



Conservation Challenge No. 2

Discussion document on ecosystem structure and function

How can we use concepts of structure and function to integrate the ecosystem approach into marine monitoring?

**Marine Resources Assessment Group (MRAG) &
World Conservation Monitoring Centre (UNEP-WCMC)**

**May 2007
Revision 1**

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ISSN 1751-5289 (online)
ISBN 978 1 86107 595 6

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This report should be cited as:

MRAG & UNEP-WCMC (2007)

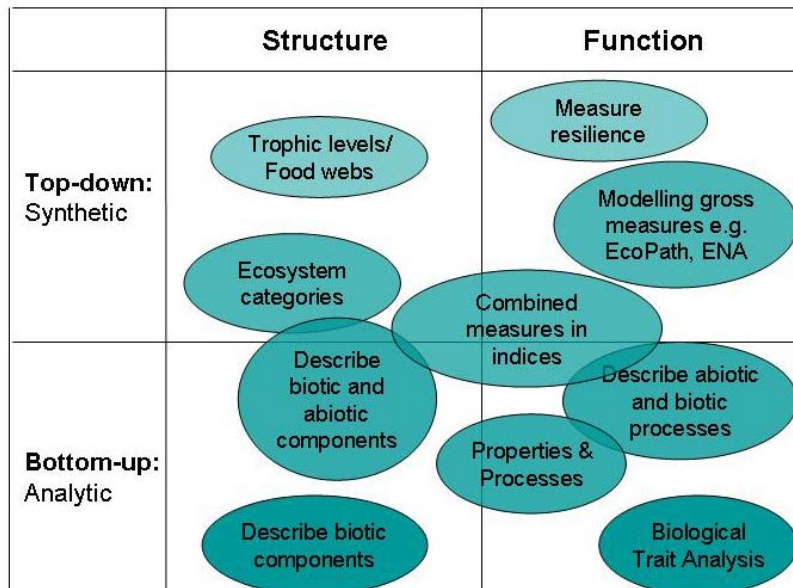
How can we use concepts of structure and function to integrate the ecosystem approach into marine monitoring?

Conservation Challenge, No. 2 Joint Nature Conservation Committee, Peterborough

Executive Summary

There are key policy drivers for implementing an ecosystem approach in marine management, including the UK Safeguarding Our Seas Strategy and the EU marine strategy directive. Marine monitoring needs to respond to the needs of the managers, while also providing information to understand the underlying system. The concepts of ecosystem structure and function provide a potentially useful framework by which monitoring can provide both an integrated view of the ecosystem as well as key indicators easily communicated to decision-makers. There are still considerable challenges in defining concepts of structure and function. Such concepts need to be applicable across all ecosystem components (e.g. pelagic, sea-surface and benthic environments) and different scales (i.e. local to regional scales).

This discussion document is part of a consultation process to arrive at consensus on practical definitions for ecological structure and function that can guide UK marine monitoring. It presents an overview of the different definitions in use and how they differ in approach (as illustrated in the diagram below). At one end of the spectrum there are the bottom-up approaches where each element of the ecosystem is described in detail, and due to the level of detail is most often used at the local scale. At the other end of the spectrum there are a range of top-down approaches that attempt to integrate elements of the ecosystem into a reduced number of parameters, or group attributes under broader headings or categories. Some of these approaches are more synthetic than others, for example grouping attributes into categories that cover large regional scales may still allow considerable detail within each category. In contrast some modelling approaches synthesize all ecosystem processes into one or two measures, such as energy flow.



Within the document, definitions for ecosystem structure are considered first, before different approaches to understanding ecosystem function are described. Lastly there is a discussion on the challenges of monitoring marine environments at a range of different scales. This leads on to suggestions on how structure and function may be useful concepts for defining ecosystem areas, as well as providing a framework for ecosystem monitoring. Throughout the report discussion questions are raised and a feedback form is provided in Annex 1 (for quick response questions). This document will be updated following the consultation phase (ends 31st May) and stakeholders are encouraged to give their opinions and comments in whichever form suits them best.

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1 Introduction

1.1 Objective of this discussion document

The aim of this discussion document is to stimulate debate on the use of concepts of ecosystem structure and function in marine monitoring of UK waters. It asks a number of key **questions** including:

- Do the concepts of structure and function provide a useful basis to develop a framework for monitoring marine ecosystems?
- How are these concepts currently used in the context of marine monitoring, and what are the different approaches?
- Can consensus be reached on definitions that allow the concepts to be useful in practice across different scales and sectors?

This paper seeks responses and consultation from a wide range of stakeholders with the final objective to reach consensus on practical definitions of ecological structure and function that can be used in achieving a holistic approach to marine monitoring and assessment.

1.2 How to read this document

This document provides you with an overview of the current definitions and use of ecosystem function and structure, and a summary of the current debate. It aims to stimulate further discussion and asks questions throughout the text to illustrate the main issues of debate. We also ask for **your feedback** using tick-box questions in Annex 1. These are simplified questions to assist with a quick response. References are provided in Annex 4 should you wish to refer to them. Those that are used frequently are followed by numbers in brackets [#], to assist with comparison across the different sections (e.g. Bremner et al, 2006 [1]). The rest of the document is structured in the following way:

Section 1	Introduction
Section 2	Background Context
Section 3	Definitions of ecosystem structure
Section 4	Definitions of ecosystem function
Section 5	Issues of spatial scale
Section 6	Summary of different approaches
Annex 1	Feedback form for responses by 31st May
Annex 2	Comparison Tables
Annex 3	Policy drivers for Ecosystem-Based Approaches
Annex 4	Comparison of Eco-Regions for the UK
Annex 5	References

Please detach **Annex 1** and look over the questions posed before reading the remainder of the document. Details of where to send your comments or responses are given in this section.

Please note that the following terms have been used in this report and can be interpreted as:

Regional: Refers to the ‘UNEP Regional Seas’ Level

Sub-regions: Refers to country or sub-divisions within the UK

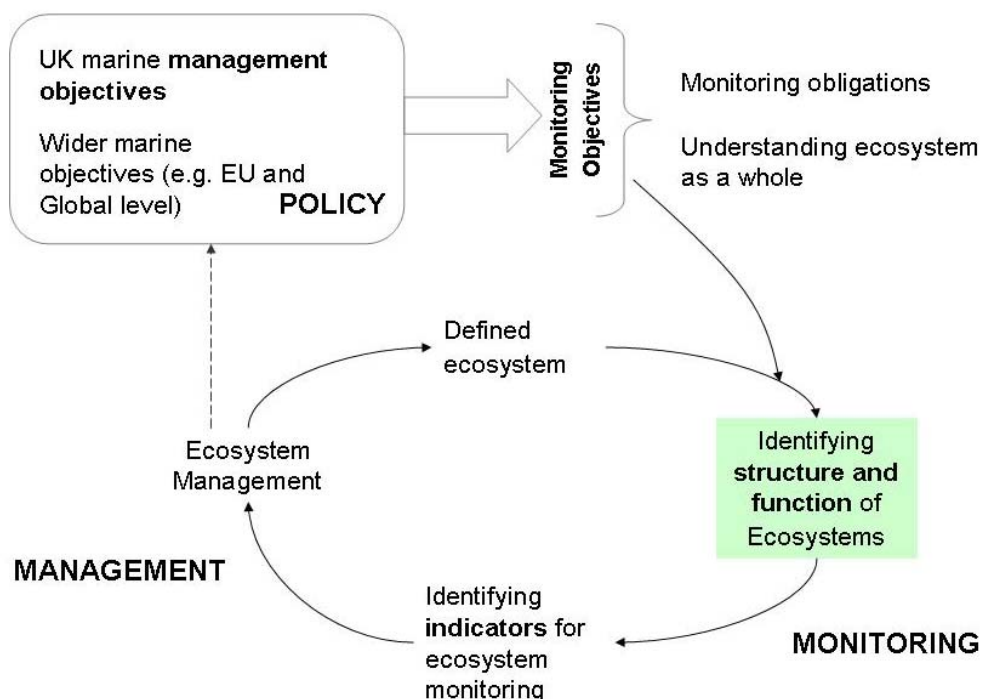
1.3 Background Context

1.3.1 Structure and function as a framework for implementing an ecosystem approach to marine monitoring

There are a number of policy drivers encouraging and requiring the use of an ecosystem approach to manage the marine environment¹. Most notably, the UK Safeguarding Our Seas Strategy of 2002 sets out a shared vision for clean, healthy, safe, productive and biological diverse oceans and seas, and commits the UK to implementing an ecosystem approach. This is also an obligation within the Bergen Declaration², which signed up to an ecosystem approach. The integrated assessment of UK seas in 2005, 'Charting Progress' is a step towards adopting the approach, and the White Paper launched in March 2007 for a Marine Bill recognises the need to implement an ecosystem approach to management especially to maintain marine biodiversity and ecosystems. These are in themselves driven by principles within the EU Marine Strategy directive.

The current development of a UK marine monitoring and assessment strategy (UKMMAS) is also responding to the requirement for holistic monitoring. One of the main challenges is designing a monitoring and assessment system that takes into account ongoing reporting obligations, while also enabling an understanding of the system as a whole. Figure 1 illustrates how the identification of structure and function could provide a framework for understanding defined ecosystems, and identifying indicators that respond to management and monitoring objectives.

Figure 1 A conceptual framework illustrating how structure and function can assist the implementation of the ecosystem approach within marine monitoring and management



¹ There are a number of different definitions of an ecosystem approach including that provided by ICES and also used within the White Paper for the UK Marine Bill: 'the integrated management of human activities based on knowledge of ecosystem dynamics to achieve sustainable use of ecosystem goods and services, and maintenance of ecosystem integrity.'

² Agreed at the end of the 5th International Conference on the Protection of the North Sea, 2002

The concepts of ecosystem structure and function provide a potential framework for translating marine objectives into marine indicators. On the one side describing the structure and function of an ecosystem incorporates all the main elements that would lead to a holistic understanding of the system, and on the other hand also would allow key 'structural' or 'functional' aspects to be highlighted as indicators of state. Indicators give a headline measure of the ecosystem and can be easily communicated to decision-makers to help in adjusting or updating management plans and policies. It is worth considering whether structure and function would provide the two main pillars of a framework, or whether there are other key principles that would form additional pillars.

1.3.2 Who is currently using concepts of structure and function?

Structure and function are not new concepts. The EU Habitats Directive requires the measurement of ecological structure and function of protected areas, and the Bergen Declaration suggests *focused research and information gathering which addresses driving forces of ecosystem variability...which are critical for maintaining ecosystem structure and function*. Safeguarding Our Seas also suggests that *an ecosystem-based approach requires a better understanding of the way ecosystems function as a whole*. The EU marine strategy directive refers to the structure and functioning of the marine environment as an integral part of the definition of environmental status.

A number of UK groups and institutions (e.g. benthic ecologists; oceanographers; fisheries ecologists and managers; and practitioners of coastal zone management) are exploring options for using concepts of structure and function as a framework for answering the key challenges of implementing the ecosystem approach. The ecosystem approach and consideration of ecosystem structure and function has also become mainstream within fisheries management, for example the ecosystem-based approach to fisheries management (EBFM) promoted within the FAO 1995 Code of Conduct for Responsible Fisheries, suggests that key principles include maintaining the characteristic structure, functioning, productivity and biodiversity of ecosystems. Outside of the UK context, the Convention on Biological Diversity (CBD) states that structure and function are two of the key concepts that are needed to understand biological organisation.

1.3.3 What are we hoping to achieve?

Despite the growing interest in the use of structure and function as a framework for marine monitoring, there are still considerable challenges in defining these concepts. Definitions need to be applicable across all ecosystem components (e.g. pelagic, sea-surface and benthic environments) and different scales and dimensions (e.g. the very local scale to a regional sea level). A number of recent reports have addressed this issue, and different approaches and definitions for structure and function are emerging.

The overall aim of this discussion document is to provoke discussion on whether it is possible and desirable to identify combined definitions for structure and function. Such definitions may provide the guiding framework for implementing the ecosystem approach within UK marine monitoring. The next step in the process will be to elaborate definitions so they can be applied practically within the marine monitoring and assessment strategy, and assist in the identification of effective indicators that will form part of the UKMMAS.

2 Definitions of ecosystem structure

This section summarises the current definitions that are being used to describe the structure of marine ecosystems. Some definitions focus on biological elements, while most cover both biological (biotic) and physical (abiotic) attributes. In order to integrate measures of ecosystem structure, wider ecosystem categories have been suggested. Other approaches focus on a description of the food web and use the measures of trophic level to give a picture of the complexity or simplicity of the ecosystem. A detailed summary of definitions for ecosystem structure is provided in Table 10 in Annex 2, page 20.

Some questions for discussion include:

- What biological and physical elements should be included in a definition of ecological structure?
- What wider categories would be most useful for describing ecological structure?
- What mechanisms could assist integration of monitoring and/or assessment across an ecosystem?

For simplified feedback questions on ecosystem structure please see Section B of the Feedback questionnaire (Annex 1).

2.1 Biological and physical elements

Some of the definitions for ecosystem structure focus on the biological elements of the ecosystem. For example Bremner et al., (2006) [1] suggest the structure of an ecosystem is the taxonomic composition, biological diversity, or presence of specific habitats or species. Other definitions suggest that ecosystem structure requires identification of both biological (biotic) and physical (abiotic) attributes (Hiscock et al., (2006) [2]; Elliot et al., (2006) [3]; and Dernie et al., (2006) [4]). Abiotic elements, such as the physical structure of the substratum or the physical and chemical structure of the water column (Dernie et al., 2006), are argued to be highly influential in determining the sorts of marine organisms that are likely to exist at a location. Examples of the abiotic and biotic attributes of ecosystem structure provided by these references are illustrated in Table 1.

Table 1 Abiotic and Biotic attributes of ecosystem structure

Attributes	References	Bremner et al., 2006 [1]	Hiscock et al., 2006 [2]	Elliot et al., 2006 [3]	Dernie et al., 2006 [4]
Biotic	Habitat types				
	Habitat preferences				
	Substrate types				
	General Biology				
	Range & Distribution				
	Reproduction & Longevity				
	Species diversity				
	Species richness				
	Biomass				
	Amounts of Chlorophyll				
	Functional Groups				
	Community Structure				
	Abiotic	Temperature			
Grain size (sediment type)					
Salinity					
Oxygen level					
Sea-bed type					

Note: This table has simplified the different terminology to assist with comparison

Hiscock et al, (2006) further differentiates between the community structure of an ecosystem (species present) and the architectural structure which is influenced by physical characteristics of the sea-bed, such as rock area (e.g. surface relief, crevices etc) and sediment type (e.g. firmness, stability). The architectural structure of an ecosystem is also influenced by living organisms, such as plants and animals that create physical structures (shells, coral skeletons). These structures are, in some cases, essential for maintaining species richness and influencing ecosystem processes, for example biogenic reefs that may be an ‘oasis’ of species richness in often apparently barren or impoverished settings. Other species may change aspects of the physical and chemical environment by trapping silt or by facilitating oxygenation of sediments through their activities. While a range of biotic and abiotic attributes can be used to define the structure of an ecosystem, Hiscock et al., (2006) [2] suggest that it may be necessary to identify ‘key structural species’ or ‘ecosystem engineers’ that play a critical role in maintaining the structural integrity of the ecosystem.

2.2 Integrating descriptions of ecosystem structure

There have been different approaches put forward for providing integrated descriptions of ecosystem approaches (Table 2). Some of these have identified classification categories under which more detailed descriptions of the ecosystem can be nested. This is currently the system being promoted within the identification of objectives for the UK marine environment (Rogers et al., 2006 [10]), and options have also been suggested by Frid & Paramour, 2006 [7], and Laffoley et al, 2006 [11]. While these approaches provide a useful way of dividing up and understanding the ecosystem, they may require an additional framework to promote integrated monitoring and management across the ecosystem.

Table 2 Integration categories for describing ecosystem structure

Rogers et al., 2007 [10]	Frid & Paramour, 2006 [7]	Laffoley et al., 2006 [11]
<ul style="list-style-type: none"> - Benthic habitats; - Sea birds & mammals; - Phytoplankton & Zooplankton; - Physical/Chemical quality of water & atmosphere 	<ul style="list-style-type: none"> - Plankton; - Benthos - Fish - Marine Reptiles & mammals; - Seabirds; - Seafloor habitats 	<ul style="list-style-type: none"> - Environmental - Economic - Social - Spatial - Temporal - Scientific - Institutional
Pauley et al., 1998 [13] - Marine Trophic Levels		

Another example of an integrated description of ecosystem structure is the calculation of **mean trophic level** (Pauley et al., 1998). This is described as the number of links in the food-web from a fished resource to the bottom of the food web (level of primary production). Decreases in mean trophic level (i.e. simplification of the food web) have been associated with fishing pressure and commonly referred to as ‘fishing down the food chain’. Other impacts of fishing on ecosystem structure include changes in the relative abundance of species; indirect impacts on predator-prey or competition relationships; modification to the structural habitat (e.g. damage to benthic habitats through certain fishing gear use); and consequences of by-catch (e.g. increasing abundance of scavenging species) (Gislason, 2001).

This section reveals that the main approaches to defining ecosystem structure are either analytic (describe considerable detail) or synthetic (where information is combined either under categories or within integrated measures).

3 Definitions of ecosystem function

This section compares the different definitions for ecosystem function. Some definitions focus on the role of biodiversity, while others describe abiotic and biotic processes. It may be possible to define a series of categories (based on ecosystem function) which could be broken down into further divisions (i.e. indicators or indices). This would need to take account of important concepts such as ecosystem resilience and potential ‘changes of state’; long-term changes; smaller changes that cause degradation but may not lead to any initial loss in ecosystem function; and the linkages between ecosystem structure and function.

Some of the questions that arise for discussion include:

- Is ecosystem function directly related to biodiversity?
- What properties and processes describe ecosystem function?
- What type of classification scheme for ecosystem function could be understood across different ecosystems at different scales?
- How does ecosystem function relate to goods and services?
- Should structure come first in describing an ecosystem, or should ecosystem functions precede this before the biological and physical elements are described?
- How can we visualise the linkages between structure and function?

For simplified feedback questions on ecosystem function please see Section C of the Feedback questionnaire (Annex 1). For further details on the references please see Table 10 in Annex 2, page 20.

3.1 The Biodiversity-Function Debate

There is an ongoing debate on the contribution of biodiversity to ecosystem functioning. It is often assumed that biodiversity contributes directly to ecosystem function and a number of hypotheses³ relate to this, although it is difficult to illustrate in practice. Some approaches (e.g. Bremner et al., 2006 [1]; Hiscock et al., 2006 [2]) identify key ‘biological traits’ that contribute to ecosystem function (see Table 3 for examples). These approaches tend to use the following summary definition of ecosystem function by Naeem et al., 2004, which emphasizes the role of biological species and habitats to functioning: *‘the activities, processes or properties of ecosystems that are influenced by its biota.’*

Table 3 Biological Traits identified as indicators of functioning

1 Maximum size	10 Living location	19 Defence mechanisms
2 Growth rate	11 Body form/exposure potential	20 Movement type
3 Longevity	12 Degree of flexibility	21 Mobility
4 Time to maturity	13 Attachment degree	22 Migration
5 Reproductive method	14 Attachment strength	23 Sociability
6 Fecundity	15 Resource capture method	24 Predictability
7 Propagule dispersal	16 Food type	25 Recruitment variability/success
8 Body design	17 Energy transfer efficiency	26 Biogenic habitat provision
9 Living habit	18 Tissue components	27 Scale of habitat provision

Source: Bremner et al., 2006 [1]

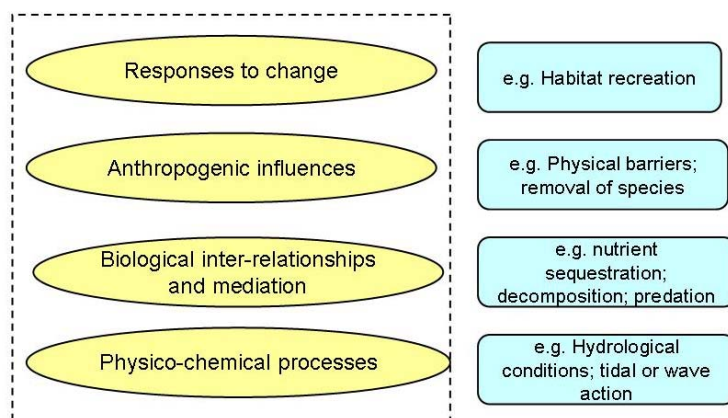
³ The *redundancy theory*, where biodiversity provides an insurance policy and a buffer to future change; the *rivet popper theory*, where function may change when specific species or groups of species are lost; and the *idiosyncratic hypothesis*, where function changes with changes of species richness but the direction and magnitude of change cannot be predicted (Robson et al., 2006).

Other authors suggest that species should be considered within their functional groups irrespective of their taxonomic affinities (Hughes et al., 2005 [9]), and important ecosystem functions should be identified first, before the contributing biodiversity characteristics (Robson et al., 2006 [5]). A practical example is provided by Pasquer et al. (2004) [12] who review the biological carbon pump, and examine the structure and function of four species of phytoplankton and their role in the process. Another example from the fisheries management literature (described in Goodman et al., 2002) involves the identification of significant food web interactions, before considering the ‘habitat needs’ of the organisms involved in these interactions throughout their life history stages.

3.2 Processes and Properties

Elaborating beyond biodiversity, some definitions consider the physical, chemical and biological properties and processes which contribute to ecosystem function (Elliot et al., 2006 [3]; Hiscock et al., 2006 [2]). Functioning within ecosystems is often referred to as processes, or groups of processes, that link different structural elements together: for example the transfer of energy up the food chain (a biotic process), or the flow of water with the tide (an abiotic process). Elliot et al., 2006 [3] suggest that these processes can be categorised hierarchically into four types, as illustrated in Figure 2. They also suggest that the importance of these processes is different for different habitats. For example, wave energy is an important physico-chemical process within inter-tidal ecosystems, but is less important in estuaries.

Figure 2: Hierarchical categorisation of processes



Source: adapted from Elliot et al., 2006 [3]

Other definitions distinguish between ecosystem properties and processes, (Hiscock et al., 2006 [2]), as illustrated in Table 4, and provide another way of categorising ecosystem functions.

Table 4 Properties and processes in marine ecosystems

Properties		Processes
Large Scale	Community level	
Temperature range	Assemblage (biotope)	Water quality affected by movement of water masses Gas exchange Nutrient exchange Primary and secondary production Bioturbation Reef-building, and Propagule dispersal brought about by movement of water masses Sedimentation
Salinity including maxima and minima	composition	
Substratum type	Trophic structure	
Light regime	Resilience	
Turbidity	Resistance	
Residual current strength and direction		
Strength of wave action		
Strength of tidal streams		
Stratification of the water column		
Nutrient status, and		
Contaminant levels		

Source: Hiscock et al., 2006 [2]

3.3 Integrated measures of ecosystem function

There are also approaches to identify gross measures of ecological processes by calculating energy budgets and fluxes. Rogers et al (2007) [10] suggest that the most important indicators of function and processes are those that involve one or more of the ecosystem components (e.g. trophic links; mass or energy flux). Diaz & Cabido (2001) also define function as: '*the flow of energy and materials through biotic and abiotic components of the ecosystem*'. An example of applying this in practice is provided by Vassallo et al. (2006) [8] who use thermodynamic and network analysis to assess environmental quality of coastal ecosystems.

Other integrated measures of ecosystem function involve the use of indices. Within the US National Coastal Condition Report (EPA 2004) structural and functional parameters are integrated into five primary indices, namely: water quality index, sediment quality index, benthic index, coastal habitat index, and fish tissue contaminant index. Integrated ecosystem models provide another approach. Models such as EcoPath (Christensen & Walters, 2004) have developed from the measurement of mean trophic level (as described in the structure section). A number of different inputs such as diet composition, production and consumption of the species in question are required as inputs, so the model can provide indices estimates including energy efficiency, ascendancy and effectiveness of nutrient cycling. In a similar way Ecological Network Analysis (ENA) allows the integration of different parameters for ecosystem structure and quantifies aspects of the ecosystem such as competition, energy transfer, nutrient cycles, recycling, and resilience.

Resilience is also often considered an integrated indicator of an effectively functioning ecosystem (Elliot et al., 2006 [3]; Dernie et al., 2006 [4]; Hughes et al., 2005 [9]), although it may be difficult to measure in practice. One option, however, would be to measure the time ecosystems take to recover following a disturbance. A related concept is that of 'ecosystem health' which has been used in, amongst other places, the Large Marine Ecosystem approach to monitoring. This essentially involves measuring a response of the ecosystem to some human intervention, such as pollution, as an indication of the impact on the efficient functioning of the ecosystem, which is an aspect of its resilience. This is largely taking the ecosystem and its function to be a black box with the measured impact response parameter being an integrated signal of the net changes to function caused by the perturbation.

3.4 Ecosystem goods and services

Ecosystem goods and services are considered by some as good indicators of ecosystem function. The UK BRAG report (Robson et al., 2006 [5]) uses the following definition of ecosystem function which focuses on processes that benefit humans: '*...the capacity of natural processes and components to provide goods and services that satisfy human needs directly or indirectly...*'

Within this report, the services provided by biodiversity are categorised into four areas: *Provisioning services* which provide food; *Regulatory services* providing stability (e.g. salt marshes reduce shore erosion); *Cultural Services*; and *Supporting Services*: support at key life-cycle stages (e.g. sea grass habitats providing fish nurseries). In a similar way Frid & Paramour, 2006 [7] and Laffoley et al., 2006 [11] provide examples of ecosystem goods and services (Table 5)

Table 5 Comparison of identified ecosystem goods and services

Frid & Paramour, 2006 [7]	Laffoley et al., 2006 [11]		
<ul style="list-style-type: none"> - Atmospheric gas assimilation and climate regulation - Nutrient recycling (including store of CO₂) - Changes to waste assimilation - Habitat functions - Food provisions - Biodiversity for society 	Biodiversity benefits <ul style="list-style-type: none"> - Provision of spawning conditions & habitats - Resilience - Future use of species - Recreation - Flood & storm protection - Biogeochemical cycling - Waste degradation; - Gas & climate regulation 	Economic benefits: <i>Direct</i> <ul style="list-style-type: none"> - Raw materials - Food & employment - Genetic resources - Medical resources - Ornamental resources - Spiritual & cultural values - Education opportunity - Coastal tourism - Recreation - Physical environment - 	<i>Indirect:</i> <ul style="list-style-type: none"> - Flood & storm protection - Nutrient cycling - Climate regulation - Bioremediation of waste Functional habitats

Elliot et al. (2006) [3] consider ecosystem services to be ecosystem functions that lead to direct benefits for humans. There is therefore some overlap between identified functions and identified goods and services (Table 6, overleaf). Nutrient regeneration, for example, is described as an ecosystem process in Dernie et al. (2006) [4] and as an ecosystem service in Frid & Paramour (2006) [7]. There is concern that focusing entirely on a goods and services approach may overlook important ecosystem functions that are not directly used by humans, but that may be important for the overall resilience of the ecosystem, such as the role of sea-grass and algal beds in nutrient cycling (Hiscock et al., 2006 [2]).

3.5 Linkages between structure and function

Ecological structure and function are intrinsically linked and some definitions provide examples on how they interact. Bremner et al. (2006) [1] point out how habitats that may be similar in their physical structure are different in their ecological function due to the hydrological regime or import/export processes. In a similar way, Hiscock et al. (2006) [2] explain how processes act together to influence the properties and structural elements of marine ecosystems. Some of these processes may be on a large scale. For example, the water currents around the UK have implications for the type of ecosystems that exist, and the recovery of habitats following disturbance (i.e. currents carrying ‘replacement’ larvae).

Elliot et al. (2006) [3] describe three different ways that structure and function interact.

Environment-Biology	Where the physico-chemical system creates the niche for organisms e.g. reduced water currents allow muddy substrata
Biology-Biology	Where resultant community is modified by biological processes e.g. predation and competition
Biology-Environment	Where biology influences physio-chemical system e.g. import or export of materials such as nutrients

Table 6 Comparison of the elements identified as ecosystem function and ecosystem goods and services

Reference		1	2	3	4	5	6	7	11	
		Bremner et al., 2006	Hiscock et al., 2006	Elliot et al., 2006	Derric et al., 2006	Robson et al., 2006	Vierros et al., 2006	Frid & Paramour, 2006	Laffoley et al., 2006	
		Functions					Services			
Abiotic	Energy cycling/transfer									
	Nutrient cycling/regeneration									
	Abiotic habitat provision									
	Tidal flow									
	Flushing rate/fresh water input									
	Heat flux									
	Residence time of a water mass in an estuary									
	Erosion-deposition cycles (of sediment)									
	Gas assimilation & climate regulation									
	Waste assimilation/degradation									
Biotic	Biotic habitat provision									
	Diversity									
	Growth									
	Primary production									
	Plankton									
	Benthic organisms									
	Predation									
	Decomposition									
	Food supply									
	Productivity									
	Spawning conditions									
	Habitat provision									
	Adult immigration & emigration									
	Modification of physical processes									
Human activities	Future use of species									
	Recreation									
	Flood & storm protection									
	Raw materials									
	Employment & Tourism									
	Genetic & medical resources									
	Cultural values									
	Education/Science									
	Fisheries & aquaculture									
	Oil & Gas									
	Mining									
	Cables									
	Shipping									

Note: The elements provided here are only examples provided in the references. The authors may recognise a much larger array of functions.

4 Applying concepts of structure and function to issues of scale

Marine monitoring currently takes place at a range of different scales, ranging from water body (Water Framework Directive) and protected areas (Habitats Directive) at a local scale to ocean level processes. Before planning marine monitoring it is often necessary to identify the ecosystem to be monitored and determine the scale at which monitoring needs to take place.

There are therefore the following related questions:

- What are the main challenges of describing ecosystem structure and function at different scales?
- What is the most useful definition of structure and function that can be applied at the local, national and regional scales?
- What definitions of structure and function allow us to integrate elements of different dimensions of the ecosystem e.g. the water column, benthic or pelagic environment?
- Can concepts of structure and function be used to i) define ecosystem boundaries for monitoring and ii) describe the ecosystem once the boundaries have been defined?

4.1 Challenges of Scale

A key challenge in marine monitoring is the range of disciplines and sectors involved, and the different scales at which they understand marine ecosystems. While benthic ecologists work at the level of species or habitats (while taking into consideration larger scale processes), oceanographic studies often consider ocean-level processes over a large scale. The different dimensions of the marine environment (water column, benthic and pelagic environments) are often difficult to understand in an integrated manner.

Ecosystems also have ‘moving boundaries’. While some habitats may stay relatively stable and consistent over time (e.g. communities on rocky substratum); other systems (e.g. pelagic) can be highly variable. Changes can occur in the short-term with changes in currents or in line with decadal shifts. Some species inhabit different scales of the ecosystem at different stages of their life-cycles, such as a pelagic state during larval stages and a benthic existence as an adult.

4.2 Application of structure and function definitions to different scales

The definitions that have been described so far have been used at a variety of scales (See Table 9, page 16). At one end of the spectrum, Bremner et al. (2006) [1] uses ecological structure and function to describe habitats within special areas of conservation (SACs) on a local scale. At the other end of the spectrum, Vassallo et al. (2006) [8] investigate the ocean level biological carbon pump, but through investigating the structure and function of micro-organisms (phytoplankton).

A number of papers suggest the need for *nested scales* where units of measurement start at the individual cell or species level and build up to encompass an ecosystem. The range of approaches is illustrated in Figure 3. The World Bank (2006) gives details on management zones beginning with community Marine Protected Areas

(MPAs) building up through biosphere reserves and finally to Large Marine Ecosystems (LMEs). Laffoley et al (2006) is also more focused on management zones rather than the strictly ecological units provided in the Australian and Netherlands models and the biological organisation reformulated by Elliot et al. (2006) [3].

Figure 3 Different approaches to the nested scales of ecosystems

Provinces	Eco-zone: >62,500km ²	Ecosystem	Wider Seas	Large Marine Ecosystem (LME)
	Eco-province: 2,500-62,000km ²			Integrated Coastal Zone Management (ICZM) (zoned seascape)
Biomes	Eco-region:100-2500km ²	Community	UK Regional Sea	Biosphere Reserve
Geomorphic units	Eco-district:625-10,000ha		Component Landscape	Habitat
1 ^o biotopes (different assemblages)	Eco-section:25-625ha	Population		
2 ^o biotopes (different substratum)	Eco-series:1.5-25ha		Individual	
Biological factors/species	Eco-tope:0.25-1.5ha	Cell		
	Eco-element<0.25ha			

Australian model Netherlands model Elliot et al, 2006 Laffoley et al, 2006 World Bank, 2006

Note: The relationship between these different approaches has been estimated.

A key consideration is whether definitions of structure and function can be used, at each of these levels, to describe the important components of the ecosystem. There is the danger that narrow definitions may leave out important aspects of the ecosystem. For example a focus on species assemblages or abiotic processes at a habitat level may not consider processes such as decadal shifts in water currents. Another important question is whether monitoring can be matched with management units. There may not be an issue where management areas fully represent the ecosystem, but could present problems where management areas are aligned with resource use and do not constitute sensible monitoring areas or do not allow an understanding of the entire system.

4.3 Using structure and function to define marine ecosystem boundaries

There is a range of current or proposed options for defining the boundaries of ecosystems within the UK waters, as summarised in Table 7 below, and detailed in Table 11 (in Annex 2, page 22) and in the Figures in Annex 4. While it is not the focus of this paper to reach consensus on these boundaries, it is interesting to consider whether structure and function are useful concepts for both defining areas, and monitoring defined ecosystems.

Table 7 Different approaches to defining ecosystem boundaries in the UK marine environment (Note: For more detail see Table 11 in Annex 2)

Approach
Special Areas of Conservation [A]
UK Regional Seas [B]
OSPAR Areas [C]
ICES Fishing blocks [D]
ICES Eco-regions [E]
EU Marine Strategy [F]
Bio-geographical regions (EU) [G]
Marine Eco-regions [H]
Self Organising Maps [I]
Large Marine Ecosystems (LMEs) [J]

The majority of approaches above use elements of ecosystem structure to define ecosystem boundaries. For example, physical components - such as temperature, depth and water currents - are used to define the UK Regional Seas. Hydrological, oceanographic and bio-geographic elements are used to define areas proposed in the EU Marine Strategy Directive. Other areas may have been defined along political boundaries (e.g. OSPAR areas); according to stakeholder use (Vierros et al., 2006 [6]); or based on areas suitable for management (e.g. ICES Fishing blocks).

By contrast, a wider range of information is often required to describe the ecosystem once its boundaries have been defined. The Large Marine Ecosystem (LME) approach (Duda & Sherman, 2002) requires monitoring that covers biological and physical attributes of the ecosystem, as well as socio-economic and governance elements. Within each of these modules a series of indicators is identified (Table 9). Some of these require measurement of abundance or species presence (e.g. biodiversity), while others measure composite indexes such as 'health indices'. The LME approach is currently used at a global level to define very large areas of ocean. An interesting consideration is whether similar modules can be used to categorise ecosystems monitoring at the UK level.

Table 8 Modules (Categories) used within the LME approach

1) Population & Ecosystem Health Module	3) Socio-economic module	5) Governance Module
<ul style="list-style-type: none"> • Eutrophication • Bio toxins • Pathology • Emerging disease • Health indices 	<ul style="list-style-type: none"> • Human forcing • Sustainability of long-term socioeconomic benefits • Integrated assessments 	<ul style="list-style-type: none"> • Adaptive management • Stakeholder participation
2) Productivity Module	4) Fish & Fisheries module	
<ul style="list-style-type: none"> • Photosynthetic activity • Zooplankton biodiversity • Oceanographic variability 	<ul style="list-style-type: none"> • Biodiversity • Finfish • Shellfish • Demersal species • Pelagic species 	

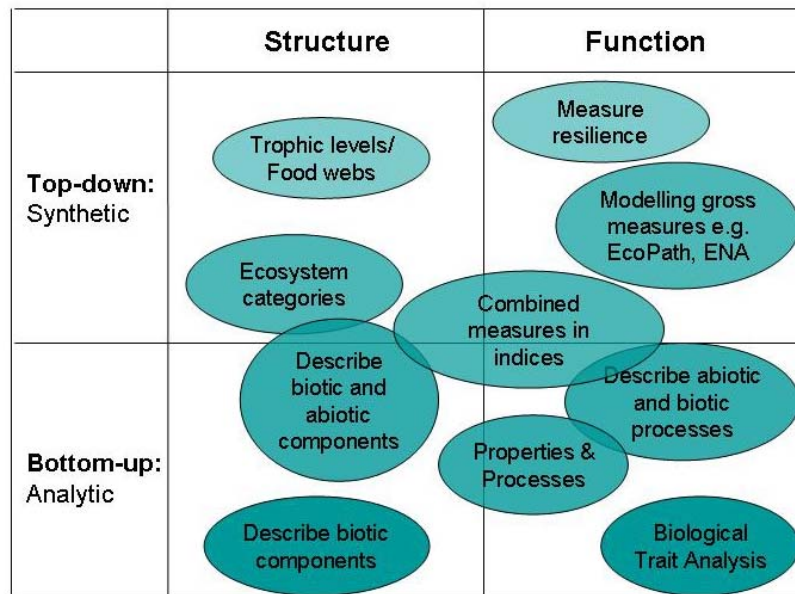
There are only a few approaches that use ecosystem function to define ecosystem boundaries. One example is the use of Self Organising Maps (SOMs⁴) which model functional components (as well as structural components) and develop maps that illustrate areas with similar functioning characteristics. SOMs can be used to rapidly identify regions of similarity and can address potential short-comings of administrative zones that do not represent ecosystem functionality.

⁴ Also see UNEP 2006 www.unepwcmc.org/resources/publications/UNEP_WCMC_bio_series/27.htm

5 Comparison of definitions to structure, function & scale

This document has provided an overview of the different approaches and definitions to ecosystem structure and function. The range of models that have been described are summarised in Figure 4.

Figure 4 Range of models for defining ecological structure and function



At one end of the spectrum there are bottom-up approaches where each element of the ecosystem is described in detail, and due to the detail is most often used at the local scale. At the other end of the spectrum there are a range of top-down approaches that attempt to integrate elements of the ecosystem into a reduced number of parameters, or group attributes under broader headings or categories (for example the LME approach). Some of these approaches are more synthetic than others, for example grouping attributes into categories that cover large regional scales may still allow considerable detail within each category. In contrast some modelling approaches synthesize all ecosystem processes into one or two measures, such as energy flow. Alternatively indices are also used that combine different aspects of structure and function, but require a judgement on what is considered important within different environments.

Monitoring at a local scale often focuses on the biological structure of the ecosystem and considers function as an influence of the biodiversity present. However there are also approaches that consider the biological, chemical, and physical processes that make up ecological function. A key question is whether structure or function provides the initial framework. Some definitions investigate important functions of an ecosystem and then consider how biodiversity contributes to this. Others suggest that the goods and services should be identified first before structural elements are described. However, it is worth noting that while the goods and services approach is probably of primary interest to policy makers, it may ignore important process of the ecosystem that underpin efficient and resilient functioning.

There is a move towards spatial management of the marine environment, which will need to be supported by marine monitoring. Structure and function have been used in varying degrees to define marine 'eco-regions', and a range of different zoning techniques have been suggested for UK and European waters. An interesting consideration is whether the use of structure and function may improve zoning for marine monitoring.

Each of the definitions mentioned has advantages and disadvantages when using them practically at different scales and for different ecosystem components. For example biological trait analysis is particularly effective for assessing habitats, but may not be suitable for monitoring ecosystems on a regional sea level. The challenge will be to determine whether there is an effective way of combining the bottom-up and top-down approaches so that we are able to sufficiently monitor detailed elements of significant habitats, but also scale-up monitoring or assessments to provide information to managers at the ecosystem level. It may be necessary to develop a worked example of how definitions of structure and function can be practically applied at a range of scales and environments.

Table 9 overleaf (p.16) also provides further analysis of the different approaches and illustrates which models the different references fall into. This categorisation is to some extent subjective, so we welcome your feedback on this.

Table 9 Comparison of different definitions of structure and function monitoring and mapping ecosystems

	Definition of Structure & Function	Structure				Function				Scale				
		Biological (Biotic)	Biotic/Abiotic	Integrated Categories	Trophic Levels	Biodiversity focus	Properties Processes	Integrated measures	Goods & Services	Local	Sub-Regions (within UK)	UK-wide	European	Global
1	Bremner, Paramour & Frid, 2006	■				■				■				
2	Hiscock et al., 2006		■			■	■			■				
3	Elliot et al., 2006		■				■	■			■			
4	Dernie et al., 2006		■				■				■			
5	Robson et al., 2006 (BRAG UK)	■							■	■				
6	Vierros et al., 2006		■						■			■	■	
7	Frid & Paramour, 2006			■					■		■	■		
8	Vassallo et al., 2006		■					■						■
9	Hughes et al., 2005					■								
10	Rogers et al., 2007			■				■	■		■			
11	Laffoley et al., 2006		■	■					■			■		
12	Pasquer et al., 2007	■				■							■	■
13	Pauley et al., 1998				■									■
	Use of structure & function to define ecological zones	Structure				Function				Scale				
		Political or Administrative boundaries	Biological (Biotic)	Biotic/Abiotic	Integrated Categories	Trophic Levels	Biodiversity focus	Properties Processes	Integrated measures	Goods & Services	Local	Sub-Regions (within UK)	UK-wide	European
A	SACS		■	■			■				■			
B	UK Regional Seas			■							■	■		
C	OSPAR Regions	■								■	■			
D	ICES Fishing boxes	■										■	■	
E	ICES Eco-Regions ⁵		■	■	■	■			■		■			
F	EU Marine Strategy			■							■	■	■	
G	Bio-geographical regions								■					■
H	Marine Eco-regions (MEOW)								■					■
I	Self Organising Maps		■	■				■			■			
J	LMEs		■	■	■	■		■	■		■			■

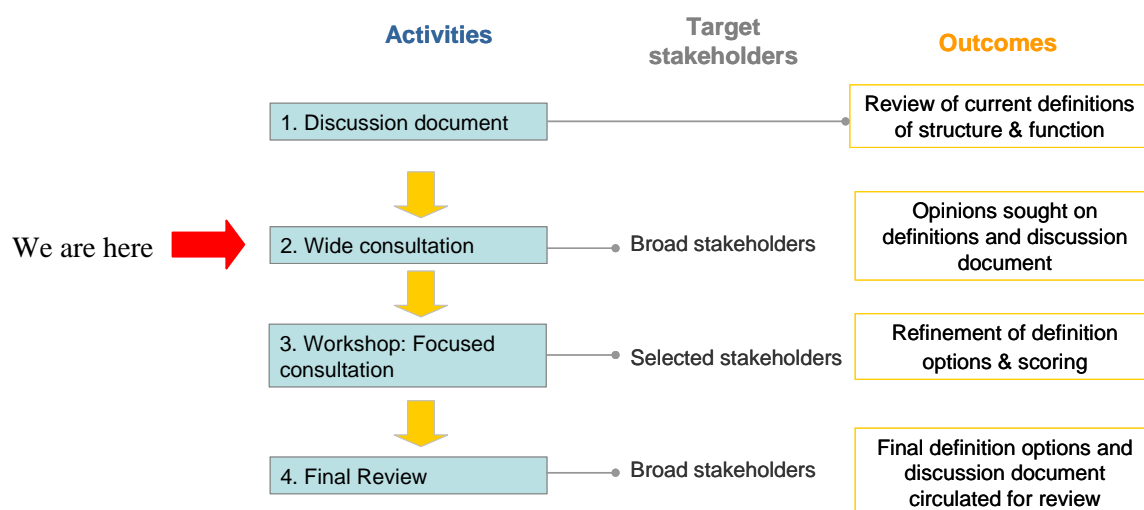
6 Annex 1: Your Feedback

6.1 Introduction

6.1.1 Why do we want your feedback?

This is a *discussion document* to stimulate debate. We would like it to evolve and reflect current uses of ecological structure and function. The document is by no means exhaustive. We invite you to identify gaps or biases in the report and provide your comments. It is intended to be a collaborative work that results in consensus and we welcome a lively debate.

6.1.2 What is the process of consultation?



6.1.3 Where to send your feed-back?

Please send your comment by 31st May either by email, fax, post (or verbally) to:

Charlotte Howard
c.howard@mrage.co.uk
Tel: ++(0)207 255 7776
Fax: ++(0)207 499 5388

MRAG Ltd
18 Queen Street
London
W1J 5PN

6.2 Questions

Please review the questions below to frame your comments. You can either use these tick boxes to give your comments, or feel free to give your opinions in another format. The questions cover the following:

- A) *General questions*
- B) *Specific questions on ecosystem structure*
- C) *Specific questions on ecosystem function*
- D) *Your opinions or comments on this discussion document*

FEEDBACK FORM

A) General Questions

A1	Name	
A2	Organisation	
A3	Email address	
A4	Your area of expertise	
A5	The scale(s) you work at	

A6) Are concepts of structure and function useful for marine monitoring?

Yes	No	Please explain

B) Questions on Ecosystem Structure

B1) Should a definition of ecosystem structure include a breakdown of the biotic and abiotic elements of ecosystem structure?

Yes	No	Comments

B2) Should a definition categorise structural elements by their functional role in the ecosystem?

Yes	No	Comments

B3) Do you have a preferred definition of ecosystem structure?

Yes	No	Provide details

C) Questions on Ecosystem Function

C1) Should a definition of function include a breakdown of the biotic and abiotic processes?

Yes	No	Comments

C2) Should function be measured using integrated characteristics such as energy flow?

Yes	No	Comments

C3) Should a definition of ecosystem function focus on ecosystem goods and services?

Yes	No	Comments

C4) Should ecosystem function be split into properties and processes?

Yes	No	Comments

C5) What aspects do you think should be used within a practical definitions of structure and function?

Structure			Function			
Biological (Biotic)	Physical (Abiotic)	Wider categories	Biodiversity	Properties & Processes	Integrated measures	Goods & Services

C6) Do you have a preferred definition of ecosystem function?

Yes	No	Provide details

D) Your comments on this discussion document

D1) What additional definitions or approaches that should be considered in this discussion document?

D2) What other literature should be considered?

7 Annex 2: Detailed Comparison Tables

Table 10 Comparison of structure and function definitions used in marine monitoring (Definitions are summarised and columns are blank where no information in the reference is provided)

Reference	Structure	Function	Spatial Scale	Temporal Scale
1 Bremner, Paramour & Frid, 2006	<ul style="list-style-type: none"> - <i>Taxonomic composition</i> of communities - Biological diversity - Presence of specific habitats or species 	Activities, processes or properties of ecosystems that are influenced by its biota <i>Naeem et al. (2004)</i>	Applied to SAC areas	
2 Hiscock et al, 2006	<ul style="list-style-type: none"> - <i>Architectural structure</i>: Non biological - <i>Community structure</i>: Biological (relative abundance of species) NB: overlap between abiotic & biotic	Mode of action by which the system fulfils its purpose or role, as determined by its component elements. Ecosystems functioning mediated by <i>activities of species</i> and species that provide critical services are <i>key functional species</i> . Also refers to: Activities, processes or properties of ecosystems that are influenced by its biota <i>Naeem et al. (2004)</i>	<i>Nested approach</i> : ecosystems can be large as the north sea and small as bacterial in the gut of a fish NB: <i>Connectivity</i> between ecosystems	<ul style="list-style-type: none"> - <i>Seasonal variation</i>: presence & absence of species - <i>Long-term variation</i>: cyclic patterns
3 Elliot et al, 2006	<ul style="list-style-type: none"> - <i>Composition of the biological community &</i> - <i>Quantity and distribution of the abiotic materials</i> NB: overlap between abiotic & biotic	The rate (higher-level) processes within and between structural components within an ecosystem. A healthy ecosystem is one that functions well and has capacity to resist or recover from disturbance: <i>resilience</i> .	<i>Nested approach</i> : Units of measurement: <ul style="list-style-type: none"> - Cell; - Individual; - Population; - Community; - Ecosystem 	
4 Dernie et al, 2006	<ul style="list-style-type: none"> - Abiotic & - Biotic factors 	Processes, or groups of processes, that link different structural elements together. 1) <i>Physical & chemical environmental processes</i> e.g. pH, salinity, stratification 2) <i>Biological mediated processes</i> e.g. predation, competition 3) <i>Marine food webs</i> , productivity & nutrient cycling The ability for a ecosystem to maintain its structure and functional integrity when subject to stressors is described	<i>Nested approach</i> : of seas in wider regional seas context	

			<i>as resilience</i>		
5	Robson et al, 2006 (BRAG UK)	- Biodiversity	The sum of all natural processes within the ecological subsystems.	Recognises that ecosystems operate at many spatial & temporal scales	
6	Vierros et al, 2006			Units of measurement: Spatial areas defined by <i>stakeholders use of space</i>	Map <i>stakeholder-use</i> over time
7	Frid & Paramour, 2006	- Species & Habitats	Processes and activities that keep a system working. Activities, processes or properties of ecosystems that are influenced by its biota <i>Naeem et al. (2004)</i>	Units of measurement: <i>Marine landscape types</i>	Evidence for changes needed on <i>long time frames</i>
8	Vassallo et al, 2006	- Biodiversity - Abiotic & Biotic components linked to ecosystem function	Flow of energy and matter between interdependent biotic and abiotic components.		
9	Hughes et al, 2005		Dynamic and complex processes that support or undermine resilience		
10	Rogers et al, 2007	- Species - Habitats; - Physical & chemical components	Important properties of ecosystem: resilience; persistence & productivity Ecosystem function and processes that involve one or more of the ecosystem components: trophic links, mass/energy flux etc	<i>Unit of measurement:</i> Separate management regions need to be identified using boundaries of physical and biological processes	
11	Laffoley et al, 2006	- Biological communities		<i>Nested scales</i> - Wider sea - Regional sea - Component landscape scale - Habitats	<i>Elements discussed:</i> - Irreversible changes - Past impacts, shifting baselines - Long-term political ambition
12	Pasquer et al, 2007	- Abundance; - Diversity - Influencing factors: light & nutrients	Functioning of species e.g. role of phytoplankton in biological carbon pump		

Table 11 Different approaches to ecosystem scale (and mapping) and their relation to concepts of structure & function (columns are blank where no information in the reference is provided)

	Approach	Reference	Scale	Categories that are used to define this area	Are concepts of structure & function used in defining the area?
A	Special Areas of Conservation (SACs) (NB – SACs + SPAs = Natural 2000 sites; terrestrial SACs & some inter-tidal/estuaries = SSSIs)	Protected areas extracted from World Database on Protected Areas (WDPA) in April 2007 supplied by UNEP World Conservation Monitoring Centre (UNEP-WCMC) (WDPA custodian).	Initially land-area and territorial seas (out to 12nm), now extended to 200nm. (work underway to identify offshore SACs & SPAs)	Annex 1 habitats: - Representatively; - Relative area of habitat; - <i>Conservation of structure & function</i> - Global assessment Annex 2 Species: - Proportion of UK population - Conservation of important features for species - Isolation of species; - Global assessment Additional principles: - Priority status - Rarity - Geographic range - Special UK responsibilities - Multiple interest	Structure and Function is used as part of the criteria to select Annex 1 habitats. The relevance of both criteria depends on the habitat.
B	UK Regional Seas	Vincent et al, 2004 (JNCC Report)	Modified from ICES fishing boxes and regional seas defined by OPSAR (overlap with waters of neighbouring countries) RS1 Northern North Sea RS2 Southern North Sea RS3 Eastern Channel RS4 Western Channel & Celtic Sea RS5 Atlantic South West Approaches RS6 Irish Sea RS7 Minches & WesternScotland RS8 Scottish Continental Shelf RS9 Faroe-Shetland Channel RS10 Rockall Trough & Bank RS11 Atlantic North West Approaches	- Temperature - Depth - Currents	Physical attributes (temp, depth & current) are the main concepts used to define the regional sea areas.
C	OSPAR areas (NBN Gateway)		North-east Atlantic further divided into: OB1 Arctic (deep sea) OB2 Atlantic (deep sea) OB3 Boreal (shelf & slope) OB4 Boreal-Lusitanian (shelf & slope)	Politically defined areas	Areas used to monitor biodiversity and marine pollution against the objectives of the convention

Approach	Reference	Scale	Categories that are used to define this area	Are concepts of structure & function used in defining the area?
		OB5 Lusitanian-Boreal (shelf & slope)		
D	ICES Fishing areas http://www.fishonline.org/information/maps/ices.php Created by the Danish Institute for Fisheries Research (DIFRES). ICES 29 November 2006 Hans Mose Jensen	ICES Areas (or boxes) labelled from I to XVI. The various ICES Areas are also sub-divided into rectangles that can allow further disaggregation of the data.	- Selected areas for aggregating fisheries data	Neither structure nor function is used to define the areas.
E	ICES Eco-regions (proposed) Created by the Danish Institute for Fisheries Research (DIFRES). http://www.ices.dk/marinenewworld/fishmap/ices/ (CEFAS)	Greenland and Iceland Seas Barents Sea Faroes Norwegian Sea Celtic Seas North Sea South European Atlantic Shelf Western Mediterranean Sea Adriatic-Ionian Seas Aegean-Levantine Seas Oceanic northeast Atlantic	- Contours of and the integrity of regions shelves - Taking into account existing political, social and economic management divisions	Biological structure is not used to define the area, but is used to describe the ecosystem once the boundaries are mapped. Categories of structure include: Oceanographic/Biographic/Ecology Physical •Salinity & stratification •Circulation & transport Biological •Phytoplankton •Fish/shellfish •Seabirds •Marine mammals Habitats •Coastal habitats •Offshore habitats •Deep-sea habitats Impacts are also mapped e.g.: Hazardous substances; Eutrophication; •Fishing activities; Maritime transport; Offshore gas; Climate Change; Habitat disturbance; Litter
F	EU Marine Strategy Directive EU Parliament & Council Proposal COM (2005) 505 final SEC (2005) 1290	Marine sub-regions of North East Atlantic: - Greater North Sea including Kattegat; English Channel, marine waters of Belgium, Denmark, France, Germany, Netherlands, Sweden & UK - Celtic Seas : marine waters of UK & Ireland	Stated as using hydrological, oceanographic & bio-geographic aspects.	Within these areas required to monitor: - Physical & chemical elements : bathymetric; temp; currents; salinity - Habitat types : physical & chemical characteristics, mapped special habitat

Approach	Reference	Scale	Categories that are used to define this area	Are concepts of structure & function used in defining the area?	
		<ul style="list-style-type: none"> - Bay of Biscay & Iberian Coast: marine waters of France, Portugal & Spain; - Atlantic Ocean: waters of Portugal surrounding the Azores & Madeira, and of Spain surrounding Canary Islands 		<p>types; other special areas</p> <ul style="list-style-type: none"> - Biological elements: description of biological communities associated with habitats (plankton, benthic & fish); Population dynamics; Abundance - Other attributes nutrient cycling; state of chemical pollution; other elements 	
G	Bio-geographical regions	Council Directive 92/43/EEC (adopted 23 rd Oct 2000)	Steppic; Pannonian; Black Sea; Boreal; Continental; Atlantic (most UK) Alpine Macaronesian Mediterranean (Gibraltar)	Temperature tolerances	
H	Marine eco-regions	www.worldwildlife.org/MEOW/	Coasts & Shelves (up to 200nm) (Does not cover pelagic or deep benthic environments) UK waters covered by three to four of the eco-regions: - 71: - 36: - 225:	Mosaic of existing and recognised spatial units (Nest within broader tiers of Realms & Provinces)	Based on current administrative or spatial units therefore not necessarily using structure or function to define the areas
I	Self-organising maps	UNEP 2006 www.unep-wcmc.org/resources/publications/UNEP_WCMC_bio_series/		Statistical methods used to recognise patterns in structure or function (Artificial Neural Networks 2: ANNs)	Can use either structure or function (process) elements to define an area Can be applied to any scale and define functional units
J	Large Marine Ecosystem (LME)	Duda & Sherman (2002) http://www.edc.uri.edu/lme/clickable-map.htm	LME: Celtic-Biscay Shelf LME: North Sea	<ul style="list-style-type: none"> •Population & Ecosystem Health Module •Productivity Module •Socio-economic module •Fish & Fisheries module •Governance Module 	

8 Annex 3: Policy drivers for the Ecosystem Approach

An ecosystem can be described as a dynamic complex of plants, animals and micro-organisms and their environment. These interact as a functional unit and can be considered in terms of both structural and functional attributes, either biotic (biological) or abiotic (non-biological).

There are a number of drivers for use of the ecosystem approach (**Table 12**).

Table 12: Drivers for the ecosystem approach

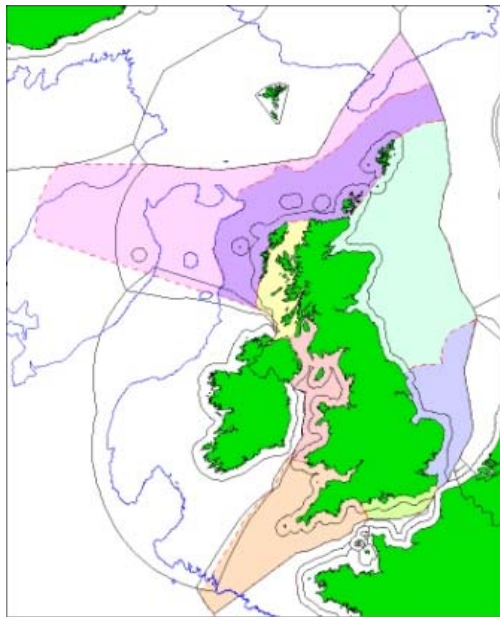
<p>Global drivers Convention on Biological Diversity (CBD, 1992): A strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.</p> <p>Regional drivers ICES defines the ecosystem approach as the integrated management of human activities based on knowledge of ecosystem dynamics to achieve sustainable use of ecosystem goods and services, and maintenance of ecosystem integrity.</p> <p>European drivers Proposed EU Marine Strategy Directive: Whereby human activities affecting the marine environment will be managed in an integrated manner promoting conservation and sustainable use in an equitable way of oceans and seas.</p> <p>National drivers UKMMAS: entails taking into consideration all elements that make up the ecosystem (physical, chemical and biological variables) as well as activities taking place there in order to ensure that biodiversity, health and integrity of the marine environment is maintained in the longer term.</p>
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A useful view of the paradigm shift to ecosystem management can be summarised below:

Individual species	⇒	Ecosystems
Small spatial scale	⇒	Multiple scales
Short-term perspective	⇒	Long Term
Humans independent of system	⇒	Humans part of ecosystem
Management unconnected to research	⇒	Adaptive management (Learning by doing)
Managing commodities	⇒	Sustainable production of goods and services

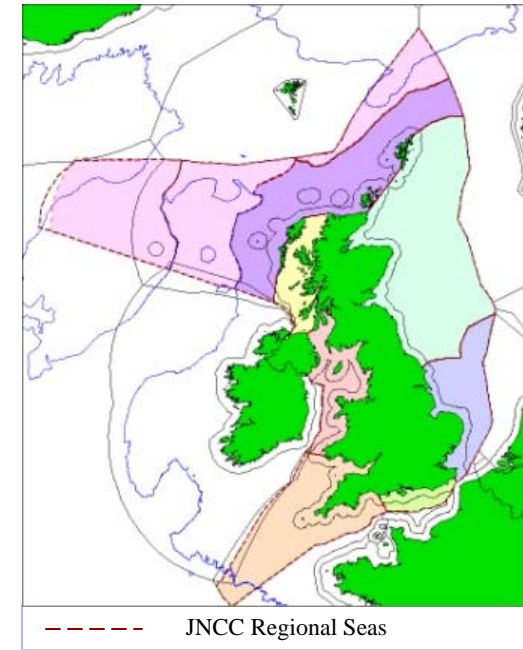
Source: NOAA

9 Annex 4: Comparison of Eco-Regions

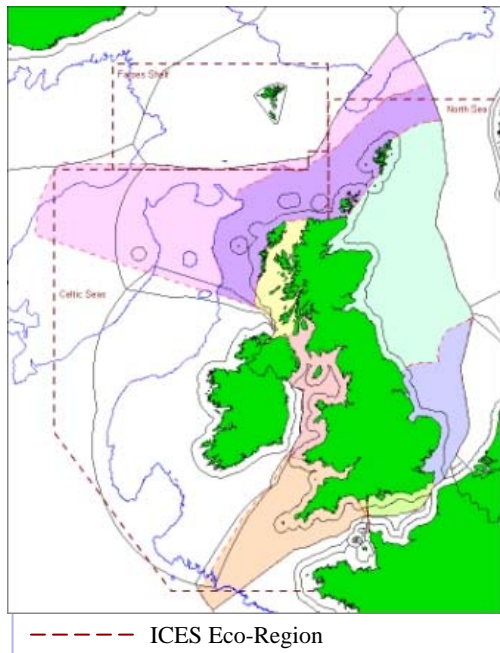


Reporting Areas for Charting Progress (Defra, 2005)

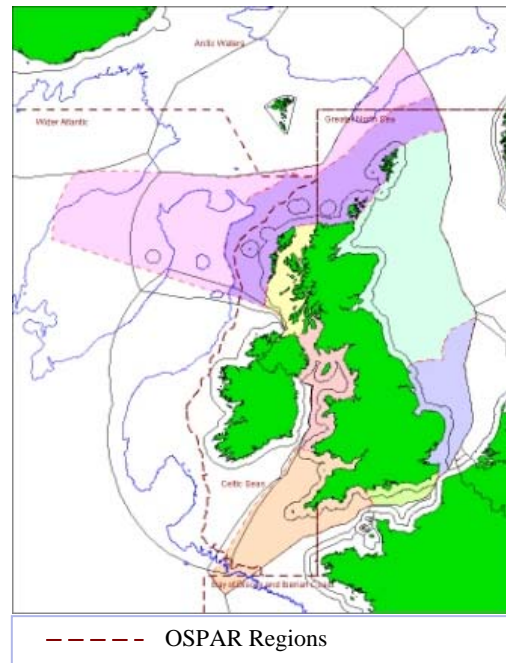
- Rockall Trough & Faeroe/Shetland Channel
Atlantic North West Approaches
 - Scottish Continental Shelf
 - Northern North Sea
 - Southern North Sea
 - Eastern English Channel
 - Western English Channel, Celtic Sea & South-West Approaches
 - Irish Sea
 - Minches & West Scotland
- 1500 depth contour
 EEZ boundaries



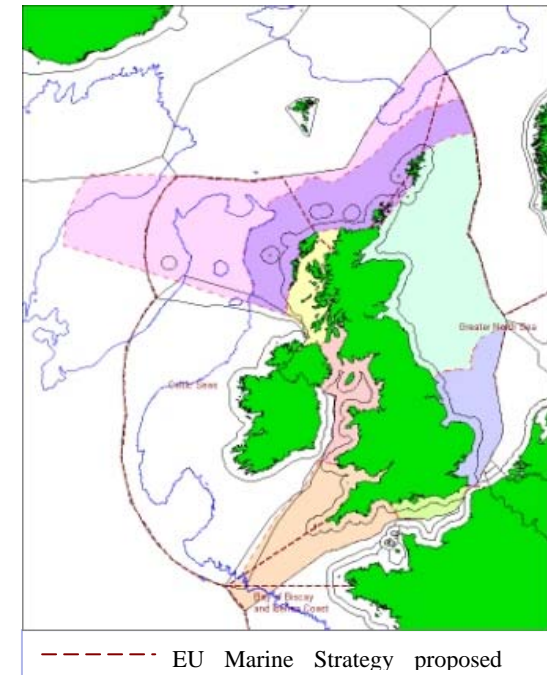
--- JNCC Regional Seas



--- ICES Eco-Region



--- OSPAR Regions



--- EU Marine Strategy proposed

10 Annex 5: References

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