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

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

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SUMMARY

It is recognised that much of the information and knowledge currently available to develop an ecosystem approach to fisheries management in Europe is not being used effectively as it is so widely dispersed (Connolly and Rice, 2005). The aim of this Work Package was to integrate the existing knowledge on ecological and socio-economical issues in the North Sea region.

Chapter one gives an overview of this knowledge, starting with a description of the physical and chemical features of the North Sea that form the conditions within which the biological features have evolved and now depend. The biological features are described, from benthic and algal communities to the fish communities, marine mammals and sea birds. The first section of this chapter also provides a description of Good Environmental Status (GES) and the process of determining and managing GES. The second section considers the human activities occurring and impacting on the North Sea environment, including an overview of existing activities and potential future activities. The final section of chapter one provides a description of the socio-economic environment. This section focuses on fisheries management at an European scale, but with specific attention for North Sea issues. It provides an overview of the institutional setup underlying the governance system of the Common Fisheries Policy (CFP) of the European Union. The position and jurisdiction of the Commission, Scientific, Technical and Economic Committee for Fisheries (STECF), Regional Advisory Councils (RACS) and the European parliament are also described. Reform of the current CFP framework is also discussed in the light of on-going criticism that it is not able to ensure efficient and uniform control and enforcement of its legislation. In response to this criticism, 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. Existing and potential fisheries management tools are also described. These tools can be divided into three overarching groups; input (e.g. area and time restrictions) and output (e.g. TACs and discard regulations) management, as well as economic incentive mechanisms (e.g. Individual Tradable Quotas and subsidies). Finally, there is an overview of the socio-economic considerations of European fisheries and fishing dependent communities.

Chapter two focuses on four fisheries cases studies in the North Sea, chosen based on their importance in the area, their likely impact on the environment and data availability. The first case study is the mixed flatfish beam trawl, a Dutch dominated fishery in the southern North Sea mainly targeting valuable flatfish species as sole (*Solea vulgaris*) and plaice *(Pleuronectes platessa)*. This fishery is heavily debated due to the high impact of the heavy beams used on habitat structure. The second case study is the sandeel industrial fishery, which is controlled by the Danish and Norwegians and it is the largest single species fishery in the North Sea. This fishery is under pressure due to the low standing stock of the North Sea sandeel. The third case study is the herring pelagic fisheries, which is possibly one of the best managed fisheries in which a number of the actors active in this fishery have received the Marine Stewardship Council (MSC) label. The final case study is the mixed demersal whitefish trawl fishery predominantly active in the Northern North Sea which targets demersal roundfish species including cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*). Following the description of these fisheries case studies, this chapter attempts to combine the impacts of the case study fisheries, with the effect of socio-economic component, on an extended list of ecological components (e.g. habitats, the food web, all individual components of the food web etc.) in a pressure matrix, termed the Social and Ecological Component by Pressure Matrix (SECPM). The SECPM provides an overview of the interactions between the fishery and various component of the fishery system, ecological and socio-economic. The matrices by case study were followed by and extensive description of the impact on the specific Ecological components, which is supporting evidence for the inclusion of the interaction in the SECPM.

Chapter two also identifies the problem of synergistic effects of the fisheries cases studies with other human activities and drivers (e.g. climate) and demonstrates that studies which consider the impact of specific activities in isolation may underestimate their system-level effects. Even though climate control is beyond the scope of North Sea management, it effects need to be considered in assessment and management of human activities and impacts within the region. Finally, this chapter describes two models for calculating the effect of the fisheries cases on the mortality of benthic and fish communities. These models are available for further use within the MEFEPO project.

The aim of Chapter 3 was to identify and collate data from national and international marine consultative initiatives. However, it became clear that previous stakeholder consultations and responses have revealed very little information that could be used in a forward-looking manner to support the MEFEPO project in the development of operational objectives and identification of operational challenges to introducing an ecosystem approach. This is because the present governance framework at both national and international level is very dynamic, and consultative processes are undergoing rapid changes, and the introduction of the Regional Advisory Councils (RACs) has set a new standard for stakeholder consultation. There is limited information on the performance of this type of stakeholder consultation, therefore details of this important vehicle for stakeholder consultation in the EU cannot be incorporated at this stage. However, this work is planned for the next work packages of the MEFEPO project.

1 Overview of the North Sea

The boundaries of the North Sea have been delineated by a number of organisations (including OSPAR and ICES) for management purposes. MEFEPO will use the North Sea boundaries as delineated by the North Sea Regional Advisory Council (NS RAC) (Figure 1.1) as this spatial unit is used to present socio-economic information on the fishing industry to the European Union.
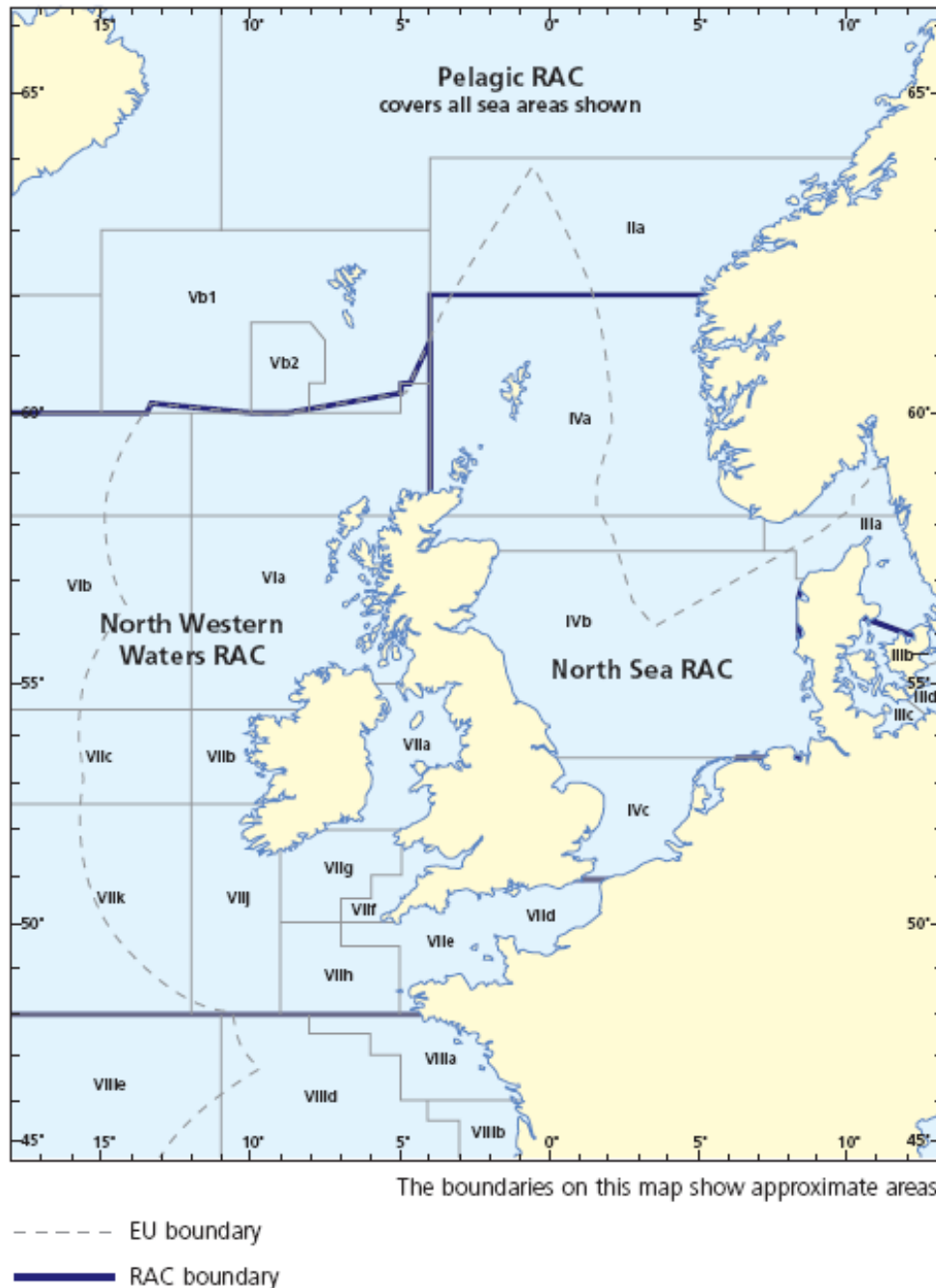
Figure 1.1 The boundary of the North Sea RAC (Defra, 2006)

1.1 Ecological environment

The North Sea is a semi-enclosed, temperate, shelf sea which covers an area of 750,000 km^2 with a volume of 94,000 km^3 (Ducrotoy et al., 2000). It is surrounded by the British Isles, the Scandinavian Peninsula, and the mainland of north-western Europe. The physicochemical environment of the North Sea is dependent on a number of interlinked variables including depth, temperature, salinity and freshwater input.

1.1.1 Physical and Chemical Features

1.1.1.1 Topography and bathymetry of the seabed

The topography of the North Sea can be broadly described as having a shallow (<50m) south-eastern part, which is separated by the Doggerbank from a deeper (50–100m) central part that runs north along the British coast (Figure 1.1.1). The central northern part of the shelf gradually slopes down to 200m before reaching the shelf edge. The deepest part of the North Sea is to the north in the Norwegian Trench which runs to the east along the Norwegian coast into the Skagerrak with depths exceeding 700m (Winther and Johannessen, 2006). Further to the east, the Norwegian Trench ends abruptly in the Kattegat which has a depth profile more shallow and similar to the main part of the North Sea (Figure 1.1.1).

The bathymetry of the North Sea strongly influences the circulation of water as it affects the stratification of water and the extent to which wind mixing occurs (Winther and Johannessen, 2006) (discussed in detail in Section 1.1.1.2.2.).
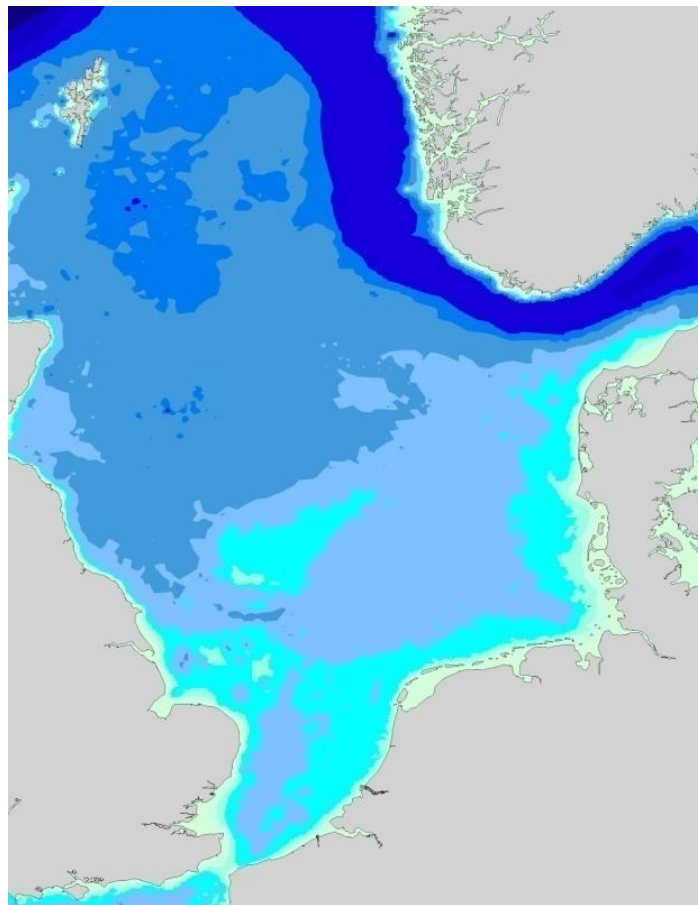
Figure 1.1.1 Bathymetry of the North Sea (shallow areas, pale blue; deepest areas, dark blue)

1.1.1.2 Annual and seasonal temperature regime

The surface temperatures of the North Sea follow a strong annual cycle (Figure 1.1.2). However, spatial variations do occur (Table 1.1.1). These variations are related to depth and whether stratification occurs, but also other factors such as exposure to oceanic influences, the input of freshwater from the Baltic Sea and riverine inputs from the major European rivers such as the Rhine and the Thames (Becker and Pauly, 1996). Towards the south east, there is a greater amplitude in temperature variation as the area is largely coastal with low salinities and reduced depths (OSPAR, 2000).

Figure 1.1.2. Monthly mean sea surface temperature for January–December 2008 (BSH, 2008).
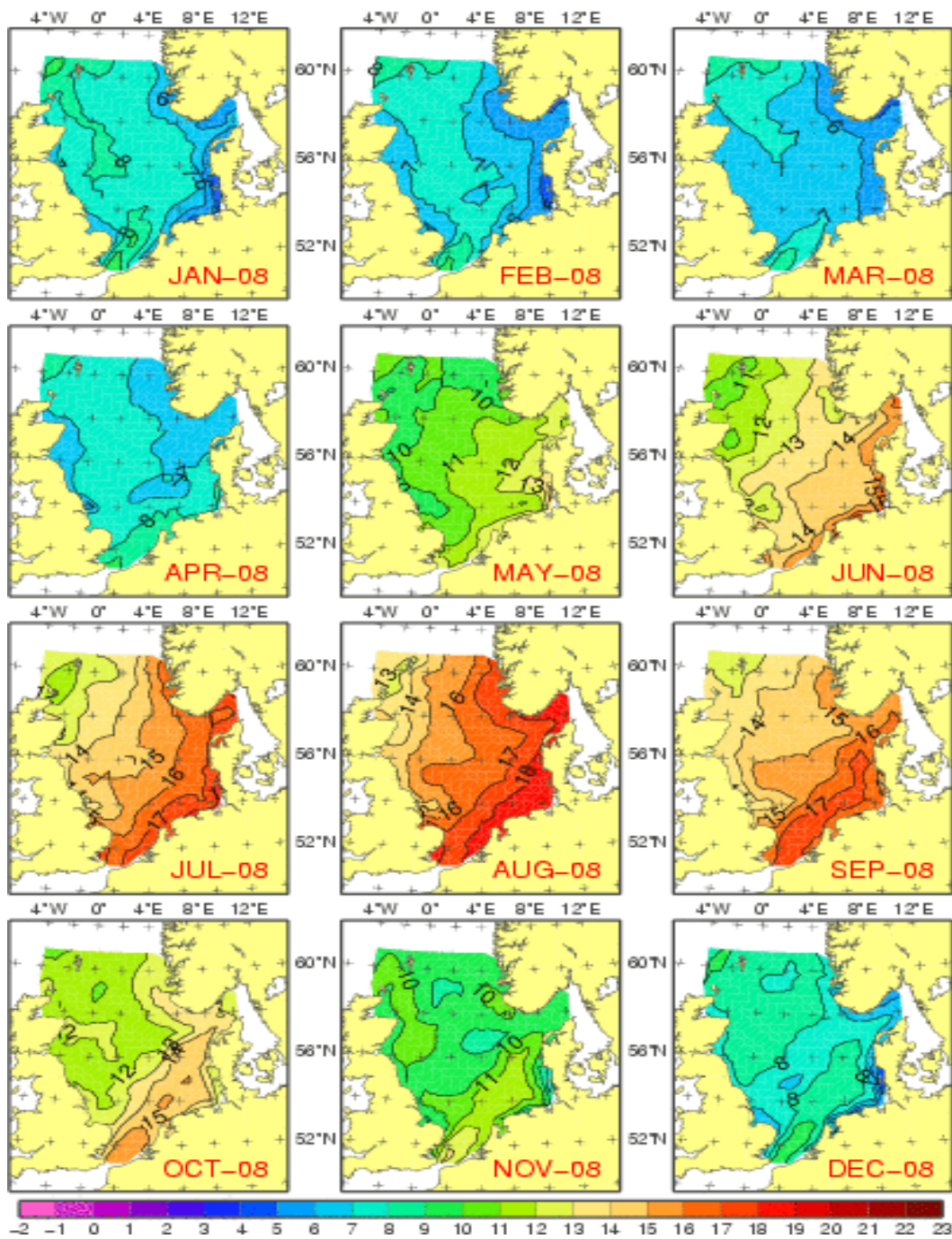
Table 1.1.1. Temperature ranges in North Sea waters (OSPAR, 2000).

Water mass	Temperature (°C)
Atlantic water	7-15
Atlantic water (deep)	5.5-7.5
Channel water	6 - 18
Baltic water	0 - 20
Northern North Sea water	6 - 16
Central North Sea water	5 - 10
Southern North Sea water	4 - 14
Scottish coastal water	5 - 15
Continental coastal water	0 - 20
Norwegian coastal water	3 - 18
Skagerrak water	3 - 17
Skagerrak coastal water	0 - 20
Kattegat surface water	0 - 20
Kattegat deep water	4 - 15

The long-term variability in the surface temperature of the North Sea is closely correlated with the nature of the atmospheric circulation of the North Atlantic (OSPAR, 2000) and the North Atlantic Oscillation Index (NAOI). Long-term changes in the temperature of the North Sea have been observed over the past 4 decades. Between 1969 and 1993, the lowest observed temperatures in the northern Atlantic inflow decreased by approximately 1°C. Conversely, the highest temperatures in the northern Atlantic inflow increased by approximately 1°C, and by approximately 2°C in the North Sea (OSPAR, 2000).

Overall, a high degree of annual, inter-annual and decadal scale changes have been observed in both temperature and salinity. The mildest winters in the 50, perhaps even 130, years prior to 1996 were observed between 1989-1994 (Becker and Pauly, 1996), whilst the winters of 1942 and between 1977-1979 were the coldest in the second half of the twentieth century (Ducrotoy et al., 2000). North Sea winter bottom temperature has increased by 1.6 °C over 25 years (since 1979), with a 1°C increase in 1988–1989 alone (Dulvy et al., 2008).

The Helgoland Roads standard station demonstrates that, since the cold winter of 1996, sea surface temperature has been above the 30-year mean (1971–2000), with positive anomalies of 0.5–1.0 °C. In 2006, March and April revealed negative anomalies up to −1 °C, but positive anomalies exceeded 1 °C continuously from June to December, with maximum anomalies of 2.7 °C in October and 2.3 °C in December. The warm conditions in the North Sea that had lasted since summer 2006, continued in the second quarter of 2007. The temperature anomalies in the first quarter were positive by 0–1 °C in the northern North Sea and by 2–4 °C in the south-eastern part. These high positive anomalies persisted in April but were somewhat reduced to 1–2 °C in the south-eastern area in June (ICES, 2008b). Spatial variation in the temperature between the northern and southern North Sea and the German Bight is shown in Figure 1.1.3.
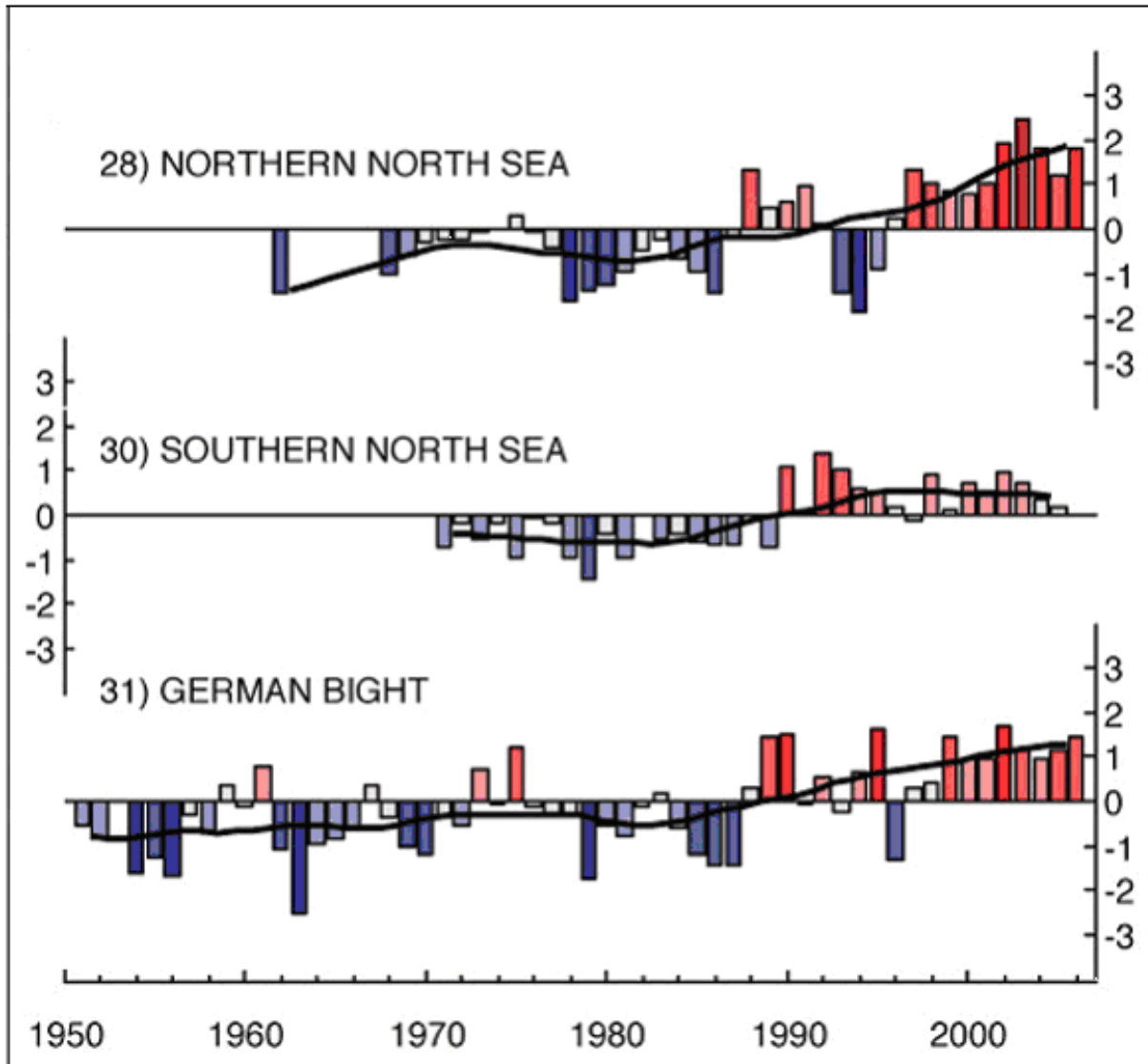
Figure 1.1.3. Temperature anomalies, normalized in relation to the standard deviation (e.g. a value of +2 indicates 2 standard deviations above normal) (Tasker (Ed.), 2008).

1.1.1.2.1 Water exchange

The North Sea is connected to the open seas in three areas. The main connection is through the wide northern boundary to the North Atlantic, but exchanges also occur through the narrow Dover Strait to the English Channel, and via the Fair Isle Current through the Shetland and Orkney Isles. The inflow of water through the northern boundary of the North Sea is estimated to be 1,300,000 m^3 s^{-1}, through the Dover Straits at 150,000 m^3 s^{-1} and between the Shetland and Orkney Isles at 300,000 m^3 s^{-1} (The Marine Forum, 1990).

The main input of water to the North Sea is the North Atlantic Current which enters from the north and runs close to the Norwegian coast. The pathways of the North Atlantic Current are very important as they are one of the key factors affecting the climate of the area bringing warm subtropical waters further north than any other current of the Northern Hemisphere. This keeps the Norwegian Sea and parts of the Barents Sea free from ice (Withers and Johannessen, 2006).

1.1.1.2.2 Circulation

The currents of the North Sea tend to form a counter-clockwise cyclonic circulation pattern (Figure 1.1.4.), as waters which enter from the north are transported to the western coast, whilst waters which enter through the Channel move up the Dutch/Belgian coast (Turrell, 1992). The majority of waters eventually leave the North Sea through the Skagerrak via the Norwegian Coastal Current.
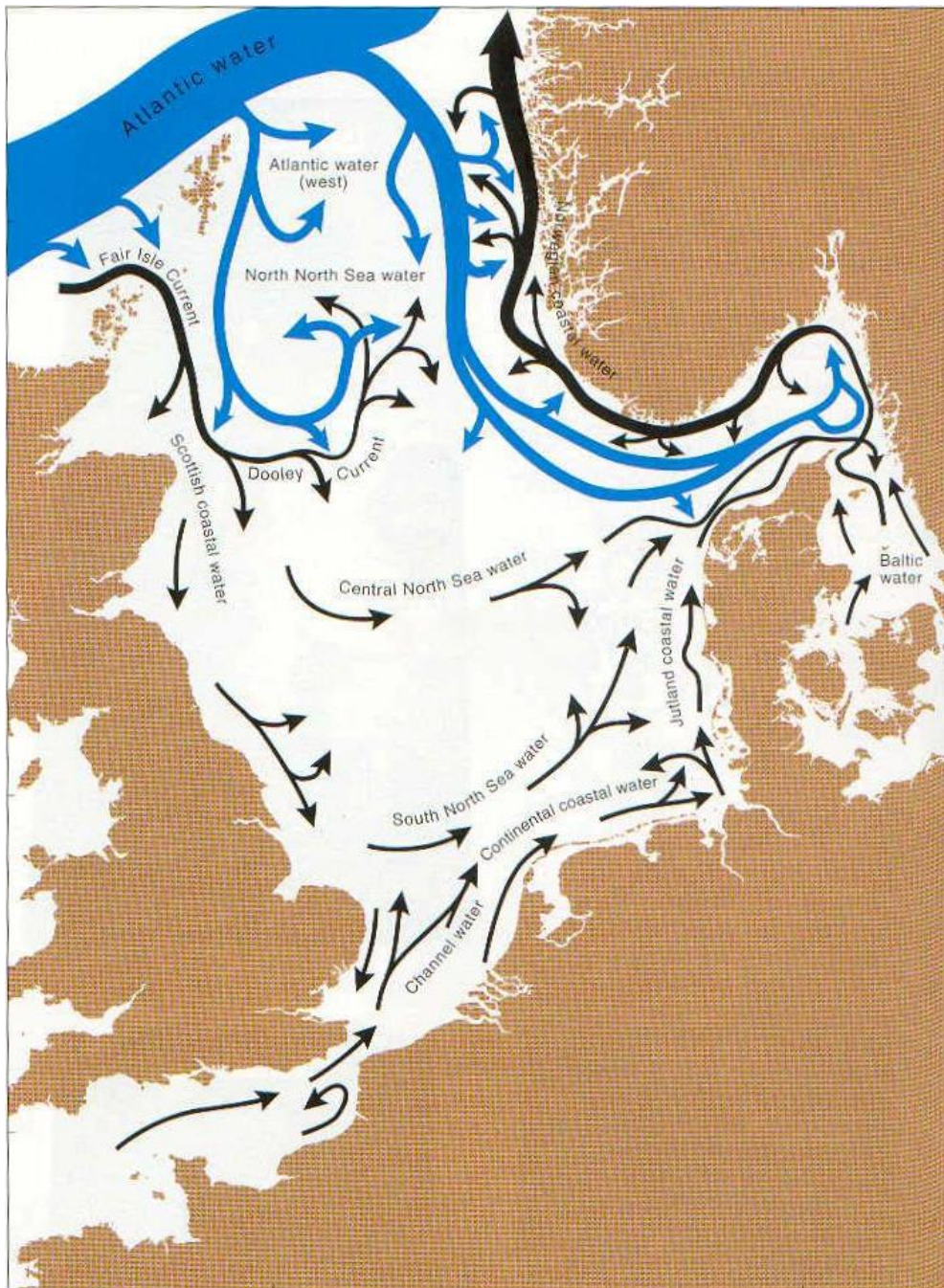
Figure 1.1.4. Schematic diagram of water circulation in the North Sea. The width of the arrows indicates the magnitude of volume transport, blue arrows indicate the flow of Atlantic water and black arrows indicate the flow of other water types (Turrell, 1992;OSPAR, 2000). Tidal currents are strong in the southern North Sea, especially the coastal regions (ICES, 2008e).

The bottom topography and the land surrounding the North Sea are important drivers of water circulation and also influence the vertical mixing of the water column (NSTF, 1993). Stratification of the water column during the summer months, which decouples the upper layer of the water column from the lower layer, result in different circulation patterns as the lower layer is more strongly influenced by the topography of the seabed (Angel, 1990). The NORWECOM (NORWegian ECOlogical Model system) model of mean currents suggests that significant differences in circulation occur between years (Delhez et al., 2004). For example, there was tendency for water to outflow via the Channel in 1980, with relatively weak inflows from the north, whilst in 1990, there were unusually large inflows of Atlantic water into the North Sea.

Circulation in the North Sea is presented as an anti-clockwise gyre driven mainly by wind forcing. However, observations indicate that the pattern may be reversed temporally as a result of wind forcing, or split into two separate gyres in the north and south; water circulation may even cease for limited times (Kauker and von Storch, 2000).

The main inflow consists of relatively warm (at least during winter) and more saline North Atlantic water along the shelf break into the Norwegian Trench and also around the Shetland and Orkney Islands. Changes in zooplankton and fish distributions have been linked to the strength of these inflows (Corten and van de Kamp, 1996; Corten and Lindley, 2003). Atlantic water also enters into the southern North Sea via the Channel (Hughes and Lavín, 2005). The Kattegat and eastern Skagerrak are strongly influenced by brackish surface water entering from the Baltic. However, the bottom water layer is of oceanic origin and runs below the brackish water layer in the opposite direction. There are a number of frontal systems (e.g. Fair Isle, Flamborough, Frisian front and Skagerrak) but they vary considerably in time and space depending on wind forcing, current strength and the physical properties of the different water masses.

Long term changes in the North Sea ecosystem appear to be driven by two processes. Climatic fluctuations are the most influential environmental factor in the northern, western and central areas of the North Sea, as primary production and the timing of the spring bloom are dependent upon the stratification of the water column. Anthropogenic nutrient inputs are more influential than climatic variations in the southern and eastern areas of the North Sea where there is little or no stratification of the water column (Dickson et al., 1988; Clark and Frid, 2001).

1.1.1.2.3 Residence time

The mean flushing time for the North Sea is estimated to be twelve months (Otto et al., 1990).In the deeper areas of the Skagerrak, the water has a longer residence time of an estimated 2-3 years (The Marine Forum, 1990). However, it is possible that it could be renewed rapidly due to inflow of the dense waters which form during winter over the more shallow areas west of the trench (Ljøen, 1981).

1.1.2 Spatial and temporal distribution of salinity

Water salinity is not uniform across the North Sea (Table 1.1.2.). Seasonal changes in the salinity of open areas of the North Sea are small (32 - 34.5ppt) (Figure 1.1.5.), although annual changes in surface salinity have been recorded (Ducrotoy et al., 2000). The annual variation in salinity results from changes to the North Atlantic current system, changes to the input of freshwater and the intensity of vertical wind mixing (OSPAR, 2000). The pronounced spatial variation in the salinity of the southern North Sea and the weak average seasonal cycle are determined by variations in freshwater run-off and the inflow of Atlantic water (Ducrotoy et al., 2000).

The salinity of water in coastal areas is generally lower than in open areas due to the greater effects of river inflow. Also, there are likely to be greater variations in the salinity of coastal areas as their relatively shallow depth means they are more likely to be influenced by precipitation and evaporation (Prandle et al., 1997).

Relatively high salinities were observed in the North Sea in the 1920s, at the end of the 1960s, and from 1985-95. Whereas, in the late 1970s, and for most of the 1980s, the salinity of the North Sea was relatively low (OSPAR). Predicting trends in salinity variation is difficult (Laane et al., 1996).

Table 1.1.2. The salinity (ppt) of water in the North Sea (OSPAR, 2000).

Water mass	Salinity
Atlantic water	>35.0
Atlantic water (deep)	>35.0
Channel water	>35.0
Baltic water	8.5 – 10.0
Northern North Sea water	34.9 - 35.3
Central North Sea water	34.8 - 35.0
Southern North Sea water	34.0 - 34.8
Scottish coastal water	33.0 - 34.5
Continental coastal water	31.0 – 34.0
Norwegian coastal water	32.0 - 34.5
Skagerrak water	32.0 – 35.0
Skagerrak Coastal water	25.0 – 32.0
Kattegat surface water	15.0 - 25.0
Kattegat deep water	32.0 - 35.0
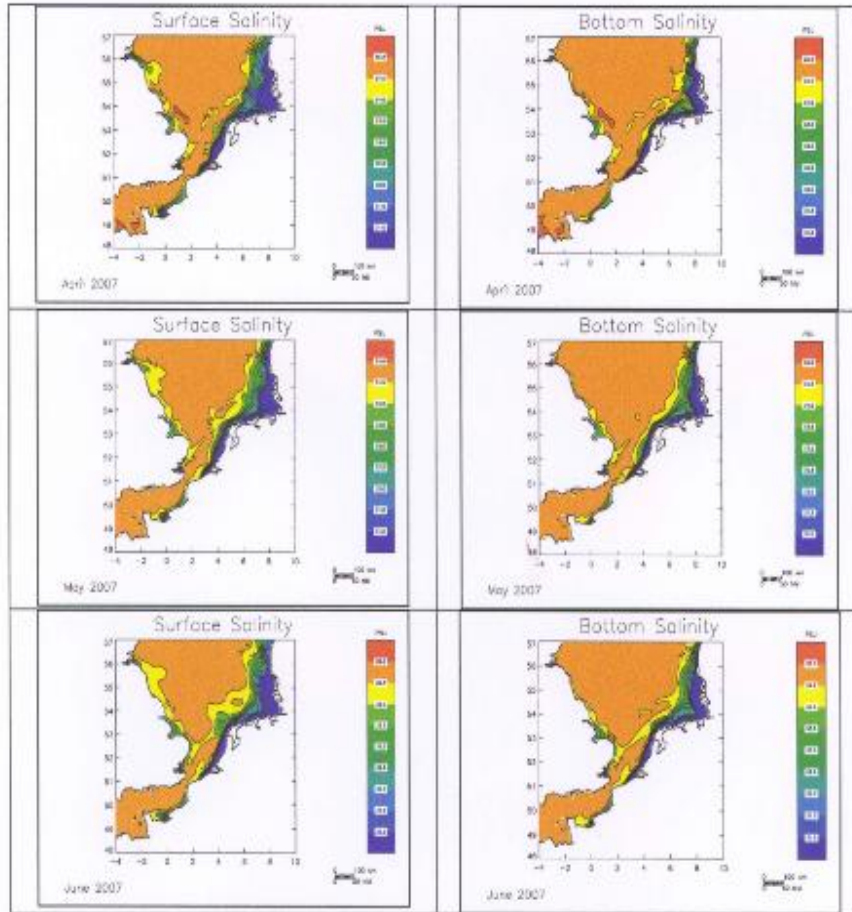
Figure 1.1.5. Monthly average surface and bottom salinity computed with the Optos_nos model in April, May and June 2007 (MUMM Belgium in NORSEPP, 2007).

1.1.3 Spatial and temporal distribution of nutrients

Primary production in the marine environment is determined by the level of dissolved and particulate forms of nitrogen, phosphorus and silicon in the benthic and pelagic system. In the North Sea, nutrient concentrations have a strong seasonal cycle (Prandle et al., 1997). Concentrations peak in December-January, and decline rapidly with the onset of the primary production during the spring bloom, until June-July when the nutrients become limiting and cause a decline in phytoplankton production (Prandle et al., 1997).

The typical concentration of nutrients entering the North Sea from the north in the winter are 12μmol/l nitrate, 0.8μmol/l inorganic phosphate and 6μmol/l silicate (NSTF, 1993). However, inputs of nutrients from adjacent seas into the Greater North Sea are difficult to assess as there is high variability in the annual fluxes due to the changes in the transport of water resulting from changes in the NAOI (OSPAR, 1998, 2000; Reid et al., 2001).

Major nutrient inputs enter the North Sea through rivers and account for between 65-80% of the total nitrogen and 80-85% of the total phosphorus input into the North Sea (Table 1.1.3) (OSPAR, 2000). However, estuarine processes affect the nutrient concentrations and care should be taken in interpreting these values in terms of net inputs.

Table 1.1.3 Summary of direct and riverine inputs to the Greater North Sea in 1996 (OSPAR, 1998).

North Sea Area		Kattegat		Skagerrak		North sea (main body)		Channel	
		lower estimate	upper estimate	lower estimate	upper estimate	lower estimate	upper estimate	lower estimate	upper estimate
Cd	(t)			3.1	3.2	19.0	33.0	2.4	2.4
Hg	(t)			0.1	0.1	7.2	8.4	0.5	0.5
Cu	(t)	23.0	23.0	104.0	104.0	778.0	812.0	151.0	151.0
Pb	(t)	7.0	7.0	26.0	26.0	686.0	733.0	81.0	81.0
Zn	(t)	70.0	704.0	511.0	511.0	4554.0	4679.0	475.0	475.0
y-HCH	(kg)			34.0	34.0	690.0	735.0	135.0	143.0
PCBs*	(kg)			0.0	10.0	285.0	959.0	95.0	97.0
NH_4-N	(10^3 t)			6.5	6.5	75.0	78.0	21.0	21.0
No_3-N	(10^3 t)	26.0	26.0	18.0	18.0	499.0	505.0	87.0	87.0
Po_4-P	(10^3 t)			0.3	0.3	30.0	32.0	20.0	20.0
Total N	(10^3 t)	41.0	41.0	37.0	37.0	729.0	741.0	109.0	109.0
Total P	(10^3 t)	1.0	1.0	1.0	1.0	53.0	54.0	10.0	10.0
SPM	(10^3 t)			272.0	272.0	8376.0	8523.0	550.0	550.0

ΣPCBs (sum of IUPAC Nos 28, 52, 101, 118, 153, 138, 180).

Riverine input is the load conveyed by a river to the point of entry into the marine area. This is usually a point of unidirectional freshwater flow immediately upstream of any tidal influence. Direct input is any aquatic input to a river or estuary downstream of the riverine monitoring point or directly into coastal waters. Direct inputs into the Greater North Sea decreased for nitrogen and phosphorus between 1990 and 1996, while the river inputs increased for nitrogen and phosphorus until 1995 (OSPAR, 2000). The pattern of riverine input varies as it follows the pattern of water flow. Overall, a general downward trend of phosphorus and nitrogen inputs in the region has been observed (NSTF, 1993; Bakker et al., 1999). Other studies have

observed a general increase in the level of nutrient inputs, from rivers, run-off and the atmosphere into the North Sea in recent years (Ducrotoy et al., 2000).

Silicate input has remained constant in recent decades and is often the first limiting nutrient of the spring bloom (NSTF, 1993). This promotes the growth of phytoplankton that are not limited by silicate such as *Phaeocystis* sp.. Marine phytoplankton require nitrogen and phosphorus in a 16:1 ratio, so nitrogen tends to be the limiting nutrient in contrast to freshwater systems where phosphorus is most commonly limiting (Nybakken, 1993). When there is a surplus of nitrates, phosphorus may become limiting (NSTF, 1993).

Anthropogenic input of nutrients may cause eutrophication and its associated adverse biological effects. The heaviest impacts are reported in estuaries and fjords, the Wadden Sea, the German Bight, Kattegat and eastern Skagerrak (Richardson and Heilmann, 1995; OSPAR, 2000). In turbid areas such as estuaries, the turbidity may restrict photosynthesis and maintain a hyper-nutrified system because the algae cannot utilise the nutrients, whilst in less turbid areas, eutrophication may occur (Salomons et al., 1989).

Analyses of the sources of dissolved inorganic nitrogen (DIN) in the southern North Sea during winter indicate that the principle source of dissolved nitrate is from recycled dissolved organic nitrogen (DON) already in the system, rather than new inputs of nitrate (Hydes et al. 1999). Fifteen consecutive monthly surveys of the southern North Sea determined that oceanic and riverine inputs of phosphate, nitrate and silicate were insufficient to support the observed seasonal variability and postulated that the seasonal cycle is maintained by internal recycling (Prandle et al., 1997). Therefore, the high productivity of the North Sea is most likely maintained by both the total amount of nutrients that are supplied to the system and the high degree of recycling.

The North Sea has a large freshwater input from several major rivers including the Rhine and the Elbe. The total riverine input to the North Sea is around 300 km^3 year^{-1} from a heavily populated and industrialised catchment area of approximately 850,000 km^2 (Ducrotoy et al., 2000; OSPAR, 2000) (Table 1.1.4.). Additionally, the rate of excess of precipitation over evaporation was estimated to be 3000 m^3 s^{-1} (The Marine Forum, 1990). The total input of freshwater entering the southern North Sea was estimated at approximately 190 km^3 yr^{-1} which was dominated by the Rhine (Anonymous, 1983).

Table 1.1.4 Freshwater inputs to the North Sea (Ducrotoy et al., 2000).

Area	Run-off (km^3 yr^{-1})	Catchment area (km^2)
Scotland (including the Forth)	16	41 000
Norway	58-70	45 000
Skagerrak and Kattegat	58-70	102 200
East coast of England (including Tyne, Tees, Humber and Thames)	32	74 500
Denmark and Germany (including the Wadden Sea)	32	219 900
The Netherlands and Belgium (including Wadden Sea, Rhine, Meuse and Scheldt)	91-97	221 400
English Channel (including Seine)	9-37	137 000
Total North Sea	296-354	841 500

1.1.4   pH, pCO2 profiles

Atmospheric levels of carbon dioxide (CO_2) have increased with the industrialisation of human activities. Activities such as the burning of fossil fuels and deforestation have led to the prediction that levels of CO_2 will increase to between 700-1000 ppm by the end of the century. This compares to pre-industrial levels of 280 ppm and current levels of approximately 380 ppm (Blackford and Gilbert, 2007).

The effect of the increase in CO_2 on global ecology is difficult to predict, partly due to a lack of knowledge of the processes which are likely to be affected, but also due to the fact that the North East Atlantic is estimated to have absorbed 23% of the global anthropogenic carbon inventory despite only covering 15% of the global ocean area (Sabine et al., 2004).

The relatively high concentrations of anthropogenic CO_2 within the North Atlantic are due to the relatively high level of biological activity in the basin (Schuster et al., 2009). The uptake of CO_2 by sea water leads to a decrease in pH (Figures 1.1.6 and 1.1.7). Changes in ocean chemistry can have extensive direct and indirect effects on organisms and the habitats in which they live. One of the most important consequences of increasing ocean acidity relates to the production of shells and plates out of calcium carbonate. This calcification process will most likely be reduced at lower pH, limiting the formation of shells and plates.
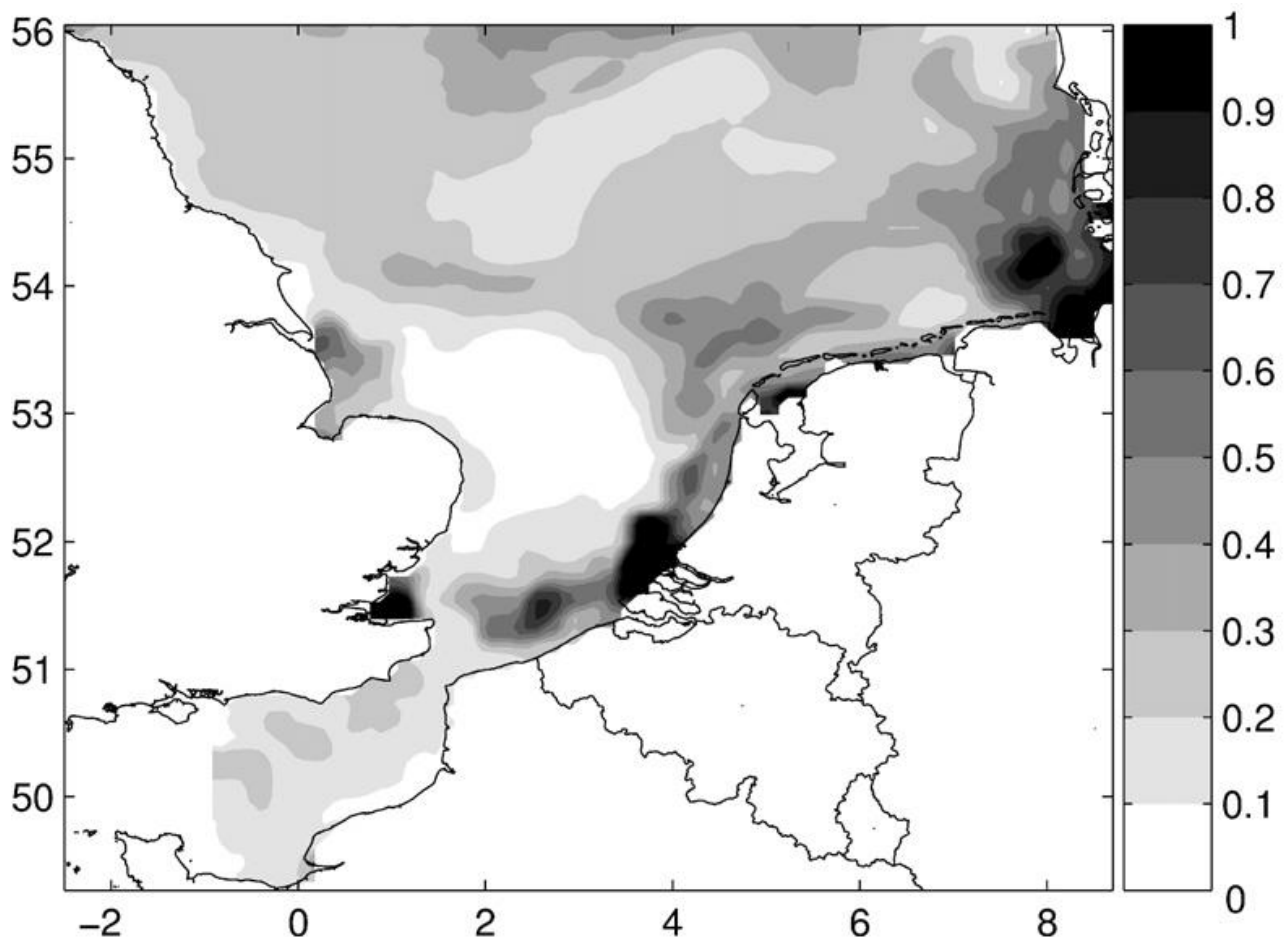
Figure 1.1.6 Map of the modelled annual pH range simulated across the southern North Sea domain (Blackford and Gilbert, 2007)
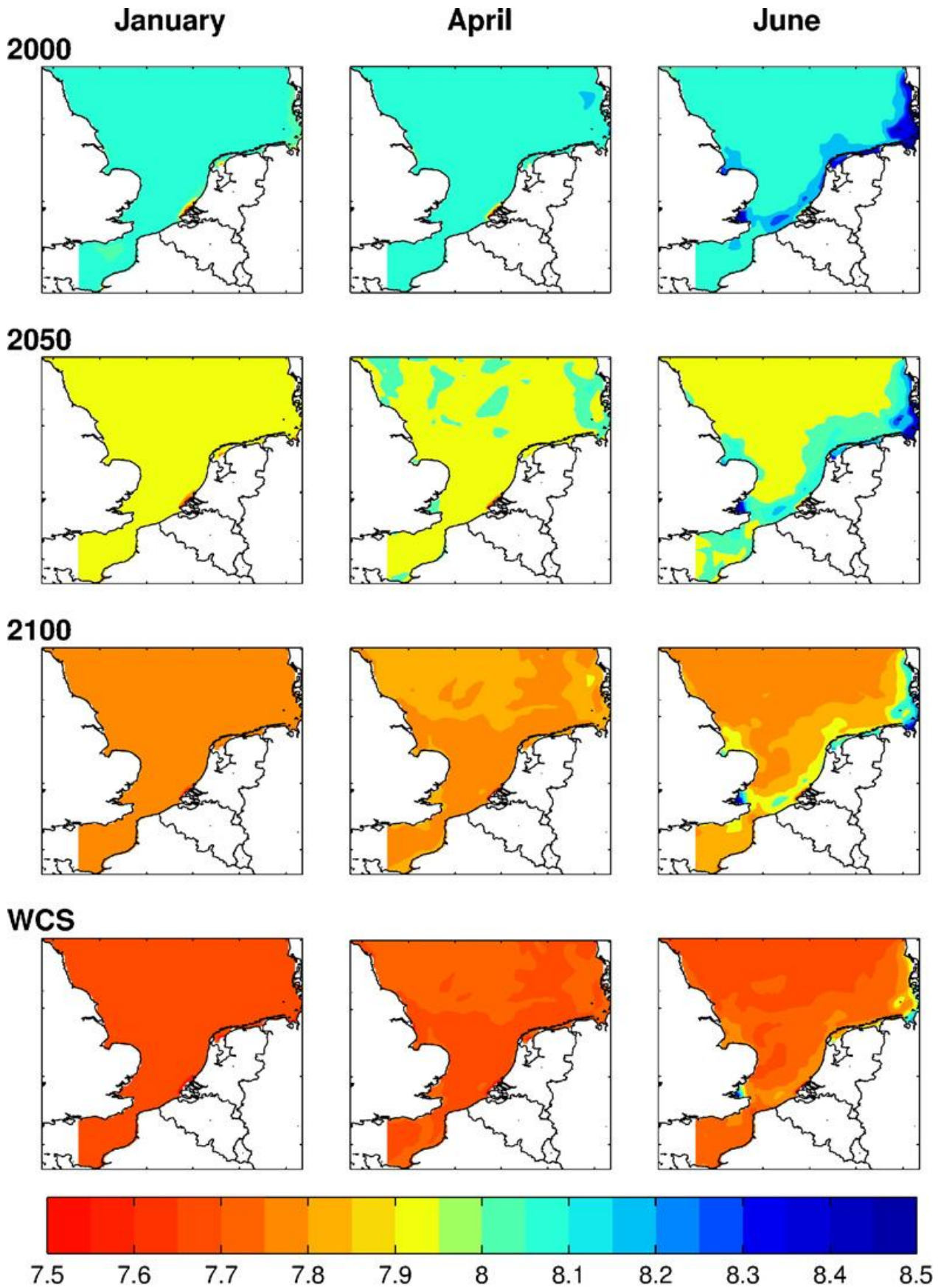
Figure 1.1.7 Monthly mean surface pH values for (left to right) January, April and June and (top to bottom) simulations for the years 2000 (atmospheric CO_2=375 ppm), 2050 (500 ppm), 2100 (700 ppm) and the 2100 worst case scenario (WCS) (1000 ppm) (Blackford and Gilbert 2007).

1.1.5 Habitats

Hydrodynamic conditions affect the deposition of substrate particles and therefore the distribution of substrate types. The deeper coastal areas of the north-eastern North Sea are of low energy and characterised by soft substrates; the west of the North Sea has higher energy, larger areas of gravel and coarse sand (Figure 1.1.8.).

Figure 1.1.8. The distribution of sediment types in the North Sea (OSPAR, 2000).

The North Sea could be regarded as a single ecosystem; however, it is more normal to envisage a number of ecologically distinct regions. These are distinguished on the basis of differences in their dynamics rather than the result of any degree of ecological isolation. The North Sea is an open system with continual exchange of water, nutrients, larvae etc. around the system and with free connections to neighbouring sea areas. Longhurst (1998) proposed ecologically based subdivisions on the basis of depth and mixing for the NE Atlantic including the North Sea and North West Waters RAC regions. During winter the boundaries between mixed and thermally stratified shelf water are prominent and relatively stable. They are principally (i) across the western entrance of the English Channel, (ii) across the northern Celtic Sea at the mouth of the Irish Sea, (iii) within the Northern Irish Sea, and along a line from northeast England to the Friesian Coast. Thus he proposed (Figure 1.1.9):

- A central area of vertically mixed water occupying most of the English Channel and the Southern North Sea (zone 1a) as well as the central Irish Sea (zone 1b).

- Stratified areas occupying the northern part of the North Sea above a line from Denmark to Yorkshire on the east coast of England and the whole of the outer Atlantic-facing shelf from Shetland to Spain, interrupted off Ushant by an extension of No 3 (2).

- A transitional zone between Nos. 1 and 2 across the shelf sea where fronts migrate with the tidal cycle. This occupies the western English Channel with an extension to the shelf edge off Ushant (3b), the northern Irish Sea (3c) and an arc across the central North Sea from the Scottish east coast south to offshore of Yorkshire across to off the Dutch Coast and then north to Denmark (3a).
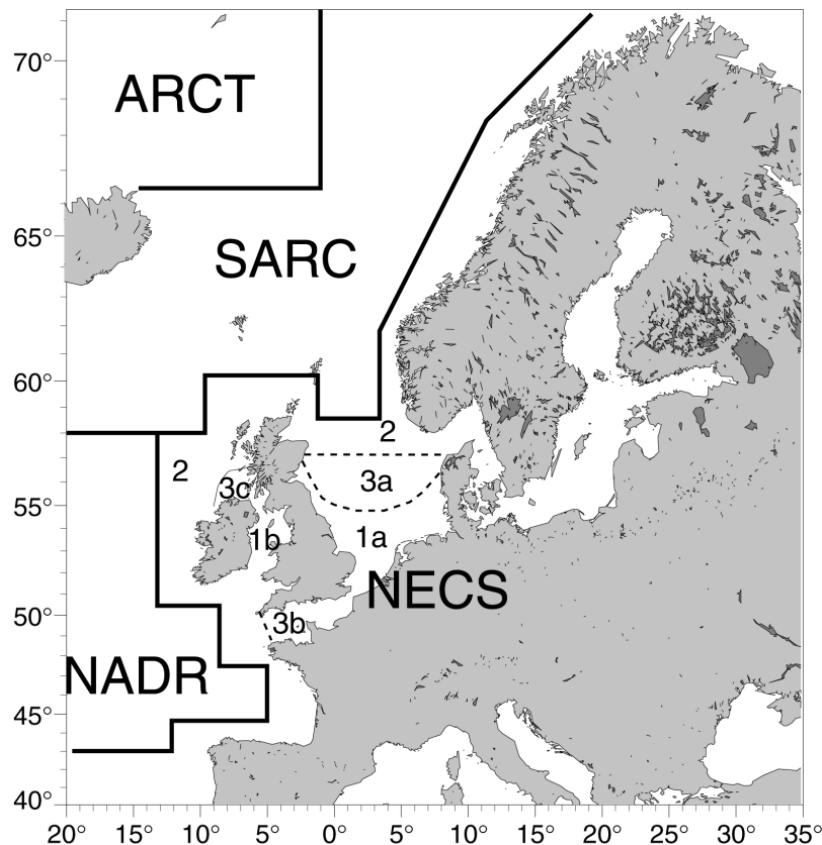
Figure 1.1.9. Provinces in the northeast Atlantic (Longhurst, 1998). NECS, Northeast Atlantic Shelves; SARC, Atlantic Subarctic; ARCT Atlantic Arctic; and NADR, North Atlantic Drift Province. The 6 areas denoted by 1a,b, 2, 3a,b,c are those proposed by Longhurst (1998) (see text above) based on the ecology.

Two other Provinces are of interest, the North Atlantic Drift Province (NADR), which consists of deeper waters off the Shelf and the Atlantic Subarctic Province (SARC) to the north. Although Longhurst (1988) did not propose subdivision, the SARC may usefully be broken into deep, off-shelf, and shallow, shelf, waters. As such Longhurst's zones can be considered as the basic habitat units for the water column.

Bottom dwelling organisms live in intimate contact with the sea floor and so are heavily influenced by the nature of the substrate. This is most obvious for organisms needing to attach to the substrate, for example on rocky reefs. Analysis of the distribution of infaunal and epifaunal organisms in the North Sea have shown their distributions to be correlated with substrate, depth and water flow. These in turn all correlate with the nature and quantity of production available (less in deep water, intermediate in suspension in strong flows, and highest in sediments where light particles are deposited) (Duineveld et al., 1991; Kunitzer et al., 1992; Basford et al., 1993; Kröncke, 1995; Pearson and Mannvik, 1998; Rees et al., 2007). Thus, the starting point for describing the occurrence of benthic habitats is knowledge of seabed substrates. At the crudest level such information is available from geological surveys and for the North Sea can be considered well resolved in part due to the activity of the oil and gas sector (Figure 1.1.10.).
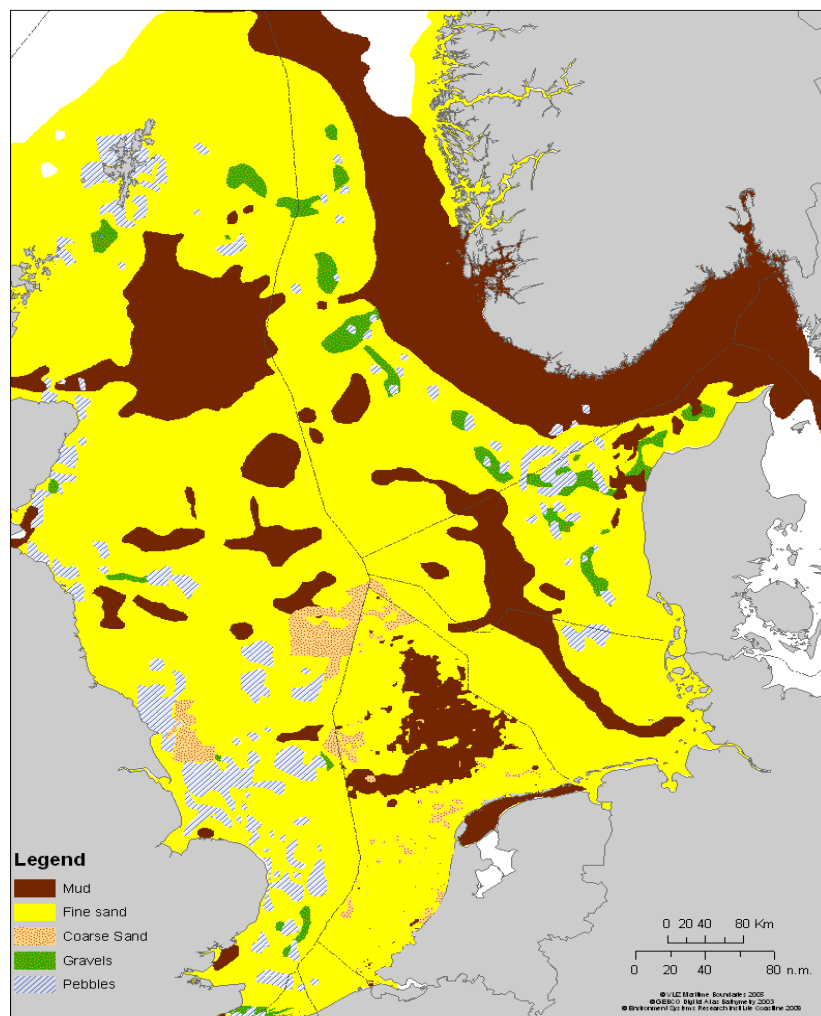
Fig. 1.1.10 Sediment map based on a Seabed sediment map of English Channel and North Sea, modified by (Carpentier, 2008) after "Seafloor sediment of the North Sea" from the MARGIS project (Duphorn et al., 1970; Figge, 1981; Larsonneur et al., 1982; Augris et al., 1995); British Geological Survey, (BGS) 1977-1993; Danish Geological Survey (GEUS), 1992) extended with a more detailed map of the Dutch Maritime area.

Hydrographic surveys to produce navigational charts provide additional information on sea floor depth and, by inference, slopes. Figure 1.1.11 illustrates this process for the Belgian sector of the North Sea using highly resolved sediment and bathymetric data to produce the spatial distribution of marine landscapes. This approach can be enhanced by including information on bottom currents where available (e.g. Figure 1.1.12). The MESH project (http://www.searchmesh.net/) attempted to utilise all available information in order to make a predictive map of the distribution of marine seabed landscapes, and by extension habitat units. The MESH marine landscape map for the North Sea (Figure 1.1.13.) provides a starting point for the development of marine spatial management for seabed systems and will be refined as additional data becomes available.

Each marine landscape is indicated with the following codes:
1 coarse grains (400 - 600 μm +> 600 μm)/weak to moderate slopes
2 coarse grains (400 - 600 μm +> 600 μm)/steep slopes
3 medium grains (350 - 400 μm)/weak to moderate slopes/ dunes
4 medium grains (350 - 400 μm)/weak to moderate slopes/ no dunes
5 medium grains (300 - 350 μm)/weak to moderate slopes /dunes
6 medium grains (300 - 350 μm)/weak to moderate slopes/no dunes
7 medium grains (250 - 300 μm)/weak to moderate slopes
8 silt to very-fine sand (0 - 150 μm)/high bed stress
9 fine sand (150 - 250 μm) / weak to moderate slopes
10 fine sand (150 - 250 μm) / steep slopes
11 silt to very-fine sand (0 - 150 μm) / low bed stress
12 medium grain size (250 - 400 μm) / steep slopes
13 gravel fields
14 weak to moderate slopes / dunes
15 weak to moderate slopes / no dunes
16 steep slopes / no dunes
17 steep slopes / dunes

Figure 1.1.11 The Belgian shelf sectors of the North Sea (a) bathymetry, (b) median grain size distribution and (c) seabed marine landscape (Schelfaut 2005).
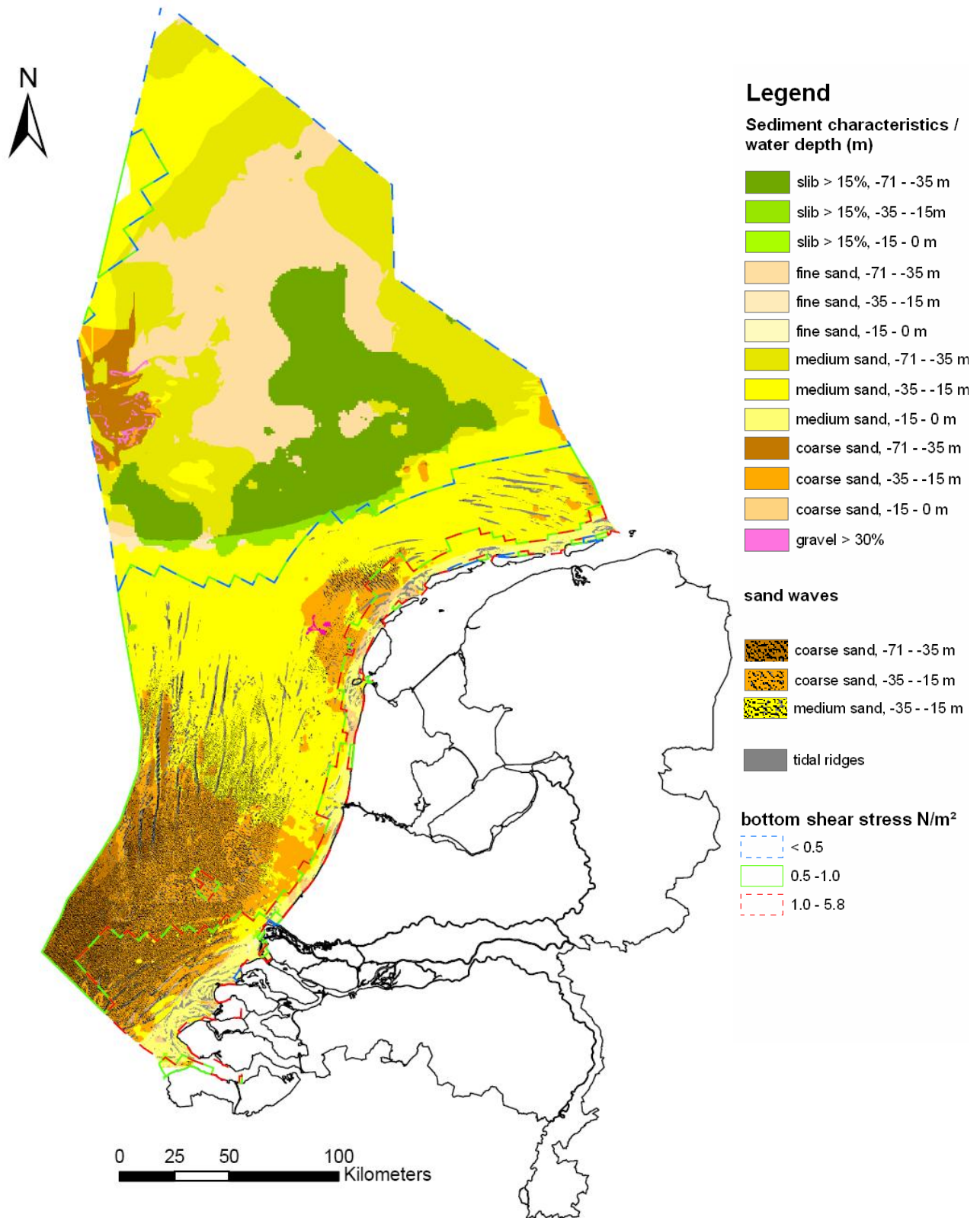
Figure 1.1.12. Marine-landscape map of the Dutch Continental Shelf (Doornenbal et al., 2007).

UKSeaMap
Seabed landscapes

Types

- Subtidal sediment bank
- Shelf mound or pinnacle
- Shelf trough
- Continental slope
- Canyon
- Deep ocean rise
- Deep water mound
- Pockmark field
- Lagoon
- Estuary
- Ria
- Sealoch
- Embayment
- Barrier beach
- Sound
- Bay
- Iceberg plough-mark zones
- Carbonate mound
- Photic rock
- Aphotic rock
- Shallow coarse sediment plain - weak tide stress
- Shallow coarse sediment plain - moderate tide stress
- Shallow coarse sediment plain - strong tide stress
- Shallow mixed sediment plain - weak tide stress
- Shallow mixed sediment plain - moderate tide stress
- Shallow mixed sediment plain - strong tide stress
- Shallow sand plain
- Shallow mud plain
- Shelf coarse sediment plain - weak tide stress
- Shelf coarse sediment plain - moderate tide stress
- Shelf coarse sediment plain - strong tide stress
- Shelf mixed sediment plain - weak tide stress
- Shelf mixed sediment plain - moderate tide stress
- Shelf mixed sediment plain - strong tide stress
- Shelf sand plain
- Shelf mud plain
- Warm deep-water coarse sediment plain
- Cold deep-water coarse sediment plain
- Warm deep-water mixed sediment plain
- Cold deep-water mixed sediment plain
- Warm deep-water sand plain
- Cold deep-water sand plain
- Warm deep-water mud plain
- Cold deep-water mud plain

Figure 1.1.13 The distribution of marine landscape features in UK seas based on modelling thematic layers of geophysical and hydrographic data (JNCC, 2006).

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1.1.6 Biological Features

1.1.6.1 Biological communities associated with the predominant seabed and water column habitats

The movement of water around the North Sea continually redistributes the drifting organisms that comprise the plankton. While it is possible to distinguish the plankton of different regions on the basis of complex statistical analyses, these do not represent distinct communities. Similarly the high mobility of the fish fauna, of which many species have a range across the entire North Sea, makes the distinction of separate communities rather arbitrary.

Sedentary bottom dwelling organisms offer more scope for categorisation into communities. Petersen, carried out a wide ranging survey of the shallower parts of the North Sea in 1914-1922 using a quantitative grab sampling technique and classified the benthos into seven distinct 'communities', which he named after the dominant species. He implied no biological linkages between the species in these 'communities' merely that they tended to occur together in space. More recent studies in the North Sea have confirmed the link between particular assemblages of species and the distribution of sediment types and other physical factors, principally temperature, depth and bottom current stress (Duineveld et al., 1991;Kunitzer et al., 1992) and these distributions have remained broadly similar over a period of 14 years (Rees et al., 2007). The importance of such physical factors has provided an impetus to the prediction of the distribution of areas of seabed sharing similar environmental conditions, so called marine landscapes, as potential correlates of the spatial distribution of biological habitats and assemblages (Figure 1.1.13).

1.1.6.2 Population description of angiosperms, macro-algae and invertebrate bottom fauna

In the North Sea, marine angiosperms (higher plants) are represented by seagrasses and are restricted to intertidal and shallow water areas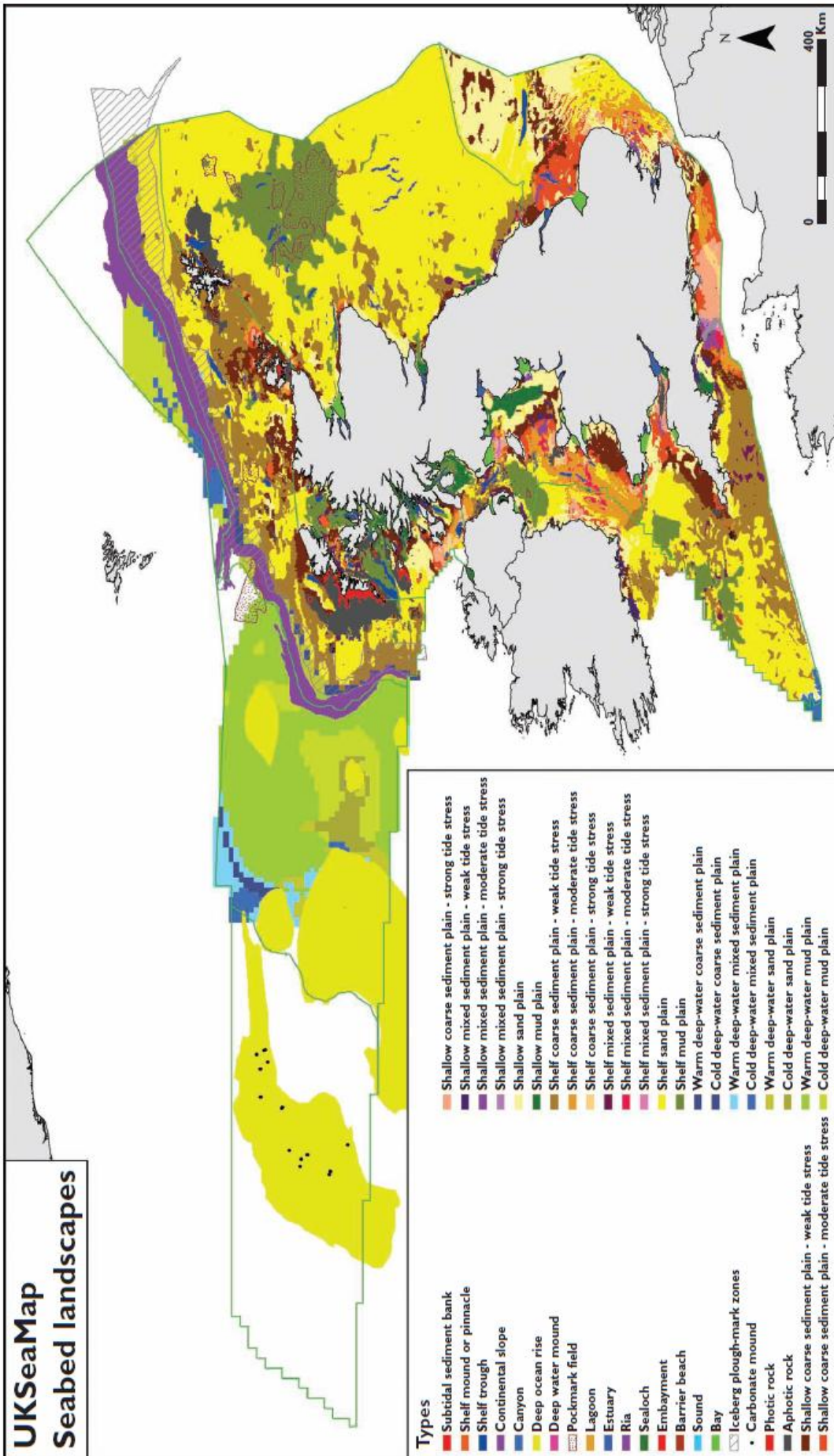, primarily in estuaries and sheltered coastal banks such as the north Norfolk coastal and Waddensee. These seagrass beds have a high conservation status and are subject to protection under various nature conservation designations. The seagrasses provide habitat and nursery areas for a variety of other species including fish and important feeding grounds for some species of bird.

Macroalgal assemblages are only able to grow where there is light and suitable substrate. They are therefore restricted to relatively shallow waters. In the southern North Sea, turbidity generally restricts their occurrence to waters less than 10m deep, while the lack of hard substrates prevents the development of stable communities. Exceptions are the offshore islands of Helgoland and the chalk reefs of Norfolk and around Flambrough Head on the east coast of England. Elsewhere macroalgae are restricted to highly scoured and mobile substrates such as old bivalve shells, gravels and oyster/mussel reef habitats. These support fast growing 'weedy' species such as filamentous red and green algae.

Petersen (Petersen 1913) first described, quantitatively the invertebrate fauna occurring in the North Sea and in subsequent papers developed the concept of 'benthic communities'. Petersen named each assemblage after the dominant taxa but recognised that the communities were not fixed and immutable assemblages but graded into each other along gradients of depth, sediment composition and in estuaries, salinity. Subsequent surveys using ever more extensive survey designs and more sophisticated statistical approaches have tended to confirm these broad conclusions (Rees et al., 2007). The infauna are generally dominated by polychaete worms, bivalve molluscs and ophioroids (brittlestars). In areas of highly mobile sediments crustaceans become more common, while in areas of low flow and high mud deposition burrowing echinoids increase.

1.1.6.3　The structure of fish populations

Over 230 species of fish are known to inhabit the North Sea, of which 11 are the main targets of major commercial fisheries (cod, haddock, whiting, saithe, plaice, sole, mackerel, herring, Norway pout, sprat, sandeel). Norway pout, sprat and sandeel are predominantly the targets of industrial fisheries, where the catch is converted into fish meal and oil, while the other species are the targets of fisheries where the catch is used for direct human consumption. A full description of the status of the target stocks along with non-target stocks which are harvested is described in section 2.4.

Fish species richness is lowest in the central North Sea and highest in Scottish waters, in the Kattegat and in the Channel area. When the community is split into its northerly and southerly components, the former reaches the highest diversity in waters typically deeper than 100m and the latter in waters less of 50m (Figure 1.1.14.). The area of high richness of northerly species extends from Scottish waters along the Norwegian trench into the Kattegat. High richness of southerly species is not restricted to the southern North Sea but is observed also along the Scottish coast and in the Kattegat (Daan, 2006). The species richness of fish in the North Sea, has increased over a 22-year period and this rise has been linked to higher water temperatures. Over eight times more fish species displayed increased distribution ranges in the North Sea (mainly small-sized species of southerly origin) compared with those whose range decreased (primarily large and northerly species) (Hiddink et al., 2006). The cause of the changes in richness and distribution are still under debate, but are usually ascribed to climate change (increase in water temperature) (Perry et al., 2005; Hiddink et al., 2006; Dulvy et al., 2008) and fishing (decrease of predation pressure) (Daan et al., 2005).

Most of the variability in fish stocks is due to variation in egg and larval survival, which is thought to be regulated by density-independent factors such as sea temperature and currents affecting larval drift to nursery grounds, as well as density-dependent predation on the eggs and larvae. Annual variability in recruitment of juveniles to the parent stock can differ by a factor of 5 for plaice, 50 for sole and more than 100 for haddock. Most species show annual or inter-annual movements related to feeding and spawning (OSPAR, 2000).
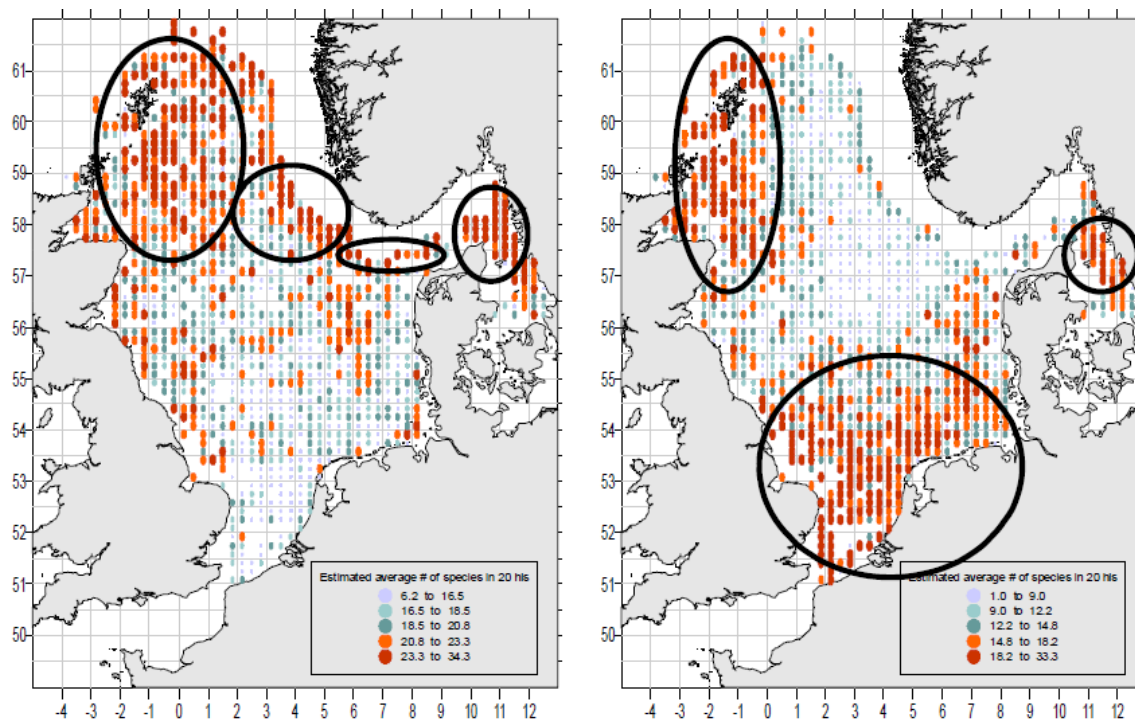
Fig 1.1.14 Estimated total number of species recorded after 20 hauls by 10nm by 10nm rectangle for northerly (left panel) and southerly (right panel) species separately (Daan, 2006).

1.1.6.4 Population dynamics of marine mammals and reptiles

Although a range of marine mammal species have been sighted in the North Sea, only a few are considered truly resident species. The resident cetacean species are minke whales (*Balaenoptera acutorostrata*), harbour porpoise (*Phocoena phocoena*) and white-beaked dolphin (*Lagenorhynchus albirostris*). A range of other cetacean species are sighted in addition to the resident species. There are also small populations of bottlenose dolphins (*Tursiops truncates*) in the northern and central North Sea. The minke whale is the most abundant by biomass, although harbour porpoise is most abundant by number (Table 1.1.5.); the North Sea may represent the key habitat for harbour porpoises globally (ICES, 2008b).

Table 1.1.5 SCANSII abundance estimates for cetaceans in the North Sea in 2005 (SCANS II, 2006).

Species	Geographical Area	Abundance estimate
Harbour porpoise	Inner Danish waters, Kattegat & Skagerrak	23 227
	Northern North Sea	37 968
	Central North Sea	58 706
	Southern North Sea and Channel	134 434
White-beaked dolphin	Northern & central North Sea	10 562
Bottlenose dolphin	Northern and central North Sea	652
Minke whale	Northern and central North Sea	10 541

Abundance of harbour porpoise seems stable as there was little change in estimated abundance between the two SCANS surveys (1994 and 2005), although a southward shift in distribution was observed between the two surveys (Figure 1.1.15). Changes in prey distribution is considered to be the most likely explanation for this shift, although other factors cannot be discounted (ICES, 2008b).
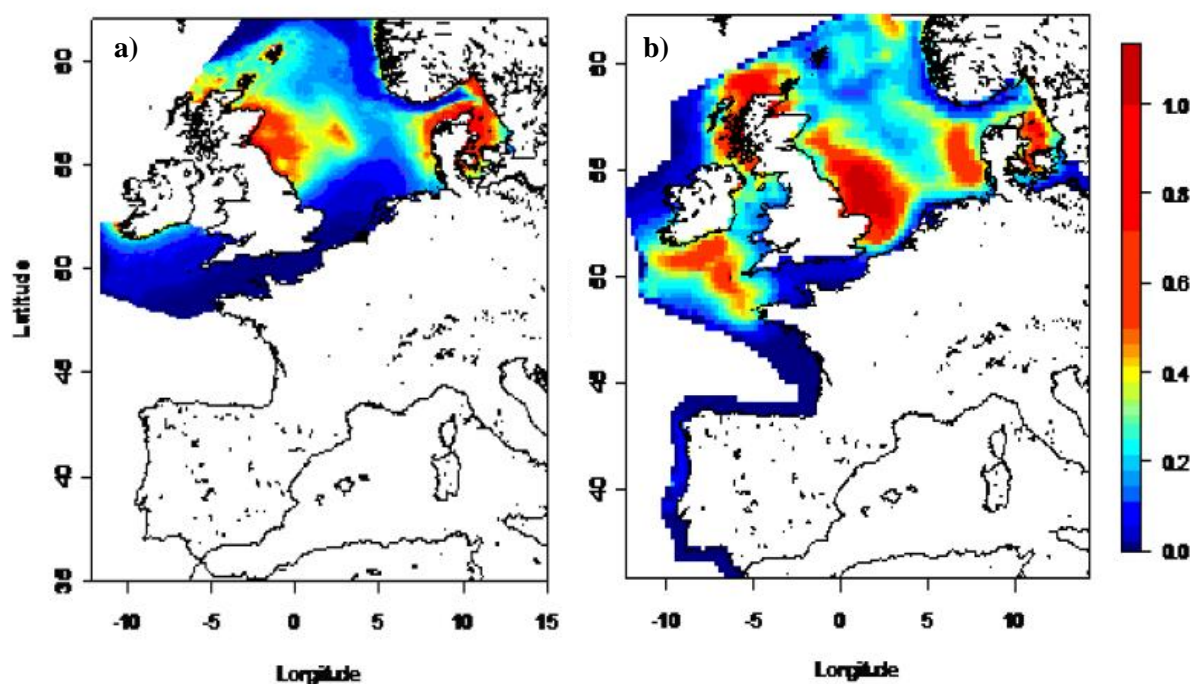
Figure 1.1.15 Harbour porpoise abundance (individuals km^{-2}) from a) SCANS survey 1994, and b) SCANS II survey 2005.

Two pinniped species breed within the North Sea, the harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*). Both are coastal species due to the need for haul out sites, although they can make extensive foraging trips. Both species have undergone large changes in population numbers over the last century. Population numbers reached a low point in the 1970s when a combination of hunting and pollution reduced the populations. However, since then, numbers of both species have increased considerably. Grey seals occur almost exclusively around northern Britain, whereas harbour seals are more widely distributed around North Sea Coasts. In 2002 the UK North Sea grey seal population was estimated at 54,600 (OSPAR, 2005).

On the basis of surveys mainly conducted between 1997 and 2002 the total North Sea harbour seal population (including the Kattegat and Skagerrak) was estimated at about 50,000 individuals (OSPAR, 2005). The harbour seal population has been significantly affected by two outbreaks of the phocine distemper virus (PDV) in 1988 and 2002. The impact of the PDV outbreaks is clearly visible from counts of seal numbers in the Wadden Sea (Figure 1.1.16.). Discussion of the interaction between seal populations and the case study fisheries can be found in section 2.
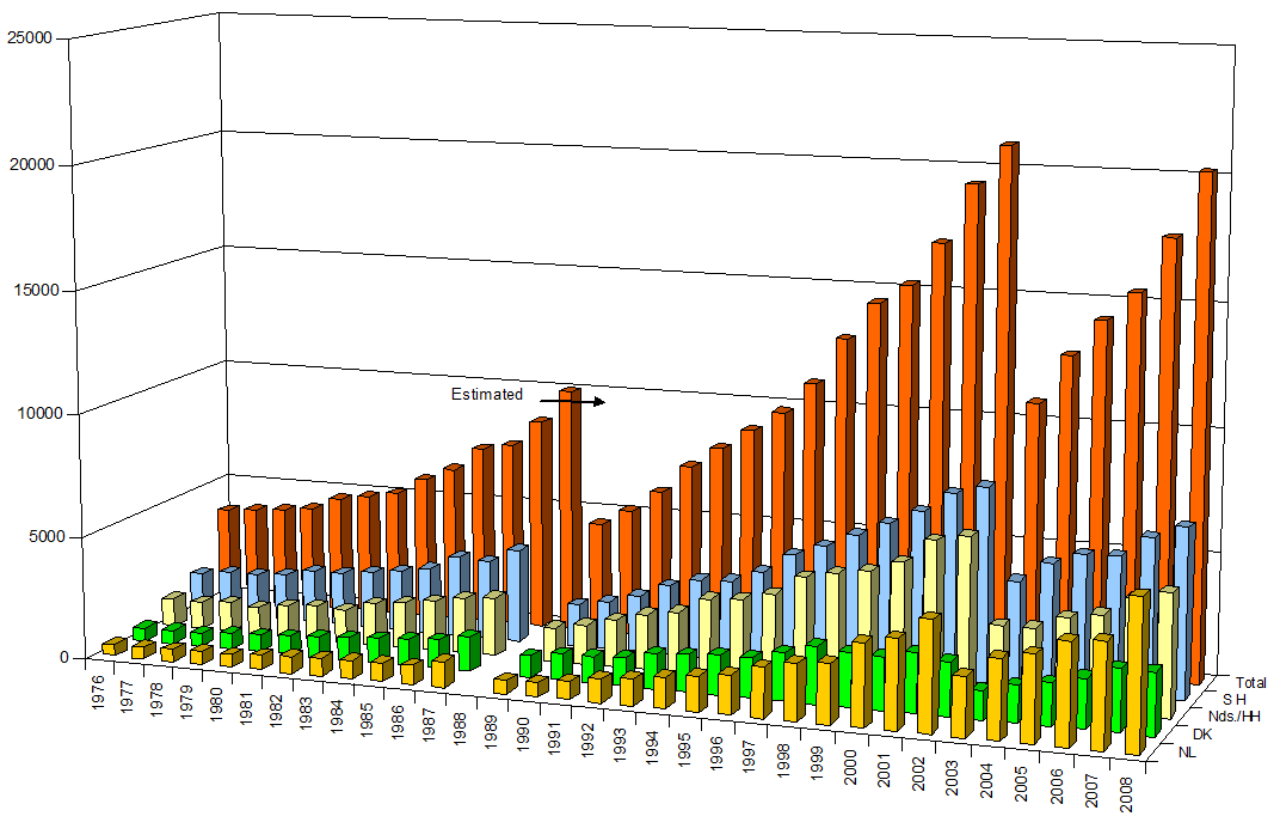
Figure 1.1.16 Numbers of harbour seals counted in the Wadden Sea,. NL- Netherlands; DK- Denmark, Nds-Niedersachsen; SH- Schleswig-Holstein (Trilateral Seal Expert Group, 2008).

1.1.6.5 Population dynamics of seabirds

Approximately 2.5 million breeding pairs of seabirds, from 28 species, occur around the North Sea coasts. Significant changes in the size and composition of the North Sea seabird community have occurred over the last century, illustrated by changes in the scavenging seabird community off northeast Britain (Fig 1.1.17). The alterations in the North Sea seabird community are predominantly attributed to changes in discarding of fish and offal at sea over this period, in addition to a reduction in hunting of some species such as cormorants. The extent of interactions with other factors cannot be fully established (ICES, 1999). Recent estimates of seabird population abundance over the last decade indicate that 12 species are increasing, 4 decreasing and 4 have stable populations; the status of the remaining 8 species is unknown (ICES, 2008b).

Increases in large scavenging seabirds can have negative impacts on smaller seabirds through competition for nesting sites and direct predation (e.g. Heubeck et al., 1997). For example, in the early 1950s in the German Wadden Sea terns comprised 60% of the sea bird community and large gulls 40%. By the early 1980s the seabird community was dominated by large gulls which made up 83% of the breeding population (ICES, 1999). Interaction between the case study fisheries and seabird populations is discussed in section 2.
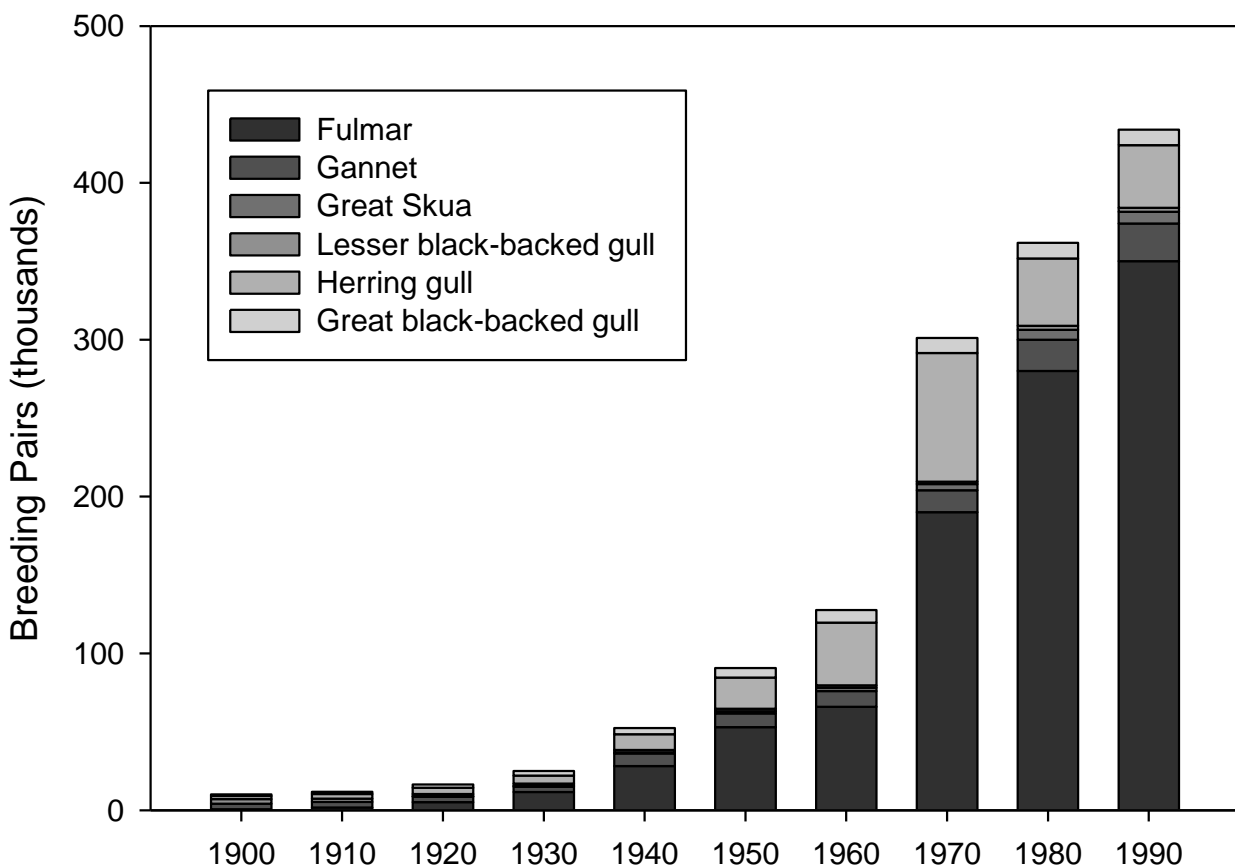
Figure 1.1.17 Pairs of scavenging sea birds off northeast Britain (ICES, 1999).

1.1.6.6 Inventory of non-indigenous, exotic species

Fourteen species of marine alga (or 15 taxa including two subspecies of a single species of green alga), five diatoms, one angiosperm and 30 invertebrates have been identified as non-native in British waters. The majority of these species are red algae, polychaete worms, crustaceans and molluscs. No non-native sponges, bryozoans or echinoderms have been found in British waters. Although the frequency with which introduced

species have been recorded in Europe has increased with time, there is no trend in the number of non-natives which have become established in Britain. In general, species were found to have established if they were introduced from similar latitudes of either hemisphere. More than half of non-native species introduced to Britain are considered to have been introduced in association with shipping; the remaining non-native marine algae are believed to have been established in association with deliberate introductions of shellfish for mariculture. Of the species deliberately introduced for aquaculture, only some of the bivalve molluscs have become established in the natural environment beyond the confines of their cultivation.

The success of non-natives has, where known, been due to a combination of reasons. Of the species that have spread, the marine algae did so fairly rapidly, while the invertebrates tended to spread more slowly. The method of spread, e.g. in association with shipping, was often the same as their method of introduction for both fauna and flora.

The direct effects of non-native species on the marine environment in British waters are in general not as detrimental as reported from elsewhere in the world. Commercially, some economically important species have been introduced, but some associated pests and parasites adversely affecting native species have also been unintentionally introduced. Control methods, where applied to nuisance species, are fairly ineffective and no non-native marine species have yet been successfully eradicated from British waters. The different aspects of the biology and etiology of non-natives are discussed in relation to determining their presence, monitoring their distribution and developing ways of avoiding further introductions (Eno et al., 1997).

1.1.7 What constitutes Good Ecological Status?

1.1.7.1 Good environmental Status (GES)

The aim of the newly adopted Marine Strategy Framework Directive (MSFD) is to achieve Good Environmental Status (GES) for each of the descriptors detailed in Annex I by 2020. The Directive identifies marine regions for which 'strategies', including detailed programmes of measures, will need to be drawn up by Member States in close cooperation with one another and also with any third country sharing the same region.

ANNEX I

Qualitative descriptors for determining good environmental status

(Referred to in Articles 3(5), 9(1), 9(3) and 24)

1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.

2) Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.

3) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

5) Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.

6) Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

7) Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.

8) Concentrations of contaminants are at levels not giving rise to pollution effects.

9) Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.

10) Properties and quantities of marine litter do not cause harm to the coastal and marine environment.

11) Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

The first four years of implementation of the MSFD will need to result in the first three elements of the strategy, described in articles 8-10, namely the initial assessment, determination of GES and the establishment of environmental targets and indicators (see Figure 1.1.18.). The preparatory phase will then be finalised with the definition of a coordinated monitoring programme. The formulation of a programme of measures and its entry into force in 2015-2016 should address (overcome) the gap between the existing and desired status. A six-yearly review of the strategy elements can be used to have a structured approach to 'adaptive management'.
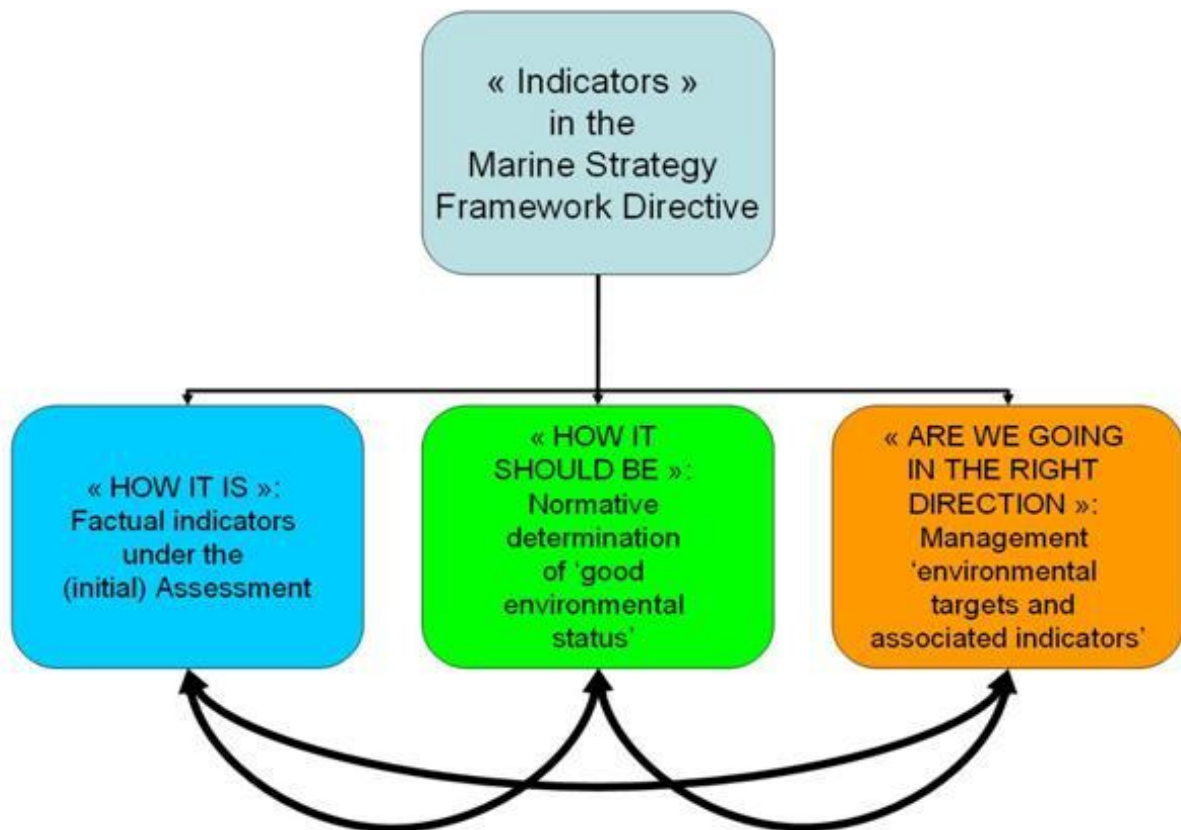
MSFD Article 8	MSFD Article 9	MSFD Article 10
+ Annex III of characteristics, pressures and impacts	+ Annex I on descriptors of 'good environmental status'	+ Annex IV on characteristics to be taken into account
FICTITIOUS EXAMPLE - RELATIONSHIPS		
o Indicator on levels and trends of TBT in sediment and biota	o Ecological quality objective on degree of biological effect (e.g. imposex) on snail populations	o Yearly indicator showing degree of compliance of ships with IMO AFS Convention and whether new TBT still enters the marine environment
RESPONDING TO:		
Annex III elements: "A description of the situation with regard to chemicals, including chemicals giving rise to concern, sediment contamination, hotspots, health issues and contamination of biota (especially biota meant for human consumption)" Introduction of synthetic compounds (e.g. priority substances under Directive 2000/60/EC which are relevant for the marine environment such as pesticides, antifoulants, pharmaceuticals, resulting, for example, from losses from diffuse sources, pollution by ships, atmospheric deposition and biologically active substances),	Annex I element: (8) Concentrations of contaminants are at levels not giving rise to pollution effects.	Annex IV element: (2) Need to set [...] (c) operational targets relating to concrete implementation measures to support their achievement.
DPSIR: S	DPSIR: S (Impact based)	DPSIR: R

Figure 1.1.18. The indicators in the MSFD and their relationship

1.1.7.1.1 Generic approach to develop a framework that determines GES

GES is not arbitrary, it is defined and the methods by which it will be made operational under the MSFD should be 'justifiable'. To that end the task is to progress from the very general descriptors in the MSFD Annex I to a common understanding of what GES is, and how it should be quantified. The aim is not to prescribe the boundaries between good and bad, but to agree on a generally applicable mechanism to get from observational data to a status assessment output. The key terms in these works are *descriptors, criteria,* and *methodological standards*.

The MSFD Annex I contains 11 *descriptors*, and for each brief descriptions of the key aspects of GES.

The MSFD Article 1(6) defines *criteria* in very general terms as "distinctive technical features that are closely linked to qualitative descriptors". In our interpretation, the task is to make the descriptors more concrete and 'quantifiable'. This can be done by describing how a set of indicators of the marine ecosystem change with decreasing environmental status, taking into account:

- other relevant legislation/policies
- the relevant spatial scale (European/region/sub-region/specific habitats/other)
- the relevant characteristics/pressures/impacts from Annex III

The outcome should be extended versions of each of the GES descriptors and should provide a common conceptual framework applicable throughout Europe. For many of the descriptors, such conceptual frameworks are already available (e.g. eutrophication, fish stocks), in which case the task is to verify if there is a need for modifications to meet the MSFD requirements, and to determine whether refinement at the sub-regional scale is needed. However, for some descriptors (e.g. food web components) where data is lacking, the process must essentially start from scratch.

Methodological standards are not defined in the MSFD; in our interpretation, the task is to agree on how to quantify the relevant indicators related to the (extended) descriptors ('*criteria'*). The outcome should be to agree on what information/data is needed to quantify GES and on a generally applicable mechanism to progress from observational data to a status assessment output. It will be necessary to agree how to quantify the relevant aspects of the descriptor, and to identify minimum data requirements, taking into account spatial and temporal variability. The *methodological standards* should be generally applicable (at EU level) wherever possible, but can be refined at sub-regional level if necessary.

1.1.7.1.2 Application of the framework

The Member states will contemporaneously make an assessment of the current status and define, within a common approach, a set of specific characteristics of GES (Article 9(3)) for their waters (in the sub-regional context).

The status assessment shall take into account the indicative lists of elements set out in Table 1 of Annex III and, in particular, physical and chemical features, habitat types, biological and hydro-morphology features. It shall also take into account the pressures or impacts of human activities in each marine region or sub-region, having regard to the indicative list set out in Table 2 of Annex III.

To determine GES, Member States shall consider each of the qualitative descriptors listed in Annex I and identify those descriptors which are to be used for their marine region or sub-region. When a Member State considers that it is not appropriate to use one or more of those descriptors, it shall provide the Commission with a justification in the framework of the notification made pursuant to Article 9(2).

1.1.7.1.3 *Current situation and way forward to determine GES*

Indicators already exist for some of the descriptors and are adopted to reflect the status of this descriptor. However, at present this is not specifically aimed at describing the status in relation to GES. Therefore a process has been started by the Commission, DG Environment, who has commissioned its Joint Research Centre (JRC) and the International Council on the Exploration of the Sea (ICES) to develop a formal Commission proposal on GES.

This work should take into account the best scientific methodologies available and the implementation process with respect to other policies/directives (e.g. Common Fisheries Policy, Water Framework Directive (WFD), Nitrates Directive, Biodiversity Action Plan, Alien Species Strategy, etc.). The results should be relevant for all the regions identified in the MSFD and should be applicable consistently by the Member States in their regional context for the determination of 'good environmental status' (i.e. objective setting). Formal consultation of the proposal with the regional sea conventions and all interested parties, including stakeholders, should take place pursuant of the EU level common implementation strategy groups.

As a first step in this process, an expert meeting was conducted aimed at developing this framework for two descriptors for which frameworks to describe their status (although not in terms of GES) already exist. We will present and discuss these approaches for the following two descriptors:

(3) "Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock" based on the existing management under the Common Fisheries Policy (CFP) aimed at keeping all commercial stocks "within safe biological limits (SBL)".

(5) "Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters" based on respectively the EU Ecological Status Working Group Eutrophication Activity and EU WFD Intercalibration process.

These two approaches can be considered the first steps in a process of developing a generic framework that eventually should be able to identify whether GES is achieved for all MSFD descriptors. As this process takes place within the duration of MEFEPO, we chose not to pre-judge the outcome of this process by attempting to determine GES for one or more descriptors but rather to follow closely the developments in this process and incorporate this into MEFEPO.

For each of the two descriptors the approach and first step of the process is presented below:

Descriptor (3): "Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock."

For this descriptor, the existing advice provided by ICES was used whereby three criteria can be applied to determine whether a stock is within safe biological limits (SBL): SSB>SSBpa, F<Fpa or SSB>SSBpa and F<Fpa (Piet and Rice, 2004).

Based on this, the framework that determines if GES is achieved consists of criteria for different configurations of indicators and reference points, or trends based on one or more of the aspects of the commercial fish stocks, that are assumed to reflect the environmental status. According to the MSFD, to achieve GES based on exploited fish populations requires:

- the population to be within safe biological limits (SBL) and,

- the age and size distribution to be indicative of a healthy stock.

In order to establish whether or not a stock is within SBL we used information from the stock assessment process currently conducted within the ICES area. This area overlaps with MSFD regions NE Atlantic and

Baltic Sea. In the Mediterranean there is a scientific agreement on status and appropriate reference levels for a number of stocks, while for the Black Sea such information is in the process of becoming available.

The stock assessment process and scientific advice of stocks management in the ICES area aims to keep stocks within SBL. This is assumed to be true provided the stock's potential for recovery (next year's recruitment) is not compromised and it is not overfished (compromising the health of the stock e.g. in terms of its "age and size distribution"). SBL are reflected by two indicators:

> - A state indicator: Spawning Stock Biomass (SSB), which has to be above a limit reference value (Blim) below which there is a chance that next year's recruitment will be impaired. A precautionary reference value Bpa was created to account for the uncertainty in these estimates.

> - A pressure indicator: Fishing mortality (F), with its limit reference value (Flim) to prevent overfishing. A precautionary reference value Fpa was created to account for the uncertainty in these estimates.

These indicators and reference values implicitly define GES as the avoidance of harm to the stock. A more ambitious reference point for the achievement of GES comes from the UN summit in Johannesburg in 2002 and is also adopted by the CFP, i.e. F should be ≤ Fmsy, where Fmsy is the F at which maximum sustainable yield is achieved. The Fmsy value will usually be below Fpa and certainly below Flim. The assumption behind this is that a stock exploited at Fmsy would be exploited sustainably, which can be considered to be both "within SBL" as well as having an "age and size distribution indicative of a healthy stock". To what extent especially the latter part of this assumption holds may, however, require further consideration because the assessment of the fishing mortality rate in relation to MSY is a pressure indicator and does not provide direct information on the state of the resource. In addition, the estimate of Fmsy is largely independent of stock size but highly dependent on the exploitation pattern (the extent to which different age groups or size groups are being removed by fishing). Consider that the term "within safe biological limits" means that, at a minimum, a fish stock is harvested at a sustainable rate. In practice this implies that the fishing rate should be no greater than that estimated to give the maximum sustainable yield (F_{MSY}).

However, fishing at or below Fmsy does not automatically imply a size and age distribution that is indicative of a healthy stock, merely that it is being exploited sustainably. Continued fishing at Fmsy, should result in stock biomass stabilising at a stable equilibrium with a particular age and size structure. However, to decide whether such an age and size structure represents GES requires consideration of criteria established in relation to other MSFD descriptors. For example, size and age structure are potentially important components of descriptor 4 relating to food webs.

For (sub) regions for which no formal stock assessments are conducted we present a configuration of the conceptual framework based on abundance estimates that come from existing monitoring programmes, for example RV surveys and landings information. These data are considered the minimum type of information available for any commercially exploited species. Different selections of commercial stocks can be used for this exercise; the most obvious selection would be all stocks for which a stock assessment is conducted and thus estimates of F and SSB together with their reference values are available. Alternatively a subset could be used consisting of specific indicator species where criteria for inclusion might be: (1) combinations of stocks that together make up xx% of the biomass or (2) based on the quality of the assessments (Figure 1.1.19).

The following examples show how different configurations, consisting of indicators in combination with different reference points or trends, can provide different levels of GES. The status of the commercial stocks can then be expressed as the proportions of commercial stocks in a specific (sub) region at each of the levels. The approaches shown here mostly apply to commercially exploited fish species; the extent these approaches can be used for shellfish needs to be assessed.

The temporal and spatial scales are determined by stock boundaries and yearly assessments. A key will need to be developed to match stocks with the (sub) regions identified in the MSFD, to aggregate stocks into their appropriate (sub) regions.
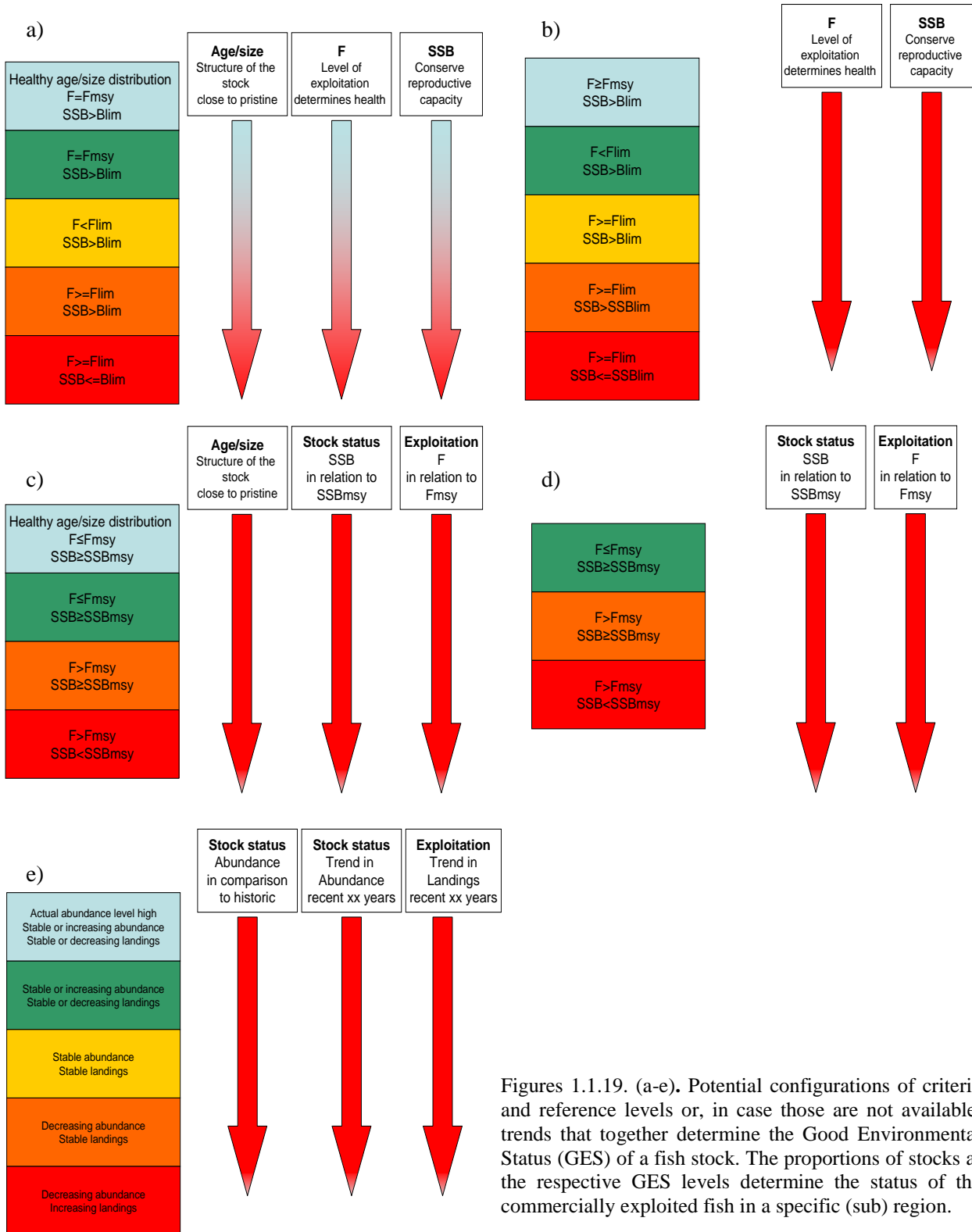
Figures 1.1.19. (a-e). Potential configurations of criteria and reference levels or, in case those are not available, trends that together determine the Good Environmental Status (GES) of a fish stock. The proportions of stocks at the respective GES levels determine the status of the commercially exploited fish in a specific (sub) region.

Descriptor (5)

For the descriptor "Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters" two main European activities have contemplated harmonization of eutrophication assessments and classification criteria: the EU Ecological Status Working Group Eutrophication Activity and the EU WFD Inter-Calibration Process. Both activities, consider all water categories: lakes, rivers, coastal and transitional waters.

The Eutrophication Activity evaluated the existing European policies and international agreements, which directly or indirectly include requirements on eutrophication, and developed guidance for a common EU approach for eutrophication assessment. The guidance was developed in consultation with the relevant working groups – WFD-CIS ECOSTAT WG, EMMA, ND and UWWTD Committees. This guidance aims to achieve common conceptual understanding of the process, taking into consideration the specific requirements of the WFD.

The aim of the WFD Inter-Calibration Exercise was to reach a common understanding of what is meant by "good ecological surface water status" across water categories and geographic areas.

1.1.7.1.4 Conceptual Framework

The conceptual framework provides means for identifying the critical processes specific to different water categories. To provide a link with type specific assessments (i.e. determination of reference conditions and classification), holistic checklists need to be derived for different water categories highlighting the critical processes and biological/ physicochemical parameters under the headings of causative factors, primary or direct effects, and secondary or indirect effects. The level of detail included in the checklists reflects the specificity of the eutrophication process in the different water categories.

The Conceptual Framework of Eutrophication adopted is based on the OSPAR Comprehensive Procedure (Appendix 1), which has been adjusted to be more generic and take into consideration the WFD requirements and terminologies. It includes results from discussions held at a joint workshop on Marine Assessment and Monitoring with emphasis on eutrophication, JRC, Black Sea Commission and Helsinki Commission (Istanbul, Turkey, 21-22 April 2004) and in the Eutrophication Workshop on a Common Assessment Methodology (Ispra, 14-15 September 2004). The conceptual framework provides an effective means of identifying the critical processes for eutrophication and the similarities in the manifestation of these processes across different aquatic environments. However, it must be tailored to identify the aspects of eutrophication which are distinct for different water body categories and types.

WFD normative definitions

In the context of the EU Eutrophication Activity, the WFD Common Implementation Strategy (CIS) Working Group on Ecological Status prepared a report on the interpretation of the WFD concept of ecological status in the context of eutrophication. This report presents a proposal for a common understanding of the WFD's normative definitions in the context of nutrient enrichment (see European Commission, 2005), which is necessary to underpin the ecological status classification in the context of eutrophication.

It is agreed that, as a general rule, aquatic flora quality elements have an earlier response to nutrient conditions than other elements, for example benthic invertebrates or fish. Thus, interpretation of normative definitions is based on aquatic flora elements. For example the condition of phytoplankton, phytobenthos, macroalgae and angiosperms would not be consistent with good environmental status unless there is a negligible probability (i.e. risk) of accelerated plant growth and/or disturbances in the balance of the taxonomic composition of the plant quality elements (see figure 1.1.20.). Otherwise, this would be

considered a 'significant undesirable disturbance' to the aquatic ecosystem (European Commission, 2005) which is a direct or indirect measure of anthropogenic impact on an aquatic ecosystem that appreciably degrades the health or threatens the sustainable human use of that ecosystem.
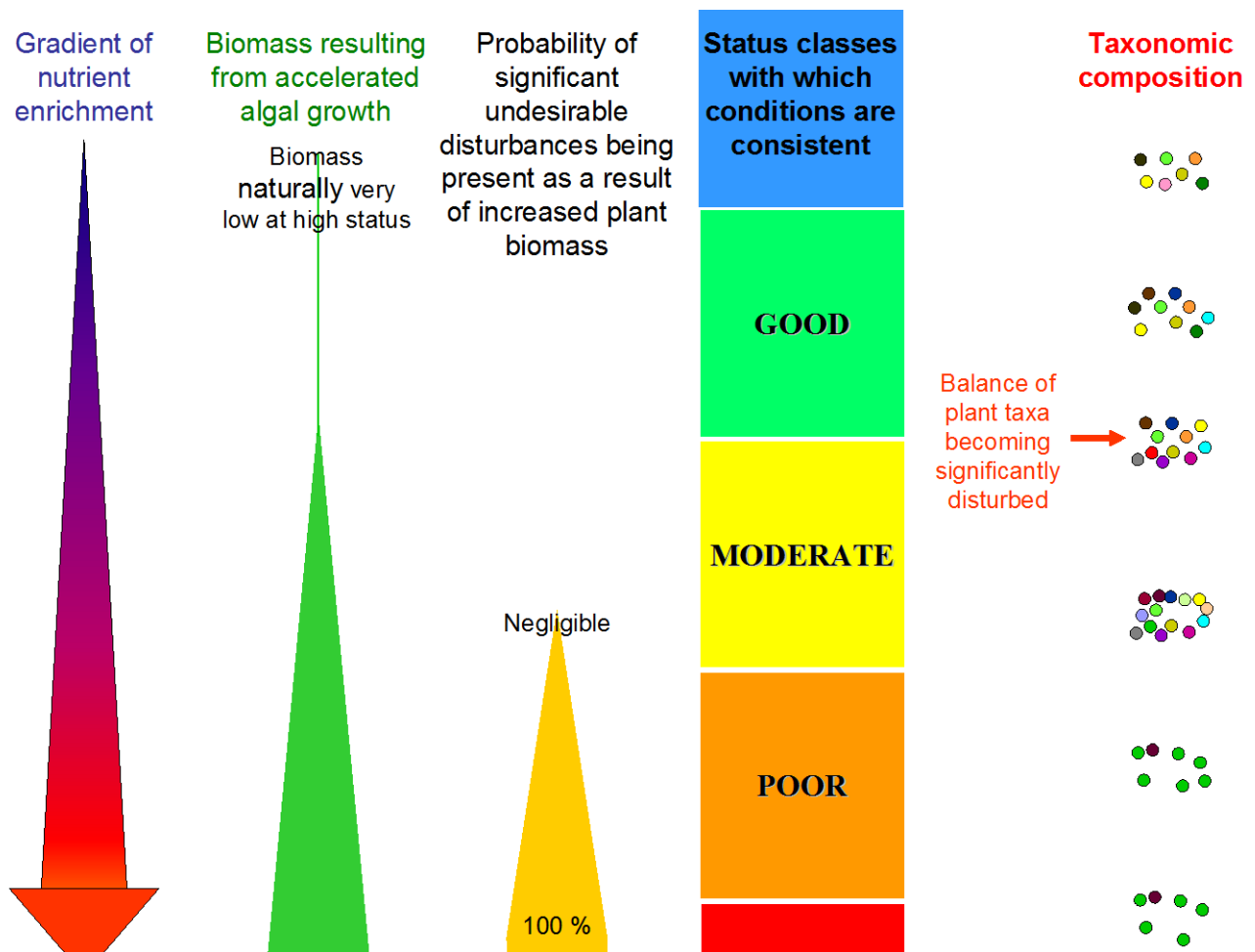
Figure 1.1.20. Ecologically undesirable changes in the balance of aquatic flora taxa may occur earlier along an increasing nutrient enrichment gradient than ecologically undesirable disturbances resulting from changes in the biomass of that flora (e.g. in some lakes that at reference conditions are low in nutrients and plant biomass) (from European Commission, 2005)

WFD intercalibration

The WFD prescribes the assessment of ecological quality of surface waters using an Ecological Quality Ratio (EQR). The EQR is defined as the relationship between the current observed value and the reference condition value for a given ecological quality element. Reference conditions correspond to very low pressure, with only minimal human impacts from industrialisation, urbanisation and intensive agriculture and vary across Europe due to geographical differences. To account for these differences, the WFD requires that water bodies are differentiated into 'ecotypes' within geographical regions and to derive type specific reference conditions for the appropriate ecological quality elements.

The WFD requires an Intercalibration Exercise, that aims to reach a common understanding of what is meant by 'good ecological surface water status'. This concept needs to be comparable between the EU Member States, consistent with ecological definitions in the WFD and the basis for the environmental objectives in river basin management plans. The Intercalibation Exercise was carried out by the EU Member States, and facilitated by the Commission (JRC), during 2001-2007. The aim is to set ecological quality class boundaries

between "high-good" and "good-moderate" status. These boundaries are based on definitions of reference criteria and the application of a Boundary Setting Protocol (BSP) (Figure 1.1.21.) in line with the normative definitions for status class boundaries for each quality specified in the WFD. The process of 'boundary setting' was applied to biological data compiled in collaboration with expert networks and research projects (such as STAR and REBECCA). This process aimed to ensure that class boundaries are ecologically meaningful and consistent with WFD definitions.

The Coastal and Transitional Waters Intercalibration Exercise is carried out within four Geographical Intercalibration Groups (GIGs) – Baltic, Black Sea, Mediterranean and North East Atlantic. Common Intercalibration types shared by Member States within each GIG were defined for the Intercalibration exercise.

The results of the first Intercalibration Exercise are the status boundaries for the benthic invertebrate fauna quality element (all GIGs), metrics and boundaries representing the phytoplankton quality element (all GIGs), metrics representing the macroalgae and angiosperms quality elements (Baltic, Mediterranean and NE Atlantic GIGs) and provisional boundaries for the fish quality element (NE Atlantic GIG only).
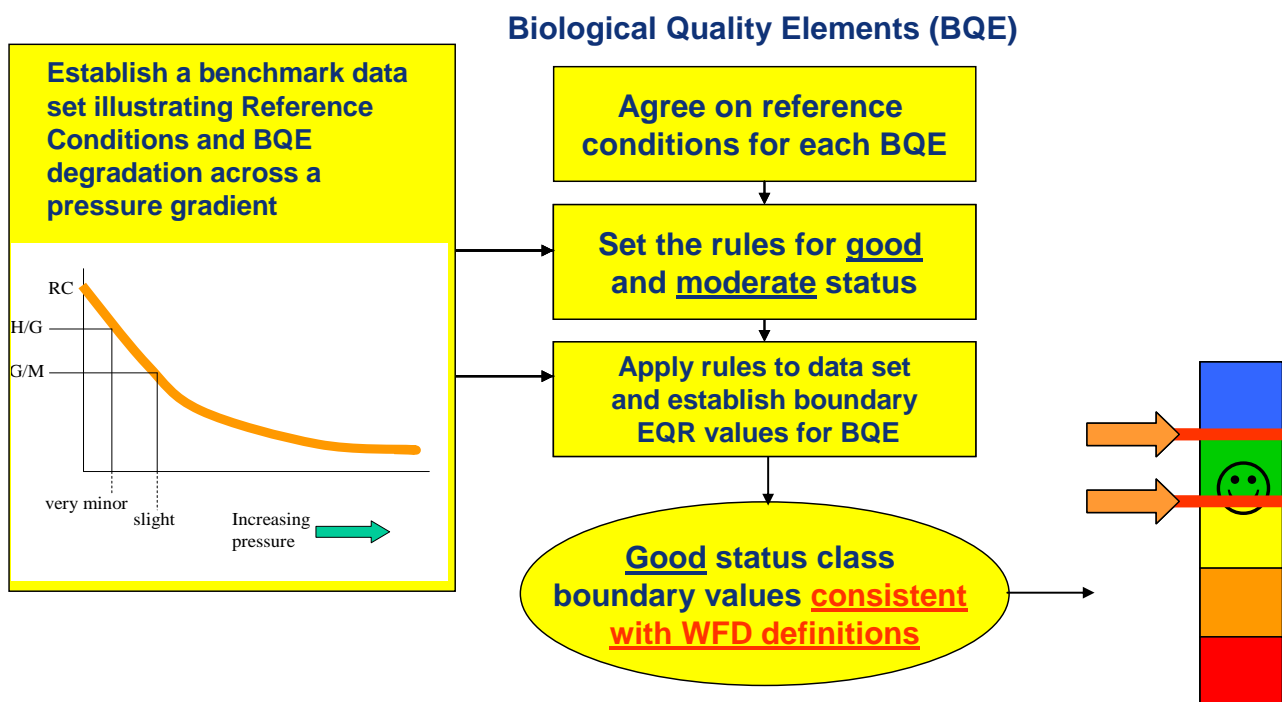
Figure 1.1.21. Ecological class boundary setting procedure followed by the WFD intercalibration.

Determining GES

To that end the above approach needs to be linked to the elements in the MSFD Annex 3 Tables. The main elements from these tables relevant regarding GES for descriptor (5) were considered to be:

- Physical and chemical features: spatial and temporal distribution of nutrients.
- Biological features: all biological 1st 3 features.
- Other features: description of any other features or characteristics typical of or specific to a marine region or sub-region.
- Main pressure: nutrient and organic matter enrichment

1.1.7.1.5 Conclusion

Based on previous work on determining the status of the environment, the first steps in the process of developing a generic framework that can determine GES for descriptors (3) and (5) indicate that it is possible to come up with a generic framework that can be applied to all descriptors. However, before GES can be determined, attention is needed to agree how to quantify the relevant aspects of the descriptor through the selection of appropriate indicators, establishing reference values and identifying minimum data requirements, taking account of spatial and temporal variability.

1.2   Human Activities

The most important activities at sea and in coastal zones are shipping, oil and gas extraction, energy production (wind farming), tourism, aquaculture, dumping, aggregate extraction, and fishing. These activities impact on the ecosystem goods and services as well as on each other. Below we briefly review these different activities and their extent, distribution and impacts.

1.2.1   Shipping

The North Sea contains some of the busiest shipping routes in the world and a significant proportion of western European imports and exports of goods and materials are transported by ship. Shipping, and its attendant infrastructure and activities, can have a number of negative impacts on the marine environment due to both routine and exceptional activities including:

- discharges of oil and waste;
- introduction on invasive species (predominantly from ballast waters);
- noise and disturbance;
- coastal habitat alteration and loss (associated with harbour facilities and dredging);
- loss of cargo (especially if containing hazardous substances);
- air pollution from exhaust emissions; and
- chemical releases from anti-fouling systems.

Table 1.2.1. Categories of pressures and impacts associated with shipping and related activities.

Physical loss	Physical damage	Other physical disturbance	Interference with hydrological processes	Contamination with hazardous substances	Systematic and/or intentional release of substances	Nutrient and organic matter enrichment	Biological disturbance
X	X	X		X	X		

In reference to chemical releases from anti-fouling systems, the use of TBTs has been increasingly restricted under both international (IMO) and regional (EU) regulations. Since 1st January 2008 the application of TBT based antifouling paints on EU flagged vessels has been banned and ships with TBT based paints are banned from visiting EU ports under EC regulation 782/2003. The North Sea has been established as a Special Area under MARPOL Annex I (oil); establishing a code of conduct for tankers travelling through Special Area waters.

However, shipping also has a positive impact on the socio-economic well-being of the North Sea coastal region, providing an essential role in the transport of goods and the conduct of free trade, and generating a large number of both sea and land-based employment.
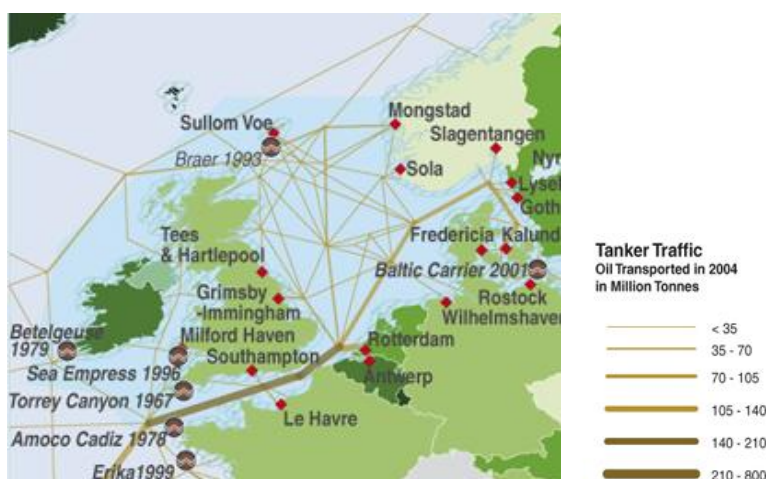
Figure 1.2.1 Tanker traffic in 2004. Source: UNEP/GRID-Europe.

1.2.2 Shipping Marine Aggregate Extraction

Table 1.2.2. Categories of pressures and impacts associated with aggregate extraction and related activities.

Physical loss	Physical damage	Other physical disturbance	Interference with hydrological processes	Contamination with hazardous substances	Systematic and/or intentional release of substances	Nutrient and organic matter enrichment	Biological disturbance
X	X	X					X

In 2006, 87.5 million tonnes of marine aggregates were extracted by countries bordering the North Sea (European Aggregates Industry statistics 2006) providing important materials to the construction industry. Aggregate dredging can have a number of direct and indirect effects on benthic communities due to direct removal of organisms and substrate, re-suspension of material and possible alteration in sediment transport (Kenny and Rees, 1996; Newell et al., 1999; Desprez, 2000; Boyd et al., 2005; Cooper et al., 2007). The extent and duration of impacts varies depending on local sediment types and natural levels of disturbance. Organisms in the path of dredging operations will be directly removed. Mobile scavenging organisms are the first to arrive following dredging activities, the area is then usually recolonised by fast growing opportunistic r-selected species (Kenny and Rees, 1996; Desprez, 2000). Although species richness may return to pre-impacted levels reasonably rapidly after extraction events, reduced density and biomass of organisms can persist for many years (Kenny and Rees, 1996; Desprez, 2000; Boyd et al., 2005). Aggregate extraction only occurs in localised licensed areas and although local impacts can be notable, the impact on a regional level is limited.
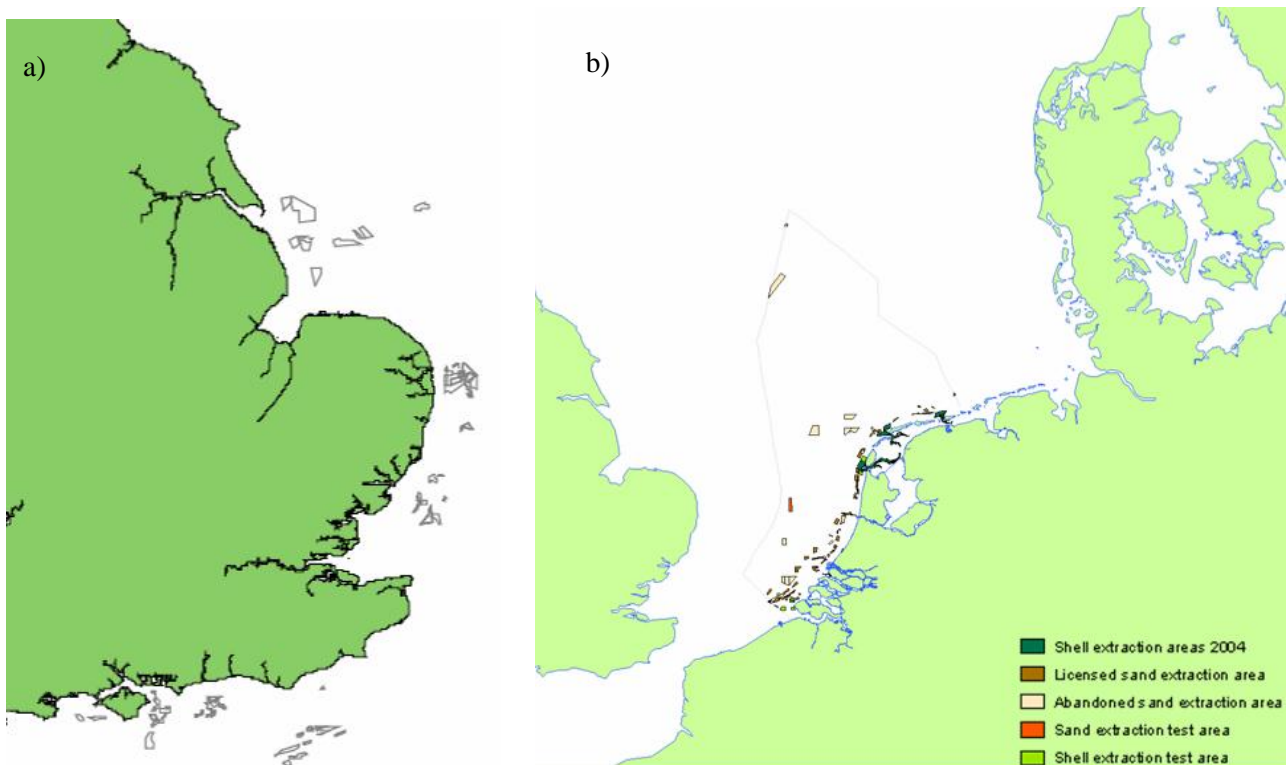
Figure 1.2.2. Licensed aggregate extraction sites off: a) UK in 2009, and b) Netherlands 2004. Sources: a) Crown Estate and b) "de Noordzee atlas" http://www.noordzeeatlas.nl/en/index.html, Dutch Directorate-General for Public Works and Water Management.

1.2.3 Offshore wind farms

Table 1.2.3: Categories of pressures and impacts associated with offshore wind farms and related activities.

Physical loss	Physical damage	Other physical disturbance	Interference with hydrological processes	Contamination with hazardous substances	Systematic and/or intentional release of substances	Nutrient and organic matter enrichment	Biological disturbance
X	X	X					

The first offshore wind turbines were installed at Vindeby off the coast of Denmark in 1991. The Vindeby array consists of 11 turbines capable of producing 5 MW. As of 2008, offshore wind farms across the EU have a capacity to produce 1,471 MW; capacity is predicted to rise to 37,441 MW by 2015 (European Wind Energy Association). A large proportion of the existing and proposed wind farm sites are located in the North Sea. The rapid expansion of offshore wind generation is supported at national and regional levels as one of the key technologies to allow governments to achieve Kyoto target for emissions reductions. The European Commission's Strategic Energy Review (November 2008) strongly supported the vision of a large expansion in offshore power generation and included support for development of a North Sea offshore grid. This vision has also received EC support and the establishment of significant offshore wind farms around the North Sea should be viewed as a realistic prospect.

Wind farms can impact the marine environment during construction, operation and decommissioning. The impacts of wind farms include obstructing flyways for seabirds, causing underwater noise and vibration, and habitat modification due to the introduction of turbine mountings and cables, and alteration of sediment in their close vicinity. Underwater noise will be most significant during construction; marine mammals will be able to hear pile driving operations and may take avoiding action (Brandt et al., 2011). Fish may also perceive noise up to 80 km from source, but the range over which avoidance action will occur is less certain (Thomsen et al., 2006). The operation noise of wind farms will be limited in comparison and noise related behavioural responses will occur over a very limited range. In addition to their ecological impacts, wind farms can compete for space with, and displace, other maritime activities, for example fishing.
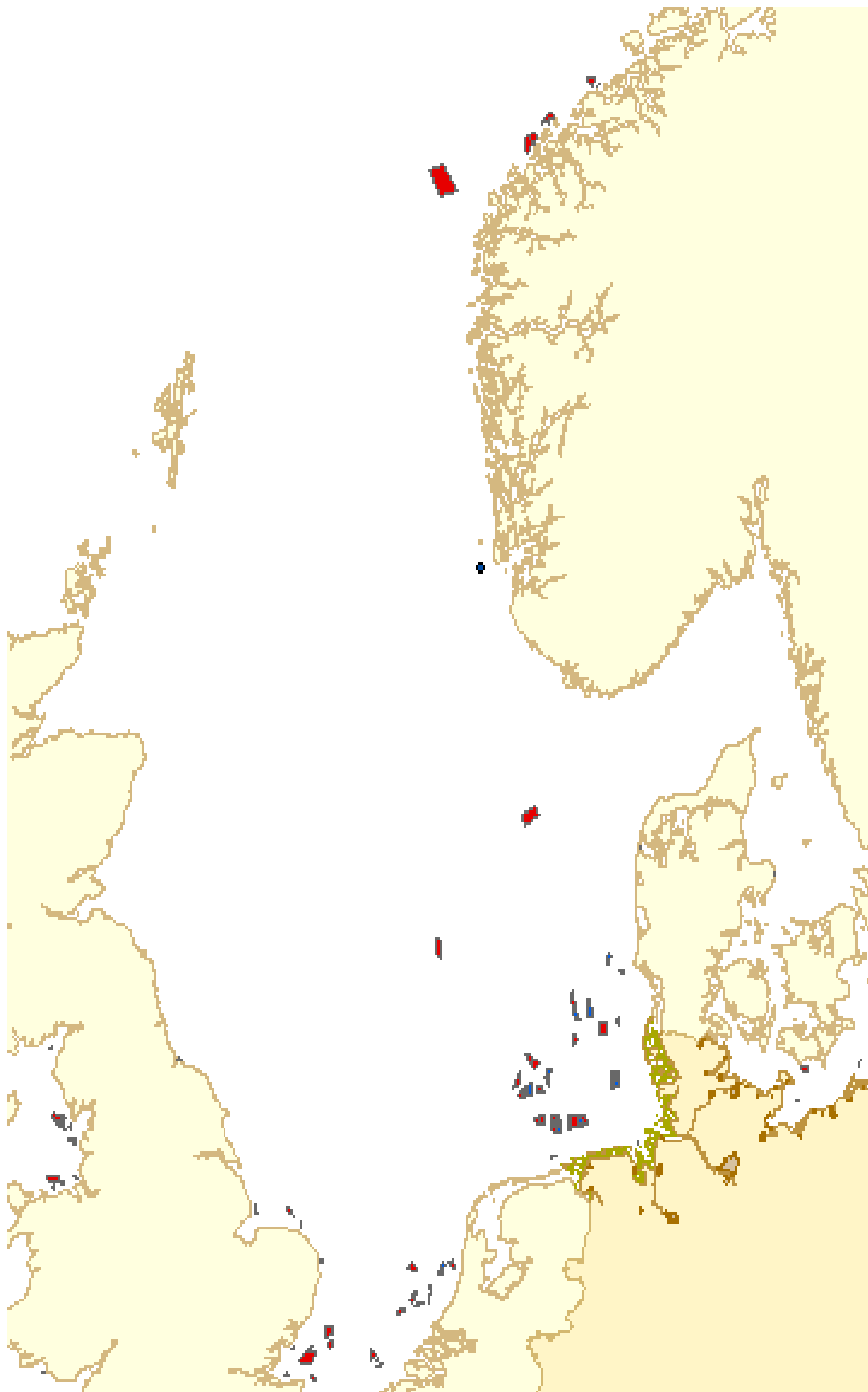
Figure 1.2.3. Operational (green), authorised (blue) and application (red) sites of offshore wind farms in the North Sea. Source: OSPAR database on offshore wind-farms, 2008 update.

1.2.4 Tourism

Table 1.2.4. Categories of pressures and impacts associated with tourism and related activities.

Physical loss	Physical damage	Other physical disturbance	Interference with hydrological processes	Contamination with hazardous substances	Systematic and/or intentional release of substances	Nutrient and organic matter enrichment	Biological disturbance
X		X		X			X

Tourism is a rapidly expanding industry within the European Union; in the ten year period 1998-2008 tourist arrivals in the European Union increased by almost 40% and a significant proportion of the tourist activity is concentrated in the coastal zone. Impacts from tourism on the marine environment tend to be concentrated in littoral areas, although direct and indirect impacts extend to the offshore environment (OSPAR 2008). The main impact from tourism is related to habitat loss and modification resulting from coastal development, such as an increase in hard surfaces, coastal defences and harbours. There can be further direct impacts on coastal habitats by intense frequentation of sensitive habitats such as wetlands and coastal dunes. Direct offshore impacts are mainly related to boating activities and include disturbance related to noise, anchoring, and deliberate or accidental releases of substances such as litter and oils. Recreation fishing, and in some cases diving, can cause direct removals of biological component of the ecosystem. However, impacts of tourism are not all negative; tourism can provide an important source of income to coastal areas, and tourism that depends on good environmental status provides incentives to protect or improve environmental status. 'Eco-tourism' also plays a role in increasing environmental awareness.
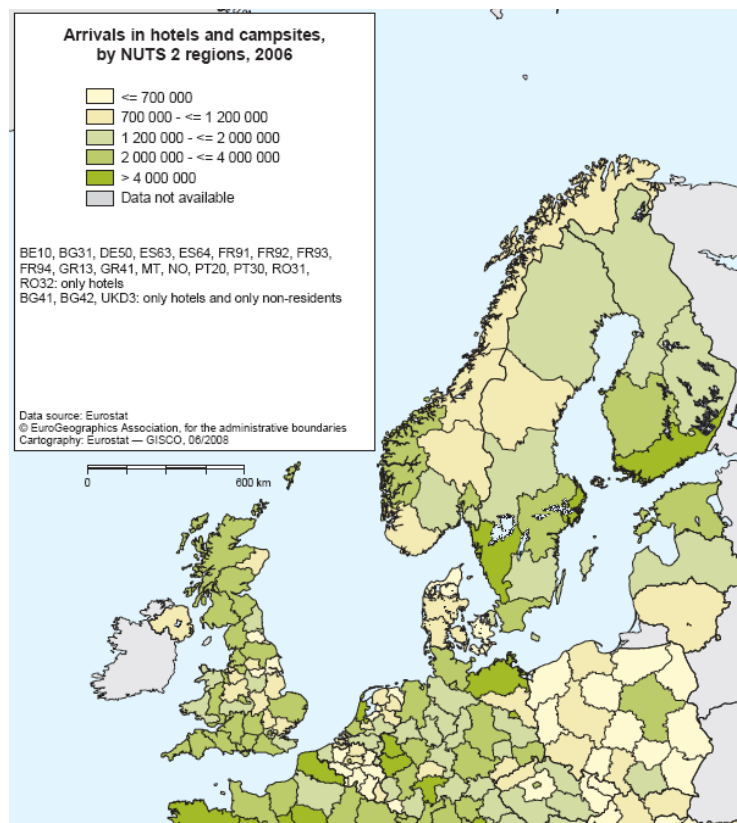
Figure 1.2.4 Arrivals in hotels and campsites by NUTS 2 statistical region, 2006. Source: Eurostat

1.2.5 Aquaculture

Table 1.2.5. Categories of pressures and impacts associated with aquaculture and related activities.

Physical loss	Physical damage	Other physical disturbance	Interference with hydrological processes	Contamination with hazardous substances	Systematic and/or intentional release of substances	Nutrient and organic matter enrichment	Biological disturbance
X					X	X	X

Marine aquaculture is undertaken by most states bordering the North Sea, with both fish and shellfish species are cultured. The main finfish species is salmon (*Salmo salar*) although an increasing range of species, such as cod and turbot, are likely to be cultured as production and husbandry practices improve. Shellfish culture in the North Sea is confined to molluscs, including blue mussels, oysters and scallops. Marine aquaculture can have a number of impacts on the marine environment; the main impacts are nutrient release (feed and faeces), chemicals applied for 'medicinal' purposes, compromise of natural population structure due to genetic interaction between wild populations and escaped farm conspecifics, and farmed sites acting as a source of pathogens. Regulation and monitoring of aquaculture with in Europe is increasing to mitigate the effects of marine aquaculture within European waters (Read and Fernandes, 2003).
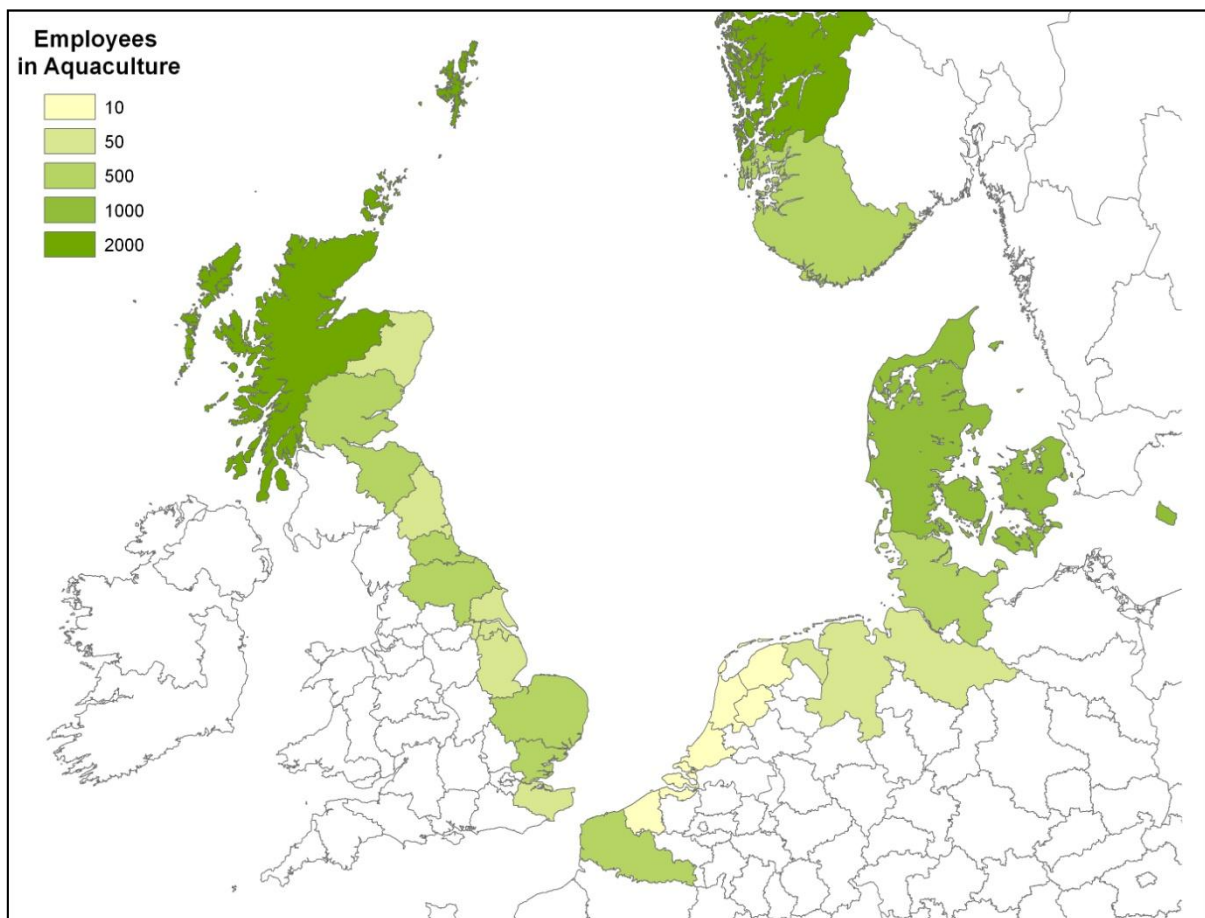
Figure 1.2.5 Number of employees in aquaculture by NUTS 2 statistical unit for 2005. Source data from: (Salz et al., 2006, except data for Norway provided by the Norwegian Directorate of Fisheries).

1.2.6 Dumping

Table 1.2.6. Categories of pressures and impacts associated with dumping and related activities.

Physical loss	Physical damage	Other physical disturbance	Interference with hydrological processes	Contamination with hazardous substances	Systematic and/or intentional release of substances	Nutrient and organic matter enrichment	Biological disturbance
X	X	X		X	X		

Dumping of waste materials at sea has been increasingly regulated over the years and materials that can be dumped at sea are limited to dredged materials, waste from fish processing and inert material of natural origin. Dumping of industrial waste at sea was phased out in 1993, dumping of sewage sludge was banned under the OSPAR convention in 1999, and, since 2004, dumping of ships and bulky waste has also been banned under the OSPAR convention. Acceptable impacts of dumping of waste of materials that are still permitted to be disposed of at sea are generally confined to smothering in the location where the materials are deposited. There may be associated releases of contaminants of materials dredged from previously contaminated areas, such as industrialised estuaries, although this issues is becoming less prevalent as modern regulations prohibit the release of contaminants and the 'stock' of pre-contaminated sediments in actively dredged shipping channels decreases.

1.2.7 Oil and Gas

Table 1.2.7. Categories of pressures and impacts associated with the oil and gas industries and related activities.

Physical loss	Physical damage	Other physical disturbance	Interference with hydrological processes	Contamination with hazardous substances	Systematic and/or intentional release of substances	Nutrient and organic matter enrichment	Biological disturbance
X	X	X		X	X		

Oil and gas extraction from the North Sea is a major economic activity. The main areas for oil extraction are located in the northern North Sea, in the UK and Norwegian sectors; the main area for gas extraction is in the shallower southern North Sea, in the UK, Dutch and Danish sectors (Figure 1.2.7). Although total oil production from the North Sea remains over 4 million barrels per day, North Sea oil production has declined since its peak in 1999. The impacts of the oil and gas industry include habitat modification and creation, and the release of chemicals into the sea. However, the use of chemicals in the oil and gas industry is strictly controlled and there has been a continual trend towards tighter regulation of releases by the petrochemicals industry in European waters.
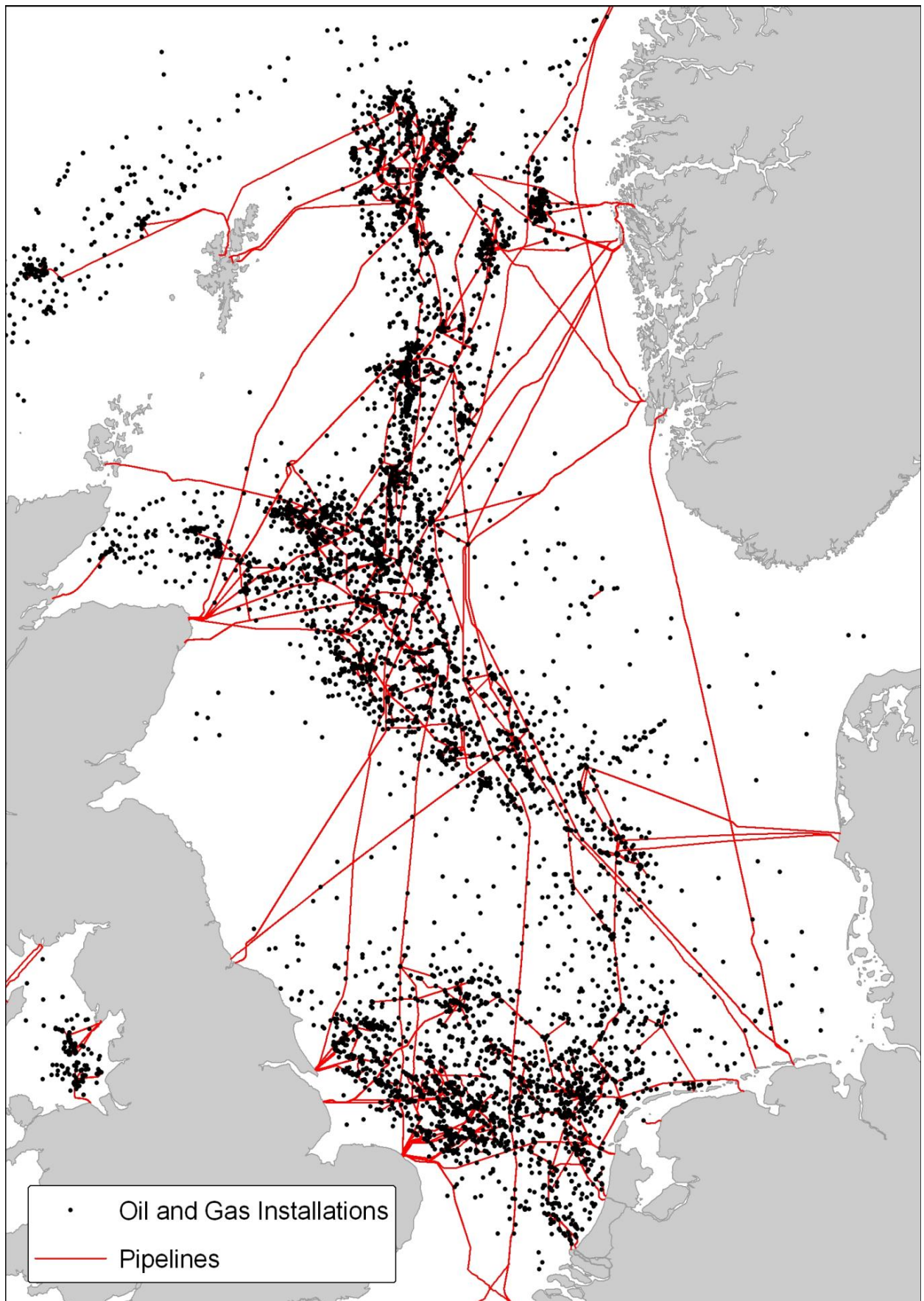
Figure 1.2.7. Location of main offshore oil and gas fields in the North Sea. Source: Clarkson Research Services Limited for data on the oil and gas installations; windfarm data is from OSPAR.

1.2.8 How human activities are likely to develop

1.2.8.1 Introduction: human activities and the marine ecosystem.

The impact of human activities on the ecosystem is closely related to the specific activities being undertaken. Trends in these human activities are influenced by a multitude of factors including supply and demand, changes in population, consumer preferences, development of markets, regulation and technology, and the political environment.

The most important trends are examined below, and include demand and supply of fish and fish products, trends in fisheries and aquaculture, marine tourism, off shore wind farming, off shore oil- and gas extraction and marine transport

1.2.8.2 Trends and Developments

1.2.8.2.1 World demand for fish and fish products

In 2004, about 75% (105.6 million tonnes) of estimated world fish production was used for direct human consumption. The remaining 25% was destined for other products, in particular the manufacture of fishmeal (for animal feed) and fish oil; the majority of which consisted of natural stocks of small pelagics. Ninety % of the fish production (excluding China) used in non-direct human consumption was reduced to fishmeal/oil; the remaining 10 % 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, although it is considered that latterly this increase in consumption has been driven by China; when China's consumption is excluded, the *per capita* fish supply has been stable at about 14.2 kg since the mid-1980s (van Hoof & Payne, 2007).

During the 1990s, global *per capita* fish supply, excluding China, was relatively stable at 13.2−13.8 kg. This can be attributed mainly to faster rate of 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 an increase in global *per* capita fish supply, of approximately 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 example, fish protein contributes to, or exceeds, 50% of the total animal protein intake in some small island developing states, as well as in a number of sub-Saharan Africa or Asian countries e.g. Bangladesh, Equatorial Guinea, the Gambia, Guinea, Indonesia, Myanmar, Senegal, Sierra Leone and Sri Lanka.

The predicted EU population increases are less rapid than elsewhere in the world. However, 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, with a predicted increase in the proportion of older people with a preference for healthy food (fish rather than meat).

The main future trends in global demand for fish and fish products will predominately by driven by the growing population and therefore an overall increase in demand for fish. With changing income and associated food preferences, and emphasis on 'healthy' food, a substitution effect will occur with demand switched from terrestrial animal protein to marine animal protein.

1.2.8.2.2 Consumer preferences

Consumer preferences change over time and within Europe over the past decades there has been increased consumer awareness of the link between food stuffs and diet and health aspects. This change is reflected by an increase in consumption of fish and fish products (fish emulates a healthy image based on fish being a 'natural' product and the health aspects of omega 3 fatty acids) and the development of functional foods and nutraceuticals. Functional food or medicinal food is any fresh or processed food which is purported to have a health-promoting and/or disease-preventing property beyond the basic nutritional function of supplying nutrients. *Nutraceuticals*, refers to food, or parts of food, that provide medical or health benefits, including the prevention and treatment of disease. This includes processed food made from functional food ingredients, or fortified with health-promoting additives, for example "vitamin-enriched" products, and also, fresh foods (e g vegetables). Fermented foods with live cultures are often also considered to be functional foods with probiotic benefits.

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

New household patterns are emerging with an increase in families where both parents work outside of the home and more single-person households, and this has led to a trend towards products that require less time and effort in preparation, for example products that are ready-to-eat or ready-to-cook. As a result consumer demand has moved away from utilising raw ingredients to fish and fish products being part of a composite product. This of course has an effect on the demand for raw products: away from i.e. fish being sold as fresh and whole, towards fish being an ingredient in a process of product preparation.

In contrast, discriminating consumers want to have the best raw materials 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 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.

1.2.8.2.3 Supply of fish and fish products

The demand for fish and fish products shows an upward trend, and between the 1950s and 2004, fish production from fisheries and aquaculture increased from 20 million tonnes to some 140 million tonnes. Fish production from wild fisheries is current stable and increased demand is being met by aquaculture production. The growth over the past 20 years is mainly due to increased production in China (including aquaculture production).

European production of fish products has shown a steady decline. Hence, in order to meet European demand there is a need to import fish products from outside the EU. The demand for continued exploitation of European fish resources will persist, alongside an increase in demand for aquaculture production.

1.2.8.2.4 International fish trade

Over the past 20 years, trade flow of fish around the world have increased, which can in part be attributed to an increase in fish consumption in Western Europe and America, which has been met by increased fish production and trade elsewhere (including from aquaculture). Furthermore, due to an increase in *per capita* income, fish importing has increased significant in some countries, for example China has rapidly emerged as a fish importer for direct human consumption. World trade flows in fish have also increased as more raw fish is exported for processing, after which the final consumer product or half-product is re-exported. It is estimated that global export and re-export of fish increased by approximately 400% between 1980 and 2001.

The EU is increasingly dependent on imports of fish and fishery products to meet its needs. In 2005, the EU imported more than €14 billion worth of fish and fishery products; exports were valued at €2.5 billion, thus the EU's trade deficit in fish and fishery products continued to widen and reached a new record of €11.7 billion. The majority of imports go to Spain (20%), 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.

1.2.8.2.5 Trends in fishing fleets

Fishing fleets are of varying size and structure, and use different gears. Technology is always advancing; therefore fleet size and capacity are ever-changing parameters. As a result the number of fishing vessels and/or the gross tonnage only provides an approximate indication of the fishing capacity of a given fleet.

The majority (81%) of EU fishing vessels are less than 12 metres in length and only 4% are larger than 24 metres in length; only in Belgium and the Netherlands are smaller vessels in the minority. In the remaining Member States, vessels of less than 12 metres in length make up over two thirds of the fleet; in Finland and Greece the makeup over 90% of the total fleet. 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 in both) closely followed by Italy (24.8 years), Portugal (24.7 years) and Ireland (24.4 years). The youngest fleets were located in Belgium (16.7 years), 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 they provide a proxy for the pressure on the fish stocks. Excess power is considered to be one of the major factors of over capacity which has led to overfishing. Despite the drop in fishing fleet capacity experienced by the EU fleet in the past 15 years, chronic overcapacity persists which undermines conservation measures. The Multi-Annual Guidance Programmes (MAGPs) implemented through the CFP have proven inadequate and in the reformed CFP (January 2003) have been replaced by a more simple entry/exit regime. Advances in technology and design mean that newer vessels exert more fishing pressure than older vessels of equivalent tonnage and power; therefore fish resources remain overfished despite a reduction in the size of the fleet.

In the period from 1989 to 2004, there was a reduction in the EU fishing fleet capacity: 23% in terms of power, 15 % in terms of tonnage and 23 % in terms of the number of vessels. Reductions also occurred in New Member State (NMS) fleets (80 % in tonnage and 5 % in number). However, the EFTA fleet (Iceland and Norway) increased in terms of tonnage (+ 34%) and power (+ 33%) despite the drop in numbers (- 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 fished greater depths and 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 becoming more apparent with the result that it is increasingly difficult for the EU to conclude bilateral fisheries agreements which would grant EU fleets access to the surplus fish resources in third country waters. Moreover, EU distant water fishing fleets are becoming less and less competitive as the fleets of new emerging fishing nations are operating at lower costs.

1.2.8.2.6 *Trends in aquaculture*

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, and in 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; 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 from this technique is decreasing. Extensive fish farming can be found in Italy mainly for mullet production, in Spain for seabream and seabass, and in Portugal for sole. Extensive production is relatively low-tech with low energy input and as such is considered a relatively eco-friendly practice although this is accompanied by low yields. Integrated aquaculture schemes (polyculture; the production of algae and animals of different trophic levels) have been 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 substantial specialist equipment, including mechanical filters, UV reactors, biofilters, CO_2 stripping and oxygenation systems, and 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, with improved controls and less diseases, and also a reduction of environmental impact though the reduction of releases of phosphorus, nitrogen and organic matter.

A large proportion of farmed fish in Europe is produced in *cages*, for example salmon, cod and halibut in northern Europe, and seabass and seabream in southern Europe. Fish have been reared in open sea net cages since the sixties, which allow a supply of good quality water. Cages were originally made from wood, and then polyethylene, with feed distributed by hand. However, large farms with hinged steel cages, which have a feeding system with feed blowers and appetite controlled feeding are now used.

The circumference of a single cage has increased from 70 m to 160 m diameter and the capacity from 20 tonnes to 1000 tonnes in one net cage, and several thousand tons per location. Production has increase from 600 tonnes per employee to 1000 tonnes per employee, and production costs have decreased from about €5/kg in 1999 to €2/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%; thus salaries account for approximately 5 to 10% of production costs.

Research and development is currently being undertaken to improve cage technology with the aim of improving floating fish farms 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 as the number of sheltered in shore locations for fish cages is limited due to conflicts in the coastal zone with other activities and users, and visual pollution. It is envisaged that offshore development could increase productivity and fish welfare, and thus the quality of the product; development is driven by private companies. To date there has been no clear technological trend for offshore systems, and research has predominately been on cage design rather than on operational aspects.

1.2.8.2.7 Recreational Fisheries

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

Total expenditure on recreational fishing across Europe is estimated to exceed an average of €25 billion a year (Dillon, 2004). By comparison, the value of commercial landings in the 15 EU member states in 1998 was estimated at €20 billion (Pawson et al., 2007). In its report on the problems encountered by inshore commercial 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 for the same fish, and identified this as an issue that 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). 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 predict 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.

1.2.8.2.8 Activities in Coastal Areas

Within the EU, the majority of fishing communities have been getting smaller as quotas and fleets have been progressively reduced, and thus jobs in fishing and associated industries have become less common. Many coastal communities are dependent on the fishing industry and in some areas of the European coast there are few employment opportunities outside of 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.

Small-scale, or in certain cases even large-scale, aquaculture has developed and in some cases outstripped the income from wild fisheries in areas that are suitable for such activity, for example 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 appropriate. 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 utilised for 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, 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 coastlines of many European countries have long been favoured holiday and tourist destinations, particularly in summer, and jobs have also been created to support tourism, for example in the accommodation, entertainment and catering industries. Although these employment opportunities tend to be seasonal, they are often lucrative. Ports have historically been crucial to the economies and 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 in activities both in the coastal zone and open sea, competition between sectors is rising. There is managed competition for space in European waters between those wishing to erect coastal or offshore wind farms, 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 in coastal areas. Traditional fishing activities are no longer able to meet the demand for fish and shellfish due to the increasing human population, and intensive aquaculture has now taken over large expanses of suitable coastline, affecting the availability of both onshore space and sub-tidal habitat and space, further adding to the pressure on coasts. Additionally, the need to dispose of waste, through rivers or directly into the sea, has increased alongside population increases and 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.

1.2.8.2.9 Trends in marine tourism

The marine tourism industry has developed over the centuries from one that consisted 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 for more affluent groups. In Europe, pressure on leisure time is predicted to lead to an increase in trips but of shorter duration. The growing aging population who are still of good health will increase demand for leisure activities, with an emphasis on cultural aspects, particularly programmes designed for the older traveller.

It is expected that for marine tourism there will be growth in both mass tourism and special interest tourism. The marine ecosystem is likely to be affected by developments in the cruise industry, recreational fisheries at sea and particularly in the use of the coastal zone for recreation.

However, development of tourism activities is closely related to general economic trends. In a downward economical situation (such as the current worldwide economic crisis), the tourism sector is rapidly affected. Therefore, long-term upward trend in demand for leisure activities can and will be affected by short-term declines in response to the economic climate.

1.2.8.2.10 Trends in off shore wind farming

Overall, the European wind market is expected to grow at a rate of over 9 GW annually from 2007 through 2010, due to annual investments approaching €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 (WindFacts, 2009).

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, it is predicted that wind power could meet 11.5% to 12.7% of global electricity demand in 2020, and 20.2% to 24.9% in 2030 (WindFacts, 2009).

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, which equates to an average increase of 9.5 GW per year between 2008 and 2020. In 2007, wind energy capacity in the EU increased by 8.5 GW (WindFacts, 2009).

1.2.8.2.11 Trends in off-shore oil and gas extraction

Over the past five years the deep water oil and gas industry has grown. The global industry continues to face a decline in shallow water production, falling reserves and poor shallow water prospects. However, deep water 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 the banking crisis and oil price decline, as capacity constraints within the supply chain and rapid inflation have 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. Smaller projects in Europe and in South East Asia are most at risk and could see potential delays and cancellations.

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

1.2.8.2.12 Trends in marine transport

Around 90% of global merchandise is transported by sea, of which high quality European shipping is on the frontline; this includes trade to and from Europe, within Europe and global cross-trades. In the mid 2000s the growth in world trade was more marked in relation to 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 World Trade Organisation (WTO) negotiations mean that the process of global economic integration is likely to 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 2001. 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 the last quarter in 2003 to early 2004, showing almost unprecedented 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 in response 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 international and regional trades in Asia.

International shipping is 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.

Further reading and sources on which this section is based in appendix 2.

1.3 Socio-economic 'environment'

1.3.1 Institutional Governance Setup of Fisheries Management in the North Sea

1.3.1.1 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 further confusing what is already a complex system. Figure 1.3.1 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.[1]
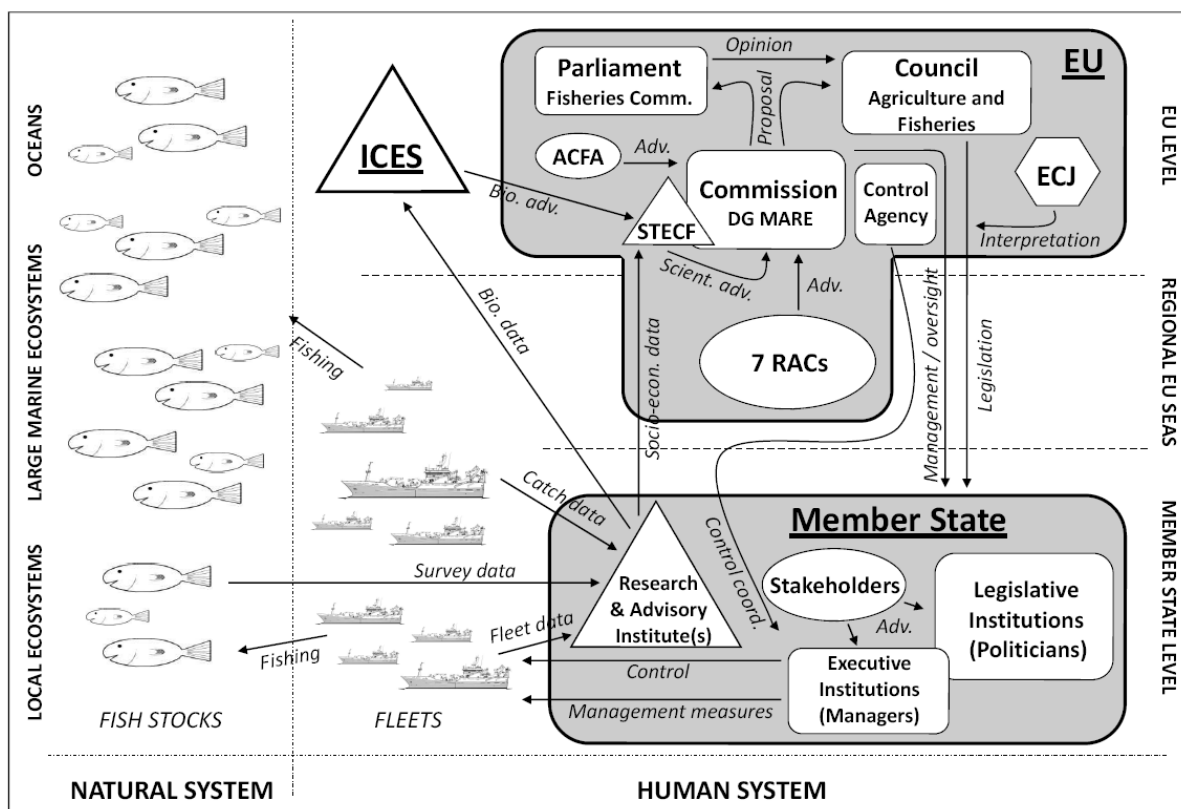
Figure 1.3.1: The Institutional Setup for Fisheries Management in the EU[2] The scientific bodies are depicted as triangles, legal bodies as hexagons, stakeholder bodies as eclipses, and policy/management bodies as 'soft' rectangles.

Although the model in Figure 1.3.1 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.

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[1] 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).

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

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 the national level. Whilst this may not be particularly relevant for countries such as Denmark where fisheries management is highly centralised (Hegland and Raakjær, 2008a), 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)[3], 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.

It should be noted that one significant fishing state operating in the North Sea, namely Norway, is not a member of the EU. The setup for governance relating to fisheries management in Norway will be dealt with separately in section 1.3.8.1.

1.3.1.2 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 of the European Communities, 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[4] 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 of the European Communities, 1970a;Council of the European Communities, 1970b). Since 1983, the policy has undergone reforms in 1992/93 (Council of the European Communities, 1992) and 2002/03 (Council of the European Union, 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 ultimately stands and falls by (Gezelius and 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 conservation of 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.

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[3] 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).

[4] 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).

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, 2008), the output that the CFP has delivered *vis-à-vis* indisputable core objectives of fisheries management has been far from impressive. According to Sissenwine and Symes (2007), at present the situation is characterised by:

- significant overcapacity in the EU member states' fleets compared to available resources;

- poor profitability in large parts of the catch industry;

- overexploited stocks above what comparable regimes worldwide have been able to deliver;

- lack of legitimacy of the management framework among industry stakeholders and conservationist non-governmental organisations (NGOs) alike;

- 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 all other aspects. 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)[5] for individual fish stocks in specific sea areas, to distribute the fishing opportunities into national quotas to the member states (Hegland and Raakjær, 2008b). This allocation key ensures relative stability in relation to fishing opportunities between member states, but it is at the 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'[6], 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. (European Court of Auditors, 2007;Sissenwine and Symes, 2007;Commission of the European Communities, 2008e;Gezelius and Raakjær, 2008;Raakjær, 2008).

In the following sections we will, with reference to Figure 1.3.1, 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. As previously mentioned, Norway will be dealt with separately in section 1.3.8.1.

1.3.1.3   EU level Institutions and Actors

The formulation, adoption and implementation of EU fisheries legislation is, as is evident from Figure 1.3.1, 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 is that a unit within the Directorate General for Maritime Affairs and Fisheries (DG MARE) (which is the relevant directorate-general within the

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[5] 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.

[6] 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.

Commission of the European Communities (Commission)), drafts the envisioned piece of legislation. In this process, DG MARE incorporates input from stakeholders and/or scientific bodies to varying extents depending on the nature of the proposal. 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[7] 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 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, 2008b).

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 1.3.1.

1.3.1.3.1 *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 1.3.1.3.3). 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 1.3.1, 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), overseeing that 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 1.3.1.3.5).

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, 2008b).

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).[8] 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 needed to draft the proposal, DG MARE is particularly dependent on information from other sources, as there is limited in-house scientific capacity (Commission of the European Communities, 2003). The International Council for the Exploration of the Sea (ICES) (see section 1.3.1.3.6) and the Scientific, Technical and Economic Committee for Fisheries (STECF)

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[7] 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.

[8] 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; Directorate E: Baltic Sea, North Sea and landlocked member states; Directorate F: resources (DG MARE administration). Information from DG MARE's website: http://ec.europa.eu/dgs/fisheries/organi/oganig_en.pdf (accessed 18 February 2009).

(see section 1.3.1.3.1.1) are of particular importance in these instances. The Regional Advisory Councils (RACs) (see section 1.3.1.4.1) 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 always be taken for granted in general and in fisheries in particular (see Hegland 2006: 223, footnote 2 for an illustrative example). The Commissioners can then accept the proposal (in which 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 (2008a) 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 political 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.

1.3.1.3.1.1 Scientific, Technical and Economic Committee for Fisheries

The Scientific, Technical and Economic Committee for Fisheries (STECF) is an 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 of the European Communities, 2005). STECF forms internal sub-groups, which can include experts from outside the STECF (Commission of the European Communities, 2003).

STECF and its sub-groups draw to a large extent on the same (limited) pool of expertise as ICES(see section 1.3.1.3.6), 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 to 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 of the European Communities, 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."*

However, it should also be noted that the issues are being discussed by a different combination of scientists and the conclusions may reflect changes in the balance between scientists with different opinions or perspectives.

1.3.1.3.1.2 Advisory Committee on Fisheries and Aquaculture

The Advisory Committee on Fisheries and Aquaculture (ACFA) is a consultative body that was set up by the Commission in 1971 to provide stakeholder input from European-level stakeholder groups and umbrella-organisations on fisheries matters (as opposed to the RACs, see section 1.3.1.4.1). The mandate of the ACFA 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 of the European Communities, 1999;Commission of the European Communities, 2004;Hegland, 2006).

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

1.3.1.3.2 European Parliament

As described in section 1.3.1.3, the European Parliament (EP, Parliament) consists of democratically elected parliamentarians from the 27 member states and 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 being a democratically elected body and as such representing the voice of the EU citizens.

Most of the work on fisheries resolutions is carried out in the standing Committee on Fisheries, which reviews the issues summarised in a report drafted by one of its members and chooses whether or not to adopt 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. However, the Council is not obliged to implement the Parliament's opinion under the consultation procedure (see section 1.3.1.3.3). 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 although, again, there is no obligation to do so (Hegland, 2004;Hegland, 2006).

Given its status in the consultative procedure, the power of the Parliament is 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 and its parliamentarians as a route for lobbying the Commission (Lequesne, 2000). It is 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 1.3.1.4.1). 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 would give the EP considerably more power.

1.3.1.3.3 Council of the European Union

In the Council of the European Union (Council), the member states are each represented by their minister who has responsibility 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 of 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.[9] 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 a simple majority of member states (in some cases other than fisheries two third 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 in 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 91 votes or abstentions (or a simple majority of member states or votes representing more than 38% of the EU population).[10]

The question of how often a member state finds itself in the favourable position to decide if a proposal is adopted or not thus depends (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'*

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[9] 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.

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

(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, 2008a): 153, drawing on Hegland 2004).

In practice, only a limited number of fisheries issues 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 the Commission can also 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 upwards to the higher ranking civil servants in the Permanent Representatives Committee (Coreper). Only the most 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. Informal communication serves multiple purposes, for example leaking one's own or learning other countries' positions in order to explore possible compromises or gaining a better understanding of other member states' underlying motives (Hegland 2004).

1.3.1.3.4 Community Fisheries Control Agency

The recent establishment[11] 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. The objective of the CFCA is to strengthen the uniformity and effectiveness of enforcement across the EU territory, by assisting the organisation of operational cooperation and coordination of monitoring and enforcement activities among member states (Council of the European Union, 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. Furthermore, the agency does not have any powers to sanction member states (Council of the European Union, 2005). The agency had a staff of 49 in 2008 (Community Fisheries Control Agency, Undated-b) and is amongst the seven smallest EU level agencies out of the 30 examined in (Egeberg et al., Undated). In practice the main task of the CFCA is to adopt 'joint deployment plans' (for

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[11] Operational from 2007 in Brussels and physically set up in Vigo, Spain, in 2008.

specific stocks in specific sea areas) with the aim of coordinating the use of the different member states' human and material resources for control and inspection. It also aims to solve 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 joint deployment plans (Council of the European Union, 2005;Community Fisheries Control Agency, Undated-a).

1.3.1.3.5 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 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.

1.3.1.3.6 International Council for the Exploration of the Sea[12]

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 although the EU is its largest client. ICES consists of 20 member states[13] and six affiliate states (Australia, Chile, Greece, New Zealand, Peru, and South Africa). 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. 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 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).

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[12] This section builds in part on information from the ICES website: http://www.ices.dk/ (accessed 16 February 2009).
[13] 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.

1.3.1.4 Institutions and Actors at Regional EU Seas Level

There are relatively few institutions situated at regional levels (Figure 1.3.1). Common to all the regions discussed in the MEFEPO project is the presence of a Regional Advisory Council (RAC) and 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.

1.3.1.4.1 Regional Advisory Councils

Seven Regional Advisory Councils (RACs) were set up under the CFP following the reform in 2002. These are stakeholder fora, consisting predominantly of representatives of the fisheries sector, defined as *"the catching sub-sector, including ship-, 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 two-thirds of the seats. The remaining third 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 for 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 of the European Union, 2002). The Commission (or the member state authorities) is not obliged to follow a recommendation from an 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 (Baltic Sea RAC, North Sea RAC, South Western Waters RAC, North Western Waters RAC and Mediterranean RAC.) or specific types of fisheries (Pelagic RAC and Distant Waters RAC) (Council of the European Union, 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 1.3.1). 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 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 with dissenting opinions recorded in the resolution (Council of the European Union, 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 provided evidenced of the considerable capacity of the Pelagic RAC to overcome these challenges.

1.3.1.4.1.1 North Sea RAC[14]

The North Sea RAC was the first RAC declared operational in 2004, following an initiative from the North Sea Commission Fisheries Partnership (see section 1.3.1.4.2), and covers ICES area IV and sub-area IIIa.

According to Hegland and Wilson (2008), the North Sea RAC is 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 1.3.1 outlines the membership of the North Sea RAC in relation to both the GA and the ExCom.

The North Sea RAC has set up five working groups: Demersal Working Group, Flatfish Working Group, Spatial Planning / MPAs Working Group, Kattegat & Skagerrak working group, and a Socio-economic Focus Group.

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[14] This section builds for the most on information from the North Sea RAC's website: http://www.nsrac.org/ (accessed 12 February 2009).

Table 1.3.1. Membership of the North Sea RAC as of February 2009[15].

Organisation	Representing	GA	ExCom
Aberdeen Fish Producers Organisation	Producer organisations of Scotland	X	
BirdLife International	Environmental NGO	X	X
Bundesverband der Deutschen Fischindustrie und des Fischgrosshandels	Fish processors of Germany	X	
Comité National des Pêches Maritimes et des Elevages Marins	Fishermen of France	X	X
Cooperative Maritime Etaploise	Producer organisations of France	X	
Danmarks Fiskeriforening	Fishermen of Danmark	X	X
Deutscher Fischerei Verband	Fishermen of Germany	X	X
EUCC - The Coastal Union	Environmental NGO	X	X
European Anglers´ Alliance	Recreational Anglers	X	X
European Association of Fishing Ports and Auctions	European ports and auction	X	X
EU fish processors and traders	Fish processors and traders	X	X
European Transport Worker´s Federation	Crewmen	X	X
European Bureau for Conservation & Development	Environmental NGO	X	X
Federación Española de Organizaciones Pesqueras	Producer organisations of Spain	X	X
Federatie van Visserijverenigingen	Fishermen of Netherlands	X	
Federation Internationale de la Peche Sportive en Mer	Sport Angling	X	
FROM NORD	Fishermen of France	X	
Living Sea	Environmental NGO	X	
National Federation of Fishermen's Organisations	Fishermen of England, Wales & North Ireland	X	X
Nederlandse Vissersbond	Fishermen of Netherlands	X	
North East Scotland Fishermens Organisation	Producer organisations of Scotland	X	
North Sea Women´s Network	North Sea fishing communities	X	X
North Atlantic Producers Association	Producer organisations of Poland	X	X
Rederscentrale	Fishermen of Belgium	X	X
Regional Fisheries Co-Management of Halland	Swedish charitable thrust	X	
Scottish Fishermen's Federation	Fishermen of Scotland	X	X
Seafood Choices Alliance	International trade association	X	
Seas at Risk	Environmental NGO	X	X
Stichting van de Nederlandse Visserij	Fishermen of Netherlands	X	X
Stichting voor Duurzame Visserijontwikkeling	Fishermen of Belgium	X	
Sveriges Fiskares Riksforbund	Fishermen of Sweden	X	X
Union des Armateurs à la Pêche de France	Boat owners of France	X	X
Union Nationale des Syndicats Marins-Pecheurs CFTC	French crewmen's trade union	X	
World Wide Fund for Nature	Environmental NGO	X	X

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[15] Based on information from the North Sea RAC's website and information from its secretariat.

1.3.1.4.1.2 Pelagic RAC[16]

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. As such the Pelagic RAC is also relevant for the North Sea.

Like the North Sea RAC, the Pelagic RAC is also among the most active of the RACs and has *"developed a great deal of institutional momentum"* (Hegland and Wilson 2008: 6). Table 1.3.2 outlines the membership of the Pelagic RAC in relation to both the GA and the ExCom. 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.

Table 1.3.2: Membership of the Pelagic RAC as of February 2009[17]

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	

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[16] This section builds for the most on information from the Pelagic RAC's website: http://www.pelagic-rac.org/ (accessed 12 February 2009).

[17] Based on information from the Pelagic RAC's website and information from its secretariat.

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	International	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	International	Industry	X	
WWF European Policy Office	International	Other interests	X	X

1.3.1.4.2 North Sea Commission[18]

The North Sea Commission is an international organisation founded in 1989 to facilitate and enhance partnerships between regions with a role in managing the challenges and opportunities offered by the North Sea. The organisation is host to two initiatives of particular interest to fisheries governance in the North Sea: the North Sea Women's Network and the North Sea Commission Fisheries Partnership.

The North Sea Women's Network aims to, among other things, create a European Federation of Women in Fishing Communities by linking up with other existing EU networks. The network was born out of the need for an organisation to represent women in the North Sea RAC to ensure that the needs of women in fishing communities are taken into consideration in the RAC's deliberations.

The North Sea Commission Fisheries Partnership is a group of predominantly fishers and scientists aiming to promote the integrated and sustainable management of shared fish stocks in the North Sea. The Partnership can be seen as the precursor of, and was instrumental in the creation of, the North Sea RAC (see section 1.3.1.4.1.1) and it consists of national fisheries research organisations from North Sea countries, representatives from fishermen's associations and the North Sea Commission.

The current membership is as follows:

– Aberdeenshire Council, Aberdeen, Scotland

– North Sea Commission, Telemark, Norway

– Department of Sea Fisheries, Oostende, Belgium,

– Danmarks Fiskeriundersøgelse, Charlottenlund, Denmark

– Danmarks Fiskeriforening, Esbjerg, Denmark

– National Federation of Fishermen's Organisations, Grimsby, England

– CEFAS, Lowestoft, England

– Bundesforschungsanstalt für Fischerei, Hamburg, Germany

– Deutscher Fischerei Verband, Hamburg, Germany

– Stichting van de Nederlandse Visserij, Rijswijk, The Netherlands

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[18] This section builds on information from the North Sea Commission's website: http://www.northseacommission.info/ (accessed 12 February 2009).

- Institute for Marine Resources and Ecosystem Studies (IMARES), IJmuiden, The Netherlands

- Norges Fiskarlag, Egersund, Norway,

- Institute of Marine Research, Bergen, Norway

- Fisheries Research Services Marine Laboratory, Aberdeen, Scotland

- Scottish Fishermen's Federation, Aberdeen, Scotland

- Institute of Marine Research, Lysekil, Sweden

- Sveriges Fiskares Riksforbund, Finspåg, Sweden

1.3.1.5   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. Thus 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, based on features of selected EU member states, we 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, for example 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.

1.3.1.5.1 The role of the EU Member States in the CFP Governance System

The conservation of resources is a fundamental pillar of the CFP and under the exclusive competence of the EU, however, this does not mean that member states are powerless to protect marine resources. Importantly, as described in section 1.3.1.3.3, 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 1.3.1.3.1), 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 within their own waters. The basic regulation (Council of the European Union, 2002) and more detailed legislation (e.g. (Council of the European Communities, 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. 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). Adjustment of capacity deals with the question of how to determine which vessels 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 in practice differs from member state to member state; something considered further in the following section. However, in Figure 1.3.1 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, predominantly from industry but increasingly from conservationist NGOs, offering advice both to managers and politicians either through formal or informal channels; and (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. Furthermore, if the state has delegated responsibilities to regional governments, there may be a more complicated picture (see 1.3.1.5.2).

1.3.1.5.2 Variations of National Governance Approaches in Selected EU Member States[19]

The current fisheries governance landscape in Europe is diverse in terms of dominant forms of institutional design. Much of this variation is attributable to the varying political traditions across member states.

In Denmark (and the non-EU member state Norway, see 1.3.1.5.3), the national governance systems are largely influenced by the political environment in Scandinavia where 'negotiation economies' prevail (Hoel et al., 1997;Hersoug, 2005;Christensen et al., 2007;Hegland and Raakjær, 2008a), applying a centralised consultation of user-groups and stakeholders in the decision-making process. This tradition is rooted in the co-operative movement, which started more than a century ago. Policy-making in Denmark fits the tradition of corporatist management, involving industry and user-groups in 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 regional levels as well. In parallel to the rather structured official system (with a relatively clear 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 of imbalanced representation, with over-representation of the fishing industry in state and autonomous communities' consultative bodies providing limited space for

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[19] This section draws intensively on van Hoof et al. (2005).

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, 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 industry participation is very fragmented (Symes, 1996).

1.3.1.5.3 Norway

1.3.1.5.3.1 The National Framework within which the Norwegian Fisheries Operate

Except for the supra-national level which the EU-authorities constitute, the Norwegian institutional set-up very much resembles that of the EU member states (see Figure 1.3.1). The highest authority in Norway is the Ministry for Fisheries and Coastal Affairs, which is responsible for issuing laws and regulations. The executive administrative body is the Directorate of Fisheries, which is a decentralised authority consisting of seven regional offices spread along the coast, in addition to the main office.

Traditionally, fisheries stakeholders have been organised in two types of organisations; 1) the Norwegian Fishermen's Association, encompassing all participants in the harvesting sector, and 2) the Fishermen's sales organisations, of which there is one for pelagic species and several geographically dispersed organisations for demersal species.

The sales organisations are owned by the fishers and have legally protected monopolies in their respective areas regarding the purchase of fish from fishers. Despite the existence of a small organisation for coastal fishers, the Norwegian Fishermen's Association has had a virtual monopoly on representing the interests of the fishers (Gezelius, 2008).

Practically all aspects of (marine) fishing activities are regulated, implemented and executed by the four above mentioned agents. The Ministry never adopts any regulation or law without consulting the Fishermen's Association, and laws and regulations are only adopted in consultation with this Association. On the other hand, The Fishermen's Association takes the task of "disciplining" the members, representing all from small coastal fishers to large shipping companies. Hence, when the Fishermen's Association has approved a proposal from the Ministry, it has the support of virtually the whole fishery industry. This means that most of the fishery policy in Norway is decided by mutual agreements between the Ministry and the Fishermen's Association. The policy is carried out by the Directorate of Fisheries and the Fishermen's sales organisations. The Ministry has delegated crucial parts of the control functions, such as reporting landed harvests, to the Fishermen's sales organisations. Thus, it has made these organisations responsible for part of the implementation and enforcement of laws and regulations.

The very strong inclusion of industry stakeholders in the Norwegian fishery policy has probably made the implementation and enforcement of laws and regulations relatively smooth. For example, the introduction of TACs was in Norway treated as a question of administrative realisation of predefined political aims, rather than as a political tug-of-war regarding the political concerns that would rule the implementation agenda (Gezelius, 2008). Whereas 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), the Norwegian fisheries management typically has been implemented as a bottom-up process (Gezelius 2008). Having made the Fishermen's sales organisations responsible for parts of the enforcement of the regulations, such as the collection of data on landed harvests, also reduces the problem with incomplete and unreliable catch data.

1.3.1.5.3.2   The International Framework within which the Norwegian Fisheries Operate

Norway works through two channels in order to influence the management of commercially important straddling stocks, which they share with other countries (Ministry of Fisheries and Coastal Affairs, 2008):

1) Bi- and multi-lateral agreements with other countries about quotas on specified shared stocks in international waters and specification of access to quotas in the economic zones of other countries and vice versa.

2) Participation in international organisations regulating fishing activities in international waters.

Agreements are renegotiated annually, and the most important bilateral agreements Norway has are with the EU, Russia, Greenland and the Faroe Islands. The agreement with the EU is a framework agreement, entered into in 1978 and is based on mutual understanding of common responsibility for the management of stocks in the North Sea, and mutual access to fisheries within the economic zones of the countries. The Norwegian and EU quotas in the North Sea, the Norwegian fisheries west of the British Islands and the EU fisheries in the Norwegian economic zone in the Barents Sea are negotiated annually.

Norway has a three-country agreement with Iceland and Greenland on capelin, and a three-country agreement with the EU and the Faroe Islands on mackerel. Norway also has a five-country agreement with EU, Iceland, Faroe Islands and Russia with respect to herring.

Norway is member of several international organisations whose aim is to regulate the fishing activities in international waters. Among the most important are the Northwest Atlantic Fisheries Organisation (NAFO) and the Northeast Atlantic Fisheries Commission (NEAFC). The most important tasks of these organisations are to set principles for the management of the common stocks and decide which stocks are necessary to regulate. As an example, the parties in NEAFC have decided to implement ecosystem based management of all resources in its mandatory area.

1.3.1.6   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 (if necessary by means of qualified majority vote (QMV)) 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 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*[20]. 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 complicated 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;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 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 1.3.1); 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.

1.3.2 Selected Reforms of the Current EU Fisheries Governance System

1.3.2.1 Providing a Level Playing Field for the Industry across EU[21]

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 predicted to enter into force from 2010.

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[20] 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).

[21] 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).

1.3.2.1.1 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 only). 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 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 (2008b) 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. Although there was variation across member states, the picture that the report painted was of a system that generally was not functioning properly.

The second 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, although positive developments were duly noted, came to similar conclusions, for example it was noted:

"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 this 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 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 of the European Communities, 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,

"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."[22]

1.3.2.1.2 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 not feasible

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[22] Cited from http://ec.europa.eu/fisheries/cfp/control_enforcement/why_reform_en.htm (accessed 20 February 2009).

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 of the European Communities, 2008a;Commission of the European Communities, 2008b).

As for the remaining three options, both sub-options under option one were found to be unable 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:

> *"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 of the European Communities, 2008b): 5)

The proposed reform along the lines of the third option, currently embodied by the Commission's proposal (Commission of the European Communities, 2008d), 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 areas where the risk of infringements is highest; and reducing the administrative burden partly by using modern technologies. The proposed reform also aims to 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 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 of the European Communities, 2008d;Commission of the European Communities, 2008c).

1.3.2.2 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 has the EU 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 differences are taken into consideration in decision making. A continuation of this effort towards increased regionalisation and stakeholder involvement is likely to be an important part of the upcoming 2012 reform.

1.3.2.2.1 *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 1.3.1.3.1.2). 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[23] in at least two ways.

Firstly, the lack of inclusion of industry stakeholders particularly has been considered to have in part *contributed to the situation of widespread non-compliance with the CFP regulations*, which has come to be regarded as irrational, arbitrary decisions from a distant bureaucratic centre - the Commission – who are 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, fishing 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, particularly those 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.[24] The failure to include this knowledge and therefore to give the industry a feeling of partial ownership over 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 1.3.2.3 beneath) and technical legislation from the Commission. The lack of inclusion was particularly noted by industry stakeholders who felt that their experience-based knowledge was not taken into account by managers, politicians or scientists.

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[23] 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.

[24] 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 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.

Besides the failure to include stakeholders, the CFP has also been accused of being too centralised and lacking in consideration of the different situations in different marine areas of the EU. Aside from the Mediterranean, which has for various reasons never been included fully in the CFP, the CFP framework has largely been applied as a 'one-size-fits-all' management system covering all EU waters; despite, for example, there being little similarities between the fisheries taking place in the Baltic Sea and the fisheries taking place off the coast of Portugal. There has been considerable reluctance in the Council to experiment with regionally 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*
>
> *(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)

1.3.2.2.2 Regionalisation and Greater Involvement of Stakeholders

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 (see section 1.3.1.4.1 for further detail). The RACs constitute so far the most important response to the criticism that (particularly at sub-EU level) stakeholders have not been included to a sufficient degree in the decision-making process at EU level, and that earlier and more consistent 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, particularly for industry stakeholders (Hegland 2006).

RACs were proposed by the Commission as purely advisory bodies in 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 differences between the consensus and other preferences of DG MARE (Hegland and Wilson, 2008).

The extent to which the role of the RACs and the RAC regions will be rethought in the 2012 reform remains uncertain. However, it should be noted that in their review of the CFP award, Sissenwine and Symes (2007) gave special attention to the concept of regionalisation as an option for future management under the CFP. Furthermore, in the first official document from the Commission on the 2012 CFP reform, entitled *Reflections on further reform of the Common Fisheries Policy* ((Commission of the European Communities, 2008e): 8), a move to greater use of *"regional management solutions"* is also mentioned as a major, longer

term reform possibility (possibly post-2012), although the Commission does not 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 may lend support to regionalisation of the CFP.

However, turning again to the way stakeholders are increasingly, directly involved in CFP decision-making, in addition to the increased focus on including stakeholders through the RACs, the Commission is also more frequently inviting stakeholder contribution to proposed initiatives by means of open consultations announced on its website. Table 1.3.3. demonstrates that open consultations attract contributions from a wide variety of stakeholders however, the extent to which these consultations impact on Commission policy is not clear.

Table 1.3.3: Contributions received: open consultation on control reform (consultation closed 5 May 2008)[25]

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 Organisations de Producteurs dans le secteur de la pêche
	Europêche/COGECA
	SHOAL: Shetland Oceans Alliance
NGOs	WWF
	Coalition for Fair Fisheries Arrangements
	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
Individuals	Prof. Corrado Piccinetti
	Johnny Woodlock, Sea Fisheries Advisory Group, Irish Seal Sanctuary

Overall, in terms of industry involvement, the Commission document on the 2012 reform strongly emphasises the need to move past the present decoupling of rights and responsibilities so that it becomes

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[25] From http://ec.europa.eu/fisheries/cfp/governance/consultations/consultation_280208_contributions_en.htm (accessed 23 February 2009).

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 of the European Communities, 2008e): 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 of the European Communities, 2008e): 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. Stakeholders are increasingly consulted through RACs or in other ways, however there is still little or no role for them in terms of decisions making or responsibility for management functions.

1.3.2.3   Restructuring the Scientific Advice System relating to the CFP

The system that feeds scientific advice to the CFP decision-making process has in recent years been criticised on a number of points. The following sections highlight some of the main issues and briefly examines what has happened in response to the demand for reform and restructuring.

1.3.2.3.1 Describing the Problem

One of the major issues with the scientific advice system for EU fisheries management has been the imbalance between the status and quantity of biological advice compared to advice based on other forms of science. As indicated in Figure 1.3.1, which is the simplified picture of the institutional set-up, biological institutions dominate the picture. STECF does include economic expertise and most member states institutions or individuals also 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.

In the few cases, where socio-economic aspects are being considered they do not address important social issues, such as community development, and long-term societal effects are rarely considered during the development of management measures. Economic analyses are often of a bio-economic nature or merely an addition of cost and earning data in a short term perspective. Overall, the availability of comparable and quality checked data is considered higher for biological issues than economic or socio-economic issues.

A further issue has been the inability (or lack of interest from the biological advice system) to include fishermen's experience-based knowledge in analyses, or to give fishermen a better understanding of how the biological advice system works. This mirrors concerns about the limited inclusion of stakeholders in the overall CFP decision-making process presented above. It is considered that the lack of transparency and openness of the biological advice system has 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; that its supporting scientific processes, which are fundamental for CFP outcomes, have taken place behind closed doors has not been conducive for the general support of the CFP. To many of those outside of this process, the system appears to be a black box: catch data (sometimes of questionable quality) is inserted at one end and TACs come out of the other end.

A final issue related to scientific advice for the CFP is timing, in particular the fact that 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, 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 know in advance what fishing opportunities will be open to them in the coming year.

1.3.2.3.2 *Reforms of the Scientific Advice System*

The scientific advice system has recently 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 non-biological issues available and thus conducive for a strengthening the possibility of advice from scientific disciplines not just 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 impacted on the science system and strengthened the role of stakeholders in that process. ICES now have a range of stakeholder institutions with which it can interact. Moreover, ICES has reorganised its internal committee structure to facilitate the kind of integrated advice that will be needed for implementing an EAFM.

In response to the timing issue, ICES has streamlined its processes to make 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, from 2008 advice will come earlier and this will allow more time to hear stakeholders views and eventually also allow the industry to know its fishing opportunities earlier.

1.3.3　Management tools

The management tools used to control fishing activities can be divided into three overarching groups; input and output management, and economic incentive mechanisms. In the following sections we briefly describe some central tools within these 3 groups; more detailed study of management tools will be carried out in WP3.

1.3.3.1　Input management

Input management measures aim at controlling the input used in a fishery. The concept is to restrict (control) the input used in a fishery along different dimensions; area restrictions, time restrictions, entrance restrictions, gear restrictions, bycatch reduction devices.

Area restrictions refer to the closure of some physical area in the ocean, permanently or for a limited time period, for all fishing activity or for some fishery/gear/vessel types.

Time restrictions refer to the limitation of time spent on fishing, be it individual time limitations, such as days at sea, or overall limitations such as seasonal closures with regard to a fishery, gear or vessel type.

Entrance restrictions usually apply to (types of) vessels. It is used to prevent certain types of vessels from taking part in specific fisheries or to regulate the number of vessels taking part in these fisheries. Typically this kind of restriction is formulated such that vessels need a permission or licence to take part in a fishery managed by entrance restrictions.

Gear restrictions are used to regulate the types of gears to be used in specific fisheries. It is also applied to regulate the properties or amount of gear, e.g. mesh size, number or size of gillnet, traps, etc.

There also exist regulations that impose bycatch reduction devices upon vessels taking part in specific fisheries. This is in order to reduce the catch of vulnerable and non targeted species in a specific fishery.

Input restrictions have long historic traditions and are very common in fisheries, and all the above may be present in one single fishery. Regulating what is taken out of a fishery, or output regulation, is more recent, but has been present in industrial fisheries for many decades.

1.3.3.2　Output management:

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

TAC (total allowable catch) is a fundamental regulatory tool in the CFP, and it sets the upper limit for the total catches of each commercial species for the EU. The total catch is then divided between each member state according to specific distribution formula, and it is then up to each member state to perform a further distribution on vessel types, gear types or according to other criteria.

Individual quotas imply that the member states distribute their share of the total quota (TAC) or parts of it to vessels (i.e. their owners). Usually the vessels already active in a fishery are assigned quotas for free (grandfathering), and the allocation of these quotas to individual vessels (owners) is usually carried out based on historic catches and participation in a fishery. As the intention of quotas is often to limit or reduce the effort or participation in a fishery, new participants usually have to buy quotas.

Bycatch regulations involve rules for what type and/or age/size of bycatch species can be landed and/or the absolute or relative size of the bycatch.

Minimum landing size implies that the fish or other catch which is landed must be above a specified minimum size.

1.3.3.3 Economic incentive mechanisms

These are measures with which a manager (the authorities) tries to direct the behaviour of the fishers in specific (preferred) directions. The most prominent examples are tradable quotas, taxes and subsidies.

Individual tradable quotas (ITQs) are individual quotas (see above) that can be bought and sold (or leased) in a market. This implies that when a vessel (owner) is assigned a quota he/she may sell the whole or part of the quota to other vessel owners, depending on the limitations set. Usually there will be restrictions with regard to whom the quota may be sold. Allocating quotas to individuals (vessels) based on historic catches does not take into consideration economic efficiency. With tradable quotas, the idea is to develop a market for quotas such that the most efficient fishers (vessels) are those that appropriate the largest share of the TAC.

Tradable effort quotas are similar to ITQs, only here the entities of trade are some input or effort limitation, most commonly days at sea. Here again the most efficient agents can pay the highest price, leading to more efficient fisheries.

Depending on how the quotas are set, the fishery may create so called "resource rent", i.e. profits in excess of normal profits and remuneration of capital and labour, due to the fact that fish is a free input supplied by nature. Similar resource rent can be secured in an open access fishery where effort is limited by taxes or fees;

Taxes/fees: a tax on catch or inputs in the fishery reduces the effort exerted in an open access fishery, and the resource rent is appropriated through the tax. Likewise, a licence fee can function as a fixed tax lifting the start-up costs of fishing and thereby limiting effort.

Subsidies to fishery activities have been relatively widespread. Historically they have been applied both to harvests and to inputs. The most common subsidies today refer to ship building and buy-back or decommissioning schemes in order to reduce the number of vessels in a fishery. Some "green policy" subsidies have also been applied, in order to encourage less polluting or more environmentally friendly fishing technologies.

Table 1.3.4. Management tools and their dispersion in selected EEA member states

	Portugal	Spain	France	Nether-lands	UK	Ireland	Denmark	Norway
Input management								
Area restrictions	X	X	X	X	X	X	X	X
Time restrictions	X	X	X	X	X	X	X	X
Entrance restrictions	X	X	X	X	X	X	X	X
Gear restrictions	X	X	X	X	X	X	X	X
Bycatch reduction dev.		X	X	X	X	X	X	
Output management								
TAC	X	X	X	X	X	X	X	X
IQ/EQ	X	X		X	De facto		X	X
Bycatch reg	X		X		X	X	X	X
Min landing size	X	X	X	X	X	X	X	
Economic incentives								
Tradable IQ	X	X		X	De facto		X	X
Taxes/fees			X	X	X			X
Tradable effort quotas	X	X		X	De facto			
Subsidies	X	X (CFP)	X	?	X (indir)	X		X (indir.)

Indir means that fishing vessels are exempted from ordinary fuel taxes.

Table 1.3.4 gives an overview of the management tools applied by some selected EEA member states. As can be seen, most countries combine a wide selection of management measures. As long as the fishery activity serves multiple aims and is subdued to several considerations, having access to a selection of

measures increases 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.

On the other hand, the combination of a series of management tools may also be the result of trying to remedy failing effect from one tool by introducing a new tool or adding new tools when the first does not have the intended effects. Hence, a combination of very many tools does not necessarily imply a good management system.

The problem with choosing 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, meaning one measure revokes the effects of another. Furthermore, with several regulations and measures, the enforcement becomes a complex task; where enforcement becomes less strict, the agents in the fishery sector may find it profitable to cheat as the probability for being caught is low. These issues will be discussed further in WP3.

1.3.4 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 is 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 fisheries, as many of the people employed in the sector do not work full time due to input restrictions and other regulations,

Below we present value added and employment, measured as FTE, in the fishery sector and in the economy as a total for selected European 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 1.3.5. Gross domestic product (GDP) and value added in the fisheries in some European fishing nations (MEFEPO partners), current prices, 2006. Source: Preparation of Annual Economic Report (SGECA 08-02), Eurostat: National accounts.

	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	1,807,462	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	1,938,979	354	0.02

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

Table 1.3.6. Total employment and employment in the fisheries and in fish processing in some European fishing nations (MEFEPO partners). 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.

	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

The value added in the fishery sector shown in Table 1.3.5. only encompasses catching the fish. No processing or transportation is included in these figures. With 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, with the exception of Denmark (0.1%) and Norway (0.3%). 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 a 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 across countries these shares are underestimates, yet it is apparent that direct fishery related employment contributes a small proportion to total national employment in the selected countries. Although the inclusion of employment from processing increases the relative shares up to a maximum of 0.88%, the picture is not changed substantially.

Comparison of Table 1.3.5 and Table 1.3.6 indicates that for the majority of countries the fisheries' contribution to 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 to this rule are Ireland, Portugal and Spain, where the fisheries' share of total employment is higher than the share of GDP, thus (labour) productivity in these fisheries is lower compared to the average labour productivity in the economy. However, the assumptions that the fisheries' share of employment is an underestimate strengthens the argument that labour productivity in the fisheries is also lower than average labour productivity in the economy for the other countries listed in Table 1.3.5 and Table 1.3.6.

As a whole, the EU is a large net importer of fish and net imports in 2006 amounting to €13,680M[26]. Measured in nominal values Norway, Denmark, Ireland and Netherlands were net exporters of fish products (although Denmark was a net importer when measured in tonnes), whereas the remaining countries were net importers of fish products (Table 1.3.7). Table 1.3.7. also demonstrates that fish products constitute a more significant share of total exports compared to their share of GDP[27]. Though aquaculture is included in the export data, it is still likely that this conclusion holds for harvested products as the average export share equals 1.17% compared to the GDP share with an average of 0.08%. Table 1.3.8 indicates that the export share of fish products exceed all countries' share of GDP. This indicates that fish products may be more important for the foreign trade of some selected European fishing nations (MEFEPO partners) than for the national production (gross value added as expressed by GDP).

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[26] 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.
[27] 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.

Table 1.3.7. Total exports and exports of fish products for some European fishing nations (MEFEPO partners), current prices, 2006. Source: Eurostat: National accounts

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

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 we have compare with agriculture. Table 1.3.8 shows that the agricultural sector clearly contributes more significantly to the national economy than the fishing sector in terms of gross value added and employment. However, it terms of labour productivity the fishing sector far surpasses the agricultural sector, thus the contribution per worker to GDP is higher in the fishing sector than the agricultural sector. Taking into consideration the subsidisation of the sectors, this conclusion is strengthened.

Table 1.3.8. Gross value added in the agricultural sector, farm labour force and productivity in the agricultural sector and the fishing sector, 2006. Source: Eurostat: Yearbook 2008

	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

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[28]. However, the narratives connected to the cases presented in the matrix in section 2.2 will give some (qualitative) information about such effects.

Furthermore, in all of the countries listed in the tables there are regions where fisheries are an important sector of the economy and where a substantial part of the population works in the fisheries or fisheries related activities. Table 1.3.9. provides examples of fisheries dependence based on 17 communities located on the coast of the North Sea in which a high share of the employment was in traditional fisheries and related industries. These shares are considerably larger than the national employment shares summarised in above (Table 1.3.6.).

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 2.2.

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

Table 1.3.9. Fisheries dependent communities around the North Sea: population, share of total employment in the fishery sector and other fishery relevant characteristics. Source: EFEP (European Fisheries Ecosystem Plan): Annex 1 Second Stakeholder Consultation.

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 Europe's 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 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 (Netherlands)	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 expense 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 expense 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

2 Interaction between the ecosystem and fisheries case studies

2.1 Description of fisheries case studies

Due to difficulties in dealing with all types of fisheries and gear types, the MEFEPO project has selected case studies that include a mixture of gear types and trophic levels across the 3 project regions (North Sea, North West Waters and South West Waters). In the North Sea RAC region, four fisheries are selected (Table 2.1.1) for their socio-economic importance and their impact on the North Sea ecosystem; the rationale for their selection is discussed below.

Table 2.1.1. The four case studies selected for the North Sea RAC region and their targeted species.

Case study	Target species
Mixed flatfish Beam trawl	Sole (*Solea vulgaris*) Plaice (*Pleuronectes platessa*)
Sandeel industrial fisheries	Sandeel (*Ammodytes* sp.)
Pelagic herring fisheries	Herring (*Clupea harengus*)
Demersal mixed whitefish fisheries	Cod (*Gadus morhua*) Haddock (*Melanogrammus aeglefinus*) Whiting (*Merlangius merlangus*)

2.1.1 Mixed flatfish Beam trawl

The beam trawl derives its name from the beam supported by the two shoes at either end. The net is attached to the beam, shoes and ground rope, thus the mouth of the net is held open regardless of the speed at which it is towed. Shoes of the beam glide across the surface of the seabed and prevent the beam from sinking into soft substrata. In some cases, the shoes of the beam are enhanced with wheels to reduce the drag. Beam trawls are deployed with tickler chains to disturb or dig out the target species. The larger beam trawls can be fitted with more than 20 tickler chains and penetrate soft sands to a depth of more than 6 cm. Beam trawls with standard tickler chains tend to be fished over clean ground as on rougher grounds the net would soon fill with rocks. To be able to fish on rougher ground chain mats are added, along with a flip up gear fitted to the ground rope.

In the North Sea, two principal métiers are usually distinguished: "large vessels" with an engine power of 221 kW or more, and "eurocutters", with an engine power <221 kW and a maximum length of 24 metres. The large vessels deploy two 12m beam trawls and are not allowed to fish inside the 12 mile coastal zone or the "plaice box", whereas eurocutters deploy two 4.5m beam trawls and are allowed to fish inside those areas (Piet et al., 2007;Rijnsdorp et al., 2008).

Mesh size regulations applying to beam trawls prohibit the use of any mesh size between 32 to 119 mm in the greater North Sea, north of 56° N. However, it is permitted to use a mesh size range 100 to 119 mm within the area enclosed by the east coast of the UK between 55° N and 56° N and by straight lines sequentially joining the following geographical coordinates: a point on the east coast of the UK at 55° N, 55° N 05° E, 56° N 05° E, a point on the east coast of the UK at 56° N, provided that the catches taken within this area with such a fishing gear and retained on board consist of no more than 5% cod. In the southern North Sea, it is permitted to fish for sole south of 56° N with 80- 99 mm meshes in the cod end, provided that at least 40% of the catch is sole, and no more than 5% of the catch is composed of cod, haddock and

saithe (*Pollachius virens*) (ICES, 2008f). In the Skagerrak, Beam trawls with a mesh size >80mm can fish between 132 and 155 days per year, and in the Kattegat beam trawlers are not allowed.

The case study focuses on the beam trawl fisheries targeting sole and plaice. These beam trawlers using mesh sizes of 80-89mm centred on the southern North Sea take the majority of the catches of plaice and sole and are much more important than other gear categories in terms of both weights and numbers removed (STECF, 2008c). However, in efficiency terms, the large beam trawls with a mesh size >100mm are most efficient in capturing plaice, with a ninth place for the beam trawl with a mesh size of 80-89mm (Table 2.1.2.). For the capture of sole the most efficient gears are trammel nets and gillnets with a third place for the beam trawl with a mesh size of 80-89mm fishing in the Eastern Channel and a fifth place for these gears fishing in the North Sea and Skagerrak (Table 2.1.3.)(STECF, 2008c).

Table 2.1.2. Top 10 most efficient gear categories for catching plaice. Ranking is based on the CPUE in 2007. Table modified from (STECF, 2008c), which categorized the gears even further based on special condition specified in annex IIA to Council Reg. 40/2008.

Rank	Gear	Mesh size (mm)	Area	CPUE 2007
1	Beam trawl	>120	North Sea, Skagerrak	2038
2	Beam trawl	>120	North Sea, Skagerrak	1968
3	Beam trawl	100-120	North Sea, Skagerrak	1853
4	Beam trawl	100-120	North Sea, Skagerrak	1634
5	Beam trawl	100-120	North Sea, Skagerrak	1631
6	Gillnets	110-150	North Sea, Skagerrak, Eastern Channel	1512
7	Beam trawl	>120	North Sea, Skagerrak	1468
8	Trawls	100-120	North Sea, Skagerrak, Eastern Channel	1448
9	Beam trawl	80-89	North Sea, Skagerrak	1202
10	Trawls	100-120	North Sea, Skagerrak, Eastern Channel	1139

Table 2.1.3.: Top 10 most efficient gear categories for catch sole. Ranking is based on the CPUE in 2007. Table modified from (STECF, 2008c), which categorized the gears even further based on special condition specified in annex IIA to Council Reg. 40/2008.

Rank	Gear	Mesh size (mm)	Area	CPUE 2007
1	Trammel net		Eastern Channel	854
2	Gillnets	<110	North Sea, Skagerrak, Eastern Channel	830
3	Beam trawl	80-89	Eastern Channel	656
4	Trammel net		North Sea, Skagerrak	654
5	Beam trawl	80-89	North Sea, Skagerrak	352
6	Trawls	70-90	Skagerrak	185
7	Trammel net		North Sea, Skagerrak, Eastern Channel	142
7	Beam trawl	100-120	Eastern Channel	142
9	Gillnets	110-150	North Sea, Skagerrak, Eastern Channel	125
10	Trawls	70-90	North Sea, Skagerrak, Eastern Channel	118

Other species landed by the beam trawl are flatfish species e.g. turbot (*Psetta maxima*), brill (*Scophthalmus rhombus*), dab (*Limanda limanda*) and lemon sole (*Microstomus kitt*); Roundfish species e.g. cod, haddock, whiting, monkfish (*Lophius piscatorius*), tub gurnard (*Trigla lucerna*) and seabass (*Dicentrarchus labrax*); Skates and rays e.g. thornback ray (*Raja clavata*); Molluscs e.g. common whelk (*Buccinum undatum*) and Crabs e.g. edible crab (*Cancer pagurus*). Besides the landed species, a part of the catch is discarded. The discards consist of undersized landed species, high-graded species (species that can be landed, but are discarded because of low value or low TAC), and non-commercial fish and benthos species. The top ten discarded species in the beam trawl in the North Sea are presented in Table 2.1.4. (STECF 2008). Undersized plaice were estimated to make up 54% of weight and 82% of numbers in the Dutch 80-89mm beam trawl, for sole this was 23% to 29% in numbers and 10% to 13% in weight (van Helmond and van Overzee, 2008).

Table 2.1.4.: Top ten discarded species by country for the beam trawl in weight and numbers based on data reported by (STECF, 2008a).

UK (n=12)		Netherlands (n=28)	Belgium (n=18)	Germany (n= 15)	
Weight	Numbers	Weight & numbers	Weight	Weight	Number
Plaice	Plaice	Dab	Plaice	Plaice	Dab
Dab	Dab	Plaice	Cod	Dab	Plaice
Sole	Sole	Scaldfish	Sole	Red starfish	Scaldfish
Lemon sole	Lemon sole	Solenette	Ray sp.	Whiting	Whiting
Cod	Common cuttlefish	Dragonet	Lemon sole	Gurnards	Gurnards
Common cuttlefish	Edible crab	Grey gurnard	Dab	Solenette	Sole
Haddock	Great Atlantic scallop	whiting	Brill	Cod	Cod
Thornback ray	Whiting	Sole	Turbot	Sole	Dragonet
Turbot	Thornback ray	Tub gurnard	Gurnards sp.	Dragonet	European flounder
Brill	Haddock	Sprat	Whiting	Starry ray	Tub gurnard

The beam trawl fishery in the North Sea has been dominated by the Dutch fleet but this has been decreasing in more recent years, for example in January 2008, 23 Dutch trawl vessels were decommissioned. However, in some cases, reflagging vessels to other countries has partly compensated these reductions (ICES, 2008f). Approximately 85% of plaice landings in the UK (England and Scotland) are landed by Dutch vessels fishing on the UK register. The decrease in fleet size may have been partially compensated by slight increases in the technical efficiency of vessels. In the Dutch beam trawl, fleet indications of an increase in technical efficiency of around 1.65% per year was found over the period 1990 – 2004 (Rijnsdorp et al., 2006). The beam trawl effort has spread out from the coastal and offshore areas of the southern North Sea, into coastal areas of Germany and Denmark and northern offshore areas of the Doggerbank and central North Sea since the 1970s, but effort was concentrated again in more southern offshore fishing areas in the 1990s. These changes in effort allocation reflect a change in targeting from sole to plaice in the 1970s, and back to sole during the 1990s (Rijnsdorp et al., 2008).

The direct economic value of the North Sea beam trawl fleets in 2003 is represented in Table 2.1.5. (STECF, 2008b). In terms of total gross national product the beam trawl fisheries are not very important. However,

fishing is one of the most important traditional industries around the North Sea and is vital to local economies. The high price of fuel and the relatively low biomass of sole and plaice jeopardize the survival of the large beam trawl fleet (Rijnsdorp et al., 2008). A number of vessels have already switched to other fishing methods such as 'twinrigging' (12 vessels) and 'snurrevaed' or 'fly-shooting' (5 vessels). Also of interest are technical developments, mainly to reduce fuel consumption, including pulse trawling (Van Marlen et al., 2006) and sumwing (www.sumwing.nl). The prospects of the fleet are further threatened by the impacts of this fishery on the ecosystem. Because beam trawling has a high potential to cause collateral damage to other components of marine ecosystems, including fish and benthic invertebrate communities as well as seabed habitat, it has long been the focus of considerable scientific attention. Due to the impacts on the ecosystem, this fleet is in the line of fire of various NGO's; Greenpeace describes beam trawling as "one of the most destructive forms of bottom trawling" and WWF says: "Bottom trawling is described as the most destructive of all fishing practices".

Table 2.1.5. Total number of vessel, the value of the landings and the employment of the beam trawl fleet in 2006. The fishery by the beam trawl fleet is not exclusively based in the North Sea (STECF, 2008b).

Country	Gear	Number of vessels	value of landings (mEuro)	employment (FTE)
Belgium	<24m.	49	18.86	178
	24-40m	53	69.15	352
Germany	<24m.	247	39.3	
Netherlands	<24m.	188	47.3	502
	24-40m.	42	36.1	210
	>40	84	139.2	525
UK	<24m.	60	6.4	109
	24-40m.	52	26.9	281
	>40	15	15.2	84
Denmark	<24m.	29	10	59
	24-40m.	6	7	31
Total		825	415.41	2331

2.1.2 Sandeel industrial fisheries

The industrial fisheries main target species are sandeel and Norway pout (*Trisopterus esmarki*) using (pelagic) trawls with a mesh size as small as 5mm. Less important industrial fisheries exist for sprat (*Sprattus sprattus*), horse mackerel (*Trachurus trachurus*) and blue whiting (*Micromesistius poutassou*). The landings are reduced to extract meal and oil that are principally used to feed animals in agriculture and aquaculture. Some oil is added to human food such as biscuits and margarine.

The industrial fishery in the North Sea RAC region is predominantly practiced by Denmark and Norway, but some other countries also participate on a smaller scale e.g. UK, Faeroe Islands, Sweden. The landings of the industrial fisheries are the largest segment of the Danish fisheries by weight (STECF, 2008b) and the sandeel fishery is the largest single species fishery in the North Sea.

On a European scale, the industrial fisheries, with total landings at 2,970,000 tonnes, had a turnover of €211mln and 4920 jobs (STOA 101/2001) (Figure 2.1.1.). Before 2002, the Danish fleet involved fully or partly in industrial fisheries comprised more than 300 vessels and involved around 1,000 persons on board the boats (Official Journal of the European Union, written question E-2193/02). The Danish industrial sandeel fleet has changed through time, with a tendency towards fewer and larger vessels. This change was especially apparent in 2005, when only 98 Danish vessels participated, compared to 200 vessels in 2004.

The introduction of individual tradable quotas (ITQ) accelerated the change towards fewer and larger vessels, and in 2008 only 83 vessels participated (ICES, 2008f). The same tendency was seen for the Norwegian vessels fishing sandeels until 2005. In 2006, only 6 Norwegian vessels were allowed to participate in an experimental sandeel fishery in the Norwegian EEZ. In 2007 and 2008, 41 and 42 Norwegian vessels with individual quotas participated respectively. From 2002 to 2008, the average gross registered tonnage per trip in the Norwegian fleet increased from 269 to 507t. Since 1998 only 7 of the Norwegian vessels remained unaltered, all others were extended or a larger engine was installed. This likely increased the efficiency of the fleet (ICES, 2008f).

Shares in turnover of the industrial fisheries

Non-North Sea 26%
Denmark 47%
Netherlands 7%
UK 9%
Sweden 11%

Figure 2.1.1. Turnover in the European industrial fisheries, with the North Countries specified (STOA 101/2001)

The sandeel fishery is a seasonal fishery. In 2008, the season opened on 1st April, both in the EU zone and in the Norwegian EEZ. The Norwegian fishery, however, started with only one landing before 20th April and was temporarily closed in May in accordance with agreed effort limitations for the monitoring fishery (ICES, 2008f). The sandeel fishery with trawled gear with a mesh size <16mm is prohibited from 1st August till the end of the year. In addition to regulations in time, restrictions on areas are also used as management solutions, therefore smaller areas in the Norwegian EEZ were closed in 2008. The sandeel fishery in 2008 included most of the grounds that have contributed to the fishery in recent years (Figure 2.1.2), except for the most northerly fishing grounds where there have been no landings over last 8 – 12 years (ICES, 2008f).

Several species are caught as by-catch in the industrial fisheries. The by-catch of human consumption species is landed as such whilst undersized and non-consumption species are landed for reduction into fish meal and oils. The main by-catch species are herring, cod, haddock, whiting, mackerel, saithe and grey gurnards (*Eutrigla gurnardus*). The by-catch of undersized human consumption species is a topic of
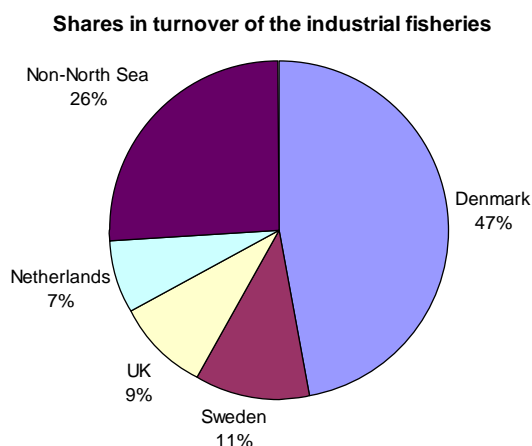
discussion owing to its possible negative effects on the catch for human-consumption. This is a discussion between fishermen, while the overall concern is whether removal by the industrial fisheries causes food deprivation for predators such as larger fish, seabirds and marine mammals. Specifically the removal of sandeel, which is a key prey linking trophic levels (Furness, 1990;Furness, 2002;Frederiksen et al., 2005). These concerns have led to the closure of an area in the Firth of Forth for sandeel fisheries since 2000 (ICES, 2008f). There is presently no decision on whether a full commercial sandeel fishery will be reopened in this area.
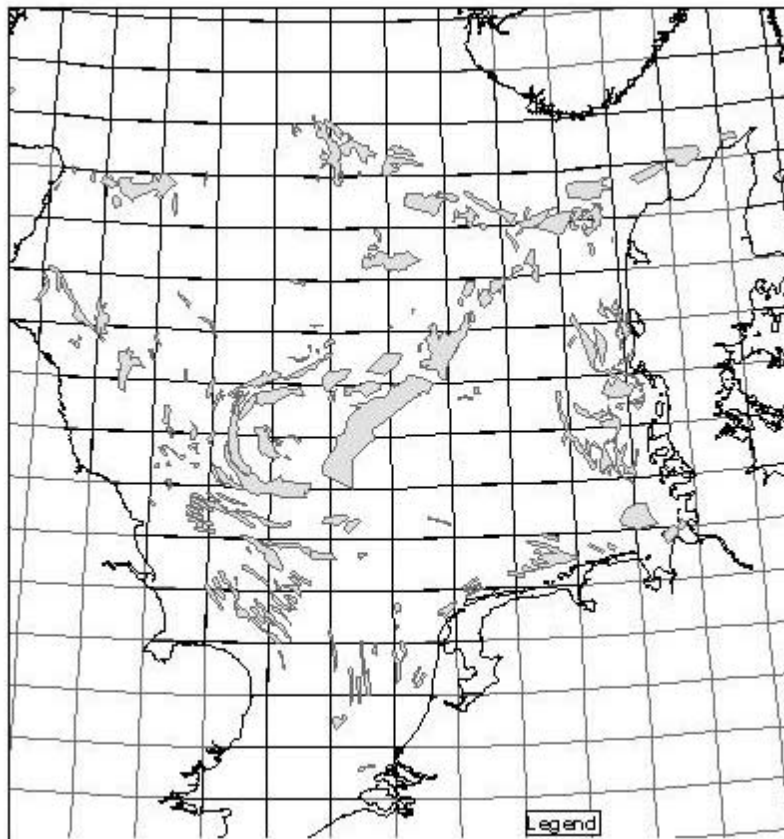

Figure 2.1.2. Spatial distribution of sandeel fishing grounds (INEXFISH, 2008).

2.1.3   Herring pelagic fisheries

Pelagic trawls target small pelagic species that usually swim in shoals. The shoals are located with the use of echo-sounding equipment. The echogram provides information on the location, size and position of a shoal in the water column, which makes this fishery very efficient in targeting fish. Theoretically, 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). Relatively large amounts of catch are released from the cooling tanks (tank slippage) or straight from the net (net slippage) also resulting in discarding.

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 herring 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 sounder attached to the net gives information on the position of the net in relation to the seafloor and the vertical opening of the net. In order to catch a shoal, the net has to be put in such a position that the net opening cuts off 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 sorted catch (landings) is transported to frosters where they are frozen into blocks of 20-25 kg fish. The duration of each fishing trip depends mainly on the catch rate and storage capacity of the ship. The vessels usually return when all freezing stores are full.

Pelagic trawls are used, amongst others, to catch herring. In the period 2000-2004 herring landings were primarily from the western and northern North Sea (ICES, 2006). The landings of North Sea herring for human consumption were 353,900 tonnes in 2007 (ICES, 2008a).

Various pelagic herring fisheries in the North Sea are certified with the Marine Stewardship Council (MSC) label. The MSC certification process recognises and rewards sustainable fishing, and certified companies have to show willingness to make their fishery sustainable. It is, however, a commercial initiative and benefits the certificated companies through higher prices and a larger sales market. One of the MSC terms is that the stock is well managed and for North Sea herring there is a well defined management system in place. Fisheries are managed through the Common Fisheries Policy of the European Union in accordance with the EU-Norway agreement.

Herring is the key pelagic species in the North Sea and is thus considered to have a major impact as prey and predator to most other fish stocks in that area (ICES, 2008a). From a biological point of view it is therefore thought to be an interesting case study.

2.1.4   Mixed demersal whitefish trawl fishery

The mixed demersal whitefish fishery targets demersal round whitefish that feed at or near the bottom. Within this fishery, an otter trawl, a large, usually cone-shaped net, is towed across the seabed. Rectangular boards (otter boards) are used to keep the mouth of the net open during trawling. The hydrodynamic forces playing on the boards push the net outwards. The otter boards have to be towed at a certain speed (depending on their size) for this effect to be achieved. The distance between otter boards during a tow is between 60 and 120 metres and the whole under-surface may come into contact with the substrate. However, only a proportion of the entire width of the gear penetrates the sea bed (EFEP, 2001). The long-term damage of such penetrations in benthic habitats depends partly on the substrate type.

Floats and/or kites on the headline and weighted bobbins attached to the foot rope maintain the vertical opening of the net. The design of the bobbins depends on the roughness of the sea bed which is fished. Otter trawls adapted for fishing over rocky grounds are known as rockhopper trawls. Tickler chains are used within this fishery, but their numbers are usually limited (EFEP, 2001). Otter trawls can be equipped with nets having different mesh sizes, which differ in target fish and in rules applying to them. The otter trawls with ≥120mm mesh, correspond to the directed whitefish fishery, with landings consisting mostly of haddock, saithe, cod, whiting, monkfish and plaice. This fishery has the highest impact in terms of both weight and numbers of cod removed in the North Sea (STECF, 2008c), gillnets are however more efficient in catching cod (Table 2.1.6.). The otter trawl is also used in a directed saithe fishery by vessels fishing under the special condition that the percentage of cod, sole and plaice in the landings should be less than 5%. This fishery also takes some haddock, but has relatively little by-catch of other roundfish species. Significant landings of saithe are also made by otter trawls with 100-119mm mesh size fishing under the same special condition.

The discards in this fishery consist of undersized target species, non-commercial species and other vertebrates (EFEP, 2001). The top ten discarded species in the demersal trawl and demersal seiner fishery are presented in Table 2.1.7., based on data from STECF (2008). Unfortunately, data is not available for the otter trawl fishery targeting whitefish specifically.

The use of otter trawls with mesh sizes of 90–99 mm is mostly associated with Danish and Swedish vessels fishing in the Skagerrak, and, to a lesser extent, the eastern North Sea. This fishery takes account for most cod landings in the Skagerrak. The same gear is used by the UK *Nephrops* fisheries. The *Nephrops* fishery in the central and northern North Sea also uses otter trawls with a mesh size of 70-89, which is also used by the whiting fishery in the southern North Sea (STECF, 2008c). Otter trawling targeting whitefish takes place across the entire North Sea with highest levels in the North (MAFCONS, 2007).

Table 2.1.6. Top 10 most efficient gear categories for catch cod. Ranking is based on the CPUE in 2007. Table modified from (STECF, 2008c), which categorized the gears even further based on special condition specified in annex IIA to Council Reg. 40/2008.

Rank	Gear	Mesh size (mm)	Area	CPUE 2007
1	Gill net or entangling net	160	North Sea, Skagerrak, Eastern Channel	4121
2	Gill net or entangling net	110	North Sea, Skagerrak, Eastern Channel	1442
3	Trawl or Danish seine	120	North Sea, Skagerrak, Eastern Channel	934
4	Longlines	-	North Sea, Skagerrak, Eastern Channel	704
5	Trawl or Danish seine	90-99	North Sea	601
6	Trawl or Danish seine	90-99	Skagerrak, Eastern Channel	553
7	Trammel net	100	North Sea, Skagerrak, Eastern Channel	512
7	Trawl or Danish seine	120	North Sea, Skagerrak, Eastern Channel	504
9	Trawl or Danish seine	70-89	Skagerrak	452
10	Trawl or Danish seine	100	North Sea, Skagerrak, Eastern Channel	382

Table 2.1.7. Top ten discarded species by country for the demersal trawl and demersal seiner in weight and numbers based on data reported by (STECF, 2008a).

UK (n=36)		France (n=19)	
weight	numbers	weight	number
Saithe	Whiting	Dab	Queen scallop
Cod	Plaice	Queen scallop	Dab
Plaice	Dab	Plaice	Pouting
Whiting	Saithe	Pouting	Plaice
Haddock	Lemon sole	Spinous spidercrab	Velvet swimcrab
Pollack	Cod	Velvet swimcrab	Dragonet
Ling	Haddock	Dragonet	Sole
Lemon sole	Nephrops	Whiting	Common cuttlefish
Thornback ray	Starry ray	Sole	Whiting
Angler	Sole	Great Atlantic scallop	Horse mackerel
Germany (n=10)		Denmark (n=14)	
weight	numbers	weight	number
Dab	Dab	Starry ray	Starry ray
Plaice	Plaice	Plaice	Dab
Gurnards	Gurnards	Dab	Plaice
Starry ray	Long rough dab	Grey gurnard	Grey gurnard
Nephrops	Starry ray	Cod	Haddock
Long rough dab	Dragonet	Haddock	Cod
Red starfish	Whiting	Lemon sole	Lemon sole
Whiting	Tub gurnard	Angler	With flounder
Horse mackerel	Horse mackerel	With flounder	Angler
Dragonet	Nephrops	Turbot	Turbot

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.

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 the MEFEPO project chose a set of variables, describing the socio-economic impacts of selected EU fisheries (see 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 will be made operational will differ between the three groups.

2.2.1.2.1 *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 it is possible 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.

2.2.1.2.2 *The economic value of catches*

The AER provides data on fish prices both on EU and on member state level.

In most fisheries several countries participate; data on prices per species (Euro/kg) are given in AER, and reflect the fact that the price of the same species can vary between countries. It would be possible to apply the price achieved in the country which has the dominant catch of the specific species; however this may be confusing and could also give a biased estimate in cases where more than one country has a substantial catch of the species. Therefore, we have chosen to construct price indices using the following methods:

1) Single species fisheries: The price index consists of the first hand price (Euro/kg), for the species in each country taking part in that fishery. A weighted average of these prices is then generated, using the country's share of the total catch in that fishery in each of the three selected sea areas for the weighting.

2) Multi species fisheries: A price index for single species fisheries is constructed as above. Then 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, a price index is made 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.

2.2.1.2.3 *Employment and productivity*

Employment is a crucial indicator of the significance of fisheries for society, and fishery based employment encompasses both the fishers (fleet) and processing labour (land plants).

Unfortunately there is no annually updated statistical report or database providing these employment data on species and fishing area level which could be utilised for the matrix. Data are not readily available for processing labour, they do exist for the fleet but require manipulation therefore we divided 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 split by gear- and vessel types within each country. However, they are not split by fishing area or species which are the two categories

utilised in the matrix. As a result, 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 but 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, the project has identified 1-3 main gear and vessel types in the countries which are most important for the specific case species. We then calculate a productivity indicator for each gear and vessel type. This is also done for the most active countries participating in the fishery. Finally, a weighted average is made of the productivity indicators above where the weights are the relative share caught by the nation-gear/vessel types in the fishery under consideration to provide 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 land based fishery activities are scarce. A report, prepared on behalf of and financed by the European Commission, called "Employment in the fisheries sector: current situation" (FISH/2004/4) 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 not available, furthermore this report has not been updated; the most recent numbers are from 2004, and the data most relevant for our purpose is from 2002-2003. Despite these limitations, this report is the only easily accessible source of data on land based fishery activity and will therefore be used as an indication of the size of land-based fishery related employment.

To demonstrate the importance of land-based fishery employment, in North Sea countries (those that fish in the North Sea), land-based employment exceeds fleet employment by more than two times (35000 *vs.* 15000). However, it is important to note that this employment cannot, entirely, be attributed 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. Furthermore, fishing activity in one sea, e.g. the North Sea, may lay the foundation for industrial activity in an adjacent sea e.g. the North Western Waters or South Western Waters. 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. It is important to note that there may have been an increase in productivity since this report was created, which would imply that for the same size of catch/raw material the land based fishery employment would be lower.

2.2.1.3 Background variables and variable correlations

Fuel is an important economic input in most fisheries (third most important, after capital and labour); changes in fuel price can therefore have a significant impact on 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 which examines fuel prices and how they affect the profitability of the fisheries and it was therefore considered relevant for inclusion in the matrix.

However, fuel consumption is a variable that is highly correlated with other decision variables in the fishery (e.g. engine power, capacity), and can vary significantly over time which may cause problems in terms of calculation and presentation which are discussed below.

The socio-economic variables presented in the matrix are usually not for a specific fishery, but rather for countries, and then divided by species and gear type within a country. Thus, presentation of these variables at fishery level utilises average country specific indicators making them less exact compared to data which are taken directly from databases. Only data on catches is directly available from an existing database (ICES), without the need for further calculations. Catches is therefore used as a basic variable, and also contributes in the composition of the two other variable groups (value of catches and employment).

When choosing variables for the matrix, they should be as independent 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 the exact nature of such interdependencies is unknown, we have little control over the variables further down the chain. As such, we have tried to choose variables which are as independent as possible in the development the socio-economic variables, i.e. variables high up 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. Fuel consumption also does not impact society directly, in the same way that employment does, and as such it cannot be regarded as a good variable 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, background and preliminary variables are developed. Some of these variables may be of interest by themselves. 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 (preliminary) 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 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. The 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 the judgement. 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 Social and Ecological Component by Pressure Matrix (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 i.e. positive employment potential but negative effects through high fuel consumption (carbon footprint is high).

Cells shaded light blue indicate areas where the review needs consider possible interactions and cumulative effects. The mechanisms for dealing with such multiple pressures on ecological components is in its infancy (Hegmann et al., 1999;James et al., 2003;Halpern et al., 2007;Foden et al., 2008;ICES, 2008e) and linking these to socio-economic interactions remains a challenge (Foden et al., 2008).

2.3 Social and Ecological Component by Pressure matrix

Impact Type (MSD & OSPAR)	Ecological components — Habitats — Seafloor	Water column	Protected habitats	Special cases	Plants — Phyto plankton	Macro algae	Invertebrates — Zoo plankton	Benthos	Vertebrates — Fish	Mammals & reptiles	Seabirds	Other groups — Non-indigenous & invasive	Fishery (Ns mixed flatfish)	Socio-economic — Catches measured in physical terms	Economic value of the catches	Employment and productivity
Barrier to species movement									■ (dark)							
Community structure or species dynamics changes			■ (dark)			▨ (light)		■ (dark)	■ (dark)							
Death or injury by collision			■ (dark)			▨ (light)		■ (dark)	■ (dark)							
Introduction [spread] of non-indigenous species & translocations																
Introduction of microbial pathogens																
Removal of non-target species								▨ (light)	■ (dark)	▨ (light)	■ (dark)					
Removal of target species								▨ (light)	■ (dark)	▨ (light)						
Heavy metal contamination									▨ (light)							
Hydrocarbon contamination									▨ (light)							
Radionuclide contamination									▨ (light)							
Synthetic compound contamination																
Changes in species or community distribution, size/extent or condition								▨ (light)								
De-oxygenation																
Input of nitrogen & phosphorus									■ (dark)							
Electromagnetic changes																
Litter																
Noise and visual disturbance									■ (dark)							
Noise disturbance									■ (dark)							
Visual disturbance			■ (dark)						■ (dark)							
Habitat structure changes	■ (dark)		■ (dark)					■ (dark)	■ (dark)							
Siltation (turbidity) changes	▨ (light)		▨ (light)													

Impact Type (MSD & OSPAR)	Ecological components												Fishery	Socio-economic components		
	Habitats				Plants		Invertebrates		Vertebrates			Other groups				
	Seafloor	Water column	Protected habitats	Special cases	Phyto plankton	Macro algae	Zoo plankton	Benthos	Fish	Mammals & reptiles	Seabirds	Non-indigenous & invasive	NS Sandeel Industrial	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																
Radionuclide 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																

Impact Type (MSD & OSPAR)	Ecological components												Fishery	Socio-economic components		
	Habitats				Plants		Invertebrates		Vertebrates			Other groups	Ns herring pelagic			
	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																
Radionuclide 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																

Impact Type (MSD & OSPAR)	Ecological components												Fishery	Socio-economic components		
	Habitats				Plants		Invertebrates		Vertebrates			Other groups				
	Seafloor	Watercolumn	Protected habitats	Special cases	Phyto plankton	Macro algae	Zoo plankton	Benthos	Fish	Mammals & reptiles	Seabirds	Non-indigenous & invasive	Ns mixed whitefish demersal	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									□							
Radionuclide 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	□		□													

2.4 Ecological Matrix elements supporting evidence

2.4.1 Mixed flatfish Beam trawl

2.4.1.1 Habitats

2.4.1.1.1 Seafloor

2.4.1.1.1.1 Habitat structure changes

Beam trawls operating on the sea floor will strongly affect benthic processes as they are designed to cause disturbance to the top layers of benthic habitats. Areas in which flatfish beam trawls are used regularly have been observed to have been homogenised as any large protuberances are removed or flattened (Auster and Langton, 1999;Johnson, 2002).

2.4.1.1.1.2 Siltation (turbidity) changes

The resuspension of sediments that occurs during the trawling process may be associated with the release of contaminants and heavy metals that have previously been stabilised in the sediments. The effects of resuspension events on nutrient fluxes have been studied although the majority of the literature is not from the North Sea. Work is currently being undertaken in the southern North Sea (Trimmer et al., 2005) and the significance of the effects of trawling on nutrient cycling and localised fluxes must be addressed in North Sea studies (Percival et al., 2005).

2.4.1.1.2 Water column habitats

Flat fish beam trawls are unlikely to have any effect on water column habitats.

2.4.1.1.3 Protected habitats

Habitats may be protected for fisheries or more general conservation purposes e.g. protection of a coral reef or the habitat of a marine mammal. Both types of protected habitat are considered here.

2.4.1.1.3.1 Community structure or species dynamics changes

In the North Sea, the plaice box was established to protect juvenile plaice in 1989. In the first years, (1989-1993) the box was closed only during the second and third quarters; in 1994 the fourth quarter was also closed and from 1995 onwards the box was closed for the year round. The box is closed to beam and otter trawlers larger than 300hp, but smaller vessels are still allowed to fish in the box. The closure of the box reduced fishing effort, although a reduced growth rate and possibly higher rate of natural mortality of plaice may have counteracted the reduction in fishing effort (Pastoors et al., 2000). Other analyses have shown that fish species composition was not significantly affected, while the size structure of the fish assemblage changed with a increase in abundance of commercial fish within marketable size-range in the box (Piet and Rijnsdorp, 1998). A later evaluation of the plaice box has indicated that the plaice box has likely had a positive effect on the recruitment of plaice but that its overall effect has decreased since it was established. The two main reasons for the positive effect are 1) at present, the plaice box still protects the majority of undersized Plaice, despite the changed distribution. 2) In the 80 mm fishery, discard percentages in the box are higher than outside. There is, however, no proof of a direct relationship between total discard mortality and recruitment (ICES, 2008f).

There is an ongoing debate on the usefulness of the box. Based on interviews, fisherman perceive the plaice box as counter-productive and describe it as a 'disaster-story' while the NGO's mention that the plaice box

has performed poorly because it has not been a fully closed area (Verweij et al., 2010). A new evaluation of the plaice box is being performed and is due at the end of 2009 (Beare et al. 2010).

Some protected habitats, such as maerl beds, *Lophelia* reefs, *Sabellaria spinulosa* reefs and *Modiolus modiolus* beds, which support high levels of biological diversity will be seriously affected by any gears which are dragged along the sea floor. The impact would affect both the biogenic habitat itself and the communities they support. However, as these habitat types are rare in areas in which flatfish beam trawls regularly operate, these encounters are likely to be accidental more than targeted.

2.4.1.1.3.2   Death or injury by collision

The beam trawls used to capture flatfish are relatively heavy and designed to be dragged along the sea floor. The sensitivity of organisms to impact from flatfish beam trawls is dependent on their size, shape and location. The protected biogenic habitats would suffer extensive mortality and injury through collision with the beam trawls (Hall et al., 2008).

2.4.1.2   Plants

2.4.1.2.1   Phytoplankton

To the best of our knowledge there are no significant effects of fishing on phytoplankton. While we acknowledge that change in the population size and distribution of plankton-feeding members of the other components may itself be a consequence of fishing effects, there is no known evidence that this is a significant driver in the structuring of North Sea plankton.

2.4.1.2.2   Macroalgae

Macroalgae may be affected by beam trawls if they are attached to hard substrates (e.g. rocks and cobbles) which are likely to be disturbed by beam trawls. As this type of substrate is likely to damage fishing gears or the catch, these areas are likely to be avoided.

2.4.1.3   Invertebrates

2.4.1.3.1   Zooplankton

Beam trawls are unlikely to directly affect zooplankton (Section 2.4.1.2.1). Indirectly there may be an effect through the food chain or the release of nutrients from the disturbance to the surface of the sediment but this is 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 meroplanktonic larvae comprises a major part of the zooplankton and this can influence system dynamics through their consumption of phytoplankton and microzooplankton. Similarly, there are certainly occasions when large, gelatinous, plankton are caught in, or macerated by, passage through nets. We are not aware of any studies that allow us to comment on the ecological consequences of this mortality.

2.4.1.3.2   Benthos

The effects of fishing on benthic populations and communities are discussed in detail in this section and the cells of the case study matrix are 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 the section on the Mixed flatfish Beam trawl 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.

2.4.1.3.2.1 Community structure or species dynamic changes

Benthic invertebrates suffer mortality both in the gears and in the towpath of the gear. There is inherent difficulty in interpreting the actual mortality (fishing disturbance) resulting from the fishing event because there is often a time lag between the disturbance by fishing event and the subsequent assessment of the invertebrate community. This allows for the incorporation of other community structuring factors such as predation, changing resource availability and immigration of animals into the disturbed area. The longer the period of time between the fishing event and post-fishing sampling event, the greater the likelihood that the sampling measures community level responses to fishing, rather than absolute fishing mortality. A number of studies have tried to reduce this effect by focusing on the actual fishing disturbance. For example, attempts have been made to estimate the annual fishing mortality of megafaunal invertebrate populations in the Dutch sector of the North Sea (Bergman and Santbrink, 2000). To minimise the influence of dispersal on the interpretation of the change in populations following a fishing event, only species that lead a predominantly sedentary lifestyle were included. All sampling of animal densities following trawling was undertaken within 24-48 hours after trawling activity to reduce the interference of other biotic and abiotic factors on the estimation of fishing mortality. There was, however, no attempt to try to exclude the effect of predation of damaged animals on the estimation of fishing mortality. It is likely that it will be difficult to quantify invertebrate mortality in the towpath of the gear that completely excludes any subsequent predation mortality. A further factor that makes it difficult to gain an accurate estimation of mortality in the towpath of the gear for disturbance indices is the influence of disturbance history on the level of mortality sustained by populations. It is widely believed that the highest levels of mortality will be sustained in an area that has not recently been trawled as residual fishing-induced mortality has been demonstrated to decrease with subsequent passes of the gear.

Benthic species that live deep in the sediment, or that are more mobile, smaller or hard bodied, are less likely to be affected by fishing activity. Within communities, 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. There is, however, some disparity between individual studies in the definition of which taxa are particularly vulnerable to fishing activities. This may be because a taxon will be vulnerable in one respect, for example having soft body parts with little armour, but 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, experienced high levels of mortality 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 (e.g. (Robinson and Frid, 2008)) but predicting the vulnerability of individual species is far from simple (Alexander et al., In prep.).

Changes in size distribution have been described for a number of areas in the North Sea (Jennings et al., 2001;Duplisea et al., 2002) and the implications of this on secondary productivity have been discussed (Hiddink et al., 2006). It is essential that we recognize that the most important ecological changes will be shifts in dominance of particular functional units. For the North Sea demersal system we still do not have the evidence to describe where this has occurred nor conclude whether or not it is as a result of fishing (Robinson and Frid, 2008). One described change is the beneficial effect of fishing activities on scavenging

populations (Rumohr and Kujawski, 2000). The interaction between these and the increases in moribund material in the towpath of the gear has been described in a number of studies in the Southern North Sea and Irish Sea but the implications of this at the population level and the scale of the North Sea are not known. The importance of the physical features of habitats in determining the community structure of benthos is well-documented (Duineveld et al., 1991;Hall et al., 1994;Hall, 1994).

The case study Mixed flatfish Beam trawl produces amongst the most severe impacts on benthos, both because it captures epifaunal and infaunal components but also because of the high mortality associated with contact with this heavy gear (de Groot and Lindeboom, 1994).

2.4.1.3.2.2 Death or injury by collision

The majority of the invertebrates that are killed by demersal fishing, die as a result of contact with the fishing gear as it passes over the seafloor (towpath mortality) (see (Robinson, 2003)). This mortality is not recorded in the catch data because the animals are killed on the seafloor and not caught in the net. The mortality is however 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 possible high survival rates after contact. 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).

2.4.1.3.2.3 Removal of non-target species

A proportion of demersal catches is made up of non-target, invertebrate, bycatch 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 bycatch is not marketable and is discarded at sea. It has been estimated that between 150,000 to 180,000 tonnes of benthic invertebrates are discarded from North Sea fisheries in a year (Camphuysen et al., 1995;Garthe et al., 1996). This figure includes discards of both target and non-target species. The total amount and catch composition of the discards varies depending on the gears used, what the vessel is targeting and the type of habitat being fished (Bergmann et al., 2002;Lart et al., 2002). In almost all cases, epifauna and shallow burying infauna are most likely to be part of the bycatch. Unfortunately, due to the lack of market value, quantification of non-target invertebrate bycatch is rare on commercial vessels and data are only available from research undertaken by a number of institutes over the last 10-15 years (e.g. (Craeymeersch, 1994;Fonds, 1994;Bergmann et al., 2002;van Helmond and van Overzee, 2008). The information that is available from these studies is almost entirely based on either discarded bycatch from Nephrops trawlers operating in the Clyde Sea (on the West Coast of Scotland), or beam trawlers operating in the southern North Sea. The data on beam trawls indicates two distinct groups of vessels, one operating in inshore waters whilst the others operated offshore. A third group distinguished are the otter trawlers. The beam trawls caught a significantly higher median volume of 'benthic invertebrates' per hour than otter trawls, with the inshore small beamers catching slightly more 'benthic invertebrates' per unit volume of fish retained than the offshore beamers. Within these three groups it was possible to detect significant differences of catch composition. However, it was more difficult to determine the reasons for these differences (Lart et al., 2002). Studies that have considered discards of invertebrates from invertebrate or fish targeted vessels have demonstrated that the volume of this component is often high in comparison to the volume of the marketable catch. Furthermore, it is clear from the limited number of studies that have quantified the discards of benthic invertebrates that total abundance and biomass of discarded invertebrates compared to the target stock, are likely to be significant at the scale of the fleet. However, as with the inclusion of any levels of discarding mortality in a disturbance

index, both the quantities of animals discarded and an understanding of the survivability of the different species following discarding is required. Table 2.4.1. provides an indication of the quantity of benthic species caught based on data from the Dutch beam trawl sampling program in 2007; the main benthic species discarded were the common starfish, comb-star, swimming crab, sea urchin and brittle star (van Helmond and van Overzee, 2008).

Table 2.4.1. Numbers of benthic species discarded per hour in 2007 for the beam trawl vessels with an engine power larger than 300 HP using 80 mm cod-end mesh size (van Helmond and van Overzee, 2008).

Latin name	Dutch name	N. per hour	Latin name	Dutch name	N. per hour
Acanthocardia echinata	Gedoornde hartschelp	1.3	*Hyas* sp.	Spinkrab	0.1
Aequipecten opercularis	Wijde mantel	0.3	*Liocarcinus depurator*	Blauwpootzwemkrab	41.0
Alcyonium digitatum	Dodemansduim	1.5	*Liocarcinus holsatus*	Gewone zwemkrab	924.0
Alloteuthis subulata	Dwergpijlinktvis	2.9	*Liocarcinus marmoreus*	Gemarmerdde zwemkrab	5.7
Anthozoa	Zeeanemonen	2.9	*Loligo forbesi*	Loligo forbesi	0.1
Aphrodita aculeata	Fluwelen zeemuis	27.5	*Loligo* sp.	Loligo	<0.1
Arctica islandica	Noordkromp	0.7	*Lunatia alderi*	Glanzende tepelhoorn	0.6
Ascidiacea	Zakpijp	116.0	*Lunatia catena*	Grote tepelhoorn	1.6
Asterias rubens	Zeester	1574.8	*Macropodia rostrata*	Hooiwagenkrab	<0.1
Astropecten irregularis	Kamster	1442.4	*Mactra coralline*	Grote strandschelp	9.3
Bolocera tuediae	Bolocera	0.5	*Mactra* sp.	Mactra	<0.1
Buccinum undatum	Wulk	19.2	*Modiolus modiolus*	Paardemossel	<0.1
Cancer pagurus	Noordzeekrab	4.0	*Mytilus edulis*	Mossel	0.1
Cerastoderma edule	Kokkel	0.1	*Necora puber*	Fluwelen zwemkrab	2.3
Ciona intestinalis	Doorschijnende zakpijp	0.1	*Norway lobster*	Noorse kreeft	0.9
Corystes cassivelaunus	Helmkrab	266.7	*Ophiura albida*	Kleine slangster	1.6
Crangon crangon	Gewone garnaal	4.0	*Ophiura ophiura*	Slangster	515.0
Crangon sp.	Crangon sp.	0.6	*Pagurus bernhardus*	P. bernhardus	243.4
Donax vittatus	Zaagje	0.2	*Pagurus* sp.	Pagurus sp.	28.0
Echinidae	Zeeegels	592.5	*Palaemon* sp.	Steurgarnaal	<0.1
Echinocardium cordatum	E. cordatum	414.1	*Pecten maximus*	St. Jacobsschelp	0.5
Ensis siliqua	Tafelmesheft	0.4	*Psammechinus miliaris*	Zeeappel	8.7
Ensis sp.	Ensis	0.2	*Sepia officinalis*	Zeekat	1.9
Flustra foliacea	Bladachtig hoornwier	0.1	*Sepia* sp.	Sepia	<0.1
Goneplax rhomboides	G. rhomboides	16.0	*Spisula* sp.	Spisula	0.7
Halichondria panicea	Broodspons	0.4			

2.4.1.3.2.4 Removal of target species

The removal of target demersal fish species by beam trawling will have an effect on total predation pressure exerted by the fish assemblage on the benthic community. Removal of large predatory fish and expansion in numbers of small gadoids and dabs has been demonstrated to lead to an increase in the total removals of benthos by predation and changes in the types of prey exploited (Frid et al., 1999).

2.4.1.4 Vertebrates

2.4.1.4.1 Fish

The case study fisheries all directly impact fish through their removal. Indirect effects may also impact fish species through a cascade starting with a direct effect of fishing on other ecological components (see previous sections).

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 through 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.

2.4.1.4.1.1 Barrier to species movement

The impact of beam trawls on habitat structures (see Section 2.4.1.1.1.1.) may indirectly affect species movement. If the habitat available for fish species that depend on these structures becomes smaller, this may result in larger distances between patches suitable for survival. Thus the beam trawl could present a barrier to the movement of species and mixing of populations. In the North Sea, this is a specific risk for fish species that depend on areas with pebbles or gravel (e.g. herring depending on gravel as substrate for their eggs). Species such as sandeel could also be affected as they specifically depend on the sandy substrates. However, a recent study found no evidence of negative effects of the beam trawl effort in the southern North Sea on the sandeel population (INEXFISH, 2008).

2.4.1.4.1.2 Community structure or species dynamic changes

Between 30-40% of the biomass of commercially important species in the North Sea is landed each year (OSPAR, 2000). However, this is a vast underestimation of total numbers removed from the system, as this estimate does not take account of discards and unobserved mortality. 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). There have been no recorded extinctions in the North Sea fish community, and often the abundance of a species has even increased due to climate change (Hiddink and ter Hofstede, 2008). However, there is concern that the main loss of species and changes in species diversity occurred before scientific records began (Anon., 1985; Knijn et al., 1993 reported in Jennings and Kaiser, 1998).

Mortality caused by fishing is not evenly distributed over species and length; mortality caused by the beam trawl is higher for larger demersal fish species, while pelagic and small specimens are much less impacted. This uneven fishing mortality has been demonstrated to lead to changes in the size composition of the community. In this scenario, the mean size of individuals in the community will decrease and small individuals will therefore form a larger proportion of the biomass. Changes in the size structure of fish communities are as much the consequence of declines in the abundance of large fish with low intrinsic rates of increase, as the consequence of increases in the abundance of small fish with higher intrinsic rates of increase (Jennings et al., 1999;Daan et al., 2005). The decrease in large species is related to fishing (Jennings et al., 1999), however the increase of smaller fish is probably a combination of indirect fishing effects and environmental changes (Daan et al., 2005;Hiddink and ter Hofstede, 2008;van Hal et al., 2010). In numerous studies, the expected changes in abundance and size structure have been observed in the North Sea demersal system (Heessen and Daan, 1996;Rijnsdorp et al., 1996;Serchuk et al., 1996;Greenstreet et al., 1999;Greenstreet and Rogers, 2000;Greenstreet and Rogers, 2006).

The indirect effect of fishing on the increase in abundance of small fish is likely to be due to a release from competition and predation. The predation pressure on small species is reduced due to the decrease in the large, often piscivorous species. The removal of the species creates space, mainly for the smaller often faster growing species and reduces competition. For example, the increase of the starry ray (*Amblyraja radiata*) may have resulted from enhanced food availability as a result of fishing on its competitors (Walker and Heessen, 1996). Changes in the strength of inter-specific competition may also allow for the increased co-existence of competitive species (Blanchard, 2001).

Changes in abundance of the demersal fish species, however have not yet lead to substitution of species within a feeding guild (Heath, 2005) or trophic cascades. The relative stability of the species compositions of the demersal guilds is presumably related to their closer association with bathymetry and sediment habitat than pelagic species, making range expansion and species substitution more difficult.

2.4.1.4.1.3 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 maturing at an earlier age would be beneficial under high fishing pressure. These changes could be compensatory changes (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 closely connected to the productivity of fisheries. By ignoring genetic change, we run the risk of reducing productivity in ways that are not easily reversed. Phenotypic changes, on the other hand, could be reversed in the short-term (Law, 2002).

Changes in growth and sexual maturation have been shown in the target species of the Mix flatfish Beam trawl in the North Sea. Plaice in the North Sea has been shown to mature at a younger age and length (Rijnsdorp, 1993;Grift et al., 2003), have increased fecundity (Rijnsdorp, 1991;Rijnsdorp et al., 2005) and a reduction in the probabilistic maturation reaction norm (Grift et al., 2003) has been observed (Jorgensen et al., 2007). The probabilistic reaction norm for maturation is defined as the probability that fish mature at a certain age and size during a given time interval (Heino and Dieckmann, 2008). A reduction in the probabilistic maturation reaction norm has also been shown for sole in the North Sea (Mollet et al., 2007).

2.4.1.4.1.4 Death or injury by 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 fish species is lower than of those hauled and later discarded (Van Beek et al., 1990;Kaiser and Spencer, 1995) but may still be significant. Fish disturbed by fishing are most likely to be stressed and more susceptible for predation (Chopin and Arimoto, 1995). Seals and birds swimming behind beam trawls predating on fish and benthos affected by the trawls have been observed (pers. obs.).

The death and injury of benthic invertebrates caused by beam trawls (section 2.4.1.3.2.), provides food and attracts demersal bottom feeders (e.g. cod, plaice, dab) (Kaiser and Spencer, 1994;Kaiser and Ramsay, 1997). Though not well studied, these indirect effects on fish diets, benthic predation rates and the resultant shifts in trophic dynamics and community structure are likely important determinants of present day ecosystem functioning (OSPAR, 2000).

2.4.1.4.1.5 Removal of non-target species

Beam trawls remove non-target species; some are landed while others are discarded. The status of landed roundfish species is discussed in relation to otter trawl fisheries in Section 2.4.4.). The status of some of the landed flatfish species is discussed below, however is it important to note that there are several species/stocks, with the exception of seabass, for which ICES has never provided management advice, and information was therefore taken from the Working Group on Assessment of New Species (WGNEW) (ICES, 2007b).

Brill (*Scophthalmus rhombus*)

No assessment for brill in the North RAC region is performed. Attempts to assess the Channel fishery indicated that the Channel stock was not heavily overexploited, but that a reduction in fishing effort was required to get an increase of 10% of the observed production (Ulrich, 2000). Landings of brill are shown in Figure 2.4.1. this is likely to be most of the brill caught because only the very small specimens are discarded (ICES, 2007a).
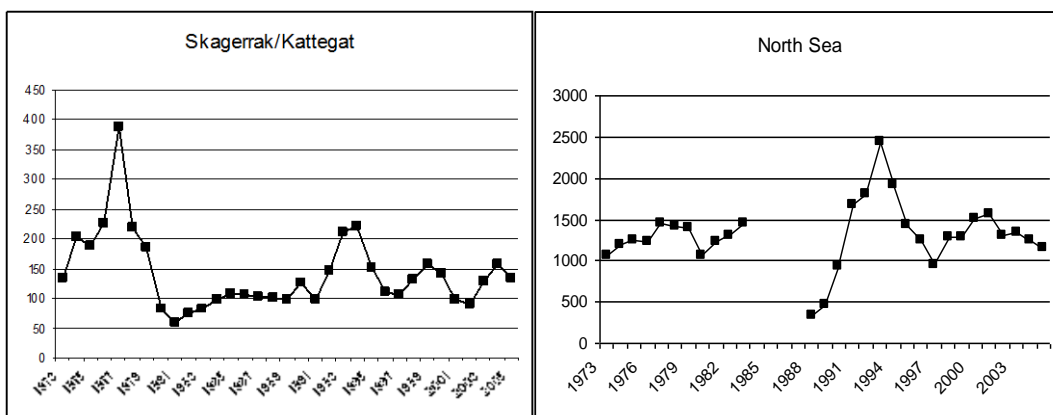
Figure 2.4.1. Landings(t) of Brill in the Skagerrak/Kattegat and North Sea (ICES, 2007a).

Turbot (*Psetta maxima*)

An assessment of turbot in the Channel fishery was made in 1999. It was concluded that fishing mortality increased from 1 to 1.5 over the period from 1984 to 1989 and decreased thereafter to 0.7 by 1995 (Dunn, 1999). The maximum sustainable yield (MSY) was given to be between 300 and 400t, which was lower than the observed catches (550t/year), however a more recent estimate put maximum sustainable production at 440 t/year (Ulrich, 2000). The landings are depicted in Figure 2.4.2.
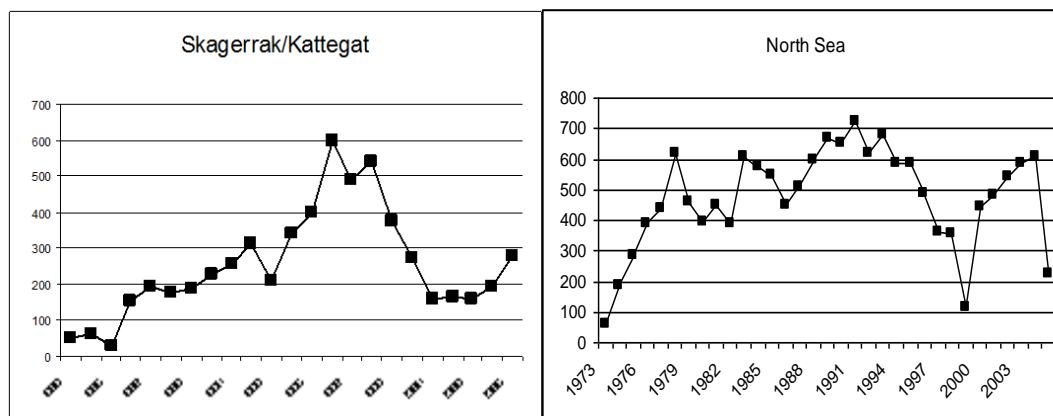
Figure 2.4.2. Landings(t) of turbot in the Skagerrak/Kattegat and North Sea (ICES, 2007a).

Dab (*Limanda limanda*)

According to the International Bottom Trawl Survey (IBTS) in Q1 in the North Sea, the abundance of dab has significantly increased in the long-term, partly due to opportunistic adaptations to trawl fisheries (Kaiser and Ramsay, 1997). Recent estimates still indicate that dab is one of the main discarded species by the beam trawl (STECF, 2008a), amounting to 60% to 70% of the total catch (Borges et al., 2005). Landings in the North Sea are shown in Figure 2.4.3. (ICES, 2007a).
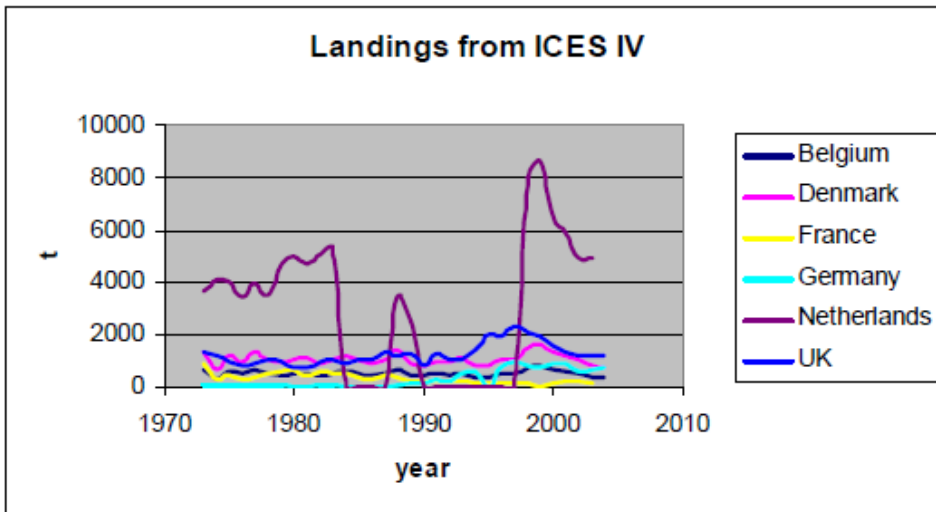
Figure 2.4.3. Dab landings, Apparent decreases in the catch are due to unreported catches by the Netherlands (ICES, 2007a).

Lemon sole (*Microstomus kitt*)

In the North Sea, lemon sole abundance has increased from ~6 fish/30 min. in 1991 to ~24 fish/30 min. in 2005 (Figure 2.4.4.). However, this rise in abundance has not been reflected in landings for Divisions IVa, b &c over the same time span (ICES, 2007a). There are currently no management measures in place for lemon sole and there is insufficient data to assess stock status.
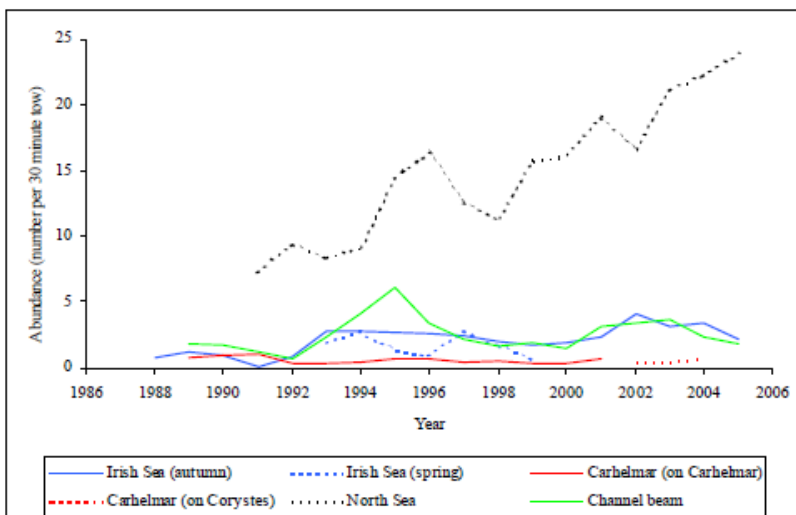
Figure 2.4.4. The number of Lemon sole caught per 30 min. in various CEFAS surveys. North Sea black dotted line (ICES, 2007a).

In 2005 ICES provided advice for the demersal elasmobranches for 2006, stating that "Target fisheries for common skate (*Dipturus* batis) and thornback ray (*Raja clavata*) should not be permitted, and bycatch in mixed fisheries should be reduced to the lowest possible level". Moreover, ICES advised that "if the fisheries for rays continue to be managed with a common TAC for all ray species, this TAC should be set at zero for 2006". No advice was provided for 2008 but a qualitative summary was given (Table 2.4.2.) (ICES, 2008c).

Table 2.4.2. A qualitative summary of the general status of the major demersal elasmobranch species in the North Sea (IV), Skagerrak (IIIa) and Eastern English Channel (VIId) based on surveys and landings.

Species	Scientific name	Area	State of stock
Common skate *	*Dipturus batis*	IVa	Depleted
Thornback ray	*Raja clavata*	IVc, VIId	Stable/increasing
		IVa,b	Uncertain
Spotted ray	*Raja montagui*	IVb,c	Stable/increasing
Starry ray	*Amblyraja radiata*	IVa,b, IIa	Stable
Cuckoo ray	*Leucoraja naevus*	IVa,b	Stable
Blonde ray	*Raja brachyura*	IVc, VIId (patchy occurrence)	Uncertain
Undulate ray	*Raja undulata*	VIId, merges with VIIe	Uncertain, reasons for concern
Lesser-spotted dogfish	*Scyliorhinus canicula*	IVa,b,c, VIId	Increasing
Smooth hound & Starry smooth hound	*Mustelus mustelus & Mustelus asterias*	IVa,b,c, VIId	Increasing
Angel shark	*Squatina squatina*	IVa,b,c, VIId	Extirpated

* likely merging with VIa & IIa

Discarded species

Discards consist of undersized landed species, high graded species (species that can be landed, but are discard because of low value or low TAC) and non-commercial fish. The Dutch beam trawl has an estimated overall discard rate of 71%–95% (Lindeboom and De Groot, 1998), and of these discards, 80% consisted of flatfish species, mainly plaice and dab (Van Beek 1998). Survival rates of discards were estimated at less than 10% for sole and plaice (Van Beek et al., 1990). Even if there is no initial mortality owing to hauling and exposure to air, fish died in survival tanks after a couple of days. Dragonets (*Callionymus lyra*) had a final mortality of between 68 and 97%, cuckoo rays (*Leucoraja naevus*) had a mortality of 41% after 5 days (Kaiser and Spencer, 1995). The mortality of plaice and dab at the end of the survival experiment was 61% and 76% respectively. The mortality of Lesser-spotted dogfish (*Scyliorhinus canicula*) was only 10% after 6 days (Kaiser and Spencer, 1995).

There are spatial and seasonal pattern in the discards. The highest flatfish discards occurred near the coast, decreasing further off shore. This findings mirror the distribution of juvenile flatfish (Van Beek 1998). A seasonal pattern in the discards showed that discards where highest in quarter 2 and 3 (Van Beek 1998).

The effect of discarding can be a loss of income through the loss of potential growth and contribution to stock replacement (Catchpole et al., 2005). The direct loss of potential income through the discarding of commercial species in the North Sea has been calculated at 70% of the total value of the annual landings for the Dutch beam trawl fishery and 42% of the annual landings for the UK roundfish fishery (Cappell, 2001).

The extensive discarding of commercial species in the North Sea results in substantial forgone potential yield, and discards are considered a serious impediment to rebuilding depleted stocks.

2.4.1.4.1.6 Removal of target species

The mixed flatfish beam trawl fishery mostly targets the flatfish plaice and sole. These species are annually assessed by ICES within the Working Group on Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). During such assessment, the Spawning Stock Biomass (SSB), fishing mortality (F) and recruitment is estimated and corrected every year. These estimations are used to provide annual advice on the Total Allowable Catch (TAC) at which the stock is kept at a sustainable and productive level. ICES has implemented the precautionary approach in its advice on fish stocks and catch levels. This is done by setting reference points at which management action should be taken. ICES identifies 'limit' and 'precautionary' reference points for SSB (B_{pa} and B_{lim}) and F (F_{pa} and F_{lim}). The intention is that stocks are managed so that they do not – if at all possible – exceed the precautionary limit reference points.

As the name implies, the mixed flatfish beam trawl fishery catches a mixture of its target species. The fishermen, however, are able to control their catches in such a way that one of the two target species dominates. This is done by fishing in the central/northern North Sea to catch more plaice, or in southern waters to catch more sole. This is driven by fishermen's individual TACs and market price of the species. Sole is the overall dominant target species for the beam trawl fleet (Quirijns et al., 2008;Rijnsdorp et al., 2008).

Plaice (*Pleuronectes platessa*)

In the North Sea RAC region, plaice assessments are done for two management units: Division IIIa (Skagerrak/Kattegat) and Subarea IV (North Sea).

Plaice in Division IIIa

The latest data available for this stock are too sparse to revise the assessment or advice from last year, apart from updating the landings time series. Landings in 2007 are estimated at 8,786 tonnes for the Skagerrak and Kattegat area combined (ICES, 2008f). Various surveys in the latest year give a reasonably consistent result for the eastern part of the area. The status of the western part is more uncertain, due to potential mixing with North Sea plaice and limited survey coverage (ICES, 2008f).

According to the 2007 assessment (ICES, 2007c), SSB has been decreasing since 1992 and has been below B_{pa} (24 000 t) since 1996. There has been an increase in the last two years due to a succession of good recruitment in 2003-2005, after a decade of below average recruitment (GM=43 500). However, estimates for the latest year classes (2004-2005), from commercial and survey data, are not high. Fishing mortality is high and has consistently been estimated over F_{pa} (0.73). The reference point for this stock was set at a time when there had been no sign of recruitment impairment, and B_{pa} was set around the Lowest Observed Spawning Stock (1989). Since then, SSB has decreased below B_{pa}, without showing any reduced recruitment. In contrast, the largest recruitments in the recent years have been observed at the lowest levels of SSB (Figure 2.4.5). There is thus no sign of impaired recruitment. A revision of the Precautionary Reference Points on the same bases may be considered (ICES, 2007c).
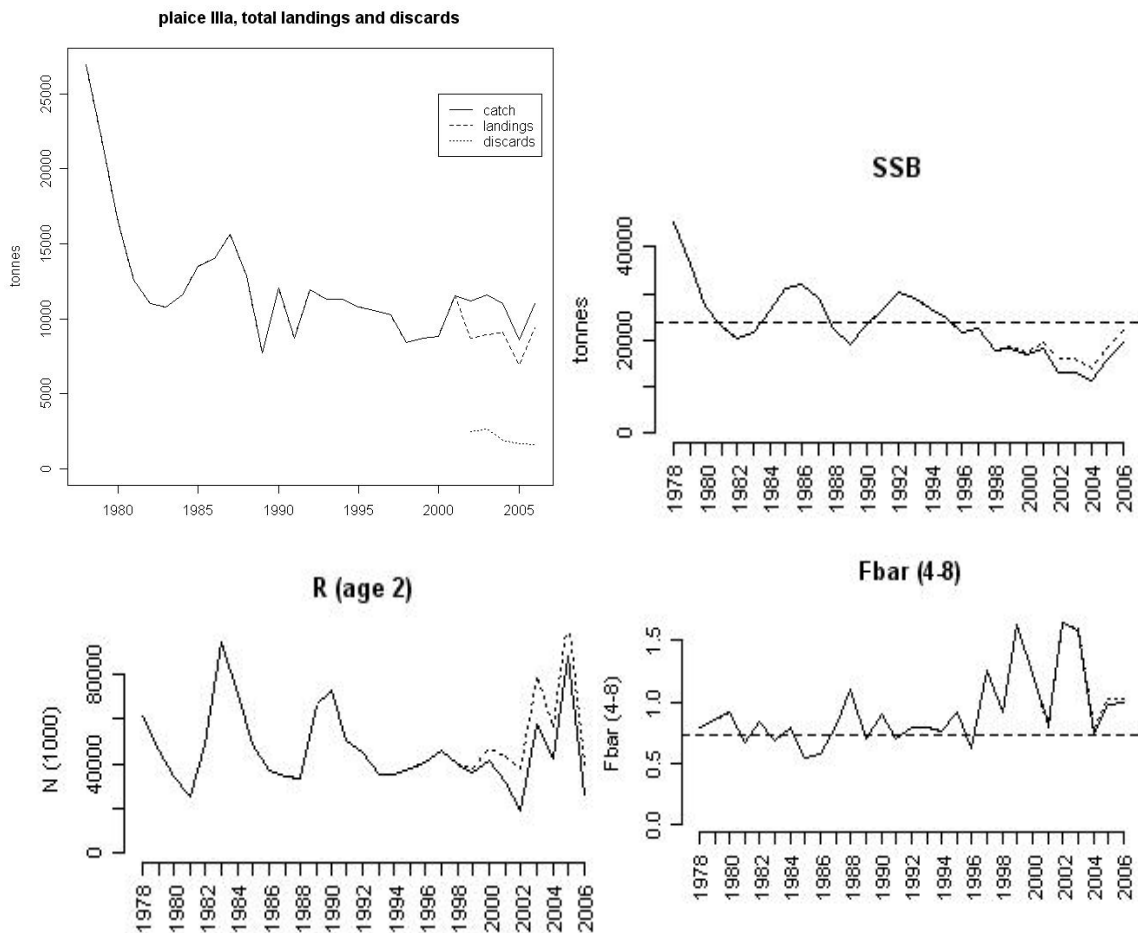
Figure 2.4.5. UpperLeft, total catch (black line),total landings (dashed line) and discards (dotted line) of plaice in division IIIa. Upper right, estimated Spawning Stock Biomass (SSB); lower left, recruitment at age 2. Lower right, Fbar, average fishing mortality for the age classes 4-8 (ICES, 2008f).

Plaice in Subarea IV

Landings in 2007 are estimated at 49,744 tonnes in the North Sea. Based on the most recent estimate of SSB (in 2008) and fishing mortality (in 2007), ICES classified the stock as having full reproductive capacity and as being harvested sustainably (ICES, 2008f). SSB around 254k tonnes is now estimated to have increased above the B_{pa} (230kt). Fishing mortality including discards is estimated to have decreased from 0.43 in 2006 to 0.39 in 2007, which is below F_{pa} (0.60). However, it is above the rate expected to lead to high long-term yields and low risk of stock depletion. Recruitment has been below the long-term average since 2004. However, recruitment in 2007 is of average strength (Figure 2.4.6.).
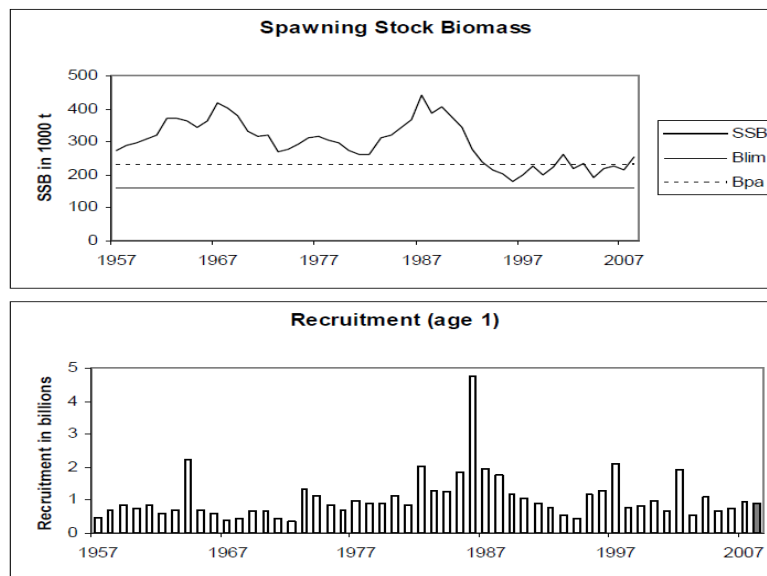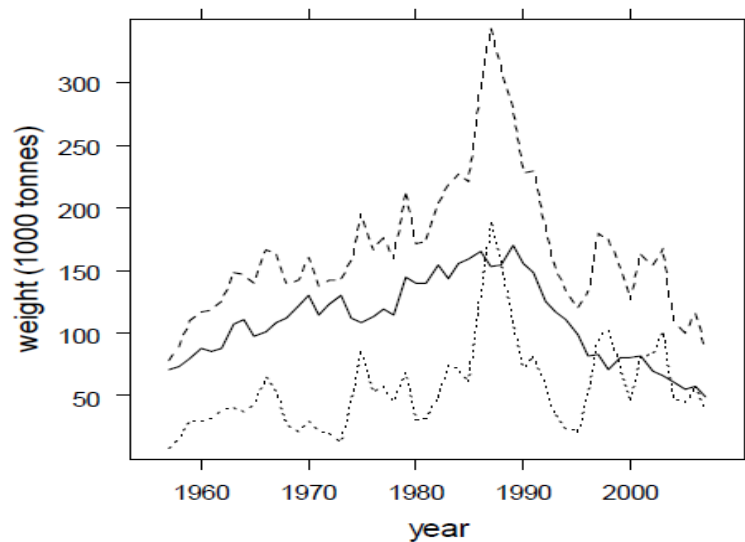
Figure 2.4.6. (A) total catches (dashed lines), landings (dotted) and discards (black line) of plaice in Subarea IV; (B), Estimated Spawning Stock Biomass (SSB) and (C) recruitment at age 1, predicted values are shaded (ICES, 2008f).

Sole (*Solea vulgaris*)

Like plaice, sole is also assessed as two separated management units: Division IIIa and Subarea IV.

Sole in Division IIIa

Catches of sole in Division IIIa in 2007 were estimated at 541 tonnes. Based on the most recent estimates of SSB (in 2008) and F (in 2007), ICES classifies the stock as having full reproductive capacity and being harvested sustainably. SSB has increased since 1998 to 3133 tonnes in 2008, which is well above B_{pa} (1060t). Fishing mortality has decreased from 2006 to 0.21 in 2007 which is well below F_{pa} (0.30) (ICES, 2008f). Recruitment at age 2 is estimated at 4764 thousand in 2007 (Figure 2.4.7.).

Sole in Subarea IV

Based on most recent estimate of SSB (19k tonnes in 2008) and fishing mortality (0.43 in 2007), ICES classifies the stock as having reduced reproductive capacity and as being at risk of being harvested unsustainably (ICES, 2008f). SSB has fluctuated around the precautionary reference points for the last

decade and is now below B_{lim} (25 kt) and B_{pa} (35 kt). Fishing mortality has declined since 1995 and is currently estimated to be above F_{pa} (0.4) (Figure 2.4.8.). Year classes 2003 and 2004 are weak, year class 2005 is strong, and the assessment indicates that year class 2006 is below average. The predicted SSB in 2010 is largely dependent on the above-average recruitment of year class 2005. Due to the high fishing mortality SSB has declined, making the fishery and SSB more dependent on incoming year classes and these can therefore fluctuate considerably between years (ICES, 2008f).
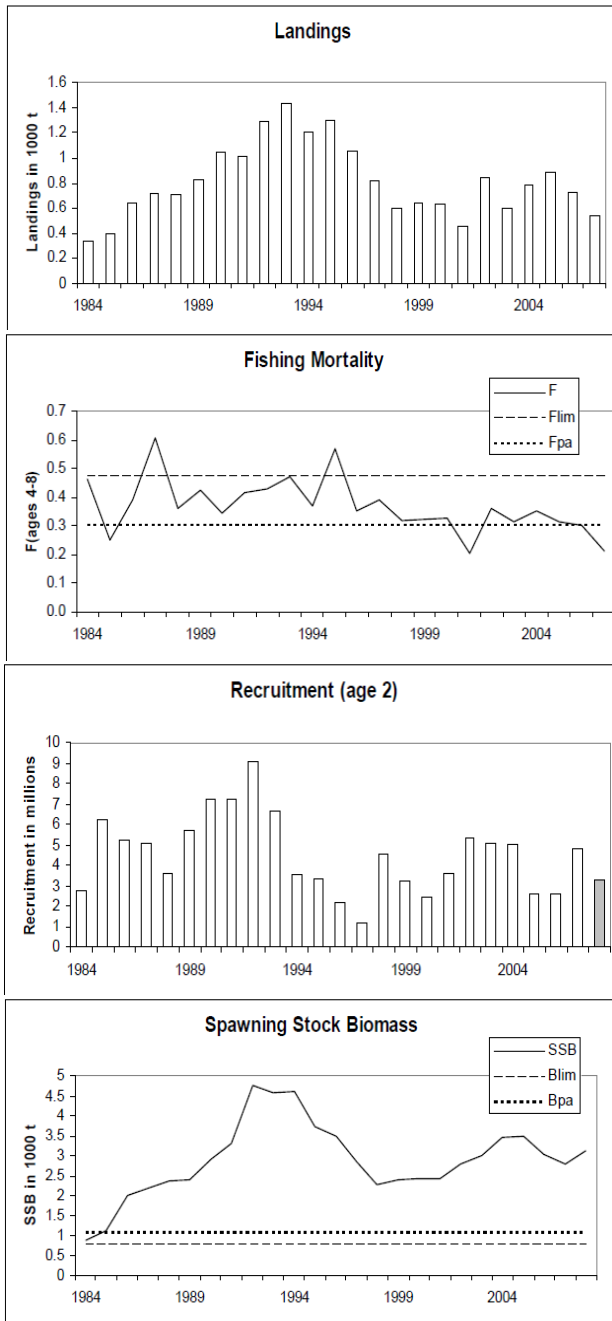
Figure 2.4.7. Sole in Division IIIa. Landings, fishing mortality, recruitment at age 2, and SSB. Predictions are shaded (ICES, 2008f).
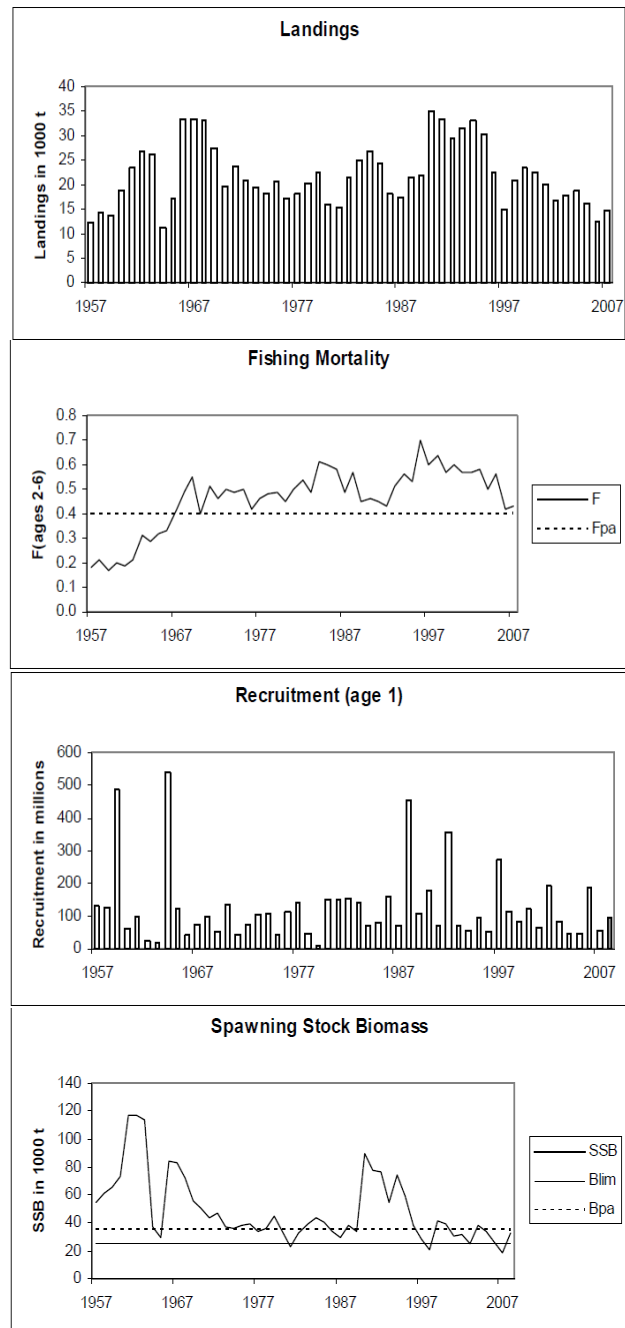
Figure 2.4.8. Sole in Subarea IV. Landings, fishing mortality, recruitment at age 2, and SSB. Predictions are shaded (ICES, 2008f).

2.4.1.4.1.7 Synthetic compound contamination

Beam trawls re-suspend 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 affect respiration and other physiological and neurological processes. Heavy metal uptake in organisms from water tends to be proportional to the concentration in the water. Heavy metals may accumulate within organisms, 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 accumulation can occur through the food chain resulting in high concentrations in predator species (INEXFISH, 2006).

Polycyclic Aromatic Hydrocarbons (PAHs) can also accumulate in marine species and have been demonstrated to have a deleterious effect on the vitellogenesis of fish from natural populations as well as in laboratory experiments (Vethaak and ap Rheinallt, 1992;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 explosion at Chernobyl in 1986 heavily contaminated the North Sea (Kempe and Nies, 1987) and other waters with radioactive material. Radioactivity was 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 is more scarce 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.

2.4.1.4.1.8 Input of nitrogen & phosphorus

Beam trawls resuspend the sediment, this 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 will 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 food for the benthos which will enhance secondary production. This enhanced secondary production will enhance the food availability of fish species. It will increase the carrying capacity of the system which is beneficial 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. Periods of anoxia in the North Sea may be relatively short due to rapid restoration of the oxygen content by tidal movement (Beukema, 1992), however, affected communities may require a few years to recover.

2.4.1.4.1.9 Noise and visual disturbance / Noise disturbance / Visual disturbance

Noise and visual disturbance caused by beam trawlers can result in an avoidance reaction and stress. This can make fish more susceptible to predation and possibly pathogens. Visual disturbance by resuspension of sediments could lead to difficulties during foraging for visual hunters.

2.4.1.4.1.10 Habitat structure changes/ Habitat structure changes – abrasion

The effect of beam trawlers on habitat structure is discussed in section 2.4.4.1.1.1. 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.

2.4.1.4.2 Mammals & reptiles

There are two main ways that fisheries interact with marine mammal populations, direct mortality caused by fishing gear, and indirect trophic effects whereby the fishery affects the food webs that support the mammals.

The North Sea beam trawl fleet causes very little direct mortality on marine mammals, although occasional bycatch of harbour porpoise (*Phocoena phocoena*) by the beam trawl fleets has been reported (Commission Staff Working Paper, 2002). Between 2002-2008, 753 separate beam trawl hauls by English and Welsh vessels were observed in ICES IV by the CEFAS Catch and Discard Sampling Program (CDSP), the only marine mammal observed in the catch was a single harbour porpoise. It is considered that these limited incidents have no significant impact at the population level (ICES, 2006).

The indirect trophic effects of fishing on marine mammals could be negative due to prey depletion if both are targeting the same species, or positive if the fishery is targeted at species that compete with marine mammals for the same prey. There are two resident cetacean and two resident pinniped species in the North Sea. The two resident cetacean species are the harbour porpoise (*Phocoena phocoena*) and the bottlenose dolphin (*Tursiops truncates*). Harbour porpoise in the North Sea 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) (Börjesson et al., 2003;Santos et al., 2004). Harbour porpoise diet varies spatially and seasonally, generally reflecting local survey abundance, and as such harbour porpoise are considered generalist opportunistic feeders (Santos et al., 2004). Less is known of bottlenose dolphin diets in the North Sea, however a limited study off the east coast of Scotland found that the diet consisted of fish, cephalopods and crustaceans, but was predominantly made up of gadoids (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 North Sea have been found to predate on a range of fish, cephalopods and other invertebrates (Thompson et al., 1996;Tollit and Thompson, 1996;Brown and Pierce, 1998;Hall et al., 1998). Fish are the major component of harbour seal diet, including 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). Like cetaceans, seals have an opportunistic diet that generally reflects the local survey abundance of fish in the size range in which they feed.

The diets of the cetacean and pinniped species in North Sea encompasses both species that are directly targeted by the beam trawl fleet, and species that are the prey items of targeted species. Therefore the beam trawl fleet could cause negative and positive indirect impacts on marine mammals. However their wide ranging opportunistic diets suggest that they will be reasonably robust to alterations in prey abundance. The beam trawl fleet is not considered to have a significant effect on marine mammal populations in the North Sea.

2.4.1.4.3 Seabirds

Fishing can affect seabird populations through direct mortality, prey reductions, and feeding subsidy from discarding of whole organisms and offal.

There is no evidence that beam trawling causes any direct mortality on North Sea seabirds.

It has been estimated that discards (including offal) can account for up to 30% of the total food consumed by scavenging seabirds in the North Sea (ICES, 1996). Further estimates suggest that this discarding could support between two and six million scavenging seabirds in the North Sea depending on the assumptions used (Furness et al., 1992;Camphuysen and Garthe, 2000). Associated with this there has been a large increase in seabird numbers in the North Sea over the last century, corresponding with an increase in fishing effort and discarding (ICES, 1999). Thus discarding is thought to have led to a significant increase in seabird numbers in the North Sea (ICES, 1999). In addition to the general increase in scavenging seabird numbers there has been a change in species composition partially driven by changes in foraging behaviour associated with the increased contribution of discards to diets, and the feeding hierarchy associated with competition for discards (ICES, 1996). It should be noted that whilst many discard consuming seabird species have increased in number since 1900, it is hard to discriminate between the effect of discarding and other factors such as changes in 'natural' food supply, reductions in direct persecution of seabirds and climatic effects (ICES, 2003).

The beam trawl fleet is responsible for a considerable proportion of the discarding that occurs in the North Sea. The beam trawl fleet discarded 42% (by number) of all fish discarded by English and Welsh vessels in the North Sea between 2003-2006 (Enever et al., 2009). The considerable proportion of total discarding generated by the beam trawl fleet indicates that the beam trawl fleet is likely to play a significant role in discarding and food subsidy of scavenging seabirds. However it is difficult to disentangle the effects of discarding by the beam trawl fleet from the effects of discarding by other sectors of the North Sea fishery. The extent to which the beam trawl fleet contributes to food subsidy of scavenging seabirds may vary as fishing practices change in the future, in particular technical gear regulations and restrictions on discarding may have significant effects on the extent of discarded material available to seabirds. For example Enever et al. (2009) demonstrated that the introduction of technical regulations for nephrops trawls in 2002 led to a reduction in discarding of small gadoids.

2.4.1.5 Other groups

2.4.1.5.1 Non-indigenous & invasive

There is no evidence of any effect of the beam trawl fishery on non-indigenous or invasive species.

2.4.2   Sandeel industrial fisheries

2.4.2.1   Habitats

2.4.2.1.1   Seafloor

2.4.2.1.1.1   Habitat structure changes

The effects of fishing on habitat are related to the physical disturbance by bottom gears in contact with the seafloor. Typically the gears used in the sandeel fisheries disturb the benthos occasionally but the impact is mitigated as the habitat is generally dynamic sand where the level of natural disturbance is high and the fisheries are seasonal allowing recovery periods (ICES, 2006). Any indirect effects on the physical and chemical attributes are likely to be small.

2.4.2.1.2   Water column

The sandeel fisheries are unlikely to affect the water column habitat.

2.4.2.1.3   Protected habitats

The sandeel box was established off the NE coast of Scotland initially to protect the food resources of kittiwakes (Frid et al., 2005). A number of internationally important seabird colonies occur in this area, including the Isle of May and the Farne Islands. The Isle of May hosts around 70,000 pairs of breeding seabirds per year alone. While outside the breeding season these birds range over large areas and take a variety of prey, during breeding sandeels are a very important component of the diet of adults and young. During the breeding season, the birds' foraging is also restricted to sites relatively close to the breeding grounds. In the 1980s a number of inshore areas were exploited for the first time by industrial fisheries targeting the sandeels. At this time there were a number of spectacular breeding failures by the seabirds. For example, in 1998, 4300 pairs of kittiwakes on the Isle of May raised less than 200 young (a pair normally raises 1 or 2 chicks from a clutch of 3 eggs). While the evidence of a fishery–seabird interaction is only circumstantial, it was sufficient to prompt a precautionary response. Industrial fishing in the 'sandeel box' (which covers the inshore area from eastern Scotland down to NE England) is closed if the breeding success of kittiwakes in the nearby colonies falls below 0.5 chicks per pair for 3 successive years. The fishery does not reopen until breeding success has been above 0.7 for 3 consecutive years. Thus management of this fishery is based on an ecosystem objective (seabird population health), is precautionary (the link is not yet proven), and uses kittiwake breeding success as a biological indicator of the ecosystem effects of the fishery (Frid et al., 2005). As of December 2003, the closure of the 'sandeel box', pertaining to the landing and retaining on board of sandeels, was continued and in the future the area may become a permanent conservation area (Council Regulation (EC) No 2287/2003 of 19 December, 2003). Monitoring is in place to assess the status of the sandeel stock and the effects of the closure.

2.4.2.2   Plants

2.4.2.2.1   Phytoplankton

Sandeel fishing is unlikely to have an effect on phytoplankton except indirectly though the food web.

2.4.2.2.2   Macroalgae

Sandeel fishing is unlikely to have an effect on macroalgae as it is unlikely that the two will occur in the same area.

2.4.2.3 Invertebrates

2.4.2.3.1 Zooplankton

Sandeel fishing is unlikely to have an effect on zooplankton except indirectly though the food web.

2.4.2.3.2 Benthos

2.4.2.3.2.1 Community structure or species dynamics changes

Typically the gears used in small mesh fisheries do not impact on the seafloor and so do not directly impact the benthos, although if one interprets sandeels as being at least partially benthos, then there is a direct effect via their removal (ICES, 2006).

2.4.2.4 Vertebrates

2.4.2.4.1 Fish

2.4.2.4.1.1 Community structure or species dynamic changes

There has been little evaluation of the consequences of fishing small mesh targeted species for their main prey. The prey of these pelagic species generally comprise phytoplankton and zooplankton including juvenile fish and eggs (Macer, 1966). The ICES stomach sampling projects in 1981 and 1991 showed that sandeel, Norway pout and sprat provided more than 50% of the food of saithe and whiting, and between 1-30% of the fish-based feed of species such as cod, mackerel and haddock (Gislason, 1994). Greenstreet (1996) investigated the diet composition of the main predators in the North Sea and demonstrated that industrial fish species form a valuable proportion of the food for predatory fish. The consumption in the North Sea of sandeels by commercial fish, seabirds and other fish/marine mammals has been estimated as 1.9, 0.2 and 0.3 million tonnes per year, respectively (ICES, 1997). Cod, haddock, whiting, mackerel, saithe, grey gurnard and starry ray are by far the greatest predators of sandeels (Pope and Macer, 1996). Sandeels comprise 40-60% of the fish biomass consumed and 15-25% of the total biomass in the North Sea (ICES, 1997). Changes in the size of the sandeel stocks in the North Sea clearly have potential implications for its main predators. However, investigations into the local effect of the closure of an industrial fishery off the east coast of Scotland (ICES, 2004b) indicated that there was no beneficial effect (i.e no increase) on gadoid predator biomass in the region, which was ascribed to the fact that fish predators mainly target 0-group sandeels (Greenstreet, 2006). The fishery targeted older sandeels, so there was a mismatch between the predatory fish needs and the fishery target stock (from (ICES, 2006)).

The North Sea sandeel stock is known to consist of different sub-stocks (ICES, 2008f), with (sub-)stocks on the Viking/Bergen Banks, in the western North Sea off Scotland, and the (separately-managed) Shetland stock known to be distinct. Local stock depletion could lead to genetic loss.

2.4.2.4.1.2 Death or injury by collision

Animals may be injured by different parts of the fishing gear used in sandeel fisheries, or may find certain parts of the fishing process more stressful than others. Fish tend to be injured by pressure changes on hauling, crushing and the abrasive action of other species' spines or scales. Due to the small mesh size, only the smallest fish will be able to escape from the net to get injured or die. This will be negligible, and thus not contribute to large extra mortality.

2.4.2.4.1.3 Removal of non-target species

The sandeel fishery is generally considered a "clean" fishery with little by-catch (Raakjær Nielsen and Mathiesen, 2006). If there is by-catch, the undersized and non-consumption species are landed for reduction purposes, while some human consumption species are landed as such. The species landed in the Danish sandeel industrial fisheries are shown in Table 2.4.3. The status of most of the stocks of non-target species, except for Norway pout, is discussed in the herring fisheries section 2.4.3 and otter trawl fisheries section 2.4.4.

Table 2.4.3. Landings of the sandeel industrial fisheries averaged for 1996-1999 and 2000 (DIFRES website).

	landings (X 1000t)	
Species	1996-1999	2000
Sandeel	611.9	540.5
Sprat	4.9	2.4
Herring	4.8	2.1
Norway pout	2.1	0.6
Other species	2	1.2
Whiting	1.8	1.5
Blue whiting	1.4	0.7
Haddock	0.7	1.2
Mackerel	0.5	0.4
Horse mackerel	0.4	0.3
Cod	0.2	0.1

Norway pout in Subarea IV and Division IIIa

Based on the most recent estimates of SSB at 146438t, ICES classifies the stock at increased risk of suffering reduced reproductive capacity. The 2008 year class is estimated at 83371 million, which is around 70% of the long-term average (Figure 2.4.9.) (ICES, 2008f).
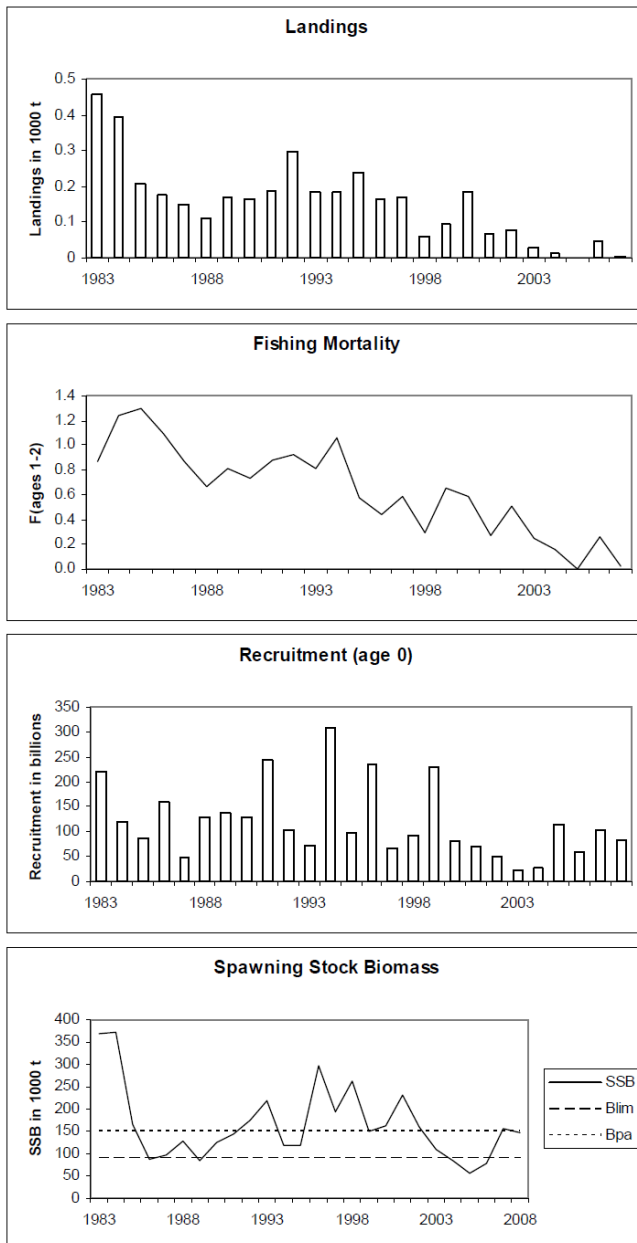
Figure 2.4.9. Norway pout landings, Fishing mortality, recruitment at age 0 and SSB in Subarea IV and Division IIIA (ICES, 2008f).

2.4.2.4.1.4 Removal of target species

There are five sandeel species in the North Sea: the small sandeel (*Ammodytes tobianus*), lesser sandeel (A. *marinus*), the smooth sandeel (*Gymnammodytes semisquamatus*), the great sandeel (*Hyperoplus lanceolatus*), and Corbins sandeel (*Hyperoplus immaculatus*) (Knijn et al., 1993). The lesser sandeels, small sandeel, great sandeel and smooth sandeel comprise the majority of commercial catches.

Sandeel in Division IIIa

The available information on sandeel in Division IIIa is inadequate to evaluate stock trends relative to risk, so the state of the stock is unknown. The only recent data available are official landings statistics which have been variable and provide only a limited basis for scientific advice (ICES, 2008f), Figure 2.4.10.

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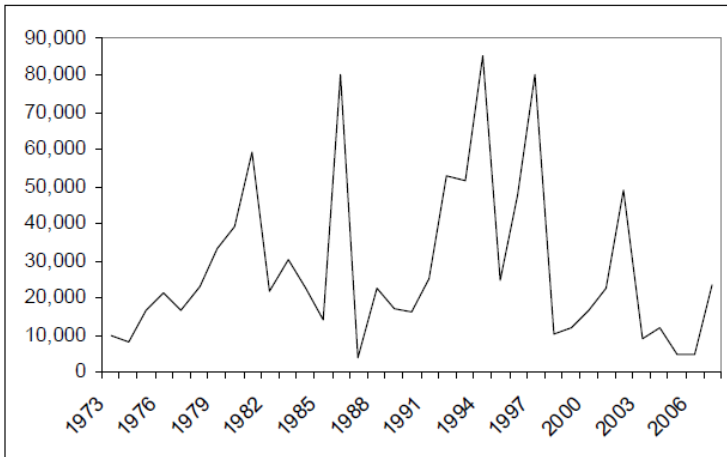
Figure 2.4.10. Landings of sandeel in Division IIIa (ICES, 2008f)

Sandeel in Subarea IV

Average landings of sandeel in Subarea IV in the last 20 years were 666 000 t a year and total landings in 2008 were 335 000 t (ICES, 2008f). Based on the most recent estimate of SSB at 631,104 tonnes, ICES has classified the stock as having full reproductive capacity; however the stock has been forecast to decline below Bpa at the start of 2009. Fishing mortality has been decreasing since 2001 and is now close to its lowest historical level, but the present absolute level is uncertain (Figure 2.4.11). In the absence of an F reference point, the state of the stock cannot be evaluated with regard to sustainable harvest. The high natural mortality of sandeel and the few year classes in the fishery make the stock size and catch opportunities largely dependent on the size of the incoming year classes (ICES, 2008f). A distinct change in the stock dynamics of sandeel seems to have occurred since 2003, following historic low recruitment in 2002 and continued below average recruitment since then. The low recruitment has been linked to changes in the environmental conditions (Van Deurs et al., 2009). The increase in stock size from 2006 to 2008 is due to a reduction in fishing mortality in 2006 and in 2007.
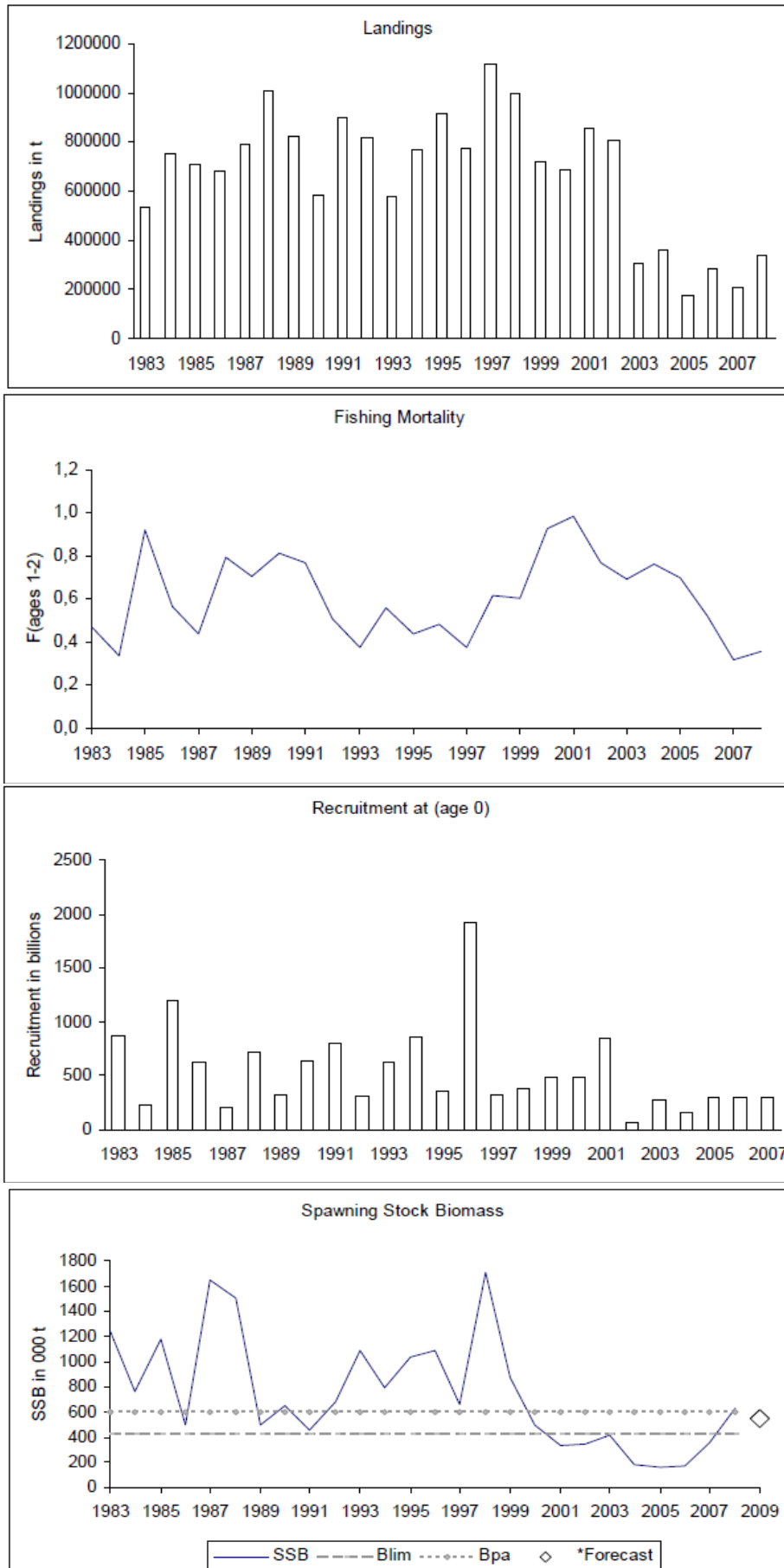
Figure 2.4.11: Sandeel in Subarea IV. Landings, fishing mortality, recruitment at age 0, and SSB (ICES, 2008f).

2.4.2.4.2 *Mammals & reptiles*

The effects of the North Sea industrial sandeel fishery on marine mammals are similar to that of the beam trawl fleet (refer to Section 2.4.1.4.2 for full discussion). Industrial sandeel fisheries are considered to only cause minimal direct mortality of marine mammals although occasional reports of bycatch of mammals exist (ICES, 2006). Sandeels feature in the diets marine mammals in the North Sea, however North Sea marine mammals are opportunistic feeders and a direct link between sandeel numbers and cetacean populations has yet to be demonstrated in any population (ICES, 2006).

2.4.2.4.3 *Seabirds*

Many seabirds prey extensively on sandeels (Tasker and Furness, 1996), and in particular black-legged kittiwakes (*Rissa tridactyla*) show limited switching to other prey types. On a North Sea wide scale sandeel fishing is not considered to have a notable impact on seabird populations (ICES, 2006). However concerns have been raised that sandeel fisheries may impact seabird populations when sandeel fishing occurs close to breeding colonies and localised breeding failure has been noted following depletion of local sandeel populations (ICES, 1996), particularly in the case of kittiwakes (Tasker et al., 2000). Following the closure of the sandeel fishery based on the Wee Bankie, off eastern Scotland, breeding success in kittiwakes increased as the sandeel population increased within the closed area (Daunt et al., 2008). None of the other seabird populations in the area responded to the increase in sandeels (Daunt et al., 2008). However the introduction of the Wee Bankie sandeel fishery closure coincided with an environmentally mediated increase in sandeel productivity in the area, therefore it is difficult to establish the relative extent to which local sandeel abundance is controlled by fishing and environmental factors (Greenstreet, 2006).

2.4.2.5 Other groups

2.4.2.5.1 *Non-indigenous & invasive*

There is no evidence of any effect of the sandeel fishery on non-indigenous or invasive species.

2.4.3   Herring pelagic fisheries

2.4.3.1   Habitats

Although the herring fisheries operate in pelagic habitats they are unlikely to affect either pelagic or benthic habitats.

2.4.3.2   Plants

Herring fisheries are unlikely to affect plants expect possibly phytoplankton indirectly through the food web.

2.4.3.3   Invertebrates

2.4.3.3.1   Zooplankton

Herring fisheries are unlikely to affect zooplankton expect possibly indirectly through the food web.

2.4.3.3.2   Benthos

2.4.3.3.2.1   Removal of target species

Typically the gears used in pelagic fisheries do not impact on the seafloor and so do not directly impact the benthos. However large discards or slippage of the catch may cause considerable local harm to the benthos in terms of organic enrichment and disturbance to the benthic community (ICES, 2006).

2.4.3.4   Vertebrates

2.4.3.4.1   Fish

2.4.3.4.1.1   Community structure or species dynamic changes

Herring is an integral and important part of the pelagic ecosystem in the North Sea. This species is mainly a planktonic feeder. However, there are numerous records of them taking small fish, such as sprat and sandeels, on an opportunistic basis (ICES, 2008a). As plankton feeders they form an important part of the food chain up to the higher trophic levels. Juvenile and adult herring are an important food source for both demersal fish and sea mammals. Herring is therefore considered as the key pelagic species in the North Sea (ICES, 2008a).

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).

Herring 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.

2.4.3.4.1.2   Death or injury by collision

Impacts of the pelagic herring fisheries in terms of injury and death to marine fish caused by fishing gears are likely to be similar to that of the beam trawl fleet (refer to Section 2.4.1.4.1.4 for full discussion).

2.4.3.4.1.3 Removal of non-target species

The pelagic herring fishery operated in the water column and has therefore only negligible bycatches of demersal species. As the fishery targets shoals it is thought to be a relatively clean fishery with considerably less bycatch of non-target fish species than the bottom trawls (ICES, 2008a). However, shoals may consist of mixed species (most notable of herring and mackerel), which could result in non-target species being landed and/or discarded (van Helmond and van Overzee, 2007). The status of some of the non-target species are discussed below.

In addition, the inshore use of purse seines in the Skagerrak may take demersal fish as bycatch in shallow areas, especially in the inner parts of fjords (ICES, 2006). The status of demersal species is discussed in the beam trawl section (refer to section 2.4.1.).

Northeast Atlantic mackerel *(Scomber scombrus)*

Northeast Atlantic mackerel is assessed within ICES by the Working Group of the Assessment of Mackerel, Horse mackerel, Sardine and Anchovy (WGMHSA). The advice for the Northeast Atlantic stock includes three stock components, namely Southern, Western and North Sea mackerel. In parts of the year these components mix in the distribution area. The advised TAC is split into a Northern (IIa, IIIa,b,d, IV, Vb, VI, VII, VIIIa,b,d,e, XII, XIV) and a Southern (VIIIc, IXa) part (ICES, 2008g). The stock assessment shows that fishing mortality in 2007 was estimated to be just above F_{pa} (0.23). SSB has increased by 40% since 2002 and is now above B_{pa} (2300000t) (Figure 2.4.12.). Based on the most recent estimates of fishing mortality, ICES classifies the stock as being harvested at increased risk (ICES, 2008g).

No data on the actual amount of bycatch of mackerel are available. ICES (2008e) states that the reported landings of mackerel in Divisions IIIa and IVb,c from 1997 onwards might seriously underestimate catches due to discarded bycatch.
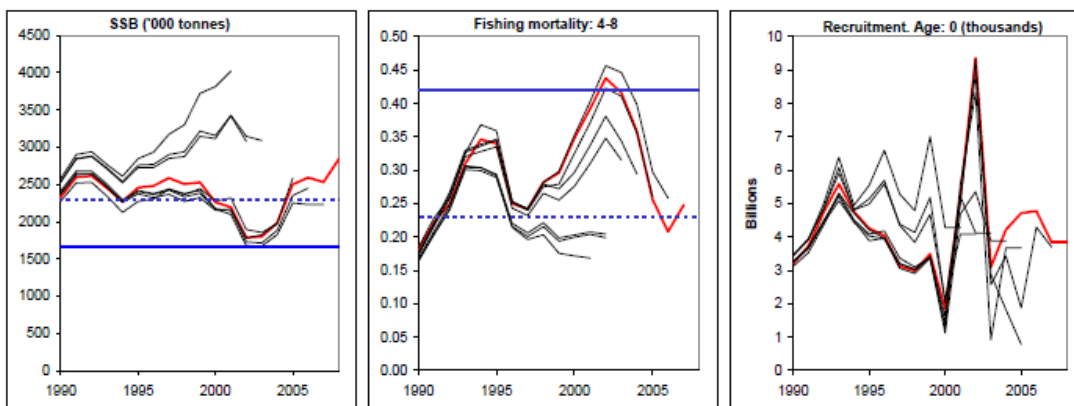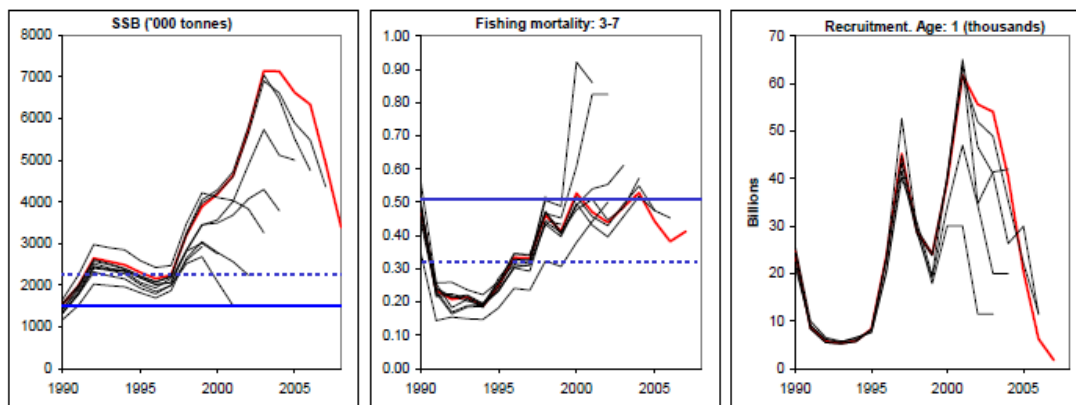

Figure 2.4.12. Historical reconstruction of the Spawning Stock Biomass, Fishing mortality and recruitment of Northeast Atlantic mackerel (combined Southern, Western, and North Sea spawning components) (ICES, 2008g). With new information the reconstruction is adjusted ever year with the red line showing the most recent reconstruction. The solid line indicates the limit value (B_{lim}, F_{lim}), the dotted line indicates the precautionary value (B_{pa}, F_{pa}).

North Sea horse mackerel (*Trachurus trachurus*)

North Sea horse mackerel is also assessed within ICES by WGMHSA. The advice for the fishery in 2009 is the same as the advice given in 2007 for the 2008 fishery: "ICES reiterates the recommendation made since 2002 to limit the catches to below 1982-1997 average of 18,000t. It is necessary to constrain the fishery until there is more information about the structure of horse mackerel stocks, and sufficient information to show that higher exploitation rates are sustainable" (ICES, 2008g).

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 (Figure 2.4.13) (ICES, 2008g).

Figure 2.4.13. Historical reconstruction of the Spawning Stock Biomass, Fishing mortality and recruitment of blue whiting combined stock (Subareas I-IX, XII, and XIV) (ICES, 2008g). With new information the reconstruction is adjusted ever year with the red line showing the most recent reconstruction. The solid line indicates the limit value (B_{lim}, F_{lim}), the dotted line indicates the precautionary value (B_{pa}, F_{pa}).

Discarded species

Theoretically, the use of echo-sounding equipment 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 size of fish are too small, or the fish have poor quality (ICES, 2008a). Relatively large amounts of catch are released from the cooling tanks (tank slippage) or straight from the net (net slippage) also resulting in discarding.

A study by Pierce et al. (2002) monitored the bycatch 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% (Pierce et al., 2002). 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.

2.4.3.4.1.4 Removal of target species

North Sea herring and herring in Division IIIa is assessed within ICES by the Herring Assessment Working Group for the Area South of 62°N (HAWG).

Based on the most recent estimates of SSB and fishing mortality, ICES classifies the North Sea herring stock (autumn spawners) as being at risk of having reduced reproductive capacity and at risk of being harvested unsustainably. The SSB in the autumn in 2007 was estimated at 0.98 million t, and is expected to remain below B_{pa} (1,300,000t) in 2008. F_{2-6} was estimated at 0.33, well above the precautionary limit (0.25) (Figure 2.4.14.). All year classes since 2002 are estimated to be among the weakest since the late 1970s (ICES, 2008a).

Herring caught in Division III are a mixture of North Sea Autumn Spawners (NSAS) and Western Baltic Spring Spawners (WBSS). NSAS is assessed within the North Sea herring stock assessment while the WBSS in Division IIIa and Subdivisions 22-24 is assessed separately. No reference points have been defined for this stock. Consequently the state of the stock cannot be evaluated. ICES (2008a) states that the SSB has been stable over a number of years and is around the lowest level since the beginning of the time-series. Fishing mortality has also been stable well above any proxy of F_{msy}. Recruitment has declined since 2003 and is now at the lowest observed level (ICES, 2008a) (Figure 2.4.15.).
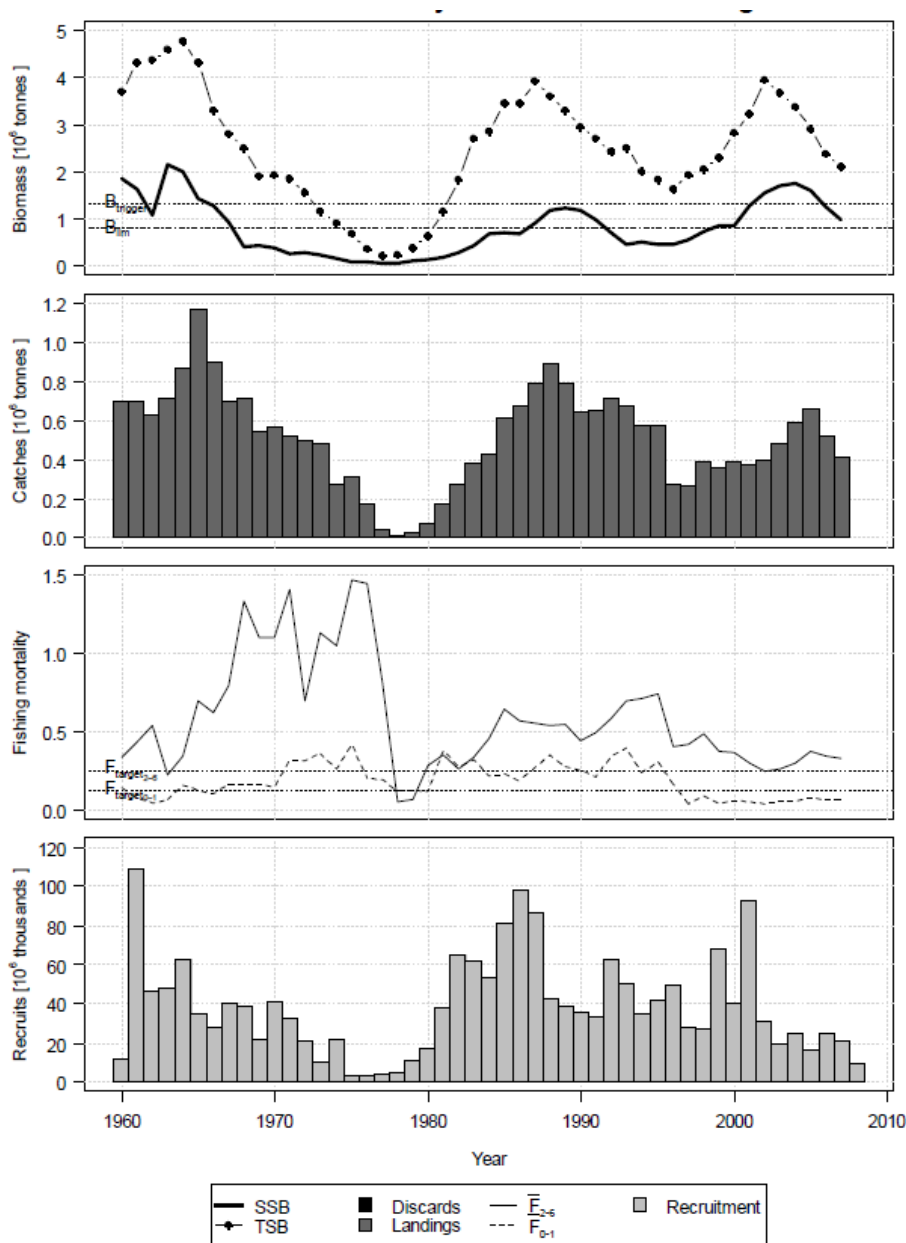
Figure 2.4.14. Herring in Subarea IV, Divisions VIId and IIIa, stock summary. Fishing mortality is expressed as averages over ages 2-6 (dots) and 0-1 (line) (ICES, 2008a).
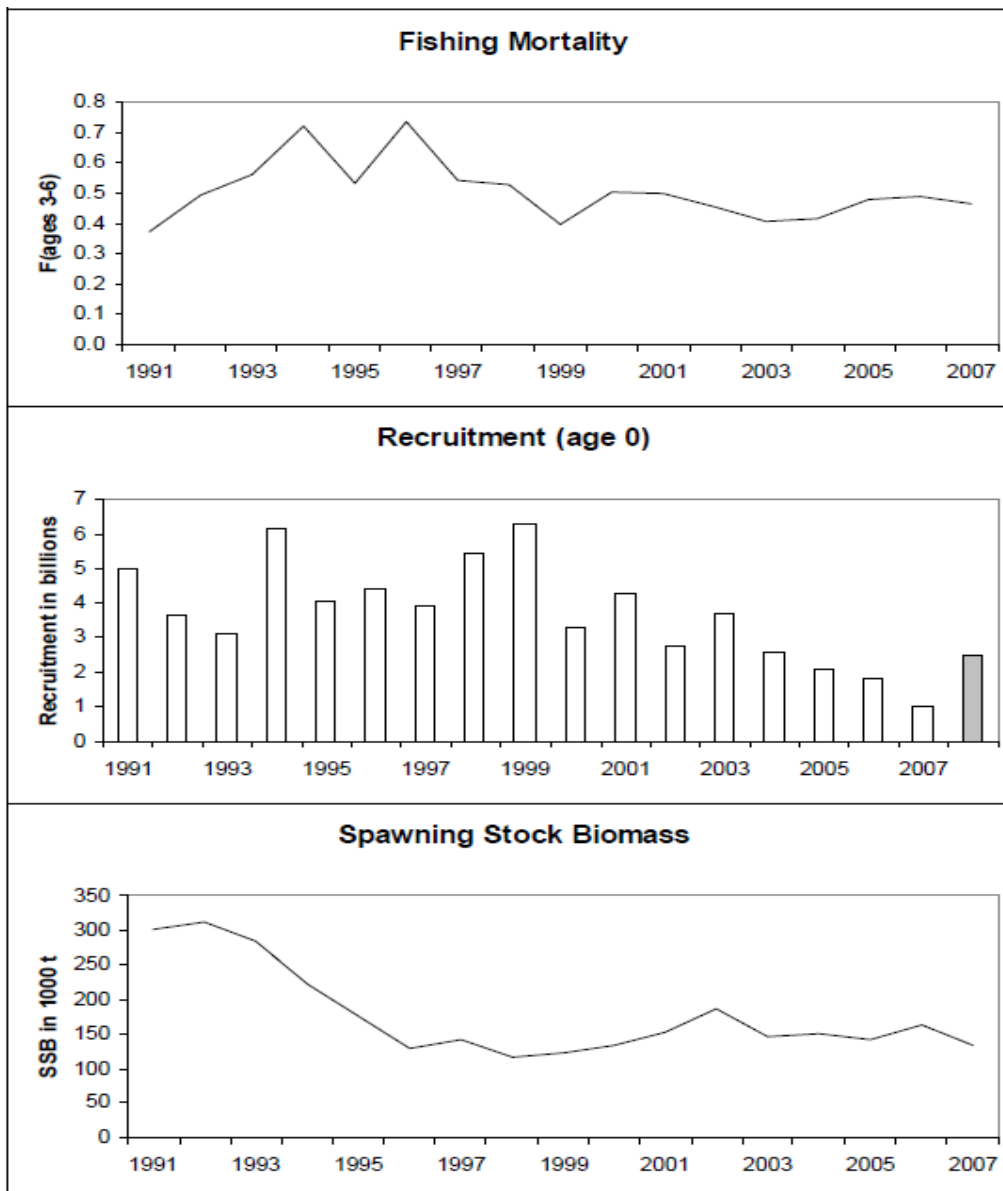
Figure 2.4.15. Herring in Subdivisions 22-24 and Division IIIa (spring spawners). Fishing mortality, recruitment, and SSB. Recruitment prediction is shown shaded (ICES, 2008a).

2.4.3.4.1.5   Noise and visual disturbance / Noise disturbance / Visual disturbance

Noise and visual disturbance caused by pelagic fisheries can result in an avoidance reaction and stress. For further information see the beam trawl section (section **2.4.1.4.1.9**).

2.4.3.4.2 *Mammals & reptiles*

The effects of the North Sea herring trawl fleet on marine mammals are similar to that of the beam trawl fleet (refer to Section 2.4.1.4.2 for full discussion).

Occasional bycatch of pilot whale (*Globicephala melaena*), other small cetaceans and seals by the North Sea pelagic herring trawl fleet has been reported (Commission Staff Working Paper, 2002;ICES, 2006;Couperus, 2008), however it is considered that these incidents are infrequent. In general the marine mammals in the

North Sea are opportunistic feeders capable of switching diets to reflect local abundance and therefore robust to the effects of prey removal by the pelagic herring fleet. It is considered that the pelagic herring trawl fleet has no significant impact at the population level (ICES, 2006).

2.4.3.4.3 *Seabirds*

Lipid rich pelagic fish such as herring provide an important prey source for many seabirds (ICES, 1996), so the pelagic herring fleet acts as a competitor with seabirds foraging for herring. Few seabirds are highly dependent upon herring, and most are capable of prey switching behaviour. However reproductive failure of Norwegian puffins (*Fratercula arctica*) was associated with the collapse of the herring fishery (Barrett et al., 1987). Other seabirds in the North Sea are considered robust to changes in the herring population (ICES, 1996). Pelagic fisheries tend to produce low levels of discards and are not thought to cause notable food subsidy for seabirds (ICES, 2006).

2.4.3.5 Other groups

2.4.3.5.1 *Non-indigenous & invasive*

There is no evidence of any effect of the herring fishery on non-indigenous or invasive species.

2.4.4 Mixed demersal whitefish trawl fishery

2.4.4.1 Habitats

2.4.4.1.1 Seafloor

2.4.4.1.1.1 Habitat structure changes

The effects of fishing on habitat are related to physical disturbance by bottom gears in contact with the seafloor. In summary, these include 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) (cited in Jennings and Kaiser, 1998) estimated that otter boards could penetrate up to 15cm in the soft mud of the Baltic Sea, and sometimes the doors may be fitted with metal shoes to prevent them penetrating too far into the sediment (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 – 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 size of the opening (Rijnsdorp and Leeuwen, 1996). Some disturbance may be generated by the underside of the trawl also. This may be especially visible in areas with complex biogenic structures, as all the components of the trawl are capable of impacting the habitat (Collie et al., 2000b).

2.4.4.1.1.2 Siltation (turbidity) changes

For otter trawls, the main agent of sediment disturbance appears to be limited to the otter boards as these are the only part of the gear to penetrate the sediment to any extent. The physical effect of dragging any gear across the sea bed results in the displacement of substrate (Dayton et al., 1995;Pilskaln et al., 1998;Schwinghamer et al., 1998). However, in shallow areas, the amount of sediment re-suspended by trawls was less than that suspended by storms (Churchill, 1989) and may explain why the impact of fishing in areas of high natural disturbance is less than the more stable habitats.

2.4.4.1.2 Water column

The demersal whitefish fisheries are unlikely to affect the water column habitat.

2.4.4.1.3 Protected habitats

Habitats may be protected to protect fisheries or for more general conservation purposes such as protection of a coral reef or the habitat of a marine mammal). Both types of protected habitat are considered here.

2.4.4.1.3.1 Community structure or species dynamics changes

Some protected habitats, such as maerl beds, *Lophelia* reefs, *Sabellaria spinulosa* reefs and *Modiolus modiolus* beds, which support high levels of biological diversity will be significantly affected by any gears which are dragged along the sea floor. Impacts affect both the biogenic habitat itself and the communities they support.

2.4.4.1.3.2 Death or injury by collision

The sensitivity of organisms to impact by otter trawls is dependent on their size, shape and location. The protected biogenic habitats would suffer extensive mortality and injury through collision with the otter boards and trawl net (Hall et al., 2008).

2.4.4.2 Plants

2.4.4.2.1 Phytoplankton

To the best of our knowledge there are no significant effects of fishing on phytoplankton. While we acknowledge that change in the population size and distribution of plankton-feeding members of the other components may itself be a consequence of fishing effects, there is no known evidence that this is a significant driver in the structuring of North Sea plankton.

2.4.4.2.2 Macroalgae

Macroalgae may be affected by otter trawls if they are attached to hard substrates (e.g. rocks and cobbles) which are likely to be disturbed. As this type of substrate is likely to damage fishing gears or the catch, these areas are likely to be avoided.

2.4.4.3 Invertebrates

2.4.4.3.1 Zooplankton

Otter trawls are unlikely to directly affect zooplankton (Section 2.4.1.2.1). Indirectly there may be an effect through the food chain or the release of nutrients from the disturbance to the surface of the sediment but this is 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 meroplanktonic larvae comprises a major part of the zooplankton and this can influence system dynamics through their consumption of phytoplankton and microzooplankton. Similarly, there are certainly occasions when large, gelatinous, plankton are caught in, or macerated by, passage through nets. We are not aware of any studies that allow us to comment on the ecological consequences of this mortality.

2.4.4.3.2 Benthos

The effects of fishing on benthos populations and communities are discussed in detail in this section. By case study the cells in the matrix are 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 is discussed in the section on the Mixed flatfish Beam trawl and will be referred to here, along with an attempt to determine how the mixed whitefish fishery would contribute to the overall change.

2.4.4.3.2.1 Community structure or species dynamic changes

The swept demersal gear of the otter trawl impacts the benthic community. The effect will correspond to the effects of the mixed beam trawl case study (section 2.4.1). However the effects will be less severe owing to the lower impact to the bottom (Hall et al., 2008); this assertion is support by a study which demonstrated that beam trawls caught a significantly higher median volume of 'benthic invertebrates' per hour than otter trawls (Lart et al., 2002).

There is however only partial spatial overlap with the mixed beam trawl fisheries in the North Sea. Therefore in the Northern part of the North Sea which is mainly fished by the otter trawl fisheries the relative impact on the benthic community can be severe.

2.4.4.3.2.2　Death or injury by collision

See mixed beam trawl case study (refer to Section 2.4.1. for full discussion).

2.4.4.3.2.3　Removal of non-target species

Removal of non-target species in the mixed demersal whitefish trawl fishery is likely to be similar to that of the beam trawl fleet (refer to Section 2.4.1 for full discussion).

2.4.4.3.2.4　Removal of target species

Impacts of the mixed demersal whitefish trawl fishery on target species is likely to be similar to that of the beam trawl fleet (refer to Section 2.4.1 for full discussion).

2.4.4.4　Vertebrates

2.4.4.4.1　Fish

2.4.4.4.1.1　Barrier to species movement

Like the beam trawl, the otter trawl operates close to the bottom. The otter trawl impacts habitat structures (section 2.4.4.1.1.1.) and therefore also indirectly affects species movement (refer to Section 2.4.1. for full discussion).

2.4.4.4.1.2　Community structure or species dynamic changes

The mortality caused by the otter trawl is higher for larger roundfish species, while pelagic and small specimens are much less impacted. This 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. The consequences of such changes are described in the beam trawl section (refer to Section 2.4.1 for full discussion).

2.4.4.4.1.3　Death or injury by collision

Impacts of the mixed demersal whitefish trawl fishery in terms of injury and death to marine fish caused by fishing gears are likely to be similar to that of the beam trawl fleet (refer to Section 2.4.1.3.2.2 for full discussion).

2.4.4.4.1.4　Removal of non-target species

The mixed demersal whitefish fishery removes non-target species, of which some are landed while others are discarded. These non-target species consist of other roundfish and flatfish. The status of flatfish species and rays are discussed in the beam trawl section (2.4.1.). The status of some of the roundfish species are discussed below.

Saithe (*Pollachius virens*)

Saithe in Subarea IV (North Sea, Division IIIa (Skagerrak), and Subarea VI (West of Scotland and Rockall) was last assessed in 2008 (ICES, 2008b). The stock assessment shows that from 1984 to 1998 the SSB of saithe appeared to be below B_{pa} (200,000t), and was below B_{lim} (106,000t) from 1990 to 1993. In the late

1990s the SSB increased and is estimated to have been at or above B_{pa} since 1998. The fishing mortality appears to have declined since 1986, and has been below F_{pa} (0.4) since 1997 (Figure 2.4.16.). Based on the most recent estimates of SSB (in 2008) and fishing mortality (in 2007), ICES classified the saithe stock as having full reproductive capacity and being harvested sustainably (ICES, 2008f).

In 2007 WGNSSK estimated saithe landings in IV and IIIa to be around 93,618 tonnes. The total yield of saithe is depicted in Figure 2.4.4.4.1.4.1. (ICES, 2008f).

In 2004 the EU and Norway agreed to implement a long-term plan for saithe in the Skagerrak, North Sea and west of Scotland. The management plan was evaluated by ICES in 2008 and is considered to be consistent with the precautionary approach in the short term (<5 years) (ICES, 2008f).
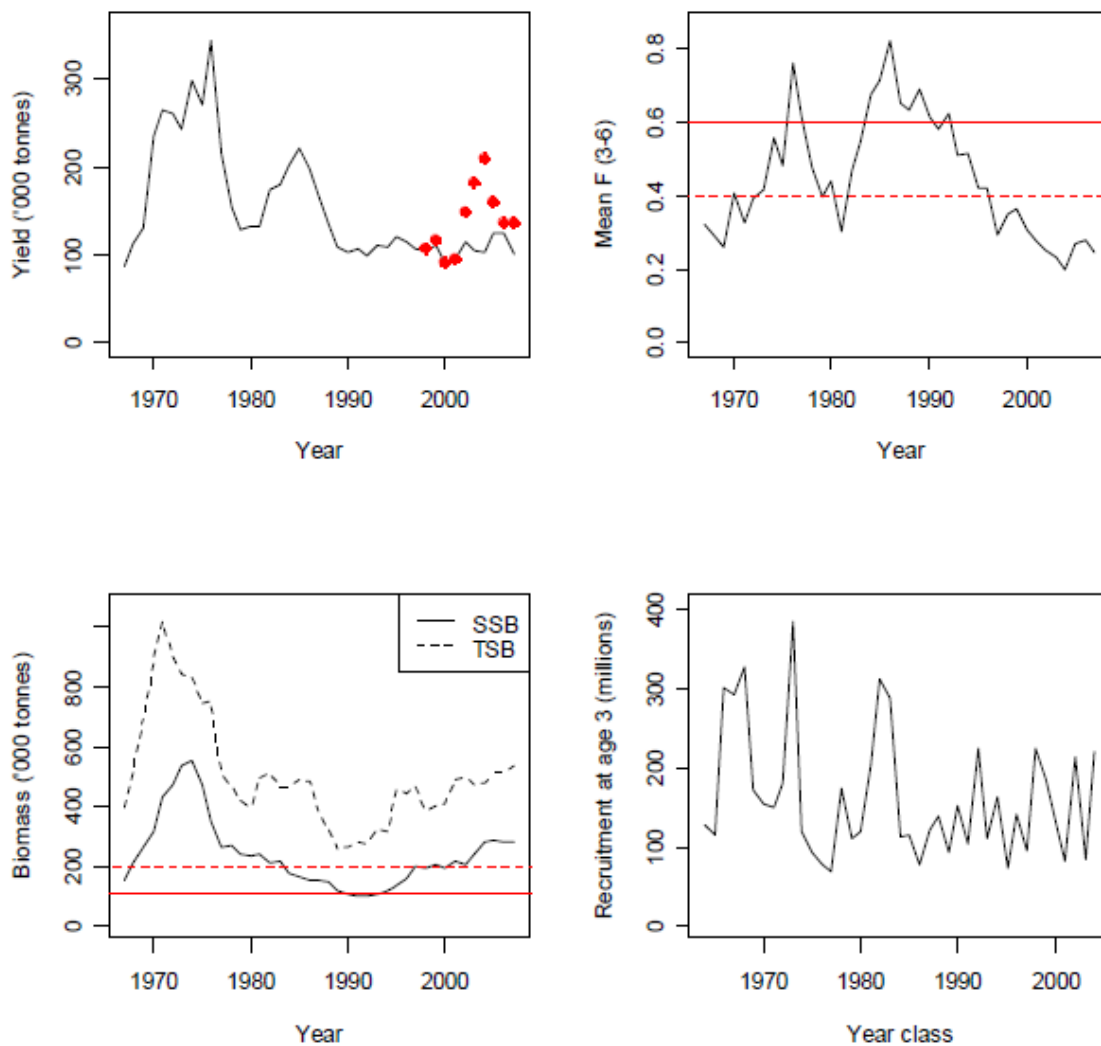
Figure 2.4.16. Stock summary for saithe in Subarea IV, VI and Division IIIa. Yield (top left plot), fishing mortality (top right plot), SSB (bottom left plot) and recruitment (bottom right plot). The red dot in the yield graph are TACs. The dotted horizontal red lines indicate F_{pa} and B_{pa} while the solid horizontal red lines indicate F_{lim} and B_{lim} (ICES, 2008f).

Gurnards

Gurnards are often not sorted by species when they are landed. This is reflected in the catch statistics where different species of gurnards are often reported into one generic category of "gurnards". Only some countries

report landings of grey gurnard (*Eutrigla gurnardus*), tub gurnard (*Trigla lucerna or Chelidonichthys lucernus*), and red gurnard (*Aspitrigla cuculus or Chelidonichthys cuculus*) separately (ICES, 2007a).

Of the four gurnard species found in the North Sea, grey gurnard is by far the most abundant (Heessen and Daan, 1996). For the North Sea and the Skagerrak/Kattegat data are available of grey gurnard from the International Bottom Trawl surveys (IBTS). Based on IBTS survey data, Heessen & Daan (1996) suggest that there may be three sub-populations of grey gurnard in the North Sea and Skagerrak/Kattegat: one north-west of the Dogger Bank, one around Shetland and one in the Skagerrak/Kattegat. ICES (2007a) suggests that there is indeed an area with low abundance between the North Sea and the Skagerrak, but that a more or less continuous distribution exists between the central and north western North Sea. Grey gurnard may well be separated from grey gurnard in the Channel (ICES, 2007a). The status of the stocks in areas IIIa, IV and VIId,e is not known but catches from the IBTS survey in the North Sea show a marked increase since the late 1980s (Figure 2.4.17.) (ICES, 2007a).

Beare et al. (2004) have suggested, based on a long time-series of CPUE (1925-2003) from FRS surveys, that the abundance of the southern species (including tub gurnard and red gurnard) has increased over the last decade. Only some countries report landings of tub gurnard and red gurnard separately. ICES (2007a) reported landings of tub gurnard in the North Sea by Denmark, the Netherlands and France and of red gurnard by Belgium, France, the Netherlands and the UK. The summed values are presented in Figure 2.4.18. However, the data may be incomplete.
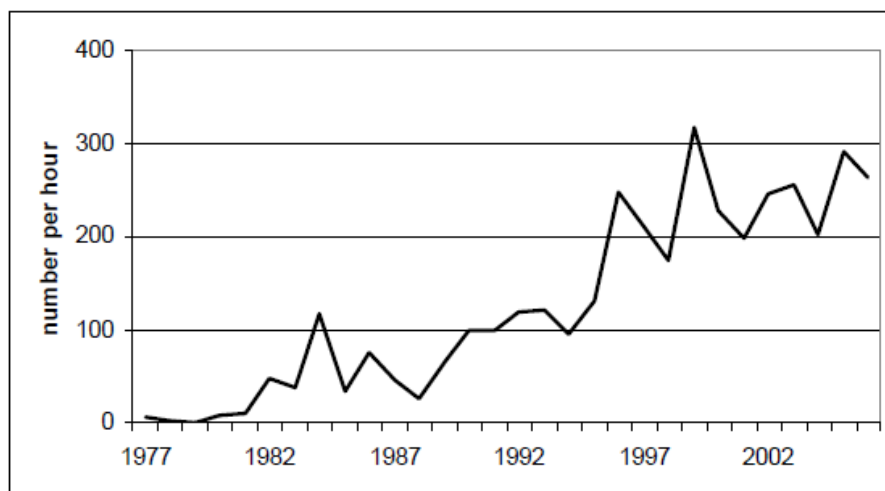

Figure 2.4.17. Average catch rate (number per hour for all length classes combined) of grey gurnard in the North Sea (excl. Skagerrak and Kattegat), based on quarter 1 IBTS (ICES, 2007a).
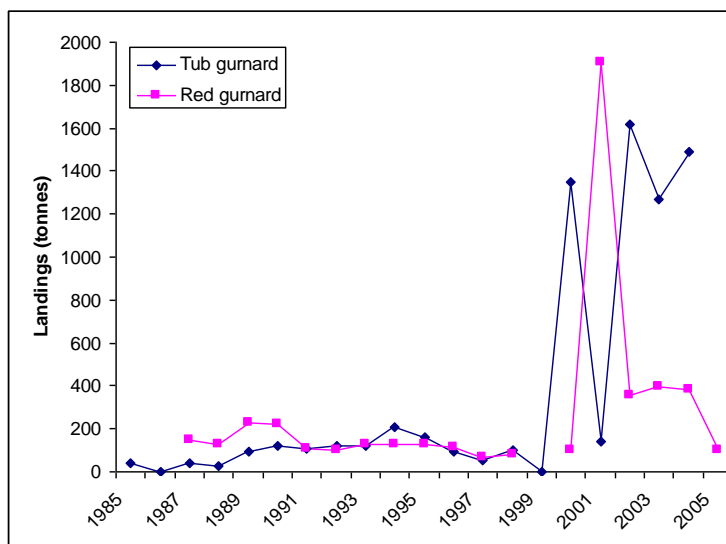
Figure 2.4.18. Total landings in tonnes of tub gurnard (reported by Denmark, the Netherlands and France) and red gurnard (reported by Belgium, France, the Netherlands and UK) (ICES, 2007a).

Seabass (*Dicentrarchus labrax*)

SGBASS (ICES, 2004a) and Pawson et al. (2007) analysed seabass stock trends. In both analyses no biological reference points were proposed. WGNEW (ICES, 2007a) states that both assessment approaches require consistent landings and effort data. Given the fact that the stock status of seabass is unknown, WGNEW recommends that effort should not be allowed to increase and that additional data that could be used for assessments should be collected (ICES, 2008d).

Striped red mullet (*Mullus surmuletus*)

The North Sea is one of the three main areas for the exploitation of striped red mullet. WGNEW (ICES, 2007a) has provided landings data of striped red mullet per country. For the North Sea, landings data is available from France, UK and the Netherlands. It appears that France is the main contributor for striped red mullet landings (Figure 2.4.19.). For stock assessment, biological sampling information must be supplemented in the southern North Sea (ICES, 2008d).
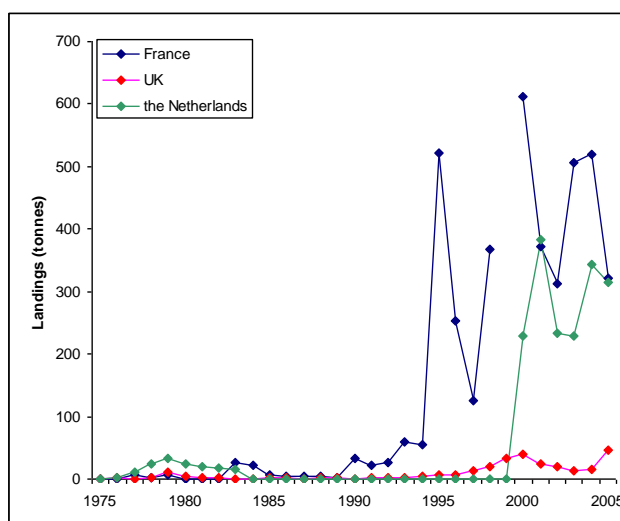

Figure 2.4.19. Striped red mullet landings (in tonnes) from IVa and IVb by country (ICES, 2007a).

<u>Discarded species</u>

Besides the target and non-target species that are landed, a part of the catch is discarded. The discards consists of undersized target species, non-commercial species and other vertebrates (EFEP, 2001).

Within STECF, information was brought together for the top ten discarded species in the demersal trawl and demersal seiner fishery. (STECF, 2006) reported discard rates (in weight) by species and year for the demersal trawl and seine (DTS) (Figure 2.4.20.). Unfortunately data is not available for only the otter trawl fishery targeting whitefish.
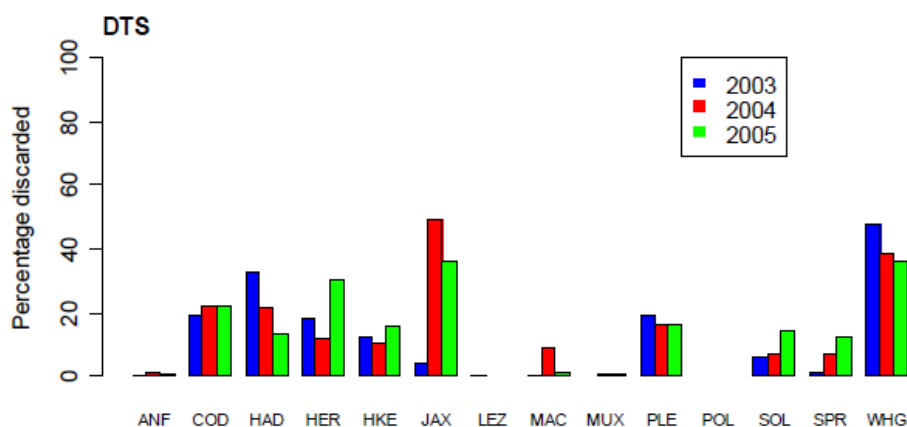
Figure 2.4.20. Discard rates (in weight) by species and year for demersal trawl and seine (DTS). ANF=anglerfishes, COD=cod, HAD=haddock, HER=herring, HKE=hake, JAX=horse mackerel, LEZ=megrim, MAC=mackerel, MUX=mullets PLE=plaice, POL=Pollack, SOL=sole, SPR=sprat, WHG=whiting (STECF, 2006).

2.4.4.4.1.5 Removal of target species

The mixed demersal whitefish fishery mostly targets demersal round whitefish that feed at or near the bottom. Cod, whiting and haddock are the main target species within this fishery. These species are annually assessed by ICES within WGNSSK. ICES has implemented the precautionary approach in its advice on fish stocks and catch levels; this approach is described in the beam trawl section (Section 2.4.1).

<u>Cod</u> (*Gadus morhua*)

Cod in Subarea IV (North Sea), Divisions VIId (Eastern Channel) and IIIa (Skagerrak) was last assessed in 2008 (ICES, 2008f). The stock assessment shows that the SSB of cod has been below B_{pa} (150,000t) since 1982 and below B_{lim} (70,000t) since 1999, with a historical low in 2006. The SSB has shown an increase since then but remains below B_{lim}. Fishing mortality has shown a decline since 2000, and is currently just below F_{pa} (0.65) (Figure 2.4.21.) (ICES, 2008f).

The European Commission has adopted a cod recovery plan wherein a limited catch of cod remains possible. ICES considers the EU recovery plan as not consistent with the precautionary approach and advises that a zero catch offers the best opportunity for the stock to recover (ICES, 2008f).

WGNSSK estimated cod landings in IIIa and IV in 2007 to be 2.9 and 19.7 tonnes respectively. This estimate is based on annual data (ICES, 2008f).
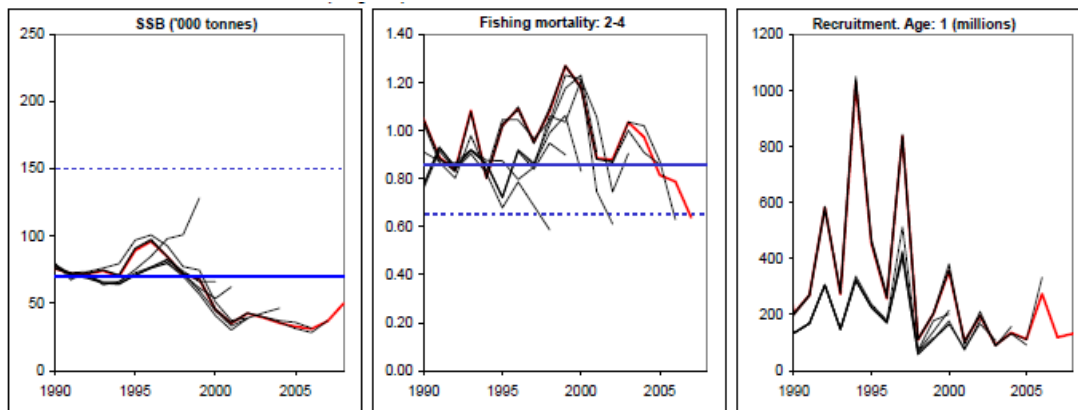
Figure 2.4.21.: Historical reconstruction of the Spawning Stock Biomass, fishing mortality and recruitment of cod in Subarea IV, Divisions VIId and IIIa (ICES, 2008f). With new information the reconstruction is adjusted ever year with the red line showing the most recent reconstruction. The solid line indicates the limit value (B_{lim}, F_{lim}), the dotted line indicates the precautionary value (B_{pa}, F_{pa}).

Haddock (*Melanogrammus aeglefinus*)

Haddock in Subarea IV (North Sea), Divisions IIIaN (Skagerrak) was last assessed in 2008 (ICES, 2008f). The stock assessment shows that through time the SSB has been mostly above the precautionary limit (B_{pa}=140,000t). The fishing mortality seems to have declined since 1990 and has been below F_{pa} (0.7) since 1996. Based on the most recent estimate of SSB (in 2008) and fishing mortality (in 2007), ICES classified the stocks as having full reproductive capacity and being harvested sustainably (Figure 2.4.22). SSB in 2008 is estimated to be above B_{pa}. Fishing mortality in 2007 is estimated to be below F_{pa} but above the target F_{HCR} (0.3) specified in the EU-Norway management plan (ICES, 2008f).

WGNSSK estimated haddock landings in IV and IIIaN in 2007 to be 30.5 and 1.6 tonnes respectively. The total yield (including landings, discards and industrial bycatch) of haddock is depicted in Figure 2.4.22. (ICES, 2008f).
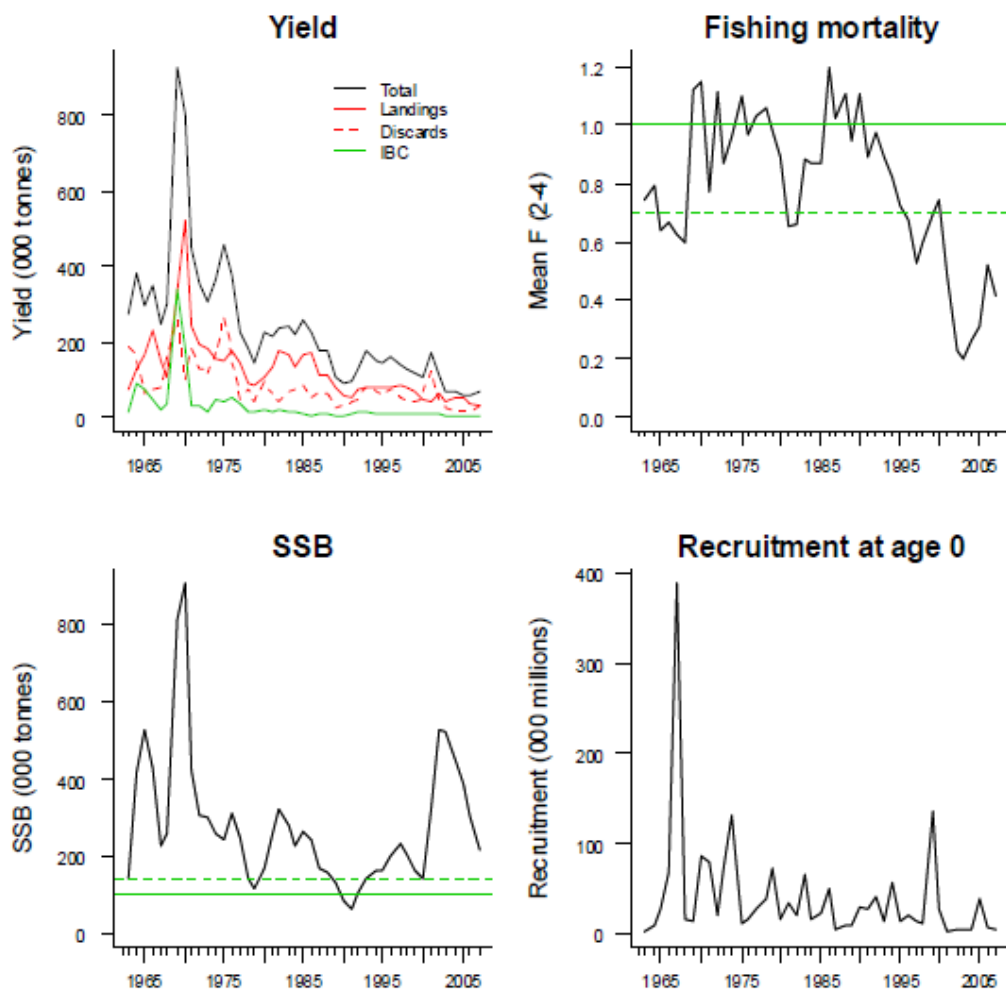
Figure 2.4.22. Stock summary for haddock in Subarea IV and Division IIIaN. Yield (top left plot), fishing mortality (top right plot), SSB (bottom left plot) and recruitment (bottom right plot). The dotted horizontal green lines indicate F_{pa} and B_{pa} while the solid horizontal green lines indicate F_{lim} and B_{lim} (ICES, 2008f). IBC = industrial bycatch.

Whiting (*Merlangius merlangus*)

Whiting in Subarea IV (North Sea), Division VIId (Eastern Channel) was last assessed in 2008 (ICES, 2008f). The EU and Norway have agreed on reference points for this stock. However, ICES considered that these reference points are not applicable to the current assessment (ICES, 2008f). In the absence of defined reference points, the state of the stock cannot be evaluated.

In 2008 the working group provided information on whiting in Subarea IV and Division VIId. An analytical assessment estimated SSB in 2008 as being at the lowest level since the beginning of the time-series in 1990. Fishing mortality has decreased through the time-series, but increased in recent year to twice F_{max}. The recruitment has been very low since 2001. As a result of the very low recruitment ICES cannot recommend any fishing mortality above F_{max} of 0.19 in 2009 (Figure 2.4.23.)(ICES, 2008f). WGNSSK estimated whiting landings in Subarea IV in 2007 to be 16.2 tonnes (ICES, 2008f).

In 2007 the working group stated that no assessment of the whiting stock in IIIa was possible. The available information then appeared to be inadequate to evaluate spawning stock or fishing mortality. Survey information (1980-2007) shows a decline in the stock size since 2002 and the stock is now below the average of the time-series (1980-2007) (ICES, 2007c).
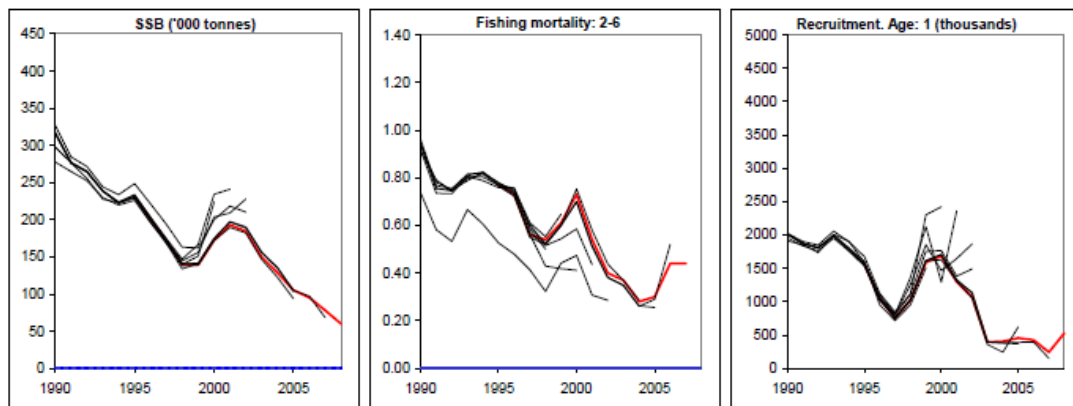
Figure 2.4.23. Historical reconstruction of the Spawning Stock Biomass, Fishing mortality and recruitment of whiting in Subarea IV and Division VIId (ICES, 2008f). With new information the reconstruction is adjusted ever year with the red line showing the most recent reconstruction. No reference points are defined.

2.4.4.4.1.6 Heavy metal contamination / Hydrocarbon contamination / Radionuclide contamination / Synthetic compound contamination

Otter trawls resuspend the sediment, this may result in increased levels of contaminants that have previously been stabilised in the sediment (ICES, 2006;ICES, 2007b). The consequences of increased levels of contaminants are described in the beam trawl section (**2.4.1**).

2.4.4.4.1.7 Noise and visual disturbance / Noise disturbance / Visual disturbance

Noise and visual disturbance caused by otter trawlers can result in an avoidance reaction and stress. For further information see the beam trawl section (Section 2.4.1).

2.4.4.4.2 Mammals & reptiles

The effects of the North Sea otter trawl fleet on marine mammals are similar to that of the beam trawl fleet (see Section 2.4.1 for full discussion).

The North Sea otter trawl fleet causes very little direct mortality on marine mammals, although occasional bycatch of harbour porpoise (*P. phocoena*) by the North Sea otter trawl fleets has been reported (Commission Staff Working Paper, 2002). Between 2002-2008, 2,712 separate otter trawl hauls by English and Welsh vessels were observed in ICES IV by the CEFAS CDSP and the only marine mammal observed in the catch was a single harbour porpoise. The porpoise was partially decomposed and therefore must have died prior to encountering the otter trawl.

As with the beam trawl fishery, the otter trawl fishery removes both prey and competitors of marine mammals. The marine mammals in the North Sea are opportunistic feeders capable of switching diets to reflect local abundance. It is considered that the otter trawl fleet has no significant impact at the population level (ICES, 2006).

2.4.4.4.3 Seabirds

The effects of the North Sea otter trawl fleet on seabirds are similar to that of the beam trawl fleet (refer to Section 2.4.1 for full discussion).

The North Sea otter trawl fleet causes very little direct mortality on seabirds, although occasional mortality of gannets (*Morus bassanus*) by the North Sea otter trawlers has been reported (Commission Staff Working Paper 2002). Between 2002-2008, 2,712 separate otter trawl hauls by English and Welsh vessels were

observed in ICES IV by the CEFAS CDSP and there have only been two recorded incidents of seabird mortality associated with trawling activity.

The otter trawl fleet is responsible for a considerable proportion of the discarding that occurs in the North Sea. The otter trawl fleet discarded 39% by weight of all fish discarded by English and Welsh vessels between 2003-2006 in the North Sea (Enever et al., 2009). The considerable proportion of total discarding generated by the otter trawl fleet indicates that the otter trawl fleet is likely to play a significant role in discarding and food subsidy of scavenging seabirds in the North Sea. Discarding by the otter trawl fleet may have led to increases in seabird numbers in areas of the North Sea, although it is hard to disentangle the effect of otter trawl discards on seabird numbers from discarding by other fleets and other factors influencing seabird populations (ICES, 2003).

2.4.4.5 Other groups

2.4.4.5.1 Non-indigenous & invasive

There is no evidence to suggest that the mixed demersal whitefish trawl fishery has a direct effect on any non-indigenous or invasive species. However the altered food web might create a structure more prone to invasion than an uninterrupted system.

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 could 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, 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 dinoflagellate, jellyfish, and disease (Jackson, 2008).

Therefore management should at least have an idea of and consider the synergistic effects of the various anthropogenic activities in the marine environment. The relationship with non-anthropogenic forcing factors, e.g. climate changes, also 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 anthropogenic activities.

Here, we will focus on the synergistic effects of the fisheries case studies with other human activities. It should be noted 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. An overview of threats is provided rather than a full description of what would be the result of the synergistic effects; the intention being to highlight key threats, rather than undertake an extensive review of possibilities. Management should consider these threats and manage each anthropogenic activity in such a way that even the synergistic effect will not cause the ecosystem aspects to exceed the sustainable reference points.

2.5.1 Mixed flatfish Beam trawl

The effects in relation to the beam trawl fisheries concern mainly the demersal fish stocks, benthic communities and sediment structures (see Norse matrix). All other activities which affect these ecosystem aspects could potentially have synergistic effects with the beam trawl fisheries.

Other specific topics to mention are:

- The effect of the beam trawl on demersal eggs, like herring and sandeel could be synergistic with effects from fisheries targeting these species.

- Oil rigs, pipe and telephone lines, windmill park, shipping: these structures form obstructions for the beam trawlers and installation may decrease the amount of fishing grounds. Furthermore, there could be also risks for the environment through collisions e.g. oil pipe breakage.

- Coastal nursery grounds: impacts in the coastal nursery areas of the target species, e.g. eutrophication, pollution and tourism, could affect recruitment to the fishery and synergistic effects could reduce the populations below the reference points.

- Resuspension could enhance and prolong effects of eutrophication, and pollutants.

2.5.2 Sandeel industrial fisheries

The effects in relation to the sandeel industrial fisheries concern mainly the sandeel, herring and sprat stocks, the juveniles of other species and the food production for higher trophic levels (mammals and birds)(see Norse matrix). All other impacts affecting these ecosystem aspects could potentially have synergistic effects with the sandeel industrial fisheries.

Other specific topics to mention are:

- Activities that affect the seabed: fisheries that utilised beam trawls may affect eggs and aggregations of sandeel. Other activities, for example aggregate extraction and offshore construction (e.g. oil platforms, pipes, cables and windmill parks) may also impact on the seabed.

- Aquaculture: the increasing demand for fish food for use in aquaculture is increasing the pressure on these species that are used to produce fish meal e.g. sandeels.

- Climate change: indirect effects of climate change on sandeels have been demonstrated e.g. changes in the copepod composition which are the main food items for juvenile sandeel (Van Deurs et al. 2009).

2.5.3 Pelagic herring fisheries

The effects in relation to the pelagic herring fisheries concern mainly the herring stocks (see Norse matrix). All other impacts affecting these ecosystem aspects could potentially have synergistic effects with the pelagic herring fisheries.

Other specific topics to mention are:

- Activities that affect the seabed: fisheries that utilised beam trawls may affect demersal herring eggs. Other activities, for example aggregate extraction and offshore construction (e.g. oil platforms, pipes, cables and windmill parks) may also impact on the seabed.

- Pile hammering in the construction of windmill parks: the sound produced by the hammering may cause problems for pelagic herring larvae.

2.5.4 Demersal mixed whitefish fisheries

The effects in relation to the demersal mixed whitefish fisheries concern mainly the demersal fish stocks, benthic communities and sediment structures (see Norse matrix). All other impacts affecting these ecosystem aspects could potentially have synergistic effects with the beam trawl fisheries.

Other specific topics to mention are:

- Coastal nursery grounds: impacts in the coastal nursery areas of the target species, e.g. eutrophication, pollution and tourism, could affect recruitment to the fishery and synergistic effects could reduce the populations below the reference points.

- Nephrops fisheries: interaction between the whitefish fisheries and the Nephrops fisheries may occur; whitefish fisheries discard Nephrops while the Nephrops fishery discards smaller demersal species.

2.6   Models of fishing effects

In the matrix, in previous sections, the effect of the fisheries case studies is discussed on various ecosystem components. To be able to discuss and assess these effects quantitatively and on a spatial scale, two models of fishing effects will be described. The first model assesses the direct effect of beam trawling and otter trawling targeting fish on all the main fish species in the demersal North Sea fish community (Piet et al., 2003;Piet et al., 2009). The second model assesses the effect of beam trawling, otter trawling targeting fish and nephrops, and seine fishing on benthic invertebrates and epibenthos (MAFCONS, 2007).

2.6.1   Modelling the mortality of fish

The direct impact of fishing on the fish community is quantified by estimating the mortality of fish species. A model to provide these estimates of mortality was developed during the EFEP project (Piet et al., 2003). This work has been extended during the project MAFCONS (MAFCONS, 2007) and has resulted in a model framework that combines (1) abundance data of all the main fish species in the demersal North Sea fish community, (2) international effort data along with (3) estimates of species- and size-dependent catch efficiency in different fishing gears (Piet et al., 2009).

1) Data from the International Bottom Trawl Survey (IBTS) and the Dutch Beam trawl Survey (DBTS) are used with Virtual Population Analysis (VPA) to estimate absolute abundance of all demersal species (Fraser et al., 2007). Abundance for each cm-class of fish above 10 cm is estimated for each ICES-rectangle covered by the IBTS.

2) An international fishing effort database was recently compiled by (Greenstreet et al., 2007), including data for all nations with significant fishing interests in the North Sea, for the period 1997 to 2004. From this database, effort of the otter trawl targeting fish and beam trawl are used.

3) Species and size-dependent catch efficiencies for the otter trawl and beam trawl were used. Catch efficiency was determined by:
   - Positioning of fish in the water column
   - Herding of fish by the gear
   - Escapement of fish below footrope of the net
   - Retention of fish in the net

The model estimates the catches of the otter and beam trawls. These combined catches are considered as the mortality inflicted by the gears. Thus no survival of discards or further mortality by escapees or injury by the net is considered. For species which have a legal minimum landing size (MLS), the landings are estimated using the MLS. With the estimates of the landings the model outcomes were validated using international

landings (Greenstreet et al., 2007) and discards data (STECF, 2006) for five target species: cod, haddock, whiting, sole and plaice. This showed that, depending on its configuration, the model could reproduce recorded landings and discards of these species reasonably well. This suggests that the model could be used to simulate fishing mortality rates for non-target fish species, for which few data are currently available.

The modelled mortality estimates of the non-target species estimated are based on the assumption that the catchability of non-target roundfish or flatfish species is equal to that of similar sized commercial species of the same type. Catchability depends on both gear efficiency, defined as the fraction of the fish present in the path of a trawl that is retained by the gear, and the distribution of fish in relation to the distribution of the fleet (Rijnsdorp et al., 2006). The assumption on gear efficiency is likely to hold for non-target species. However, within an ICES rectangle it is likely that skippers are able to locate patches with higher than average abundance of commercial fish and thereby lowering the relative impact on the non-target fish. Better understanding of fish dispersion processes and effort distribution, as well as estimates of gear efficiency would considerably enhance the model outcomes.

The model estimates the mortality of each length class of each species by ICES-rectangle split up for the different gears. To visualise the outcomes they are summed for four groups: non-target roundfish; non-target flatfish; elasmobranches; and commercial species. The absolute mortalities in tonnes by length of these groups summed over the whole North Sea are presented in Figure 2.6.1. For the same groups the spatial distribution of the proportional mortalities (proportion caught relative to the abundance of that group in the rectangle) is presented (Figure 2.6.2.). Proportions over 100% occur due to redistribution of fish after trawling. The redistribution of the fish is calculated by dividing the effort in twelve steps after each step the fish redistribute according to their original proportional distribution.
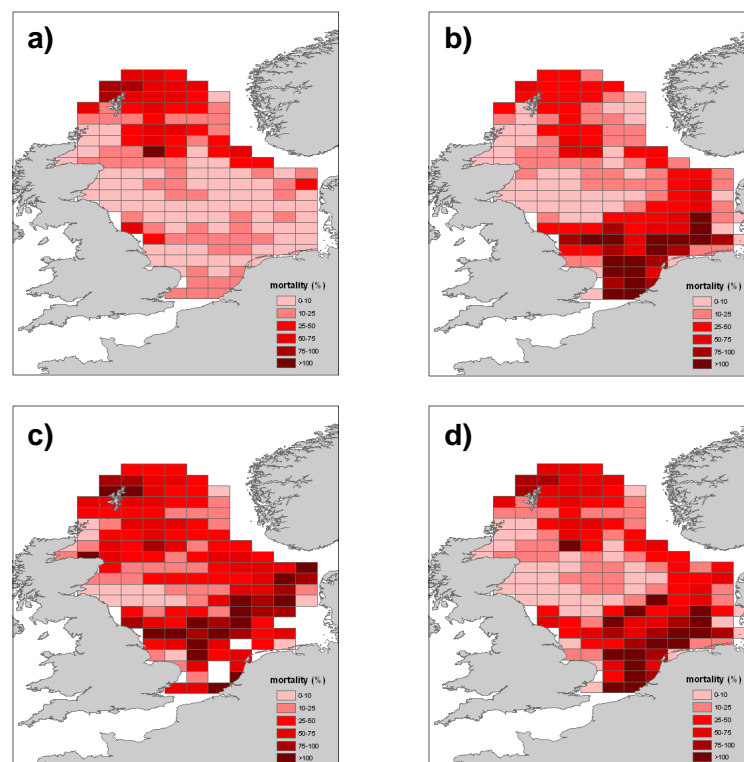

Figure 2.6.2. Spatial variation in modeled estimates of relative annual mortality (absolute biomass removed expressed as a percentage of standing stock biomass) for (a) non-target roundfish, (b) non-target flatfish, (c) elasmobranches and (d) commercial species (Piet et al., 2009).

2.6.2 Modelling the mortality of benthos

The model is used to make comparisons of the relative impact on epibenthic communities. In the model the international fishing effort for each gear type, beam trawl, otter trawl (fish and Nephrops) and seine (Greenstreet et al., 2007), is assumed to be distributed evenly within each 1x1 nautical mile (approximately) grid square within a ICES-rectangle but the distribution of effort between grid cells matches the observed micro-distribution of effort (described by a Poisson distribution). The impact of a gear on the benthos of an area of sea floor is set for each gear type, i.e. a set proportion of the benthos is killed by a single haul. Subsequent passages of a gear over that area remove the same proportion of the remaining fauna. With multiple passages of gear in an intensively fished area, cumulative mortality therefore approaches an asymptote. The set mortalities by gear were based on average mortalities calculated across 12 benthic invertebrate phyla. These mortalities were 0.25 for beam trawl, 0.1 for the two otter trawls and 0.05 for Seine gears. The spatial variation in the abundance and distribution of the epibenthic fauna was used, on which the mortalities were inflicted. The model estimates the proportion of killed benthic biomass due to fishing on a spatial scale as shown in Figure 2.6.3. (Greenstreet et al., 2007).

In reality the proportion of the remaining fauna killed decreases on each subsequent gear passage; the most vulnerable individuals are likely to be removed first and subsequent passes occur on a higher proportion of resistant individuals (deeply buried, sheltered by a stone etc.). Because of this the model would tend to overestimate the degree of mortality of the benthos. Conversely, the first passing of the trawl may uncover burrowed animals which are then killed by the next trawl. Hence for some species the model may underestimate mortality. Furthermore, the model does not take any account of the mobility of benthic invertebrates; in its current form it essentially assumes that these are static. By ignoring the mobility, the model would tend to under estimate the degree of mortality of the benthos. Future development of the model will take account of both these sets of circumstances. For the comparison of relative impacts especially between the gear types these assumptions are not a big issue, but care should be taken in considering exact levels of impact (ICES, 2006).
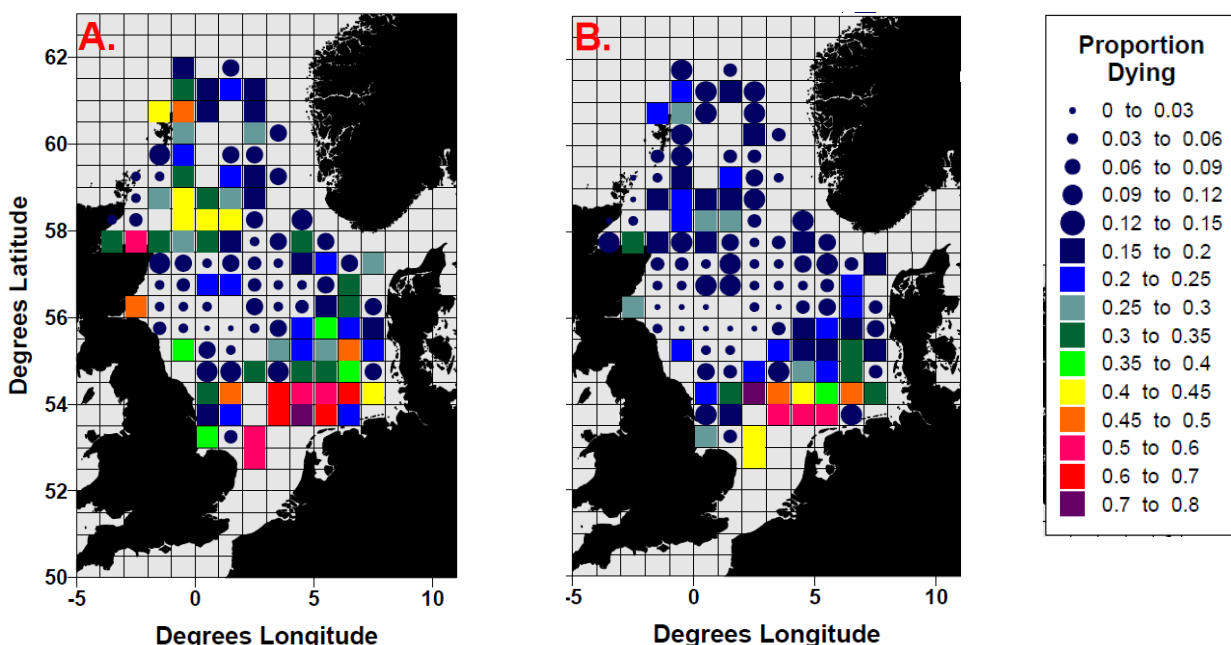

Figure 2.6.3. Modelled impact of four major fishing categories on the benthic community of the North Sea. Maps show total modelled annual mortality of all four gears combined, given the average annual distribution of beam trawl, otter trawl targeting fish, otter trawl targeting Nephrops and Seine gear fishing activity between 2001 to 2004, and (A) assuming community averaged "per fishing event" mortality rates for each gear type that were dependent on species composition in each rectangle, or (B) assuming generic "per fishing event" mortality rates of 25% (beam trawl), 10% (both otter trawls), and 5% (seine net) across all rectangles.

3 What people think

The ultimate objective of the MEFEPO project is developing operational Fisheries Ecosystem Plans for three regional seas (North Sea, North West Waters and South West Waters). As a basis for this, data from national and international marine consultative initiatives was considered. However, while identifying and collating this data, it became clear to the research team that previous stakeholder consultations and responses have revealed very little information that could be used in a forward-looking manner to support the MEFEPO project in developing operational objectives and identifying operational challenges to introducing an ecosystem approach. This is because the present governance framework at both national and international level is very dynamic, and consultative processes are undergoing rapid changes where the introduction of the Regional Advisory Councils has set a new standard for stakeholder consultation. There is limited information on how this type of stakeholder consultation is performing, and thus details of this important vehicle for stakeholder consultation in the EU cannot be incorporated at this stage.

Furthermore, the views articulated by stakeholders are often associated to the management regime in place at the time of the consultation. As several countries have introduced new management regimes since the consultations took place, e.g. ITQ-based management measures, the views presented by stakeholders may be outdated. Nevertheless, previous stakeholder consultation processes have provided background information about stakeholder perceptions within the broader categories of ecological, social and economic issues.

In terms of obtaining a detailed understanding of the institutional and governance issues, the section on institutional set-up for governance serves an important purpose in this first technical report, by laying a solid foundation for the work in subsequent work packages (Section 1.3). This need was not envisioned when the project was formulated, but is a necessity for the MEFEPO project which is focussed on making operational Fisheries Ecosystem Plans. However, operationalisation does not take place in a vacuum. Rather, the operational models developed must 'respect' the path dependence created by the present structures. Therefore, it is vital to start the discussion on operationalisation from a common perception of the current institutional framework, which we have to work within and adapt. Likewise it is crucial to be at least aware of the main on-going reform of the CFP discussions as the institutional elements are already under negotiation, and they might create windows-of-opportunity for reform. These elements have been added to section 1.3.

This is not to say that stakeholder consultation is not important, but this information must be up-to-date, and this is the reason for the slight change in the approach taken in WP1. In WP4 there will be a substantial interaction with stakeholders in relation to institutional and governance issues in relation to ecosystem-based fisheries management in the EU. Subsequent WPs will provide structured stakeholder dialogue to uncover stakeholder perceptions of ecological, social and economic issues related to ecosystem based fisheries management. The MEFEPO project will benefit from consultation with stakeholders and thus information on views, but has also largely benefitted from the analysis and the added description of the current institutional/governance framework, which ecosystem-based fisheries management in the EU need to operate within.

4 Conclusions

This document gives an overview of present knowledge of the North Sea ecosystem and the human activities that affect it, with specific focus on four fisheries case studies, their impact and economic perspective, the institutional governance setup of fisheries management and a vision on human activities. Furthermore, it describes the process around the determination of Good Environmental Status (GES) as used in the Marine Strategy Framework Directive (MSFD). This process took place during 2009 as a joint operation of JRC and ICES and will proceed in 2010. The work on GES is being further developed in work package 2 in parallel with the JRC/ICES process.

The North Sea marine system is reviewed in all its aspects, which makes it difficult to give a single classification of its state. We can conclude that various issues affect the state of different aspects of the ecosystem. The main issues are human activities, specifically the fisheries case studies described. We found many synergistic effects between fisheries and other human activities. This means that studies which consider the impact of specific activities in isolation may misjudge their system-level effects. There is a strong need for a comprehensive framework, a Fisheries Ecosystem Plan (FEP), to assess the outcome of the complex interplay between different activities and their effects.

Climate change is also an issue in the North Sea system, and even though manipulating climate is beyond the scope of North Sea management, it effects need to be considered in assessment and management of human activities and impacts. In many cases the effects of climate change are synergistic with the effects of human activities.

This comprehensive review is a valuable document for future work within the project MEFEPO and in developing and implementing an operational FEP for the North Sea region. The data presented in this document are building blocks for such an FEP and identify gaps that need attention to successfully develop it. The knowledge gaps of the ecosystem as well as the human activities lie mainly in the area of spatial and temporal resolution of the data. The features and activities are known, but for successful management, the spatial and temporal aspects are of major importance. This is a gap we have to accept in this project, but it is advised to put effort into this to minimise this gap to improve the success of FEPs.

Another knowledge gap lies in the interaction between socio-economic components and ecological impacts. The goal was to combine both sides, the socio-economy and ecology, in the Norse Matrix, by determining the effect of specific management tools on the impact types. However, this was unsuccessful due to problems in linking each tools, through its effects, directly to the impact types. In many cases the management tools do not even have an effect on some of the impact types but rather affect the economic status of the sector. Further work in this area is planned for work package 3 of this project. Work package 5 will build on this and will use the models presented in Section 2.6 and combine these with socio-economic models. Appendix 3 gives useful equations to quantify the different socio- economic variables. The spatially and temporally explicit models described in chapter 2.6 will also be in an attempt to work around the lack of space- and time-explicit data.

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Appendix 1: Conceptual Framework of Eutrophication

Based on OSPAR COMPP modified
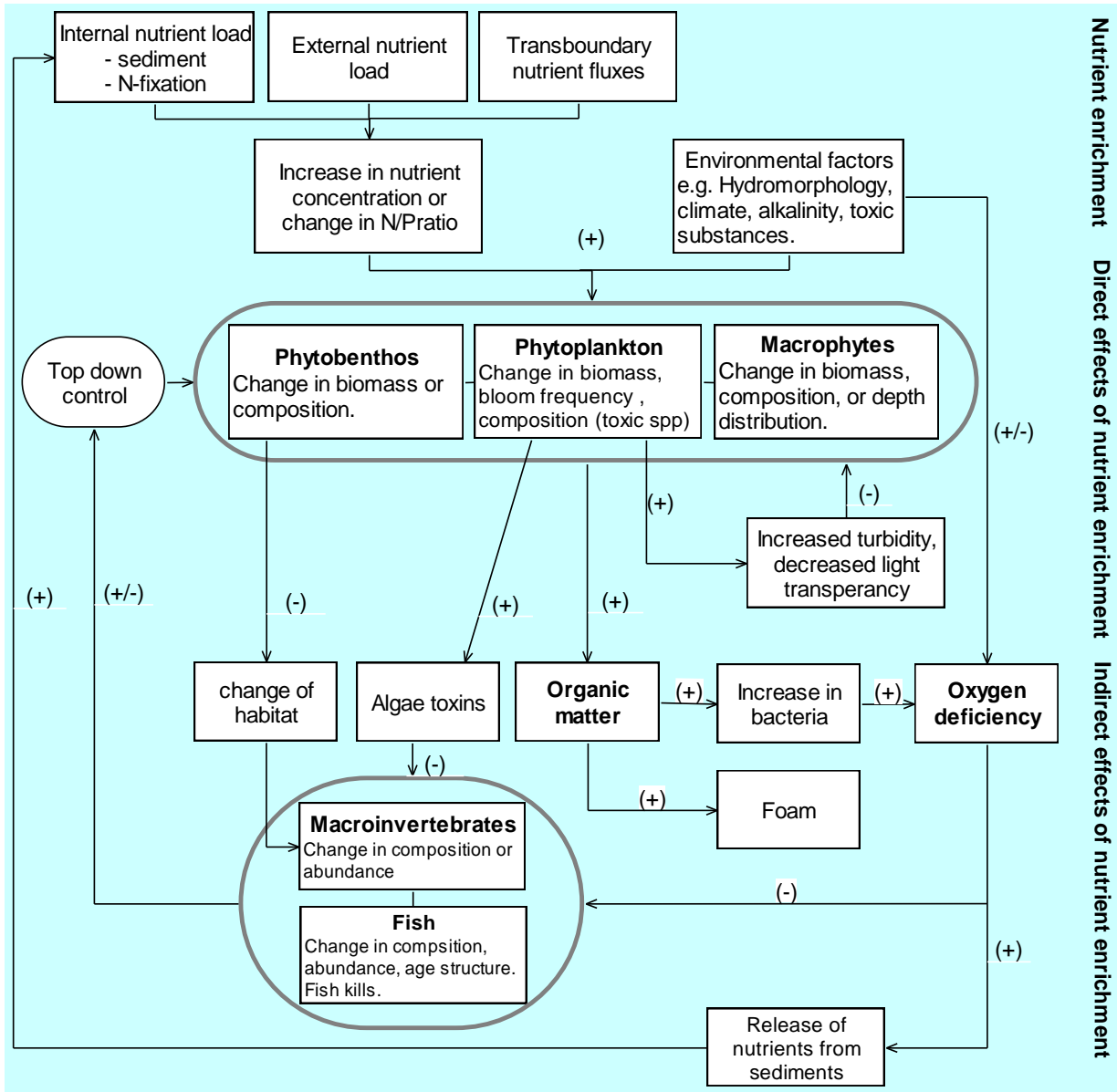
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Appendix 3: Socio-economic variables

G1 Catches measured in physical terms

      1) Catch of species j by country k in sea l (background)

$$x_{jkl} \tag{1}$$

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)

$$X_{hkl} = \sum_{j=j(h(l))} x_{jkl} \tag{2}$$

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)

$$X_{hl} = \sum_{j=j(h(l))} \sum_{k} x_{jkl} \tag{3}$$

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

$$X_k = \sum_j \sum_l x_{jkl} \tag{4}$$

X_k – total catch measured in tonnes of all species and in all seas for country k

   5)   Total catch in sea l

$$X_l = \sum_j \sum_k x_{jkl} \tag{5}$$

X_l = total catch in sea l measured in tonnes

   6)   Relative size of case h in sea l (matrix)

$$r_{h(l)} = \frac{X_{hl}}{X_l} \tag{6}$$

$rh(l)$ = 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)

$$P^S_{\ j} = \frac{\left(\sum_{k=k(h(l))} P_{jk} * x_{jk} \right)}{X_{jk(h(l))}} \tag{7}$$

$k(h(l))$ – 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)

$$P^M{}_h = \frac{\sum\limits_{j=j(h(l))} \sum\limits_{k=k(h(l))} P_{jk} * x_{jk}}{X_{hk(h(l))}}$$ (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

$$P_k = \frac{\sum\limits_{j} P_{jk} * x_{jk}}{X_k}$$ (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

$$P_l = \frac{\sum\limits_{j} \sum\limits_{k=k(h(l))} P_{jk} * x_{jk}}{X_{lk(h(l))}}$$ (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

$$V_l = (P_l * X_l) * 1000$$ (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)

$$Q^S_{hl} = \frac{V^S_{hl}}{V_l} \qquad \text{when case h is a single species fishery} \qquad (13a)$$

$$Q^M_{hl} = \frac{V^M_{hl}}{V_l} \qquad \text{when case h is a multi species fishery} \qquad (13b)$$

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)

$$Z_{gk} = \frac{EMPL^{dir}_{gk}}{X_{gk}} \qquad (14)$$

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

$$Z_{lh} = \frac{\sum\limits_{k=k(h(l))} \sum\limits_{g=g(h(l))} EMPL^{dir}_{gk}}{\sum\limits_{k=k(h(l))} \sum\limits_{g=g(h(l))} X_{gk}} \qquad (15)$$

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

$$Z_k = \frac{\sum\limits_{g} EMPL^{dir}_{gk}}{X_k} \qquad (16)$$

Z_k = employment measured in FTE per 1000 tonnes catch for country k

17)   Productivity indicator for sea l

$$Z_l = \frac{\sum\limits_{g} \sum\limits_{k=k(h(l))} EMPL^{dir}_{gk}}{X_l} \qquad (17)$$

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

$$EMPL^{dir}_l = (Z_l * X_l)/1000 \qquad (18)$$

$EMPL^{dir}_l$ = total direct employment, measured in FTE, in the fisheries in sea l

19) Total direct employment (fleet) in case h in sea l (background)

$$EMPL^{dir}_{lh} = (Z_{hl} * X_{hl})/1000 \qquad (19)$$

$EMPL^{dir}_{hl}$ = direct employment, measured in full time equivalent, in fishery (case) h in sea l

20) relative importance of a fishery according to employment (FTE)

$$s_{hl} = \frac{EMPL^{dir}_{hl}}{EMPL^{dir}_l} \qquad (20)$$

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

$$EMPL^{ind}_l = \sum_{kr=kr(l)} PRO_{krl} \qquad (21)$$

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)

$$F_{gk} = \frac{FCosts_{gk}}{X_{gk}} \qquad (22)$$

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

$$F_{lh} = \frac{\sum_{k=k(h(l))} \sum_{g=g(h(l))} FCosts_{gk}}{\sum_{k=k(h(l))} \sum_{g=g(h(l))} X_{gk}} \qquad (23)$$

$g(h(l))$ – 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

$$F_k = \frac{\sum_g FCosts_{gk}}{X_k} \tag{24}$$

Zk = employment measured in FTE per 1000 tonnes catch for country k

25) Productivity indicator for sea l

$$F_l = \frac{\sum_g \sum_{k=k(h(l))} FCosts_{gk}}{X_l} \tag{25}$$

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

$$FCosts_l = (F_l * X_l)/1000 \tag{26}$$

$FCosts_l$ = total fuel costs, measured in million Euros, in the fisheries in sea l

27) Total fuel costs in case h in sea l (background)

$$FCosts_{lh} = (F_{hl} * X_{hl})/1000 \tag{27}$$

$FCosts_{lh}$ = direct employment, measured in full time equivalent, in fishery (case) h in sea l

28) relative importance of a fishery according to employment (FTE)

$$f_{hl} = \frac{FCosts_{hl}}{FCosts_l} \tag{28}$$

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.