Options for Delivering Ecosystem-based Marine Management

The NE Atlantic: Additional information on status of threatened ecological characteristics relevant to the Marine Strategy Framework Directive

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ODEMM Partners

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Regional Sea description

The North-east Atlantic is one of the most heavily exploited marine regions on Earth (Halpern *et al*. 2008) (Fig. 1c). The NE Atlantic can be divided into 5 sub-regions: (1) the Greater North Sea, (2) Celtic Sea, (3) Irish Sea, (4) Bay of Biscay (and Iberian Coast), and (5) Atlantic Ocean (deep-water), each of which providing valuable ecosystem goods and services (EGSs).

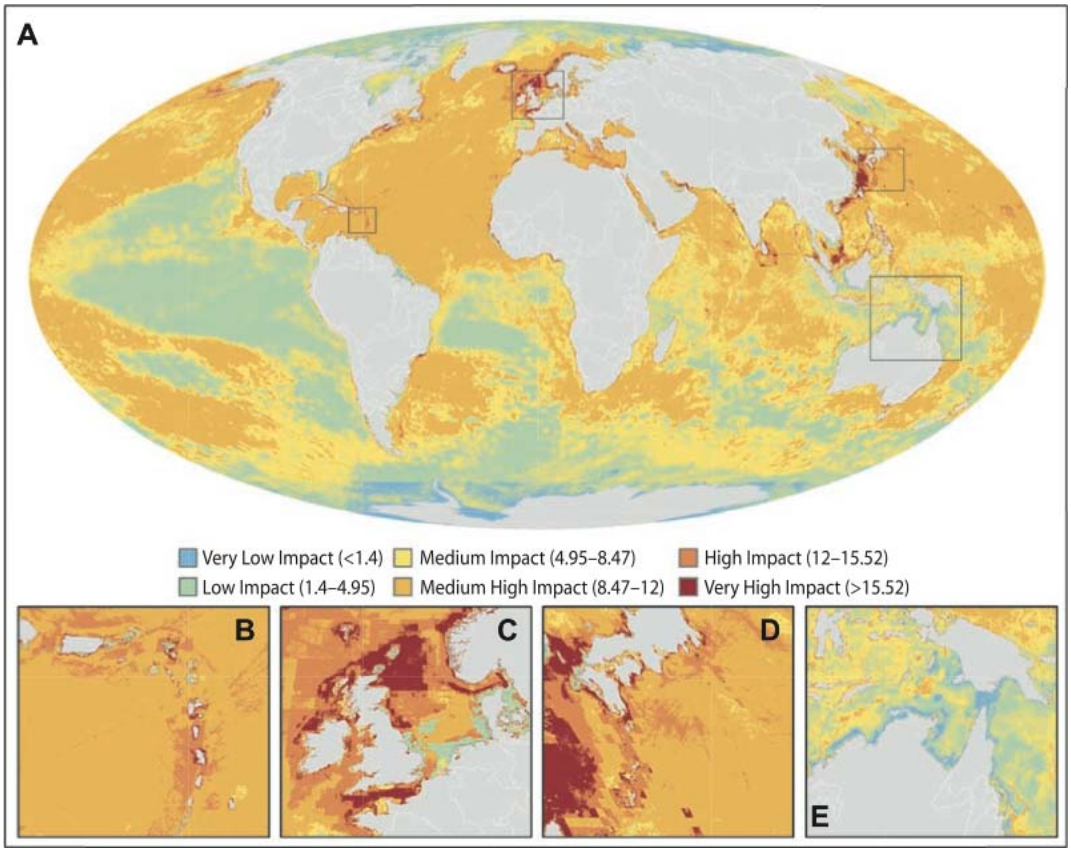

Figure 1. Global map of cumulative impacts showing highly impacted regions of the Eastern Caribbean (B), North-east Atlantic/North Sea (C), Sea of Japan (D), and one of the least impacted regions off northern Australia (E). Redrawn with permission (Halpern et al. 2008, Science Publishing).

The North Sea is a relatively shallow marginal sea (average depth 95m) and located between the UK, mainland Europe and Scandinavia, the North Sea supports all 20 sectors identified by the ODEMM project. Approximately 750,000 km^2 in area, the North Sea presents a diverse ecosystem comprising deep fjords, sandy beaches and wide mudflats. Dense populations of surrounding countries have led to heavy industrialisation and utilisation of the North Sea's marine resources. Over 230 spp. of fish are supported including cod, haddock, mackerel, plaice and sole, as well as large populations of plankton, migratory and resident birds, marine mammals and plants (QSR 2010, OSPAR).

The Celtic Sea, lying off the south coast of Ireland, and west of the southern UK and northern France is bounded by the continental shelf and the Atlantic Ocean. Like the North Sea, the Celtic Sea is relatively shallow, on average between 90 – 100 m to the northeast (St. George's Channel) and reaching depths of up to ~150 m to the southwest where sand ridges, similar in depth to the northeast region, are interspersed with deep toughs (Hardisty, 1990). The Celtic Sea supports many of the sectors found within the North Sea.

The Irish Sea separates the island of Ireland and Great Britain. Connected to the Atlantic Ocean via the St. George's Channel to the south and the North Channel to the north, the Irish Sea is of important economic significant supporting shipping, transport, fisheries and power generation.

The NE Atlantic is a heavily exploited regional sea. All 20 of the sectors identified in ODEMM as those contributing to the current status of its ecological components are active within the region (see ODEMM linkage tables for a description of sectors). However, any assessment of status and/or trend using indicators, such as range and distribution, should be treated cautiously as other factors (e.g. environmental conditions; climate change) may greatly influence any observed pattern(s). This is further complicated by the wide variety of overlap among Descriptors, attributes and indicators.

Sector activities in the North East Atlantic maritime areas contribute 1.8% to the regional Gross Domestic Product, in addition to contributing a 2.1% employment rate (OSPAR 2010). The fishing and tourism industries are the largest employers followed by shipping (OSPAR 2010). Coastal tourism is important for France, Spain and Portugal. Non-renewable and renewable energy production in the NE Atlantic represents some of the largest of these sector activities globally. Particularly, the renewable energy sector is seeing fast growth due to increasing energy demands by growing populations in the region. This growth meets the objectives of EU renewable energy directives (EC 2009), for sustainable energy production. Denmark, Netherlands, and Norway host some of the main European seaports, and are world leaders in the aggregate and navigational dredging sectors (EC 2006; OSPAR 2010). All these sector activities promote regional economic development and growth, yet to the detriment of North East Atlantic marine ecosystems.

Coastal areas in the North-East Atlantic are densely populated, more so than inland areas, and are either highly industrialised or used intensively for agriculture (OSPAR 2010). Most populations in some areas of Northern Europe are concentrated in coastal settlements (OSPAR 2010). The highest coastal populations are on the Iberian and North Sea coasts (with over 500 inhabitants per km_2) and lowest in both the Artic Waters (with fewer than 10 inhabitants per km_2 in some remote areas) and the wider Atlantic, which is dominated by High Seas (OSPAR 2010). Coastal areas with low and high population densities can exert pressures on the sea. One of the major challenges facing the North East Atlantic region will be the demand for marine ecosystem services and resources by the region's increasing population. This will require innovative strategies and co-operation between countries to meet sustainable growth and development, without compromising the ability to achieve GES for MSFD descriptors.

Availability of Information: Regional Summary

The NE Atlantic Member States are well placed to undertake their Initial Assessment obligations (Article 8, Directive 2008/56/EC) in which they must assess the current environmental status of the NE Atlantic region and the impact of human activities by 2020. OSPAR, a Regional Advisory Council for the NE Atlantic has led a coordinated effort of systematic and standardised collection of environmental data in the region. This has led to the availability of a broad assessment of the region (e.g. Quality Status Reports), which provides a good basis for the initial assessment of the NE Atlantic region (see OSPAR 2010 for the most recent report). The structure of QSR, however, does not fit the Marine strategy framework, in that the compilation of ecological characteristics, pressures and impacts is by use of the environment (e.g. human impacts) rather than by ecological characteristics as per the MSFD.

Information relevant to the assessment of some GES descriptors is not also presented in QSR. For example, the status of predominant habitats in UK territorial waters has been evaluated by the UK government (DEFRA, 2010) and does not extend beyond that area. As such, the current status of the NE Atlantic described herein is described using a combination of the information described with QSR 2010, but supplemented by Member State specific information, such as that compiled within the UK's status assessment: Charting Progress 2 (DEFRA, 2010), or by ICES (e.g. Fish IBTS stock summary information, www.ices.dk).

Information was available for all ecological characteristics outlined in the MSFD (Annex III, Table 1, Directive 2008/56/EC) and a summary of this information is presented below (more detailed descriptions of this data are available for download from the ODEMM website (www. liv.ac.uk/odemm/outputs/data). Further information to

undertake the regional pressure assessment (for GES Descriptors 2, 5, 6, 7, 10 and 11) was compiled using a combination of published literature and expert judgement by ODEMM partners from the Regional Sea.

The primary areas of concern and likelihood of failure to achieve GES for each descriptor in the NE Atlantic were identified (Table **1**). Of the 16 components listed in Annex III of the MSFD as recommended for assessment, representatives of 50% (8) of these components are currently considered to either be in poor or threatened status as assessed under the Habitats Directive (HD) or Water Framework Directive (WFD) criteria. Not all species or habitats within each ecological characteristic type are in poor or threatened status. For example, several marine mammals such as bottlenose dolphin, common dolphin and harbour porpoise are considered to be in favourable conservation status, as indicated by the four of their five attributes, namely: abundance, range, habitat and future prospects (Article 17, Council Directive 92/43/EEC).

Status assessments indicate currently threatened ecological characteristics include commercial and listed fish species, predominant and listed habitats, marine mammals and reptiles, seabirds, plankton, and bottom flora and fauna. Status information was unavailable for: Topography, temperature, salinity, pH/pCO2, nutrients and oxygen, and contaminants, however, trend information was available for all with the exception of topography/bathymetry where no information was available.

Where status and trend information was not appropriate for evaluation of a GES descriptor, a pressure assessment was used. Following the approach and criteria developed within ODEMM, several threats to the marine environment arising from human activities were identified. Those sectors that contribute potentially detrimental pressures affecting an ecological characteristic (or achievement of GES for pressure-impact descriptors e.g. Marine litter) include Aquaculture, Coastal Infrastructure, Fishing, Military, Non-renewable Energy (Oil & Gas), Research, Shipping and Telecommunications. Assessment of the contribution of each sector to current status or the highest threat to the marine environment and its components will be evaluated in later ODEMM work packages.

Table 1. A Summary of Areas of Concern, Risks to GES, and Confidence in Risk Assessment of GES Descriptors in the NE Atlantic. Each GES Descriptor is described by one or more components: ecological characteristics, pressure and/or impacts information (see Chapter 2 in Deliverable 1). The components used to evaluate each descriptor are shown in more detail in the following summary tables and outline the availability of information and criteria used to assess current status and trends of components in each Regional Sea. * indicates a pressure assessment approach was used, either in part or in its entirety, to evaluate the descriptor. Risk assessment criteria and confidence assessment definitions are described in ODEMM Deliverable 1).

GES Descriptor	Problems	Areas of Concern	Risks to GES	Risk Confidence
1a. Plankton	Yes	Plankton assemblages in the North Sea are currently stable, but a decline in coldwater zooplankton species (i.e. *Calanus finmarchicus*) since the 1960s indicates a change in dominance	Low-moderate	Low-moderate
1b. Fish	Yes	Several species of fish are at risk or in poor status due to reduced spawning stock biomass (SSB). Some regional variation in the reproductive capacity of those stocks. Two species (cod and hake) are at increased risk from over-fishing. Several Habitats Directive listed species are currently in unfavourable (inadequate) condition, but none are expected to go extinct in the next 10 years	Moderate	Moderate-high
1c. Marine Mammals	Yes	27% of listed marine mammals are currently in unfavourable status (Habitats Directive), but many species are stable or increasing in one or more assessment criteria	Low-moderate	Low
1d. Seabirds	Yes	Several seabird species are in unfavourable status under the Birds Directive and decreasing breeding population sizes have been reported throughout the region	Moderate	Moderate
1e. Predominant Habitats	Yes	Several predominant habitat types are in moderate or poor status, however, the assessment has only been undertaken in the UK territorial waters. Status assessment was undertaken using a pressure assessment after Robinson et al. (in prep) and a moderate/poor status indicates a decline in the area of the habitat, but habitats are not expected to disappear	Moderate	Low
2. Non-indigenous species (NIS)*	Yes	Species of non-indigenous have increased in abundance and extended their range throughout the NE Atlantic region	High	Moderate-high
3. Commercial fish and shellfish	Yes	Several species of fish are at risk or in poor status due to reduced spawning stock biomass (SSB). Some regional variation in the reproductive capacity of those stocks. Two species (cod and hake) are at increased risk from over-fishing and there has been a decline in catch size of many species indicating long-term degradation of stocks	High	High
4. Food webs	Yes	A reduction in primary producers (zooplankton) has been observed in North Sea regions, as well as a decrease in the number of top predators including fish and seabirds affecting the balance of the food web	High	Moderate
5. Eutrophication*	Yes	Nutrient concentrations continue to decline throughout the region in response to various EU Directives, although in some sub-regions concentrations can deviate from normal levels	Moderate	High
6. Seafloor Integrity*	Yes	Human activities such as agriculture, aquaculture, coastal infrastructure, fishing, non-renewable energy (oil and gas), military and research activities and shipping contribute widespread and persistent pressures that have detrimental effects on several aspects of the NE Atlantic ecosystem	High	Moderate
7. Hydrographic conditions*	Yes	Widespread increases in Sea surface temperature (SST), ocean acidification and reductions in dissolved oxygen. Coastal infrastructure and non-renewable energy (oil & gas) introduce changes in wave exposure, emergence regime, water flow rate changes in addition to widespread introduction of synthetic and non-synthetic compounds into the water column.	Not assessed	Not assessed
8. Contaminants	Yes	Contaminants in sediment and biota are stable or reducing in concentration following the introduction of several EU legislative tools, but some localised areas of high concentrations remain	Moderate	High
9. Fish and Shellfish Contamination	Yes	Contaminants in biota are stable or reducing in concentration following the introduction of several EU legislative tools, but some localised areas of high concentrations remain	Low-moderate	Low-moderate
10. Marine Litter*	Yes	Large quantities of litter are removed from beaches and the water column each year and quantities are not reducing	High	Low-moderate
11. Energy (Underwater noise)*	Yes	Trends indicate an increase in shipping and a marked increase in renewable energy activities leading to greater levels of underwater noise throughout the region	High	High
12a. Habitats Directive Habitats	Yes	Based on a one-out, all-out approach as per the Habitats Directive (Article 17) guidance, 90% of listed habitats are in unfavourable condition.	High	Moderate
12b. Habitats Directive Species	Yes	The dolphin, *Lagenorhynchus albirostris* is the only species of 27 reported that is in favourable condition based on the one-out, all-out approach of the Habitats Directive with 57% of criteria unfavourable.	High	Moderate

Ecosystem Components

Poor or threatened components

Of the 16 components listed in the MSFD as recommended for assessment in the NE Atlantic, representatives of 50% (8) of these components are currently considered to either be in poor or threatened status as assessed under the Habitats Directive (HD) or Water Framework Directive (WFD) criteria. Not all species or habitats within each component type are in poor or threatened status. For example, several marine mammals such as bottlenose dolphin, common dolphin and harbour porpoise are considered to be in favourable conservation status, as indicated by the four of their five attributes, namely: abundance, range, habitat and future prospects (Article 17, Council Directive 92/43/EEC). However, there are some examples where some, but not all indicators, suggest favourable conservation status. For example, the indicators *range*, *population size* and *habitat* of sperm whales in UK and Irish waters are considered to be in favourable conservation status, but their *future prospects* are considered to be unfavourable (JNCC Article 17, Council Directive 92/43/EEC). Following the 'one out – all out' approach, the *overall assessment* of status is therefore unfavourable for all listed marine mammals.

Current threatened components within the NE Atlantic include commercial and listed fish species, predominant and listed habitats, marine mammals and reptiles, seabirds, plankton, and bottom flora and fauna. Regional examples of specific species or habitat types are shown in Table 2 below. Of the remaining seven components, status information is unavailable for six. The remaining component, non-native species, is not formally assessed for status but there is evidence that a number of species are widely established throughout the region. Of the six components where status information is unavailable (i.e., topography, temperature, salinity, pH/pCO2, nutrients and oxygen, and contaminants), trend information is available for each with the exception of topography/bathymetry where no information is available.

Fish – Commercial Fish Species

The status of 22 commercially exploited fish species were evaluated (ICES 2009; FAO 2009) in the NE Atlantic region using a combination of two primary indicators:

- Spawning stock biomass (SSB); and
- Fishing Mortality (F).

Spawning Stock Biomass (SSB)

In total, 16 species were assessed using SSB criteria. Of those species, 6 are currently at full reproductive capacity and 10 are classified as being at increased risk or poor status. Not all species are threatened across the whole region; in some sub-regions recorded as being at increased risk/poor status species and in others at full reproductive capacity e.g., *Clupea harengus* (herring), *Trisopterus esmarkii* (Norway pout/poor cod), *Pleuronectes platessa* (Plaice) and *Solea solea* (Sole).

Species below full reproductive capacity include:

1. Cod
2. Haddock
3. Hake
4. Herring
5. Mackerel
6. Norway pout
7. Plaice
8. Sole
9. Spurdog
10. Whiting

Fishing Mortality (F)

The extent to which Fishing Mortality (*F*) affects commercial fish species was estimated for seven species. Of those, five species are widely harvested sustainably (haddock, herring, plaice, saithe and sole), however, in some sub-regions, i.e. Division VIIa, VIId (Eastern Channel), and VIIe (Western Channel), plaice and sole are at increased risk (ICES, 2009). Cod *Gadus morhua*, and hake *Merluccius merluccius* are currently reported as being at increased risk from fishing mortality throughout the NE Atlantic region.

Maximum Sustainable Yield (MSY)

In 2009, the International Council for the Exploration of the Sea (ICES) began development of a strategy for the transition of the current precautionary-based advice (i.e. impaired recruitment estimates) to an MSY framework with an aim to achieve high sustainable long-term yield. The European Union has subscribed to the MSY approach by adopting a specific MSY policy that aims to adjust fishing mortalities to the levels corresponding to MSY by 2015. To date, MSY 'trigger points' have yet to be defined for the majority of species.

Table 2. Summary of ecosystem components (and species) currently assessed as below Favourable Conservation Status (FCS) or Good Ecological Status (GEcS). In some cases, there are multiple indicators available for each component e.g., Fish – indicators include SSB, Population size, Habitat, Future Prospects, and Overall Assessment. # Indicates status is reported as inadequate or moderate.

Fish	**Predominant Habitat**	**Listed Habitats**
Allis shad	Deep-sea bed#	Atlantic salt meadows
Atlantic salmon	Littoral sediment	Coastal lagoons#
Cod	Pelagic water column#	Estuaries
European sea sturgeon	Sublittoral sediment	Large shallow inlets and bays
Mackerel		Mediterranean salt meadows (*Juncetalia* spp.)#
Norway pout		Mudflats and sandflats not covered by seawater at low tide
River lamprey#		Sandbanks which are slightly covered by seawater all the time
Sea lamprey#		
Spined loach		
Spurdog		
Twaite shad#		
Whiting		
Seabirds	**Bottom flora and fauna**	**Marine Mammals and Reptiles**
Diver spp.	European freshwater crayfish	Common Seal#
Petrel	Freshwater pearl mussel	Green turtle#
Shearwater		Harbour seal#
Shelduck		Sperm whale
Stellar's Eider		
Storm-petrel		
Tern spp.		

Predominant Habitats

There are seven predominant habitat types found in the NE Atlantic ranging from littoral rock to deep-sea bed. Both status and trend information is available for each habitat type (e.g., Charting Progress 2, DEFRA). Three of the seven habitats are considered to be in good status (GEcS) as described under the WFD assessment criteria, and four habitats in either moderate or bad condition (Table 3). Charting Progress 2 (DEFRA) also indicated trends in habitat condition. Trends were only described where sufficiently long-term trend data of relevant indicators were available to indicate if the ecosystem component was in decline, stable or improving.

Table 3. Current status and trends of predominant habitat types in the NE Atlantic.

Attribute	Indicator (Characteristic species)	Status (GEcS)	Trend
Littoral rock and other hard substrata	*Fucus* spp., *Mytilus*, *Crassostrea*, Barnacles	Good	Decline
Littoral sediment	Seagrass, zoobenthos	Bad	Decline
Infralittoral rock and other hard substrata	*Fucus* spp., *Mytilus* spp.	Good	Stable
Circalittoral rock and other hard substrata	*Mytilus* spp.	Good	Stable
Sublittoral sediment	Seagrass, zoobenthos	Bad	Stable
Deep-sea bed		Moderate	Decline
Pelagic water column	Phytoplankton colour index	Moderate	Stable

Source: Charting Progress 2 (2010) DEFRA.

Listed Habitats

There are 10 habitats in the NE Atlantic listed under the Habitats Directive (Table 4). Of those, five are considered to be in bad or deteriorating condition, and a further two in inadequate or deteriorating condition. Listed habitats in good, bad or inadequate condition are as follows:

Table 4. Current status and trends of listed habitat types prevalent in the NE Atlantic.

Listed Habitat	Failing Indicator	Inadequate Status (GEcS)	Poor Status (GEcS)
Atlantic salt meadows	• Structure & Function • Future Prospects		✓
Coastal lagoons	• Future Prospects	✓	
Estuaries	• Structure & Function • Future Prospects		✓
Large shallow inlets and bays	• Structure & Function • Future Prospects		✓
Mediterranean salt meadows (*Juncetalia* sp.)	• Structure & Function • Area	✓	
Mudflats and sandflats not covered by seawater at low tide	• Structure & Function • Future Prospects		✓
Sandbanks which are slightly covered by seawater all the time	• Structure & Function • Future Prospects		✓

Marine Mammals and Reptiles

Status or status and trend assessments using five indicators have been undertaken for 23 species of marine mammals and reptiles in the NE Atlantic (see also listed species). Indicators include: Abundance, Habitat, Range, Population Size and Future Prospects. The five indicators were also combined in an Overall Assessment using the "one out - all out" approach (see Habitats Directive criteria guidelines).

Of the 23 species assessed, only 4 are considered to below Favourable Conservation Status and classified as being in unfavourable conservation status under the criteria of the Habitats Directive. The species and failing status indicators are shown in Table 5 below.

Table 5.Unfavourable (inadequate) conservation status species in the NE Atlantic.

Marine Mammals and Reptiles	Failing Indicator	Region (Sub region)
Common seal	Abundance	NE Atlantic (UK)
Green turtle	Population size	NE Atlantic
Harbour seal	Population size	NE Atlantic
Sperm whale	Future Prospects	NE Atlantic (UK)

Seabirds

There is considerable diversity of seabirds found throughout the European Union, many of which listed as species for conservation under the Birds Directive (Council Directive 2009/147/EC). Considerable public interest coupled

with the legislative protection afforded to many bird species has resulted in information describing the status (and trends) of those species being widely available. A comprehensive overview of the status of both individual species and the assemblage of birds within the European Union is reported in *Birds in the EU: A status assessment* (Birdlife International 2004).

Of the 453 terrestrial and marine species listed in that report, seven species are classified as being in unfavourable conservation status as evaluated using estimates of the indicator *breeding population size*. Trend information is also available describing four of the seven threatened species. Seabird species classified as being in unfavourable status are shown in Table 6 below.

Table 6. Unfavourable conservation status species and population size trends in the NE Atlantic.

Seabird species (Common name)	**Scientific Name(s)**	**Trend**
Petrel	*Pterodroma* spp.	N/A
Shearwater	*Puffinus* spp.	N/A
Storm-petrel	*Pelagodroma* spp. *Hydrobates* spp. *Oceanodroma* spp.	N/A
Diver spp.	*Gavia* spp.	Stable
Shelduck	*Tadoma* spp.	N/A
Stellar's Eider	*Polysticta* sp.	Stable
Tern	*Sterna* spp.	Decline
All spp. (assemblage)	**Unfavourable**	Decline

Source: Birdlife International 2004 Birds in the EU: A status assessment.

Benthic flora and fauna

There is little information describing the extent, condition and distribution of benthic flora and fauna; primarily due to the difficulties (and cost) associated with sampling marine habitats. However, species are often associated with a predominant habitat. In fact, habitats (e.g., biotopes) are commonly differentiated or described by an individual or suite of characteristic species (e.g. EUNIS classification). Therefore, the distribution of habitats may be used as a proxy in lieu of relevant indicators to describe the status of marine benthic flora and fauna.

There are a large number of marine habitats (biotopes), each described with a varying degree of detail. Under the EUNIS classification scheme, there are five levels (tiers) of classification. ODEMM is using the broadest classification corresponding with EUNIS Level 2. There are seven level two marine habitats and these correspond with the predominant habitats described in Table 3 above. Descriptions of distribution and extent of each habitat type have been collated using a combination of survey and modelled data (UK Sea Map, JNCC, 2010). For example, the NE Atlantic has large areas of Littoral sediment (EUNIS Code A2), which is comprised of multiple biotopes such as saltmarsh habitat (A2.5), fucoid mats (A1.32) and littoral rockpools (A1.41). A description of the indicator species associated with each biotope is available from www.jncc.gov.uk.

Temperature

There is no status assessment for temperature, but trend information is available and described using two indicators: (1) sea surface temperature (SST), and (2) sea bottom temperature. Long-term data sets describing both SST and SBT are available with temperatures recorded annually from 1870 and 1902 respectively. An increase in SST temperature is indicated by time series data (BSH 2010; NOAA 2010) with large annual fluctuations in any given year. Within UK seas, two 'points of change' are apparent; firstly, between 1920 and 1935, average SST rose by approximately 0.2^{o}C (~0.01^{o}C per annum) from the previous average of 10.9^{o}C to 11.1^{o}C. This was followed by a 50-yr period of relative stability (Fig. 1). Secondly, since the early 1980s, the rate at which SST increased year-on-year accelerated to ~0.02^{o}C per annum corresponding to an increase in SST of ~0.8^{o}C over the 30-yr period between 1980 and today (Fig. 1). This rate change has been mirrored in annual mean SST observations for the Atlantic Ocean (NOAA, 2010).

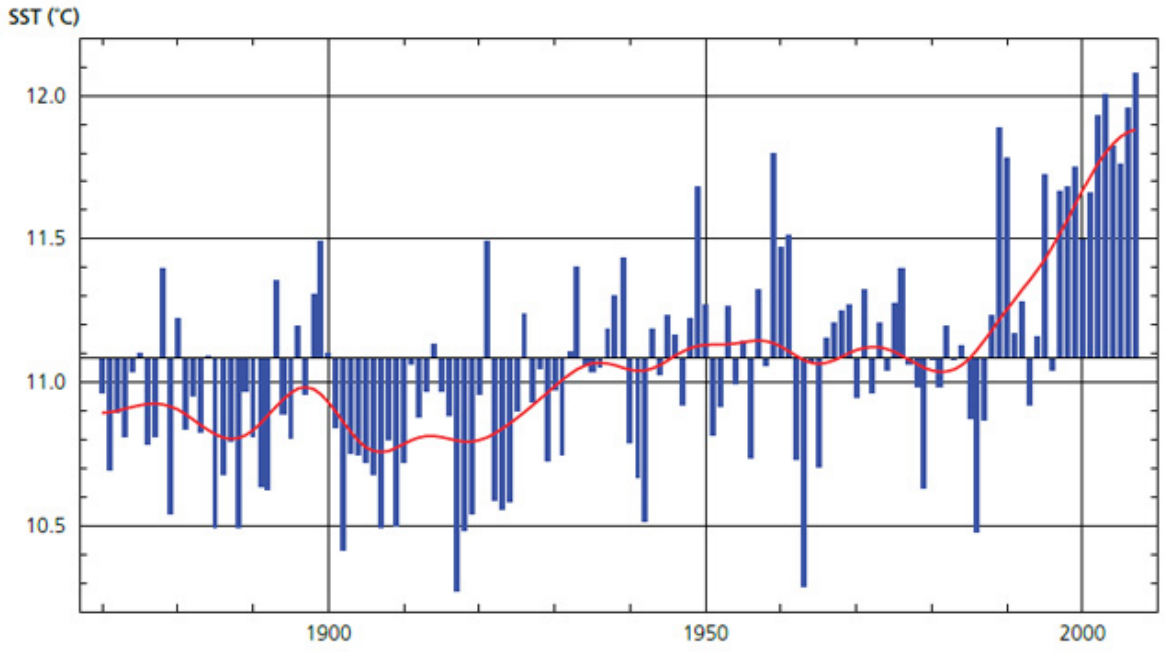

Figure 1. Annual average sea surface temperature (SST) of UK territorial waters (HadISST data set), between 1984 and 2010 and 1870 and 2007 respectively. Blue bars show deviates of the annual average from the 1961-1990 average, and the red line shows annual averages after smoothing with a 21-point binomial filter (after Rayner *et al*. 2003). (Source: Charting Progress, DEFRA).

North Sea winter bottom temperatures have also risen, on average by 1·6°C over 25 years, with a 1°C increase occurring between 1988–1989 alone (Fig. 2 below). However, this is interspersed with some periods of cooling in localised areas (e.g. Neumann et al. 2009; Dmitrenko et al. 2009). The warming bottom temperatures have coincided with a long-term shift towards a positive NAO phase, a northward shift in the Gulf Stream and stronger Atlantic inflow into the northern North Sea (Dulvy et al. 2008).

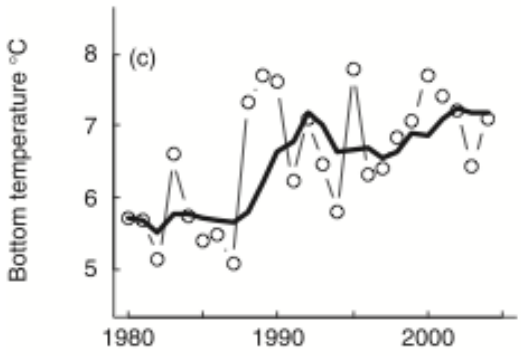

Figure 2. Mean bottom temperature from (a) the North Sea and North East Atlantic (1980–2004) (redrawn from Dulvy et al. 2008). Annual values are represented by the connected points with the 5-year right- aligned running mean represented by the bold line.

Salinity

In the NE Atlantic, salinities typically range from between 34.9 and 36.0 ‰. Individual water types may show changes of the order of 0.1 ‰ on time scales of years to decades. Global and Atlantic regions at northern Europe latitudes (e.g. UK; Ireland; Germany; northern France) have long exhibited decreases in salinity over time (Bindoff &

Willebrand *et al.* 2007). This pattern has not been mirrored by Atlantic waters adjacent to the UK where salinity has increased by up 0.1 ‰ over a similar period (NOC).

pH/pCO2

In the NE Atlantic, there are few data describing pH. As a proxy, pCO_2 (measured as: atmospheric CO_2, aragonite and calcite estimates) can be used in lieu of direct pH measurements. However, pCO_2 data is highly variable with patterns influenced by both interannual and decadal changes in pCO_2 making trend assessment difficult. Nonetheless, current trends suggest that the increase in atmospheric CO_2 coupled with increasing solubility of aragonite and calcite is resulting in increasing ocean acidification (or decreasing pH) (see Orr et al. 2005), however, the rate at which increases in pCO_2 are occurring over are not clear.

Nutrients and oxygen

Nutrients are critical determinants of primary production in marine systems. In particular, Nitrogen (*N*) and Phosphorus (*P*) are among the main limiting elements for phytoplankton development, determining the maximum yield of biomass and affecting all processes linked to the turnover of organic matter (Brockman et al. 1994). Concentrations (mg l^{-1}) of dissolved nitrogen (DIN) and phosphorus (DIP) in the NE Atlantic have steadily decreased over the past 20 to 25 years, primarily as a result of active measures my Member States to reduce discharges by 50%. This target has largely been met for phosphorus, but not for nitrogen. Member States bordering the NE Atlantic achieved, on average, discharge reductions of 55 ± 24% and 31 ± 17% for phosphorus and nitrogen respectively since 1985, (QSR 2010; ICES/MUDAB/UBA Digital North Sea Atlas).

New areas of hypoxia (dissolved oxygen concentration below 2mg l^{-1}) are being observed globally (Chan *et al.* 2008; Greenwood *et al.* 2010) and are predicted to have introduced 'dead zones' which affects more than 245,000 km^2 of marine ecosystems worldwide (Diaz and Rosenberg, 2008). In the NE Atlantic, oxygen concentrations can be highly variable and reach below 0.6 mg l^{-1} or exceed 1.3 mg l^{-1} (Karstensen *et al.* 2008). Due to this high variability, identifying clear trends in dissolved oxygen (DO) concentrations in the NE Atlantic is difficult but suggests that DO concentrations are stable or declining (see Upton et al. 1993; Greenwood et al. 2010; MUDAB).

European and international instruments in place to reduce nutrient input include:

- EU Urban Waste Water Treatment Directive (91/271/EEC);
- EU Nitrates Directive (91/676/EEC);
- EU Integrated Pollution Prevention and Control (IPCC) Directive (2008/1/EC);
- EU Water Framework Directive (2000/60/EC);
- EU National Emissions Ceiling Directive (2001/81/EC);
- MARPOL Annex VI; and
- UNECE Convention on Long-range Transboundary Air Pollution (Gothenburg Protocol).

Chemicals and Contaminants

If current legislative instruments continue to result in a reduction in the concentration of hazardous chemicals (e.g. PAHs, POPs, TBT, nonylphenols) at the existing rate, a third of OSPAR priority chemicals are expected to be phased out in the OSPAR area by 2020 (QSR 2010). Notable reductions (for the period 1990-2006) include heavy metals (Cadmium, Lead and Mercury) albeit at different rates within different Member States.

Trends in PAH concentrations measured in fish and shellfish are predominantly downward, although many estuarine, urbanised and industrial locations throughout the NE Atlantic continue to introduce PAHs posing a threat to biota (QSR 2010).

Polychlorinated biphenyls (PCBs) were banned in the mid-1980s and in some areas, concentrations are close to zero. In general, PCB concentrations are in decline, however, despite European-wide action, not all inputs have

been eliminated. Atmospheric transport and direct discharge into the water column continues to play an important role in their distribution throughout the NE Atlantic region.

A global ban on the use of TBT as an anti-foulant was introduced in 2008. The Ecological Quality Objective (EcoQO) for TBT uses imposex as the metric for monitoring TBT contamination. The EcoQO states that the average level of imposex in a sample of not less than 10 female dogwhelks *Nucella lapillus* (or similar gastropod species) should be consistent with exposure to TBT concentrations below the environmental assessment criterion for TBT. Since 2003 when monitoring began, TBT-specific effects have been variable among applicable NE Atlantic (OSPAR) sub-regions i.e. North Atlantic, North Sea, Celtic Sea, and Bay of Biscay/Iberian coast. Data suggests a general reduction in TBT concentration in the North Sea, and no change in the North Atlantic. Data describing occurrence of imposex in the Celtic Sea and Bay of Biscay is insufficient to support any trend analysis (QSR 2010).

The progressive reduction of pesticides, such as lindane, endosulfan, dicofol and pentachlorophenol (PCP) for agricultural use since 1998 has now ceased for nearly all substances resulting in a clear decrease in atmospheric deposition (measured as concentration within animal tissue). Trends are largely downward throughout the NE Atlantic region, with some sub-regions barely affected. Some localised areas are still greatly affected e.g. Brittany coasts, German Bight, and some northern UK estuaries, although concentrations are remnants of historic use of those areas.

References

All references are available for download from the ODEMM metadatabase (www.liv.ac.uk/outputs/data.html)

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