A CoastNET Conference

Developing Management, Monitoring and Indicators to Deliver the Ecosystem Approach in the Coastal and Marine Environment

October 6th
SOAS University of London
Russell Square, London

Post Conference Notes: Edited by Bob Earll, CMS

Chairmen:

John Roberts	Defra
Stuart Rogers	CEFAS
Mike Elliott	IECS, University of Hull

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Introduction

There is a considerable body of work currently underway to develop indicators and monitoring programmes for the marine and coastal environment. This is being driven by Government in response to International commitments to the ecosystem approach, through the pragmatic requirements of European Directives and Policy, and initiatives such as Defra's approach to developing Marine Stewardship in offshore waters and the coastal zone. There are however a host of challenges that are to be confronted when considering the commitments required to meet this task.

The conceptual framework and challenges of application

The coastal and marine science community is now well versed in the language and methodologies of monitoring, and contributes to the sampling of a large number of attributes at a variety of scales, however, there are host of challenges on issues like cost effectiveness, duplication and adequacy of funding. An integral part of an effective management system is the use of these monitoring data for the development of indicators. Ideally these should communicate the effectiveness of management in meeting policy objectives, by identifying when features of the human or biological environment move beyond acceptable boundaries and trigger remedial management action. Work on indicators is developing fast, and an assessment of the plethora of different activities in the UK is timely. Whilst the DPSIR approach can help us understand and map what type of indicator we are measuring, there are a number of other important issues relating to indicators, particularly the need for multiple indicators to work together as an integrated set.

Current approaches to management, indicators and monitoring derive from three different conceptual strands:

1. The long standing monitoring tradition in the coastal and marine environment which has covered surveillance, monitoring point at sources and compliance monitoring.
2. The work on indicators related to biodiversity assessment that gathered momentum in the mid 1990s deriving from commitments to sustainable development at the Rio Earth Summit
3. The management systems approach is pervasive throughout society and provides a unifying language and approach to this work.

This conference will present a generic conceptual framework that clearly demonstrates the links between all the major components of policy and management, monitoring, indicators and management action, and the feedback between these elements. It will illustrate the roles and linkages of science, management and policy and the use of management tables for any attribute. The presentations will highlight a wide range of issues that relate to implementing these ideas in practice. Examples will range from the requirements of site management for nature conservation, through to the practical needs of legislative drivers such as the Water Framework and Habitats Directives.

The final session will bring together key points from these activities, and hear how Defra are progressing their work on the development of a monitoring strategy. The final discussion will explore the range of issues surrounding current monitoring activities and the parallel development of indicators, and highlight opportunities for greater collaboration in order to make best use of intellectual and financial resources.

Aim and objectives

The aim of this conference is to use a conceptual approach to marine management to help progress work on the development of management indicators and monitoring programmes that encourage their delivery in a more cost effective and co-ordinated manner. The objectives of the meeting will be to:

- Share and test the proposed conceptual structure and in particular demonstrate the links between management, monitoring and indicators,
- Focus on current UK activities on indicators and monitoring that address national and international Stewardship initiatives, and highlight the opportunities provided by the development of the Defra monitoring strategy,
- Highlight the common issues in the work of key policy sectors, and identify gaps and overlaps in coverage, the challenges of funding and co-ordination, and opportunities for greater collaboration within the science community.

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The organisers would like to thank the chairmen of the three sessions for their constructive contribution to the conference they were:

- **John Roberts** Head of Maritime and Waterways Division, Defra
- **Stuart Rogers** CEFAS
- **Mike Elliott, IECS**

Contents

Developing Management, Monitoring and Indicators to deliver the Ecosystem Approach

Delegates' Key Points

Prepared by Bob Earll, CMS, Candle Cottage, Kempley, Gloucestershire GL18 2BU
October 26th, 2004.

Introduction and Method

At the beginning of the conference delegates were alerted to the fact that their views would be sought at the end of the second session of the conference on what they saw as the **key issues to emerge** from the first two sessions of presentations. At the end of the second session delegates were asked to compile a key issues list then select ***one that they thought to be the most important***. These were written on to post-its , handed in and typed. Virtually all the delegates participated and 114 responses were obtained.

It is informative to regard each individual response to the key point question in isolation and a range of important points are made.

The responses become more interesting when grouped because they then give some sense of the weight of peoples views, relationships between views and priorities. The points have been collated into this grouped listing under some broad headings (Table 1); this is not a precise science but the groups do provide interesting information.

Table 1 The Groups of responses number under each of the main categories

Topic	Total in each category
• Integration between organisations in the way the overall approach works	12
• Integration – the need for greater collaboration co-ordination etc	19
• The approach – systematic linkage of steps	11
• Vision and high level principles: sustainable development, the ecosystem approach and ecosystems,	8
• Objectives – clarity	7
• Indicators	23
• Monitoring	6
• Communication – feedback to management	7
• Science – understanding	6
• Data	8
• Timescales	3
• Funding – costs	2
• Miscellaneous	2
	N = 114

Observations

1. Implicit in the majority of these responses to the key issue question are two ideas:

i) that there should be far greater integration (collaboration, co-operation, co-ordination) between organisations working in this area

ii) that the respondents clearly understood the linkage between steps (in the management cycle) e.g. vision – objectives – indicators – monitoring – communication – feedback. Often responses mentioned two or more parts of the management process.

2. The ecosystem approach can be taken to be a way of implementing the three pillars of sustainable development (environmental, economic and social) (Laffoley et al 2004) and / or to recognise the need to translate *ecosystem understanding* (in the scientific sense of the word) into high level decision making.

Other methodology points

- The individual contributions are identified
- The groups of similar commented are labelled
- There are some comments in square brackets which have been inserted by RE.
- Similar points have been spaced together

Key issues listing

Integration between organisations in the way the overall approach works
[Integration includes words like collaboration, co-ordination, co-operation]

1. *Leadership and clarity of purpose* based on a strategic view not a specific sectoral or 'driver' based view.
2. Co-ordination of activities. *Leadership* – to promote the above.
3. How do we develop and deliver a consistent approach to biological monitoring across agencies? Who will *lead?*

4. Co-ordination between organisations in developing indicators, understanding and combining monitoring programmes – making the most of scarce resources.
5. Co-ordinated action by the relevant agencies and authorities to ensure that the best environmental outcome is achieved using the limited resources which are available.
6. Collaborative work across organisations to produce, evaluate and implement the concept of indicators. To recognise limitations or its uses. To also review lessons learned from previous studies/post. To base information/performance or indicators on time series data sets.

7. A marine bill and some kind of *marine agency* to put all this good thinking into practice.
8. Centralise data and thinking through an *integrated marine agency* or additional forum for integrating current agencies with marine and terrestrial competencies. Make data available.

9. Develop & process to speed up the acceptance of new ideas in international policy fora.
10. Practicality – achievable goals paramount in the chaos/inertia of marine management
11. Knowing why things are being done/proposed. Too many sheep (induced by "directive fever") and not enough cunning sheepdogs.
12. It's the politics, stupid!! [Yes – I think we've spotted that!]

Integration – the need for greater collaboration, co-operation etc

13. Clear need for greater integration in a number of respects e.g.: between regulators/to incorporate social and economic objectives/between various organisations collating information e.g. OSPAR and BAP all collating info on similar species/habitats/for integrated forward planning.

14. Better co-ordination of existing initiatives to produce indicators for the marine environment.

15. Integration overlap and co-operation of the major monitoring/management agencies to implement relevant and cost-effective environmental monitoring.

16. Establish a forum for science/policy/management to establish appropriate and cost-effective monitoring strategies; quicken the process of adding science to legislation.

17. Integration of monitoring and developing WFD model for wider application.

18. Integration of multi-scale monitoring and supporting anthropogenic signals from natural/climatic variability.

19. Integrating indicators and monitoring strategies to build effective monitoring networks.

20. That all of the groups which carry out monitoring should begin to work outside their areas of direct regulatory responsibility.

21. To establish an agreed core set of UK marine indicators together with targets that will fulfil our national and international requirements – then we can effectively re-focus resources collaboratively to deliver effective management of the ecosystem.

22. The integration of the numerous organisations to deliver merchandised, useful and effectively communicable assessments techniques which can direct management to achieve sustainable development.

23. Integrating Habitats and Water Framework Directives aims for achieving 'good' status.

24. Ability to incorporate monitoring carried out as a statutory responsibility by industry/marine uses into national monitoring strategies. e.g. the use of monitoring data collected by the aggregation industry/wind farm developers.

25. Continuity in approach between the Environment Agency's WFD programme and English Nature's approach to the implementation of the habitats directive regarding favourable conditions and good ecological status.

26. [A concern] The attempt to shoe horn everything into one plan, rather than building linkages with programmes already set up (and working) for different objectives.

27. Lack of a cohesive integrated monitoring program to deliver information for directives and indicators.

28. Co-ordinating monitoring strategies to ensure limited funds/resources etc are used well.

29. Issue – how to achieve identification and implementation of a coherent UK marine monitoring programme, with strong co-ordination between bodies involved in monitoring to ensure that monitoring is targeted, fit for purpose, with appropriate indicators to meet management objectives for sustainable development (and taking into account existing monitoring commitments e.g. compliance for E U Directives).

30. Integration of water framework directive and habitats directive.

31. If the water framework directive is main tool to integrate monitoring and assessment, should we extend concept to marine waters?

The approach – systematic linkage of steps
[Vision – objectives – indicators – monitoring – communication – feedback – adaptive management]

32. Systems approach to use of indicators.

33. Recognising the value of management systems and monitoring programmes in terms of predicting and anticipating change/pressures i.e. moving away from acting retrospectively.

34. Management planning & stakeholder participation – considering the whole cycle in an integrated & inter-disciplinary manner with consideration of differing stakeholder groups, how they influence and are drivers, impact within the system and how they can be manipulated for better understanding.
35. Set targets and indicators for the vision and goals for the sea proposed by the RMNC. Create a hierarchical framework of indicators that will lead to greater responsive efficiency and effectiveness in operational monitoring.
36. Objectives, indicators and monitoring must be developed in that order and reflect the requirements of the previous stage

37. A strategic approach to habitat monitoring is required due to the many overlapping *designations*.
38. Multiple and un-aligned drivers re *legislation*.
39. Clarify it: Objectives – could be informed by our *various legal obligation*s, but not only these. What state of the seas do we want to see? Spell out. Otherwise all the monitoring etc will never properly address this question.
40. How do we link monitoring of ecosystem condition to the *legal framework* and the decision – making process? Linked to that is how do we achieve the above cost-effectively? How far could the work that Simon Brockington described help?

41. Predicting effects from human impacts.
42. Distinguishing between natural and human (direct) pressures that impact on habitat and species communities.

Vision & high level principles: Sustainable development, the Ecosystem Approach, and ecosystems

43. *.An ecosystem approach should be used to attain sustainable development.* Therefore monitoring and indicators should reflect this and be based on environmental/social/economic. Monitoring and

indicators should include all possible impacts including land based activities. Meeting legislative requirements will not necessarily attain sustainable development.

44. What is the Ecosystem in this (monitoring/management) context?

45. A sound knowledge of exactly what sustainable development means and the difference between SD and Sustainability. Indicators of sustainability may not be indicators for sustainable development.

46. Ensure that economic and social indicators link to environmental ones to ensure a true ecosystem approach.

47. Integrating an ecosystem approach into economic and social decision-making process.

48. Integration of management, monitoring and indicator is massively important but so is integration of ecological, social and economic imperatives to set management & monitoring objectives and hence decide on indicators. Need cross disciplinary collaboration e.g. ecological indicators can also be classified as economic goods and services that can be valued and hence also used as economic indicators.

49. Ecology – economic – social. Stuart Rogers (and others) stressed importance (essential) of achieving "balance". Who or what is expected to achieve and/or deliver this and when?

50. To ensure that all groups/individuals are talking the same 'language' and have common aims and understanding of objectives and approaches of the ecosystem approach.

Objectives - clarity

51. How do we identify objectives which will satisfy all needs? Different agencies may have differing objectives on the same subject.

52. Determining clear questions and objectives to address (ensuring they are specific).

53. Critical need for clear objectives and to focus monitoring/PI's on objectives and management to meet those objectives.

54. Importance of well defined objectives – what you/society want from the system.

55. Clarity in policies and objectives so that we can establish appropriate monitoring and indicators.

56. Careful selection of conservation objectives.
57. Setting conservation objectives with a realistic prospect of being able to monitor them.

Indicators

58. Providing indicators that the public can value and understand.
59. Finding an easily understandable headline indicator for the state of the seas.
60. Finding good indicators for environmental problems, especially pressure indicators.

61. Developing an indicator for the marine/coastal environment equivalent to the wild birds indicator. Suggested indicator : fish stocks.

62. Lack of awareness of the function and power of indicators at all political levels.

63. In many cases, there is a management framework e.g. policy/legislation driver and we know how to monitor (when we're told what to monitor). The 'link' that's missing is adequate indicators to link one to the other. I think, that to date, we haven't picked the right indicators (suite of….)

64. Need indicators that are more than 'indicators of change'. They need to distinguish between natural (e.g. climate) and anthropogenic (e.g. pollution, disturbance).

65. Developing effective indicators of pressures (-> impacts)/or UK seas to highlight the level of activities to wider public.

66. Do we have sufficient indicators to say with confidence that our seas are safe, healthy, productive and biologically diverse? If not, what new ones should be developed and used?

67. Developing management, monitoring and indications and models to deliver the ecosystem approach. Many policy questions require models to make predictions. More need for investigative monitoring.

68. Indicator species – effective.

69. Develop set of marine "headline" indicators of ecosystem health that will promote UK gov "buy-in" from both fishery and environmental departments.

70. Selecting meaningful indicators.

71. Integrating results and agreeing "state".
72. What ecosystem parameters are the best measures of sustainability (environmental)? i.e. of ecosystem 'health'.
73. How indicators actually relate to "ecosystem health".

74. Relevance of indicators.

75. Indicators to deliver the *ecosystem approach.*

76. Identification of appropriate indicative standards (and indicators). (Those which are realistic and provide useful information).
77. How do we choose an appropriate significance level (i.e. 95% or 80% etc) to determine probability of detecting when a target level has been attained or when a limit has been passed? Where should the burden of proof lie?
78. Selecting indicators and reference points which reliably inform management.
79. How to establish a datum for any indicator/index i.e. how is the norm to be established for any indicator?
80. How do we cope with climate induced shifting baselines?

Monitoring

81. Development of focussed and relevant monitoring that is *fit for purpose*.

82. Lack of rigorous scientific basis in design and implementation of monitoring, programmes – limits utility application.

83. Undertaking assessment and monitoring activities to improve our stewardship of the seas, not just to comply with legislation.

84. Access/use of monitoring data from a range of (public and private) sources – making the best of what we have.

85. Gain as much as possible from monitoring – data availability etc. Published results/reports including joined up thinking by all parties.

86. Monitoring that takes into account dynamic aspects e.g. climate change/NAO etc.

Communication – Feedback to management

87. Linking monitoring results clearly back to management action required.

88. Understanding the needs of managers and communication of results (monitoring) to improve decision-making.

89. Establishing/improving channels of communication between those developing monitoring and reporting protocols, both within the UK and Europe-wide. It is desirable to reduce duplication of effort and ensure standardisation of interpretation e.g. definition of terms such as 'ecosystem health'.

90. Communication between science and management (many examples presented but the one that sticks is who told the wind farm developer to monitor plankton)?

91. Formal communications between scientists and managers at beginning of management cycle to agree on a set of worthwhile indicators and plan the monitoring and reporting.

92. Better communication between all bodies and institutions undergoing monitoring to make this more efficient and effective. Sharing data.

93. Communication/co-ordination of responsibility between key organisations.

Science - Understanding

94. To increase our knowledge of function within biological communities so once shifts/changes have been identified within communities, they can then be understood and used to formulate biological indicators of disturbance.

95. How best to develop an integrated use of hindcast and nowcast modelling of the coastal marine environment putting in-situ sampling and surface remote sensing into temporal and spatial context (and trans national) as part of a monitoring programme for UK and NW shelf.

96. The identification of key indicators for use in complex marine systems

97. Need for long-term data-sets/need for scientifically robust indicators

98. Not having a good understanding of ecosystem functioning, natural fluctuations and dynamism and what constitutes a natural, healthy state makes conservation objectives and management difficult as pool baseline data.

99. Introduce more knowledge of marine natural processes, less dependence on distorting and over-simplified indicators? = Science "on top", not "on tap". [that is to say the exact reverse of the Churchill quote!]

Data

100. Develop a useable central data store. Review benthic data from all available sources in order to understand distribution, rarity and sediment preferences of benthic species.

101. Lack of coherent, integrated national marine environment baseline information.
102. Integration of data and information across agencies and departments to promote better decision making and general management.

103. Accessibility a need for collaboration and data sharing (though difficult in practice).

104. Data sharing – only in an ideal world?
105. Transparency and sharing of data and co-operation between organisations.
106. Sharing data and other resources.

107. Recording and making available knowledge of past change and reasons for those changes in spp and biotopes from experienced (usually elderly) scientists and naturalists and from literature e.g. marine fauna.

Timescales

108. Implications and timescales of WFD for resources and target.
109. Timescales – social, political timescales. Need for regular reporting (each year). Management timescales (e.g. WFD cycle time – 6 years). Ecosystem timescales – 10 years ++.
110. Various directives etc, are they achievable within target time frames? Cost of WFD implementation – adequate?

Funding - costs

111. Preparing and implementing and agreeing the indicators for both coastal and marine indicators and funding the required surveillance and monitoring.
112. Scale/cost of effective monitoring

Miscellaneous

113. Exchanging biodiversity. [? I don't know what this means?]

114. Please put comments on ineffective mussel stock assessments in the Wash into perspective. (Wash mussel stocks and bed distribution are greater than they have been for seven years as a result of better management)! [That's progress then!]

Management, Monitoring and Indicators – An overview

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Introduction

Over the last 30-40 years there has been a growing concern and awareness of the need for greater environmental protection and need to implement high level principles like sustainability and the ecosystem approach (Table 1). This has been mirrored in various measures with specific regard to the coastal and marine environment. This concern has been accompanied by the increase in various policy measures at international, European, national and local levels. The latest of these particular initiatives, the Water Framework Directive is prompting a further round of debate and intensive work about management, monitoring and indicators. Like many previous initiatives it is adding another layer of complexity to an already perplexing and confusing picture.

Table 1. Why are we doing this?

Before presenting the structure it is important to remind ourselves and ask the question - why we are considering this topic again?

There are a variety of answers and personal perspectives

- The historic concern over chemical pollution and human health
- The oiling of sea birds
- The decline in the great whales
- The seabird breeding failures
- The failure of the fisheries and the decline of the fishing industry
- Not bathing in raw sewage and its accompanying products
- The wide scale destruction of marine seabed habitats by fishing
- Decimation of high level predators – sharks, rays, cetaceans
- Toxic chemicals and hormone mimics

Etc etc

This list is still depressingly very long

People have cared and continue to care - what do you care about?

We know how failure can be expensive and destructive to resources and livelihoods.

There is considerable duplication and we seem to be endlessly debating how we go about this process - fashions and word games – when we have all the elements to do it already in place.

The aim of the day

To take a step back and reflect upon what we are doing, the systems and the scale.

In the first three presentations we have taken a general and co-ordinated view of the current work on

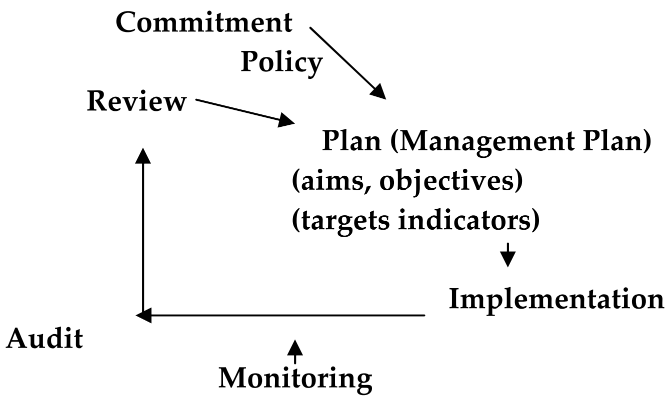
- Monitoring
- Indicators and
- Management

in order to produce a simple – management framework – [condition table, indicator row] - see below. [*This is not new!*]

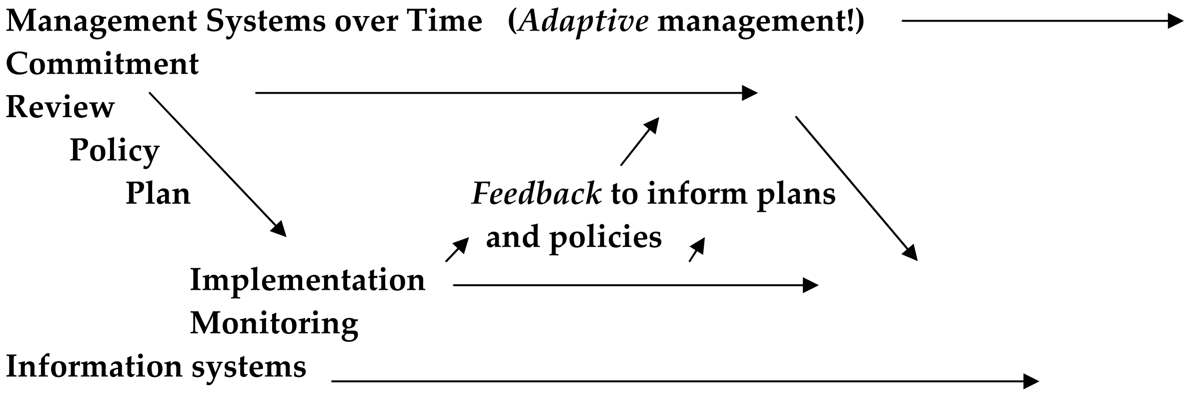
These first three papers will reflect upon aspects of this framework and in the first presentation – the ***overall picture is what is presented.*** This is important because there are simple and well understood management system approaches that have gained wide recognition and application ***throughout society*** that have been used to give us both ***the language*** we use and ***the process*** to deliver helpful outcomes. [The current fashion seems to be to call this 'adaptive management'! but good management always has been adaptive and management systems facilitate this] Figures below.

Management, monitoring and indicators are all inextricably linked but are often disconnected as if they are able to exist in isolation.

Management System Cycle – it provides our language



Management Systems over Time (*Adaptive* **management!)**



INDICATORS Features, Attributes, etc
Physical and chemical oceanographic
Planktonic
Benthic, fish, birds, mammals etc
Ecosystem function – Ecosystem Approach
Social – sustainable development / Ecosystem Approach
Economic – sustainable development / Ecosystem A
How many are there? 200 – 300 ?

1. Legal Drivers

WFD	Habitat & Species Directive	OSPAR & NMMP	Fisheries	BAP	Etc etc
X	X				
			X		
	X			X	

2. DPSIR Mapping

Drivers	Pressure	State	Impacts	Response
x				
		x		
			x	
				x

3. Geographic scale

Local	Regional	Whole Sea
X		
X	X	X
		X
		X

Table 1. A Management framework showing the progression from objectives to using attributes as indicators of performance, and assessing progress against a scale to inform a feedback process.

Feedback Loop

Management Objectives	Indicator (Attribute, feature)	Measurement Methodology Monitoring	Variation of Measures	Grading schemes	Management Action
Determined by society through policy and legislators through conventions and legal drivers or pragmatic management	Determined by the management objective. May be long standing or might have to be new to meet new demands	Appropriate – fit for purpose – to measure the management objectives and specific attribute	The variation in the indicator will determine the application of the grading system 	Grades used to ***communicate*** performance High Good Moderate Poor Bad	Determined by the grading system and would be appropriate to the attribute
The disciplines involved in different parts of this work - Linking policy to science and management					
Determined by society, policy makers and informed by science, and managers	Determined by science with legislators	Determined by scientists	Measured by scientists, under-pinned by basic understanding of the particular attribute	Determined by managers (who are mainly scientists) BUT must have the ability to communicate to society and legislators	Undertaken by management and officers

A Management Framework

The term 'indicator' is being used here collectively to include other terms like attribute, feature, EQO, etc; in essence it is an item that is being measured and reported in a management context.

The tables preceding illustrate two main areas -

1.The number of indicators being measured and their properties

The number of indicators [features, attributes, EQOs] are considerable (N=200-300?] and these can be assessed overall in relation to

- Legal drivers – the measures that prompt their measurement
- The DPSIR (Drivers, Pressures, State, Impact, Response) analysis tool – to inform one of the type of indicator being used
- The geographic scale over which the indicator is being used

A full tabulation would provide an insight into the totality of what is being done but this doesn't seem to exist.

This conference is concentrating on the biological and oceanographic indicators, but whatever view one takes of the ecosystem approach the same management framework applies to social and economic indicators or those which try to assess ecosystem function.

2. The management framework for each indicator (or set of indicators)

Some key overarching points:

This management framework is, in effect, very similar to the condition table approach and is no more than another way of illustrating the management system process.

At its heart is the concept that the indicator is measured and reported and that this has implications for management and policy. This is the ***feedback loop*** essential for ***adaptive management***.

This approach has at its core ***the linkage*** (integration) of policy, science and management.

Because of this linkage it is vital that a wide cross section of interests is involved in ***developing the table as a whole*** – i.e. not just policy, scientists or managers in isolation.
There is no point in having indicators that can't be measured, or that can't be reported, or have no management significance, etc.

It is important that the management table is developed iteratively.

The outcome of the process has implications for many parts of the community – eg the bathing water results – the public, water companies, investment OFWAT, Government, EU officials etc. Indicators by their very nature have a wide spread resonance.

The description below pulls out some of the key points of this framework.

Management objectives Clarity of objectives is important to effective management and so who and how these objectives are framed are extremely important. There are moves to include many more people in the process of framing indicator objectives (ie increasing 'participation'), however, this is not universal (e.g. WFD implementation). In fact the current mismatch of river performance indicators (a positive message) set again the likely WFD characterisation process (a negative message) only goes to show why you can't just let one group of people decide what the objectives and hence indicators should be.

Indicators The things that are to be measured. We need a much better description of what is currently being done. The total number is likely to be huge. [See Stuart Roger's paper – and above].

Measurement methodology – Monitoring The methods have to be appropriate, worthwhile relative to our understanding of the system, fit for purpose, quality assured etc. [See Mike Elliott's paper]. There is a good deal of monitoring for monitoring's sake, 'because that's what the Directive says', which seems to bear little relation to real need or any aspect of normal ecosystem functioning.

Variation of measures The measurement methodology will provide a variation in the values being measured. In indicators of natural systems or pollutants this variation needs to be well understood in relation to its significance in relation to the environment so that it can be matched to a grading scheme.

Grading schemes A variety of these now exist which vary depending on the legislative drivers. The function of grading schemes is to be able to communicate the outcome of the monitoring assessment. To use an everyday example – my daughter passes A level Russian with an A star – I need know nothing about Russian, the measurement process or variation to know she has done well and what it might mean for her future career (management outcomes). This indicator works for the individuals sitting the exam, teachers of Russian, and Government Education advisors. *The grading system has a prime communication function.*

The current grading systems vary from binary systems – pass fail – Bathing Water Directive assessments; EU ICZM and sustainability indicators (Gilbert see conference pack) to multi-grade systems (5 or 7 levels) for the WFD and Habitats Directive, with or without targets imposed or with statistical tests attached.

There are other schemes which involve multiple measures, the failure of anyone of which means that there is an overall failure; there are various rules which can be applied such as *default to the worst case.*

Management actions

Clearly for any given indicator the management options will vary as will the constituents affected. If there are no management options there is little point in developing the indicator in the first place. Adaptive management should mean that the messages from the monitoring are acted upon in a constructive manner. There are also examples of carrying on monitoring simply *because the*

Directive said so, where evidence over many years has shown no serious issues i.e. uniform low levels of pollutants.

Some conclusions

This approach is not new - It might work and it might not

This approach can work in an environmental setting and the Bathing Water Directive indicators is a good example of how measurement, reporting and investment over 20+ years has gradually lead to a major improvement in the quality of bathing waters.

The gradual increase of diversity of fish in the Thames – highlighted by the return of the salmon – is a success story which has employed this management framework approach.

The example provided by Richard Gregory in this conference also shows how an indicator such as farmland bird can start to develop high profile resonance which affects many aspects of society.

This approach *may not work* – the annual review process of the Common Fisheries Policy is a good example of how this management system approach has failed to deliver any significant gains. [It is also a good example of the failure of participation in indicator design and delivery by all the parties involved].

The approach might not work because parts of the process go horribly wrong – e.g. monitoring measurements of *Modiolus* beds in Strangford Lough or intertidal mussels in the Wash.

Costs

Some points in no particular order:

- Whilst much of the debate focuses on the things that are being measured and the process side of what is being done, the financial costs of these programmes are considerable and need to be understood far more effectively.

- In assessing the investment going into this type of work by many agencies for UK plc there is clearly an enormous financial commitment.

- Many such initiatives – for example the Biodiversity Action Plan process – don't have the money to do much of the monitoring required.

- One wonders what the Audit Commission would make of this investment. Are we getting value for money from our current sectoral approach?

- Many of the issues of duplication, monitoring for its own sake (not being adaptive) all have considerable cost implications.

- We know some of the costs of getting the management framework and the monitoring process wrong (see the reasons why we are doing this).

Organisational and cultural issues

Leadership Given the scale of what is being done by a multitude of agencies in the marine and coastal environment there is a clear need for leadership at the highest level to provide guidance through the plethora of initiatives and help deliver value for money.

High level leadership and direction are especially important at the scale of whole and regional seas where inter-country and multiple agencies are involved.

Spatial management There is growing scope for inter-agency collaboration – co-ordination on indicators and monitoring frameworks at spatial scales especially including the local level. This collaboration could help make sensible programmes affordable.

Communication and transparency Agencies measuring and monitoring health and other interested parties not being able to access that information with a variety of excuses put forward e.g. Strangford *Modiolus* beds.

Marine Monitoring - lessons from the past and present for the future

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Outline of the Presentation

The presentation takes a wide overview of the nature of marine monitoring, the types of monitoring, its history and its use in management decisions. It discusses **why** we monitor, **how we design** monitoring strategies and protocols and in particular **when**, **where** and **how** we monitor based on **what** we have decided (or even been told) to monitor. The different types of monitoring in existence will be described using examples together with the value and use of those different types. Therefore it covers surveillance, condition, compliance, operational and diagnostic (investigative) monitoring.

It will illustrate the fact that often monitoring has covered those aspects which **can be** measured rather than those which **need to be** measured, hence not always providing the data and information relevant to decision makers. It is also necessary to indicate the past nature of marine monitoring by providing examples where monitoring strategies have not made the distinction between what is '**nice to know**' rather than what is '**needed to know**'.

It is of concern that the terminology used to describe these types of monitoring differs between those doing the monitoring - by the different statutory bodies and with different reasons for carrying out the monitoring. Hence the presentation indicates the confusion caused by the production of data and information for marine management.

It will be emphasised that monitoring is required to provide background information, to inform environmental management systems, and to provide the data by which compliance with indicators and the triggering of actions by passing thresholds occurs. Hence the use of the monitoring in reporting changes in quality, compliance with standards and the meeting of objectives is paramount. Despite this, we have created systems in which data are gathered for not the correct reason, that they are of an insufficient spatial and temporal resolution to be of use, and that their quality is insufficient for answering questions especially when the data require to be combined within and between geographical areas.

Examples will be taken from the monitoring connected with compliance with EU directives, the National Marine Monitoring Plan, licence compliance and operational considerations, such as those of the dredging undertakers. These will show the merits and disadvantages of taking a statistical approach and a highly structured decision-making approach used by the marine policy implementing organisations.

The monitoring strategies will be linked to the other presentations via the DPSIR approach in which indicators are defined for Pressures, Status and Impacts and where those indicators are then tied into the monitoring. Hence the nature of the monitoring has to cover the cause and effects of change together with the monitoring of responses to that change by socio-economic and legislative drivers.

The presentation will be given on the IECS website (http://www.hull.ac.uk/iecs) under *Events and Conferences* (NB in addition, the presentation: *M Elliott - Monitoring and modelling for compliance: principles, networks, consistency and tools* which was given at an earlier CIWEM/CMS conference, is also given on the website.)

Further Reading:

Elliott, M & VN de Jonge (1996) The need for monitoring the monitors and their monitoring. *Marine Pollution Bulletin* **32** 248 - 249.

Elliott, M, TF Fernandes & VN de Jonge. (1999) The impact of recent European Directives on estuarine and coastal science and management. *Aquatic Ecology* **33** 311-321.

Elliott, M T Fernandes & JR Pomfret (1999) Transforming baseline data to accessible information for coastal zone managers. In: Bridge, L (Ed.) *Info-Coast '99 Symposium Report*. Coast*Link*, Coastal & Marine Observatory at Dover, UK and EUCC-UK, Brampton, UK, p41- 44

Elliott, M & KL Hemingway (Eds) (2002) *Fishes in Estuaries.* Blackwell Science, Oxford, pp636.

Elliott, M & VN de Jonge. (2002). The management of nutrients and potential eutrophication in estuaries and other restricted water bodies *Hydrobiologia* 475/476, p513-524.

Hiscock, K, M Elliott, D Laffoley & S Rogers (2004). Data use and information creation: challenges for marine scientists and managers. *Marine Pollution Bulletin*, 46: 534-541.

McLusky, DS & M Elliott. (2004) *The Estuarine Ecosystem: ecology, threats & management*, 3rd Edn. OUP, Oxford.

Indicators and their application in the Ecosystem Approach

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Indicators of change are an integral part of the assessment and monitoring of human activities, and are important in making the objectives of an ecosystem approach operational. Recent activity has been driven largely by commitments made for the achievement of key international ecosystem targets. Principle amongst these are the undertakings in the World Summit on Sustainable Development (WSSD), and at OSPAR / HELCOM 2003, that by 2010 we will halt biodiversity decline, and encourage the application of the ecosystem approach for the sustainable development of the oceans.

The OSPAR Commission has specific obligations for the protection and conservation of ecosystems and biological diversity. Appendix V of the OSPAR Strategy (OSPAR, 1998) requires contracting parties to control human activities that have an adverse impact on species and habitats, and this will be achieved through a number of measures, including the use of a network of marine Protected Areas, and the agreement on a range of Ecological Quality Objectives (EcoQO) for the marine environment. The EU Water Framework Directive requires that member states assess the ecological status of transitional and coastal waters by 2006, to prevent deterioration and achieve "good status" in all bodies of surface water and groundwaters by 2015 (EU, 2000). The EU Habitats and Birds Directives require the conservation of listed species and habitats, principally through the establishment of the Natura 2000 site network, to ensure the maintenance of habitats and species at favourable conservation status (EU, 1979, 1992). Many other national monitoring programmes support a plethora of other assessments of marine environmental quality and status.

Recently, the ecosystem-based approach to management has been developed through the selection of desired states of the physical and biological components of the ecosystem, and the management of activities to achieve them. Using measures of the state of the natural environment has resonance with the general public, for whom this is the ultimate expression of success or failure of management. Despite the difficulties that can be experienced in identifying causal links between human activity and environmental state descriptors, it is nevertheless expected that such indicators will ultimately contribute to the effective control of activities that impact the ecosystem.

This talk summarises the role of indicators in the ecosystem approach to management, and gives an overview of the qualities of good indicators, and the need for agreed objectives and clear reference points. By reviewing a selection of indicators against the DPSIR framework, which groups indicators according to whether they describe Driving Force, Pressure, State, Impact and Response, patterns in indicator use have become apparent (Table 1). The implications of this for the UK science community undertaking research and monitoring, are reviewed. Key outcomes are;

- The scientific community has selected a set of criteria for good indicators, but finding robust and quantitative indicators with these properties is a challenge.
- Making best use of rigorous performance indicators, together with more general qualitative descriptors of ecosystem components, will be a useful approach.
- In many cases, several years of monitoring data may be necessary to show statistically significant improvements in state.
- A combination of the current suite of state and response indicators, with the EEA DPSIR model of driving force, pressure, state, indicator and response, provides one useful framework in which indicators of the marine environment could operate. Other, possible frameworks should be explored.
- Greater efforts need to be devoted to the optimisation and coordination of monitoring data to provide evidence of moving towards the objectives.
- More coordination of the various national and international indicator initiatives is essential.

Table 1. Mapping a selection of proposed and operational marine ecosystem indicators onto the DPSIR (Driving Force, Pressure, State, Impact and Response) framework. Ecosystem indicators used are the ten proposed OSPAR EcoQO (normal font lower case letters), the England Biodiversity Strategy (upper case bold font), and EU Headline biodiversity indicators (upper case *italic* font). Indicators under development to assess the Favourable Condition (Hab. Dir.) and Good Ecological Status (WFD) of most or all ecosystem components are represented in the final row of the table.

[1] This EcoQO (reference points for commercial fish SSB and F) can be both State and Impact depending on which reference point is used.
[2] This EcoQO 'Local sand-eel availability to black-legged Kittiwakes' could be either a State of fish stock indicator, or Pressure indicator for sea birds (ICES, 2004a).
[3] This EcoQO 'imposex in dog whelk' is a State indicator (ICES, 2004a), but could also be an Impact indicator.
[4] Indicator taken from the OSPAR RID 2000 riverine inputs survey: results from the UK (Defra, 2004c).

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	D	P	S	I	R
Physical / Chemical habitat		**M5** RID[4]	**M2** u, s		
Nutrients		RID[4]	t *WEU04* *WEU13*		
Ph/Zoo plankton			q, r		
Benthos			o, p, n[3]	m	
Fish		**H6**	a[1], l, j[2] *FISH01*	a[1]	*FISH08*
Seabirds		f, j[2]	**M1** k	g, h	
Marine mammals		**M6**	c, d	e	
(most or all ecosystem components)			**M3** b *BDIV02* *BDIV03* WFD, Hab. Dir.		**H8** *BDIV010*

Turning science into policy: the wild bird indicator

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The publication by the UK Government of a set of indicators to measure sustainability and the Quality of Life back in 1999 arguably marked a turning point in wildlife conservation. Five years on, the impacts of this decision are can be seen in a range of countryside policies and initiatives. People will be familiar with standard measures of our lifestyles, such as air quality, crime figures, education qualifications, and road traffic. In the late 1990s, however, the creation of the sustainable development strategy focused attention on the environment and the need for wildlife indicators to complete the full picture. Various ideas were considered but an index based on the population trends of common countryside birds was adopted as one of the 15 headline indicators of the Quality of Life, representing wildlife. This move was significant as the unfolding story told by the indicator, coupled with detailed research, has driven a sea-change in attitudes towards land-use and a significant shift in policy in the UK. Studies in the 1980 and 1990s first alerted us to the potential problems facing farmland biodiversity, but it was not until the publication of the wild bird index that the sheer scale of the problem became apparent and policy makers began to take notice. At the same time, worrying declines in woodland birds began to emerge, that had gone almost unnoticed. The Government's response was to pledge to reverse the long-term declines of woodland and farmland birds; a Public Service Agreement defined a target to reverse the decline of farmland birds by 2020. With this target came a detailed delivery plan that defined how the target was measured and how it will be achieved. The success of the wild bird index stems from fact that it reduces masses of complex information into a simple, attractive summary. It has all the properties of an effective indicator: being quantitative, simplifying, policy relevant, scientifically credible, responsive to change, easily understood, realistic to collect, and susceptible to analysis.

Key points

Biodiversity indicator, indicator, quantitative, simplifying, policy relevant, scientifically credible, responsive to change, easily understood, realistic to collect, and susceptible to analysis.

Site Management: from theory to application – are we closing the loop?

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The number of designated marine conservation sites has increased in recent years. Consequentially, there has been a growing imperative to solidify our skills in marine site management. Whilst the long history of terrestrial site management in the UK has provided a good skill and experience base to help develop approaches to marine site management, it has also restricted its development.

The application of traditional terrestrial site management theory at site level in the marine environment has helped reveal key areas of the site management process that require modification and improvement to fit the circumstances of the marine environment. Weaknesses in any individual link in the management chain will likely confound the effectiveness of the entire management and site protection process.

In order to forestall such weaknesses, it is essential to ensure that:

- **conservation objectives** fully encompass the aims of the site's designation, uninfluenced by limitations of monitoring or any tendency to 'cherry pick'.
- **management objectives** properly represent the management needs of the site (as determined by the site's conservation objectives), not being limited by the willingness of site managers to undertake management action.
- **performance indicators** (attributes and targets), against which both the achievement of conservation objectives and management objectives will be assessed, are fit for purpose.
- **performance indicators** take full account of the inherent dynamism of the marine environment so that the ability for such dynamism to confound results is minimised.
- **performance indicators** and their monitoring goes beyond the reporting level of *"We have a problem Houston"*, to providing a level of feedback that informs the types of changes that may be required to site management.
- **monitoring** of performance indicators is planned and executed strategically, at least at site level; *e.g.* where data for one feature can inform the condition of another and where monitoring data from one site informs the assessment of another.
- where anthropogenic impacts are of concern and natural dynamism is not, then biological monitoring strategies are based on methods of detecting ecological impacts.

Even only cursory examination of our developing marine site protection programmes reveals that our application of marine site management contains weak links that require strengthening. This further implies the need for improvements to our management philosophies.

The challenges of management and monitoring for the Water Framework Directive

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The Water Framework Directive (WFD) was transposed into UK law on January 1st 2003 (Article 24). The Environment Agency was empowered as the "Competent Authority" to implement the Directive. Article V requires the competent authority to complete an initial characterisation and assessment of significant anthropogenic pressures and impacts on river basin districts. For marine waters this includes transitional waters (estuaries) and coastal waters to 1 nautical mile in England and Wales and Northern Ireland and to 3 nautical miles in Scotland.

The initial characterisation is to be reported to the EU in March 2005 and provides the basis for planning the further implementation of the directive. The Agency, SEPA and Environment and Heritage Service are in the process of finalising the pressures and impacts analysis in time for reporting to Defra in December 2004 and are now beginning to focus on environmental monitoring and classification.

Classification tools are in the process of being developed for all elements for transitional and coastal waters for the UK through the work of the Marine Task Team reporting to the WFD UK Technical Advisory Group. **The elements include marine plants (macroalgae, phytoplankton, chrlorophyll, sea grass and saltmarshes), macroinvertebrates (soft and hard substrata), transitional fish, supporting physico-chemical conditions (e.g. dissolved oxygen and nutrients), hydromorphological conditions (tidal regime and morphology) and chemical status (priority substances and other polluting substances).** The classification tools will provide the basis for the assessment of status of water bodies.

The classification tools will assess water body status on a scale of high, good, moderate, poor and bad ecological status with high equating to the reference condition that has minimal anthropogenic disturbance. Each status class also requires an assessment of the physico-chemical and hydromorphological conditions which support the biological functioning of the biological elements. Chemical status will also be assessed for a range of EU specified priority substances (Annex X) and member state defined " other specific polluting substances" (Annex VIII). All of these parameters will be combined to provide an overall assessment of the status of a water body.

The pressures and impacts analysis provides the basis for building and targeting this assessment programme which in turn will provide management information to direct programmes of measures that may be required in order to achieve the objectives. The assessments and requirements for programmes of measures are published in draft river basin district plans for consultation in 2008.

The pressures and impacts analysis has split water bodies into 4 categories to assist further planning in the UK;

1. At Risk - where pressures and impacts are significant and programmes of measures can start as soon as is practical or may well already be underway
2. Probably at Risk - where pressures are significant but the available information on impact is poor and for which further information will be needed
3. Probably Not at Risk – where pressures are not thought to be significant but where the confidence in the available information on pressures and impacts is low.
4. Not at Risk of failing WFD objectives – where pressures are not significant and the confidence in the available information is high.

Article V only requires water bodies to be reported to the EU as At Risk (1 and 2 above) or Not At Risk (3 and 4 above).

The Directive defines and sets out requirements for surveillance, operational and investigational monitoring.

Surveillance monitoring *'shall be carried out at sufficient surface water bodies to provide an assessment of the overall surface water status within each catchment or subcatchments within the river basin district'* (Annex V, 1.3.1.). This implies that surveillance sites should span all risk categories and water body types but concentrate on high and good status water bodies. WFD Surveillance monitoring requires all elements to be assessed and it is envisaged that the surveillance network will provide the 'anchor' for monitoring data, with a stable network maintained in order to assess trends.

Operational monitoring shall be undertaken to: '-establish the status of those bodies identified as being at risk of failing to meet their environmental objectives and assess any changes in the status of such bodies resulting from the programme of measures'. Operational monitoring need only assess parameters indicative of the biological quality element, or elements, most sensitive to the pressures to which the water bodies are subject. Operational monitoring will also be undertaken in all water bodies where priority substances are discharged and where "other pollutants" are discharged in significant quantities. This latter point has important implications for the current compliance monitoring associated with the Dangerous Substances Directive.

Investigative monitoring shall be carried out: *' where the reason for any exceedances is unknown; where surveillance monitoring indicates that the objectives set out in Article 4 for a body of water are not likely to be achieved and operational monitoring has not already been established; in*

order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives; or to ascertain the magnitude and impacts of accidental pollution;
and shall inform the establishment of a programme of measures for the achievement of the environmental objectives and specific measures necessary to remedy the effects of accidental pollution'.
Investigative monitoring will become a statutory requirement when status has been confirmed as being worse than good or a water body has deteriorated, where consensus about what has caused the failure or deterioration has not been reached. This will include the investigation of the effects of accidental pollution. Investigative monitoring will be required to further justify programmes of measures and specific measures to remedy the effects of accidental pollution. Investigative monitoring is not used to classify but to help define the operational network.

The implementation of such an ambitious programme particularly in transitional and coastal waters has never been attempted in the UK. The implementation would appear to mean a significant increase in monitoring activity particularly in transitional and coastal waters for England and Wales where previously very little monitoring was undertaken. The presentation will set out the requirements for monitoring dictated by the directive and highlight the challenges facing the Environment Agency in implementation against a backdrop of reductions in grant in aid. **Current Agency monitoring activities will be discussed and compared with the Directives requirements and suggestions for new ways of working will be highlighted including the need for multi-purpose and flexible approaches to monitoring involving all government agencies.**

For further information see:

www.environment-agency.gov.uk/wfd
www.wfduk.org
www.sepa.org.uk/wfd
www.ehsni.gov.uk

Marine monitoring under the Habitats Directive and the ecosystem approach

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English Nature, alongside the other statutory country conservation agencies (Countryside Council for Wales, Scottish Natural Heritage) and Environment and Heritage Service Northern Ireland are responsible for delivering the monitoring, assessment and reporting requirements of the EC Habitats and Birds Directives. To achieve this a structured system of assessment – referred to as Common Standards Monitoring or CSM – has been developed to enable setting of conservation objectives and reporting on the condition of features within protected sites. English Nature is currently introducing the use of Common Standards to assess the ecological condition of all terrestrial, freshwater and marine SSSI's and Natura 2000 sites.

The marine CSM has been developed to cover an ecological assessment each of the Annex 1 (Habitats e.g. subtidal sandbanks, mudflats, reefs, estuaries etc) and Annex 2 (species – seals and dolphins) which are referred to in the Habitats Directive. For the habitats assessments individual features are generally monitored using a hierarchical method whereby the following levels are recorded:

1) Extent of the feature
2) Range of principle communities or biotopes
3) The species composition of principle biotopes
4) Presence or absence of rare species or those characteristic of the site

The features which are assessed at each site are published by English Nature under the Regulation 33 advice packages. A key point of CSM is that data is gathered from as many different sources as possible, including from Environment Agency, Seafisheries Authorities, academia, developers and our own staff. Within English Nature contractors are used to obtain ecological data from areas which are difficult to access e.g. subtidal reefs or large exposed mudflats.

The acquisition of monitoring data currently supports three different requirements:

1) Reporting site condition targets: EN have a statutory responsibility to report on the condition of N2k sites (through JNCC) on a six yearly cycle.
2) Informing management: The condition assessment forms a central part in assessing the success of the site management schemes, and condition assessments are reviewed by all relevant authorities

3) The assessment process yields data on understudied habitats which can be used to assess the health and status of the wider environment. These habitats form a key part of the ecosystem, and an assessment of their health is a crucial part of understanding the health and functionality of the wider environment. Development of indicators is required in order to aggregate site based data upwards to inform assessment of the wider environment.

The UK is committed to delivering sustainable exploitation of the marine environment through an Ecosystems Approach to management. One of the main aims of sustainable development is to balance the needs of society, economy and environment. Thus one of the future priorities for English Nature is to develop a programme of assessment of the social & economic benefits of designated sites using a range of indicators as developed under the World Conservation Union's Programme on Marine Protected Areas. Typical examples of areas to be tackled may include an assessment of how the financial and non-financial benefits of the sites are quantified & distributed, and compatibility between management and local culture. The use of these indicators will be trialled at Plymouth, The Wash, Thanet and Berwickshire Coast in the near future with the expectation of improving ecosystem management at local levels.

Detecting undesirable disturbance in the context of eutrophication in marine ecosystems

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Introduction

The need to define ***undesirable disturbance*** arises from the definitions of ***eutrophication*** in the Urban Waste Water Treatment Directive (UWWTD) and the Nitrates Directive, and in OSPAR's *strategy to combat eutrophication.* The three definitions are similar, and the first part of the OSPAR (2003) definition is representative:

> *"Eutrophication" means the enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned...*

A water identified as suffering from ***eutrophication*** is labeled as *sensitive* under the UWWTD, *nitrate-vulnerable* under the Nitrates Directive, and a *problem area* under OSPAR's strategy. The consequences of such identification include requirements for *more stringent* treatment of urban waste water before its discharge, reduction in the use of nitrate fertilizers on land, and measures *to reduce or to eliminate the anthropogenic causes of eutrophication*. The last is an explicit requirement of OSPAR's strategy and might well be required under the Water Framework Directive (WFD). The practical implications of such measures extend far beyond particularities of sewage treatment and nitrate fertilizer use to the need to control nutrient release by agriculture, aquaculture, transport and urban development in general.

Because nutrient enrichment and accelerated algal growth are not in themselves harmful, a diagnosis of eutrophication can be properly made only when *undesirable disturbance to the balance of organisms ... and to the quality of the water ...* is demonstrated. Given the need to do this for UK salt waters, Defra commissioned a 2-stage study aimed at defining ***undesirable disturbance*** *in the context of eutrophication* and at proposing a monitoring strategy for detecting such disturbance. In stage 1 of the work (Anon, 2004a), the ***Undesirable Disturbance Study Team* (*UDST*)** concluded that:

***undesirable disturbance** is a perturbation of a marine **ecosystem** that appreciably degrades the **health** or threatens the **sustainable human use** of that ecosystem[,]*

whilst pointing out that a variety of anthropogenic and natural causes of ecosystem disturbance operated in UK salt waters. The latter were seen as comprising all UK continental shelf waters including the WFD's *coastal waters* and its *transitional waters* to an inner limit where the flora and fauna cease to have a substantial marine component.

Stage 2 of the study (Anon, 2004b) concerned development of a UK assessment methodology for ***undesirable disturbance*** in coastal and marine waters, and led to the ***checklist*** appended to this paper. The checklist summarizes the stage 2 methodology; the rest of the present paper aims to give an overview of related issues considered during the study.

Ecosystem health

According to Odum (1959)

> *any area of nature that includes living organisms and nonliving substances interacting to produce an exchange of materials between the living and nonliving parts is an ecological system or **ecosystem**.*

Since its purely factual definition in like terms by Tansley in 1935, the word ***ecosystem*** has acquired a halo of associated ideas, including those of the *balance of nature* and of *ecosystem health*. According to Costanza *et al*. *(*1992), a healthy ecosystem, like a healthy human body, is a system that functions well and is able to resist or recover from disturbance. However, the concept is more than a metaphor, because ***ecosystem health*** has quantifiable components which can be understood in terms of presently or potentially rigorous ecological theory. These components (Mageau *et al*, 1995) are its ***vigour*** and ***organization***, its ***resistance*** to disturbance, and its ability, called ***resilience***, to recover from disturbance. As seen by the UDST, the ***vigour*** of an ecosystem is related to the biologically-mediated fluxes of energy and materials through the ecosystem, and to the ability of the biological community to replace disturbed parts through population growth or the production and settlement of larvae. An ecosystem's ***organization*** (also called its ***structure***) involves its biological community's physical structure, food web structure, and biodiversity. The community's activities can structure the environment (for examples, through increasing sediment cohesion or building reefs), and ***resilience*** can also depend on features of the environment as well as those of the biological community.

These ideas are illustrated in Figure 1. Part (a) deals with ***vigour***, and suggests how enrichment of an *oligotrophic* ecosystem can at first improve its *trophic* (or nutritional) status to a condition of ***optimal*** vigour (which was the original meaning of *eutrophic*) and then take it to a ***dystrophic*** state. Part (b) deals with ***organization*** (or ***structure***), and suggests that an ecosystem impacted by anthropogenic factors may, because of its ***resistance*** to disturbance, initially show little response to increasing pressure. Pushed beyond a certain point, however, change becomes rapid, and may culminate in a radically altered state from which recovery is slow. An example would be the occurrence of extensive deep water anoxia, resulting in the widespread elimination of the macrobenthos. A key operational need is to detect a ***trend*** towards such a widespread ***undesirable disturbance*** before the ecosystem has reached the limit of its **resistance**.

The use of the concept of ecosystem health for defining undesirable disturbance requires the spatial extent of an ecosystem to be defined. For present purposes the system that is identified should have some hydrographical unity – so as to minimize the variability resulting from combining ecohydrodynamically different waters – but should not be so small that its state is overwhelmingly determined by outside events. Examples of suitably-sized ecosystems might be Belfast Lough, the Firth of Clyde, or the stratified region in the western Irish Sea. Given an ecosystem approach to undesirable disturbance, ***small-scale disturbances*** are not considered a cause for concern (they can be dealt with by *Allowable Zone of Effect* procedures) unless they impact on a *conservation feature*, in which case appropriate legislation applies irrespective of whether the disturbance has undesirable consequences for ecosystem health. Ecologists customarily distinguish episodic ***pulse*** from sustained ***press*** disturbances. Local, ***pulse***, ***disturbances*** are considered to be of little concern; a ***widespread pulse disturbance*** would be of concern if it brought an ecosystem to a ***crisis*** as a result of weak ***resistance***. ***Extensive press disturbances*** give the most concern as they can lead to a ***crisis*** from which the outcome may be a large change in ***biome*** or ***ecological quality status***. Such outcomes will be ***undesirable disturbances***, and movement towards the crisis would itself be a cause for concern. Crisis is here used by analogy with the point in an illness after which the patient either recovers or irreversibly changes state (and status), and is shown in Fig. 1(b) by the point at which the graph of structure against pressure begins to descend steeply.

Natural disturbance, and natural variability, are features of all ecosystems, and indeed, in *intermediate disturbance theory* (Connell & Sousa, 1983) are seen as an important generator of biodiversity. Anthropogenic disturbance must be thus be assessed against natural variability and disturbance. In relation to ecosystem ***vigour***, the UDST saw one of the key requirements for health as being the maintenance of good ***coupling*** between primary producers and their consumers. Should this coupling break down extensively in time or space, the result would be an excess of organic matter which could impact adversely on deep water and benthic communities. It is this breakdown which is the cause of ***dystrophy***, and not high production as such.

The balance between producers and consumers is to be seen as part of the community's ***structure***. Also part of the structure are some aspects of biodiversity. The UDST concluded that what was crucial for health was not a certain total number of species but, rather, the maintenance of a proper balance amongst ***guilds*** of benthic animals or, more generally, amongst ***lifeforms*** of organisms. An example benthic guild is that of large burrowing animals. These play a vital role in the benthic community and for the geochemical state of the sediment by flushing pore waters more rapidly than diffusion can. A number of species can do the work; characteristically, not all are found at any given location or in any given sample.

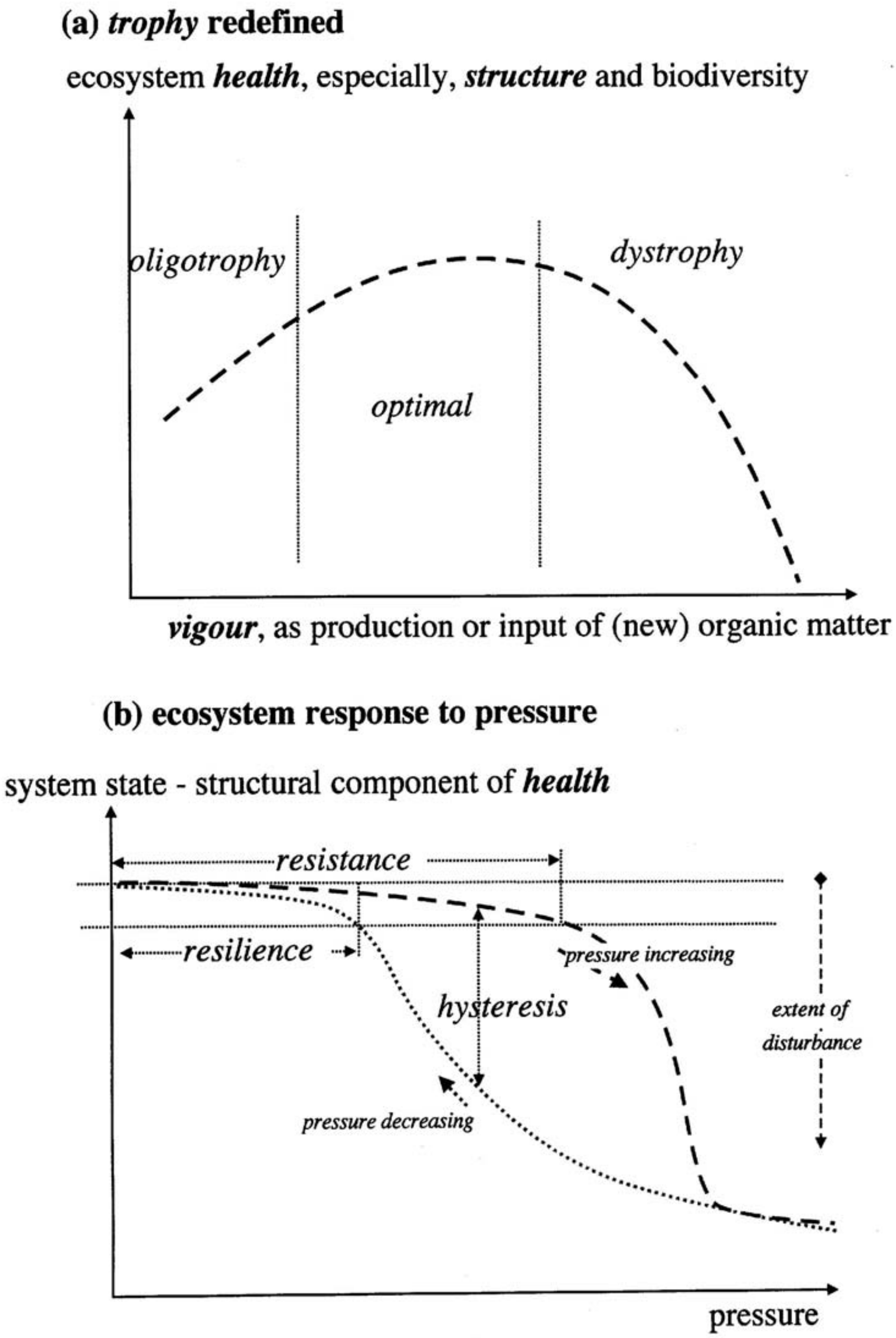

Figure 1. Ecosystem health

Mapping to OSPAR and WFD criteria

EC and OSPAR definitions of eutrophication include *undesirable disturbance to the balance of organisms*. Stressing the need to maintain the structural component of ***ecosystem health*** is a restatement of the need to avoid such an undesirable disturbance**.** Of the 5 OSPAR ***Ecological Quality Objectives*** (***EcoQO***s) considered for application to UK waters (Painting et al., 2004), winter nutrient concentrations are used here only as indicators of pressure. Objectives referring to chlorophyll, phytoplankton indicator species, dissolved oxygen and zoobenthos are considered below. It is proposed that WFD *poor* status can be equated with an undesirable disturbance to ecosystem health. Good health corresponds either to *high* status (when no disturbance can be detected against a background of natural variability) or *good* status (when disturbance is just detectable). WFD *moderate* status does not correspond to an undesirable disturbance or to poor ecosystem health; indeed, system vigour might be *optimal* as defined above. However, an ecosystem in this state, albeit only moderately altered from reference conditions, could be on the brink of rapid change if its ***resistance*** is about to be overwhelmed. Thus a trend from *good* to *fair* status may give cause for concern by suggesting that an ecosystem is tending towards (although has not yet reached) dystrophy, poor health and undesirable disturbance.

Ecohydrodynamics

Ecohydrodynamics takes account of biogeographical variation in the species available to populate an ecosystem as well as of the physical structure and dynamics of a water body (and the effect of these physical and biological factors on the sea-bed). Biogeography is exemplified by the decreasing abundance of copepods of the genus *Calanus* with distance from the shelf break, and physical dynamics by the difference between stratified and mixed water. Ecohydrodynamics controls a water body's response to nutrient enrichment and thus the likelihood and nature of disturbance. A comprehensive knowledge of ecohydrodynamic types in UK waters is needed to supply reference conditions against which to assess disturbance. A simplified typology is used in the ***checklist***, described below, to specify which parts of the proposed methodology be used in a given water body. This typology distinguishes:

- shallow clear waters, in which the euphotic zone includes the seabed, and where ***phytobenthos*** are characteristically important;
- optically deep ***mixed waters*** where phytoplankters are unlikely to be stimulated by nutrient enrichment;
- ***offshore stratified waters***[1], which naturally have a nutrient-depleted surface layer during summer and so where extra nutrients can stimulate phytoplankton growth and production, and bring about deep-water oxygen depletion;

[1] The category includes waters that are thermally stratified from late spring through early autumn, those that are thermohalinically stratified, perhaps for a greater part of the year, and frontal regions of intermediate seasonal stratification. Some typologies might distinguish these different stratification regimes.

- ***Regions of Freshwater Influence (ROFIs***), which are highly variable inshore waters that are characteristically energetic because of tidal and wind-wave stirring, turbid with suspended sediment, and with a moderate or high freshwater content which may bring about intermittent stratification;
- ***Regions of Restricted Exchange (RREs),*** which are inshore, semi-enclosed waters whose dynamics and eutrophication risk depends on the rate of water exchange with the sea; the category includes ***fjords*** (some of which have ***basin deep water***[2]), rias, other types of estuary, and coastal embayments and straits.

Freshwater, in addition to potentiating stratification and circulation, is also the main bringer of anthropogenic nutrients into many UK waters. However, diffuse inputs from the atmosphere, and point sources such as fishfarms, may also need to be considered. Furthermore, UK offshore waters influenced by Atlantic inflow would, under natural conditions, have higher nutrients than inshore waters. Finally, submarine ***optical*** conditions are critical in some cases, in determining whether phytobenthos or phytoplankton may grow, and are themselves altered by phytoplankton growth.

Measurement issues

Detection of disturbance requires measurement, followed by categorization, of ecosystem properties. What, in general, should be measured? Some definitions will be useful. A ***state variable*** is one of a set of continuous variables that together uniquely define the state of a system such as an ecosystem. ***Status*** refers to a division of all possible states into a set of categories which can be arranged in a ranked sequence and associated with judgments about desirable and undesirable ecosystem conditions. An ***indicator*** is any continuous variable that points to some aspect of the state or health of an ecosystem. Such variables may be scalar or vector, state variables or derived variables including statistics, or time derivatives sometimes identified as rates or fluxes. They can include the abundance or health of organisms belonging to ***indicator species***. Finally, ***index*** (plural *indices*) is used to mean a non-dimensional variable formed from a ratio, or ratios, of indicator(s) to reference value(s).

Figure 2 illustrates the idea of ecosystem state. The 2-dimensional diagram of Fig. 2(a) is drawn in a phase or state variable space defined by only two variables, y_1 and y_2, and is intended to represent a multidimensional space which cannot be drawn. However, the plotted variables could also be understood as statistics, summarizing more complex variation. The stippled doughnut is the region that includes all those states of the ecosystem that are normal for the type-specific conditions, taking account of seasonal and interannual, variation and spatial patchiness. The system is deemed to be healthy while

[2] The upper waters of most fjords exchange regularly with the sea as a result of wind-driven, tide-driven, or density-driven, circulation, the density driven circulationr esulting mainly from differences in freshwater content. ***Basin deep water,*** below the depth of a fjord's entrance sill, can be isolated from the regular circulation and flushed at intervals that may be irregular and sufficiently long for the water to become depleted of oxygen.

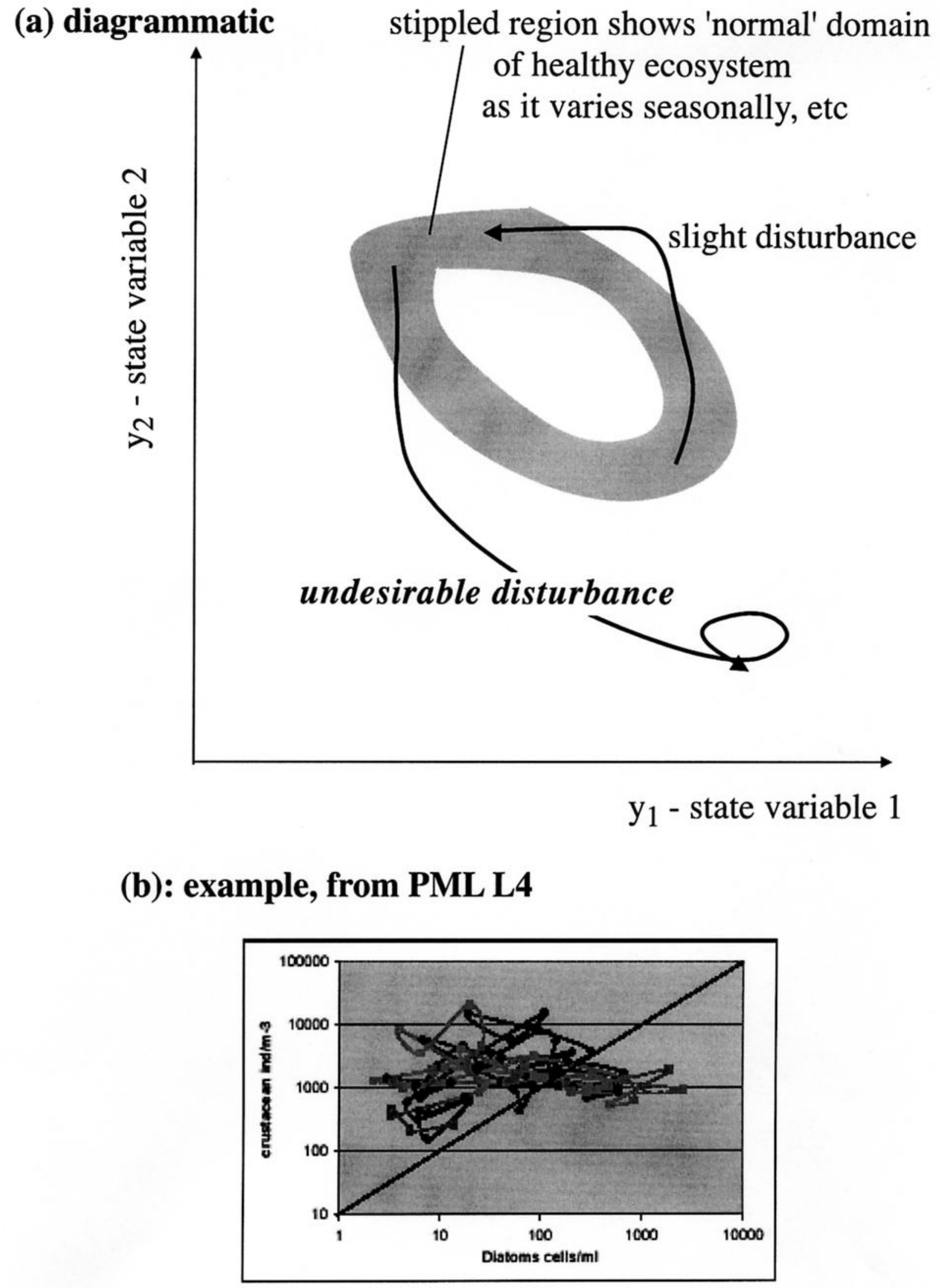

Figure 2: Ecosystem state

its state remains within, or is capable of returning rapidly to, the doughnut. Bad health consists of sustained movement away from the doughnut, and this is shown as constituting an ***undesirable disturbance***. The movement could lead to a new stable state or region or attraction - i.e. another doughnut - might be healthy in absolute terms, but nevertheless ***undesirable*** because of the change of state and perhaps ***biome***, or it could clearly be less healthy, as in the case of a benthos smothered by a blanket of particulate organic matter.

Fig. 2(b), taken from the time series data collected at the PML L4 station in the English Channel, instances such a state-space plot, the two state variables being diatom abundance and copepod abundance (and these are of course bulk statistics, derived by aggregating abundances of species). Weekly values over a 2 year period are plotted against each other. The diagram brings out the extent of the week-to-week and internnual variability that must be taken into account, in addition to the seasonal changes, in making an adequate description of system state.

In the present context it is necessary to distinguish disturbance caused by nutrient enrichment from that due to other causes. In the case of existing undesirable disturbance, this can be done by seeking theoretical or empirical links to nutrient enrichment; and, in the case of trends in indicators, by looking for correlation with trends in nutrient loading. In both cases it is important to have simultaneous data from reference sites, which provide a control on changes at the disturbed sites. The use of validated ***numerical models*** may allow the impact of added nutrients (as opposed to other pressures) to be quantified.

Pelagos

Nutrient enrichment of the ***pelagic*** part of a marine ecosystem can impact on phytoplankton, pelagic microheterotrophs (bacteria and protozoa) and metazoan zooplankton. Criteria for assessing such impact include:

- existing UK quality standards, such as the *Comprehensive Studies Task Team* (*CSTT*) eutrophication threshold of 10 mg chl m^{-3} in summer;
- the OSPAR *ecological quality elements*: phytoplankton chlorophyll; phytoplankton indicator species for eutrophication; dissolved oxygen;
- the WFD *biological quality elements* (contributing to *ecological quality status*) of phytoplankton, composition and abundance of taxa, biomass, and frequency and intensity of blooms;
- ***ecosystem health*** indicators relating especially to ***structure*** and ***vigour***;
- statistics relating to sustainability of human use, such as the frequency of ***Harmful Algal Blooms*** *(HABs)*.

Four sets of indicators seem useful for detecting undesirable disturbance of the pelagic part of marine ecosystems:

- bulk indicators of ecosystem state, especially water transparency and the concentrations of chlorophyll and of sub-pycnocline oxygen, which in turn may act as pressures on other ecosystem components;

- indicators of ecosystem ***structural health*** that involve identification and enumeration of microplankters (including phytoplankters) and zooplankters;
- flux measurements, indicative of ***vigour*** or ***dystrophy***, especially annual primary production, and deep-water oxygen consumption rate;
- frequency statistics, such as those for HABs.

The UDST proposed the following strategy for monitoring:

(1) identify waters which could be at risk from undesirable disturbance because of nutrient ***enrichment*** plus ***ecohydrodynamic*** conditions that allow nutrient-fuelled increases in production without effective ***coupling*** to consumers, or which favour accumulation of organic matter below a pycnocline;

(2) in waters where disturbance is possible, consider chlorophyll concentrations, the frequency of HABs, and in appropriate cases, transparency, and deep-water oxygen; if these breach an appropriate (type-specific) EcoQO or if they show an trend, year-on-year, that correlates with nutrient increases, then further study is required except in the case of small water bodies where it might be more cost-effective to assume undesirable disturbance;

(3) further study should involve estimation of annual primary production and the monitoring of plankton composition for comparison with a reference conditions.

Chlorophyll concentration has long been used as an indicator of phytoplankton biomass and photosynthetic potential, and can be measured both by standard water sampling methods and operational use of in situ fluorometry. Increased chlorophyll concentration decreases ***transparency*** and thus impacts on the phytobenthos in shallow waters.

There is no linear mapping from production to disturbance, and the level of production at which ecosystem ***vigour*** passes beyond an optimum to a ***dystrophic*** condition in which there is a danger of hypoxia or anoxia in deep water or sediment, depends on ecohydrodynamic conditions and the effectiveness of ***coupling*** between primary producers and their immediate consumers. In seasonally-stratified, or basin, deep waters, measurement of minimum oxygen concentration and rate of consumption are needed to assess this. Annual primary production should be measured in all large water bodies by an efficient methods combining measurement of photosynthetic parameters with routine measurements of chlorophyll and calculations of light penetration (Fig. 3). The possibility of ***dystrophy*** should be considered above a ***net microplankton production*** of 200 g C m^{-2} yr^{-1}. This is lower than Nixon's (1995) threshold of 300 g C m^{-2} yr^{-1} for ***eutrophic*** conditions, but is a precautionary value, and its surpassing points to a need for further study rather than diagnosing undesirable disturbance. It is likely that dystrophy will in fact only occur at much higher levels of production.

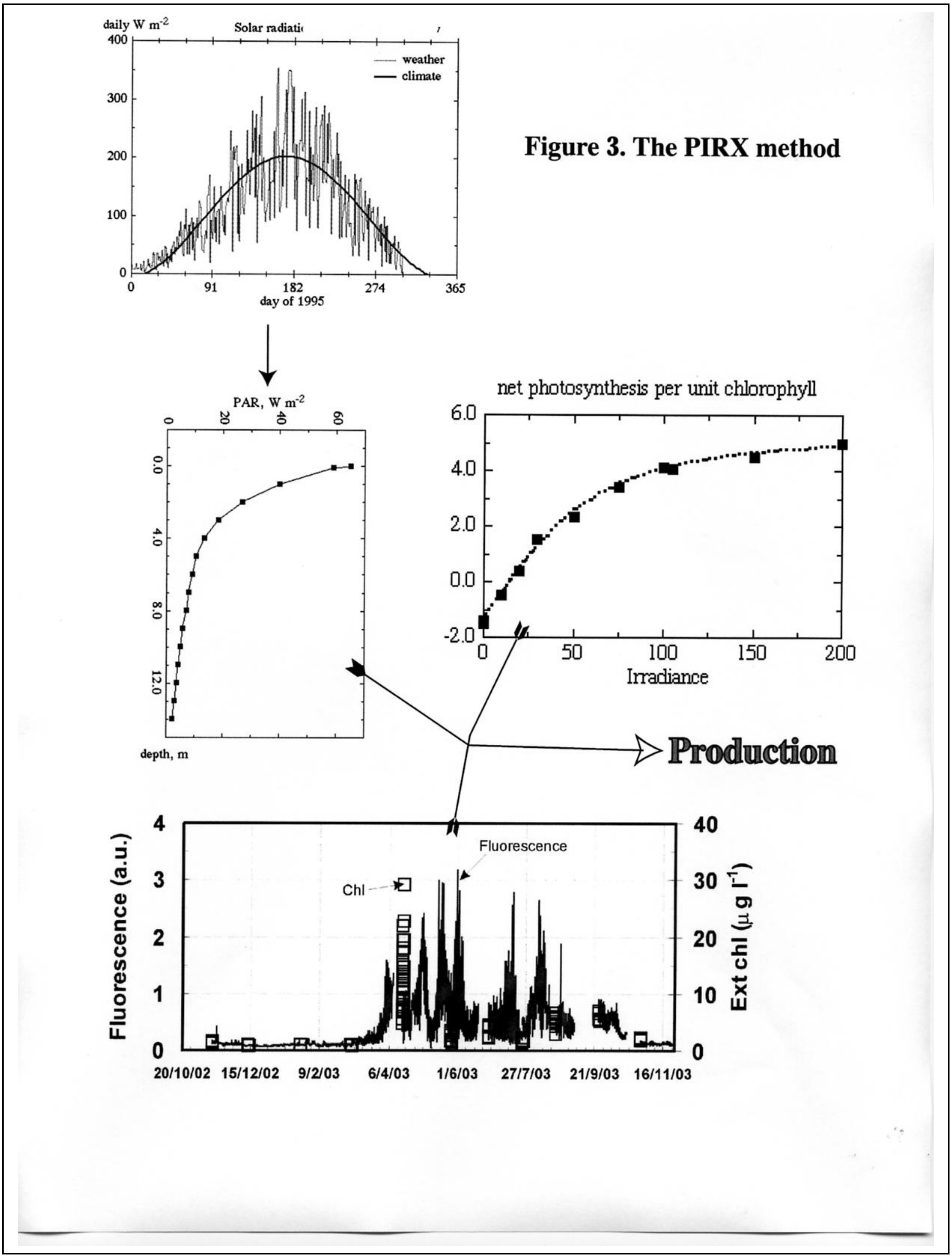

Figure 3. The PIRX method

Infrequent HABs are not a cause for concern, even if they result in local nuisances, on in local mortalities of fish or benthos. They are often natural. However, a trend of increase in the frequency of HABs, compared with a reference condition, is a cause for concern. There is a need for an agreed definition and co-ordinated record of HABs. This record should initially be restricted to large-biomass events (including Red Tides) which either cause a documented nuisance or kills of wild farmed animals, or contain species with the potential to do this. For the present, incidents involving ***Shellfish-Vectored Toxins*** (***SVT***s) should not be counted, but studies of the relationship between these and nutrient levels are desirable.

Remote sensing of phytoplankton and primary production is presently of limited operational value in the optical class 2 conditions of most UK coastal waters, where the main optically active constituents are suspended particulates and yellow substance. However, there are waters where remote sensing can be used to record the occurrence and extent of HABs, given a minimum sea-truth, and such regions should be identified as part of ecohydrodynamic typing. Example images can be obtained from the Plymouth Marine Laboratory Remote Sensing Group (www.npm.ac.uk/rsdas/) and include those at http://www.npm.ac.uk/rsdas/projects/ shetland_bloom/.

Monitoring of the structure of the plankton requires high frequency observation of each component, including the main taxonomic and functional groups of phytoplankton, pelagic protozoa and metazoan zooplankton. The time series maintained by the Plymouth Marine Laboratory at the L4 station in the English Channel (see: http://www.pml.ac.uk/L4) exemplify the resolution needed. Continuous Plankton Recorder Survey data are less useful because the recorders select for certain organisms and are not deployed close to shore. However, they are vital for documenting long-term, wide-area, changes, such as those due to climate change and fisheries, which impact on reference conditions for eutrophication. The study team concluded that that there are no individual species of phytoplankton, or indeed zooplankton, which are useful indicators of eutrophication. Instead there is a need for holistic analysis of plankton ***state.*** Data should be plotted, perhaps in a statistical reduction of multidimensional state variable space, for comparison with ***envelopes*** obtained under reference conditions. Sustained deviation from the envelope diagnoses ***undesirable disturbance.*** A ***phytoplankton trophic index (PTI)***, and a ***plankton community index (PCI)***, should be developed to simplify this task. Studies should be carried out with candidate PCIs to find one that is a good indicator of the efficiency of producer-consumer ***coupling***.

Phytoplankton are the crux of the matter in diagnosing eutrophication, not only because they provide the initial response to nutrient enrichment, but also because it is now clear that they encompass a huge range of taxonomic and functional diversity which cannot be ignored in assessing the health of marine ecosystems. Monitoring is initially likely to emphasise the role of diatoms and armoured dinoflagellates, but must ultimately include the smaller algae and the protozoa that help control them. Human microscopical examination of plankton samples must for the present remain the core method of analysis. Flow cytometry may be worth considering for smaller phytoplankters. Two other methods, presently non-operational may repay further study. Both relate to the photosynthetic accessory pigments that differ amongst the major taxa of phytoplankton. The pigments can be chemically separated using HPLC, or distinguished by their different spectral light absorptions.

Automated devices, including moored ***Smartbuoys***, and ***Ferryboxes*** on ships making regular crossings, can measure physical and optical variables and the concentrations of chlorophyll and nutrients. They can thus provide the high frequency data needed especially in regions of high physical variability (such as ROFIs) and could allow estimation of pelagic ecosystem ***resistance*** to nutrient pressure by measuring the yield of chlorophyll from nutrient. Finally, they can take and preserve samples for phytoplankton.

Benthos

The benthic environment and the macrozoobenthos respond to disturbance in well-characterized ways. However, few of these responses are unique to the pressure of nutrient enrichment or offer sensitive indicators of undesirable disturbance in the context of eutrophication. In shallow waters, natural physical disturbance is often the dominant effect. and the deep water benthos is often impacted by fisheries gear. So far as the consequences of nutrient enrichment are concerned, the main effects are likely to be:

- subtle changes of benthic community structure resulting from increased food supply;
- intense local pulse disturbances resulting from sinking Red Tides;
- chronic changes in community structure as deep water oxygen content falls and/or the anoxic region of the sediment extends towards the surface;
- catastrophic widespread destruction of deep water benthos associated with extreme hypoxia and anoxia.

The latter would of course be an *undesirable disturbance*, and has occurred in the deep water of the Baltic Sea as a result of increased nutrient loading of water which experiences long intervals of stagnation (Fonselius & Valderrama, 2003; Laine et al., 1997). Excepting a few sea-lochs, UK waters are not at risk of this. Monitoring against undesirable disturbance must thus be able to detect relatively subtle changes in community structure, or changes in environmental conditions that drive these. Such conditions include sediment organic carbon content and deep-water and sediment oxygen concentrations. Indicators for the state of benthic communities include: **indicator species** as such; indicators of groups of species known to be disturbance- sensitive or insensitive; and holistic measures of community ***structure*** including ***diversity indices*** and ***trophic indices***. The last are those derived from data on the relative abundance of different feeding types or ***guilds***, and are perhaps better called ***Benthic Community Indices*** (***BCIs***). All such measures of structure are subject to the great natural variability of the benthos, and so need many replicate samples to provide a precise value. The UK National Marine Monitoring Programme is currently reviewing some of these indexes.

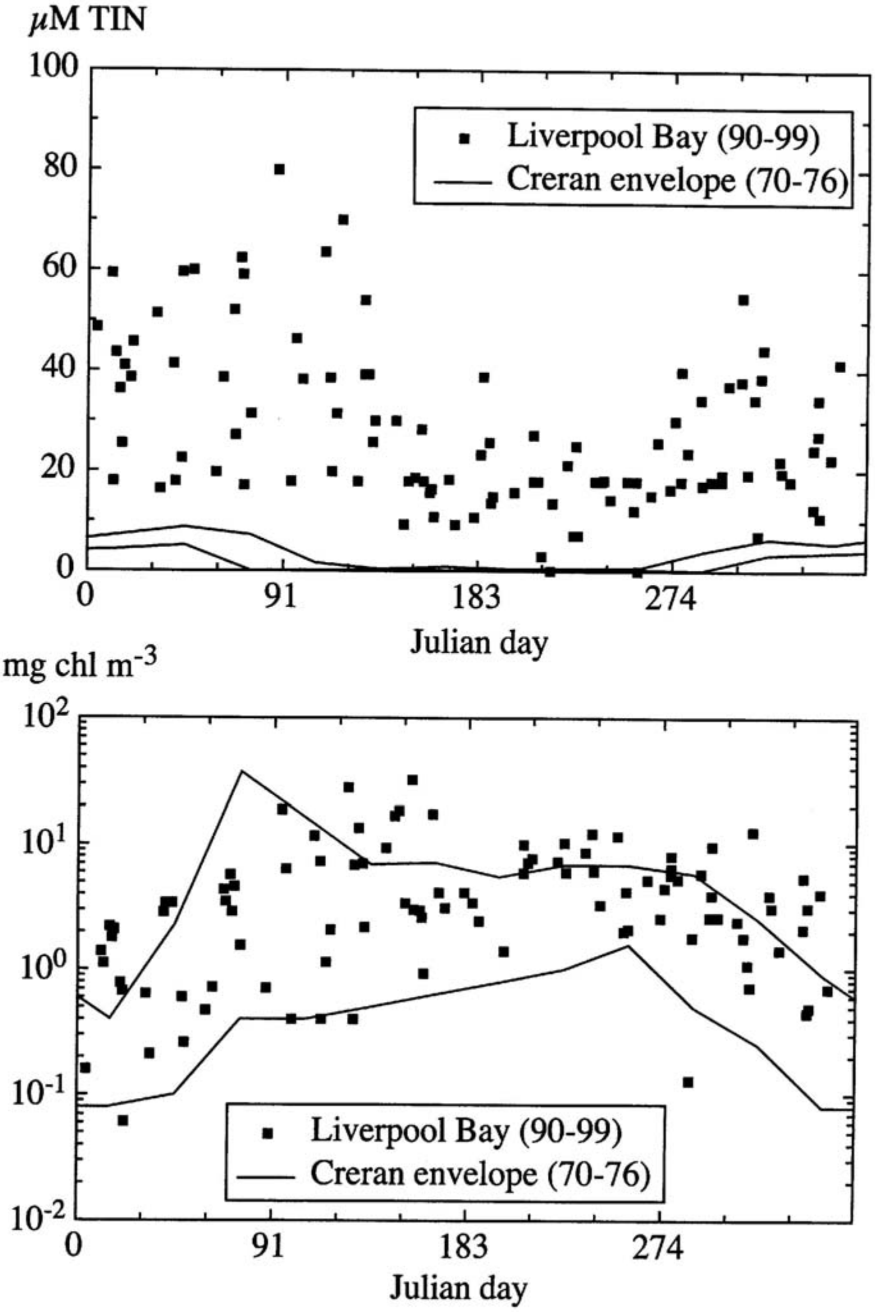

Fig. 4. Liverpool Bay - Fairway compared with Loch Creran

New techniques involving imaging are likely to prove useful. Cameras on towed benthic sleds can serve to estimate, for example, the population density of burrows in muddy sediments and thus the abundance of the burrowing animals. *Sediment Profile Imagery (SPI)* can be used to measure the depth of the ***Redox Potential Discontinuity*** (***RPD)*** which is a good indicator of habitat quality in soft sediments (e.g. Nilsson & Rosenberg, 1997).

Taking account of these considerations, the proposed monitoring strategy is to evaluate:

- **minimum concentrations**, and **rates of consumption**, of **oxygen** in seasonal and basin deep water, together with **RPD depth** measured by **SPI**, as indicators of ***vigour*** in the sense of relating to conditions that can lead to ***dystrophy***;
- values of one or more relevant ***BCI*s**, such as the ITI or AMBI, together with estimates of the population of an **indicator species** such as *Nephrops norvegicus* (an important bio-engineer in deep mud sediments and sensitive to low oxygen concentrations), as indicators of the ***structure*** component of ecosystem health.

In respect of deep water oxygen, the UDST suggested that concentrations should remain above 4 mg L^{-1}. It seems that the RPD should be deeper than 2 cm to allow the existence of a *normal* macrobenthic community, but this needs further investigation, and the value may depend on ecohydrodynamic type. Similarly, ranges of values of the ITI and AMBI have been proposed for *normal* conditions or *good* or *high* quality status (Codling & Ashkey, 1992; Borja et al., 2004), but such ranges need further investigation in relation to the specific types of environmental pressure and disturbance resulting from nutrient enrichment. Thus it is recommended that monitoring be used to compare indicator values with an appropriate reference condition and examine trends over time. Differences and trends should be further examined for correlation with nutrient levels.

Phytobenthos

Some of the tools being developed for assessment of WFD biological quality elements by the *Marine Plants Task Team* (*MPTT*) may provide indicators of undesirable disturbance due specifically to nutrient enrichment. So far as the phytobenthos is concerned, only two undesirable consequences of eutrophication occur on UK coasts. They are the mass blooming of macroalgae on tidal flats, and seagrass decline. These problems occur mainly on sedimentary shores in localized areas.

The concept of *macroalgal indicator species* is not useful in terms of estimating ecological quality. All the nuisance or opportunist green and brown seaweeds are important members of their communities under good conditions. It is the loss of other species rather than the gain of these indicators that is the problem. A better method is to use bulk features of cover by the opportunists, including:

- Area covered;
- Biomass density;
- Evidence of adverse effects due to the weed cover.

One criterion for eutrophication proposed by the MPTT is that it has occurred when more than 25% of the available intertidal area is covered with green macroalgae of greater than 25% cover. The intertidal areas included in this assessment are soft-sediment only, as high levels of macroalgae can naturally occur on rocky shorelines. A second criterion is that of (annual maximum) biomass exceeding 1 kg m^{-2}. Adverse effects can include:

- Invertebrate fauna reduced, in general, or numbers of commercially exploited shellfish, such as cockles, reduced in particular;
- Wading bird feeding distribution modified;
- Floating rafts of weed affecting boating activity, or deposited weed smothering other salt marsh vegetation, or anoxia in surface sediment layer (e.g. top 2 cm), or public complaints about odour.

Four tools have been proposed by the MPTT for the assessment of sea-grass beds. They are:

- ***areal cover*** and ***density*** **(**as shoot density or % cover) as non-destructive indicators of abundance;
- ***progress of the Wasting Disease*** (in subtidal seagrass species only) and ***epiphyte cover***.

None of these indicators are specific to eutrophication, and so it is necessary that trends in their values by examined for correlation with trends in nutrients. Because of the important conservation status of seagrasses, any correlated trend of decreasing abundance or health should be deemed an ***undesirable disturbance***.

Checklist

The parts of the methodology developed by the UDST for the monitoring and diagnosis of ***undesirable disturbance*** due to anthropogenic nutrients have been synthesized in a checklist, which is appended to this document. The main steps in using the methodology are:

- assess ecohydrodynamic type (and thus, in principle, the reference conditions);
- assess nutrient loading, and hence identify water bodies/ecosystems where there is potential for undesirable disturbance in the context of eutrophication;
- use bulk and frequency indicators, and in some cases tools such as that of the CSTT eutrophication model, in comparison with reference conditions, to make a provisional diagnosis of nutrient-induced disturbance;
- use correlation between (adverse) trends in these indicators and in nutrients to support the provisional diagnosis or to identify water bodies or shores that should be subject to continued detailed monitoring;

- use primary production (a part of ***vigour***), and indicators of planktonic and benthic community ***structure***, to assess departures from good ***ecosystem health***; in some cases the state of populations of indicator species will form part of the health assessment.

In addition to analyses for trends and correlations, most indicators are also to be assessed against an appropriate EcoQO. Two types of EcoQO are considered here:

- the value of an indicator shall not exceed (or not fall below) a certain standard value, which may be absolute or may relate to reference conditions;
- no more than 5% of values of an indicator shall fall outside of an ***envelope*** of variability defined for the appropriate reference condition; the envelope may be either that of property plotted against time, or that in phase space (Y_1-Y_2 etc plots).

Envelope plots are particularly appropriate in the case of the plankton, because of the very large amount of natural short-term, seasonal and inter-annual variability shown by both bulk measures of plankton components and the abundance of individual species in UK salt waters. An example property-time envelope plot is given in Fig. 4.

The checklist include several possible diagnoses:

- ***insufficient data***;
- a ***trend*** towards undesirable disturbance related to nutrient enrichment;
- ***undesirable disturbance*** due to nutrient enrichment.

Given that water bodies and ecosystems will be assessed only if they have been identified as at risk because of nutrient enrichment under sensitive ecohydrodynamic conditions, the remedies for ***insufficient data*** are simple. Either data collection must be started urgently, or else the *precautionary principle* must be invoked and action to reduce nutrient inputs taken as if ***undesirable disturbance*** had been diagnosed. An identified adverse ***trend*** implies that a water body or shore should be the subject of continued frequent monitoring. It does not mean that action <u>must</u> be taken to reduce nutrient inputs because increasing primary production might on balance be more beneficial than harmful to ecosystem health. The diagnosis of ***undesirable disturbance*** may be made at several stages in the analysis. The ideal diagnosis will take account of all indicators, including those relating to ecosystem structure and vigour, and this is what the study team recommends for large water bodies - not only because of the cost implications of the diagnosis but also because of the unknown long-term risks of misunderstanding the state of a large part of our salt waters. However, a provisional diagnosis from bulk or frequency indicators may be accepted as final in the case of smaller water bodies or shores, where the cost of measurement of structure and vigour may outweigh the cost of nutrient reduction.

Finally, the UDST suggested that there should be a 4-year study of the Irish Sea, including adjacent waters such as the Firth of Clyde and the sea-loughs of Northern Ireland, with the aim of testing and using the methodology developed in this work on ***Undesirable Disturbance***, building on existing and planned programmes. Having tested and refined the methodology and checklist in the (broader) Irish Sea, it should be applied to other UK waters, commencing with an identification of ecohydrodynamic regions and characterization of the plankton communities therein under reference conditions.

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Figure legends

1. Ecosystem *health* and undesirable disturbance. The primary components of *health* are good ***structure*** and optimum ***vigour***. These lie behind the ecosystem's ***resistance*** to pressure and ***resilience*** in recovering from disturbance. (a) relates health to vigour as this increases with nutrient enrichment; (b) shows the typically non-linear response of structure to pressure.

2. Ecosystem state. (a) is a diagram relating state and disturbance; (b) plots data from the Plymouth Marine Laboratory L4 station, available at http://www.pml.ac.uk/L4.

3. The 'PIRX' method of estimating primary production. PIRX is an acronym combining Photosynthesis as a function of Irradiance, taking account of Respiration, and multiplying by chlorophyll concentration (X) to get production.

4. **Envelopes of variation for DAIN** (called here, *total inorganic nitrogen (TIN))* **and chlorophyll at the Fairway station in Liverpool Bay, 1990-1999** (EA data), compared with envelopes for supposedly pristine Loch Creran during the 1970s (re-analysed by Tett & Edwards, 2003, who give primary sources).

Integrating International and European targets into UK practice

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Since 1992, the UK government conservation agencies have undertaken a considerable body of work focussed on the implementation of the EC Habitats Directive (92/43/EEC), particularly to meet the requirement to select Special Areas of Conservation (SACs) for Annex I habitat and Annex II species features. This follows the UK's traditional approach to site-based protection of marine habitats and species. More recently, the focus has switched to developing and implementing schemes to monitor and assess the status of the designated features in these SACs (see talk by Simon Brockington, English Nature). The total area of Special Areas of Conservation (SACs) is approximately 13000 km^2 but despite the considerable success of the SAC designation programme, these protected sites cover only about 8% of seabed within UK inshore waters (within the 12 nautical mile limit) or 1.8% within the UK's designated continental shelf (source: JNCC designations database for SAC boundaries, percentages are derived from using JNCC GIS data). This site-based approach links with the management of spatially constrained pressures and impacts such as dumping, construction, extraction or disposal via fixed installation. Such an approach does not accord with wide-ranging pressures and impacts such as diffuse pollution, fishing or climate change that occur throughout UK seas.

Current initiatives recognise that this site-based approach must be complimented with a more detailed consideration of the wider marine environment to deliver an effective marine environmental protection policy. In addition to the UK's obligation to implement legislation from the European Union (for example the Water Framework Directive, Habitats Directive), the UK is signatory to a series of international conventions and agreements that address the entire marine environment. For benthic habitats and species, the Oslo and Paris Convention (OSPAR) and the Convention on Biological Diversity (CBD) through its Biodiversity Action Plan (BAP) process are perhaps the most important international instruments. Contracting Parties to OSPAR are currently taking steps towards implementing the biodiversity protection measures in Annex V though establishing an 'ecologically coherent network' of marine protected areas, and protecting an agreed list of threatened and declining habitats and species (see http://www.ospar.org for more details). It is proving a challenge to establish the known locations of these habitats and species before we even consider assessing their status. The Göteborg Target set by the EU - 'biodiversity decline should be halted [in the EU] with the aim of reaching this objective by 2010' will similarly prove a challenge in the marine environment. Finally, a key requirement of the EC Habitats Directive is the assessment of whether the listed habitats and species are at 'Favourable Conservation Status' throughout the territory of Member States, not simply in the series of SACs.

All these international conventions and agreements, together with EC Directives, have targets for marine environmental protection that apply to UK seas in their entirety. Establishing whether UK seas meet these targets, particularly those areas subject to spatially dispersed pressures and impacts from anthropogenic activities, poses a significant challenge to future monitoring programmes. It is a challenge that must be met if the UK is to fulfil its commitments under these international instruments.

However, in the real world of finite resources, it is clear that the UK monitoring strategy will need to be a multi-sector (public, academic and private), multi-disciplinary approach where the unrestricted sharing of data and information is the key underlying principle. Work is currently underway to improve the coordination, harmonisation and efficiency of current national and international monitoring , and tools either have already been developed, or processes are in place, to facilitate such co-operation and data sharing. JNCC is involved in two examples: the National Biodiversity Network Gateway (http://www.searchnbn.net) provides species sample data available over the internet to support biodiversity assessment; and a marine habitat mapping project called **M**apping **E**uropean **S**eabed **H**abitats, or MESH (http://www.searchMESH.net) part funded by EC INTERREG IIIB, is collating data on the distribution of habitats and communities, also for delivery over the internet. Nevertheless, data sharing is currently the exception rather than the norm in the UK. Furthermore we must recognise that it will not be possible to standardise survey techniques across all studies and programmes and therefore we will have to develop more novel approaches to assessing the status of habitats and species based on variable data, particularly with respect to survey effort. DEFRA and the UK government conservation agencies are trying to tackle this problem through targeted research – for example with Plymouth Marine Laboratory, but there remains some way to go before we have acceptable tools for biodiversity assessment.

Therefore, in summary, when developing a monitoring strategy, we must adopt a flexible approach that considers local pressures and impacts (one of the UK's strengths) and a strategy to assess the wider marine environment (a weakness) so that the UK can report on its progress towards achieving internationally agreed targets for marine environmental protection. The key take-home messages are:

- The UK is party to a series of internationally agreed targets for marine environmental protection that apply to all UK Seas (out to approximately 200 nautical miles)
- A traditional, local, site-based monitoring strategy will not be sufficient to provide information to assess the UK's progress towards these international targets
- Any future UK monitoring strategy will need to embody a multi-sector, multi-disciplinary approach based on data-sharing to effectively report on the status of UK seas.

Developing a UK Marine Monitoring Strategy

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In 2002, the Government set out its vision for the conservation and sustainable development of the marine environment in the Marine Stewardship Report. This stewardship, using an ecosystem based approach, must be informed by the best available scientific evidence, as part of our aim to assess and improve the indicators which we use. In order to develop better integration of marine environment monitoring and observation across the UK, two important and related new initiatives have been started. These are the preparation of a State of the Seas Report, due for publication in 2005, which brings together all the various monitoring results and looks at what they tell us in an integrated way. Also setting up of a Marine Monitoring Coordination Group which has a remit to coordinate the various types of monitoring and observations which are needed to properly assess whether the seas are clean, safe, healthy, productive and biologically diverse and develop appropriate monitoring strategies.

Defra chair the Marine Monitoring Coordination Group and thus far we have action plans from the four monitoring sectors which comprise:

- Physical processes and climate : (IACMST GOOS Action Group)
- Environmental Quality and Human impacts: (Marine Environment Monitoring Group)
- Habitats and Species: JNCC
- Fisheries: CEFAS and FRS

These sectors also represent the way in which evidence was collated for the State of the Seas report. As we move into the final evidence collation phase and try to draw conclusions on the state of our seas we are faced with a number of challenges. We know that the monitoring programmes, whilst delivering sound evidence to report compliance with national and international legislation are less informative in ascertaining the overall state of our seas. Consequently, the monitoring strategy must address these lessons learnt from integrated reporting and move us forward.

This presentation will outline some of the lessons learnt from combined reporting from the monitoring sectors and discuss the challenges we face in monitoring the marine ecosystem in the future.

For example we have scientific and technical questions:

How do we take account of climate change impacts?
How do we distinguish between natural and anthropogenic changes?
How do we monitor our seas to cover all temporal and spatial scales?

And we also have management and coordination questions:

How do we combine our compliance driven monitoring with surveillance with the wider aspects of ecosystem health monitoring we need to deliver the stewardship agenda?

and

Where do responsibilities lie for coordination of field work, setting standards, reporting etc for the additional science we need to undertake?

As Defra and the MMCG address these issues we will be consulting with you as stakeholders and welcome comments and feedback to Beth Greenaway at the above address.

Review of the marine environmental indicators reporting on the biodiversity aspects of ecosystem health

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The UK has a range of marine conservation policies and commitments, however, it is not always clear how effective the various actions are in achieving particular conservation objectives, if at all. The setting of environmental targets and indicators, which can inform decision-making and help measure and report on environmental changes and progress towards environmental goals and objectives are now the norm for the UK Government.

While most environmental indicators describe the quality of a particular aspect of the environment, a more recent trend has been to try to identify indicators that reflect and report on ecosystem structure and function. These are often grouped into a 'suite' of indicators. This approach is in line with a desire for a more ecosystem-based approach to management that is being advocated by many fora and organisations, and is particularly relevant to the marine environment.

The RSPB commissioned a review of the marine environmental indicators reporting on the biodiversity aspects of ecosystem health. The review looks at the present range of indicators that the UK has signed up to both domestically and internationally and comments on those best-suited to give an overview of marine ecosystem health.

Gubbay, S (2004) *A review of marine environmental indicators reporting on biodiversity aspects of ecosystem healt*h. The RSPB, Sandy, UK.

A copy of the report can be obtained from:
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