-catch animals were positioned in front of the camera and the subsequent predator aggregations investigated. Densities of scavenger species up to 200 times that of the background population were observed, and aggregations of some species persisted for up to 3 days suggesting that the survival rate for damaged benthos is low. The most frequently recorded scavengers, and therefore presumably those species most likely to benefit from discards as a food source, were: *Asterias rubens* L., *Astropecten irregularis* (Pennant), *Liocarcinus* spp Stimpson, *Pagurus* spp *Fabricius* and *Callionymus lyra* L.

2.4.4.3.2.3 Removal of non-target species

From http://www.ukmarinesac.org.uk/activities/fisheries/f1_5_3.htm:

The maximum impact of scallop dredging on non-target species may not be immediate, suggesting that some indirect ecological changes such as exposed organisms becoming more vulnerable to predation, may be taking place (Currie and Parry, 1996). In one study a 20-30 % decrease in abundance of most species was recorded 3.5 months after dredging, and some differences were still apparent after 8 months. Fragile groups such as nemerteans (unsegmented worms) were directly affected and showed considerable damage (Currie and Parry, 1996). In another study more than 50 % of the common taxa of macro-fauna were affected and significant differences from adjacent reference plots were still apparent after 3 months (Thrush *et al*., 1995). The collection and sorting of stones and shells by the dredge can also have an impact by removing encrusting sponges, hydroids, and small anemones and, by reducing habitat complexity may lead to increased predation on juveniles of some harvestable species (Auster *et al*., 1996). Burrowing and tube dwelling infauna may be less affected than epifauna (Bullimore, 1985). In a study carried out in the Skomer Marine

Nature Reserve off the coast of Wales the numbers of sea anemones, *Cerianthus lloydii*, *Mesacmae mitchellii*, and the sand mason worm, *Lanice conchilega*, within and alongside dredge paths were similar to pre-dredge levels several weeks later. In contrast fragile species such as the bristle worm, *Filograna implexa*, and the ross coral, *Pentapora foliacea*, appear to be particularly vulnerable (Bullimore, 1985; Collie *et al*. 1996). Slow growing species will not be able to recover to pre-dredging numbers or sizes even if there is dredging ceases for several years. In common with other forms of dredging, predatory fish, whelks and hermit crabs are attracted to the track to feed on damaged and exposed animals (Caddy, 1973; Chapman *et al*., 1977).

2.4.4.3.2.4 Removal of target species

See section 2.1.5.

2.4.4.4 Vertebrates

2.4.4.4.1 Fish

There is a small by-catch of commercial fish species such as Monkfish (*Lophius piscatorius*) and Black Sole (*Solea solea*), however the quantities involved are small. Scallop fishermen are given a quota allowance for this by-catch which is relative to the quantity of scallop landed and this figure must be recorded in an EU logbook.

Jenkins et al. (2001) observed the dab, *Limanda limanda* and the dogfish *Scyliorhinus canicula* preying on dead or damaged benthic individuals on the seafloor. The effect of this food source on fish populations has not been assessed.

2.4.4.4.1.1 Barrier to species movement

Scallop dredges operate on and in the seafloor which have the effect of smoothing out the surface, with pits and depressions being filled in and mounds removed (Currie & Parry, 1996). Thus the trawled habitat becomes homogenised, and may result in larger distances between suitable patches for survival and reproduction (see section 2.4.4.1.1).

2.4.4.4.1.2 Community structure or species dynamic changes

The impact of scallop fisheries on the community structure of fish populations has not been assessed, but as the fish by-catch is relatively low it is likely any interaction if it exists is weak.

2.4.4.4.1.3 Species life history changes

The impact of scallop fisheries on the life history of fish populations has not been assessed, although there is a possibility that the disturbance of the bottom by the dredge could prevent herring eggs from developing. However, as herring generally spawn in inshore areas the overlap with the scallop fishery is small and any interaction is likely to be insignificant at the population level.

2.4.4.4.1.4 Death by injury or collision

Jenkins et al. (2001) investigated the impact of scallop dredging on species that encountered the dredge but remained on the seabed. No fish species were recorded as injured or killed in this study.

2.4.4.4.1.5 Removal of non-target species

Bottom fishing reduces production of benthic infauna (Jennings et al., 2001) and megafauna (Hermsen *et al*., 2003) thereby reducing the energy available for fish production. Structural epifauna plays a dual role by providing a habitat for many of the small, fragile invertebrates that are important prey species (Collie *et al*., 1997) and also by providing juvenile fish protection from predators. Removal of this epifauna requires juvenile fish to forage for longer periods, thereby exposing them to higher levels of predation (Walters and Juanes, 1993). Second-order effects of demersal fishing are well documented but not well quantified; consequently the impact of such interactions at a population level is unknown.

2.4.4.4.1.6 Removal of target species

The impact on fish populations of harvesting scallops has not been assessed.

2.4.4.4.1.7 Heavy metal contamination / Hydrocarbon contamination / Radio-nucleotide contamination

See section 2.4.2.4.1.6.

2.4.4.4.1.8 Input of nitrogen and phosphorous

See section 2.4.2.4.1.7.

2.4.4.4.1.9 Noise and visual disturbance

See section 2.4.2.4.1.8.

2.4.4.4.1.10 Habitat structure changes

The potential impact of changes to habitat structure by scallop dredging on fish populations was considered in section 2.4.4.4.1.1 and 2.4.4.4.1.3.

2.4.4.4.2 Mammals and reptiles

There is no known direct interaction between scallop fisheries and marine mammals or reptiles although indirect ecosystem interactions via the food chain may exist.

2.4.4.4.3 Seabirds

There is no known direct interaction between scallop fisheries and seabirds although indirect ecosystem interactions via the food chain may exist.

2.4.4.5 Other groups

2.4.4.5.1 Non-indigenous and invasive species

There is no known interaction between scallop fisheries and non-indigenous and invasive species.

2.5 Synergistic effects of the case study fisheries with other human activities

Human activities on land and sea will indefinitely have an effect/impact on the ecosystem. This is what we have to accept and what we have to deal with. Improper use however can lead to transformations in the system, that can range from smaller reversible changes to large scale “catastrophic” shifts (Scheffer et al., 2001;Scheffer and van Nes, 2004). Here, you can think of fishing through (Essington *et al*., 2006) or down the food web (Pauly *et al*., 1998), the slippery slope to slime (e.g. increase of jelly fish, related to overfishing, eutrophication, climate change, translocation and habitat modification) (Richardson et al., 2009), ecological changes due to oil spills (Teal and Howarth, 1984;Peterson *et al*., 2003) or other pollutions (De Metrio *et al*., 2003;Porte *et al*., 2006).

Effects of single activities can be managed in relation to their impact on the environment, but their synergistic effects with other anthropogenic, or even non-anthropogenic impact, could still lead to disasters. Synergistic effects of habitat destruction, overfishing, introduced species, global warming, acidification, toxins, and massive runoff of nutrients are transforming once complex ecosystems like coral reefs and kelp forests into monotonous bare bottoms, transforming productive coastal seas into anoxic dead zones, and transforming complex food webs topped by big animals into simplified, microbially dominated ecosystems with boom and bust cycles of toxic dinoflagellates, jellyfish, and disease (Jackson, 2008).

Therefore fisheries management should at least have an idea of and consider the synergistic effects of the various anthropogenic effects on the marine environment. But also the relationship with non-anthropogenic forcing factors, e.g. climate, needs to be considered. For example: fish stocks which are depleted (by fishing) are at higher risk of collapse due to small changes in their environment (Brander 2005). The synergistic effects of climate change are threats for all human activities.

Here, we will focus on the synergistic effects of the fisheries case studies with other human activities. It should be realized that most, if not all, of the synergistic effects with fisheries will result in a further decrease in the target fish stocks or other biological components. Therefore, a full description of what would be the result of the synergistic effects is not given here rather an overview of threats is presented. The intention is not to give an extensive overview of possibilities and what ifs, but to point at serious threats. Management should consider these threats and manage each anthropogenic effect in such a way that even the synergistic effect will not cause the ecosystem aspects to exceed the sustainable reference points.

2.5.1 North East Atlantic Mackerel

The synergistic effects in relation to the pelagic mackerel fisheries concern mainly the mackerel stocks themselves. Mackerel depend on a relatively short food chain, therefore all impacts that affecting the pelagic ecosystem could have potentially serious synergistic effects.

Other specific topics to mention are:

- Mackerel eggs and larvae are pelagic consequently any human activity that effects the pelagic environment (e.g. pollution, nutrient input and trawling) could have synergistic effects on mackerel stocks.

- Pile hammering. By the construction of windmill parks the poles of the windmills are hammered into the substrate. The sound produced by the hammering can cause problems for pelagic larvae.

2.5.2 Dublin Bay Prawns

The synergistic effects in relation to the prawn trawl fisheries mainly concern demersal fish stocks, benthic communities and sediment structures. All other impacts affecting these ecosystem aspects could potentially have synergistic effects.

Other specific topics to mention are:

- Fishery interactions such as the impact of discarded fish and the abundance of predators such as cod can have positive and negative effects on the prawn populations.

- Resuspension of fine sediments could enhance and prolong the effects of land-based eutrophication. The prolonged effects could be a threat in the case where pollutants are resuspended.

- *Nephrops* larvae are pelagic consequently any human activity that effects the pelagic environment (e.g. pollution, nutrient input and trawling) could have synergistic effects on prawn stocks.

2.5.3 Northern Hake

The synergistic effects in relation to the northern hake fishery concern mainly demersal fish stocks, benthic communities and sediment structures. All other impacts affecting these ecosystem aspects could potentially have synergistic effects.

Other specific topics to mention are:

- Anthropogenic effects in the coastal nursery areas of the target species, e.g. eutrophication, and pollution, could risk the recruitment to the fishery and synergistic effects could reduce the populations below the reference points.
- The first stages of the hake life cycle are pelagic and are more likely to be related to environmental effects, whereas later stages are demersal are more likely to be related to biological interactions such as predator prey relationships.

2.5.4 Scallops

The synergistic effects in relation to the scallop dredge fisheries concern mainly the benthic communities and sediment structures. All other impacts affecting these ecosystem aspects could potentially have synergistic effects with the scallop dredge fisheries.

Other specific topics to mention are:

- The effect of the scallop dredging on demersal eggs (e.g. herring) which could have synergistic effects with other fisheries.

•	Industrial uses of marine areas such as gravel extraction, telephone lines, windmill parks and shipping. Such structures and activities form obstructions for the scallop fleet and decrease the amount of available fishing grounds.

•	Anthropogenic effects in the coastal nursery areas of the target species, e.g. eutrophication, pollution and tourism, could risk the recruitment to the fishery and synergistic effects could reduce the populations below the reference points.

2.6 References

Allen, Y., Matthiessen, P., Scott, A. P., Haworth, S., Feist, S. & Thain, J. E. (1999) The extent of oestrogenic contamination in the UK estuarine and marine environments - Further surveys of flounder. Science of the Total Environment, 233, 5-20.

Auster, P. J. & Langton, R. W. (1999) The effects of fishing on fish habitat. Fish Habitat: Essential Fish Habitat and Rehabilitation (eds L. Benaka), pp. 150-187. American Fisheries Society, Bethesda, Maryland.

Ball, B., Munday, B. & Tuck, I. (2000) Effects of otter trawling on the benthos and environment in muddy sediments. Effects of fishing on non-target species and habitats (eds M. J. Kaiser & S. J. de Groot), pp. 69-82. Blackwell Science, Oxford.

Barrett, R. T., Anker-Nilssen, T., Rikardsen, F., Valde, K., Rov, N. & Vader, W. (1987) The Food, Growth and Fledging Success of Norwegian Puffin Chicks Fratercula arctica in 1980-1983. Ornis Scandinavica, 18, 73-83.

benthic megafaunal production on Georges Bank. Mar. Ecol. Prog. Ser., 260, 97–108.

Bergman, M. (2000) The fate of discarded invertebrates from the Clyde Nephrops fishery. University of London.

Bergmann, M., Wieczorek, S. K., Moore, P. G. & Atkinson, R. J. A. (2002) Discard composition of the Nephrops fishery in the Clyde Sea area, Scotland. Fisheries Research, 57, 169-183.

Beukers-Stewart, B. D., Vause, B. J., Mosley, M. W. J., Rossetti, H. L. and Brand, A. R., 2005. Benefits of closed area protection for a population of scallops. Marine Ecology Progress Series, 298: 189–204.

Beverton, R. J. H. (1990) Small marine pelagic fish and the threat of fishing; are they endangered? Journal of Fish Biology, 37, 5-16.

Blanchard, J.L., Dulvy, N.K., Jennings, S., Ellis, J.R., Pinnegar, J.K., Tidd, A. and Kell, L.T. 2005. Do climate and fishing influence size-based indicators of Celtic Sea fish community structure?ICES Journal of Marine Science, 62: 405-411.

Borges, L., van Keeken, O., van Helmond, A. T. M., Couperus, B. & Dickey-Collas, M. (2008) What do pelagic freezer-trawlers discard? Journal of Marine Science, 65, 605-611.

Borges, L., van Keeken, O., van Helmond, A. T. M., Couperus, B. & Dickey-Collas, M. (2008) What do pelagic freezer-trawlers discard? Journal of Marine Science, 65, 605-611.

Bradshaw, C., Veale, L.O., Hill, A.S., & Brand, A.R. 2001. Effects of scallop dredging on gravelly seabed communities. In: Kaiser, M.J. & de Groot, S.J., eds. Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Fishing News Books

Brander, K. (2005) Cod recruitment is strongly affected by climate when stock biomass is low. ICES Journal of Marine Science. 62: 339-343.

Briggs, R.P., 1992. An assessment of nets with a square mesh panel as a whiting conservation tool in the Irish Sea Nephrops fishery. Fish. Res. 13, 133-152.

Brockmann, U., Billen, G. & Gieskes, W. W. C. (1988) North Sea nutrients and eutrophication. Pollution of the North Sea: an assessment (eds W. Salomens), pp. 348-389. Springer-Verlag, Berlin.

Brown, E. G. & Pierce, G. J. (1998) Monthly variation in the diet of harbour seals in inshore waters along the southeast Shetland (UK) coastline. Marine Ecology Progress Series, 197, 275-289.

Bullimore, B. 1985. An investigation into the effects of scallop dredging within the Skomer Marine Reserve. Skomer Marine reserve Subtidal Monitoring Project. Report to the Nature Conservancy Council.

Caddy, J. F. 1973. Underwater observations on tracks of dredges and trawls and some effects of dredging on a scallop ground. Journal of the Fisheries Research Board of Canada, 30: 173–180.

Chapman, C.J., Mason, J. & Drinkwater, J.A.M. 1977. Diving observations on the efficiency of dredges used in the Scottish fishery for the scallop, Pecten maximus (L). Scottish Fisheries Research, Report No.10. 16pp.

Chopin, F. S. & Arimoto, T. (1995) The condition of fish escaping from fishing gears--a review. Fisheries Research, 21, 315-327.

Collie, J. S., Escanero, G. A. & Valentine, P. C. (2000a) Photographic evaluation of the impacts of bottom fishing on benthic epifauna. ICES Journal of Marine Science, 57, 987-1001.

Collie, J. S., Hall, S. J., Kaiser, M. J. & Poiner, I. R. (2000b) A quantitative analysis of fishing impacts on shelf-sea benthos. Journal of Animal Ecology, 69, 785-798.

Collie, J.S., Escanero, G.A. & Hunke, L. 1996. Scallop dredging on Georges Bank: photographic evaluation of effects on benthic epifauna. ICES C.M. 1996/Mini:9.

Collie, J.S., Escanero, G.A., Valentine, P.C., 1997. Effects of bottom fishing on the benthic megafauna of Georges Bank. Mar. Ecol. Prog. Ser. 155, 159–172.

Constable, A. and R. Holt. 2007. Bottom fishing in high-seas areas of CCAMLR. Document SC-CAMLR-XXVI/10. CCAMLR, Hobart, Australia: 18 pp.

Couperus, A. S. (2008) Monitoring of incidental catches of cetaceans by Dutch Pelagic trawlers in 2007. CVO 08.007, pp. 16.

Currie D.R. & Parry G.D. 1996. Effects of scallop dredging on a soft sediment community: a large scale experimental study. Marine Ecology Progress Series. 134:131-150.

Dahl, K., and Kirkegaard, E. 1986. Stomach contents of mackerel, horse mackerel and whiting in the eastern part of the North Sea in July 1985. ICES CM 1986/H:68, 17 pp.

De Metrio, G., Corriero, A., Desantis, S., Zubani, D., Cirillo, F., Deflorio, M., Bridges, C. R., Eicker, J., de la Serna, J. M., Megalofonou, P. & Kime, D. E. (2003) Evidence of a high percentage of intersex in the Mediterranean swordfish (Xiphias gladius L.). Marine Pollution Bulletin, 46, 358-361.

DEFRA, 2009. Submission by the United Kingdom - Exclusion of groups of vessels from the effort management system under the provisions of Article 11(2) of the ‘Long-term plan for cod stocks’, Council Regulation (EC) No 1342/2008.

Dobby, H., Bailey, N., and Campbell, N. 2007. The use of underwater TV surveys in the provision of advice for *Nephrops* stocks around Scotland. ICES CM 2007/O:23.

Drinkwater K.F. (2005) The response of Atlantic cod (Gadus morhua) to future climate change. ICES Journal of Marine Science, 62: 1327-1337.

Dunn, E. and Steel, C., 2001. The impact of longline fishing on seabirds in the north-east Atlantic: recommendations for reducing mortality. JNCC, 108.

Eleftheriou, A., and Robertson, M. R. 1992. The effects of experimental scallop dredging on the fauna and physical environment of a shallow sandy community. Netherlands Journal of Sea Research, 30: 289–299.

Essington, T. E., Beaudreau, A. H. & Wiedenmann, J. (2006) Fishing through Marine Food Webs. Proceedings of the National Academy of Sciences of the United States of America, 103, 3171-3175.

Farina, A.C., Freire, J., Gonzalez-Gurriaran, E. (1997) Demersal fish assemblages in the Galician continental shelf and upper slope (NW Spain): Spatial structure and long-term changes. Estuarine, Coastal and Shelf Science, 44: 435 454.

Fock, H., Uiblein, F., Köster, F., von Westernhagen, H. (2002) Biodiversity and species environment relationships of the demersal fish assemblage at the Great Meteor Seamount (subtropical NE Atlantic), sampled by different trawls. Marine Biology, 141: 185-199.

Foden, J., Rogers, S. I. & Jones, A. P. (2008) A critical review of approaches to aquatic environmental assessment. Marine Pollution Bulletin, 56, 1825-1833.

Fonseca, M.S., Thayer, G.W., Chester, A.J. & Foltz, C. 1984. Impact of scallop harvesting on eelgrass (Zostera marina) meadows: implications for management. N.Am.J.Fish.Mnt., 4:286-293.

Furness, R. W., Ensor, K. & Hudson, A. V. (1992) The use of fishery waste by gull populations around the British Isles. Ardea, 80, 105-113.

Furness, R.W., Hudson, A.V., Ensor, K., 1988. Interactions between scavenging seabirds and commercial fisheries around the British Isles. In: Burger, J. (Ed.), Seabirds and Other Marine Vertebrates. Competition, Predation, and Other Interactions. Colombia University Press, New York, pp. 240-268.

Galtsoff, P.S., 1964. The American Oyster Crassostrea oirginica Gmelin. Fish. Bull., 64: 440 pp.

Giannakourou, A., Orlova, T., Assimakopoulou, G.,and Pagou, G. 2005. Dinoflagellate cysts in recent marine sediments from Thernaikos Gulf, Greece. Effects of resuspension events on vertical cyst distribution. Cont. Shelf. Res., 25, 2585 – 2596.

Gilkinson, K., Paulin, M., Hurley, S. & Schwinghamer, P. (1998) Impacts of trawl door scouring on infaunal bivalves: results of a physical trawl door model/dense sand interaction. Journal of Experimental Marine Biology and Ecology, 224, 291-312.

Groenewold S & M Fonds. 2000. Effects on benthic scavengers of discards and damaged benthos produced by the beam-trawl fishery in the southern North Sea. ICES Journal of Marine Science 57: 1395-1406.

Hall, A. J., Watkins, J. & Hammond, P. S. (1998) Seasonal variation in the diet of harbour seals in the south-western North Sea. Marine Ecology Progress Series, 170, 269-281.

Hall-Spencer, J. M., and Moore, P. G. 2000. Impact of scallop dredging on maerl grounds. In Effects of Fishing on Non-Target Species and Habitats: Biological, Conservation and Socio-economic Issues, pp. 105–117. Ed. by M. J. Kaiser, and S. J. de Groot. Blackwell Science, Oxford, England, UK. 399 pp.

Hall-Spencer, J., V. Allain and J.H. Fosså. 2002. Trawling damage to Northeast Atlantic ancient coral reefs. Proc. R. Soc. Lond. B, 269 (1490): 507–511.

Halpern, B. S., McLeod, K. L., Rosenberg, A. A. & Crowder, L. B. (2007) Managing for cumulative impacts in ecosystem-based management through ocean zoning. Ocean and Coastal Management, 1-9.

Hammond, P. S., Hall, A. J. & Prime, J. H. (1994) The diet of grey seals around Orkney and other island and mainland sites in north-eastern Scotland. Journal of Applied Ecology, 31, 340-350.

Heath, M. R. (2005) Changes in the structure and function of the North Sea fish foodweb, 1973-2000, and the impacts of fishing and climate. ICES Journal of Marine Science, 62, 1202-1202.

Hegmann, G., Cocklin, C., Creasey, R., Dupuis, S., Kennedy, A., Kingsley, L., Ross, W., Spaling, H. & Stalker, D. (1999) Cumulative Effects Assessment Practitioners Guide. Prepared by AXYS Environmental Consulting Ltd. and the CEA Working Group for the Canadian Environmental Agency, Hull, Quebec, Canada. pp.

Hermsen, J. M., Collie, J. S. & Valentine, P. C. (2003). Mobile fishing gear reduces

Hiddink, J. G. & ter Hofstede, R. (2008) Climate induced increases in species richness of marine fishes. Global Change Biology, 14, 453–460.

Hill, A. S., Brand, A. R., Wilson, U. A. W., Veale, L. O. & Hawkins, S. J. (1996) Estimation of bycatch composition and the numbers of by-catch animals killed annually in the Manx scallop fishing grounds. Aquatic Predators and their Prey (eds S. P. R. Greenstreet & M. L. Tasker), pp. 111-115. Blackwells Science, Oxford, UK.

Hill, B.J. & Wassenberg, T.J. 1990. Fate of discards from prawn trawlers in Torres Strait. Australian Journal of Marine and Freshwater Research, 41: 53–74.

Huxley, T. H. (1883) ‘Inaugural address’, The Fisheries Exhibition Literature, International Fisheries Exhibition, London Vol. 4, pp. 1–22. pp.

ICES (1996) Seabird/fish interactions, with particular reference to seabirds in the North Sea. ICES Cooperative Research report, 216, pp. 87.

ICES (2002) Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 2002/ACE:03, pp. 193.

ICES (2003) Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES C.M. 2003/ACE:05, pp. 193.

ICES (2006) Report of the Working Group on Ecosystem Effects of Fishing Activities (WGECO), 5-12 April 2006, ICES Headquarters. Copenhagen. ACE:05. 174 pp., pp.

ICES (2007b) Report of the Working Group on Ecosystem Effects of Fishing Activities (WGECO). pp.

ICES (2008a) Report of the Herring Assessment Working Group South of 62 N (HAWG), 11-19 March 2008, ICES Headquarters, Copenhagen. ICES CM 2008/ACOM:02. 601 pp.

ICES (2008a) Report of the Herring Assessment Working Group South of 62 N (HAWG), 11-19 March 2008, ICES Headquarters, Copenhagen. ICES CM 2008/ACOM:02. 601 pp.

ICES (2008e) Report of the Working Group on Ecosystem Effects of Fishing Activities (WGECO), May 6-13 2008, Copenhagen, Denmark. ICES CM 2008/ACOM:41. 269 pp.

ICES (2008g) Report of the Working Group on Widely Distributed Stocks (WGWIDE), 2–11 September (ICES CM 2008/ACOM:13). pp.

ICES 2008. Workshop and training course on Nephrops burrow identification (WKNEPHBID). ICES CM 2008/LRC:03

ICES 2008.Workshop and training course on *Nephrops* burrow identification (WKNEPHBID). ICES CM 2008/LRC:03

ICES 2009a. Study Group on Nephrops Surveys (SGNEPS) ICES CM 2009/LRC:15

ICES 2009b. ICES. 2009. Report of the Benchmark Workshop on Nephrops (WKNEPH), 2–6 March 2009, Aberdeen, UK. ICES CM 2009/ACOM:33. (awaiting publication).

ICES, 2006. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim, 9 - 18 May 2006, Bilbao, Spain, ICES CM 2006/ACFM:29.

ICES, 2009. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk, and Megrim, 5-11 May 2009, ICES CM 2009/ACOM:08.

ICES, 2009. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk, and Megrim, 5-11 May 2009, ICES CM 2009/ACOM:08.

ICES. 1992. Report of the study group on ecosystem effects of fishing activities. ICES C.M.1992/G:11.

ICES. 2007. Workshop on the Use of UWTV Surveys for Determining Abundance in Nephrops Stocks throughout European Waters. 17–21 April 2007, Heraklion, Crete, Greece. ICES CM 2007/ACFM:14. 198 pp.

Ignacio Olaso, José L. Gutiérrez, Begoña Villamor, Pablo Carrera, Luis Valdés and Pablo Abaunza (2005). Seasonal changes in the north-eastern Atlantic mackerel diet (Scomber scombrus) in the north of Spain (ICES Division VIIIc). Journal of the Marine Biological Association of the UK, 85 , pp 415-418

INEXFISH (2006) The role of anthropogenic and non-anthropogenic forcing factors on the biology of exploited species. WP 1 Deliverable – review Annexes 1-6 Proposal/Contract no.: FP6- 022710 Incorporating extrinsic drivers into fisheries management., pp.

Jackson, J. B. C. (2008) Ecological extinction and evolution in the brave new ocean. Proceedings of the National Academy of Sciences, 105, 10.1073/pnas.0802812105 11458-11465.

James, E., McColl, V., Tomlinson, P. & Fry, C. (2003) Literature review/scoping study on cumulative effects assessment and the Strategic Environmental Assessment Directive. Environment Agency Project Report PR SE/730/03 (carried out by TRL Ltd). pp.

Jenkins, S.R., Beukers-Stewart, B.D. and Brand, A.R. 2001. Impact of scallop dredging on benthic megafauna: a comparison of damage levels in captured and non-captured organisms. Marine Ecology Progress Series. 215: 297-301.

Jennings, S., Kaiser, M.J., 1998. The effects of fishing on marine ecosystems. Advances in Marine Biology 34, 201–352.

Johnson, A. (2002) Review of national and international literature on the effects of fishing on benthic habitats. pp. 72.

Johnson, L. L., Collier, T. K. & Stein, J. E. (2002) An analysis in support of sediment quality thresholds for polycyclic aromatic hydrocarbons (PAHs) to protect estuarine fish. Aquatic Conservation: Marine and Freshwater Ecosystems, 12, 517-538.

Jones, J.B. 1992. Environmental impact of trawling on the seabed: a review. New Zealand Journal of Marine and Freshwater Research. 26: 59-67.

Jones, K.B, Neale, A.C., Nash, M.S., Van Remortel, R.D., Wickham, J.D., Ritters, K.H. and O'Neill, R.V. 1986. Predicting nutrient and sediment loadings to streams from landscape metrics: A multiple watershed study from the United States Mid-Atlantic Region. Landscape Ecology. 16: 301-312.

Kaiser, M. J. & Spencer, B. E. (1995) Survival of by-catch from a beam trawl. Marine Ecology Progress Series, 126, 31-38.

Kaiser, M. J., Clarke, R., Hinz, H., Austen, M. C. V., Somerfield, P. J. & Karakassis, I. (2006) Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series, 11, 1-14.

Kaiser, M. J., Ramsay, K., Richardson, C. A., Spence, F. E. & Brand, A. R. (2000) Chronic fishing disturbance has changed shelf sea benthic community structure. Ecology, 69, 494-503.

Kelly, C.J., Codling E.A. and Rogan, E. (2006) The Irish Sea cod recovery plan: some lessons learned. ICES Journal of Marine Science, 63: 600-610.

Krost, P., Bernhard, M., Werner, F. & Hukriede, W. (1990) Otter trawl tracks in Kiel Bay (western Baltic) mapped by side-scan sonar. Meeresforschung, 32, 344-353.

Lamarck, J. B. M. (1809) Philosophie Zoologique, ou exposition des Considérations relatives à l'histoire naturelle des Animaux; à la diversité de leur organisation et des facultés qu'ils en obtiennent. Dentu et l'Auteur, Paris. pp.

Law, R. (2002) Selective fishing and phentotypic evolution: past, present and future. ICES CM 2002/Y:11.

Lockwood, S.J., 1988. The Mackerel. Its Biology, Assessment and the Management of a Fishery. Fishing Book News Ltd. Farnham, Surrey England. 181 pp.

Mayer L.M., Schick D.F., Findlay R.H., Rice D.L. (1991) Effects of commercial dragging on sedimentary organic matter. Mar. environ. Res. 31:249-261.

Mehl S. and Westgård T. (1983) The diet and consumption of mackerel in the North Sea. ICES CM 1983/H:34. 30 pp.

Millar, R. B. & Fryer, R. J. (1999) Estimating the size-selection curves of towed gears, traps, nets and hooks. Reviews in Fish Biology and Fisheries, 9, 89-116.

Myers, M., S. , Johnson, L. L. & Collier, T. K. (2003) Establishing the causal relationship between Polycyclic Aromatic Hydrocarbon (PAH) exposure and hepatic neoplasms and neoplasia-related liver lesions in English sole (Pleuronectes vetulus). Human and Ecological Risk Assessment, 9, 67-94.

OSPAR (2000) Quality Status Report 2000 Region II - the Greater North Sea. London: OSPAR Commission. pp.

Overholtz. W.J, S.A. Murawski, and K.L. Foster (1991) Impact of predatory fish, marine mammals, and seabirds on the pelagic fish ecosystem of the northeastern USA. In Daan, N., and M. Sissenwine (eds.), Symposium on multispecies models relevant to management of living resources, The Hague, Netherlands, October 1989, p. 198-208. Int. Counc. Explor Sea, Mar. Sci. Symp. 193.

Peterson, C. H., Rice, S. D., Short, J. W., Esler, D., Bodkin, J. L., Ballachey, B. E. & Irons, D. B. (2003) Long-Term Ecosystem Response to the Exxon Valdez Oil Spill. Science, 302, 10.1126/science.1084282 2082-2086.

Pierce, G. J., Dyson, J., Kelly, E., Eggleton, J. D., Whomersley, P., Young, I. A. G., Santos, M. B., Wange, J. & Spencer, N. J. (2002) Results of a short study on by-catches and discards in pelagic fisheries in Scotland (UK). Aquatic Living Resources, 15, 327-334.

Pinnegar, J. K., Jennings, S., O'Brien, C. M., and Polunin, N. V. C. 2002. Long-term changes in trophic level of the Celtic Sea fish community and fish market price distribution. Journal of Applied Ecology, 39: 377-390.

Planques, A., Guilen, J., and Puig, P. 2001. Impact of bottom trawling on water turbidity and muddy sediment of an unfished continental shelf. Limnol. Oceanogr. 46: 1100-1110.

Porte, C., Janer, G., Lorusso, L. C., Ortiz-Zarragoitia, M., Cajaraville, M. P., Fossi, M. C. & Canesi, L. (2006) Endocrine disruptors in marine organisms: Approaches and perspectives. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, 143, 303-315.

Povinec, P. Fowler, S. and Baxter, M. 1996. Chernobyl and the marine environment: The radiological impact in context. IAEA Bulletin 38(1): 18-22.

Prime, J. H. & Hammond, P. S. (1990) The diet of grey seals from the south-western North Sea assessed from analyses of hard parts found in faeces. Journal of Applied Ecology, 27, 435-447.

Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk, and Megrim, 30 April–7 May 2008 (ICES CM 2008/ACOM:07).

Report of the Working Group on the Celtic Seas Ecoregion, 13–19 May 2009 (ICES CM 2009/ACOM:09).

Richardson, A. J., Bakun, A., Hays, G. C. & Gibbons, M. J. (2009) The jellyfish joyride: causes, consequences and management responses to a more gelatinous future. Trends in Ecology & Evolution, 24, 312-322.

Riemann, B. & Hoffmann, E. 1991. Ecological consequences of dredging and bottom trawling in the Limfjord, Denmark. Marine Ecology Progress Series, 69:171-178.

Rijnsdorp, A. D. & Leeuwen, P. I. (1996) Changes in growth of North Sea plaice since 1950 in relation to density, eutrophication, beam-trawl effort, and temperature. ICES Journal of Marine Science, 53, 1199-1213.

Robinson, L. (2003) The Ecological Disturbance of Fishing in Demersal Fish and Benthic Invertebrate Communities. MAFCONS Report 2003; 003. pp.

Robinson, L. A. & Frid, C. L. J. (2008) Historical Marine Ecology: Examining the Role of Fisheries in Changes in North Sea Benthos. AMBIO: A Journal of the Human Environment, 37, 362-372.

Rochet, M-J., Péronnet I., and Trenkel, V. M. 2002. An analysis of discards from the French trawler fleet in the Celtic sea. ICES Journal of Marine Science, 59: 538 552.

Rumohr, H. & Krost, P. (1991) Experimental evidence of damage to benthos by bottom trawling, with special reference to Arctica islandica. Helgoländer Meeresuntersuchungen, 33, 340-345.

Ruttenberg, K.C. (2003) The Global Phosphorous Cycle. Treatise on Geochemistry. W.H. Schlesinger, Elsevier. 8:585-643.

Santos, M.B. and Pierce, G.J. 2003. The diet of harbour porpoise (Phocoena phocoena) in the Northeast Atlantic. Oceanography and Marine Biology: an Annual Review 2003, 41, 355–390

Santos, M.B., Clarke, M.R. and Pierce, G.J., 2001. Assessing the importance of cephalopods in the diets of marine mammals and other top predators: problems and solutions. Fish. Res. 52, pp. 121–139.

Santos, M.B., Pierce, G.J., Learmonth, J.A., Reid, R.J., Ross, H.M., Patterson, I.A.P., Reid, D.G., Beare, D., 2004a. Variability in the diet of harbor porpoises (Phocoena phocoena) in Scottish waters 1992-2003. Marine Mammal Science 20, 1-27.

Scheffer, M. & van Nes, E. H. (2004) Mechanisms for marine regime shifts: Can we use lakes as microcosms for oceans? . Progress In Oceanography, 60, 303–319.

Scheffer, M., Carpenter, S., Foley, J. A., Folke, C. & Walker, B. (2001) Catastrophic shifts in ecosystems. Nature, 413, 591-596.

Schiff, K.C. 2000. Sediment chemistry on the mainland shelf of the southern California Bight. Marine Pollution Bulletin Vol. 40, No. 3, pp. 268-276.

Schwinghamer, P., Gordon, D. C., Rowell, T. W., Prena, J., McKeown, D. L., Sonnichsen, D. & Guigne, J. Y. (1998) Effects of experimental otter trawling on surficial sediment properties of a sandy bottom ecosystem on the Grand Banks of Newfoundland. Conservation Biology, 12, 1215-1222.

Scott, A. P., Katsiadaki, I., Witthames, P. R., Hylland, K., Davies, I. M., McIntosh, A. D. & Thain, J. (2006) Vitellogenin in the blood plasma of male cod (Gadus morhua): A sign of oestrogenic endocrine disruption in the open sea? Marine Environmental Research, 61, 149-170.

Sea Fish Industry Authority. 1993. Benthic and ecosystem impacts of dredging for pectinids (reference 92/3506). Consultancy Report No.71.

Sharp, B.R., Parker, S.J. and Smith, N. 2009. An impact assessment framework for bottom fishing methods in the CAMLR convention area. CCAMLR Science, 16: 195:210.

Simmonds, E. J. 2007. Are reported catches sufficient to account for biomass in the NE Atlantic mackerel stock. ICES CM 2007/ACFM:31/WD:11

STECF (2008a) Evaluation of the STECF/SGMOS 07-04 Working Group on discards pp.

STECF. 2005. Commission Staff Working Paper. 21st Report of the Scientific, Technical and Economic Committee for Fisheries (Second Plenary Meeting). Brussels, 7–11 November 2005.

Stevens, P. M. 1987: Response of excised gill tissue from the New Zealand scallop Pecten novaezelandiae to suspended silt. New Zealand journal of marine and freshwater research 21: 605-614.

Stratoudakis, Y., Fryer, R.J., Cook, R.M., Pierce, G.J., Coull, K.A., 2001. Fish bycatch and discarding in Nephrops trawlers in the Firth of Clyde (west of Scotland). Aq. Liv. Res. 14 (5), 283–291.

Teal, J. M. & Howarth, R. W. (1984) Oil spill studies: A review of ecological effects. Environmental Management, 8, 27-43.

Thompson, P. M., McConnell, B. J., Tollit, D. J., Mackay, A., Hunter, C. & Racey, P. A. (1996) Comparative distribution, movements and diet of harbour and grey seals from the Moray Firth, N.E. Scotland. Journal of Applied Ecology, 33, 1572-1584.

Thrush, S.F., Hewitt, J.E., Cummings, V.J. & Dayton, P.K. 1995. The impact of habitat disturbance by scallop dredging on marine benthic communities; what can be predicted from the results of experiments? Mar.Ecol.Prog.Ser., 129:141-150.

Tollit, D. J. & Thompson, P. M. (1996) Seasonal and between-year variations in the diet of harbour seals in the Moray Firth, Scotland. Canadian Journal of Zoology, 74, 1110-1121.

Trenkel, V. M., and Rochet, M-J. 2003. Performance indicators derived from abundance estimates for detecting the impact of fishing on a fish community. Canadian Journal of Fisheries and Aquatic Sciences, 60: 67e85.

Trenkel, V. M., Pinnegar, J. K., Rochet, M-J., and Rackham, B. D. 2004. Different surveys provide similar pictures of trends in a marine fish community but not of individual fish populations. ICES Journal of Marine Science, 61: 351e362.

Tully, O., Hervas, A., Berry, A., Hartnett, M., Sutton, G., O'Keefe, E. and Hickey, J., 2006. Monitoring and Assessment of Scallops off the South East Coast of Ireland. Fisheries Resource Series, Bord Iascaigh Mhara (Irish Sea Fisheries Board), Dun Laoghaire, Ireland, Vol. 5, 2006, 20 pp.

Ulltang, O. (1980) Factors affecting the reaction of pelagic fish stocks to exploitation and requiring a new approach to assessment and management. Rapports et Procès-verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 177, 489-504.

Utting, S., Millican, P.F., 1998. The role of diet in hatchery conditioning of Pecten maximus L; a review. Aquaculture 165, 167–178.

Van Beek, F. A., Van Leeuwen, P. I. & Rijnsdorp, A. D. (1990) On the survival of plaice and sole discards in the otter-trawl and beam-trawl fisheries in the North Sea. Netherlands Journal of Sea Research, 26, 151-160.

van Helmond, A. T. M. & van Overzee, H. M. J. (2007) Discard sampling of the Dutch pelagic freezer fishery in 2006. CVO Report 07.010. pp.

Veale, L.O., Hill, A.S. and Brand, A.R. 2000. An in situ study of predator aggregations on scallop (Pecten maximus (L.)) dredge discards using a static time-lapse camera system.. Journal of Experimental Marine Biology and Ecology. 255: 111–129.

Vethaak, A. D., Lahr, J., Kuiper, R. V., Grinwis, G. C. M., Rankouhi, T. R., Giesy, J. P. & Gerritsen, A. (2002) Estrogenic effects in fish in The Netherlands: some preliminary results. Toxicology, 181-182, 147-150.

Walters and Juanes, 1993C.J. Walters and F. Juanes , Recruitment limitation as a consequence of natural selection for use of restricted feeding habitats and predation risk taking by juvenile fish. Can. J. Fish. Aquat. Sci. 50 (1993), pp. 2058–2070.

Watson, P. S. 1981. Seabird observations from commercial trawlers in the Irish Sea. British Birds 74:82-90.

Winters, G. H. & Wheeler, J. P. (1985) Interaction between stock area, stock abundance, and catchability coefficient. Canadian Journal of Fisheries and Aquatic Sciences, 42, 989-998.

Woodhead, D. S. (2003) A possible approach for the assessment of radiation effects on populations of wild organisms in radionuclide-contaminated environments? Journal of Environmental Radioactivity, 66, 181-213.

Yamamoto, G., 1964. Studies on the propagation of the scallop Patinopecten yessoensis (Jay) in Mutsu Bay. Fish. Res. Board Can. Trans. Ser., 1054: 68.

3 What people think

2.1 What consultations have been done in North Western Waters

The North Western Waters Regional Advisory Council (NWWRAC) was established in September 2005 in accordance with Council Decision 2004/585/EC, which set out a common framework for Regional Advisory Councils. The NWWRAC is composed of representatives from fishermen's organisations, fish producer organisations, processors, traders and other market organisations, women's groups, environmental organisations and groups, aquaculture producers, consumers and representatives of recreational or sport fishing. The principal aim of the NWWRAC is to bring together stakeholders from across Europe, to advise the Commission on matters of fisheries management in respect of the North Western Waters - ICES areas Vb (EC waters), VI, VII; i.e. the NWW study region for the MEFEPO project. Within that context, the parties concerned may make recommendations and suggestions to the Commission and the competent national authorities regarding the NWW. These comments and recommendations provide an excellent distillation of the views of various stakeholders in the NWW and are available on the NWWRAC website (www.nwwrac.org).

The European Commission regularly seeks the views of citizens and stakeholders when it develops policy and legislation. Many of these are open public consultations in the area of maritime affairs and fisheries. Details of previous public consultations, including information about the responses received and the follow-up taken are available on the fisheries consultation website (http://ec.europa.eu/fisheries/partners/consultations/).

3.1 Stakeholder impressions of the marine environment, socio-economic and governance issues

One important issue raised by the NWW RAC recently is that of ICES assessments (1st April 2010). According to the RAC, ICES cannot provide assessments for 57% of the stocks under its purview. This inability is mainly due to a deficiency in the fisheries data available to the scientists. Needless to say the problem has serious consequences. The NWW RAC has suggested a task group to identify and tackle the issues. In its reply, the EC states that the problem is being investigated and that the organisation of such a task group within the NWW RAC is welcomed.

On the 20th of June 2008 the NWW and SWW RACs issued a joint statement on the 'crisis' facing European fishermen and producers. The three main points were:

- The massive importation of products from third countries with access to the Community market at very low prices at first sale, leaving those products landed by European fleets in a situation of competitive disadvantage. This disadvantage has been indeed aggravated by the strength of the euro in the international market.
- The confusion of the consumer about the origin of the products and the conditions (economic, environmental and social) of their exploitation.
- The economic crisis highlighted by the unstoppable rise of fuel prices that cannot be passed on to the sale price, even though all the services related to the fishing activity are increasing: gears, lubricants, paintings, costs of transport etc.

The importation and consumer confusion issues are still pertinent. In its reply to the Green Paper on the Reform of the CFP, the Federation of Irish Fishermen (FIF) states that

'Europe imports nearly 65% of its fish and fish product requirements, but far from the European fishermen getting premium prices, the market share for wild caught fish from EU fleets is being eroded; at present, first point of sale prices are at a 20 year low for many species.'

According to the NWW RAC (22nd of April 2009), the problem of rising fuel prices was dealt with in record time with the publication of Council Regulation (EC) No 744/2008: 'Instituting a temporary specific action aiming to promote the restructuring of the European fishing fleets affected by the economic crisis'. However the proposal to reduce capacity of the fishing fleets by 30% to bring them in line with the existing resources again '*ignores the fact that EU producers contribute little more than 40% of the fish that European citizens consume*'.

3.2 Stakeholders preferred management tools and regimes

The Reform of the Common Fisheries Policy

In its reply to the Green Paper on the Reform of the CFP (Department of Agriculture, Fisheries and Food, 2009) it was stated that Ireland

'is strongly of the view that the cost benefit to the Member State and the coastal communities therein will be fundamentally and negatively impacted should new systems be introduced that promote the sale of fishing opportunities and quotas at international level, for example ITQs'

Ireland, as a member state, will not support the privatisation of a public resource such as fish quotas. Rather the current policy should be maintained where the responsibility for quota management rests with the member state.

At the outset of the CFP the Irish fishing fleet was not of a sufficient size to take full advantage of the new principle of relative stability in allocating TACs. Despite the discrepancy between the volume of fish which Ireland contributes (through its large and productive EEZ) and the share of fish stocks it has received from the CFP, Ireland believes that

'Relative Stability and its attendant TACs and Quotas, whilst imperfect, must remain the primary community mechanism to manage fish stocks'

Ireland also fully supports the adoption of an ecosystem approach to fisheries management. It is seen as a 'critical regional management tool' which will see a greater role for the RACs. As a first step towards EAFM the phased introduction of MSY is encouraged.

In contrast, in its reply to the green paper the Federation of Irish Fishermen (FIF) states that it is completely opposed to MSY being the over-arching policy objective. The top-down approach to the enforcement of regulations was also criticised by the FIF. The FIF see this reform as an opportunity to 'standardise Member States compliance and enforcement regimes'. A shift from top-down to bottom-up management is echoed in many of the responses. Local management of small artisanal fisheries is advocated by a number of respondents.

3.3 Linkages between the three perspectives on the system (ecological, economic and social)

Fisheries management needs to support the 'three pillars of sustainability' (ecological, social and economic). One of the greatest challenges of management is searching for ways of achieving these objectives simultaneously. The economic and social pillars can be considered subsidiary to the ecological pillar since the loss of an ecological resource base will mean that no social and economic benefits can be derived for the seas. However, as noted in section 1.4.3, scientific advice from ICES is centred on the biology of the fish stock. With the broad range of marine stakeholders involved in the RACs since 2005 this imbalance is now being redressed. The reform of the CFP in 2012 will likely strengthen this linkage between the three perspectives on the system:

' The fisheries sector can no longer be seen in isolation from its broader marine environment and from other policies dealing with marine activities…..The Common Fisheries Policy therefore requires us all to take a fresh look at the broader maritime picture as advocated by the Integrated Maritime policy (IMP) and its environmental pillar, the Marie Strategy Framework Directive '

Reform of the Common Fisheries Policy. Green Paper (2009)

4 Conclusions

4.1 State of the marine environment

The following are very brief summaries of the state of the marine environment in the two main OSPAR Regions in the NWW. For slightly more detailed summaries broken into four areas of the NWW see section 1.1 of this report.

Celtic Seas (OSPAR Region III)

The OSPAR Quality Status Report 2000 concluded that the status of the Celtic Seas (Region III) was generally good. But of concern were: pollution of urban estuaries, extensive development of coastal areas, critical depletion of some fish stocks, hormone disruption due to hazardous substances and pollution, and climate change. The OSPAR QSR 2010 has recently been published and notable improvements in this region have been reported as:

- Reduction of Radionuclides
- Reduction of Tributyltin (TBT)
- Recovery of some fish stocks

However ongoing concern remains in a number of areas, particularly:

- Damage to the seabed due to benthic trawling (particularly in shallow areas)
- Increasing pressure from human activities (especially the mostly unknown effects of off-shore developments for renewable energy)
- Certain fish stocks remain low (recovery plans for cod have not been effective in rebuilding the Irish Sea stock and by-catch remains a problem in some parts of the region)
- Unacceptable levels of hazardous substances at some locations (for example PAH and PCB concentrations in sediment and fauna in the Irish Sea)
- High levels of litter (again around the Irish Sea, mainly from terrestrial sources)

23 species and 11 habitats in Region III are now considered under threat. 3.5% of the region is now part of a Marine Protected Area (MPA).

The three priority areas identified by OSPAR for future focus were to:

1. Develop spatial planning
2. Reduce litter
3. Develop sustainable fisheries

Wider Atlantic (OSPAR Region V)

The other OSPAR region of concern for the MEFEPO NWW area is the Wider Atlantic. The 2000 QSR reported that the status of this region was 'good but far from pristine'. The main areas of concern were: overfishing, large numbers of fish and marine mammals killed accidentally, lack of information about the impacts of climate change, damage to fragile habitats, expansion of the oil and gas industry, and increasing inputs of hazardous substances, oil and litter.

Since then, the QSR 2010 lists as successes in the region:

- Some international cooperation to control fishing (particularly the North East Atlantic Fisheries Commission, NEAFC, regulating discards, gill-netting and other impacts)
- Protecting deep-sea habitats (again the work of NEAFC but also OSPAR and the EU with regard to closing areas to bottom-fishing at least on a temporary basis)

Unfortunately the list of ongoing concerns contains more points:

- Long-lived species slow to recover
- Bluefin tuna 'in trouble'
- Increasing industrial activity (search for oil and gas expected to reach high seas)
- Difficulty establishing MPAs in the high seas

21 species are considered under threat as well as 7 habitats. 0.2% percent of the region is protected (MPA).

The three priority areas identified by OSPAR for future focus were to:

1. Improve and continue monitoring of fisheries in the region
2. Help the recovery of fish stocks
3. Protect (with MPAs) the Mid-Atlantic Ridge and isolated sea-mounts

4.2 Major gaps in knowledge

The OSPAR QSR 2010 concludes that there is poor knowledge of the status of marine mammal populations in the Celtic Seas (Region III). Certain species are only censused every five to six years, the bare minimum to assess their status.

In the Wider Atlantic (Region V) information is limited to such an extent that there was not enough new information to establish trends since the last report in 2000. Improved long-term monitoring is required for habitats such as the continental margin, sea-mounts and the abyssal plain. OSPAR has particularly identified the need for detailed habitat maps so it is clear where to focus this improved monitoring.

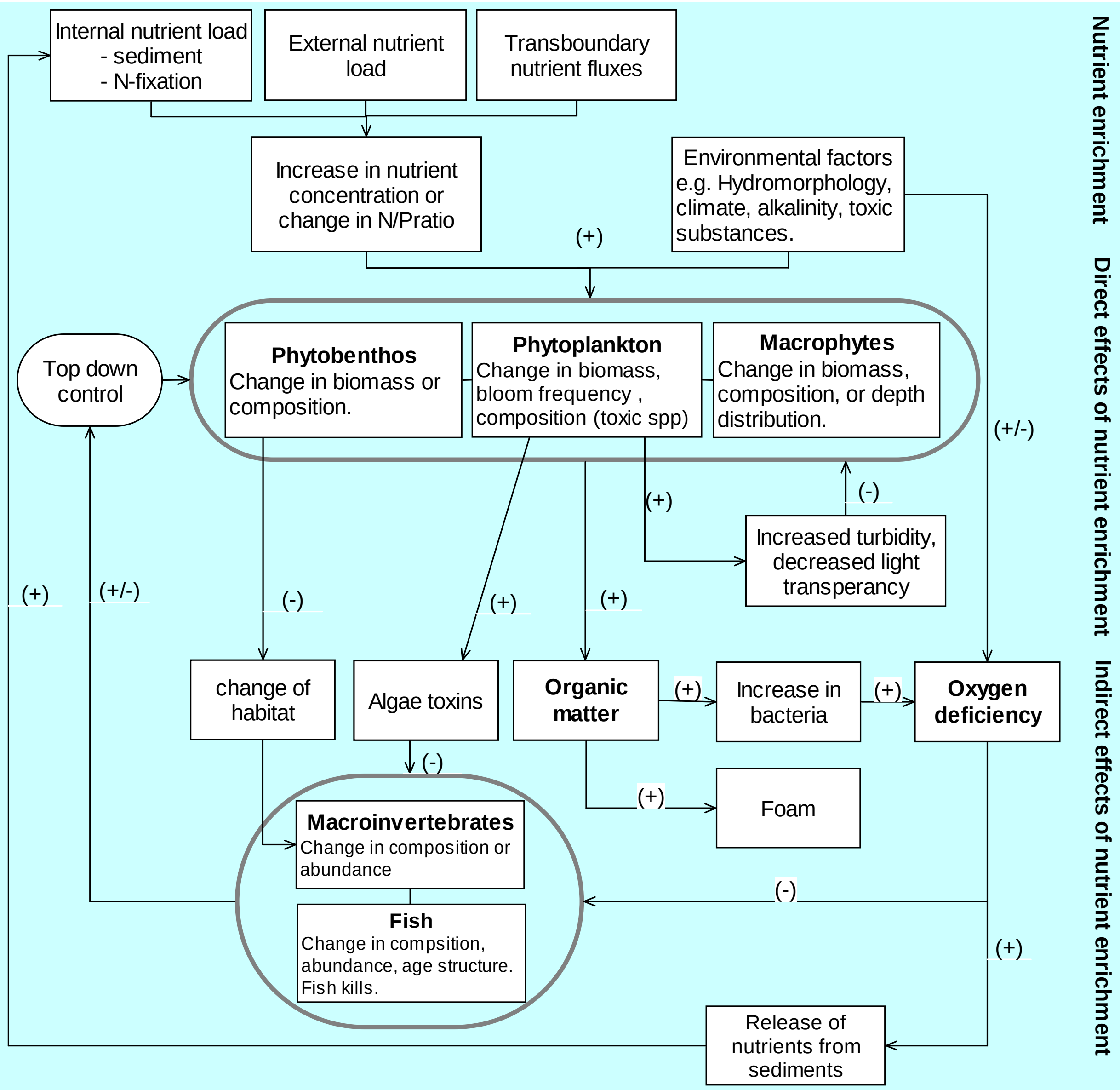
4.3 State of the management / governance system and how it is perceived

As can be seen in section 1.4.3 the downfalls of the Common Fisheries Policy are well documented. However, the reports summarized in section 3 indicate that, despite the imperfections, the majority of NWW stakeholders support the continuation of the CFP after its 2012 reform. Since this reform will incorporate ecosystem based fisheries management, the results of Making the European Fisheries Ecosystem Plan Operational will be timely and relevant.

Appendices

Appendix 1: Conceptual Framework of Eutrophication

Based on OSPAR COMPP modified



Appendix 2: Further reading section

Sources:

- "World Intellectual Property Organization" http://www.wipo.int/patentscope/en/
- Basiron, M.N. (1998) Marine Tourism Industry - trends and prospects
- Belk, R. W., T. Devinney, et al. (2005). "Consumer ethics across cultures." Consumption, Markets and Culture 12(2): 275-289.
- Blancheton JP, 2004. Recirculation systems towards closed systems. Diversification in Aquaculture, European Fisheries and Aquaculture Research organisations (EFARO), Budapest February 2004. EC MUTFISHARE Concerted Action.
- Caswell, J. A. (1998). "How labelling of safety and process attributes affects markets for food." Agricultural and Resource Economics Review(October): 151-158.
- Caswell, J. A. and D. I. Padberg (1992). "Toward a more comprehensive theory of Food labels." American Agricultural economics association 74(2): 460-468.
- Delgado, C.L., N. Wada, M.W.Rosegrant, S. Meijer, M. Ahmed N. Wada, M.W.Rosegrant, S. Meijer, M. Ahmed Outlook for fish to 2020 Meeting Global Demand,; IFPRI – Woldfish center, October 2003.
- European Commission – Eurostat (http://epp.eurostat.ec.europa.eu)
- European Environment Agency (http://themes.eea.europa.eu/)
- FAO (2005a). Ethical issues in fisheries. Rome, FAO.
- FAO, (2005b). Discards in the World's Marine Fisheries: An Update. FAO Fisheries Technical paper 470.
- FAO, (2007) The state of World Fisheries and Aquaculture 2006 , FAO, Rome 2007
- Franz, N. (2005). Overview of Organic Markets. Rome, Globefish: 102.
- Fredheim A, 2004. Offshore fish farming construction- Diversification in Aquaculture, European Fisheries and Aquaculture Research organisations (EFARO), Budapest February 2004. EC MUTFISHARE Concerted Action.
- Harper, G. and Makatouni (2002). "Consumer perception of organic food production and animal welfare." British Foos Journal 104(3-5): 287-299.
- Honkanen, P., B. Verplanken, et al. (2006). "Ethical values and motives driving organic food choice." Journal of Consumer Behaviour(5): 420-430.
- Jennings, S., K.J. Warr, S.P.R. Greenstreet, and A.J.R. Cotter, Spatial and temporal patterns in North Sea fishing effort. In: M.J. Kaiser, and S.B. de Groot (Eds) Effects of fishing on non-target species and habitats. Oxford: Blackwell Science (2000) pp. 3–14.
- Larcombe, P., Morris, D. J., and O'Brien, C. M. (2008). In recognition of inevitable uncertainties: from fisheries management to managing marine resources. In Advances in Marine Science: 50 years on from Beverton and Holt. Ed. by A. Payne, J. Cotter and T. Potter. Blackwell, Oxford
- Nicholls, R. J. (2007). The threat to coastal populations and ecosystems. In Climate change impacts, adaptation and vulnerability. A meeting to present and discuss the results of the Intergovernmental Panel on Climate Change Working Group II, Fourth Assessment, 18/19 September 2007. WMO/UNEP. Available at http://www.rgs.org/NR/rdonlyres/E6426EAE-9895-481B-B97C-CEBA01467AE5/0/IPCCRNicholls18Sept2007.pdf
- Nierentz, J. Overview of Production and Trade – the Role of Aquaculture Fish Supply, FAO GLOBEFISH. Global Trade Conference, May 2007, China.;

- Oliver, R. L. and R. S. Winer (1987). "A framework for the formation and structure of consumer expectations: Review and propositions." Journal of Economic Psychology(8): 469-499.
- The Fifth Edition of the Global Perspectives Subsea Market Update, Infield Energy Analysts, p analysis of the global subsea sector; 2004 through to 2013.
- Toften, K. (2007). Nye krav til miljøvennlig og etisk sjømat: Trusler eller muligheter for norsk sjømatnæring? Tromsø, Fiskeriforskning: 10.
- van Hoof, L. Project coordinator (editor), Payne, A. (editor). Iversen, A., Evrard, M., Pinnegar, J., Tserpes, G., Antoine, L., Cahu, C., Lamblin, V. (2008). The Future of Fisheries and Aquaculture: Trends and Developments, Project Report FEUFAR, available at www.feufar.eu

Appendix 3: Socio-economic variables

G1 Catches measured in physical terms

1) Catch of species j by country k in sea l (background)

$$x_{jkl} \qquad (1)$$

x_{jkl} = catch measured in tonnes of species j by country k in sea l

l – refers to sea, l = (North Sea, NWW, SWW)

The North Sea encompasses the following sea areas: ICES: IIIa, IVa, IVb, IVc, VIId

Northwestern waters (NWW) encompass the following sea areas: ICES: VIa, VIb, VIIa, VIIb, VIIc, VIIe, VIIf, Viig, VIIh, VIIj, VIIk, XII

Southwestern waters (SWW) encompass the following sea areas: VIIIa, VIIIb, VIIIc, VIIId, VIIIe, IXa, IXb, X and CECAF: 1.11, 1.12, 1.13, 1.2, 2.0

k – refers to country

j – refers to species

For each sea 3-4 cases (fisheries) are specified. Some of these cases are single species fisheries, and then the species referred to by j coincides with the case (fishery) Some of the cases are multispecies fisheries, and then the case will consist of all the species j defined as belonging to the specific case (fishery).

North Sea cases: i) Flatfish-beam trawl, ii) Herring-pelagic trawl, iii) Sandeel - trawl,

iv) Whitefish-demersal trawl

NWW cases: i) Nephrops (Lobsters), scallops-dredge, ii) Western Mackerel, Hake, Monk, Megrim - Mixed trawl fish

SWW cases: i) Hake, nephrops, horse mackerel - Mixed demersal trawl, ii) sardines-purse seine, iii) mixed demersal lines, iv) *Nephrops norvegicus* – North Biscay.

2) Total catch of species belonging to case h in sea l by country k (background)

$$X_{hkl} = \sum_{j=j(h(l))} x_{jkl} \qquad (2)$$

Xhkl = total catch measured in tonnes of species belonging to case h in sea l by country k

h(l) – refers to case (fishery) h in sea l, h(North Sea) = (Herring, sandeel, whitefish, flatfish),
h(NWW) = (Nephrops, Scallop, Mixed trawl fish),
h(SWW) = (sardines, mixed demersal trawl fish, mixed demersal line fish)

j(h(l)) – defines all species belonging to case (fishery) h in sea l

In the case of single species fisheries $X_{hkl} = x_{jkl}$

3) Total catch of species belonging to case h in sea l (background)

$$X_{hl} = \sum_{j=j(h(l))} \sum_{k} x_{jkl} \qquad (3)$$

X_{hl} = total catch measured in tonnes of species belonging to case h in sea l (background)

4) The aggregated catch of all species for country k

$$X_k = \sum_{j} \sum_{l} x_{jkl} \qquad (4)$$

X_k – total catch measured in tonnes of all species and in all seas for country k

5) Total catch in sea l

$$X_l = \sum_{j} \sum_{k} x_{jkl} \qquad (5)$$

X_l = total catch in sea l measured in tonnes

6) Relative size of case h in sea l (matrix)

$$r_{h(l)} = \frac{X_{hl}}{X_l} \qquad (6)$$

rh(l) = total catch in case h in sea l relative to total catches in sea l

G2 The economic value of the catches

As there is no continually registration of sea area specific prices, the price indices have to be country specific.

In single species fisheries we only need to take the average over country-specific prices for the countries that (most actively) takes part in the fishery (case). We take a weighted average where the countries relative share of the total catch of the species under consideration serves as weight. In multi species fisheries we have to take the average both over country specific prices per species and over species.

7) Average price of fish caught in single species cases (background)

$$P^S{}_j = \frac{\left(\sum_{k=k(h(l))} P_{jk} * x_{jk}\right)}{X_{jk(h(l))}} \quad (7)$$

k(h(l)) – defines the most active countries taking part in the fishery defined in case h in sea l, e.g. k(herring(North Sea)) = (Denmark, Norway, UK, Netherlands)

Pjk - price on species j in country k

xjk – total catch of species j by country k

Xjk(h(l)) = aggregated catch of species j (the species in case h in sea l) by the most active countries taking part in the fishery defined by case h in sea l

PSj = weighted average price of species j measured in Euro/kg

8) Average price for fish caught in multi species cases (background)

$$P^M{}_h = \frac{\sum_{j=j(h(l))} \sum_{k=k(h(l))} P_{jk} * x_{jk}}{X_{hk(h(l))}} \quad (8)$$

j(h(l)) – defines the main species belonging to case (fishery) h in sea l

Xhk(h(l)) = aggregated catch of species in case h by the most active countries taking part in the fishery defined by case h in sea l

$P^M{}_h$ = weighted average price on species in case h measured in Euro/kg

9) Weighted average price of all species caught by country k

$$\mathrm{P_k} = \frac{\sum_{\mathrm{j}} \mathrm{P_{jk}} * \mathrm{x_{jk}}}{\mathrm{X_k}} \quad (9)$$

Pk(h(l)) = weighted average price of all species caught by country k

X_k – total catch by country k measured in Euro/kg

10) Weighted average price of all species caught by the countries most actively taking part in the fisheries defined by case h in sea l

$$\mathrm{P_l} = \frac{\sum_{\mathrm{j}} \sum_{\mathrm{k=k(h(l))}} \mathrm{P_{jk}} * \mathrm{x_{jk}}}{\mathrm{X_{lk(h(l))}}} \quad (10)$$

Xlk(h(l)) = aggregated catch of all species in sea l by the most active countries taking part in the specified cases (fisheries) in this sea

Pl = weighted average price measured in Euro/kg of all species by the most active countries taking part in the fishery in case h, where case h belong to sea l

11) Value of total catches in sea l

$$V_l = (P_l * X_l) * 1000 \tag{11}$$

Vl = total value of all catches in sea l

12) Value of catches in case h in sea l

$V^S{}_{hl} = (P^S{}_j * X_{hl}) * 1000$ when case h is a single species fishery (12a)

$V^M{}_{hl} = (P^M{}_h * X_{hl}) * 1000$ when case h is a multi species fishery (12b)

Vthl = total value of total catches in case h in sea l, t=S, M

13) Relative size of case h in sea l, when measured in nominal values (matrix)

$Q^S{}_{hl} = \frac{V^S{}_{hl}}{V_l}$ when case h is a single species fishery (13a)

$Q^M{}_{hl} = \frac{V^M{}_{hl}}{V_l}$ when case h is a multi species fishery (13b)

G3 Employment and productivity

As for values of catches, there are no sea-specific data on employment. Data on employment are mainly given on country-level, but within each country employment measured as full time equivalents are given for specific gear and vessel types. Hence, we construct productivity indices, both country specific, encompassing all gear and vessel types, and fishery (case) specific, encompassing the most important gear and vessel types participating in the fishery (case) under consideration.

14) Productivity indicator for gear/vessel type g in country k (background)

$$Z_{gk} = \frac{EMPL^{dir}{}_{gk}}{X_{gk}}$$

(14)

Xgk = total catch for gear/vessels type g in country k

EMPLdirgk = total fleet employment for gear/vessel type g in country k

Zgk = number of full time equivalent employment (FTE) per 1000 tonnes catch for gear/vessel type g in country k

15) Productivity indicator for case h in sea l

$$Z_{lh} = \frac{\sum_{k=k(h(l))} \sum_{g=g(h(l))} EMPL^{dir}{}_{gk}}{\sum_{k=k(h(l))} \sum_{g=g(h(l))} X_{gk}}$$

(15)

g(h(l)) – defines the gear/vessel types that counts for the largest share of total catches in case (fishery) h in sea l

Zlh = weighted average of FTE per 1000 tonnes catch for the (most active) gear/vessel types and countries taking part in fishery (case) h in sea l

16) Productivity indicator for country k

$$Z_k = \frac{\sum_{g} EMPL^{dir}{}_{gk}}{X_k}$$

(16)

Z_k = employment measured in FTE per 1000 tonnes catch for country k

17) Productivity indicator for sea l

$$Z_l = \frac{\sum_{g} \sum_{k=k(h(l))} EMPL^{dir}{}_{gk}}{X_l}$$

(17)

Z_l = weighted average of employment measured in FTE per 1000 tonnes catch in sea l and where the most actively participating countries in the fisheries (cases) in sea l are used as weights

18) Total direct employment in the fisheries in sea l

$$EMPL^{dir}{}_{l} = (Z_l * X_l)/1000$$

(18)

$EMPL^{dir}{}_{l}$ = total direct employment, measured in FTE, in the fisheries in sea l

19) Total direct employment (fleet) in case h in sea l (background)

$$EMPL^{dir}{}_{lh} = (Z_{hl} * X_{hl})/1000$$

(19)

$EMPL^{dir}{}_{hl}$ = direct employment, measured in full time equivalent, in fishery (case) h in sea l

20) relative importance of a fishery according to employment (FTE)

$$s_{hl} = \frac{EMPL^{dir}{}_{hl}}{EMPL^{dir}{}_{l}} \quad (20)$$

s_{hl} = direct employment in fishery (case) h in sea l relative to total direct employment in all fisheries in sea l

For each country participating in the fishery (case) the vessel/gear types catching the major share of total catches for that fishery are included

21) Total indirect employment in the selected sea areas

$$EMPL^{ind}{}_{l} = \sum_{kr=kr(l)} PRO_{krl} \quad (21)$$

PRO_{krl} = number of persons working in fish processing in country-region kr (NUTS-2 level) bordering sea l

$kr(l)$ – refers to country-region kr bordering to sea l

Fuel consumption and fuel costs

22) Fuel indicator for gear/vessel type g in country k (background)

$$F_{gk} = \frac{FCosts_{gk}}{X_{gk}} \quad (22)$$

X_{gk} = total catch for gear/vessels type g in country k

$FCosts_{gk}$ = total fuel costs for gear/vessel type g in country k

F_{gk} = fuel costs per 1000 tonnes catch for gear/vessel type g in country k

23) Fuel indicator for case h in sea l

$$F_{lh} = \frac{\sum_{k=k(h(l))} \sum_{g=g(h(l))} FCosts_{gk}}{\sum_{k=k(h(l))} \sum_{g=g(h(l))} X_{gk}} \quad (23)$$

g(h(l)) – defines the gear/vessel types that counts for the largest share of total catches in case (fishery) h in sea l

Flh = weighted average of fuel costs per 1000 tonnes catch for the (most active) gear/vessel types and countries taking part in fishery (case) h in sea l

24) Fuel indicator for country k

$$F_k = \frac{\sum_g FCosts_{gk}}{X_k}$$

(24)

Zk = employment measured in FTE per 1000 tonnes catch for country k

25) Productivity indicator for sea l

$$F_l = \frac{\sum_g \sum_{k=k(h(l))} FCosts_{gk}}{X_l}$$

(25)

Fl = weighted average of fuel costs measured as million Euros fuel costs per 1000 tonnes catch in sea l and where the most actively participating countries in the fisheries (cases) in sea l are used as weights

26) Total fuel costs in the fisheries in sea l

$$FCosts_l = (F_l * X_l)/1000$$

(26)

$FCosts_l$ = total fuel costs, measured in million Euros, in the fisheries in sea l

27) Total fuel costs in case h in sea l (background)

$$FCosts_{lh} = (F_{hl} * X_{hl})/1000$$

(27)

$FCosts_{lh}$= direct employment, measured in full time equivalent, in fishery (case) h in sea l

28) relative importance of a fishery according to employment (FTE)

$$f_{hl} = \frac{FCosts_{hl}}{FCosts_l}$$

(28)

f_{hl} = direct employment in fishery (case) h in sea l relative to total direct employment in all fisheries in sea l

For each country participating in the fishery (case) the vessel/gear types catching the major share of total catches for that fishery are included

Variables

The main idea behind the selected variables is to give a picture of the relative importance of each of the selected fisheries (cases) in the three sea areas. Because there is a difference between the biological and the economic aspects of the fisheries, we choose to show the relative importance of each fishery measured in quantities (tonnes), nominal values and employment. In order to avoid giving a non-representative image of the relative importance of the selected fisheries, data should be given for three subsequent years. This at least reduces the probability for showing a-typical situations with regard to the fisheries in the three sea areas.

Seen from a local community point of view the fishing activity may have spill over effects to other sectors. When this is the case the importance of a fishery to the local community is larger than just the size of the fishery activities, and a reduction in the fishery activity may have effects on the local community which are far more comprehensive than is predicted. An important concept here is threshold levels, which points to the fact that when the fishing activity drops below a (lower) level many other related activities will loose their justification or economic foundation. We do not take such circumstances into consideration.

Data

The basic data sources for the selected variables are ICES Fishery data base and Annual Economic Report (AER) from DG Mare. ICES data base provides numbers on catches divided on country, fishing area and species. These are sufficient to calculate the variables 1-3.

The annual report from DG Mare provides a selection of nominal measures, including income (value of landings), gross value added, and also data on employment and number of vessels taking part in the specific fisheries. However, these data are not distributed on species, but rather on type of fleet. They are presented for each MS, but not on a sea area level, such as North Sea, NWW or SWW.

Finally, when it comes to a more comprehensive overview of the fishery employment the only existing source (on EU level or above) is the report “Employment in the fisheries sector: current situation” (FISH/2004/04), which is funded by the European Commission. Unfortunately, this is not a report that is processed on a regular basis, and thus we have data only for 2002-2003 on indirect employment.

AER presents data based on national statistics, which have been collected through samples, surveys and estimations. Hence, these data may give a more uncertain picture of the actual situation than does the ICES database.

Acknowledgments

We are grateful to AQUAFACT International Services Ltd., Galway, Ireland for undertaking research work to source material for the NWW Technical Report on behalf of the Marine Institute. We have incorporated most of the material from their report into this report and the accompanying atlas.

Much of the material used in this report is sourced from published material from the International Council for the Exploration of the Seas (ICES) and the Oslo Paris Commission (OSPAR). We acknowledge this input as the work of an extensive scientific community.