Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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Ecosystem Indicators for the Marine Strategy Framework Directive (MSFD)

STRIVE

Environmental Protection Agency Programme

2007-2013

SSTI Strategy for Science, Technology and Innovation

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

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EPA STRIVE Programme 2007–2013

Ecosystem Indicators for the Marine Strategy Framework Directive (MSFD)

MSFD-Support Research on OSPAR Ecological Quality Objectives

(2011-W-DS-6)

STRIVE Report

Prepared for the Environmental Protection Agency

by

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DISCLAIMER

The EPA STRIVE Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Executive Summary[1]

The Marine Strategy Framework Directive (MSFD, 2008/56/EC) aims to ensure that Europe's seas achieve Good Environmental Status (GES) by 2020, and "*has established itself as the cornerstone of all future EU regulatory measures that are applicable to the marine environment*"[2]. The MSFD was transposed into Irish law by the European Community's (Marine Strategy Framework) Regulations (SI No. 249 of 2011). The first legislative deadline was 2012, when Member States must have defined GES and indicators for sea areas under their sovereignty and jurisdiction. Monitoring programmes must be established by 2014, and measures by 2015/2016. Such strategies must contain a detailed assessment of the state of the environment, a definition of GES at regional level, as well as the establishment of clear environmental targets and monitoring programmes. Each Member State must then draw up a programme of cost-effective measures by 2015 in co-ordination with other Member States in their marine region.

It is clearly imperative that Ireland moves efficiently towards implementing the structural requirements of the MSFD. This is a complex undertaking, but it is now widely recognised that a robust template already exists in the OSPAR[3] Convention. There is a requirement in the MSFD that such regional sea conventions are used as regional co-ordinating bodies. OSPAR is an agreement signed by 15 governments, including Ireland, along the western coast and catchments of Europe that undertakes to develop an Ecosystem Approach to Management (EAM) of the marine environment of the North-East Atlantic. OSPAR has responded with a pilot project in the North Sea, identifying nine specific Ecological Quality Issues (EcoQIs) that refer to broad functional components of the system (e.g. fish and seabird communities) or to key impact descriptors (e.g. species and habitats under threat). For each EcoQI, one or more Ecological Quality Objectives (EcoQOs) have been established. EcoQOs comprise management objectives for the associated EcoQI. Monitoring changes in the 'state' of a given EcoQI, in relation to its defined EcoQO, requires the use of ecosystem indicators. Indicators are now widely used in monitoring, assessing, and understanding ecosystem status, impacts of human activities, and effectiveness of management measures in achieving objectives.

The project undertook a systematic evaluation of operational OSPAR EcoQOs with regard to their relevance and operability in implementing the MSFD in Irish waters. It was found that many EcoQOs had close potential links to components of the MSFD. Linkage tables were used to synthesise numerous reports into a simple format for assessing these relationships and also connections to other important legislative drivers such as the EU Birds and Habitats Directives. Given the number of potential indicators available in OSPAR, the project then demonstrated a systematic and objective protocol for evaluating a suite of candidate indicators for application under the MSFD. This multi-stakeholder exercise helped clarify the needs of relevant management organisations in Ireland, e.g. the National Parks and Wildlife Service, and developed a simple weighting system to facilitate indicator selection.

A fundamental factor in the implementation of the MSFD in Ireland is identification of appropriate monitoring data sets and analytical tools on which to base ongoing indicator series. Following the needs of management stakeholders, the project conducted further evaluation of a selection of OSPAR EcoQOs. These included (among others):

- Seal population trends (grey and harbour seal);

1. Please click on link for metadata and relevant data sets for this project on: http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=3003.
2. Long, R., 2011. The Marine Strategy Framework Directive: A new European approach to the regulation of the marine environment, marine natural resources and marine ecological services. *Journal of Energy and Natural Resources Law* **29(1):** 1–44.
3. OSPAR, Oslo/Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic).

- By-catch of harbour porpoise;
- Seabird population trends; and
- Eutrophication.

It was found that many of these EcoQOs were well supported by current monitoring programmes in Irish waters and could relatively easily be implemented within corresponding MSFD structures. For one fish community indicator (Large Fish Indicator, LFI), this evaluation process was extended through a comprehensive novel analysis to develop a fully functional MSFD 'Celtic Seas' subregion indicator. The issue of spatial scale is critical since GES will be considered at MSFD region and subregion scales rather than within national Exclusive Economic Zones (EEZs).

The project provides a combination of data synthesis and novel analysis that will prove valuable as national bodies in Ireland move towards full implementation of the diverse components of the MSFD. Recommendations on indicators for marine mammals, seabirds and fishes can be used to shape existing programmes to meet ongoing legislative demands. A new MSFD subregion-scale fish community indicator will ensure that Ireland leads the way in aspects of the European process. The MSFD has potential to become a powerful forum for sustainable management of the oceans and the researchers engaged in the project are committed to supporting this process.

1 Background and Objectives

Human interaction with marine systems covers a wide range of activities, from extractive use such as fishing and oil drilling to diverse recreational uses. Within the European Union (EU), management of these activities has recently been integrated through the Marine Strategy Framework Directive (MSFD) 2008/56/EC. The MSFD is based on the concept of Good Environmental Status (GES), which involves protecting the marine environment, preventing its deterioration and restoring it, where practical, while using marine resources sustainably. This holistic structure exemplifies the developing Ecosystem Approach to Management (EAM), by considering human impacts on all interacting parts of the system. Member States, including Ireland, have committed to implementing the MSFD by a stepwise process – the preparation phase in 2012 required the first assessment, definition of GES and targets and indicators. Further steps occur in 2014, 2015 and 2016 for monitoring and the programme of measures. The implementation process demands a detailed assessment of the state of the environment, a definition of GES at a regional level, as well as the establishment of clear environmental targets and monitoring programmes. GES must currently be attained by 2020.

Ireland has jurisdiction over one of the largest marine Exclusive Economic Zones (EEZs) in the EU. This vast area includes diverse ecosystems from the shallow and turbid Irish Sea to the extensive deeper waters of the Continental Shelf. Within these systems exist some of the largest remaining European populations of several fish, bird and marine mammal groups. As such, Ireland has considerable stewardship responsibility and a complex task in implementing the MSFD. This is a challenging undertaking, but a robust template already exists in the OSPAR[1] Convention. OSPAR is an agreement signed by 15 governments along the western coast and catchments of Europe, which undertakes to develop an EAM for the marine environment of the North-East Atlantic. Under Article 6 of the MSFD, there is a requirement that such existing regional sea conventions are used as regional co-ordinating bodies, and hence OSPAR officially has this role for the North-East Atlantic. In 2003, OSPAR established a commitment to EAM and commenced a case study programme in the North Sea to be fully operational by 2010. The OSPAR structure identifies nine Ecological Quality Issues (EcoQIs) that refer to broad functional components of the system (e.g. fish and seabird communities) or to key impact descriptors (e.g. species and habitats under threat). For each EcoQI, one or more Ecological Quality Objectives (EcoQOs) have been established (Heslenfeld and Enserink, 2008). EcoQOs comprise management objectives for the associated EcoQI. Monitoring changes in the 'state' of a given EcoQI, in relation to its defined EcoQO, requires the use of ecosystem indicators. Indicators are now widely used in "*monitoring, assessing, and understanding ecosystem status, impacts of human activities, and effectiveness of management measures in achieving objectives*" (Rice and Rochet, 2005).

OSPAR EcoQOs are currently implemented only in the North Sea. However, it has been recognised that "*when fully developed, the suite of EcoQOs can facilitate the determination of GES and monitoring and reporting within the regional implementation of the proposed MSFD*" (OSPAR Commission, 2007). In the MSFD framework, GES is considered in reference to 11 Descriptors, which have much in common with the nine OSPAR EcoQIs. For each descriptor, there are measurable criteria. Criteria are considered to describe qualities and characteristics of the descriptor and will be related to indicators that can track changes in state in relation to GES. Some of these indicators are already drawn directly from EcoQOs. For example, for MSFD Descriptor 4, Food Webs, one stated criterion is "*structure of food webs (size and abundance)*". The proposed indicator for this criterion is the Large Fish Indicator (LFI), for which "*guidance on setting reference levels has already been provided by OSPAR*" (Cardoso et al., 2010). Hence, it may be seen

1. OSPAR, Oslo/Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic).

that, in some cases, there is direct correspondence between the OSPAR EcoQO and MSFD structures, and indeed there are many further instances in which the MSFD cites OSPAR precedents concerning given indicators and monitoring protocol.

The OSPAR management structure can thus be interpreted to facilitate implementation of the MSFD for Irish waters. This report describes a project funded to commence this process. The project comprised four key practical objectives:

1. Produce a series of cross-referenced tables that illustrate potential linkages/common themes between individual OSPAR EcoQOs, the MSFD and other key EU legislative drivers;
2. Demonstrate a rapid evaluation protocol for candidate OSPAR ecosystem indicators with potential for application in Irish waters;
3. Describe a subset of operational OSPAR EcoQOs in terms of thresholds, case studies, current monitoring, etc., and make recommendations for implementation in the MSFD; and
4. Develop a statistically rigorous case study in MSFD indicator tuning and target setting.

2 Research Objectives and Results: Objective 1. Indicator Reference Tables

2.1 Introduction

The MSFD seeks to develop a comprehensive and holistic marine EAM mechanism. However, science and monitoring undertaken to service this framework is likely to be highly relevant to other existing EU environmental management legislation. For example, the OSPAR EcoQO for commercial fish species (Spawning Stock Biomass, SSB) is now also an indicator under MSFD Descriptor 3 (Commercial Fish). To allow for quick identification of such overlap, a reference table is produced in which common themes can be compared between components of the MSFD and potential linkages with other legislative structures identified (Table 2.1). A key issue in the implementation process is identification of suitable ecosystem monitoring data on which to base indicator series; data sets relevant to EcoQOs and the MSFD can be found online at http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=3003. For simplicity, these data are not related directly to specific indicators, but to broader EcoQO categories. Using the OSPAR framework to implement the MSFD will demand comparison of the two systems and identification of specific connections between OSPAR EcoQOs and corresponding MSFD descriptors and criteria (Table 2.2).

Table 2.1. Potential links among EU legislative frameworks.

Ecological Quality Issue	Indicators for Ecological Quality Objective (EcoQO)	Marine Strategy Framework Directive (MSFD)	MSFD indicators	Water Framework Directive	Habitats Directive	Birds Directive
Commercial fish species	Spawning stock biomass	Descriptor 1. Biodiversity			Favourable conservation status	
		Criteria: species distribution, size, condition	Range (pattern/area); population abundance, demography and structure	Fish diversity and composition	Species range, population size and condition, habitat for the species and future prospects	
		Descriptor 3. Commercial fish			Protected species	
		Criteria: fishing pressure, reproductive capacity, population age/size distribution	Fishing mortality; catch/biomass ratio			
		Descriptor 4. Food webs				Seabird 'ecological requirements'
		Criteria: productivity, high trophic level species, abundance and distribution	Predator performance; LFI; abundance trends of functional groups			
Marine mammals	Seal population trends	Descriptor 1. Biodiversity			Favourable conservation status	
	Annual by-catch of harbour porpoises	Criteria: species distribution and population size	Range (pattern/area); population abundance, demography and structure		Species range, population size and condition, habitat for the species and future prospects	
		Descriptor 4. Food webs				
		Criteria: abundance of high trophic level species, abundance and distribution	Predator performance (production); abundance trends of top predators			
Seabirds	Seabird population trends	Descriptor 1. Biodiversity			Favourable conservation status	Bird Populations
	Sand eel availability	Criteria: species distribution, size, condition	Range (pattern/area); population abundance, demography and structure		Species range, population size and condition, habitat for the species and future prospects	Specially Protected Areas
		Descriptor 4. Food webs			Protected species	
		Criteria: productivity, high trophic level species, abundance and distribution	Predator performance (production), abundance trends of top predators			
	Contaminant concentrations in seabird eggs	Criteria: concentration and effects	Concentration; pollution effects; occurrence	Environmental Quality Standards		
	Plastic particles in fulmar stomachs	Descriptor 10. Litter				
		Criteria: characteristics and impacts	Trends in amount and distribution; trends in animal ingestion			
Fish communities	Large Fish Indicator (LFI)	Descriptor 3. Commercial fish		Fish diversity and composition	Favourable conservation status	
		Criteria: population age/size distribution	Range (pattern/area); population abundance, demography and structure		Species range, population size and condition, habitat for the species and future prospects	
		Descriptor 4. Food webs				Seabird 'ecological requirements'
		Criteria: productivity, high trophic level species, abundance and distribution	Predator performance; abundance trends of functional groups		Protected species	

Table 2.1 ***contd***

Ecological Quality Issue	Indicators for Ecological Quality Objective (EcoQO)	Marine Strategy Framework Directive (MSFD)	MSFD indicators	Water Framework Directive	Habitats Directive	Birds Directive
Benthic communities	The average level of imposex in female dog whelks	Descriptor 8. Contaminants		Level of imposex in dog whelks		
		Criteria: concentration and effects	Concentration; pollution effects; occurrence			
		Descriptor 6. Sea floor			Favourable conservation status	Seabird 'ecological requirements'
		Criteria: condition of benthic community	Biogenic substrate; sensitive species; typical species	Benthic invertebrate diversity/composition	Habitat range, area, structure and function and future prospects	
Threatened/ declining habitats	Change in natural distribution	Descriptor 1. Biodiversity			Favourable conservation status	Seabird 'ecological requirements'
		Criteria: habitat distribution, range and condition	Habitat range, pattern, area, volume; typical species	Macroalgae tools, Infaunal quality index Benthic invertebrate diversity/composition	Habitat Range, area, structure and function and future prospects	
		Descriptor 6. Sea floor			Favourable conservation status	Specially Protected Areas
		Criteria: physical damage, condition of the benthic community	Biogenic substrate; extent of human impact		Habitat Range, area, structure and function and future prospects	
Eutrophication	Non-problem' area status with regard to eutrophication	Descriptor 5. Eutrophication				
	Winter concentrations of dissolved inorganic nitrogen and potassium	Criteria: nutrient levels, direct/indirect effects of nutrient enrichment	Nutrient conc./ratio; chlorophyll *a*; algae; floristic composition, dissolved oxygen	Environmental Quality Standards Phytoplankton state relevant to baseline		
	Max./mean phytoplankton chlorophyll *a* concentrations					
	Area-specific phytoplankton indicator species					
	Oxygen concentration					
	Eutrophication kills of benthic animals					
Plankton community	See Eutrophication EcoQOs					

Table 2.2. Linking OSPAR Ecological Quality Objectives (EcoQOs) to Marine Strategy Framework Directive (MSFD) descriptors and indicators.

Relevant GES descriptor	Relevant GES criterion	Relevant GES indicator	OSPAR EcoQO
D1 – Biodiversity	1.1 Species distribution	1.1.1 Species distributional range	Seal population trends; Seabird population trends
		1.1.2 Species distributional pattern	
		1.1.3 Area covered by species (benthic)	Threatened and declining habitats
	1.2 Population size	1.2.1 Population abundance/biomass	Seal population trends; Seabird population trends
	1.3 Population condition	1.3.1 Population demographics	Harbour porpoise by-catch
		1.3.2 Population genetic structure	
	1.4 Habitat distribution	1.4.1 Habitat distributional range	Threatened and declining habitats
		1.4.2 Habitat distributional pattern	
	1.5 Habitat extent	1.5.1 Habitat area	
		1.5.2 Habitat volume	
	1.6 Habitat condition	1.6.1 Condition of typical species/communities	
		1.6.2 Relative abundance/biomass of species	Seal population trends; Seabird population trends; SSB
		1.6.3 Physical, hydrological & chemical conditions	Eutrophication
	1.7 Ecosystem structure	1.7.1 Composition and relative proportions of ecosystem components	Large Fish Indicator (LFI)
D2 – Non-indigenous species	2.1 Abundance & state of NIS, in particular invasives	2.1.1 Trends in abundance, occurrence & distribution of NIS	
	2.2 Impact of invasives	2.2.1 Ratio: invasive to native species	
		2.2.2 Impacts of invasive species	
D3 – Fish and shellfish	3.1 Level of pressure	3.1.1 Fishing mortality	
		3.1.2 Catch/Biomass ratio	
	3.2 Reproductive capacity	3.2.1 Spawning stock biomass	SSB
		3.2.2 Biomass indices	SSB; LFI
	3.3 Population age and size distribution	3.3.1 Proportion of fish	SSB; LFI
		3.3.2 Mean maximum length	SSB; LFI
		3.3.3 95th percentile	SSB; LFI
		3.3.4 Size at first sexual maturation	SSB
D4 – Food webs	4.1 Productivity of key species/groups	4.1.1 Performance of key predators (productivity)	Seal population trends; Seabird population trends
		4.1.2 Large fish	SSB; LFI
		4.1.3 Abundance trends of selected groups/species	Seal population trends; Seabird population trends

Table 2.2 ***contd***

Relevant GES descriptor	Relevant GES criterion	Relevant GES indicator	OSPAR EcoQO
D5 – Eutrophication	5.1 Nutrient levels	5.1.1 Nutrients concentration	Eutrophication; Winter nutrients concentration in the water column
			Problem and non-problem areas (63 subareas)
		5.1.2 Nutrient ratios	
	5.2 Direct effects	5.2.1 Chlorophyll concentration	Chlorophyll-*a* concentrations
		5.2.2 Water transparency	
		5.2.3 Abundance of opportunistic macroalgae	
		5.2.4 Species shift	Phytoplankton indicator species
	5.3 Indirect effects	5.3.1 Abundance of perennial seaweeds and seagrasses	
		5.3.2 Dissolved oxygen	Oxygen concentration
D6 – Seafloor integrity	6.1 Physical damage, having regard to substrate characteristics	6.1.1 Biogenic substrate	Threatened and declining habitats
		6.1.2 Extent of seabed significantly affected for the different substrate types	
	6.2 Condition of benthic community	6.2.1 Presence of sensitive species	Eutrophication kills of benthic species
		6.2.2 Multi-metric indexes	
		6.2.3 Biomass/Number of individuals above specified length/size	
		6.2.4 Size spectrum of benthic community	
D7 – Hydrographical conditions	7.1 Spatial characterisation of alterations	7.1.1 Extent of area affected	
	7.2 Impact of alterations	7.2.1 Spatial extent of habitats affected	
		7.2.2 Changes in habitats	Threatened and declining habitats
D8 – Contaminants	8.1 Concentrations	8.1.1 Concentration of contaminants	The proportion of oiled common guillemots
			Contaminant concentrations in seabird eggs
			Plastic particles in fulmar stomachs
			Contaminant concentrations in seabird eggs
	8.2 Effects	8.2.1 Levels of pollution effects	Imposex in dog whelks. CEMP monitoring programme.
		8.2.2 Acute pollution events	Percentage of oiled seabirds
D9 – Contaminants in seafood	9.1 Levels, number and frequency	9.1.1 Actual levels of contaminants detected	
D10 – Litter	10.1 Characteristics	10.1.1 Beach litter trends	Litter on beach
		10.1.2 Water column & seafloor litter trends	Plastic particles in fulmar stomachs
		10.1.3 Micro-particle trends	
	10.2 Impacts	10.2.1 Animal ingestion	
D11 – Introduction of energy and underwater noise	11.1 Impulsive sounds	11.1.1 Proportion of days and their distribution	
	11.2 Continuous low frequency sound	11.2.1 Trends in the ambient noise level	

CEMP, Co-ordinated Environmental Monitoring Programme; GES, Good Environmental Status; LFI, Large Fish Indicator; NIS, non-indigenous species; SSB, spawning stock biomass.

3 Research Objectives and Results: Objective 2. Rapid Evaluation of Indicators

3.1 Introduction

Monitoring changes in the 'state' of a defined ecosystem component requires ecosystem indicators (Johnson, 2008). Indicators are now widely used in "*monitoring, assessing, and understanding ecosystem status, impacts of human activities, and effectiveness of management measures in achieving objectives*" (Rice and Rochet, 2005). It is important that the performance characteristics of indicators are understood, and that trends and current values relative to reference points (e.g. EcoQOs) can be interpreted correctly. Hence, in developing the MSFD indicators, advice was sought from expert groups co-ordinated by the International Council for the Exploration of the Sea (ICES) and the EU Joint Research Centre (JRC). The mission of the JRC is to provide "*customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies*" (Cardoso et al., 2010). The JRC co-ordinated expert task groups allocated to each of the 11 MSFD descriptors, with the aim of developing criteria and methodological standards. Identification and development of appropriate indicators was delegated to working groups co-ordinated by the ICES. These working groups decided to employ the Pressure–State–Response framework (Garcia and Staples, 2000) and thus focused on indicators capable of responding closely to changes in ecosystem state.

Following this development process, the MSFD now proposes specific indicators for each descriptor (EC, 2010) and Member States are obliged to implement corresponding monitoring programmes. However, implementation must integrate fundamental differences in ecological structure and function among marine regions in the EU (Heath, 2005). It is likely that some North Sea EcoQOs may not apply at all in other OSPAR regions (OSPAR Commission, 2010), while indicators for applicable EcoQOs may have to be redefined to be correctly interpreted (Rice and Rochet, 2005) and ecologically coherent. An associated challenge in the identification and implementation of national indicator series is the availability of monitoring data. This can comprise weakness in spatial coverage such that indicators cannot be robustly tracked across regions. In this context, the standard indicator set must be evaluated for each new marine region or system. Here, this study presents a rapid evaluation process for OSPAR indicators under consideration for application to Irish waters under the MSFD. In the current project, the emphasis of this process is not selection of an indicator suite, but to present (i) a generic protocol for future use, and (ii) a rapid evaluation and ranking of the selected OSPAR indicators, which will allow preliminary insight into application status for Irish waters.

The *Handbook for the Application of Ecological Quality Objectives in the North Sea* (OSPAR Commission, 2009a) describes a robust seven-step protocol for development of ecosystem indicators. The steps comprise:

1. Planning;
2. Information collection and analysis;
3. Proposal of an objective;
4. Preparation of a background document. "*The purpose of a Background document is to set out a justification for the EcoQO and its definition and an analysis of the applicability of the EcoQO*";
5. Quality assurance;
6. Acceptance of the background document and setting of the EcoQO; and
7. Follow-up adoption.

Informing these steps are defined 'Methodological Considerations'. These are criteria against which the functionality of proposed indicators can be evaluated. They are:

1. Relatively easy to understand by non-scientists and other users;
2. Sensitive to a manageable human activity;
3. Relatively tightly linked in space and time to that activity;
4. Responsive primarily to a human activity, with low responsiveness to other causes of change;
5. Easily and accurately measured, with a low error rate;
6. Measurable over a large proportion of the area over which the EcoQO element is to apply; and
7. Based on an existing body or time series of data to allow a realistic setting of objectives.

This structure represents the starting point in the current project. However, this project aims to assess a pool of mostly operational indicators that have already passed the OSPAR evaluation. An independent approach to indicator evaluation is thus valuable. In this regard, the well-regarded protocol of Rice and Rochet (2005) is introduced. Although framed in the context of fisheries, this protocol is intended to be broadly applicable across the marine management realm. The paper follows a similar structure to the guidance on developing EcoQOs (OSPAR Commission, 2009a), and provides a rigorous eight-step protocol for using objective criteria to select and evaluate a suite of ecosystem indicators. In Objective 2, the protocol of Rice and Rochet (2005) is modified to create a framework for rapid evaluation of established OSPAR indicators for use in Irish waters.

3.2 Methods

The protocol of Rice and Rochet (2005) is necessarily generic and requires some interpretation to serve the prime focus of this study – selection and evaluation of OSPAR indicators to serve EU environmental instruments applying to Irish waters. The original format is thus presented and specific adjustments highlighted:

1. *Identify user groups (stakeholders) and their needs, featuring the setting of operational objectives*. In the current case, objectives are dominated by the legislative requirements of the MSFD and other EU environmental management structures and this provides the 'overarching' context.

2. *Identify a corresponding list of candidate indicators*. Since the OSPAR process is ongoing, there are EcoQOs and associated indicators in various stages of development from aspiration to operation. Given the constraints of the current project, only the fully operational indicators are considered plus a small number, e.g. seabird populations that are well developed and seem likely to have strong application to the MSFD. Indicators selected for the current project are shown in Table 3.1.

3. *Rate the indicators against the screening criteria: concreteness, theoretical basis, public awareness, cost, measurement, historic data, sensitivity, responsiveness, and specificity*. For each criterion, each selected indicator was rated ('High', 'Medium' or 'Low'). This evaluation was supported by the sub-criteria described in Table 2 of Rice and Rochet (2005). The additional criteria 'Relevance to EU legislation' and 'Irish coverage' were assessed using reference tables developed for the project (Objective 1). An evaluation table for each indicator is provided in Appendix 1.

4. *Assign weights to screening criteria*. In this step, the criteria used in Point 3 above received a relative weighting. Importantly, this was essentially a qualitative process since using "*detailed quantitative scores would give a misleading sense of discriminating power among indicators*". Rice and Rochet (2005) formulate the process of indicator selection for a completely new management context, for example the marine region. For each such system, it is suggested that criterion weighting be undertaken in consultation with diverse stakeholder groups. In contrast, the current project feeds into a well-established process and weighting is largely predefined by the need for operational indicators that can serve pressing legislative demands. Additionally, a suite of indicators was considered that had passed the OSPAR evaluation process

Table 3.1. OSPAR indicators examined in the current study. Indicator in development is italicised.

OSPAR indicators
Commercial fish spawning stock biomass (SSB)
Maximum and mean phytoplankton chlorophyll *a* concentrations
Oxygen concentration
Winter concentrations of dissolved inorganic nitrogen and potassium
Proportion of large fish (Large Fish Indicator)
The average level of imposex in female dog whelks
Area-specific phytoplankton indicator species
Seal population trends
Seabird population trends
Annual catch of harbour porpoises
Eutrophication kills of benthic animals
The proportion of oiled common guillemots
Contaminant concentrations in seabird eggs
Plastic particles in fulmar stomachs
Sand eel populations

and is thus likely to fulfil theoretical requirements of functionality. As such, criterion weighting was a more generic process focused on the perspectives of selected Irish stakeholders. This process comprised a 1-day workshop in 2012 that took place in Galway, Ireland. Stakeholders were representatives of the Irish Environmental Protection Agency (EPA), the Marine Institute (MI), the Department of the Environment, Community and Local Government (DECLG), and the National Parks & Wildlife Service (NPWS). Criterion weightings (a measure of perceived relative importance: 'Most', 'Some', 'Least') derived by this stakeholder group are presented, along with a corresponding relative measure of consensus among contributing stakeholders ('Good', 'Moderate', 'Poor') (Table 3.2).

For each indicator, these criterion weightings were then used to assign a (relative) quantitative score to the ratings applied in Point 3 above. For instance, where the stakeholder group weighted a criterion as 'Most' important, this translates to scores of 9, 6, or 3, depending on whether the indicator was rated (in Point 3) 'High', 'Medium' or 'Low', respectively, against that criterion. Criteria weighted as of 'Some' importance carry scores of 'High' = 6, 'Medium' = 4, 'Low' = 2. Criteria weighted as 'Least' important carry scores of 'High' = 3, 'Medium' = 2, 'Low' = 1. The range in possible scores for a given indicator is Min. = 24 and Max. = 72. An example of this two-step process of rating indicators against criteria (Point 3) and then applying scores based on stakeholder weightings (Point 4) is given in Table 3.3. All other rapid indicator evaluations are shown in Appendix 1.

5. *Summarise the overall results*. Rice and Rochet (2005) discuss various aggregative or ordination methods for this process but ultimately recommend that each indicator is formulated and monitored separately according to appropriate monitoring data and, for example GES, thresholds. Rice and Rochet (2005) comment that "*candidate indicators may be strong on some criteria, but fatally flawed on others, and it is by no means certain that a few attractive properties*

Table 3.2. Stakeholder weightings (see Point 4 in Section 3.2): relative importance of evaluation criteria with degree of consensus. Weightings are used in rapid evaluations (Table 3.3, Appendix I) of the selected OSPAR indicators. Weighting (relative importance) decides the scoring range applied to indicator ratings (see Point 3 in Section 3.2): 'Least' scores 3, 2, 1; 'Some' scores 6, 4, 2; 'Most' scores 9, 6, 3.

Criterion	Consensus	Weighting (relative importance)
Concreteness	Good	Least
Theoretical basis	Moderate	Most
Public awareness	Good	Least
Cost	Good	Most
Measurement	Moderate	Some
Historic data	Moderate	Some
Sensitivity	Good	Most
Responsiveness	Moderate	Some
Specificity	Good	Some
EU relevance	Good	Most
Irish coverage	Good	Some

Table 3.3. Example of indicator rating against criteria (Point 3 in Section 3.2) and subsequent weighted scoring (Point 4 in Section 3.2, Table 3.2) for sand eel populations.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	Medium: stock assessments	2
Theoretical basis	High: well-understood mechanisms and concepts reconciled with theory	9
Public awareness	Medium: complex ecological concepts	2
Cost	Low: dedicated (expensive) seagoing science	3
Measurement	Medium: can model variance and bias but few historical data for reference	4
Historic data	Low: few data available for Ireland	2
Sensitivity	Low: environmental confounding in response	3
Responsiveness	Medium: may respond unpredictably – environment	4
Specificity	Medium: complex trophic processes plus fishing	4
EU relevance	High: D1 Biodiversity/D4 Food Webs	9
Irish coverage	Low: few or no data	2
		44

Table 3.4. OSPAR indicators ranked using a score based on rating against 12 criteria (Point 3 in Section 3.2) where each criterion has itself a relative importance weighting from stakeholder consultation (Point 4 in Section 3.2, Table 3.2). Indicator in development is italicised.

OSPAR indicators	Summed ratings score
Commercial fish spawning stock biomass (SSB)	69
Proportion of large fish (Large Fish Indicator)	64
Annual by-catch of harbour porpoises	60
Maximum/Mean phytoplankton chlorophyll *a* concentrations	59
Oxygen concentration	59
Winter concentrations of dissolved inorganic nitrogen/potassium	59
Contaminant concentrations in seabird eggs	58
The proportion of oiled common guillemots	57
The average level of imposex in female dog whelks	57
Area-specific phytoplankton indicator species	57
Seabird population trends	57
Seal population trends	56
Eutrophication kills of benthic animals	56
Plastic particles in fulmar stomachs	55
Sand eel populations	44

balance other severe shortcomings". In Objective 3, an individual summary is provided for each indicator evaluated, describing available data support and commenting on potential implementation in Irish waters.

6. *Decide how many indicators are needed.* Concerning the number of indicators selected, Rice and Rochet (2005) observe that "…*it is simultaneously desirable to have the fewest possible number of indicators to serve all uses, while having all key system components featuring in the objectives covered by trustworthy indicators*". The number of indicators required by EU nations is broadly defined by the requirements of the MSFD.

7. *Make the final selection of complementary suites of indicators*. Again, the indicator suite is constrained by the needs of the MSFD, and other EU legislative instruments. Instead, the operational indicators are ranked using the system described in Points 3–4 (Table 3.4). This allows for a general insight into the current status of the indicators in the Irish system.

8. *Clear presentation to all users of the information contained*. Presentation of the final indicator suite can follow a number of possible methodologies, typically dependent on the reporting objective. These objectives can comprise:

   (i) the current state;

   (ii) the dynamics of the state;

   (iii) value judgements about the state (good or poor); or

   (iv) value judgements about the dynamics (improving or worsening).

Due to data complexity, most reporting approaches employ some sort of aggregation of the indicator suite, but this can be confusing. Rice and Rochet (2005) concluded, *"The (best) solution must lie in developing reference profiles for interpreting each indicator individually".* In other words, a theoretically robust protocol and GES threshold must be developed for each indicator in each context. This is a key point that has not always been fully grasped in the policy arena. Applying indicators mechanistically between ecosystems will produce a series of numbers, but these are likely to have little ecological meaning and hence limited relevance to determining GES. In contrast, interpreting and tuning indicators properly is a time-consuming process, with few published examples (e.g. Shephard et al., 2011b).

In Objective 3, the authors are limited to discussing limits and thresholds currently used elsewhere and commenting on their likely value in Irish waters. They emphasise that this is not adequate for most of the indicators and a thorough analysis must be undertaken elsewhere. Notably, in several cases (e.g. Eutrophication) this has already been robustly undertaken for the Irish system. In Objective 4, a fully developed and ready-to-implement 'Proportion of large fish' (LFI) for OSPAR region III – the MSFD 'Celtic Seas' subregion – is provided. This comprises a multi-survey indicator series based on best available supporting data, with management recommendations. The indicator has been developed through ICES in collaboration with the relevant national fisheries experts at EU level.

3.3 Conclusions

The OSPAR indicators have been established through a rigorous scientific process and typically show considerable theoretical strength. However, they clearly have varying applicability to the Irish situation, with 'Cost' and 'EU relevance' (to multiple environmental policy drivers) being considered 'overarching' considerations. Data availability is also a critical issue – the most extensive data (spatially and temporally) are from fisheries surveys. However, this should not detract from the less comprehensive data that may be all that are available to support indicators for other ecosystem components. The direct application of OSPAR indicators to the Irish MSFD process is likely to be appropriate in a very few cases. Most indicators will require considerable interpretation and tuning if they are to become true 'ecosystem state indicators' rather than just arbitrary numerical time series. In Objective 2, a selection of candidate indicators (Table 3.1) was evaluated using a protocol that should have ongoing application. This protocol used objective criteria (Table 3.2) to provide a quick oversight of the strengths and weaknesses of selected OSPAR indicators (Table 3.3, Appendix 1). Considering current monitoring and data availability in Irish waters, indicators were also approximately ranked for relative readiness for implementation in Ireland (Table 3.4).

The authors emphasise again that **such quantitative results in indicator ranking should not be considered precise or conclusive**. Note the comment of Rice and Rochet (2005) that "*candidate indicators may be strong on some criteria, but fatally flawed on others, and it is by no means certain that a few attractive properties balance other severe shortcomings*". This explains, for example, the ranking of the 'Oiled guillemots' indicator above 'Seal population trends' even though there is an excellent seal monitoring programme in place and no data for the guillemots! The discrepancy is in indicator characteristics; the oiled guillemot indicator is highly concrete, sensitive, theoretically grounded and specific.

4 Research Objectives and Results: Objective 3. Indicator Assessments for Irish Waters

4.1 Introduction

In Objective 3, each indicator is more fully investigated. Existing monitoring programmes are described and some specific recommendations made for implementation. This process takes the form of a review, and is certainly not the technical exercise in analysis and threshold setting that will be required for the majority of indicators before they can be applied in Irish waters. The indicators considered are the same as in Objective 2 (see Table 3.1), but all five 'eutrophication/water quality' indicators are considered under 4.7 Eutrophication:

- 4.2 Seal population trends
- 4.3 Seabird population trends
- 4.4 Imposex in whelks
- 4.5 Plastic particles in fulmars
- 4.6 Porpoise by-catch
- 4.7 Eutrophication (phytoplankton indicator species, chlorophyll *a*, oxygen concentration, winter nutrients and benthic kills)
- 4.8 Oiled guillemots
- 4.9 Contaminant concentrations in seabird eggs
- 4.10 Sand eel populations
- 4.11 Commercial fish stocks (SSB)
- 4.12 Proportion of large fish

In this evaluation, EcoQOs 4.2–4.7 are defined (with the current OSPAR thresholds) and a case study implementation by a selected OSPAR state is described. For each indicator, the Irish situation is first described. An international case study is then presented to provide insight into progress made elsewhere and to provide broad information on implementation structure, including data collection and analysis and management response to changes in state. Finally, comparison is made between the Irish situation and the case study programme. Where appropriate, brief recommendations are made concerning implementation in Irish waters. For EcoQOs 4.8–4.10 (not yet initiated in Ireland), a summary is provided and the current OSPAR threshold is defined for reference. As discussed throughout this report, full implementation in the Irish marine system will often demand locally 'tuned' indicators and corresponding monitoring programmes.

4.2 Seal Population Trends

EcoQO thresholds

The current EcoQO for North Sea harbour seal population size is: "*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*". For grey seals, the EcoQO is similar: "*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 subunits of the North Sea*" (OSPAR Commission, 2009a).

Importantly, the EcoQO handbook (OSPAR Commission, 2009a) acknowledges that both seal EcoQOs are designed as indicators "*to alert that all is not necessarily well with an important part of the North Sea's mammal fauna. If the EcoQO is not met, then it is unlikely that immediate management action would be taken, instead it is intended that this event should trigger research into the causes of this change. If the cause is found to be related to a human activity, then suitable management measures might then be taken. The EcoQO trigger level is to an extent arbitrary – it is based on inspection of past seal populations, and not on modelling of populations. This was not considered* *necessary, as the EcoQO is an alerting EcoQO rather than one based on a strict target for the seal population. Such modelling might be necessary should the EcoQO be triggered*".

Current status of monitoring in Ireland

Ireland's current minimum population estimate for harbour seal (*Phoca vitulina*) numbers is 2,905 seals, based on a robust baseline assessment carried out in August 2003 (Cronin et al., 2004). For grey seals (*Halichoerus grypus*), a national breeding population assessment took place in 2005–2006 (O'Cadhla et al., 2007), with an ancillary national grey seal moult population survey being undertaken in 2007 (O'Cadhla and Strong, 2007). An estimated 1,574 grey seal pups were born in the Republic of Ireland during the 2005 breeding season. While the figure is an approximation it is considered a reliable and repeatable quantitative descriptor for future population assessments. The corresponding population estimate for the Republic of Ireland in 2005 was 5,509–7,083 grey seals of all ages. This represents an appropriate national baseline figure for the species. These assessments provide a potential indicator reference point but not evidence of a 'pristine' state that may describe GES. There are currently 10 Special Areas of Conservation (SACs) in Ireland for grey seals and 11 for harbour seals.

Grey seals

O'Cadhla and Strong (2007) showed that (i) almost 84% of pup production in Ireland occurred within seven key breeding sites, and (ii) it was possible to survey two key regional breeding areas in 1-day's flying if co-ordinated properly using the right aircraft. The proposed monitoring programme thus recommended surveying one of three breeding areas each year by aerial methods, comprising a series of five to six repeat flights in one region per year. With this survey design, the principal regions for breeding can be covered twice within the current 6-year reporting cycle, while breeding colonies off the east and south-east coasts can be assessed at least once prior to 2013 and twice per 6-year cycle thereafter. Boat-based surveys would also be carried out under the grey seal monitoring programme at key 'index' pupping sites within Roaringwater Bay SAC. Based on figures obtained in 2005, the combined data set resulting from the annual monitoring programme (regional aerial surveys + Roaringwater Bay surveys) would be expected to yield 80–86% of the national grey seal pup production and associated robust estimates of population size.

Harbour seals

Following a formal review of monitoring options, an ongoing harbour seal monitoring programme was proposed and established by the NPWS. This programme takes place during the moulting season (August–September) and comprises:

1. A national co-ordinated survey occurring within the 6-year Habitats Directive Article 17 reporting cycle, in order to produce an updated minimum estimate of the population size.

2. Annual monitoring on the ground by NPWS regional staff at key regional haul-out sites in order to deliver recurrent data on approximately 40–50% of the national population. Under the annual harbour seal monitoring programme developed and tested in 2009, it was intended that:

   (i) Each selected regional site would be surveyed on three separate sample dates during the moult season (August–September);

   (ii) Where possible, a series of hourly counts of seals at each site would occur within 2 h of low water (LW) (i.e. LW ± 2 h), to include a count at the time of LW; and

   (iii) Counts of harbour seals at all haul-out sites would occur in the afternoon where possible.

The programme was initiated with a pilot study in 2009 (NPWS, 2010). The NPWS (2010) report records that the "*pilot study in 2009 demonstrated the feasibility of carrying out co-ordinated monitoring counts at regional haul-out sites and data collection methods were tested satisfactorily in the field by the various participants involved*". The objective was to commence an updated national population assessment that would deliver an appropriate estimate that could be compared with the results of the 2003 baseline survey. In 2010, sites from the 2003 harbour seal survey were resampled (NPWS, 2011). In August 2011, a repeat national aerial survey using thermal imaging commenced in Co. Donegal and covered the entire coastline to Galway Bay.

Simultaneous aerial and ground counts were performed at seven sites of variable habitat type that are regularly monitored as part of the harbour seal pilot project. This effort and the two-way 'truthing' of aerial and ground-count data were completed in 2012.

Case study monitoring programme (UK)

Two species of seal live and breed in UK waters: grey seals and harbour seals. Grey seal pup production monitoring started in the late 1950s and early 1960s and numbers have increased consistently since. In recent years, there has been a significant reduction in the rate of increase. Boat surveys of harbour seals in Scotland in the 1970s showed numbers to be considerably lower than in recent aerial surveys, which started in the late 1980s, but it is not possible to distinguish the apparent change in numbers from the effects of more efficient counting methods. Both grey and harbour seals are listed in Annex II of the EU Habitats Directive, requiring specific areas to be designated for their protection. To date, 16 SACs have been designated specifically for seals. Seals are features of qualifying interest in seven additional SACs.

- **Grey seals**
  Each year, the Sea Mammal Research Unit (SMRU) conducts aerial surveys of the major grey seal breeding colonies in Britain to determine the number of pups born (pup production) (SCOS, 2011). The annually surveyed sites account for approximately 90% of all grey seal pups born throughout Britain. The remaining sites, producing around 10% of the pups, are surveyed less frequently. The total number of seals associated with the regularly surveyed sites is estimated by applying a population model to the estimates of pup production. Estimates of the total number of seals at less frequently surveyed breeding colonies are then added to give an estimate of the total British grey seal population. UK grey seal pup production in 2010 was estimated to be 50,174. Estimates for the Inner and Outer Hebrides were effectively the same as the 2008 estimates (changes of 0% and 0.5% per annum, respectively). The Orkney estimate in 2010 was 6.1% higher than in 2009 while the North Sea colonies increased by 8.8% between 2009 and 2010.

  A Bayesian state–space model of pup survival is used to estimate total population size with confidence intervals (CIs). Total population associated with poorly sampled sites was estimated using the average ratio of pup production to population size for all annually monitored sites. The estimated total population size for UK grey seals in 2010 was 111,300 (95% CI 90,100–137,700). Recently, a simpler Bayesian method has been trialled. This approach uses generalised additive models (GAMs) to smooth a series of pup production estimates followed by matrix models to scale results up to total population. This approach requires fewer assumptions than the current state–space models while producing similar population estimates and credibility intervals.

- **Harbour seals**
  Each year the SMRU carries out aerial surveys of harbour seals during the moult in August (SCOS, 2011). It was considered to be impractical to survey the whole coastline every year and the SMRU aimed to survey the whole coastline across 5 consecutive years. However, in response to the observed declines around the UK the survey effort has been increased. The majority of the English and Scottish east coast populations are now surveyed annually. Combining the most recent counts (2007–2010) at all sites, approximately 25,950 harbour seals were counted in the UK: 79% in Scotland, 16% in England, and 5% in Northern Ireland. For reference, including the 2,900 seals counted in the Republic of Ireland produces a total count of 28,850 harbour seals for Britain and Ireland. Overall population size is derived directly from observed counts. There have been general declines in counts of harbour seals in several regions around Scotland. These widespread declines caused concern and have resulted in the implementation of area-specific Conservation Orders by the Scottish Government, providing harbour seals with year-round protection. A targeted research programme has been

Table 4.1. Comparing Irish and UK seal monitoring programmes.

	Method	Area sampled	Period	Analysis
Harbour seals				
UK monitoring	Aerial surveys	Entire coast	5-year cycle	Observed counts
Irish monitoring	Ground and boat surveys	40–50% of haul-out sites	Annual	Observed counts
	Aerial survey	National	Every 6 years	Observed counts
Grey seals				
UK monitoring	Aerial surveys	Major colonies (90% of pups)	Annual	SMRU Bayesian state–space model
Irish monitoring	Aerial surveys	Major colonies (84% of pups)	3 years	SMRU Bayesian state–space model

SMRU, Sea Mammal Research Unit.

established, including increased monitoring to confirm the magnitude and geographical extent of the declines and comparative studies of pup survival in areas of contrasting population dynamics.

Work is currently under way to develop recommendations for spatial management units and to connect these to population structure (SCOS, 2011). Defining optimal management areas for UK seals requires an arrangement of relatively isolated groups of colonies such that management actions taken in one unit should have minimal impact on the others.

Recommendations

The 'seal population trends' EcoQOs are relevant to the 'Predator performance' Criterion of Descriptor 4 Food Webs, as well as Descriptor 1 Biodiversity. The UK operates an exemplary monitoring programme for seal populations and thus provides a benchmark for other EU states implementing national MSFD programmes. A direct comparison of UK and Irish monitoring programmes is given in Table 4.1.

The Irish monitoring programme for harbour seals also appears to be state of the art and well suited to reporting under the MSFD. Monitoring of grey seals is slightly less established but a robust programme has been proposed and is based on a similar protocol to that used in the UK, and based on the same analytical model. Both monitoring programmes were developed from peer-reviewed scientific studies.

Baseline data for Irish populations of both harbour seals (2003) and grey seals (2005) pertain to a period long after probable marked anthropogenic impacts on seal populations and hence will not provide a useful indication of GES. However, the current EcoQO for the North Sea is trend based – requiring only that populations (represented by a 5-year running mean) don't decline by more than 10%. Hence, ongoing population estimates may have immediate value as indicator metrics for the MSFD.

4.3 Seabird Population Trends

EcoQO thresholds

ICES (2008) advised the development of a seabird EcoQO, based on trends in abundance of breeding seabirds. The draft EcoQO states, "*Changes in breeding seabird abundance should be within target levels for 75% of the species monitored in any of the OSPAR regions or their sub-divisions*". Target levels used within this EcoQO are based on the magnitude of change in population size compared with preset reference levels. Target levels were set to trigger a management action about one-third of the time. This occurs when the indicator is beyond approximately one standard deviation of the mean. The upper target levels for each monitored species are defined as 130% of the baseline population size, and the lower target levels were determined as 80% of the baseline for species that lay 1 egg and 70% for species that lay more than 1 egg.

ICES (2012) recognised that "*breeding abundance represents only one aspect of seabird community health, and only partially reflects the state of the populations when they are not breeding. Insufficient data exist to estimate trends in non-breeding abundance. Data on breeding abundance have been widely collected and trends can be estimated relatively easily. Breeding abundance is a good indicator of long-term changes in seabird community structures where density-dependent effects may reduce the usability of other population parameters. However, seabirds are generally long-lived and reproduce at a relatively old age. Thus, changes in their breeding numbers are a poorer indicator of short-term environmental change than are other breeding parameters (e.g., breeding success)*".

According to the latest draft of the *OSPAR MSFD Advice Manual and Background Document on Biodiversity – Approaches to determining good environmental status, setting of environmental targets and selecting indicators for Marine Strategy Framework Directive descriptors 1, 2, 4 and 6 (Version 3.2, 5 March 2012)*[2], prepared by ICG-COBAM, recommends the EcoQO on seabird population trends as a potential common indicator to be applied by OSPAR Contracting Parties for Descriptor 1 (biological diversity) with regards to the implementation of Articles 8–10 of the MSFD.

Current status of monitoring in Ireland (Celtic Seas)

Data for OSPAR Region III were collected as part of the UK and Ireland's Seabird Monitoring Programme (SMP). The SMP is co-ordinated by the UK Government's advisor on nature conservation (Joint Nature Conservation Committee, JNCC) in partnership with other government agencies and non-governmental organisations. SMP data collection is conducted by professional and volunteer observers using standardised methods (Walsh et al., 1995). Data are available at the JNCC website (http://www.jncc.gov.uk/smp). The time series of most species extend from 1986 to 2006, but for the five species of tern, data have been regularly collected since 1969 – largely by the Royal Society for the Protection of Birds (RSPB) and BirdWatch Ireland. Ireland currently contributes to the process through voluntary programmes.

The work of the Working Group on Seabird Ecology (WGSE) (ICES, 2012) extended an earlier workshop on the seabird ecological quality indicator (ICES, 2008). In addition to the eight species mentioned in the 2008 report (northern fulmar, European shag, herring gull, great black-backed gull, black-legged kittiwake, Sandwich tern, common guillemot, and razorbill) (ICES, 2008), ICES has included data from four additional species in this update (i.e. Arctic skua, great cormorant, little tern, and roseate tern). In updating the EcoQO indicator (starting date 1986), ICES (2012) added data from 2007 to 2010, including plot counts as well as whole colony counts. Most colonies in OSPAR Region III were not surveyed in each year of the time series, so (statistical) imputation techniques were used to estimate the missing counts. The imputation methods used in this update comprise a sophisticated modified chain method developed by Thomas (1993) that was used to estimate trends.

Reference levels were set using population size estimates from Ireland and from western Britain that were obtained during complete censuses. Most species of seabird breeding in Britain and Ireland have been censused three times: during Operation Seafarer in 1969–1970 (Cramp et al., 1974), the Seabird Colony Register (SCR) census in 1985–1988 (Lloyd et al., 1991) and Seabird 2000 in 1998–2002 (Mitchell et al., 2004). Each species-specific reference level was set by following the recommendations of the ICES Workshop on Seabird Ecological Quality Indicator (WKSEQUIN) (ICES, 2008): "*They should ideally be set at a level previously observed, preferably prior to major population change, particularly resulting from anthropogenic pressures*".

For Region III, ICES (2012) estimated that the proposed EcoQO indicator was not achieved in 1986, 1989–1992, and in consecutive years during 2002–2010. The number of species not achieving targets during 2002–2010 increased from four to nine in 2008,

2. http://www.ospar.org/documents/dbase/publications/p00581_advice%20document%20d1_d2_d4_d6_biodiversity.pdf

2009, and 2010 (i.e. northern fulmar, European shag, Arctic skua, herring gull, great black-backed gull, black-legged kittiwake, roseate tern, razorbill, and common guillemot). In the last 2 years, the abundance of six species (i.e. northern fulmar, European shag, Arctic skua, herring gull, black-legged kittiwake, and roseate tern) has been below their respective lower targets, while three species exceeded the upper targets (great cormorant, little tern, and Sandwich tern). If these three species had not exceeded their targets, the draft EcoQO would still not have been achieved in consecutive years between 2005 and 2010 because the abundance of four or more species fell below lower target levels (ICES, 2012).

Case study monitoring programme (North Sea)

In response to a special request from OSPAR, the ICES WGSE provided a comprehensive advice document (ICES, 2012) on the seabird population trends EcoQO. ICES (2012) indicates that at present there is sufficient collated information to analyse the proposed EcoQO indicator for OSPAR regions II (North Sea) and III (Celtic Seas). The report by ICES (2012) on the North Sea programme will be summarised here. In 2011, ICES conducted trend assessments for 16 of 20 seabird species with breeding ranges in OSPAR Region II for the 20-year period 1991–2010. These species included: great cormorant, European shag, Arctic skua, Mediterranean gull, black-headed gull, common gull, lesser black-backed gull, herring gull, great black-backed gull, black-legged kittiwake, Sandwich tern, common tern, Arctic tern, little tern, common guillemot, and razorbill. They did not include: northern fulmar, northern gannet, great skua, and Atlantic puffin due to a lack of representative population data throughout OSPAR Region II.

Population trends were analysed using TRIM version 3.53 (Statistics Netherlands). Annual trend indices were calculated for each of the 16 species in each of the 20 years. The intermediate year 2000 was set arbitrarily as the baseline index 100. ICES noted that the proposed EcoQO was not achieved in 1991–1993, 2004, 2006 and 2008–2010. The number of species not reaching the proposed target levels increased recently from three (2007) to eight (2010), the lowest value seen within the 20-year period. Of the eight species that did not reach their respective target levels, three were above their upper targets (great cormorant, Mediterranean gull, and lesser black-backed gull) and five were below their lower targets (Arctic skua, common gull, great black-backed gull, black-legged kittiwake, and razorbill). The rest are well within or just at the target levels.

ICES (2012) identified some weaknesses in the TRIM analytical method and strongly recommended that future analysis should use complementary or alternative approaches such as the Thomas method wherein confidence intervals are estimated empirically by bootstrapping. Notably, the Thomas method is already used in the Region III (Celtic Seas) analysis. The advantage of applying the same statistical protocol across all OSPAR regions was also highlighted.

Recommendations

Data collection and analytical protocols used in the Celtic Seas (OSPAR Region III). region are considered exemplary and compare favourably to the UK case study (Table 4.2). Historical time series and suggested indicator reference points are already available. Hence, Ireland is strongly placed to implement MSFD seabird population size indicators.

Table 4.2. Comparing Irish and UK seabird population trend monitoring programmes.

	Method	Data collection	Period	Analysis
North Sea monitoring	Standardised visual counts	JNCC Seabird Monitoring Programme	Opportunistic	Annual trend indices using TRIM (Statistics Netherlands)
Celtic Seas monitoring	Standardised visual counts	JNCC Seabird Monitoring Programme	Opportunistic	Bayesian time series model with seabird ‘wizard’.

JNCC, Joint Nature Conservation Committee.

From a broader conservation perspective, ICES (2012) noted that the low abundance in Region III of roseate tern, Arctic skua and herring gull has already been highlighted by the UK and has been listed in the UK Biodiversity Action Plan and in the Red List of Birds of Conservation Concern in the UK. ICES (2012) also advised that further research be made on the decline in shag numbers and that monitoring and investigation of the recent decreases in kittiwake and fulmar numbers in OSPAR Region III be continued.

4.4 Average Level of Imposex in Female Dog Whelks

EcoQO thresholds

The average level of imposex in a sample of not less than 10 female dog whelks (*Nucella lapillus*) should be consistent with exposure to tributyl tin (TBT) concentrations below the environmental assessment criterion (EAC) for TBT (<2.0 individuals), as measured by the Vas Deferens Sequence Index (VDSI). 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 of <2.0, <0.3 and <0.3, respectively.

The justification for this EcoQO is that the female dog whelk (*Nucella lapillus*) is particularly sensitive to TBT, which has been extensively used as an anti-fouling treatment on ships. TBT is linked to the incidence of imposex in dog whelk. Imposex is the condition where female individuals develop non-functional male characteristics, eventually leading to sterilisation and a serious population decline. This phenomenon is fully developed at ambient TBT concentrations of 1–2 ng/l, and females are fully sterilised at concentrations above 5 ng/l (OSPAR Commission, 2008c).

Current status of monitoring in Ireland

Under the Water Framework Directive (WFD) framework, and aware of relevance to OSPAR and MSFD contexts, the Marine Institute and University College Dublin (UCD) have reported comprehensively on this indicator and are conducting ongoing data collection and analysis. The most recent published report (McGovern et al., 2011) involved:

"Review, selection and collation of MI datasets and external data/Review and collation of appropriate tools/Assessment process, consisting of:

(i) Data extraction, binning according to water body, and normalisation where appropriate;

(ii) Classification according to good status and less than good status for parameter matrix combinations, according to WFD water bodies;

(iii) An assessment of the confidence of this assessment;

(iv) An assessment of temporal trends for various water quality parameters; and

(v) *An expert commentary on the above and considering,* inter alia*, data available for substances where assessment criteria could not be identified and other information (such as biological effects data) that sheds light on the pollution status of water bodies*."

The majority of data presented by McGovern et al. (2011), i.e. for 1999 and 2005, derived from the monitoring process set by the OSPAR programme in 1987 to visit certain marine regions every 6 years to monitor TBT contamination (OSPAR recommends 2-year coastal sampling to evaluate recent status of specific areas; however, such a short time interval may become problematic in that whelks live for periods that exceed 2 years and in heavily impacted localities insufficient numbers of dog whelks may remain for analysis at this frequency of sampling). Data from 1999 and 2005 are supplemented by smaller research studies completed in 2007 and 2009.

The EcoQO set for TBT-specific effects for the North Sea and as applied to the wider OSPAR area for the 2010 Quality Status Report (QSR) assessment has been used to assess the imposex status evident in *Nucella lapillus* from Irish waters. The EcoQO was deemed to be met where the VDSI in *Nucella* was not found to exceed 2.0. Following the ban on TBT in structures and small vessels (<25 m) in 1987, the remaining centres of contamination occur in port regions. With International Maritime Organisation (IMO) action and EC legislation phasing out TBT, levels of organotin are likely to decline further in Irish coastal areas. The expected consequence is a further reduction in imposex in dog whelks. TBT in the environment is monitored directly in water and sediment as part of the Bantry Bay terminal monitoring programme and all seawater and sediment measurements were below the LoQ (limit of quantification) for the period assessed

The Marine Institute and UCD are currently compiling a further report providing data from an Irish survey completed in 2011. This new report (anticipated for 2013) will interpret dog whelk imposex data in Irish waters in the context of trends since 1987 (identified from a 6-year monitoring cycle) and make recommendations for an ongoing survey protocol servicing the WFD and MSFD. There will also be discussion and interpretation of long-term trends in the indicator. It is currently understood that a general decline in the level of imposex in dog whelks has been observed (Evin McGovern, 2012, Marine Institute, personal communication).

Case study monitoring programme (North Sea)

As with many EcoQOs, monitoring programmes and biological thresholds for imposex in dog whelks were developed in the North Sea. Monitoring in relation to the EcoQO on imposex in dog whelks and other gastropods is now a mandatory commitment of Contracting Parties under the Coordinated Environmental Monitoring Programme (CEMP), with eight nations submitting regular data. The arrangements for monitoring under the CEMP seek to ensure that monitoring and reporting is fully harmonised and the tools needed for harmonising monitoring are already in place (monitoring guidelines, quality assurance procedures and assessment tools).

A recent assessment of environmental status in relation to the North Sea imposex EcoQO was prepared for the 2010 OSPAR QSR. OSPAR Contracting Parties submitted data to ICES. Only time series with at least 4 years of data were used for the trend assessment and the fitted value for the last year of monitoring was used to assign an assessment class according to the Joint Assessment and Monitoring Programme (JAMP) TBT Assessment Classes (OSPAR agreement 2004–2015). This assessment (OSPAR Commission, 2010) showed that, with the exception of a limited number of locations, the EcoQO has not been met in the North Sea area, particularly in the vicinity of major ports, shipping lanes and shipyards (this is to be reviewed after a more elaborate assessment with more data). A significant trend was found at 28 stations, with 24 stations having a general downward trend indicating that the situation in general is improving. It is considered that there are still insufficient data to fully assess imposex in the North Sea. However, a full monitoring and assessment protocol is in place and trends will become apparent with additional years.

Recommendations

A key indicator of MSFD Descriptor 8 is ‘effects of contaminants’ (i.e. levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored). Imposex in dog whelk (*Nucella lapillus*) is a TBT-specific effect that can be measured and clearly linked to the cause, while direct measurement of TBT in water is technically challenging and only provides point estimates. Motivated primarily by the demands of the WFD, an Irish monitoring and reporting programme is well established and a thorough review of new and existing data will be available in 2013. The Irish programme already seems to be well integrated into the broader OSPAR process and oriented towards the MSFD.

4.5 Plastic Particles in Fulmars

Background

Marine litter, in which plastic has the dominant role, causes huge economic damage through costs for coastal clean-ups, reduced tourism, disabled ship propellers and engines, tainted fish by-catch and damage to coastal agriculture. Furthermore, marine litter causes ecological damage to a wide range of marine organisms. The northern fulmar (*Fulmarus glacialis*) is a particularly convenient species to measure plastic pollution by stomach content analysis. Like the whole group of ‘tube-nosed’ seabirds (the albatrosses and petrels), it frequently ingests plastic litter. The fulmar is particularly abundant in the North Sea, forages exclusively at sea (unlike, for example, gulls), retains slowly digesting materials in the stomach, and thereby ’integrates’ litter pollution levels encountered at sea. A pilot study concluded that stomach content analysis of beached fulmars offers a reliable monitoring tool for (changes in) the abundance of marine litter off the Dutch coast. The optimal index value is the average mass of litter in an annual sample of 40 individual northern fulmars.

EcoQO thresholds

*There should be less than 10% of northern fulmars (*Fulmarus glacialis*) having more than 0.1 g plastic particles in the stomach in samples of 50–100 beach-washed fulmars from each of four to five areas of the North Sea over a period of at least 5 years.*

Current status of monitoring in Ireland

There is currently no monitoring of plastic in stomachs of fulmars beached in Ireland.

Case study monitoring programme (Netherlands)

A monitoring programme using litter abundance in stomachs of North Sea northern fulmars has been in effect in the Netherlands since 1982 (Franeker, 2010). In 2008, the Dutch Institute for Marine Resources & Ecosystem Studies (IMARES) continued the collection of beached fulmars with the assistance of the Dutch Seabird Group through its Working Group on Beached Bird Surveys. Also, several coastal bird rehabilitation centres support the collection programme. Since the start of the Save the North Sea project in 2002, IMARES has co-ordinated similar sampling projects at a range of locations in all North Sea nations. Organisations involved differ widely, from volunteer bird groups to governmental beach cleaning projects.

Bird corpses are stored frozen until analysis. Standardised dissection methods for fulmar corpses have been published by IMARES in a dedicated manual. All plastic is removed from each stomach, broadly identified and weighed. Tests for trends over time are conducted using linear regressions fitting log-transformed plastic mass values for individual birds on the year of collection. Logarithmic transformation is needed because the original data are strongly skewed and need to be normalised for the statistical procedures. Tests for ‘long-term’ trends use the full data set; ‘recent’ trends only use the past 10 years of data (Franeker, 2010). Current data suggest a pattern of reduced plastic loads in fulmar stomachs after peak levels in the 1990s. Mean values over the most recent 5 years (2004–2008; 290 fulmars) indicate that 93% of birds had plastic in the stomach, with an average number of 27 pieces, and average mass of 0.30 g plastic. The general trend is for a reduced load of industrial plastics but increasing presence of discarded ‘user’ plastics. Amounts of ingested plastic have been more or less stable over the past 5 years (Franeker, 2010).

Recommendations

IMARES has indicated throughout the development of the northern fulmar EcoQO that there is potential to extend the successful Dutch monitoring programme to other OSPAR members. At present, only the UK participates in this system. This does not comprise a scientific rationale or management recommendation, but indicates that there is a possible route here if appropriate: email discussion (2011) between IMARES and Mary Meacle (DECLG) suggests that for a contribution of €10,000 per year (excluding VAT), IMARES would conduct analysis on Irish fulmars on the following basis:

- A multi-year contract (minimum 3 years);
- To analyse up to approximately 50 fulmars per year (dissections and stomachs);
- Fulmar corpses are collected in beach surveys, but fisheries by-catch/other mortalities can also be used;
- IMARES is not responsible for the collection system and transport of birds or stomachs to the lab in the Netherlands. A contribution may be made towards attendance of a national representative at the annual fulmar workshop. This individual would bring the collected material and participate in training and discussions;
- Results would be provided in annual national reports (potentially incorporated in international reviews);
- Timing in reports would follow the Dutch time schedule, which has a delay of approximately 1 year for the draft report and about 1.5 years for the final report; and

- In this multi-year approach, the annual cost for Ireland could be similar to that of the UK, (currently £13,000 per annum, excluding VAT); fewer birds/stomachs would not make a great reduction in price but additional birds would be relatively cheaper per bird.

IMARES observes that in most countries, volunteer groups collect beached fulmars either directly or as part of, for example, beach clean-ups (no data on the number of beached fulmars currently exist for Ireland). Often their only 'reward' is reimbursement of, for example, a project freezer, cost-free attendance at the IMARES annual workshop and their name on publications.

4.6 Porpoise By-Catch

Background

By-catch is the unintended mortality of non-target species as a result of commercial fishing. Harbour porpoises (*Phocoena phocoena*) are especially susceptible to by-catch in static nets placed near the seabed, while dolphins are susceptible to by-catch in trawl and static net fisheries. It has not yet been possible to assess whether or not the EcoQO has been met, because monitoring of the by-catch of harbour porpoises in the North Sea has not been fully implemented. In order to assess any by-catch as a percentage in this EcoQO, a best estimate of harbour porpoise numbers is needed. At present, population estimates are considered unreliable.

Those Contracting Parties that are Member States of the European Union are required under the Habitats Directive (92/43/EC) to introduce a system to monitor the incidental capture and killing of all cetaceans. In light of the results of this monitoring, Member States are required to undertake further research or conservation measures to ensure that the incidental capture does not have a significant negative impact on the species concerned. Member States also have a duty to ensure that any measures taken under the Directive are designed to maintain or restore, at a favourable conservation status, all cetaceans. In addition, certain states (but not currently Ireland) have obligations under the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS). Besides requirements to monitor abundance and distribution of small cetacean species, the ASCOBANS conservation and management plan requires that:

> "*Each party shall endeavour to establish an efficient system for reporting and retrieving by-catches and stranded specimens and to carry out […] full autopsies in order to collect tissues for further studies and to reveal possible causes of death and to document food composition. The information collected shall be made available in an international database.*"

In addition, the conservation and management plan also states that:

> "*Information shall be provided to the general public in order to ensure support for the aims of the agreement in general and to facilitate the reporting of sightings and strandings in particular; and to fishermen in order to facilitate and promote the reporting of by-catches and the delivery of dead specimens to the extent required for research under the agreement.*"

EcoQO thresholds

Annual by-catch levels of harbour porpoise should be reduced to levels below 1.7% of the best population estimate.

Current status of monitoring in Ireland

Under the auspices of the ICES, the Irish Sea Fisheries Board (An Bord Iascaigh Mhara, BIM) currently operates a by-catch monitoring scheme and submits an annual cetacean by-catch report to the EC addressing the implementation of Council Regulation (EC) No. 812/2004. The sampling methodology is similar to that used in the UK (see above). Key data for inclusion in these reports are:

- Estimated number of harbour porpoises killed per fishery;
- The geographic extent of the fishery (e.g. by ICES subarea and rectangle);
- The number of observed porpoises by-caught;
- The proportion of the fishery observed;

- Any indication of temporal (e.g. monthly or diurnal) variance in by-catch; and
- The use (and, if known, the effectiveness) of any mitigation tool (e.g. pingers) in the fishery.

Historical data

Two focused studies have been conducted: 1992–1994 and 2005–2007. The earlier study reported an observed by-catch rate of 7.02 porpoises per 10,000 km/h (gear length × period of immersion) (Tregenza et al., 1997). In 2006, two vessels participated in a trial with a total of 11 trips carried out between 30 June 2006 and 26 April 2007. A total of 107 hauls equating to 406 km gear were used in the estimation of porpoise by-catch rates. The average soak time was approximately 18.5 h for both sets of hauls. A total of seven porpoises were caught in the 107 validated control gill-net hauls. A total observed porpoise by-catch rate of 7.94 animals per 10,000 km/h was obtained for Irish vessels operating in the Celtic Seas between 2005 and 2007 (Cosgrove and Browne, 2007). This rate was slightly higher than described by Tregenza et al. (1997).

BIM used fishing effort data to extrapolate from observed porpoise by-catch rates to an overall annual estimate of porpoise by-catch. The Celtic Seas region is the most important area for Irish gill-net fisheries, with 73% (1,723 days) of national fishing effort carried out there in 2006. This figure represents almost a 10-fold decrease in fishing effort compared with 1993, when the impact of the fishery on the harbour porpoise population was a serious source of concern (Tregenza et al., 1997). Based on these days fished, an estimated 355 porpoises (±247, CV[3] 34%) were taken as by-catch by Irish gill-net vessels in the Celtic Seas in 2006. This value is 4.2 times lower than an estimated by-catch of 1,497 (±931, CV 32%) porpoises in the Celtic Seas in 1993 (Tregenza et al., 1997). The 2006 Irish by-catch estimate equates to 0.44% of the total estimated abundance of harbour porpoises in the Celtic Seas (SCANS-II, 2008) and is well below current thresholds of acceptable by-catch.

In addition to data from onboard observers, a report on the University College Cork stranding programme stated that 7% of stranded porpoises were diagnosed as having died after entanglement in fishing gear. If the proportion of animals diagnosed as by-catch is calculated based on ‘fresh’ individuals only, this increases to 11% and is consistent with findings from elsewhere in Europe (Rogan, 2008).

3. CV, coefficient of variation.

Recent data

An independent observer programme dedicated to provisions under Regulation 812/2004 was initiated during 2010 (by BIM). The objectives of the programme were to carry out observer coverage on Irish vessels in the following fisheries:

- 10% coverage of large pelagic and pair trawl fisheries in 2010 covering more than three different vessels.
- 10% coverage of small pelagic trawl fisheries in vessels >15 m covering more than three vessels during the pilot period specified in Regulation 812/2004.
- 5% coverage of demersal static net fisheries covering more than 33 vessels over 15 m and one vessel under 15 m in subareas VIa, VIIa and VIIb.

There were 111 days of observer coverage from August 2010 to March 2011 with zero cetacean by-catch reported. Most coverage was on pelagic vessels, although 5 days were observed on demersal gill nets in 2010 (Cosgrove, 2011). However, as part of a study on seal depredation, substantial observer coverage was carried out in this métier (fishing gear/technique) in 2011 and 2012. Ireland continued with a dedicated observer programme in pelagic trawl fisheries in 2011/2012 as legally required under Regulation 812/2004. Very low levels of cetacean by-catch suggest that continued monitoring conducted as part of other ongoing programmes under the EU Fisheries Data Collection Framework (DCF) would, however, provide sufficient levels of monitoring (Cosgrove, 2011).

Case study monitoring programme (UK)

- **By-catch**
  The two main species affected by fishing in UK waters are the harbour porpoise and the short-

beaked common dolphin (Pinn, 2010). The UK operates a collaborative programme designed to fulfil monitoring obligations under Regulation 812/2004 and Article 12 of the Habitats Directive and has been recognised as having one of the best by-catch monitoring schemes in place (Northridge and Kingston, 2010). This scheme relies upon good collaborative links with industry, but fisheries regulations have been enacted in England and Scotland to ensure that there is also a legal obligation for skippers and owners to take observers when requested. A team of observers dedicated to this task is co-ordinated by the SMRU (Northridge and Kingston, 2010), which subcontracts additional monitoring days from the Centre for Environment, Fisheries & Aquaculture Science (CEFAS) and the Agri-Food and Biosciences Institute (AFBINI). Supplementary data from discard surveys are also used. Marine Scotland provides data on number of trips and days spent on the Scottish pelagic fleet along with any records of cetacean by-catch (none observed since before 2005), and these observations are augmented by dedicated marine mammal by-catch observations by SMRU staff on the same fleet. SMRU observers are instructed to maintain a watch such that a clear view of the net hauling operation is maintained.

- **Fishing effort**

  In order to assess the impact of by-catch on a population, two estimates are needed: numbers by-caught and overall population abundance. Observer schemes usually monitor only a proportion of a fleet’s activities and hence the number of observed by-caught animals should be scaled up to the whole fleet. However, estimating total fleet effort can be problematic. This uncertainty is taken into account when assessing change over time, although in the UK the apparent negative trend in by-catch does mirror the decline in gill-net and tangle-net fishing activity. Fishing effort data for the UK fleet and observation levels are reported by fleet segment for each sector that is listed under Article 4 and Annex III of Regulation 812/2004. Fleet segments or métiers are described to Level 4 of Objective IV of Council Decision 2008/949. Effort data are not reliably available for the UK fleet, so the most detailed effort descriptor is days at sea by towed gears and static gears separately.

- **Biological data**

  Marine mammal observers follow a standard data collection protocol. They record the vantage point on the ship from which they are able to make their observations, and make a judgement as to the probability that they would be able to observe a by-caught mammal should this occur. Whether the animal reached the deck or fell from the net is recorded, as is its orientation in the net. Where possible, biological data are collected: one or more teeth are removed for age determination, skin and blubber samples are obtained, sex is determined, and girth, length and blubber thickness measurements are taken. The internal temperature of each animal is also recorded to estimate time of death. For safety reasons, not all by-caught mammals can be sampled, while on small boats by-caught cetaceans often cannot be brought on board and fall/are cut from the net.

- **Results**

  Observations during 2008 amounted to 190 days at sea among the identified fleets, monitoring approximately 10% of the 1,885 overall recorded fishing days at sea in all fleet segments required under Regulation 812/2004. SMRU sampling comprised six pelagic trawl vessels of more than 15 m in length during 39 trips and 114 days at sea, while Fisheries Research Services (FRS) sampled at least seven other vessels and contributed observations from 30 trips and 76 days at sea. In addition to the fishing trips monitored under Regulation 812/2004, a further 231 days at sea were achieved monitoring various other gill-net fisheries during 2008 that were not covered by Regulation 812/2004. Observations have also been collated for a further 344 days at sea among demersal trawls of one sort or another, collected by the SMRU, the AFBINI and the CEFAS (discard sampling).

  Following Council Regulation 812/2004, for 4 years running (2005–2008) there have been no observations of cetacean by-catch in any of the fleet segments listed for compulsory monitoring (SMRU, 2009). Additional monitoring was also undertaken for the purposes of Article 12 under the EU Habitats Directive and 'Scientific Studies' under Council Regulation 812/2004. These data showed that between 2005 and 2006, approximately 460–730 harbour porpoises were by-caught in the Celtic and Irish Sea areas (ICES subarea VII) (Northridge et al., 2007) (206–1,699 harbour porpoises in 2007) (Northridge et al., 2007). For 2008, the by-catch estimate of harbour porpoise in gill-net and tangle-net fisheries in the Irish and Celtic Seas areas was 498–1,409 (SMRU, 2009). The by-catch levels recorded are <1.7% of the best population estimate and are unlikely to represent a major conservation threat to either species. However, there is by-catch in many other European fisheries affecting the same biological populations. Four years of UK monitoring under Council Regulation 812/2004 suggest that the wrong fisheries segments are being targeted for monitoring. This finding has been echoed by other Member States (Northridge and Kingston, 2010). A review of the fleets currently being sampled was undertaken in 2009 and it was recommended that future coverage should include fixed gear deployed from vessels <15 m as well as demersal trawl fisheries (ICES, 2008a). The Commission may implement these recommendations.

Recommendations

Those Contracting Parties that are Member States of the European Union are required under the Habitats Directive (92/43/EC) to introduce a system to monitor the incidental capture and killing of all cetaceans. Thus, there is already a legal imperative to conduct monitoring that can directly support the harbour porpoise by-catch EcoQO. In common with the UK (Table 4.3), Ireland has done well in initiating this programme although a higher rate of fleet observer coverage is still required. As with most MSFD regions, historical data on porpoise by-catch are limited. From the perspective of indicator thresholds and GES, the data point in the early 1990s (Tregenza et al., 1997) could potentially be used as a reference point.

The fisheries monitored during an independent pilot observer programme in accordance with Regulation 812/2004 resulted in zero cetacean by-catch being observed. Based on this result, it was deemed impossible to design a sampling strategy aimed at achieving the recommended by-catch sampling co-efficient of variation no higher than 0.30 for the most frequently caught species. In fact, the legal monitoring requirement of a coefficient of variation of <30% may be impossible to achieve in North-East Atlantic fisheries and practical alternative measures have been proposed by the ICES Working Group on Bycatch of Protected Species (WGBYC). Cosgrove (2011) observed "*Five years of work have been carried out under 812/2004. It is now time for a thorough review of this regulation which results in smarter, more efficient bycatch reduction programmes which focus on fisheries where problems actually exist and where achievable targets are set*". Ireland continued with a dedicated observer programme in pelagic trawl fisheries in 2011/2012, as legally required under Regulation 812/2004. However, a very low percentage cetacean by-catch rate suggests that monitoring undertaken as part of other ongoing programmes conducted under the EU fisheries DCF would provide sufficient monitoring.

4.7 Eutrophication

Background

The relevant EcoQI (Eutrophication) comprises one overarching EcoQO and an integrated set of five sub-

Table 4.3. Comparing Irish and UK porpoise by-catch monitoring programmes.

	Method	Fishery coverage	Period	Analysis
UK monitoring	Observer (Habitats Directive)	5–10%	Monthly/Opportunistic	Time series of cetacean by-catch rate by fishery métier
Irish monitoring	Observer (Habitats Directive)	5–10%	Monthly/Opportunistic	Time series of cetacean by-catch rate by fishery métier

EcoQOs for eutrophication. The overarching strategy is:

> "*All parts of the North Sea should have by 2010 the status of non-problem areas with regard to eutrophication, as assessed under the OSPAR Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area (which consists of the (one-off) Screening Procedure and the (iterative) Comprehensive Procedure).*"

The eutrophication status of marine waters in the OSPAR area is monitored through a Common Procedure, which provides an assessment framework (comprising Harmonised Assessment Criteria) to evaluate eutrophication status and to identify areas for which actions are needed under the Eutrophication Strategy. The Common Procedure characterises areas as either:

- **Non-problem areas** (NPAs) with regard to eutrophication for which there are no grounds for concern that anthropogenic enrichment by nutrients has disturbed or may in the future disturb the marine ecosystem;

- **Problem areas** with regard to eutrophication for which there is evidence of undesirable disturbance to the marine ecosystem due to anthropogenic enrichment by nutrients; or

- **Potential problem areas** with regard to eutrophication for which 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.

The Common Procedure was enacted in 2001 and 2007 and an integrated report for the whole OSPAR area was produced (OSPAR Commission, 2009b). Since all five eutrophication sub-EcoQOs are addressed through the Common Procedure, they will be considered together.

EcoQO thresholds

1. **Winter nutrient concentrations:**
   Winter concentrations of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphate (DIP) should remain below a justified salinity-related and/or area-specific% deviation from background not exceeding 50%.

2. **Phytoplankton chlorophyll *a*:**
   Maximum and mean chlorophyll a concentrations during the growing season should remain below a justified area-specific percentage deviation from background not exceeding 50%.

3. **Phytoplankton indicator species for eutrophication:**
   Area-specific phytoplankton eutrophication indicator species should remain below respective nuisance and/or toxic elevated levels (and there should be no increase in the average duration of blooms).

4. **Oxygen:**
   Oxygen concentration, decreased as an indirect effect of nutrient enrichment, should remain above area-specific oxygen assessment levels, ranging from 4 to 6 mg O_2/l.

5. **Kills in zoobenthos in relation to eutrophication:**
   There should be no kills in benthic animal species as a result of oxygen deficiency and/or toxic phytoplankton species.

Current status of monitoring in Ireland

In common with other OSPAR Contracting Parties (including the UK), Ireland assesses eutrophication under the Common Procedure. Irish sampling is targeted towards specific EcoQOs and corresponds to the UK programme described above (both follow the Common Procedure) except where specific decisions have been made to adjust indicators to regional conditions. Examples of such interpretation for Irish waters include the use of median chlorophyll (the UK uses mean) and oxygen saturation (the UK uses oxygen concentration). The following summary is taken from Ireland's report on the second application of the common procedure (the Comprehensive Procedure) of 2007 (OSPAR Commission, 2008a). The main source of data used in this assessment is from the EPA's national estuarine and nearshore waters monitoring programme and the Marine

Institute's annual winter monitoring programme of coastal and offshore waters of the western Irish Sea and eastern Celtic Sea. The main data collection period was 2001–2005, with 63 subareas assessed. These were mainly estuaries and nearshore coastal waters, for which boundaries were those that have been developed for the WFD Article V Characterisation Report and those that had been previously identified for the purposes of the Urban Waste Water Treatment and Nitrates Directives. In addition, seven coastal and offshore waters of the western Irish Sea and eastern Celtic Sea were subjected to the initial OSPAR screening procedure as part of this assessment.

Winter nutrient sampling is carried out by the Marine institute RV Celtic Voyager in January/February of each year, and in estuarine waters by the EPA. The sampling strategy for coastal and offshore waters was amended during the course of this assessment period – from 2003 sampling was along transects from the coast. Surface seawater samples were collected from each station at a depth of 2–3 m using the onboard peristaltic pumping system. The conductivity, temperature, depth (CTD) probe was deployed at designated stations.

There are three annual summer monitoring events focused on **phytoplankton**. Sampling is carried out at multiple locations and multiple depths throughout the waterbody. Sampling is undertaken, where practicable, as close as possible to low and high water to capture tidally driven variability.

The monitoring of shellfish biotoxins and potential toxic phytoplankton species is undertaken by the Marine Institute, which maintains a detailed record of the occurrence and duration of shellfish toxicity events and potentially **toxic blooms**. Both these parameters have been taken into account in the initial assessment. At present, however, there is little evidence that the occurrence of these blooms, or associated toxicity in shellfish, in Irish waters, is related to nutrient enrichment or other forms of anthropogenic pollution.

The Irish Common Procedure report (OSPAR Commission, 2008a) indicated that the proportion of Ireland's maritime area that is classified as a problem area with regard to eutrophication is small. However, a number of estuaries, mainly located along the eastern and southern coasts, breached the winter DIN criterion. In contrast, very few areas exceeded the winter molybdate reactive phosphorus (MRP) criterion. Elevated chlorophyll levels were most frequently observed in the estuaries along the southern and north-eastern coasts. Oxygen under-saturation was observed in a number of waterbodies, with values mostly >60% saturation (or approx. 5.5 mg/l O_2).

Case study monitoring programme (UK)

Data used in the UK assessment are provided by the UK National Marine Monitoring Programme (NMMP), which implements the OSPAR CEMP for eutrophication, together with data collected for other assessments of eutrophication status. The data sets are generally 'fit for purpose', providing adequate spatial coverage and temporal resolution to carry out a good assessment. However, there are variations in data coverage between areas, reflecting the level of perceived risk and the practicalities of monitoring, and between the different parameters where, for example, there are more data available for winter nutrient concentrations and chlorophyll than for phytoplankton species. The UK assessment follows the Comprehensive Procedure Guidance as closely as possible but specific additional methods are deployed that are considered to be more rigorous and improve the quality of the assessment. In developing the approaches and thresholds to be applied on a regional basis, the UK has, as far as possible, harmonised with UK national programmes set up to implement the WFD. Area-based assessments are subject to an open peer-review process. For the 2007 enactment of the Common Procedure, a screening review was undertaken to provide assurance that areas previously identified as obvious NPAs through application of the screening procedure in 2002 were still NPAs. This took account of any known changes in pressure and through a simple evaluation based on a comprehensive, quality-assured database of winter nutrient concentrations. The following details on specific EcoQOs are taken from the UK report from the 2007 enactment (OSPAR Commission, 2008b):

- **Winter nutrients:** Nutrient concentration information focuses on (annual) winter DIN (DIN = $NO_2 + NO_3 + NH_4$) as the primary criterion and is used in each assessment area/salinity regime, normalised to the relevant salinity. Winter DIP is not used as a primary criterion, unless assessment of the winter DIN/DIP ratio suggests phosphorus limitation.

- **Chlorophyll *a*** is assessed using the (annual) 90th percentile for the March to September growing season, which will inevitably include high spring-bloom chlorophyll values and this is why the 90th percentile (rather than the 95th percentile, for example) was set. Mean and maximum levels are also reported for comparison.
- Instead of a set of individual '**phytoplankton indicator species**' an index (Devlin et al., 2007) is deployed, which includes measures of *Phaeocystis* species and any phytoplankton taxa with abundance over a defined threshold.
- Annual (summer) **dissolved oxygen** concentrations are compared against established thresholds. Best use is made of available widely distributed data on changes to benthic invertebrates and of any evidence of fish kills. There is no use for information about organic carbon/organic matter.
- In coastal and estuarine regions, information about the frequency of **toxin-producing algae** in water samples is assessed against thresholds established for food safety.

The results of the 2007 application of the OSPAR Comprehensive Procedure, which assesses the eutrophication status of UK seas, indicate that the coastal and marine waters around the UK are NPAs with respect to eutrophication and show no signs of undesirable disturbance. However, the evidence confirms that there are a number of inshore sites that are problem areas with respect to eutrophication, or are at risk due to factors such as restricted circulation.

Recommendations

The eutrophication EcoQOs are of direct relevance to criteria in Descriptor 5 Eutrophication. Existing monitoring and assessment programmes implemented in Ireland under the WFD and OSPAR should facilitate easy implementation of associated MSFD indicators. The 2007 Comprehensive Procedure Report (OSPAR Commission, 2008a) provides the parameters and assessment levels that make up the quantitative elements of EcoQOs used by Ireland to assess the trophic status of its estuarine and nearshore coastal waterbodies. Reference points may be available from historical data series including: (i) Inshore – EPA national estuarine and nearshore coastal waters monitoring programme, and (ii) Offshore – Marine Institute winter nutrients monitoring survey (1991–2009) and oceanographic standard sections (2006–2011). However, most relevant thresholds are standardised under the Common Procedure. Monitoring of eutrophication in Irish waters is highly developed and conforms to the demands of the Common Procedure. Ongoing review is focused strongly on the MSFD and progress towards implementation is well established.

EcoQOs 4.8–4.10 have not (to the authors' knowledge in 2012) been initiated at all for Irish waters and hence are briefly summarised below.

4.8 Oiled Guillemots

EcoQO thresholds

The average proportion of oiled common guillemots in all winter months (November–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.

Summary

As a result of (chronic) marine oil pollution, thousands of seabirds wash ashore on the beach every year in the North Sea. The oiled guillemot EcoQO provides a description of the proportion of oiled common guillemots (*Uria aalge*) among those found dead on beaches within the OSPAR area. It is therefore being applied as an indicator. Systematic beached bird surveys provide insight into species composition and oil rates (percentage of birds oiled of all birds found dead) and have been conducted since the early 1960s to study temporal and spatial trends in oil-related mortality in most countries bordering the North Sea. This is an example of an indicator that scores highly in most criteria (see Objective 2 and Appendix 1), but cannot currently be implemented in Ireland due to lack of supporting data. However, the EcoQO is not trend based and hence does not require historical reference data.

4.9 Contaminant Concentrations in Seabird Eggs

EcoQO thresholds

- **Mercury:**
  The average concentrations of mercury in the fresh mass of 10 eggs from separate clutches of the common tern (*Sterna hirundo*) and the Eurasian oystercatcher (*Haematopus ostralegus*) breeding adjacent to certain estuaries should not significantly exceed concentrations in the fresh mass of 10 eggs from separate clutches of the same species breeding in similar, but not industrial, habitats.

- **Organochlorines:**
  For each site, the average concentrations in fresh mass of the eggs of the common tern (*Sterna hirundo*) and the Eurasian oystercatcher (*Haematopus ostralegus*) should not exceed 20 ng/g of PCBs, 10 ng/g of DDT and metabolites, and 2 ng/g of HCB and HCH.[4]

Summary

Many coastal areas are important habitats for seabirds and are protected under the EC Birds and Habitats Directives. These areas are at the same time under pressure from pollution due to environmental chemicals. This contamination affects the coastal food web and accumulates in species at higher trophic levels, including birds. Several studies have shown seabird eggs, including those of migrating species such as terns, to be good indicators of local contamination with hazardous substances since concentrations in eggs tend to reflect contaminant uptake by the female foraging close to the colony in the days prior to egg laying. There is currently no monitoring of seabird egg contamination in Ireland. However, this is an indicator that is theoretically easy to initiate since OSPAR has defined reference points for each contaminant that are based on biological thresholds rather than historical values. A possible starting point might be to collect samples of common tern eggs from the Rockabill Island Reserve (Dublin). Since breeding birds are closely monitored on this island, a robust sampling protocol could be established. The island is also located relatively close to Dublin Bay/Harbour and could thus reflect the contaminant state of this area. Elsewhere, monitoring might possibly be combined with the oiled guillemots and plastic in fulmars indicators.

4. PCB, polychlorinated biphenyl; DDT, dichlorodiphenyl trichloroethane; HCB, hexachlorobenzene; HCH, hexachlorocyclohexane.

4.10 Sand Eel Populations

EcoQO thresholds

*Breeding success of the black-legged kittiwake (*Rissa tridactyla*) should exceed (as a 3-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.*

Summary

The EcoQO on local sand eel availability to black-legged kittiwakes has been developed as an indicator for the community of predator species that depends on sand eels as an important food resource. It is based on the assumption that if black-legged kittiwakes are unable to breed successfully for several years in succession, then it is likely that sand eel abundance is low, representing a serious risk of adverse effects on many animal species. Ireland does not currently have any dedicated sand eel data but abundance data for sprat and herring may be available from fisheries-independent surveys conducted by the Marine Institute. These fish populations are an important prey resource for several seabird species in Irish waters. Further research would be required to establish the existence of similar direct links between breeding success of Irish seabirds and food sources that are selectively extracted by humans (i.e. through fishing). Hence, this indicator is referred to as 'Sand eel populations' (Table 3.3 and Appendix 1)

4.11 Commercial Fish Stocks: Safe Biological Limits

EcoQO thresholds

Maintain the SSB above precautionary reference points for commercial fish stocks where those were agreed by the competent authority for fisheries *management. The SSB is the part of the biomass of the defined commercial fish stocks that takes part in the reproduction process. This is an important indicator of the biological health of these stocks.*

Summary

Fisheries have a major impact on marine ecosystems, both directly by affecting targeted fish stocks and indirectly through affecting the food web. This EcoQO seeks to maintain the SSB of exploited fish stocks above the agreed precautionary limits used in fisheries management. The concept of SSB is well established and has a strong theoretical basis. Monitoring and management are highly developed and supported by international expert groups co-ordinated by the ICES.

4.12 Proportion of Large Fish

EcoQO thresholds

Over 30% of fish (by weight) should be greater than 40 cm in length.

Summary

This EcoQO is fully addressed in Objective 4, where an ensemble LFI series for the MSFD Celtic Seas region is developed. This is a novel analysis, undertaken with collaborators at the ICES Working Group on Ecosystem Effects of Fishing Activities (WGECO), and will be submitted for peer-review publication.

5 Research Objectives and Results: Objective 4. Case Study Indicator Development

5.1 Introduction

The MSFD aims to achieve GES in EU waters by 2020. To facilitate progress towards GES, the MSFD establishes four European marine regions, based on geographical and environmental criteria. Two of these regions are subdivided; for example, the North East Atlantic Region is divided into four subregions: the Atlantic Ocean; the Bay of Biscay and Iberian coast; the Celtic Seas, and the Greater North Sea. Each Member State is required to develop a marine strategy for their own waters (EEZs or extended Continental Shelf areas), but GES must be achieved at the MSFD regional or subregional scale. The spatial extent, habitat heterogeneity, and ecological diversity of these MSFD subregions present a challenge for monitoring and assessment programmes, especially for widespread ecosystem components such as fish whose populations and communities may extend across the EEZs of several Member States.

In the Greater North Sea, the setting of regional-scale targets to support an EAM for fish communities is strongly facilitated by two international bottom trawl surveys (IBTSs) that cover most of the area; for example, the OSPAR EcoQO for 'fish communities' relates to the whole Greater North Sea (Greenstreet et al., 2011). Two surveys are carried out in the first (Q1) and third (Q3) quarters of each year. Several nations with economic interests in the Greater North Sea participate in each survey, and it is this level of international participation that provides sufficient research vessel resources to obtain two or more trawl samples per ICES statistical rectangle (0.5° latitude by 1.0° longitude) across almost the entire subregion. The only part of the Greater North Sea not sampled by these surveys is the English Channel. Participation in these surveys is co-ordinated through the ICES to ensure that timing of the survey work is closely synchronised, and that the vessels involved use the same sampling trawl gear and follow the same sampling protocols (ICES, 2010c). These co-ordinated international surveys produce two separate data sets, each of which contains standardised data collected following an 'even distribution in space' sampling design covering almost the entire Greater North Sea. Just as the availability of these data has facilitated the development of the OSPAR regional-scale EcoQOs, so they will prove to be invaluable in monitoring progress towards GES in respect of the Greater North Sea fish community when it comes to implementing the MSFD.

In other MSFD subregions and regions, such convenient data to monitor progress towards GES are not available. Because European seas are heavily exploited, groundfish surveys are carried out in most marine areas, but these are frequently undertaken independently by individual nations and are designed to address each nation's own particular needs (OSPAR Commission, 2010). Consequently, different national surveys may occur at different times of year and use different sampling protocols and trawl gears. Spatial coverage may often be restricted to the EEZs of the individual nations concerned, which may only comprise part of any given MSFD subregion. This may result in there being relatively little spatial overlap between surveys, potentially making it more difficult to explore the effects of different survey philosophies on the values of any ecological indicator that might be determined from the various data sets. Conversely, since most nations with a marine EEZ undertake some sort of groundfish survey to support their own fisheries interests, this means that the major EEZs within any MSFD subregion are likely to be surveyed, so that some form of potentially useable data are likely to be available from across most of each MSFD subregion (OSPAR Commission, 2010). Four jurisdictions monitor the Celtic Seas MSFD Subregion:

1. England;
2. Scotland;
3. Northern Ireland; and

4. The Republic of Ireland.

In combination, these surveys cover most of the Celtic Seas area, creating potential for some form of subregional-scale assessment. However, the various surveys in operation across the Celtic Seas MSFD Subregion use different trawl gears, follow slightly different protocols, and occur at different times of year. The question then is how a single subregional-scale assessment might be derived from these disparate and smaller-scale sources of information. (Note: The terminology is somewhat confusing. Both the Greater North Sea and the Celtic Seas constitute subregions in respect of the MSFD. However, for the purposes of this report, when considering assessment of the status of fish communities within each of these two MSFD subregions, survey data that are only available at a smaller scale are considered, i.e. obtained from only part of each MSFD subregion. For clarity, these smaller areas are termed 'subunits'.)

The simplest approach to developing subregional-scale indicators might be to ignore differences between constituent surveys and simply pool all the data by year. Using the example of the LFI, this resulting single data set could then be treated in the same way as the Q1 IBTS data that are analysed to derive the Greater North Sea LFI time series (Greenstreet et al., 2011). However, uncertainty over whether any variation in the ensuing indicator reflected actual change in the fish community or some effect of differing protocol among constituent surveys could make interpretation of such a pooled LFI difficult. An alternative approach would be to apply the methodology developed for the Greater North Sea (Greenstreet et al., 2011) to each of the individual surveys, i.e. to follow the approach exemplified by Shephard et al. (2011b) for the Celtic Sea (the southern part of the MSFD Celtic Seas Subregion), and derive separate 'optimised' LFI trends for each survey. Some form of aggregation of these individual subregional-scale LFI trends might then be undertaken to produce the required subregional-scale assessment. This approach holds the advantage of being able to identify which of the subunit-scale surveys most influences the outcome of the subregional-scale assessment, but the question now is how best to perform this aggregation? Should a straight averaging of the various subregional-scale LFI trends be carried out, or should a weighted average be determined? If the latter, what might constitute an appropriate weighting procedure – weighting by biomass of fish sampled by each survey in each year, by the number of trawl samples collected, or by a measure of the proportion of the regional area covered by each survey?

This latter debate raises a more fundamental issue – is calculation of a single regional-scale LFI trend the most appropriate way to undertake regional-scale assessments? Few marine areas as large as the subregions defined in the MSFD consist of reasonably homogenous habitats occupied by a single relatively homogenous fish community. The Greater North Sea, for example, in the north consists of relatively deep water that thermally stratifies in the summer months overlying a generally muddy/muddy sand seabed and in the south of relatively shallow water that remains thermally mixed throughout the year overlying a generally sandy/gravel seabed. Consequently, the fish community across the Greater North Sea is heterogeneous, consisting of distinct subunits that differ in their species composition (Fraser et al., 2008; Reiss et al., 2010a). Reflecting this physical and biological heterogeneity, fishing activity also varies considerably across the Greater North Sea, with beam trawling dominating in the south and otter trawl and seine netting predominant in the north. This heterogeneity could argue against single subregional-scale assessments. Perhaps subunit-scale assessments that reflect spatial variation in fish community composition and fishing activity might be more appropriate? The subregional-scale assessment required by the MSFD might then simply focus on the fraction of these subunit-scale assessments needed to meet their respective targets in order to conclude that GES at the regional scale (i.e. for any particular MSFD subregion or region) had been achieved. Thus, for example, if in the Celtic Seas MSFD Subregion four surveys provide LFI time series for four distinct spatial subunits, do all four LFIs need to meet targets set for each spatial subunit time series to decide that GES for the whole Celtic Seas Subregion had been achieved, or could the target be missed in one time series provided the other three meet theirs?

In this report, an attempt was made to address the questions posed. Firstly, the Q1 IBTS, currently used to derive the Greater North Sea LFI time series on which the OSPAR regional-scale EcoQO is based, is 'broken apart' to simulate five separate subunit-scale surveys. The spatial subunits used broadly follow Member States' EEZs, but also take account of known spatial heterogeneity in demersal fish community species composition. The various ways of recombining the information obtained from these simulated subregional-scale data sets are explored to determine which method best replicates the overall single regional-scale assessment on which the current EcoQO is based. The LFI time series derived from the Q3 IBTS and the Netherlands Beam Trawl Survey (BTS) data is considered to assess how variation in survey timing and survey trawl gear might influence regional-scale assessments when this sort of variability is present in the data. Consideration is then given to the results obtained from the five individual assessments carried out for each spatial subunit to assess the merits of the two different approaches:

1. A single 'averaged' subregional-scale assessment; or
2. An evaluation based on the outcomes of separate subunit-scale assessments.

Finally, the lessons learnt from this analysis of the Greater North Sea situation are drawn on to undertake an assessment of the status of the fish community across the whole Celtic Seas MSFD Subregion, where no subregional-scale surveys are undertaken and only data obtained from subunit-scale surveys are available.

5.2 Methods

Greater North Sea data

North Sea Q1 IBTS

The ongoing Q1 IBTS has used the same fishing gear (the Grande Ouverture Verticale (GOV) trawl) and sampling procedure since 1983. The data are extensive enough to be disaggregated into at least five spatial subunits whilst retaining sufficient information from each subunit for robust analysis. These data subsets can be used to mimic subunit-scale surveys within an MSFD subregion. Indicator metrics from these 'surveys' can then be compared with those derived from the overall North Sea IBTS (Greenstreet et al., 2011) to show how national survey time series may influence a pooled subregional-scale indicator. In addition, possible combinations of survey indicator series can be compared to suggest how ensemble metrics may be best constructed.

North Sea Q3 IBTS and BTS surveys

In Q3, there are two North Sea surveys, the Q3 BTS and the Q3 (otter trawl) IBTS. While these two surveys occur simultaneously, the selection characteristics of the two survey gears differ; the BTS is more efficient at catching flatfish and the otter trawl IBTS more efficient for gadoids. Both surveys cover much of the North Sea, including well-recognised northern (gadoid-dominated) and southern (flatfish-dominated) biogeographic areas identified from both benthic and fish community data (Fraser et al., 2008; Reiss et al., 2010a). With both surveys covering both biogeographic areas of the North Sea, a potential sampling mismatch is established that may provide insight into interaction between survey method and target fish assemblage. The BTS is likely to sample the southern fish community more representatively and efficiently while the IBTS probably better samples the northern gadoid community. It can thus be hypothesised that overall (pooled) North Sea fish community metrics derived from the BTS will be dominated by the southern area, while those based on the IBTS will be dominated by the northern area. Where biogeographic components dominate an ensemble series, possible ensemble metrics also can be compared. The three North Sea surveys (above) were used to derive and compare pooled and ensemble series of the LFI. This insight was then applied to the Celtic Seas Subregion.

Fisheries survey data were obtained from national fisheries research institutes or downloaded from the ICES DATRAS website (http://datras.ices.dk/Data_products/). Survey data were split into known biogeographic spatial components and each component (subunit) was formatted according to the established LFI protocol (Greenstreet et al., 2011; Shephard et al., 2011b). Each LFI was defined as the proportion by biomass of fish larger than a survey-specific 'large fish' threshold. The LFI 'tuning' protocol

(Greenstreet et al., 2011; Shephard et al., 2011b) was followed to optimise the LFI definition for each survey or survey subarea related to spatial subunits. This protocol comprises several key steps that ensure that the indicator is optimised for the target fish community:

- A range of 'large fish' length thresholds was examined to determine which provided the best signal- to-noise ratio ('smoothness'; highest r^2 for a fitted 5th-order polynomial).
- Consideration was given as to which fish species should be included in the assemblage. This is based on knowledge of survey selectivity and fish community dynamics, and on time series smoothness.
- ICES statistical rectangles sampled in <50% of all survey years were removed to reduce spatial bias.

Greater North Sea analysis

North Sea Q1 IBTS

The LFI series for the Q1 IBTS (1985–2011) (Fung et al., 2012) was first reproduced (r^2 > 0.95) using DATRAS data. The survey data set was then split into five North Sea subunits (north-east, NE; north-west, NW; south-east, SE; south-west, SW; Kattegat and Skagerrak, KS) based on appropriate groups of ICES rectangles. These were intended to represent nationally (rather than ecologically) defined survey areas within an MSFD subregion. The optimal LFI definition was derived for each subunit and indicator time series produced. These subunit area-optimum length threshold (AOLT) LFIs were compared with each other and with the overall pooled LFI series using correlation analysis to show how subunit-scale variability in the fish community might affect the subregional-scale LFI.

Four candidate ensemble LFI series were then derived by summarising (averaging) the five subunit series in slightly different ways:

1. Calculating the annual mean LFI from each of the four subunit LFI series;
2. Calculating a mean LFI weighted by number of ICES statistical rectangles sampled by year in each subunit;
3. Calculating a mean LFI weighted by summed annual biomass (kg/h) in each subunit; and
4. Calculating a mean LFI weighted by annual number of survey hauls undertaken in each subunit.

Each averaged LFI series was compared with the overall (pooled) Q1 IBTS LFI series using correlation analysis.

North Sea Q3 IBTS and BTS surveys

Both North Sea Q3 surveys (BTS and IBTS) were split into the same five subunits used for the Q1 IBTS. For each overall survey and each of the five subunits, an optimal LFI was defined and corresponding time series calculated. The subunit LFI series for each survey were then compared with their respective overall subregional-scale LFI series using correlation analysis. This would show whether any particular subunit series dominated the subregional series, for example whether the BTS is dominated by the southern (flatfish community) subunits.

The three subregional-scale LFIs (Q1 IBTS, Q3 IBTS and Q3 BTS) were then compared with each other to show how different sampling season (Q3 IBTS) and sampling gear (Q3 BTS) might lead to differences in subregional-scale LFIs.

Celtic Seas data

Five Celtic Seas surveys were considered:

1. Scottish West Coast (SWC) Q1;
2. SWC Q4;
3. Irish Groundfish Survey (IGFS);
4. Irish Sea VIIa Survey; and
5. UK West Coast Groundfish Survey (WCGFS).

To account for possible effects on the indicator of subunit-scale differences in fish community composition (see results for North Sea surveys), the larger IGFS and SWC surveys were split into known biogeographic areas. The Irish Sea VIIa survey and the Celtic Seas component of the WCGFS survey

(Shephard et al., 2011b) have smaller spatial footprints and less clear biogeographic structure.

SWC surveys

The main groundfish surveys carried out in waters to the west of Scotland and around the north coasts of Ireland are the first and fourth quarter SWC Surveys (Q1 SWC and Q4 SWC), respectively. A similarity analysis of fish community data from these two surveys indicated four separate biogeographic components. Each of the Q1 and Q4 SWC surveys were split according to these biogeographic subareas (Inner and Outer North and Inner and Outer South).

IGFS

The IGFS commenced in 1997 but since 2003 has been conducted on the RV Celtic Explorer. The survey covers the Celtic Seas and the waters off the west of Ireland. In 2005, the survey was extended to cover the continental shelf, partly to collect data pertinent to assessment of blue whiting stocks. Since the slope component of the survey focuses on a different fish community, the IGFS data were split into 'Main' and 'Slope' components for analysis.

Irish Sea

The Irish Sea (area VIIa) is predominantly surveyed by Northern Ireland (UK), although the IGFS extended to parts of this region for a short period. For the current analysis, only the UK data were considered, and the entire area was assumed to comprise a single biogeographic region. Data were available from 1993 to 2008.

WCGFS

The Celtic Seas LFI series produced by Shephard et al. (2011b) was included without modification. The underlying survey data already represent a spatial subarea (Celtic Seas proper) of the complete footprint of this survey.

Celtic Seas analysis

All of the Celtic Seas subunit LFIs were plotted together to show common trends and differences, and potential for use as a multi-series LFI metric. In the Greater North Sea Q1 IBTS survey, the simple mean of the five subunit-scale LFI series was most closely correlated with the overall pooled subregional-scale metric used for the OSPAR EcoQO. Hence, a mean Celtic Seas LFI was also calculated and plotted against its constituent surveys and survey biogeographic subareas.

5.3 Results

Greater North Sea surveys

North Sea Q1 IBTS

The northern subunit AOLT LFIs were more closely correlated to the subregional LFI than were the southern subunit LFIs (Fig. 5.1). Subunit LFI series from the Q1 IBTS tended to show similar broad trends to the Greater North Seas Subregion EcoQO LFI, except for in the SW subunit where the subunit LFI declined below the subregional LFI (Fig. 5.1). The subregional LFI series did reflect this subunit-scale decline, showing a corresponding decline from about 2007. However, none of the averaged LFI series captured this recent decline (Fig. 5.2). Although theory suggests that an average LFI series weighted by biomass (being the denominator of the LFI equation) should precisely reproduce the pooled series, the use of different optimal subunit LFI length thresholds prevents this here. Most subunits were strongly inter-correlated for the Q1 IBTS (Table 5.1).

North Sea Q3 surveys

Pooled subregional-scale LFI series from the Q3 IBTS and BTS differed both from each other and from the Q1 IBTS. This reflects different sampling seasons and survey gears (Fig. 5.3). For the Q3 BTS, the northern subunit LFIs were most strongly correlated (r^2) with the subregional-scale LFI: NW = 0.837, NE = 0.667, KS = 0.464, SW = 0.010, SE = 0.001. This suggests that the subregional LFI from the Q3 IBTS is dominated by samples from the northern gadoid fish community. Correspondingly, subunit LFI series were correlated among northern (including KS) subunits and among southern subunits, but not between northern and southern subunits (Table 5.1; Fig. 5.4). For the Q3 BTS, only the SE subunit was positively correlated with the subregional LFI ($r^2 = 0.129$), while the other subunits were weakly negatively correlated with the subregional LFI ($r^2 < 0.15$). This suggests that the subregional LFI from the Q3 BTS is most strongly influenced by samples from the south-eastern flatfish community, but that there are strong differences among subunits (Table 5.1; Fig. 5.4).

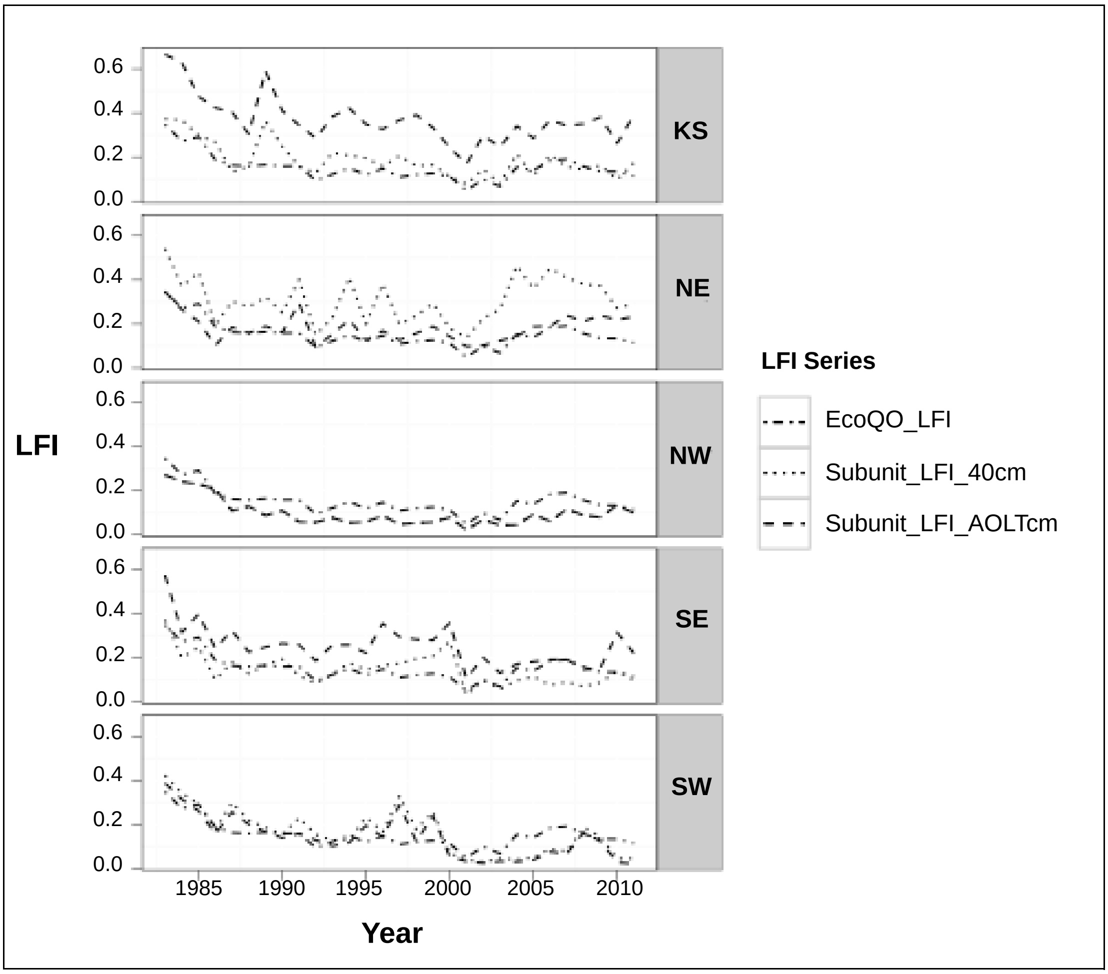

Figure 5.1. Large Fish Indicator (LFI) time series determined for five spatial subunits of the Greater North Sea based on the first quarter international bottom trawl survey (Q1 IBTS) data set. Subunits are: KS (Kattegat and Skagerrak), NE (north-east), NW (north-west), SE (south-east) and SW (south-west). In each subunit plot the regional-scale LFI time series that is the basis for the current Greater North Sea EcoQO is also shown for comparison. LFI series are shown based on each of (i) the standard 'large fish' length threshold of 40 cm used in the regional-scale analysis (Subunit_LFI_40cm), and (ii) an area-optimum length threshold (Subunit_LFI_AOLTcm). The correlations (r^2) to the regional-scale LFI of (i) the subunit 40-cm LFI and (ii) the subunit AOLT LFI are: KS (i=0.600, ii = 0.647); NE (i = 0.499, ii = 0.472); NW (i = 0.760, ii = 0.760); SE (i = 0.389, ii = 0.474); SW (i = 0.412, ii = 0.441).

Celtic Seas surveys

In common with the North Sea, there were marked differences in LFI series derived from different surveys and survey biogeographic subunits in the Celtic Seas Subregion (Fig. 5.5). A simple mean series appeared to capture overall trend among subareas, but much subarea-scale information was lost (Fig. 5.6).

5.4 Discussion

Under the MSFD, Member States are required to develop a marine strategy for their own waters (EEZs or extended Continental Shelf areas). However, indicator metrics of GES will be considered at regional or subregional scale. This disconnect in scale means that national monitoring data series will have to be considered together in subregional MSFD metrics. This study used three North Sea fisheries survey series to investigate how differences in spatial coverage, sampling season and sampling gear might influence subregional-scale LFIs. Different surveys produced different subregional-scale LFIs. Similarly, averaging across survey subunit LFIs produced

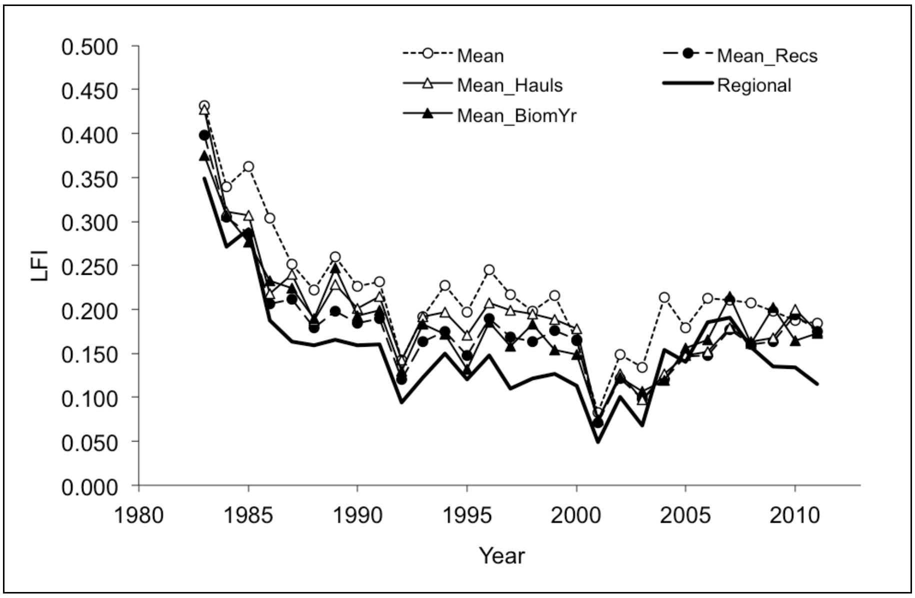

Figure 5.2. Averaged Large Fish Indicator (LFI) series from the first quarter international bottom trawl survey (Q1 IBTS). Correlations (r^2) of each averaged series to the regional (EcoQO) LFI are: mean = 0.898, mean weighted by numbers of rectangles sampled (Mean_Recs) = 0.845, mean weighted by number of sample hauls (Mean_Hauls) = 0.791, and mean weighted by standardised biomass (Mean_BiomYr) = 0.835. Note that all averaged series have larger annual values than the regional series; this is because the Kattegat and Skagerrak (KS), north-west (NW) and south-west (SW) subunit LFI series all have area-optimum length thresholds (AOLTs) smaller than the 40 cm threshold used in the regional series.

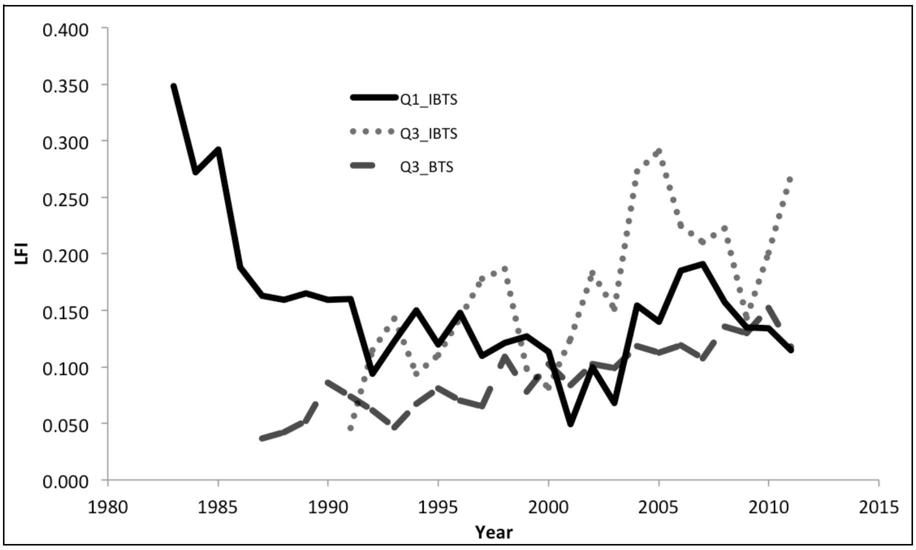

Figure 5.3. Greater North Sea regional-scale Large Fish Indicator (LFI) time series derived from the first quarter international bottom trawl survey (Q1 IBTS), Q3 IBTS and the Q3 beam trawl survey (BTS). Cross correlations (r^2) between each temporal trend are: Q1_IBTS/Q3_IBTS = 0.333; Q1_IBTS/Q3_BTS = 0.005; Q3_IBTS/Q3_BTS = 0.361. In comparisons between Q1 and Q3 surveys the Q3 survey in year y is compared with the Q1 survey in year y+1, i.e. each autumn survey is compared with the following spring survey.

Table 5.1. Correlations between Large Fish Indicator series in each of the five North Sea spatial subunits

Data set	Subregion 1	Subregion 2	Spearman *r*	Nominal *P*
1 IBTS	NW	NE	0.507	0.005
	NW	KS	0.440	<0.001
	NW	SE	0.431	<0.001
	NW	SW	0.335	0.001
	NE	KS	0.453	<0.001
	NE	SE	0.278	0.008
	NE	SW	0.235	0.032
	KS	SE	0.410	<0.001
	KS	SW	0.563	<0.001
	SE	SW	0.517	<0.001
Q3 IBTS	NW	NE	0.676	0.002
	NW	KS	0.683	0.031
	NW	SE	0.052	0.880
	NW	SW	–0.077	0.464
	NE	KS	0.605	0.022
	NE	SE	–0.283	0.532
	NE	SW	0.109	0.569
	KS	SE	–0.105	0.635
	KS	SW	0.073	0.560
	SE	SW	0.591	<0.001
Q3 BTS	NW	NE	0.453	<0.001
	NW	KS	NA	NA
	NW	SE	–0.659	0.223
	NW	SW	0.332	0.352
	NE	KS	NA	NA
	NE	SE	–0.556	0.020
	NE	SW	0.491	0.111
	KS	SE	NA	NA
	KS	SW	NA	NA
	SE	SW	0.026	0.866

IBTS, international bottom trawl survey; BTS, beam trawl survey; NE, north-east; NW, north-west; SE, south-east; SW, south-west; KS, Kattegat and Skagerrak.

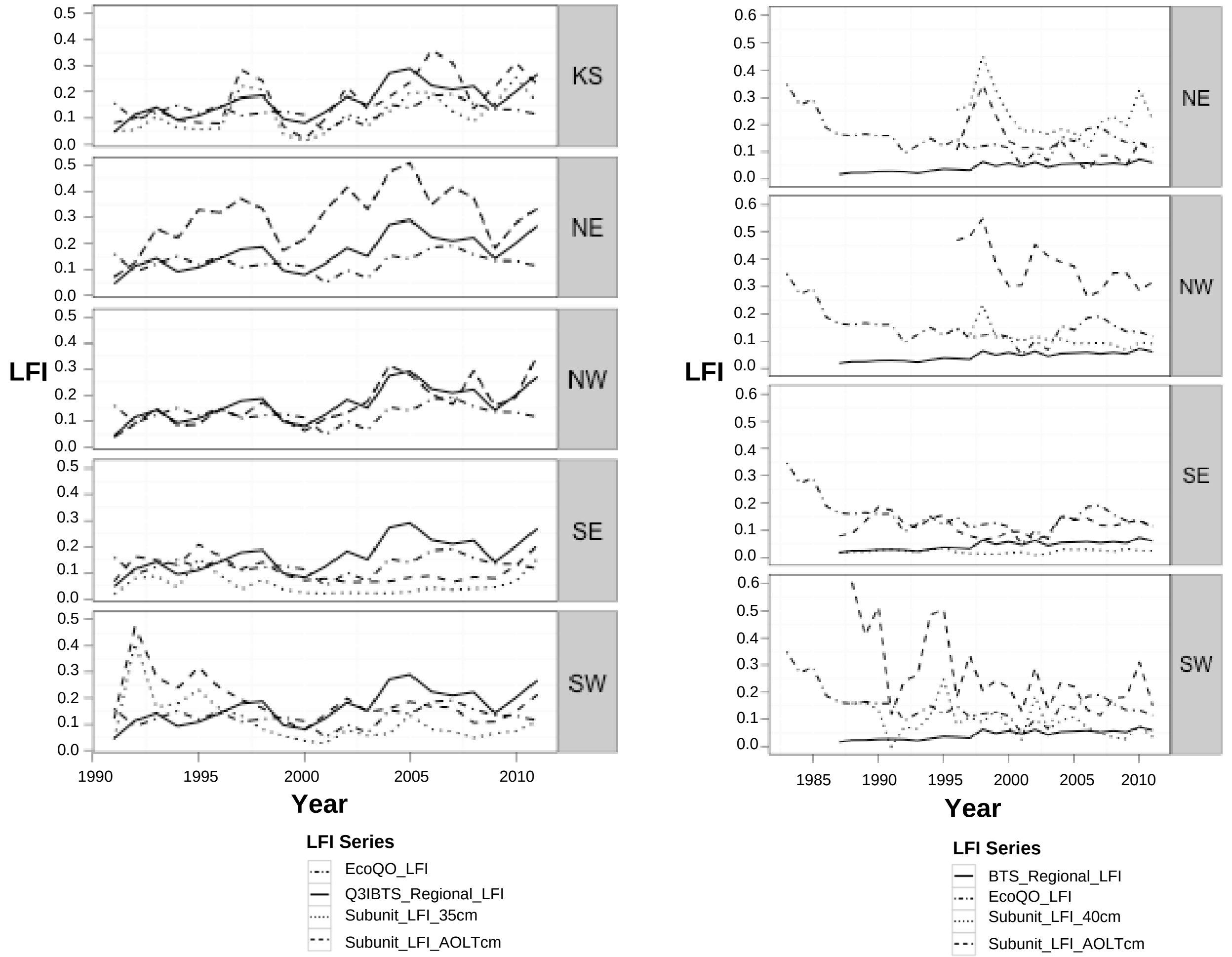

Figure 5.4. Large Fish Indicator (LFI) time series determined for five spatial subunits of the Greater North Sea based on the third quarter international bottom trawl survey (Q3 IBTS) (left panel) and Q3 beam trawl survey (Q3 BTS) (right panel) data sets. Subunits are: NW (north-west), NE (north-east), KS (Kattegat and Skagerrak), SE (south-east), and SW (south-west). Relevant overall subregional-scale LFI time series and the Q1 IBTS series which is the basis for the current Greater North Sea EcoQO LFI series are shown in each subunit. For each subunit, subunit LFI series are shown based on (i) the standard 'large fish' length threshold used in the relevant subregional-scale analysis (Subunit_LFI_35cm and Subunit_LFI_40cm), and (ii) an area-optimum length threshold (Subunit_LFI_AOLTcm).

convenient single indicator series and captured some broad trends, but masked potentially useful ecological information.

Because of methodological, temporal and spatial variation, robust pooling of ecological data series is difficult and a meta-analytical approach much more common. Ecological meta-analyses seek to measure processes and examine their systematic variation across systems and conditions while retaining study-specific data in their original context (Osenberg et al., 1999). The authors suggest that the meta-analysis concept may be valuable in developing ensemble subregional-scale fish community indicators.

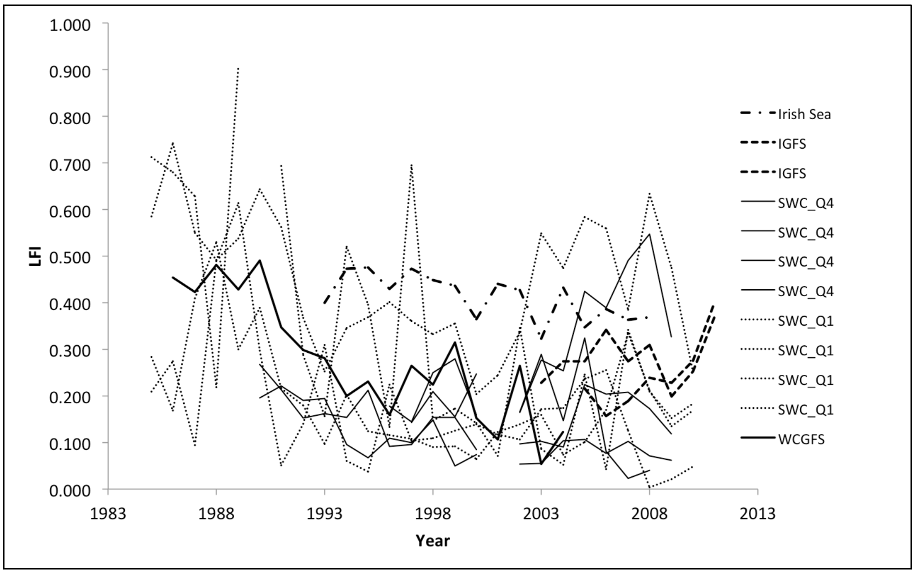

Figure 5.5. Large Fish Indicator (LFI) time series derived from Celtic Seas surveys/survey biogeographic region.

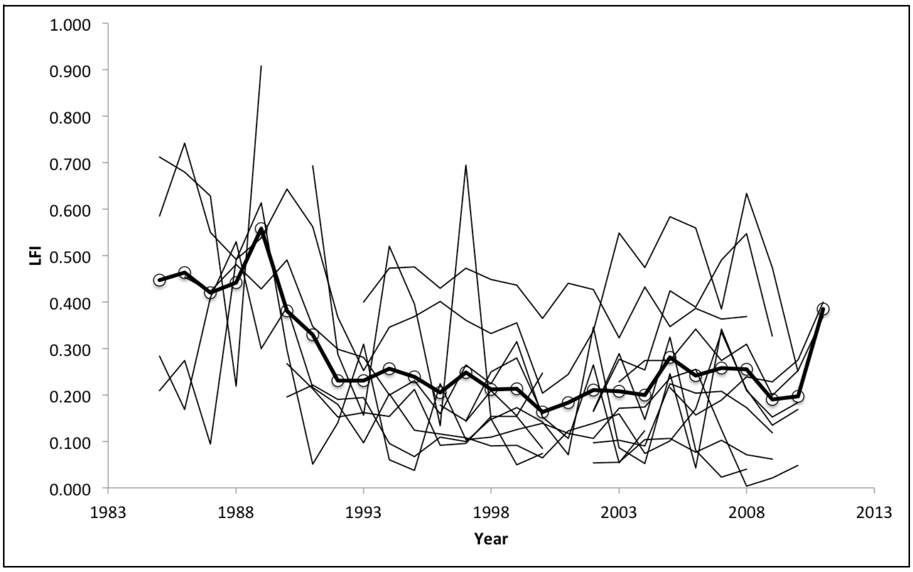

Figure 5.6. Ensemble Celtic Seas MSFD Subregion Large Fish Indicator (LFI) (heavy line with data points) with survey/survey biogeographic region LFIs (fine lines). The ensemble LFI is a non-weighted mean LFI. Individual surveys can be identified in Fig. 5.5 above.

Considering subunit indicator series separately may reveal systematic environmental processes as well as fisheries-induced shifts in fish community state. The likely cost of using multiple series is added complexity in monitoring and management compared with single indicator series. Some sort of decision criteria may need to be established so that GES can be objectively determined. The most precautionary approach would be to demand that all series within a subregion have achieved survey-specific threshold values, or are showing positive trends. Alternatively, some fixed proportion of the series should be deemed healthy with a small number/proportion of series allowed to deviate from GES for a defined period. Such a numerical approach could support an algorithmic decision rule that defined the acceptable number and period of 'failing' series and incorporated underlying variability in these series, etc.

However, the authors suggest that multiple indicator series within a subregion offer an opportunity for scientists to present robust data in a transparent and descriptive manner (Rice, 2012). Failure to understand and communicate the complex science involved in scientific stock assessments has often provoked mistrust among fisheries stakeholders. In contrast, multiple indicator series may allow for more intuitive and spatially explicit (Cotter et al., 2009) data reporting that stakeholders can relate more directly to specific marine areas/fishing grounds. In this case, management would apply at the scale of subunits, with the overall goal being GES at subregional scale. Scientific advice might thus comprise a map in which the subregion is divided into survey subunits and described, according to indicator values, at that scale. Such data can then feed directly into marine spatial planning structures (e.g. Gilliland and Laffoley, 2008) and underpin management of pressure, for example, fishing effort (Reiss et al., 2010b). For the Celtic Seas Subregion, the Irish Sea would thus be highlighted as a subunit showing long-term declines in the LFI, while the northern components of the SWC survey area might be considered to be recovering (Fig. 5.5). Progress towards GES in the Celtic Seas Subregion might thus be assumed to demand management focus on the Irish Sea. A multi-series approach could allow for improved integration of constituent surveys over time and perhaps a shift from EEZ-based to biogeography-based subunits. Such a change in emphasis could be achieved without compromising existing survey time series by using supplementary gears and/or twice-yearly sampling (Cotter et al., 2009). However, the philosophy of meta-series over subregional-scale pooled series would remain.

6 Relevance to Policy Decision Makers and Other Stakeholders

1. The OSPAR EcoQO system can contribute to the implementation of the MSFD in Irish waters. However, there are some important gaps; for example, lack of indicators of benthic or pelagic community/habitat state.

2. The project provides reference tables which link OSPAR to the MSFD and other EU legislative drivers. In addition, specific OSPAR EcoQOs and indicators are related to corresponding MSFD descriptors and indicators.

3. A generic protocol is described which can be used to rapidly evaluate any set of candidate ecosystem indicators. This is discussed in reference to developing an indicator suite for the (Irish) MSFD, with the acknowledgement that the choice of indicators for the MSFD is largely prescribed.

4. A selection of OSPAR EcoQOs having direct and key relevance to the MSFD is described and further evaluated. Evaluations consider data availability and existing monitoring programmes in Ireland, and describe a corresponding case study implementation in another EU Member State.

5. For a key fish community indicator (LFI), a 'Celtic Seas' subregional indicator is developed and presented with a GES threshold and management recommendations.

Table 6.1. Relevance to policy decision makers and other stakeholders.

Issue	Recommendation	Target	Time frame
Integration of monitoring programmes serving EU environmental legislation	There is considerable overlap between EU programmes, e.g. the MSFD and the WFD. This has been recognised in Irish water quality sampling but should be considered further for other marine ecosystem components.	EPA NPWS MI DECLG	Short term
Tuning of ecosystem indicators to serve regional marine systems	Selecting an appropriate indicator suite for a given marine region requires an objective evaluation methodology. The protocol of Rice and Rochet (2005) can be modified to serve this component of the MSFD implementation process.	EPA NPWS MI	Short term and medium term
Implementing OSPAR EcoQOs in Irish waters	Several of the OSPAR EcoQOs are directly relevant to the MSFD. In some cases, e.g. regarding eutrophication, the process is well established. In other examples, e.g. seal and seabird population trends, there is a sound framework that can be modified and extended.	EPA NPWS MI	Short term and medium term
Extending indicator series from national monitoring programmes to MSFD regional scale	Most MSFD subregions, e.g. the Celtic Seas, cover the jurisdiction of several Member States. Correspondingly, environmental monitoring in these regions has typically been conducted in a disparate fashion. Synthesising national data to develop regional indicators is a demanding task. A case study on the LFI is presented in this project.	EPA NPWS MI DECLG	Medium term

MSFD, Marine Strategy Framework Directive; WFD, Water Framework Directive; EPA, Environmental Protection Agency; NPWS, National Parks and Wildlife Service; MI, Marine Institute; DECLG, Department of the Environment, Community and Local Government; EcoQO, Ecological Quality Objective; LFI, Large Fish Indicator.

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Acronyms

AFBINI	Agri-Food and Biosciences Institute
AOLT	Area-optimum length threshold
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
BIM	An Bord Iascaigh Mhara
BTS	Beam trawl survey
CEFAS	Centre for Environment, Fisheries & Aquaculture Science
CEMP	Coordinated Environmental Monitoring Programme
CI	Confidence interval
CTD	Conductivity, temperature, depth
CV	Coefficient of variation
DCF	Data Collection Framework
DDT	Dichlorodiphenyl trichloroethane
DECLG	Department of the Environment, Community and Local Government
DIN	Dissolved inorganic nitrogen
DIP	Dissolved inorganic phosphorus
EAC	Environmental assessment criterion
EAM	Ecosystem Approach to Management
EcoQI	Ecological Quality Issue
EcoQO	Ecological Quality Objective
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
EU	European Union
FRS	Fisheries Research Service
GAM	Generalised additive model
GES	Good Environmental Status
GOV	Grande Ouverture Verticale
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
IBTS	International bottom trawl survey
ICES	International Council for the Exploration of the Sea
IGFS	Irish Groundfish Survey
IMARES	Institute for Marine Resources & Ecosystem Studies
IMO	International Maritime Organisation
JAMP	Joint Assessment and Monitoring Programme
JNCC	Joint Nature Conservation Committee

JRC	Joint Research Centre
KS	Kattegat and Skagerrak
LFI	Large Fish Indicator
LoQ	Limit of Quantification
LW	Low water
MI	Marine Institute
MRP	Molybdate reactive phosphorus
MSFD	Marine Strategy Framework Directive
NE	North-east
NIS	Non-indigenous species
NMMP	National Marine Monitoring Programme
NPA	Non-problem area
NPWS	National Parks and Wildlife Service
NW	North-west
OSPAR	Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
PCB	Polychlorinated biphenyl
QSR	Quality Status Report
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SCR	Seabird Colony Register'
SE	South-east
SMP	Seabird Monitoring Programme
SMRU	Sea Mammal Research Unit
SSB	Spawning Stock Biomass
SW	South-west
SWC	Scottish West Coast
TBT	Tributyl tin
VDSI	Vas Deferens Sequence Index
WCGFS	West Coast Groundfish Survey
WFD	Water Framework Directive
WGBYC	Working Group on Bycatch of Protected Species
WGECO	Working Group on Ecosystem Effects of Fishing Activities
WGSE	Working Group on Seabird Ecology
WKSEQUIN	Workshop on Seabird Ecological Quality Indicator

Appendix 1 Ecological Quality Objective Rapid Indicator Evaluations

Table A1.1. Commercial fish Spawning Stock Biomass.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	Medium: calculated from stock assessments	2
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	High: 'overfishing' is well recognised	3
Cost	High: derived from existing surveys	9
Measurement	High: can model variance and bias, simple thresholds	6
Historic data	High: existing survey time series for many species	6
Sensitivity	High: indicator responds mainly to fishing	9
Responsiveness	High: close correlation to fishing mortality	6
Specificity	Medium: effect of environmental forcing well studied for some species	4
EU relevance	High: proposed for Descriptor 3 Commercial Fish	9
Irish coverage	High: Strong monitoring programmes in place	6
		69

Table A1.2. Phytoplankton chlorophyll *a*.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: precisely measured data	3
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	Medium: some ecological concepts	2
Cost	Medium: seagoing science but many survey platforms	6
Measurement	High: can model variance and bias. Good historical data	6
Historic data	Medium: some potential data series	4
Sensitivity	Medium: may be variable relationship to pressures	6
Responsiveness	Medium: timescale of responses not certain	4
Specificity	Low: strong environmental forcing effects	2
EU relevance	High: relevant to Descriptor 5 Eutrophication	9
Irish coverage	High: well-established monitoring programme	6
		57

Table A1.3. Dissolved oxygen.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: precisely measured data	3
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	Medium: some ecological concepts	2
Cost	Medium: seagoing science but many survey platforms	6
Measurement	High: can model variance/bias and spatial/temporal variation	6
Historic data	Medium: some potential data series	4
Sensitivity	Medium: may be variable relationship to pressures	6
Responsiveness	Medium: timescale of responses not certain	4
Specificity	Low: strong environmental forcing effects	2
EU relevance	High: relevant to Descriptor 5 Eutrophication	9
Irish coverage	High: well-established monitoring programme	6
		57

Table A1.4. Dissolved nitrogen and potassium.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: precisely measured data	3
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	Medium: some ecological concepts	2
Cost	Medium: seagoing science but many survey platforms	6
Measurement	High: can model variance/bias and spatial/temporal variation	6
Historic data	Medium: some potential data series	4
Sensitivity	Medium: may be variable relationship to pressures	6
Responsiveness	Medium: timescale of responses not certain	4
Specificity	Low: strong environmental forcing effects	2
EU relevance	High: relevant to Descriptor 5 Eutrophication	9
Irish coverage	High: well-established monitoring programme	6
		57

Table A1.5. Large Fish Indicator.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: direct biological measurement	3
Theoretical basis	Medium: good theory mechanisms not completely understood	6
Public awareness	Medium: fishing targets big fish	2
Cost	High: derived from existing surveys	9
Measurement	High: can model variance and bias, simple thresholds, good data	6
Historic data	High: strong and available existing survey time series	6
Sensitivity	High: indicator responds mainly to fishing	9
Responsiveness	Medium: possibly 10-year time lag	4
Specificity	Medium: unclear effects of environmental forcing	4
EU relevance	High: D4 Food Webs/D1 Biodiversity	9
Irish coverage	High: strong monitoring programmes in place	6
		64

Table A1.6. Imposex in whelks.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: measured data	3
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	Low: weird biology!	1
Cost	Low: dedicated seagoing science	3
Measurement	Medium: can model variance and bias but few data and strong spatial component	4
Historic data	High: intermittent data available since 1987	6
Sensitivity	Medium: effects irreversible to possibly cumulative	6
Responsiveness	Medium: timescale of response not certain	4
Specificity	High: tributyl tin is the exclusive pressure	6
EU relevance	High: relevant to Descriptor 8 Contaminants	9
Irish coverage	High: strong historical data and analysis	6
		57

Table A1.7. Phytoplankton indicators.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: precisely measured data	3
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	Medium: some ecological concepts	2
Cost	Medium: seagoing science but many survey platforms	6
Measurement	High: can model variance and bias, good historical data	6
Historic data	Medium: some potential data series	4
Sensitivity	Medium: may be variable relationship to pressures	6
Responsiveness	Medium: timescale of responses not certain	4
Specificity	Low: strong environmental forcing effects	2
EU relevance	High: relevant to Descriptor 5 Eutrophication	9
Irish coverage	High: well-established monitoring programme	6
		57

Table A1.8. Seal population trends.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	Medium: calculated from population models based on empirical counts	2
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	High: seals are charismatic	3
Cost	Low: expensive dedicated science	3
Measurement	High: can model variance and bias	6
Historic data	Medium: some data available but spatial and temporal gaps and variability	4
Sensitivity	Medium: quite hard to relate to pressure	6
Responsiveness	Low: response to management unclear	2
Specificity	Medium: some knowledge of environmental forcing	4
EU relevance	High: proposed for Descriptor 4 Food Webs	9
Irish coverage	High: sampling covers a large area	6
		54

Table A1.9. Seabird populations.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	Medium: calculated from survey-informed population models	2
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	High: seabirds are charismatic. Data collected by stakeholders	3
Cost	Medium: expensive dedicated science but strong public contribution	6
Measurement	High: can model variance and bias	6
Historic data	High: reference points available	6
Sensitivity	Medium: quite hard to relate to pressure	6
Responsiveness	Medium: lags in response to management	4
Specificity	Low: some knowledge of environmental forcing	2
EU relevance	High: Marine Strategy Framework Directive descriptors D4 Food Webs/D1 Biodiversity	9
Irish coverage	Medium: collaborative data collection with UK but little national monitoring	4
		57

Table A1.10. Harbour porpoise by-catch.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	Medium: calculated from population models and empirical data	2
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	High: cetaceans are considered charismatic	3
Cost	Medium: dedicated observer programme	6
Measurement	Medium: can model variance and bias but thresholds are difficult	4
Historic data	Medium: some data but spatial/temporal gaps	4
Sensitivity	High: single specific pressure	9
Responsiveness	High: response to management, for example, pingers	6
Specificity	Low: some knowledge of environmental forcing	2
EU relevance	High: D4 Food Webs/D1 Biodiversity	9
Irish coverage	High: sampling coverage is considered adequate	6
		60

Table A1.11. Eutrophication kills.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: precisely measured data	3
Theoretical basis	High: well-understood mechanisms	9
Public awareness	Medium: some ecological concepts	2
Cost	Low: dedicated time-consuming science	3
Measurement	High: can model variance and bias, good historical data	6
Historic data	Medium: some potential inshore data series	4
Sensitivity	Medium: can be related to point-source events	6
Responsiveness	Medium: timescale of responses not certain	4
Specificity	Medium: some environmental complexity	4
EU relevance	High: D5 Eutrophication/D6 Seafloor integrity	9
Irish coverage	High: detailed records of blooms and toxic events	6
		56

Table A1.12. Oiled guillemots.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: observed count data	3
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	High: oiled seabirds are a highly visible environmental impact	3
Cost	Medium: dedicated science but cheap sampling	6
Measurement	Medium: can model variance/bias but thresholds unclear and unknown spatial/temporal variation	4
Historic data	Low: no data available for Ireland	2
Sensitivity	High: easily related to oil pollution	9
Responsiveness	High: clear response to management	6
Specificity	High: closely related to oil spill incidents	6
EU relevance	High: relevant to Descriptor 8 Contaminants	9
Irish coverage	Low: few or no data available	2
		59

Table A1.13. Seabird egg contamination.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: observed chemical concentrations	3
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	Medium: easy to understand, for example *Silent Spring*[1]	2
Cost	Medium: dedicated science but not seagoing	6
Measurement	High: can model variance/bias, simple thresholds and sampling coverage	6
Historic data	Low: no data available for Ireland	2
Sensitivity	High: easily related to point pollution sources	9
Responsiveness	High: clear response to management	6
Specificity	High: closely related to pollution sources	6
EU relevance	High: D8 Contaminants/D1 Biodiversity	9
Irish coverage	Low: few or no data available	2
		60

[1]Carson, R., 1962. *Silent Spring*. Houghton Mifflin, Boston, US.

Table A1.14. Plastic particles in fulmars.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	High: observed stomach contents	3
Theoretical basis	High: well-understood mechanisms and theory	9
Public awareness	Medium: easy to understand	2
Cost	Medium: dedicated science but not seagoing	6
Measurement	High: can model variance/bias, simple thresholds	6
Historic data	Low: no data available for Ireland	2
Sensitivity	Medium: response unclear	6
Responsiveness	Medium: may respond slowly due to residual litter	4
Specificity	High: closely related to pollution sources	6
EU relevance	High: D8 Contaminants/D1 Biodiversity	9
Irish coverage	Low: few or no data available	2
		55

Table A1.15. Sand eel populations.

Criterion	Rating (High, Medium, Low)	Weighted score
Concreteness	Medium: stock assessments	2
Theoretical basis	High: well-understood mechanisms and concepts reconciled with theory	9
Public awareness	Medium: complex ecological concepts	2
Cost	Low: dedicated seagoing science	3
Measurement	Medium: can model variance and bias but few historical data for reference	4
Historic data	Low: few data available for Ireland	2
Sensitivity	Low: environmental confounding in response	3
Responsiveness	Medium: may respond unpredictably – environment	4
Specificity	Medium: complex trophic processes plus fishing	4
EU relevance	High: D1 Biodiversity/D4 Food Webs	9
Irish coverage	Low: few or no data	2
		44

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil, Pobal agus Rialtais Áitiúil.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail;
- scardadh dramhuisce.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

Science, Technology, Research and Innovation for the Environment (STRIVE) 2007-2013

The Science, Technology, Research and Innovation for the Environment (STRIVE) programme covers the period 2007 to 2013.

The programme comprises three key measures: Sustainable Development, Cleaner Production and Environmental Technologies, and A Healthy Environment; together with two supporting measures: EPA Environmental Research Centre (ERC) and Capacity & Capability Building. The seven principal thematic areas for the programme are Climate Change; Waste, Resource Management and Chemicals; Water Quality and the Aquatic Environment; Air Quality, Atmospheric Deposition and Noise; Impacts on Biodiversity; Soils and Land-use; and Socio-economic Considerations. In addition, other emerging issues will be addressed as the need arises.

The funding for the programme (approximately €100 million) comes from the Environmental Research Sub-Programme of the National Development Plan (NDP), the Inter-Departmental Committee for the Strategy for Science, Technology and Innovation (IDC-SSTI); and EPA core funding and co-funding by economic sectors.

The EPA has a statutory role to co-ordinate environmental research in Ireland and is organising and administering the STRIVE programme on behalf of the Department of the Environment, Heritage and Local Government.

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