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DEGREE TO WHICH TOOLS DEVELOPED FOR THE PURPOSES OF THE WATER FRAMEWORK DIRECTIVE AND SCOTTISH CONTRIBUTIONS TO OTHER INTERNATIONAL ACTIVITIES (E.G. TO THE EU AND OSPAR) CAN BE USED TO CONTRIBUTE TO THE REQUIRED ASSESSMENTS AGAINST GOOD ENVIRONMENTAL STATUS (GES)

Marion Harrald and Ian Davies

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DEGREE TO WHICH TOOLS DEVELOPED FOR THE PURPOSES OF THE WATER FRAMEWORK DIRECTIVE AND SCOTTISH CONTRIBUTIONS TO OTHER INTERNATIONAL ACTIVITIES (E.G. TO THE EU AND OSPAR) CAN BE USED TO CONTRIBUTE TO THE REQUIRED ASSESSMENTS AGAINST GOOD ENVIRONMENTAL STATUS (GES)

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EXECUTIVE SUMMARY

The drive to improve the environmental quality of European seas is not limited to the Marine Strategy Framework Directive (MSFD). Other European Directives and international activities such as the Water Framework Directive (WFD) and OSPAR programmes that are applicable in Scottish waters have similar goals. Tools and indicators are already in use to assess the objectives of these initiatives and thus the MSFD may be able to capitalise on these pre-existing tools and their associated monitoring frameworks. Despite similarities between initiatives, there are differences in spatial scales, the environments in which they have been applied and in the level of impacts that they are capable of detecting, i.e. the WFD is designed to be sensitive to community level effects whereas the MSFD is concerned with an ecosystem or population level. Therefore, many of the pre-existing tools may require adaptation or re-calibration for use under the MSFD. In the case of certain MSFD Qualitative Descriptors, such as those concerning eutrophication, commercial fish and pollution, there are already comprehensive tools in place that could be utilised under the MSFD, although improvements and additions have been suggested. For others, such as the Descriptors on biological diversity and marine food webs, there are tools that could be adapted but together these tools lack coherence and do not encapsulate the full scope of the Descriptors. In the case of the Descriptors on seafloor integrity, introduction of energy and noise and marine litter, few relevant tools have been developed and more research may be required to understand the pressures and impacts before adequate tools can be designed.

A summary of pre-existing tools worth considering under the MSFD and the Directive or initiative they contribute to is given in Table 1.
Pre-existing tools that could contribute to assessments under the MSFD

### TABLE 1

Summary of pre-existing tools or frameworks in place developed for the EC Water Framework Directive (WFD), the EC Habitats and EC Birds Directives, OSPAR, the Common Fisheries Policy (CFP) and Scottish Government that may be considered for use or adaptation under the Marine Strategy Framework Directive.

<table>
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<th>Qualitative Descriptors</th>
<th>Pre-existing tools or frameworks</th>
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<td>(6) Sea-floor integrity</td>
<td>Benthic Invertebrates Infaunal Quality Index for coastal waters</td>
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1. INTRODUCTION

1.1 Background

The EC Marine Strategy Framework Directive (MSFD) aims to maintain biodiversity while providing seas which are clean, healthy and productive by employing an ecosystem approach to marine management. It strives to achieve ‘Good Environmental Status’ (GES) by 2020 for each of 11 Qualitative Descriptors (Annex I to the Directive). These describe high level aims pertaining to environmental quality. Exactly what GES will comprise of and how it will be assessed is under consideration by task groups established by the International Council for the Exploration of the Sea (ICES) and the EC Joint Research Council (JRC). However, it is likely that extensive monitoring by Member States will be required to underpin the assessments. Rather than develop entirely new monitoring and assessment methods, it is worth considering those that are already implemented through other Directives or International activities. The approach and the drive to reach GES bears similarities to other EU-wide initiatives, in particular the EC Water Framework Directive (2000) (WFD) and Oslo Paris Convention (OSPAR) programmes. As such, rigorous assessment methods have already been developed and monitoring networks are in place to answer their demands. Given a limited time-frame and resources, consideration should be given to whether these methods can be adapted or re-calibrated for use under the MSFD. In this document, we firstly compare the WFD and OSPAR to the MSFD. Secondly, for each of the 11 Qualitative Descriptors, we discuss the tools or methods already in use in Scotland and their applicability to assessment of GES. We also suggest other tools in the literature and other European Directives that might be more suitable. Lastly, we discuss gaps in methods and monitoring for assessment of GES.

| (8) Pollution | Environmental Quality Standards for concentrations of contaminants in water. | WFD |
|              | EACs for concentrations of contaminants in sediment and biota               | OSPAR |
|              | OSPAR Hazardous Substances Strategy                                       | OSPAR |
|              | Imposex in dog whelks (*Nucella lapillus*) or other selected gastropods EcoQO | OSPAR |
|              | Proportion of oiled common guillemots among those found dead or dying on beaches EcoQO | OSPAR |
|              | Mercury concentrations in seabird eggs EcoQO                              | OSPAR |
|              | Organohalogen concentrations in seabird eggs EcoQO                        | OSPAR |

| (9) Contaminants in fish and seafood for human consumption | Acceptable concentrations of contaminants defined in EC legislation 1881/2006, EURATOM and others (see 2.9) |
| (10) Marine litter | Plastic particles in stomachs of seabirds EcoQO |
| (11) Energy and underwater noise | No applicable tools identified | OSPAR |
1.2 Comparison of MSFD, WFD and OSPAR

The MSFD and WFD both establish a legal framework for the protection, improvement and sustainable use of European waters, while the OSPAR Convention is the legal instrument that guides international cooperation on the protection of the marine environment of the North-East Atlantic. Some of the aims of these international activities have large overlaps:

MSFD: ‘The marine environment is a precious heritage that must be protected, preserved and, where practicable, restored with the ultimate aim of maintaining biodiversity and providing diverse and dynamic oceans and seas which are clean, healthy and productive.’

WFD: ‘The ultimate aim of this Directive is to achieve the elimination of priority hazardous substances and contribute to achieving concentrations in the marine environment near background values for naturally occurring substances.’

OSPAR: ‘Our mission is to conserve marine ecosystems and safeguard human health in the North-East Atlantic by preventing and eliminating pollution; by protecting the marine environment from the adverse effects of human activities; and by contributing to the sustainable use of the seas.’

Although their approaches differ they do attempt to achieve a similar end point. The MSFD frames its objectives around 11 Qualitative Descriptors for which it aims to achieve GES and lists the pressures and impacts that may compromise its achievement throughout EU waters. Similarly, OSPAR has developed a number of Ecological Quality Objectives (EcoQOs), which are intended to provide a set of environmental indicators stating clear objectives for a healthy marine environment. Unlike the MSFD and OSPAR, the WFD does not address specific pressures and impacts but aims to attain at least good ecological status or potential in surface waters for each of four ‘quality elements’; biological (aquatic fauna and flora), hydromorphological (e.g. condition of river flow, river bed), physico-chemical (e.g. dissolved oxygen and nutrients) and chemical (pollutants). Both Directives and OSPAR emphasise the importance of an ecosystem approach and adopting the precautionary principle.

The definitions of good environmental and good ecological status differ slightly; the MSFD focuses on achieving productive seas while ensuring sustainable use, while the WFD focuses on producing water bodies with levels of distortion resulting from human activity deviating only slightly from undisturbed conditions.

MSFD: ‘Good environmental status’ means the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations…’

WFD: ‘The values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions.’

Unlike the MSFD, in which only “good” environmental status is defined, the WFD specifies 5 levels pertaining to ecological status (high, good, moderate, poor and bad) and gives normative definitions for each status class of each of the quality elements (Annex V to the Directive).

In contrast to the MSFD and WFD, OSPAR dictates its aims precisely through its various strategies and EcoQOs. Together, these form a suite of tools which indicate the condition of
Pre-existing tools that could contribute to assessments under the MSFD

a functional group. For instance, it aims to measure the impact of hydrocarbons present in the seas through determining the proportion of oiled common guillemots among those found dead or dying on beaches. This also acts as an indicator of the state of other seabirds at this trophic level in response to oil pollution. Unlike OSPAR, the WFD designs tools for each quality element and then assigns them to a certain level. For example, under the biological quality element, the Directive lists phytoplankton, other aquatic flora, fish and macro invertebrates and tools have been built to reflect disturbance to these communities, such as disturbance arising from nutrient enrichment and pollution. The overall status of the water body under the WFD will reflect the quality element with the lowest status (i.e. most affected by human activity), referred to as the ‘one out – all out principle’.

Understanding the spatial scale at which these Directives operate, is critical to realising the potential for the assessment methods that have been established. Article 3 to the MSFD states that ‘marine waters’ means,

\[ \text{‘a) waters, the seabed and subsoil on the seaward side of the baseline from which the extent of territorial waters is measured extending to the outmost reach of the area where a Member State has and/or exercises jurisdictional rights…} \]

\[ \text{\textit{b) coastal waters as defined by Directive 2000/60/EC, their seabed and their subsoil, in so far as particular aspects of the environmental status of the marine environment are not already addressed through that Directive or other Community legislation.’} \]

To clarify these statements, marine waters extend from the headland to the territorial limit (normally 200nm unless overlapping with another State) as defined by the 1982 United Nations Convention on the Law of the Sea (UN 1982). The baseline is defined as Mean High Water Springs (MHWS) as in the WFD (Directive 2000/60/EC) definition of coastal waters. Therefore ‘marine waters’ do include the intertidal zone on the landward side except for aspects already covered by the WFD or other Community legislation. Although there is no mention of estuaries (termed transitional waters under the WFD and defined therein as partly saline in character) in the MSFD, we assume these are included under the MSFD for aspects not covered by other Community legislation.

The MSFD and OSPAR cover similar spatial scales, although the MSFD encompasses all of European waters, while OSPAR covers only the NE Atlantic. Both extend to the outer reach of territorial waters. OSPAR also covers large areas of international waters in the NE Atlantic. The MSFD separates EU seas into four ‘marine regions’ (the Baltic Sea, the North-East Atlantic Ocean, the Mediterranean Sea and the Black Sea) and sub-regions (of relevance to Scotland are the Celtic Seas and the Greater North Sea which includes the Kattegat and English Channel). The WFD equivalent to marine regions are ‘ecoregions’, which cover the same overall area as the MSFD. However, ecoregions extend to only 3nm from the baseline (in Scotland) and also cover freshwater ecosystems. The WFD also includes larger sea areas such as the major Firths, the Sea of the Hebrides and the Minch, as these are internal waters, i.e. areas of water within the national baseline. Unlike the MSFD and OSPAR, which operate at a regional or sub-regional scale (OSPAR regions equivalent to MSFD sub-regions), the largest units at which WFD operates are at the level of river basin districts. Coastal areas are delineated at points of adjoining river basin districts and detailed assessments are made at a water body scale, which may only be a small number of kilometres of river or other surface water.

There could well be efficiency gains, both in the implementation of the MSFD and in the subsequent monitoring and assessment work, if it were possible to make use of work already undertaken for other drivers. For each of the 11 Qualitative Descriptors, we discuss potential tools of relevance in relation to suggestions of how GES might be assessed for each. The tools are discussed with regard to their aims, scope and the spatial scale for which they were designed.
2. DISCUSSION OF TOOLS TO IMPLEMENT THE MSFD

2.1 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

Harrald et al. (2009) proposed that assessment of this Descriptor would require two streams of assessment:

a) Habitat status: assess quality of habitats outside of designated areas in relation to designated areas that are deemed in a pristine condition.

b) Distribution and abundance of species: assess using a suite of sentinel and state indicators for each trophic level of the marine ecosystem for different geographic regions.

2.1.1 Habitat status

Habitat status could be assessed in relation to reference conditions found in marine protected areas deemed to be in good condition. Under the EC Habitats Directive (1992) and EC Birds Directive (1979), a network of European protected sites has been established, the marine components of which are known as Natura 2000 marine sites. These sites are managed to maintain the ecological integrity of the qualifying features for which they were designated. They are monitored every 6 years to assess their conservation status and are expected to maintain this as ‘favourable’ (defined in Article 1 to the Habitats Directive). Currently most of the sites with a marine component are coastal, but the Special Protection Areas for coastal bird breeding colonies are going to be extended to include their feeding grounds, up to 4 km from the seabird colony. Additionally, a further 7 Special Areas of Conservation in Scottish waters have been proposed (JNCC 2009).

OSPAR has also provided a framework for the selection of an ecologically coherent network of marine protected areas to protect, conserve and restore species, habitats and ecological processes. Fuller details of the sites that Contracting Parties have reported to OSPAR are held in the OSPAR MPA database (OSPAR 2009a). Individual biodiversity targets are set in the management plans for each protected area and OSPAR tools are available for assessing the effectiveness of these plans. It is possible that these assessments could also form the basis for assessment of habitat quality and abundance under the MSFD.

2.1.2 Distribution and abundance of species

Tools applicable to assessing species abundance and distribution have been developed under the WFD and OSPAR, although the WFD tools may need to be adapted for use in offshore waters. Details of the OSPAR EcoQOs are given in the EcoQO Handbook (OSPAR 2007a). A number of the WFD tools could be relevant to this Descriptor. However, in cases where these tools are entirely specific to inshore regions (e.g. fucoid extent, salt marsh and saline lagoons), they would not be used under the MSFD as well as the WFD (as stated in Article 3 to the Directive). We list these tools below, as an indication of what is being assessed to avoid duplication of effort by the MSFD.
2.1.2.1 WFD tools

Benthic Invertebrates Infaunal Quality Index for coastal waters

A classification tool has been developed to assess the status of invertebrates living in the soft sediment. The tool, known as the Infaunal Quality Index (IQI), relies on having defined reference conditions for different substrate types and salinity conditions. Currently, reference conditions have been fully established and intercalibrated for high salinity (>30) fine sands and muds, and should be applicable to areas further offshore. The method enables an assessment of the condition of benthic invertebrate fauna, listed in Tables 1.2.3 and 1.2.4 of Annex V to the WFD. The method has been designed to detect the impact on the quality element of general disturbance, particularly of organic enrichment and toxins (WFD UKTAG 2009a). Given sample data from offshore, it may be possible to re-calibrate the tool for use in waters >3nm from the baseline.

Fish fauna for transitional waters

A tool has been developed for the classification of fish in transitional waters. The tool uses a range of sampling methods and measures to assess disturbance to fish populations in WFD ecoregions. Reference conditions are required to classify water bodies. An ecological quality ratio is derived for a range of parameters; species composition; presence of indicator species; species relative abundance; number of taxa that make up 90% of the abundance; number of estuarine resident taxa; number of estuarine-dependent marine taxa; functional guild composition; number of benthic invertebrate feeding taxa; number of piscivorous taxa and feeding guild composition (WFD UKTAG 2009b). Such a tool may be difficult to adapt for offshore regions due to the variation of species with depth and habitats. It may also need to be adjusted to respond to different pressures; the predominant pressure in offshore areas is fishing whereas in transitional and inshore areas it is pollution.

Fucoid extent tool for transitional waters

A fucoid extent tool has been designed to detect the impact of toxic substances on fucoid macroalage. The method uses the indicative parameter "upstream fucoid site" to assess the condition of the quality element relative to reference conditions. The parameter is calculated using information on three fucoid species: Fucus ceranoides, Fucus spiralis and Fucus vesiculosus. The calculation also depends on information on the presence or absence of any other macroalgal species (WFD UKTAG 2009c). As fucoids are only found within the intertidal, this tool would overlap directly with WFD assessment and is thus superfluous to requirements under the MSFD.

Opportunistic macroalgae for transitional and coastal waters

A tool for the assessment of the nature and extent of bloom forming benthic macroalgae across transitional and coastal water bodies has been developed. The ecological quality indicator is based on abundance of species such as Enteromorpha, Ulva, Chaetomorpha and Cladophora. While such species do occur naturally, excessive amounts may be indicative of adverse environmental conditions. Therefore excessive biomass and cover of opportunistic foliose and filamentous macroalgae may be considered as moderate, poor or bad status (WFD UKTAG 2009d). As with fucoids, there should not be a requirement to assess this under the MSFD in addition to WFD assessments.
Rocky shore macroalgae for coastal waters and outer reaches of transitional water bodies

A classification tool has been developed to assess the status of rocky shore macroalgae communities under different environmental conditions. The tool uses ecological status groups to indicate shifts in the ecosystem from a pristine state (composed of late successional or perennial species) to a degraded state (composed of opportunists or annuals). These community factors are then used to create a metric from which an ecological quality status can be established (WFD UKTAG 2009e). Again, this element should be covered under WFD.

A saltmarsh tool and an intertidal and subtidal seagrass tool are in preparation although again these would directly overlap with the WFD.

2.1.2.2 OSPAR EcoQOs

Harbour porpoises by-catch

‘Annual by-catch levels of harbour porpoise should be reduced to levels below 1.7% of the best population estimate.’ (OSPAR 2007a)

Seal populations

‘Harbour seals: Taking into account natural population dynamics and trends, there should be no decline in harbour seal population size (as measured by numbers hauled out) of ≥10% as represented in a five-year running mean or point estimates (separated by up to five years) within any of eleven sub-units of the North Sea.’ (OSPAR 2007a)

‘Grey seals: Taking into account natural population dynamics and trends, there should be no decline in pup production of grey seals of ≥10% as represented in a five-year running mean or point estimates (separated by up to five years) within any of nine sub-units of the North Sea.’ (OSPAR 2007a)

Local sand eel availability to black-legged kittiwakes

‘Breeding success of the black-legged kittiwake (Rissa tridactyla) should exceed (as a three-year running mean) 0.6 chicks per nest per year in each of the following coastal segments: Shetland, north Scotland, east Scotland, and east England.’ (OSPAR 2007a)

Proportion of large fish

‘Over 30% of fish (by weight) should be greater than 40 cm in length.’ (Greenstreet and Rogers 2006)

Threatened and/or declining species and habitats

OSPAR has established a list of threatened and/or declining species and habitats in the NE Atlantic and its subregions. Inclusion of features on the list is justified by evaluation against the Texel Falal criteria. The tool is based upon presence and extent of threatened and/or declining species in the North Sea, as shown on the Initial OSPAR List. OSPAR also aims to restore and/or maintain the quality and extent of threatened and/or declining habitats in the North Sea, as shown on this list (OSPAR 2008a).
2.1.3 Conclusions and gaps

There are processes in place that could be used to address the habitats component of this element at least for inshore areas, although an increase in monitoring would be required to assess non-protected as well as protected areas. Offshore sites are still in the process of being designated under Natura and thus assessment procedures for these may not be fully developed. Nor do these offshore sites cover the full range of habitats present in Scottish waters. The MSFD does state, however, that Marine Protected Areas (MPAs) should be used as a management tool and thus there may be scope for further designation to cover previously unprotected habitats. Given limited resources, it may also be advisable to limit number of habitats monitored, perhaps in line with threatened and declining habitats as listed in OSPAR (2008a) or Annex I of the Habitats Directive.

There are two tools of particular relevance to determining the biological diversity aspect to this Descriptor. Firstly, the benthic IQI tool for soft sediment as it seems possible to re-calibrate this for use offshore. It is doubtful, however, whether a complementary tool can be made for hard substrates, as previous attempts have been unsuccessful due to environmental and geographical variation. Secondly, the tool on proportion of large fish in response to fishing pressure (one of the main pressures in offshore regions), as this has been designed as an alternative to measurements of diversity and is thought more effective. The other OSPAR EcoQOs may be useful as sentinel indicators of species at lower trophic levels but do not bear a direct link to species diversity. No applicable tools have yet been identified that assess diversity of non-commercial fish, benthic communities on hard ground and plankton communities. It is also worth considering impact of climate change in this element. Given evidence for climate induced shifts in species distribution, tools must be designed to accommodate changes if and when they occur. This could be incorporated by developing methods that do not take into account presence or absence of a particular species, but instead assess species diversity or presence of functional groups.
2.2 Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems

Harrald et al. (2009) suggested that GES could encompass sustainable levels of non-indigenous species that are not damaging to the native community. Failure to meet GES might be defined as where non-indigenous species have become ‘invasive’, i.e. they out-compete or threaten the native community. In practice, this might be exceptionally difficult to achieve as it is often not possible to predict when a non-indigenous species may become invasive. At present, we still have only a limited knowledge of the distribution of non-indigenous species in inshore waters and their impact and a much poorer knowledge in offshore waters. The EC funded DAISIE project, provides a database of known European non-indigenous species and includes information about their distribution and likely impact (www.europe-aliens.org). OSPAR and ICES are working to prepare an inventory of non-indigenous species, which may be more applicable given their offshore remits, but no relevant EcoQOs are in place as yet.

The WFD incorporates non-indigenous species into their classification by assessing presence of the species in a water body, their likely impact and the degree of risk that they present to that water body. The WFD has prepared an inventory of non-indigenous species and labelled them as being of high, medium or low impact (Appendix to WFD UKTAG 2004). The WFD process for classifying a water body is as follows:

‘A water body provisionally classified as being at high status (i.e. in reference condition) should contain no established invasive alien species listed on the high-impact and unknown-impact lists. A water body where one or more of these species is established is at risk of deterioration from high status. (The presence of established alien species on the low-impact list should not automatically cause a downgrading in status except where they are adversely affecting ecological status at a local level.)

A water body that displays the potential for significant impact from one or more established invasive alien species on the high-impact and the unknown-impact lists is at risk of failing to achieve good status. In addition, a water body otherwise classified provisionally as being at good status is at risk of deterioration where such impacts are observed. (The presence of established alien species on the low-impact list should not automatically cause a downgrading in status except where they are adversely affecting ecological status at a local level.)

The degree of risk from an alien species will vary according to the following factors, each of which should be taken into account in the risk assessment:

a) Present location: is the alien species already in the water body, in a nearby water body, further away but still in the same catchment?

b) Does the water body contain suitable available habitats to support the alien species?

c) Are there any known predators or competitors which might prevent the establishment of the alien species?

d) Are there other factors which increase the likelihood of the alien species becoming established in the water body (e.g. live-baiting by anglers, inter-basin water transfers, nearby crayfish farms, known releases of ballast water)?’ (WFD UKTAG 2004)
2.2.1 Gaps and conclusion

The WFD approach described appears well designed but practical only in cases where we have a comprehensive knowledge of the habitats, communities and pressures in which a non-indigenous species is known to occur. While this may be possible in freshwater and in some inshore regions, it is likely to require too many resources to be possible at the scale of marine regions. There is a lack of species distribution data in the offshore environment and in some cases it is difficult to define whether a species is actually non-indigenous or whether it is the result of a distribution shift. Long-term datasets to assess this often do not exist and data on impact is lacking for many species. It is also difficult to predict which non-indigenous species are going to become invasive, i.e. impact the local community, as it is often dependent on local conditions. Given these complications, it may be better to focus on known non-indigenous species of a high impact.
2.3 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

Achievement of GES could be interpreted as either when the stock is being exploited under a precautionary management plan or when the stock is being harvested inside safe biological limits (Harrald et al. 2009). The term ‘safe biological limits’ is defined by a minimum safe stock size and a maximum exploitation rate. A comprehensive framework operates for managing a number of commercial stocks at a European and National level, for which a suite of tools (stock assessments) are in place.

2.3.1 Management framework at a European level

The European Commission has the responsibility to regulate commercially exploited stocks that are assessed and those that are not under the Common Fisheries Policy. Fixing the level of the fishing quotas that can be caught by EU Member States is undertaken annually for each of the main international, demersal and pelagic stocks and Nephrops. Each Member State collects biological data, which is then analysed by ICES to assess the state of the stocks. This includes assessment of the state of the stock in relation to historical levels, the medium-term development of the stock and a short-term forecast of the spawning stock biomass and catch. The assessments form the basis for advice given by the ICES Advisory Committee (ACOM) to fisheries managers. The European Commission proposes annual Total Allowable Catch (TAC) levels and other regulatory measures such as mesh, area and fishing effort regulations. The Council of Ministers makes the final decision on the TACs for each species and the quotas are divided up between Member States.

A system of precautionary reference points are calculated for the spawning stock biomass (SSB, Bpa) of a stock and the fishing mortality (Fpa). The method aims to keep away from the limits of these factors (Blim and Flim), where the stock is vulnerable to collapse. Assessments for the current year (y) are based on a time series up to the year y-1. Estimates are given for SSB at the start of year y and estimates for F at year y-1. Advice is given for the year y+1 on the basis of catch and SSB forecasts. Warning signs that a stock may be outside of biologically safe limits may become apparent. Should the SSB sink below the “minimum biologically acceptable level” (MBAL), there is a higher chance of poor recruitment. Another warning sign is a change in age structure and a decrease in stock size and area occupied by the stock. However, it is worth noting that the precautionary reference points may change as more biological information becomes available.

OSPAR has recommended an EcoQO on commercial fish based on stock assessments that are already carried out.

a) The EcoQO should be taken, as agreed in the Bergen Declaration, as “Spawning Stock Biomass above precautionary reference points (Bpa) for commercial species where these have been agreed by the competent authority for fisheries management”.

b) On the basis of ICES work, OSPAR should compile SSB values for commercial species having populations, at least partially, in the North Sea. The assessment of the ecological status of the North Sea in year y will then be obtained by comparing the current estimates of SSB with the agreed Bpa;

c) On the same basis, OSPAR should also compile F values for the same stocks, not for the purpose of assessing the current ecological status (year y), but in order to compare this with the agreed values of Fpa and warn fisheries management authorities that, if fishing mortality is kept at that level, then there
Pre-existing tools that could contribute to assessments under the MSFD

is likely to be a risk that the SSB will fall below Bpa under average conditions of recruitment (it is possible that the catch forecasts indicate no immediate risk of SSB falling below Bpa, but the warning is a useful indication of misperformance of the fishery). (OSPAR 2007a)

2.3.2 Management framework at a National level

Finfish

Marine Scotland scientists employ the widely used virtual population analysis (VPA) model to assess commercially–important fish stocks. Records of the number of fish landed are used to estimate a so called ‘virtual population’, i.e. the number of fish that were there originally. Additional data from research-vessel surveys are built into the model and are also used to assess stock trends. A forecast is calculated of the stock size over the next 2 to 3 years (short-term) and over the next 10 years (medium-term). The short-term forecast is based on abundance estimates of the fishing fleet and surveys of eggs and larvae which can be used to assess recruitment, while the medium-term forecast is based on recruitment models.

Additionally, the Scottish Government (SG) Environmental Statistics group currently publishes a commercial finfish indicator based on the perceived status of 11 stocks of relevance to Scotland (the indicator is the percentage of stocks at full reproductive capacity). The eleven stocks that comprise the indicator include cod, haddock, herring, Norway pout, sand eel, saithe, hake and mackerel stocks (Scottish Government 2009).

For those fish that have not previously been assessed, rapid assessment protocols may be implemented until a suitable time series of data upon which to carry out a full assessment has been built up. In the case of deep water fisheries, where there are difficulties in obtaining sufficient data to assess species individually, SG is exploring a number of approaches to developing an indicator, including taxonomic diversity, size spectra and length based indices.

Shellfish

Assessments for Nephrops, the most valuable of the shellfish sector, are carried out for each stock and each sex. It is sampled at fish markets and processors and by observers on board Nephrops trawlers. The state of the stocks is assessed using length data, trends in mortality biomass and recruitment. Underwater TV surveys are also carried out as another, possibly more accurate measure of abundance (Tuck et al. 1997a and b; Marine Scotland 2009).

2.3.3 Potential framework for generating an ecosystem approach

A common criticism of traditional stock assessments is the use of a single species approach to fisheries management. The MSFD emphasises the ecosystem approach, which is taken by the EU funded MAFCONS project. MAFCONS aimed to build a size structured, species interactive model to understand the processes that structure marine communities and affects their diversity. The project aimed to quantify the consequences of particular fisheries objectives on ground fish and benthic invertebrate diversity. It firstly developed hypotheses to test the mechanisms through which disturbance of fishing may affect diversity of fish and benthic communities. It secondly investigated the relationship between fishing effort and ecological disturbance and between variation in benthic invertebrate productivity and species diversity. This project did not develop tools as such but has generated further research on
Pre-existing tools that could contribute to assessments under the MSFD defining anthropogenic activities and the pressure they inflict on the ecosystem and its components (Piet et al. 2007; MAFCONS 2006). Such research may be a valuable contributor towards this Descriptor as well as Descriptor 6 on sea floor integrity.

2.3.4 Gaps and conclusions

Given the resources and time scales required to carry out accurate stock assessments, it might be advisable to make use of outputs from assessments already in place and to collaborate with or increase resources to fisheries scientists to initiate improvements and fill gaps. Such improvements could be directed towards incorporating population structuring into well-established stock assessment methods and improving estimation of discards. Not all commercial species or those caught as bycatch are assessed and it takes time to build up a time-series long enough to determine appropriate reference levels or suitable management plans. Alternatively, assessment of GES could be carried out through a modelling approach (as in the MAFCONS projects) to investigate the consequences of a fishing activity on the disturbance to fish and benthic communities. Such an approach could provide an independent viewpoint to fisheries management from the traditional stock assessments and would be particularly useful for implementing marine spatial planning and testing the consequences of management actions such as MPAs (a management tool encouraged in the Directive).
2.4 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

There is a wide literature concerning indicators of ecosystems particularly in relation to fishing pressure (e.g. Rochet and Trenkel 2003). One approach to developing indicators that are responsive to changes in the marine food web is to measure the ratio between different trophic levels (de Leiva Moreno et al. 2000; Rochet and Trenkel 2003; Fulton et al. 2005; Link 2005). An expected impact of fishing on the food web is a decrease in the proportion of piscivorous fish. De Leiva Moreno et al. (2000) address this in their proposed index of pelagic to demersal fish biomass ratio in fishery landings. However, it is acknowledged that this ratio may also be sensitive to other pressures such as eutrophication in addition to fishing. Another ratio based indicator could be developed from findings of Fulton et al. (2005) who describe how a reduction in mean trophic level may be an indicator of fishing pressure on a community. A different approach to addressing food web indicators could be to focus on assessing abundance of vital components of the food webs, such as keystone predators and keystone prey, often a target of fisheries. Removal of such species may cause a cascade of effects through an ecosystem (Scott Mills et al. 1993) and would thus present key aspects to focus assessments on.

Currently indicators already developed for OSPAR purposes may cover certain elements of the northeast Atlantic food web but further research is necessary to develop a comprehensive suite of tools that assesses anthropogenic impacts throughout all trophic levels and ecosystems present in the MSFD regions. Those already developed have for the most part been mentioned under the biodiversity element (e.g. harbour porpoise by-catch, seal populations and local sand eel availability to black-legged kittiwakes). Other possible tools or sources of data are described below.

**Phytoplankton**

Marine Scotland monitoring data could be used as a basis for development of a phytoplankton community indicator. Marine Scotland currently monitors seven sites around the Scottish coast on a weekly basis. Samples for temperature, salinity and nutrients are taken at six sites. Chlorophyll and zooplankton are taken at two sites. These time series, which vary in length up to 12 years, are beginning to provide a valuable picture of the dynamics of the phytoplankton community in Scottish waters. The corresponding physical, chemical and biological parameters may enable understanding of the driving forces behind any observed changes in the communities.

**Zooplankton**

The SAHFOS Continuous Plankton Recorder (CPR) operates in Scottish waters and analysis of this data from the North Sea has shown how the phytoplankton community has changed over the last 50 years. However, the CPR only samples a subset of the phytoplankton population and sampling intensity may vary on a regional scale in UK waters.

**Fish**

It may be possible to develop fish indicators from assessments carried out by ICES under the Common Fisheries Policy on species representative of certain trophic levels. However, as these assessments rely on large time series it may be difficult to extend these to species
Pre-existing tools that could contribute to assessments under the MSFD

not currently assessed. Alternatively, the indicator of commercial finfish based on the status of 11 stocks of relevance to Scotland (see 2.3.2) could be used, but again this is restricted to a limited number of species. The indicator on deepwater fish community diversity, currently under development by Marine Scotland, may enable assessment extending beyond commercial species.

2.4.1 Gaps and conclusions

The OSPAR tools developed thus far provide a number of sentinel indicators, which not only assess the response of a species to a certain pressure, but act as an indicator of other trophic groups above and below them. However, these tools are not directly interlinked, they lack cohesion when used together and they do not address some levels of the food web. Obvious gaps in the current tools are the phytoplankton and zooplankton communities and fish at higher trophic levels. A more strategic approach might be required in which ratios of abundance of different trophic levels are compared from a cross-section of a representative food web. Alternatively or additionally, a more comprehensive set of sentinel indicators might be selected, preferably of keystone predators or prey species, which represent the condition of the food webs in a region.
2.5 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

It is suggested that assessment of GES could be achieved through the outcome of the eutrophication status assessments obtained via application of the OSPAR Comprehensive Procedure (Harrald et al. 2009). This method is currently in use although an evaluation should be carried out on the degree to which status assessments under the WFD for coastal waters are consistent with OSPAR eutrophication status assessments under the OSPAR Comprehensive Procedure for inshore and offshore areas. The overlap of these assessments in estuaries and coastal waters should enable an analysis of the degree of congruence or the reasons for apparent mismatch.

The OSPAR assessment method is perhaps more relevant to the MSFD than the WFD being designed to answer questions specifically on the occurrence of eutrophication. By contrast, the WFD assessment is based upon the quality status of components of the ecosystem (e.g. benthos, or angiosperms). Various combinations of the impacts on these components are then interpreted to indicate the cause of observed reductions in environmental quality. This is inherently less direct than the OSPAR approach. It is likely that MSFD will follow an OSPAR-like approach in NE Atlantic waters and will take full advantage of the assessment work already underway in OSPAR.

As an aside, it may be noted that eutrophication has thus far only been found in a few small areas of coastal and transitional waters in Scotland, and that therefore any control measures that may be necessary may be best developed through WFD and related legislation.

2.5.1 OSPAR Eutrophication Strategy

The OSPAR Eutrophication Strategy seeks to combat eutrophication in order to achieve and maintain a healthy marine environment where eutrophication does not occur. In 1997, OSPAR adopted the Common Procedure as a common framework for Contracting Parties to assess and to classify the eutrophication status of the OSPAR maritime area in two phases.

The purpose of the Common Procedure is to provide a means of establishing eutrophication status on a common basis. It aims at characterising maritime areas with regard to their eutrophication status as:

a) problem areas if there is evidence of an undesirable disturbance to the marine ecosystem due to anthropogenic enrichment by nutrients;

b) potential problem areas if there are reasonable grounds for concern that the anthropogenic contribution of nutrients may be causing or may lead in time to an undesirable disturbance to the marine ecosystem due to elevated levels, trends and/or fluxes in such nutrients;

c) non-problem areas if there are no grounds for concern that anthropogenic enrichment by nutrients has disturbed or may in the future disturb the marine ecosystem.

The Comprehensive Procedure consists of a set of qualitative assessment criteria which are linked to form a holistic assessment and area classification with respect to the eutrophication status of a given maritime area. The holistic approach is reflected in the selection and application of such common assessment parameters which reflect the main cause and effect relationships in the eutrophication process.
The elements of the Common Procedure cover sources of nutrients to marine waters, direct effects on primary production, indirect effects of increased primary production and other possibly related effects (e.g. biotoxin incidence). There has been considerable work done in the UK and elsewhere to establish assessment levels for each of the assessment parameters. Those agreed for the UK are generally set at significant (50%) deviation from background levels, or they are equivalent to the levels agreed at a UK level for the distinction between Good and Moderate quality status under the EU and WFD.

The Common Procedure has recently been applied by OSPAR Contracting Parties to provide assessments of the eutrophication status of the Convention waters. As far as Scotland is concerned, this has been done at a variety of geographical scales. Large areas of offshore waters, for example open waters in the North Sea and to the west and north of Scotland were quickly assessed as non-problem areas, as there are few if any anthropogenic nutrient inputs to these areas. (OSPAR 2009b)

By contrast, detailed assessments were made of areas such as the Solway, Clyde and Forth estuaries and firths, Montrose Basin, the Ythan estuary, and areas supporting fish farming. In most cases, they too were assessed as non-problem areas, although some small areas, such as the Ythan and Montrose were classified as problem or potential problem areas (Baxter et al. 2008).

2.5.2 WFD assessment methods

The WFD approaches eutrophication as a pressure, whereby nutrient enrichment may reduce the ecological status of a water body. For a water body to achieve good ecological status, it must achieve a good or better than good status in its biological, chemical, physico-chemical and hydromorphological quality elements. Tools that are of direct relevance to eutrophication include a tool on assessing phytoplankton for coastal waters and nutrient thresholds related to turbidity.

Phytoplankton for classification of coastal waters

Phytoplankton biomass is used as an indicator of nutrient enrichment. The 90th percentile of the chlorophyll concentration collected over the growing season (March to September inclusive) can be calculated and compared with the threshold value derived from appropriate reference conditions. The 90th percentile during the growing season should remain below thresholds set for the high/good and good/moderate boundaries for type specific conditions. Thresholds have been defined for different geographic regions (north and south of a line that extends between Flamborough Head to 55°N on the West coast). At least 5 years of data is required (Environment Agency in preparation). It may be possible to adapt this tool for use in offshore areas, although a monitoring programme would need to be established and a time series of data accumulated.

Nutrient thresholds related to turbidity

Plant growth is dependent on a supply of nutrients and light. The light that is available for growth is a product of mixing depth and optical depth (Kd). Susceptibility to nutrient enrichment is controlled by light attenuation within the water body, which in turn is partly controlled by the amount of suspended particulate matter in the water column. Effective strategies for assessment of regulatory thresholds of nutrients in coastal and transitional water bodies therefore requires an understanding of how different types of estuaries respond to nutrient inputs. To account for this, a series of nutrient thresholds related to three types of water body were established, based on the level of turbidity within the water body. The tool
Pre-existing tools that could contribute to assessments under the MSFD enables a crude estimation of the potential light climate and likely response to nutrient inputs (WFD UKTAG 2007a).

2.5.3 Gaps and conclusions

This assessment has largely already been carried out. Offshore areas were classified as non-problem areas due to the lack of anthropogenic inputs offshore. Inshore areas have been assessed under the WFD and OSPAR and have indicated only a few localised areas in Scotland where eutrophication occurs or is likely. A *de minimis* level of monitoring in offshore waters would be useful as evidence that eutrophication is unlikely to occur. The possibility of using remote sensing methods to obtain data over large areas might be considered and the applicability of the WFD nutrient plankton tool to offshore waters.
3.5 **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**

One possibility for assessment of GES is to develop an index that links physical pressures to habitat sensitivity. GES could be achieved only when activities in a given region are not permitted if the damage they cause on a certain habitat is greater than an agreed minimum (Harrald et al. 2009). The TraC MlmAS tool may be applicable to this and work is in progress to link impact of fishing activities to benthic communities.

Pre-existing tools have been developed to assess benthic communities under the WFD. In the UK, the benthic invertebrates ‘Infaunal Quality Index’ is being used for coastal waters and certain other Member States are using the AMBI. Such indices have been developed for inshore purposes and are particularly useful for measuring disturbance. However, the tools may need to be re-designed to assess impact of bottom trawling, which is the predominant pressure to the benthos offshore.

### 2.6.1 Tools for assessment of species distribution and abundance

**WFD Benthic Invertebrates Infaunal Quality Index for coastal waters**

The IQI for invertebrates in soft sediment, as described in 2.1.2.1, has been designed to detect the impact of general disturbance, particularly organic enrichment and toxins. It has so far been calibrated using data from CSEMP, the Merman database and WIMS but given data from offshore, it may be possible to re-calibrate the tool for use in offshore waters.

**AMBI (AZTI's Marine Biotic Index)**

Certain Member States are using the AMBI to assess the impact of disturbance and pollution on soft bottom benthic communities under the WFD. The AMBI includes over 4400 taxa and represents the most important communities present in estuaries and coasts. It has been successfully applied to areas of the Atlantic, Baltic Sea, Mediterranean Sea, North Sea and Norwegian Sea. The index is particularly useful for detecting temporal and spatial impact gradients and is sensitive to a range of disturbance activities such as, drill cutting discharges, submarine outfalls, harbour and dyke construction, heavy metal inputs, eutrophication, engineering works, diffuse pollutant inputs, recovery from sewage pollution, dredging processes, mud disposal, sand extraction, oil spills and fish farming (Muxika et al. 2005). The performance of the index is reduced when a low number of taxa (between 1 and 3) are found per sample or when assessing low-salinity locations or naturally-stressed locations impacted by trawling (Borja and Muxika 2005). Software to facilitate the AMBI is freely available at [http://www.azti.es](http://www.azti.es).

### 2.6.2 Tools relating impact to seafloor integrity

**WFD TraC MlmAS tool**

Under WFD a tool has been developed to assess the hydromorphological status of transitional and coastal waters (TraC) known as the TraC MlmAS (Morphological Impact Assessment System). This is a rapid assessment tool used to define and assess the morphological environmental standards for TraC water bodies.

TraC MlmAS determines the capacity of a system and the amount remaining that is available for exploitation to a proposed development and the total level of impact it might
have. The tool can be used to explore the level of risk to a new proposal by considering the impacts already inflicting a system. The results may inform where more detailed assessments or a regulatory exemption may be required on a public interest basis. The tool is not to be used in isolation but in addition to,

i. Freshwater flow standards utilising Qn95 metrics (transitional only),
ii. Expert judgement,
iii. River basin characterisation risk assessments.

TraC MImAS may be more applicable to Descriptor 7 on alteration of hydrographical conditions, but given sufficient information of seabed types it may be possible to estimate levels of disturbance to seabed integrity using this tool (WFD UKTAG 2007b).

MAFCONS

No tools, as far as is known, have been developed to assess the impact of disturbance by mobile fishing gear to benthic ecosystems. Stemming from the MAFCONS project (mentioned in 2.3.3, to understand the consequences of fisheries objectives on benthic invertebrate and ground fish diversity), a practical tool could be developed to assess fishing effects on benthic ecosystems. Information on fishing effort and other pressures in Scottish waters could be collated for different sediment types and water depths. From this it would be possible to map the spatial distribution of disturbance by fishing gear on various sediment types and their sensitivity to disturbance, to indicate where seabed integrity might be threatened.

Indications of benthic impact and habitat sensitivity to fishing gear is reviewed in Jennings and Kaiser (1998) and examples of other recent studies of relevance to Scottish waters include, the suspension of sediment by scallop dredges (Løkkeborg 2005; O’Neill et al. 2008; Dellapenna et al. 2006), and the impact of benthic bottom trawling on the habitats, invertebrate communities (Freese et al. 1999) and physical structure of soft sediments (Marine Scotland DEGREE project in progress).

2.6.4 Gaps and conclusions

Modelling using the approach taken either by the TraC MImAS tool or the modelling applied in the MAFCONS project may be applicable to developing an index relating physical impact to habitat sensitivities. One advantage of the TraC MImAS tool is that it accounts for cumulative impact, although it remains to be seen whether it can be used in relation to fishing activities rather than a development. While data on fishing effort and habitat sensitivities are largely available, there is a lack of detailed maps of seabed and habitats throughout much of Scottish offshore waters.

If it is possible to adjust the AMBI and IQI for use in offshore waters, these methods would provide an indicator of whether an area has been disturbed by anthropogenic activities and by how much. It would also be worth developing a tool or tools that could be used on hard substrates. However, a considerable amount of monitoring would be required to undertake this approach satisfactorily and thus a well ground truthed model might be more practical.
2.7 Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems

It is assumed that here the Directive is referring to developments that might inflict changes in current regime or thermal conditions. GES could therefore be interpreted as when a given proportion of developments do not cause an adverse effect on the marine ecosystem. This could encompass the planning for wet renewables (wind, wave and tidal energy), that is currently in progress; although whether such local developments are relevant to this Descriptor is scale-dependent. Assessment of GES could be through planning and regulation of activities that may affect hydrographical conditions. The WFD TraC MImAS tool (as discussed in 2.6.2) is currently being used under the WFD to assess the impact of developments in coastal and transitional waters and is being adapted for use offshore. This would provide a method to quantify the risk of a proposal according to the hydromorphological capacity of a system. It is likely that TraC MImAS is more applicable to developments that would affect hydrographical conditions than to fishing effects on the seafloor as in Descriptor 6. However, wave and tidal energy installations are still at the development and testing stages and research concerning the impacts of such developments is in its infancy. Therefore there may be a lack of data to input into the TraC MImAS. The tool would also require a more in depth knowledge of oceanographic conditions (e.g. currents and temperature) and seafloor bathymetry than is currently known for many regions.
2.8 Concentrations of contaminants are at levels not giving rise to pollution effects

GES could be assessed by measuring levels of harmful contaminants in the environment with 'good' being defined as a concentration at which the contaminant does not impact the ecosystem (Harrald et al. 2009). Monitoring to assess contaminant concentrations is already being carried out under OSPAR and for WFD status assessments. The former are predominantly concentrations of contaminants in sediment and biota, and are the basis for aspects of the assessment work carried out in relation to the OSPAR Hazardous Substances Strategy. The work under WFD is incorporated in the status assessments of WFD water bodies and is primarily based on concentrations of contaminants in water, although work is in progress to develop monitoring guidelines for biota and sediment for application in WFD.

Assessment criteria have been developed in both the WFD and OSPAR. In relation to WFD, these are Environmental Quality Standards (EQSs) for concentrations in water. A daughter Directive has defined EQS values for approximately 33 substances at EU level. In addition to these EQSs, Member States are able to define their own EQSs for substances that are of particular concern in their own waters. In all cases, the EQS values are designed to protect the most sensitive use of the water body, for example as habitat for fish or algae. EQSs are derived from toxicological data which provides information on No Effect Levels and additional safety (assessment) factors can be applied if data are relatively sparse.

A similar philosophy underlies OSPAR Environmental Assessment Criteria (EAC). These are concentrations of contaminants in sediment or biota below which unacceptable biological effects would not be expected to occur. A range of derivation methods have been used, but there is a general movement to bring the OSPAR process for developing EACs closer to the EU process for EQSs.

The processes used in WFD and OSPAR contexts to derive assessment criteria at no stage indicates that they are only applicable to near-shore waters, therefore it is likely that they will be considered applicable over the MSFD area, or at least over the NE Atlantic continental shelf. This has the added advantage that there should not be marked discontinuities between assessments under WFD and MSFD.

OSPAR assessments are increasingly taking account of biological effects measurements, and it is likely that the implementation of the MSFD Descriptor 8 will encourage the development of a wider suite of assessment criteria for biological effects. The impact of different sources of pollution may also be addressed through a collection of OSPAR EcoQOs developed to assess such pollution effects on marine species.

2.8.1 OSPAR methods

OSPAR carries out assessment work on 26 chemicals of concern to the marine environment; 16 of these are also listed under the WFD. OSPAR has developed a monitoring strategy for each chemical and has proposed methods for data collection and on suitable indicators to inform environmental quality (OSPAR 2007b).

Monitoring for certain heavy metals (PAHs, PCBs and PBDEs) in sediments and biota takes place annually under the Coordinated Environmental Monitoring Programme (CEMP) OSPAR 2008b; OSPAR 2009c). A time series of CEMP data is available dating back for varying periods of time at different stations, although generally time series include 3 - 20 years of data.

The effect of the ban on use of the antifouling tributyltin is supported by an EcoQO for TBT-specific biological effects in dogwhelks and other gastropods and is supported by monitoring
under CEMP. To assess levels of oil pollution at sea, OSPAR has also developed an EcoQO using oiled guillemots as an indicator of this, a common and widespread species sensitive to oil. (OSPAR 2007a)

OSPAR has agreed monitoring and assessment criteria for PAH and metal specific biological effects, such as EROD, ALA-D, vitellogenin production, and for a set of generalised responses in marine organisms to contaminants (e.g. fish diseases and sediment bioassays). The effects of two of these are being reported on in assessments of the Quality Status Report 2010 in collaboration with ICES. OSPAR can also provide data and advice in relation to hazardous substances collected under the Comprehensive Study on Riverine Inputs and Direct Discharges (RID) and the Comprehensive Atmospheric Monitoring Programme (CAMP).

OSPAR monitors radioactivity in seawater and biota. Periodic assessments are carried out on marker radionuclides and their anthropogenic and environmental impacts. OSPAR has established baseline concentrations of radionuclides in the marine environment and is using these to evaluate a strategic objective on acceptable levels (OSPAR 2009d). A project called ERICA is assessing the impact on marine biota (Larsson 2008). Annual monitoring is also carried out on discharges to the sea and emissions to the air as an indicator of the concentrations of radionuclides in the marine environment. OSPAR is progressing towards developing strategic objectives on radioactive substances.

2.8.2 OSPAR EcoQOs

Imposex in dog whelks (*Nucella lapillus*) or other selected gastropods

The average level of imposex in a sample of not less than 10 female dogwhelks (*Nucella lapillus*) should be consistent with exposure to TBT concentrations below the environmental assessment criterion (EAC) for TBT – that is, <2.0, as measured by the Vas deferens Sequence Index. Where *Nucella* does not occur naturally, or where it has become extinct, the red whelk (*Neptunea antiqua*), the whelk (*Buccinum undatum*) or the netted dog whelk (*Nassarius reticulatus*) should be used, with exposure criteria on the same index of <2.0, <0.3 and <0.3, respectively. (OSPAR 2007a)

Proportion of oiled common guillemots among those found dead or dying on beaches

The average proportion of oiled common guillemots in all winter months (November to April) should be 20% or less by 2020 and 10% or less by 2030 of the total found dead or dying in each of 15 areas of the North Sea over a period of at least 5 years. (OSPAR 2007a)

Mercury concentrations in seabird eggs

The average concentrations of mercury in the fresh mass of ten eggs from separate clutches of common tern (*Sterna hirundo*) and Eurasian oystercatcher (*Haematopus ostralegus*) breeding adjacent to the estuaries of the Rivers Elbe, Weser, Ems, Rhine/Scheldt, Thames, Humber, Tees, and Forth, should not significantly exceed concentrations in the fresh mass of ten eggs from separate clutches of the same species breeding in similar (but not industrial) habitats in south-western Norway and in the Moray Firth. (OSPAR 2007a)
Organohalogen concentrations in seabird eggs

For each site, the average concentrations in fresh mass of the eggs of common tern (Sterna hirundo) and Eurasian oystercatcher (Haematopus ostralegus) should not exceed: 20 ng g\(^{-1}\) of PCBs; 10 ng g\(^{-1}\) of DDT and metabolites; and 2 ng g\(^{-1}\) of HCB and of HCH. Sampling should be of ten eggs of each species from separate clutches of birds breeding adjacent to the estuaries of the Rivers Elbe, Weser, Ems, Rhine/Scheldt, Thames, Humber, Tees, and Forth, and in similar (but not industrial) habitats in south-western Norway and in the Moray Firth. (OSPAR 2007a)

2.8.3 Gaps and conclusions

Comprehensive assessment criteria have been developed under WFD and OSPAR. OSPAR assesses concentrations of substances present in sediment and biota while also monitoring for biological effects. The WFD provides EQSs designed to protect the most sensitive fauna and flora. There are a number of gaps, however, that the MSFD might address. Firstly, monitoring data on chemical and biological effects is often sparse in offshore areas. Secondly, the OSPAR and WFD lists of priority contaminants differ, and therefore the two monitoring programmes do not currently address the same set of contaminants. Thirdly, new contaminants considered a threat to the marine environment are being identified, such as brominated flame retardants, and research may be insufficient thus far to identify acceptable levels or tools to assess biological impact.

Lastly there will be considerable difficulty in mounting the same intensity of monitoring effort in offshore areas as is required in inshore water bodies under WFD. This may encourage the wider use of sediment and biota monitoring, as for OSPAR. However, there are relatively few compounds for which OSPAR EACs have been defined, compared to EQSs in water. There will be a great need to extend and improve the range of assessment criteria for contaminant concentrations in sediment and biota (and to a degree in water).
2.9 Contaminants in fish and other seafood for human consumption do not exceed levels established by community legislation or other relevant standards

Harrald and Davies (2009) concluded that a variety of methods may be required to assess GES depending on taxa (i.e. fish/shellfish), method of harvest (wild-caught/farmed) and type of contaminant:

- Chemical contamination (heavy metals, dioxins, dioxin-like PCBs) of wild fisheries: Fish or shellfish harvested from the wild could be sampled at ports. Levels of contaminants found in the seafood would reflect contaminant concentrations found in the environment in the region where the fish were caught.

- Farmed shellfish in relation to chemical contaminants: Similar to wild shellfish, farmed shellfish could be assessed at the time they are harvested or when they go to market, since the concentrations of chemical contaminants reflect environmental quality where they are farmed.

- Farmed finfish in relation to chemical contaminants: These should not be included under this Descriptor, since contaminant levels reflect the composition of their food, namely pellets and not the environment they are grown in.

- All seafood in relation to radioactivity: Potential doses of radioactivity to a consumer in a given region should be beneath limits specified in EC legislation.

- All shellfish in relation to biotoxins: If it is decided that this is included under the MSFD, the assessment should be related to ability to implement EC legislation to prevent shellfish being harvested when dangerous biotoxins are present.

While there are many tools (i.e. acceptable concentrations) available for individual contaminants, there are no tools in place to integrate across these individual assessments. Data on concentrations of contaminants in seafood generated to comply with legislation could be used as a basis to create a tool. A summary of the relevant legislation, assessments and reporting is given below which should provide most of the data required to assess GES. Acceptable thresholds for a percentage of products not containing more than the threshold values listed under the legislation will require defining.

2.9.1 Relevant legislation

The safety of fish and other seafood which has been produced or harvested for commercial production is regulated by EC Regulation 1881/2006 as amended, 853/2004, EC Shellfish Waters Directive 79/923/EEC, 87/3954/EURATOM as amended and National legislation (Contaminants in Food Scotland Regulations 2007). These regulations state maximum levels permitted for named contaminants in food, such as certain heavy metals and dioxins. The aim of the regulation is to keep these contaminants at levels that are toxicologically acceptable and to prevent grossly contaminated food from entering the food chain. The regulations also specify methods of sampling and analysis required to be used for the official control of levels of the heavy metals (Commission Regulation 333/2007) and dioxins and dioxin like PCBs (Commission Regulation 1883/2006).

Directives specific to shellfish exist due to their nature of acquiring potentially dangerous levels of toxins through feeding on toxic microalgae. They are filter feeders and thus accumulate potentially harmful toxins in their tissue from their surrounding waters. The Shellfish Waters Directive (1979) was adopted to protect and, where necessary, improve the

2.9.2 Monitoring

Food Standards Agency (FSA) has statutory functions as a competent authority for the sampling of biotoxins, E.coli and chemical contaminants in shellfish. Local Authorities have delegated competence for carrying out official control testing for histamine, parasites and chemical contaminants in fish. The food business operator has a requirement to ensure that products entering the market place comply with set levels of contaminants both chemical and microbiological. FSA is also responsible for ensuring consumers do not exceed a certain dose of radioactivity. This monitoring may be usable for MSFD purposes to assess GES for Descriptor 9.

2.9.3 Reporting

The FSA uses results from the Total Diet Study (TDS) (dating from 1966) to estimate the dietary exposures of the general UK population to chemicals in food, to identify trends in exposure, and to make assessments of the safety and nutritional quality of the food supply. The study samples 199 categories of food combined into 20 groups of similar foods for analysis. The relative proportion of each food category within a group reflects its importance in the average UK household diet and is based on an average of three previous years of consumption data from the National Food Survey. Analyses for metals and other elements in the TDS are generally carried out every three years (FSA 2009).

The Shellfish Hygiene Directive (1991) as amended includes a requirement to assess a range of contaminants of end product quality in shellfish for human consumption and includes chemical contaminants, such as PAHs (benzo[a]pyrene) and the trace metals; lead, cadmium and mercury. The FSA carries out checks on compliance with the maximum permissible levels of contaminants included by Commission Regulations and those specified in the Shellfish Hygiene Directive.

2.9.4 Gaps and conclusions

The limits written into existing legislation for acceptable contaminant concentrations should form the basis for assessments under this Descriptor. Assessments already carried out to enforce these limits are undertaken in Scotland and should provide the data required for it. In addition to defining exactly what GES will be for each type of sea food, there are a number of other issues in need of clarification. For instance, whether newer substances should be included, such as BFRs, for which acceptable levels are not included in EC legislation as yet. It is also uncertain whether marine biotoxins such as those found in shellfish should be included, although it seems likely that these would be omitted as they are already legislated under other EC Directives.
2.10 Properties and quantities of marine litter do not cause harm to the coastal and marine environment.

Harrald et al. (2009) suggest that GES could be assessed in terms of either a given percentage of marine litter per metre of strandline, a given tonnage of marine litter per tow or a given mass of microplastic per kg of sediment. GES should be set at a level that corresponds to a minimal loss of individuals from litter related deaths in a population. The WFD does not consider litter but OSPAR and a number of NGOs have undertaken a considerable body of relevant research and monitoring. Most significantly, OSPAR has developed a quantitative method for assessing the impact of floating litter on marine seabirds.

2.10.1 OSPAR surveys

Beach surveys and fishing-for-litter activities

A number of projects have been established to remove and/or monitor beach and marine litter using established methods. For instance, the Marine Conservation Society runs a volunteer project to clean and monitor beach litter known as Adopt a Beach and Beach Watch (1994 to present, MCS 2008); KIMO International developed a project for volunteer fishermen to trawl for litter, so called ‘Fishing for Litter’ (2000 to present, Hall 2000) and an EU collaboration between UK and Ireland institutions are running a project, DEEPCLEAN (2009) to retrieve lost nets and assess effects of ghost netting (2006 – present). As far as is known, there are no quantitative surveys for assessing marine litter in Scotland carried out at present. However, OSPAR has developed guidelines on ‘Fishing-for-Litter’ after work carried out by KIMO International (OSPAR 2007c) and has also recommended improved and standardised methodologies for monitoring beach litter including the establishment of reference areas. The 2000-2006 pilot beach litter project identified beaches and survey protocols for 100m to 1km stretches (OSPAR 2007d).

OSPAR EcoQO: Plastic particles in stomachs of seabirds

There should be less than 10% of northern fulmars (Fulmarus glacialis) having ten or more plastic particles in the stomach in samples of 50–100 beach-washed fulmars found in winter (November to April) from each of fifteen areas of the North Sea over a period of at least five years. (OSPAR 2007a)

This EcoQO was designed as an indicator of floating litter in the marine environment and its impact on marine species. It was based on a Dutch project dating back to 1982 in which the litter content in fulmar stomachs was measured. In 2002, this project widened to cover all countries around the North Sea, a project called ‘Save the North Sea’ (SNS). F. glacialis is a convenient species for monitoring being widespread throughout the northern OSPAR regions (Van Franeker & SNS Fulmar Study Group 2008). The 10% target was primarily a political decision as an achievable target. OSPAR originally suggested 2%, but in pristine conditions, we would expect no litter related deaths to marine species (OSPAR 2009e). Results from 2002-2006 suggested that all areas surveyed fell considerably short of the 10% target (ranging from 43 to 71%). Combined results for the Scottish Islands were 46% compared to 55% in the North Sea (Van Franeker and SNS Fulmar Study Group 2008). Further developments to this EcoQO are taking place to improve coverage of beached bird surveys and a pilot study is being conducted on the Cory’s Shearwater (Calonectris sp.) to use as a substitute for fulmars in southern OSPAR regions where fulmars do not occur (OSPAR 2009e).
2.10.1 Gaps and conclusions

Methods to implement assessment of beach litter and litter at sea do exist through OSPAR and NGOs. However, in order to set thresholds that could equate to GES we require,

a) information regarding population level effects of litter on marine species in addition to fulmars and,

b) appropriation of large-scale monitoring and assessments of litter at sea and on beaches (such as those developed by OSPAR) that can provide consistent long-term datasets on amounts of litter in the environment.
2.11 Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

2.11.1 Noise

It was proposed that for a region to achieve GES, noise levels should be beneath threshold tolerance levels for the species that exist within it (Harrald et al. 2009). Currently, activities that produce noise are assessed to comply with the Habitats Regulations (as amendments) and the Offshore Marine Conservation Regulations (2007) in relation to European Protected Species (EPS, species listed on Annex IV to the European Habitats Directive including all species of cetaceans and turtles occurring in European waters and the Atlantic sturgeon). It is now an offence to deliberately disturb wild animals of EPS in such a way as to have a likely significant effect on, a) the ability of any significant group of animals of that species to survive, breed, or rear or nurture their young; or b) the local distribution or abundance of that species (www.jncc.gov.uk/marine).

Effects of underwater noise are taken into account in regulatory advice and may lead to seasonal or spatial restrictions in certain activities. Seismic surveys are regulated by the Department for Energy and Climate Change and the relevant competent authority (the JNCC or SNH) advises on the likely effect on cetaceans and also on spawning fish. Guidelines on minimising acoustic disturbance to marine mammals from seismic surveys have been updated by the JNCC (JNCC 2004). JNCC also provides guidance on deliberate disturbance of marine EPS for English and Welsh territorial waters and the UK offshore area. This includes species guidance on for example, what would constitute a “significant group”, species that would be most sensitive to effects of disturbance and local distribution and abundance in the UK. Information is also provided on activities (seismic survey, pile driving and explosives) that cause known impacts and good practice for minimising disturbance in UK waters (www.jncc.gov.uk/page-4227; JNCC 2004).

Ideally, the MSFD would aim to protect a larger number of species than just EPS. Similar guidelines would need to be drawn up to reflect tolerances of other species and to include other sources of underwater noise, although limited research has been carried out on non-EPS. The achievement of GES, that noise levels are beneath threshold tolerance levels for the species, may need to be assessed through implementation of a suitable management strategy. GES could be defined as when a given percentage of cases in a region produce noise at a level that does not have a significant effect on a population. This would require adaptation of the JNCC guidelines to widen their scope to more species and to include more sources of underwater noise.

2.11.2 Energy

Similar to underwater noise, it is proposed that to achieve GES, inputs of thermal energy should be beneath levels that could result in an adverse effect to the marine environment for that geographical area. Outputs of heated water from coastal power stations are already regulated under FEPA (Food and Environment Protection Act) and the WFD. Discharge of produced water from oil and gas production is not assessed in terms of its thermal effects however. Assessment of GES could be through an effective management system that ensures that in a certain percentage of cases, inputs of energy are beneath a level that may cause adverse effects to the ecosystem.

2.11.3 Gaps and conclusions

No pre-existing tools have been identified that could inform either the noise or the energy component of this Descriptor. However, there are guidelines on acceptable levels of noise...
mostly for marine mammals, being particularly sensitive to noise. Until more detailed research is carried out, acceptable levels could be determined from these guidelines for certain species. In order to improve estimates of acceptable levels of noise, further research should be conducted on anthropogenic sound sources and levels, and autographic data collected (sensitivity of individuals vs. frequency of sound) on a broader range of species at risk from sound. Inputs of thermal energy from coastal power stations are already assessed under WFD but heat from offshore oil and gas production may require pressure and impact studies before a suitable level for GES can be established.
3. GENERAL DISCUSSION

Owing to the wide ranging objectives of the MSFD, it is likely that approaches may need to differ between Descriptors. Where pre-existing tools are insufficient or do not complement the aims of the objectives, new tools may be required together with the monitoring to implement the tool. The WFD approach tends to be more comprehensive than the OSPAR EcoQOs, in that it identifies pressures by looking for trends in state. While such rigour might be possible at a river basin scale, resources could be pressed to implement such a strategy at the scale of regional seas. Further, WFD assessments are designed to assess smaller scale community level effects, whereas the MSFD operates at an ecosystem scale. The OSPAR EcoQO approach provides a more attainable method by identifying specific pressures on a functional group and assessing impact on representative species.

Some of the Descriptors in the MSFD bear similarities to the OSPAR approach in that they target a certain pressure or activity that is measurable, such as eutrophication, seafood contaminants and marine litter. Others, such as biological diversity, food webs and seafloor integrity may require an approach more akin to the WFD in which the state of communities or habitats are assessed. Descriptor 11 (noise and energy) and Descriptor 7 (hydrographical conditions) might require an impact assessment approach whereby activities are assessed at the planning stage and only approved where they can prove that they are within the limits of GES.

For certain Descriptors, comprehensive assessments are already in place to comply with European or National legislation, which could be used to underpin GES. Commercially exploited fish and shellfish (Descriptor 3) are managed under the Common Fisheries Policy. Consequently for certain stocks there are already assessments, although a number of improvements could be suggested, such as incorporation of biological populations rather than politically defined stocks and developing assessments on non-assessed commercially exploited or bycatch species. Likewise, an assessment for eutrophication has already been carried out under the OSPAR Common Procedure and the WFD although whether some offshore areas also require assessment is debatable. Seafood contaminants are heavily legislated under the EU and UK regulations and much of the information required to assess GES should be attainable from existing monitoring schemes. For Descriptor 8 (pollutants) it may be possible to draw on the OSPAR Environmental Assessment Criteria along with the Environmental Quality Standards developed for the WFD, although the WFD is limited to inshore waters.

In the case of other Descriptors, there is either a lack of monitoring data or assessment tools or both. For marine litter (Descriptor 10), protocols have been described for monitoring litter at sea and on shore but no assessment tools have been developed. Data exist from the voluntary sector to support a shore based tool but no long-term litter surveys have been carried out offshore. In the case of biological diversity (Descriptor 1) and marine food webs (Descriptor 4), a number of tools have been developed through OSPAR but these cover too narrow a field and may not be interlinked. For example, tools to assess biological diversity do not cover non-commercial fish, plankton communities or benthic communities on hard ground. Similarly, OSPAR EcoQOs focus on sentinel indicators of a specific pressure but are not indicative of the quality across the entire food web. For non-indigenous species, there is data on species distribution in inshore areas but little offshore and no tools have been developed thus far. Given sufficient resources, it would be useful to map non-indigenous species distribution and their impact using the framework set out by the WFD to assess risk. However, a more feasible option might be to limit assessments to species of a known high impact and in regions where they are known to exist.

Similarly, one method to assess GES under Descriptor 10 (noise and energy) would be to map noise levels throughout a region and relate it to sensitivities of marine species of concern. However, the feasibility of this might be stretched since it could involve...
disseminating permanent or semi-permanent hydrophones throughout a region. A more realistic approach might be an extension to an Environmental Impact Assessment incorporating an assessment of the likely impact at the planning stage for various activities of concern (e.g. pile driving, seismic survey, acoustic deterrent devices), with the view that a region might fail to achieve GES should it approve an activity which involves a potentially damaging level of noise. Descriptor 7 (hydrographical conditions) and potentially Descriptor 6 (seafloor integrity) could also be assessed using an EIA approach. It may be possible to adapt the WFD TraC MlmAS tool to enable such an approach.

4. CONCLUSION

In conclusion, there are evidently a large number of tools from the WFD, OSPAR and other International activities worth considering for use under the MSFD, although pre-existing tools may well require adaptation or re-calibrating for use under a differing environment and to address ecosystem or population effects. Further, intercalibration may be necessary between tools used by different Member States and to ensure harmonisation over similar issues with other Directives. Some pre-existing tools, such as those listed to assess eutrophication and commercial fish, may require a minimal level of adaptation, while others, although effective for there own purposes, may not be directly applicable to the objectives of the Qualitative Descriptor in question, such as the OSPAR EcoQOs listed under Descriptor 4 on marine foodwebs. For other Descriptors, such as non-indigenous species, introduction of energy and noise and seafloor integrity, there are no obvious tools of relevance. However, when pre-existing tools may be translated for use under the MSFD they should have the following characteristics:

a) specific to the relevant qualitative descriptor,

b) sufficiently comprehensive to cover the entire scope of the Descriptor and where a number of tools are required, these should be systematic, coherent and complementary to each other,

c) specific to a population or ecosystem scale and sensitive to ecosystem or population level pressures and impacts.

A summary of pre-existing tools worth considering under the MSFD and the purpose they were originally developed for is tabulated below (Table 1).
Pre-existing tools that could contribute to assessments under the MSFD

### TABLE 1

Summary of pre-existing tools or frameworks in place developed for the EC Water Framework Directive (WFD), the EC Habitats and EC Birds Directives, OSPAR, the Common Fisheries Policy (CFP) and for Scottish Government that may be considered for use or adaptation under the Marine Strategy Framework Directive.

<table>
<thead>
<tr>
<th>Qualitative Descriptors</th>
<th>Pre-existing tools or frameworks</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Biological diversity</td>
<td>Assessment of ‘favourable conservation status’ of Natura sites</td>
<td>Habitats and Birds Directives</td>
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<tr>
<td></td>
<td>Benthic Invertebrates Infaunal Quality Index for coastal waters</td>
<td>WFD</td>
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<tr>
<td></td>
<td>Fish fauna for transitional waters</td>
<td>WFD</td>
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<td></td>
<td>Fucoid extent tool for transitional waters</td>
<td>WFD</td>
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<td></td>
<td>Opportunistic macroalgae</td>
<td>WFD</td>
</tr>
<tr>
<td></td>
<td>Rocky shore macroalgae for coastal waters and outer reaches of transitional water bodies</td>
<td>WFD</td>
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<tr>
<td></td>
<td>Harbour porpoises by-catch EcoQO</td>
<td>OSPAR</td>
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<td></td>
<td>Seal populations EcoQO</td>
<td>OSPAR</td>
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<tr>
<td></td>
<td>Local sand eel availability to black-legged kittiwakes EcoQO</td>
<td>OSPAR</td>
</tr>
<tr>
<td></td>
<td>Proportion of large fish EcoQO</td>
<td>OSPAR</td>
</tr>
<tr>
<td></td>
<td>Threatened and/or declining species and habitats</td>
<td>OSPAR</td>
</tr>
<tr>
<td>(2) Non-indigenous species</td>
<td>No applicable tools identified</td>
<td></td>
</tr>
<tr>
<td>(3) Commercially exploited fish and shellfish</td>
<td>Fish and shellfish Stock Assessments</td>
<td>Common CFP</td>
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<td></td>
<td>Commercial fish EcoQO</td>
<td>OSPAR</td>
</tr>
<tr>
<td></td>
<td>Commercial finfish indicator based on the perceived status of 11 stocks of relevance to Scotland</td>
<td>Scottish Government</td>
</tr>
<tr>
<td>(4) Marine food webs</td>
<td>As for Qualitative Descriptor 1 on biological diversity</td>
<td></td>
</tr>
<tr>
<td>(5) Human-induced eutrophication</td>
<td>Eutrophication Strategy (Common and Comprehensive Procedures)</td>
<td>OSPAR</td>
</tr>
<tr>
<td></td>
<td>Phytoplankton for classification of coastal waters</td>
<td>WFD</td>
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<td></td>
<td>Nutrient thresholds related to turbidity</td>
<td>WFD</td>
</tr>
<tr>
<td>(6) Sea-floor integrity</td>
<td>Benthic Invertebrates Infaunal Quality Index for coastal waters</td>
<td>WFD</td>
</tr>
<tr>
<td></td>
<td>AMBI (AZTI’s Marine Biotic Index)</td>
<td>WFD</td>
</tr>
<tr>
<td></td>
<td>WFD TraC MImAS tool</td>
<td>WFD</td>
</tr>
</tbody>
</table>
| (7) Hydrographical conditions | TraC MImAS | Physico-chemical measurements taken under the WFD | WFD
| (8) Pollution | Environmental Quality Standards for concentrations of contaminants in water | WFD
| | EACs for concentrations of contaminants in sediment and biota | OSPAR
| | OSPAR Hazardous Substances Strategy | OSPAR
| | Imposex in dog whelks (Nucella lapillus) or other selected gastropods EcoQO | OSPAR
| | Proportion of oiled common guillemots among those found dead or dying on beaches EcoQO | OSPAR
| | Mercury concentrations in seabird eggs EcoQO | OSPAR
| | Organohalogen concentrations in seabird eggs EcoQO | OSPAR
| (9) Contaminants in fish and seafood for human consumption | Acceptable concentrations of contaminants defined in EC legislation | 1881/2006 (heavy metals), EURATOM and others (see 2.9)
| (10) Marine litter | Plastic particles in stomachs of seabirds EcoQO | OSPAR
| (11) Energy and underwater noise | No applicable tools identified | |

**REFERENCES**


Commission Regulation 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs.

Commission Regulation 1883/2006 of 19 December 2006 laying down methods of sampling and analysis for the official control of levels of dioxins and dioxin-like PCBs in certain foodstuffs.

Commission Regulation 333/2007 of 28 March 2007 laying down the methods of sampling and analysis for the official control of the levels of lead, cadmium, mercury, inorganic tin, 3-MCPD and benzo(a)pyrene in foodstuffs.


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Pre-existing tools that could contribute to assessments under the MSFD


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