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Report of the Regional Ecosystem Study Group for the North Sea

5–7 April 2004
Lowestoft, UK

International Council for the Exploration of the Sea

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1 OPENING OF THE MEETING

Dr A. Kenny (Chair) opened the meeting of the Regional Ecosystem Study Group for the North Sea (REGNS) and welcomed the participants (Annex 1) to Lowestoft. He introduced the agenda and provided a brief summary of the discussion and outputs from the REGNS 2003 meeting in Nantes. Overall REGNS is required to take a strategic view on how ICES (over the medium to long term, 3 to 5 years and > 5 years, respectively) can move towards delivering ecosystem based advice underpinned by sound science utilising the data and knowledge within the existing network of ICES Working Groups.

At the 2003 meeting much time was spent defining and understanding the "ecosystem approach" and what this means to ICES, in particular which components of the Ecosystem Approach (EA) can be directly influenced by ICES. The result of these discussions resulted in new Terms of Reference being set for the group to address, these are the subject of this present report.

The ToR can be broadly divided into one of three types, namely those which address the need to; 1) develop the science (or evidence) base, to look at how ICES can contribute to the Priority Science Issues and whether these 'issues' are relevant or not in the context of Integrated Assessments (Sections 2 and 3); 2) consider ways in which ICES can contribute to more effective marine monitoring (Section 6); and 3) establish detailed plans to deliver ICES regional integrated ecosystem assessments for the provision integrated advice (Sections 4, 5, and 7).

REGNS is concentrating on the North Sea to develop a 'proof of concept' regional integrated ecosystem assessment.

2 EXISTING R&D AND THE PRIORITY SCIENCE ISSUES

At the Fifth North Sea Ministerial Conference, the Ministers agreed to adopt the ecosystem approach to management. This has been defined as integrated management of human activities based on knowledge about the ecosystem to achieve sustainable use and its protection. The implementation of an Ecosystem Approach is based on a framework that includes:

- setting of operational environmental objectives,
- monitoring the status and trends in the ecosystem,
- conducting research to obtain better insight into the workings of the ecosystem,
- assessing the status of the ecosystem and the degree of human impacts,
- providing scientifically objective advice to management,
- making appropriate policy decisions and management actions,
- involving stakeholders to improve transparency and responsibility.

A scientific expert conference related to the Fifth North Sea Conference was held in Bergen 20–22 February 2002. The aim of the expert conference was to identify priority issues for scientific research and monitoring to support the implementation of an ecosystem approach to management and protection of the North Sea.

Short-term:

1. Operational description of currents and water masses.
2. Production of the first generation habitat map of the North Sea.
3. Mapping and monitoring of spawning areas of commercial fish populations.
4. Experimental studies of the effects on benthic species, communities and habitats following closure of areas to bottom trawling.
5. Identification of threatened, declining and rare species and habitats.
6. Further development of ecological objectives and indicators for monitoring changes in the ecosystem and for measuring the effects of management actions.

Longer-term:

1. The role of species richness (including the issues of key species, species diversity, species redundancy, and rare species) for the functioning of benthic communities.

2. Mechanisms influencing transfer efficiencies between phytoplankton and higher trophic levels and the implications on ecosystem dynamics.

3. Resolution of habitats and processes influencing the population dynamics of key species.

4. Food web and life history interactions among fish populations and other ecosystem components (plankton, benthos, seabirds and marine mammals).

5. Physical and biological transport and biological and ecological effects of contaminants.

Norway (as Secretariat for the Fifth North Sea Conference) passed the conclusions of the Expert WG to ICES.

2.1 GAPS IN R&D TO DELIVER THE PRIORITY SCIENCE ISSUES

As a case study, the UK Defra R&D programmes for both fisheries and environment (summarised in Annex 2) were briefly reviewed and compared to the short- and long-term priority issues identified by the Scientific Expert Conference. A total of 136 environment projects and 56 fisheries projects commissioned by Defra since 1997 were reviewed. This highlighted gaps in addressing two of the short-term priority science issues, namely, 1) operational fisheries oceanography, and 2) study of fishery closure effects. This was also considered to be true of the R&D conducted by other North Sea states, notably Norway. However, it is important to realise that this simple case study review of UK Defra R&D has not looked in detail at the outputs, or up-take, of the programmes in relation to the priority science issues.

Essentially R&D programmes are funded either by national governments or as part of collaborative international programmes, largely via the European Commission and DG Research (see Table 1 (a(–(d)) such as the Framework Programme and Interreg. ICES does not commission its own research, but because of its role in coordinating fish stock monitoring and assessment programmes, it is potentially in a strong position to shape the research agenda, particularly if the links between advice, monitoring and R&D can be better integrated. It is generally accepted that ICES fish stock and environmental data could be better used to provide integrated assessments and to validate (modelled) predictions of ecosystem change. The use of monitoring data to validate model predictions is not new to ICES, but what represents a challenge for present and future assessments is the need to predict and model change of complex systems (ecosystems) not just fish stocks. There is therefore a need to have much more effective and transparent communication between the R&D community (DG Research) and ICES Working Groups (and vice versa). The result of this could then be measured in terms of greater evidence-based environmental policy development.

The WGs of ICES bring together scientists who are engaged in various national and international R&D projects, but the ability to effectively utilise this experience within ICES for its primary assessment and advisory function is presently limited. The priority science issues do not specifically address the issue of effective knowledge transfer between the monitoring, R&D and advisory/policy sectors. R&D targeted at addressing the issue of knowledge transfer could go a long way in making ecosystem-based management an operational reality.

How can knowledge transfer be made effective? The North Sea ecosystem has been studied extensively for many years and although we know much about its structure and function, this knowledge, because of its complexity, is not being used as effectively as it could be to address the regulatory and management needs. Setting priorities for further research therefore becomes of foremost importance. Do we continue to develop the scientific understanding of the North Sea ecosystem at the expense of making the existing knowledge more useable for policy development and the management of pollution? These priorities must be guided by the need to understand the North Sea as an ecosystem and to assess the degree of human impact on this system and how management intervention can improve environmental quality and/or sustain ecosystem function and biodiversity.

One possible solution to knowledge transfer, and one which is growing in credibility, is the development of ecosystem models. For example, results from specific R&D examining transport, fate and effects pathways of contaminants can be used to parameterise ecosystem models, at the same time the models can be subjected to sensitivity analysis to examine which attributes (parameters) of the ecosystem are most critical to its function. These, in turn, should help to focus the design of marine monitoring programmes from which the results can be fed back to validate the model predictions. The present disconnection between R&D, monitoring and advice is therefore potentially bridged by the application of such models. A good example of how this could work is provided in Annex 3.

Table 1(a). Drivers - Organisations developing the need for ecosystem science, and the setting of the science priorities are as follows:

International	North Sea Conference Process
	OSPAR
	EU Marine Strategy (DG-ENV) - EMMA WG - EAM WG - SGO WG - Habitat and Species WG
	Common Fisheries Policy (DG-FISH)
	EU Directives - WFD - Habitats - Birds

Table 1(b). Co-ordinators - The following organisations co-ordinate ecosystem science:

International	EFARO
	ICES
	OSPAR
	EuroGOOS
	GLOBEC

Table 1(c). Funders - The following organisations fund ecosystem science:

International	EU - DG-RES - DG-ENV - DG-FISH
	Interreg
	INCO
	Industry

Table 1(d). Delivery - The following routes exist through which ecosystem science is currently delivered:

International	FP6 Projects, Interreg
National UK	National Projects - FRS / CEFAS - SEPA / EA - SNH / EN / JNCC - SAMS / NERC / Universities

The study group did not have time to look at the relative spending on R&D between international and national programmes, but we suspect that most work is delivered by national programmes, whereas most of the drivers are international.

2.2 CONCLUSIONS

- REGNS concluded that the link with R&D (especially close collaboration with those that commission research) has to be strengthened in ICES. REGNS could develop R&D proposals that would establish better links between advice, monitoring and research so that present knowledge within ICES (including its data) could be more effectively utilised.

- REGNS concludes that knowledge transfer between member states and their monitoring, advisory and R&D programmes, is a key limiting step in delivering integrated assessments. The Head of Science Programmes in ICES could play a vital role in shaping the R&D agenda in order to facilitate this knowledge transfer.

3 DEVELOPING AN ICES-COORDINATED ECOSYSTEM SCIENCE PROGRAMME

The principal purpose in establishing an ICES-coordinated Ecosystem Science Programme is to provide scientific assessments for integrated environmental and ecosystem advice. The Priority Scientific Issues for the North Sea specified that such a programme should be linked to work on defining EcoQOs and on indicators for ecosystem state (and function). It also specified that the programme be closely linked to the regulatory frameworks and institutions responsible for management measures based on scientific information and advice.

A wide range of marine ecosystem research is currently under way in the ICES area and it would clearly be impractical to encompass all of this within a coordinated science programme. However, work which is relevant to the scientific advice which ICES is required to produce should, as far as possible be included. Many research programmes at national and international level aim to provide results and information which are relevant to management. Since ICES is one of the principal international institutions which converts scientific data into management advice, it would benefit both the wider research community and ICES if there was a process for integrating research more closely into ICES advice.

An ICES Ecosystem Science Programme should therefore have as its objective to coordinate research which is intended to be applied in marine ecosystem management at national and international level. The relevant funding organisations should be asked to stipulate that results from such research be communicated to ICES. The ICES Ecosystem Science Programme should provide guidance to research programmes on current issues in marine management and, where appropriate, act as a coordinator for such research.

The programme must show clearly how results are being applied in order to encourage the widest possible participation by the scientific community and to widen the scientific base for ecosystem management. At present, ICES fisheries assessments do not include environmental and ecosystem information, even though it is recognised that fish stocks are affected by their environment and interact with their ecosystem in complex ways. The means for applying a wider range of information to advise on fisheries management are being developed in ICES through its working groups on biological and environmental interactions and ecosystem effects of fishing. Such approaches have been in use for some time in most other parts of the world.

3.1 AN APPROPRIATE FRAMEWORK FOR COORDINATING R&D

The new structure for the advisory process within ICES now includes Regional Integrating Groups and these, or sub-groups of them, should provide a forum for developing appropriate guidance for Ecosystem Science Programmes. This would provide a close link between the scientific activity and the management advice, which is particularly important in the current situation where the requirements for ecosystem management are evolving rapidly and must be based on robust scientific evidence.

It is very important that the close linkage between the advisory and the scientific aspects of the development of ecosystem assessment should be fostered within the ICES Secretariat and within the ICES Science and Advisory components. The proposal (Section 5) for a REGNS workshop to produce a “proof of concept” Regional Integrated Assessment for the North Sea sets out a number of specific actions which will help to develop the necessary close links.

ICES and GLOBEC

The Bergen Declaration invited ICES and GLOBEC to contribute to the development of this programme. The ICES/GLOBEC Coordinator took part in the 2004 REGNS meeting and acted as a liaison with the International GLOBEC programme. The ICES/GLOBEC Cod and Climate Change programme has an ongoing programme of research which is planned to continue until 2009, when the GLOBEC programme as a whole ends. The programme includes a number of elements which are or will be relevant to developing an Ecosystem Research Programme for the North Sea and a continuing interaction and contribution is expected.

The GLOBEC programme also provides a link with other IGBP programmes dealing with global change and the earth system. The most relevant of these is probably IMBER, which is getting under way. There are also a number of national

GLOBEC programmes (particularly the UK Marine Productivity Programme and the German GLOBEC programme) which are highly relevant to ICES interests.

An ICES Ecosystem Science Programme would also benefit from interaction with other regional science programmes and networks (which in the context of the North Sea would mainly come from the EU and Norway).

3.2 CONCLUSIONS AND RECOMMENDATIONS

- The Secretariat should consider providing support for the Ecosystem Science Programme, through the role of the ICES Head of Science Programmes. However the support required may be greater than that which can be provided by one person. The possibility of additional help, at least during the development stage of this process, needs to be considered, with possible external funding.

- There may be scope for establishing an externally funded project to help with some of the tasks identified for action by the ICES Secretariat (e.g., data compilation, quality control, presentation and interpretation).

4 DEVELOPMENT OF ICES INTEGRATED ASSESSMENTS TO DELIVER INTEGRATED ADVICE

At the end of 2003 an intersessional group (consisting of Hein Rune Skojdal, Andy Kenny and Bill Turrell) was convened in London to draft a work plan of activities to develop an integrated assessment of the North Sea. A letter was drafted (Annex 3) which was circulated to relevant WGs explaining the rationale for a common ToR to compile status and trends data and to integrate the information thematically (see below). The resulting thematic assessments would in turn be presented as a series of papers at the 2006 ICES Annual Science Conference under the theme session on integrated assessment.

The following groups were given terms of reference for their meetings in 2004 to start planning for contribution to the 2006 North Sea Integrated Assessment:

WGITMO	25-26 March 2004	Cesenatico, Italy	S. Gollasch
WGMME	22-25 March 2004	Pasajes, Spain	Gordon T. Waring
WGECO	14-21 April 2004	ICES	C. Frid
WGPE	19-21 February 2004	Gijon, Spain	L. Edler, F. Rey
NORSEPP	24-26 March 2004	Southampton, UK	Martin Holt
WGSE	29 March-2 April 2004	Aberdeen, UK	R. W. Furness
WGOH	29 March-1 April 2004	Southampton, UK	A. Lavin
WGZE	5-8 April 2004	Hamburg, Germany	Steve Hay
WGHABD	5-8 April 2004	Corsica, France	J. L. Martin
IBTSWG	23-26 March 2004	Lisbon, Portugal	J.-C. Mahe
WGSAEM	1-5 March 2004	ICES	R. Fryer
WGMS	1-5 March 2004	Stockholm, Sweden	F. Smedes
MCWG	15-19 March 2004	Nantes, France	R. Law
WGBEC	22-26 March 2004	Oostende, Belgium	Ketil Hylland
WGEXT	30 March-2 April 2004	Vilm, Germany	S. Boyd
BEWG	19-22 April 2004	San Sebastian, Spain	H. Rumohr
WGPDMO	9-13 March 2004	Åbo, Finland	T. Lang
WGFE	2-7 April 2004	ICES	J. Ellis
WGEF	correspondence		M. Clarke

The terms of reference can be grouped broadly into three categories:

i) to summarise status and trends of:

ocean climate – WGOH
phytoplankton communities – WGPE
harmful algal blooms - WGHABD
zooplankton communities – WGZE
benthic communities – BEWG
fish species distribution and communities – WGFE
elasmobranch fish species distribution – WGEF
marine mammal populations – WGMME
seabird populations - WGSE
health status of biota and prevalence of diseases – WGPDMO
contaminants in sediments – WGMS
chemistry and contaminants – MCWG

ii) to summarise:

effects of fishing on North Sea biota – WGECO
biological effects of contaminants – WGBEC
effects of extraction of marine sediments – WGEXT
introductions and transfers of marine organisms and their consequences - WGITMO

iii) to consider:

integrated products – PGNSP
integration of fish and oceanographic data – IBTSWG
opportunities to contribute to regional integrated assessments – WGSAEM

4.1 SPECIFIC COMPONENTS OF AN ICES REGIONAL INTEGRATED ECOSYSTEM ASSESSMENT

The integration in the assessment process is foreseen to be in two steps, through the preparation of thematic integrated assessments and an overall or general integrated assessment which will draw together the results of the separate thematic assessments.

The principal integrated assessment themes (which tend to be activity based) are given in Table 2.

Table 2. Thematic Integrated Assessment Groups.

Theme	WGs	Facilitator
Eutrophication	WGPE, WGHABD, WGZE	Hein-Rune Skojldal
Conservation of Habitats and Species	BEWG, WGFE, WGEF, WGMME, WGSE, WGEXT, WGITMO	Mark Tasker
Chemical Pollution	WGPDMO, WGMS, MCWG, WGBEC	Andy Kenny
Fisheries	WGECO, Fish Stock Files, WGEIM	Clive Fox
Climate and Natural Variations	WGOH, IBTSWG,	Bill Turrell
Management and Policy Issues	PGNSP, REGNS, WGSAEM	Henrik Mosegaard

An important addition to the 'science' themes is a theme related to management and policy issues. This is in recognition of the need for a two-way exchange of information between science and policy and will allow OSPAR, DG Environment and EEA to be involved in the pilot integrated assessment process. For example, policy objectives may be set (in response to public and socio-economic demand) which the science has to respond to; by contrast, there is a need for development of scientific evidence-based policy. These two approaches of integrating policy and science may not always be compatible, and therefore both approaches must be considered.

Pollution from offshore petroleum activities and shipping, including accidents such as oil spills, would be dealt with in the pollution theme. Physical impacts from offshore structures, dredging, etc., would be dealt with under the theme on habitats and species.

A work programme leading up to the "pilot integrated regional assessment of the North Sea" and thematic ASC session in 2006 is described below, but a key component to deliver this will be convening a REGNS workshop in May 2005. This will consist of invited individuals from each of the WGs, which will then be organised into the themes as described in Table 2. Each thematic group will begin integrating their data using tools and techniques at the workshop (these have been specified in Section 7 of this report).

In order for this process to be given a realistic chance of success, there will need to be specific preparations of data during 2004 which can be examined at the ASC in Vigo, 2004. REGNS intends to hold a briefing session in Vigo (at the 2004 ASC) for representatives of the WGs invited to participate in the workshop in 2005 where the assessment process and the specific requirements of the workshop will be presented in detail. Examples of the data holdings from each WG will be requested for the Vigo meeting in order to make sure that the appropriate analytical tools, including GIS, are available for the workshop. Ideally, a suite of tools for each theme will be made available at the workshop. To help WGs prepare their contributions, REGNS will draft a "Method Paper" to be issued with a covering letter from the ICES Secretariat by the end of May 2004. The content of the method statement will be based upon the material presented in Section 7 of this report. The accompanying letter will also serve to highlight the specific ToR we are asking for each of the WGs. In addition, ToRs should be given to the relevant fish stock assessment WGs to contribute to the process. Also the WGEIM (impacts of mariculture) should be asked to summarise information on environmental effects of mariculture in the North Sea.

The 2005 workshop will take place at ICES headquaraters and be conducted over a period of 3 or 4 days and will be followed by the annual REGNS meeting over one or two days depending on the duration of the workshop.

A summary of the work programme is provided below, please note specific actions against named individuals in **bold**.

Before 2004 Annual Science Conference

	GROUP	ACTIVITY
	REGNS	• Submit REGNS Report – by 23 April (**Andy Kenny**) • **Hein-Rune Skjoldal** to mention the work of REGNS at the Dublin Dialogue Meeting – 26–27April • Book venue at Vigo – evening slot during ASC (**Mark Tasker**) • Send out Vigo meeting details, 'Method Paper' and letter to Chairs of WGs – by end May (**Bill Turrell** to draft - **Andy Kenny** to send – Copies to Theme Facilitators) • Contact Hans Dahlin / Martin Holt to consider joint PGNSP and REGNS proposal for a Specific Support Action – by end May (**Andy Kenny**) • Letter to David Griffith seeking ICES endorsement of REGNS process – by end May (**Andy Kenny**) • Follow up calls to WG Chairs by Theme Facilitators – By end June - Habitats and Species (**Mark Tasker**) - Chemical Pollution (**Andy Kenny**) - Eutrophication (**Hein-Rune Skjoldal**) - Oceanography (**Bill Turrell**) - Fisheries (**Clive Fox**) Initiate Policy / Management dialogue (**Henrik Mosegaard**) – by End June Initiate Socio-economic considerations (**John Pinnegar**) – by ASC Initiate REGNS website at Secretariat ASAP (**Keith Brander**)

At 2004 Annual Science Conference

	GROUP	ACTIVITY
5	REGNS Nominated Experts	Convene meeting of WG representatives and set out the objectives of the workshop meeting, namely: 1) Outline basic REGNS objectives and process 2) Outline REGNS timetable 3) Outline the integration process (not REGNS, but experts themselves) 4) Inspirational demonstration of what we need, using Canadian example (see Section 8). 5) Allow WGs to provide feedback to REGNS 6) Where possible, WGs to show examples of their summary data / indicators (spreadsheet version of data) 7) Explain the 2005 Workshop, specifically: - workshop objectives - date and venue - who should attend - type of data they will make available / data formats - level of summary interpretation needed - data exchange / communication path before workshop (website) - role of ICES data centre / Secretariat

6	ACE ACME ACFM	Review report from REGNS Consider opportunities and gaps Consider REGNS Terms of Reference for all relevant Expert Groups and Advisory Committees for 2005 Confirm support for REGNS process
8	CONC	Consider feedback from REGNS, ACE and ACFM Allocate/confirm Terms or Reference for all relevant Expert Groups for 2005 Confirm 2006 Theme Session Confirm support for REGNS process

2005 Working Year

	GROUP	ACTIVITY
9	Expert Groups Annual Meetings	Fully address 2005 Terms of Reference to consolidate and provide input to REGNS workshop (if possible) and 2005 REGNS meeting at the 2005 ASC in Vigo.
10	REGNS	Review feedback and input from Expert Groups and Advisory Committees as provided in 2004 Review progress with REGNS process Convene Workshop to produce a preliminary "proof of concept" Integrated Ecosystem Assessment for the North Sea
11	REGNS Nominated Experts	"Proof of Concept" Workshop

At 2005 Annual Science Conference

	GROUP	ACTIVITY
12	REGNS Nominated Experts	Convene meeting of WG representatives. Objectives of meeting; 1) Review output from "Proof of Concept" Workshop 2) Discuss gaps / improvements 3) Set jobs for 2006 WG meetings
13	ACE ACME ACFM CONC	Review report from REGNS Consider opportunities and gaps Consider REGNS Terms of Reference for all relevant Expert Groups and Advisory Committees for 2006 Confirm support for REGNS process

2006 Working Year

	GROUP	ACTIVITY
14	Expert Groups Annual Meetings	Finalise input to the 2006 ASC Theme Session
15	REGNS	Review feedback and input from Expert Groups and Advisory Committees as provided in 2005 Review progress with REGNS process Prepare for 2006 Theme Session
16	Nominated Experts	Submit final papers to Theme Session (August 2006)

At 2006 Annual Science Conference

	GROUP	ACTIVITY
17	REGNS Nominated Experts ACE ACME ACFM CONC	Attend 2006 ICES North Sea Integrated Ecosystem Assessment Theme Session
18	ACE CONC	Consider future of REGNS process

5 PROPOSED REGNS WORKSHOP "PROOF OF CONCEPT" REGIONAL INTEGRATED ECOSYSTEM ASSESSMENT FOR THE NORTH SEA (MAY 2005, ICES HQ)

Proposal for a Workshop to produce a preliminary "proof of concept" integrated ecosystem assessment for the North Sea to be held in conjunction with the REGNS annual meeting in May 2005, ICES headquarters.

5.1 TERMS OF REFERENCE

1. Produce a preliminary "proof of concept" integrated ecosystem assessment for the North Sea in time for presentation at the Advisory Committees and the 2005 Council Meeting.
2. Compile and synthesise material from the twenty identified "source" WGs, which have been requested to provide data, information and indicators.
3. Produce summary presentations of the material as an overview (e.g., using methods for re-scaling and reducing dimensionality; "traffic lights", etc.)
4. Identify gaps in the material provided and the subjects covered.
5. Review patterns and interactions among the indicators. Preliminary description of system behaviour (e.g., evidence for "regime shift" in late 1980s) and strength of attribution of causes of observed changes.
6. Comment on how to measure impacts of past management actions at the system level.

7. Consider and comment on issues of predictability and impact of future management actions.

8. Advise on future monitoring and modelling required for improved integrated ecosystem assessment.

9. Advise on designing the scientific and institutional requirements for integrated ecosystem assessment.

5.2 JUSTIFICATION

The workshop will be held in Copenhagen in May 2005, immediately before or after the meeting of REGNS. It will include participants from some of the "source" WGs and one or two experts who have experience of methodology for summarising indicators (data) for integrated ecosystem assessment. The participation of members of source WGs will provide expert interpretation of their material and will give these groups a role in shaping the process for preparing an integrated assessment, as well as providing feedback to their groups.

The success (and timeliness) of the workshop products will depend on excellent preparation and sustained support through to completion. It is unlikely that this can be provided entirely at the national level and is possibly a task that the post of ICES Head of Science Programmes could undertake in part. The task will include good communication with a wide range of source WGs; compiling their material in a standard form for joint analysis; facilitating early availability of data, information and indicators for analysis by workshop members and other interested scientists; early compilation and dissemination of working documents and draft to workshop participants; overseeing additional work to ensure timely production of the report (editing, preparation of figures and tables, etc.). Individual members of REGNS will take responsibility for facilitating (but not necessarily leading or drafting) the work on each of the six themes identified (Table 2).

REGNS notes that staff time from ICES will be needed in order to adequately prepare for the workshop and to provide the necessary support, particularly IT and data management/GIS support.

6 REGIONALLY COORDINATED AND INTEGRATED INTERNATIONAL MARINE MONITORING PROGRAMMES

At the 2003 meeting it was agreed to examine the UK and Norwegian monitoring programmes in greater detail, specifically, 1) to compare the respective national programmes in terms of their spatial and temporal coverage and the determinands measured, and 2) to consider how the information is used and reported.

An up-date on the UK marine monitoring strategy was presented by Dr Kenny, explaining how coordination was being achieved by Defra through each of the sectors with responsibility for marine monitoring (fisheries, conservation, pollution and ocean climate). What has emerged as a result of this initiative is that coordination and integration of monitoring needs to occur at all levels of organisation to ensure effective delivery. This means closely examining the routes by which information on monitoring is exchanged between policy divisions within governments, programme managers, surveyors (data collectors) and assessors (data/information managers). Because this exchange of information and development of coordinated plans is entirely dependent on communication between many people across many organisations, it is not surprising that the process is very difficult to manage. Indeed it is the view of REGNS that it would be counter-productive to try and actively manage the whole process; rather, what is emerging are a number of national and international initiatives which have the same common goal of coordinating and integrating the marine monitoring effort. Such initiatives are largely driven by individuals who are closely involved with the implementation of the monitoring programmes in response to the policy drivers. The most successful of these are very close to the operational activities of the programmes themselves. For example, annual surveys are planned by project managers who have responsibility for delivery of the programmes. They are responding to the immediate needs imposed by drivers such as the Water Framework Directive and the OSPAR JAMP/CEMP. Close cooperation and integration is therefore emerging between individuals and organisations where there is the most need to do so. This is a process of evolution, whose goal has already been set by the policy makers at national and international fora.

What is needed, therefore, is some recognition and steer for this as an emerging process and for ICES to draft a framework that can be used to steer future international monitoring coordination initiatives. This is very different from saying what coordination needs to be undertaken as to a large extent this is already under way.

Because of the above and also given the limited amount of time at the meeting to discuss this requirement, REGNS set it as a lower priority. By achieving the delivery of integrated assessments and the provision of ecosystem advice the monitoring plans will emerge; trying to set out the monitoring needs ahead of an integrated assessment does not make sense, and in terms of making more efficient use of resources, other groups such as the Group of Directors of Fisheries

Research Organisations of the European Union (EFARO) are examining best use of research vessels (see Annex 4) and this is being progressed at the national level in the UK by a specific group. Clearly it would make sense for REGNS not to duplicate the work of these groups, but is should examine ways in which it can add value to their ToR and to report to ICES on their deliberations. For example, as a result of a recent UK workshop (Annex 5), the following was concluded:

- 60–70% of UK cruise programme time is devoted to routine monitoring with fish surveys accounting for the largest single portion.

- Most of the UK coastal and shelf waters are surveyed at least annually.

- The three UK fisheries laboratories should develop an integrated ecosystem monitoring programme. The programme should concentrate on demersal trawling surveys in the first instance which can be developed by additional physical, chemical and ecological measurements. CFRD Working Group.

7 THE ICES ADVISORY STRUCTURE, DATA, INFORMATION AND ANALYTICAL TOOLS NEEDED TO DELIVER A REGIONAL INTEGRATED ECOSYSTEM ASSESSMENT FOR THE NORTH SEA

7.1 INTRODUCTION

In 2003, SGAWWP (ICES 2003a) suggested a new structure for advice provision by ICES that strives to integrate ICES advice (across fisheries, ecosystem and environmental areas), as well as reduce workload in some areas and be more responsive to client needs. This structure is illustrated in Figure 8.1. The SGAWWP report was considered by the Consultative Committee and the Delegates at the ICES 2003 Statutory Meeting who commented primarily on the timetable for change.

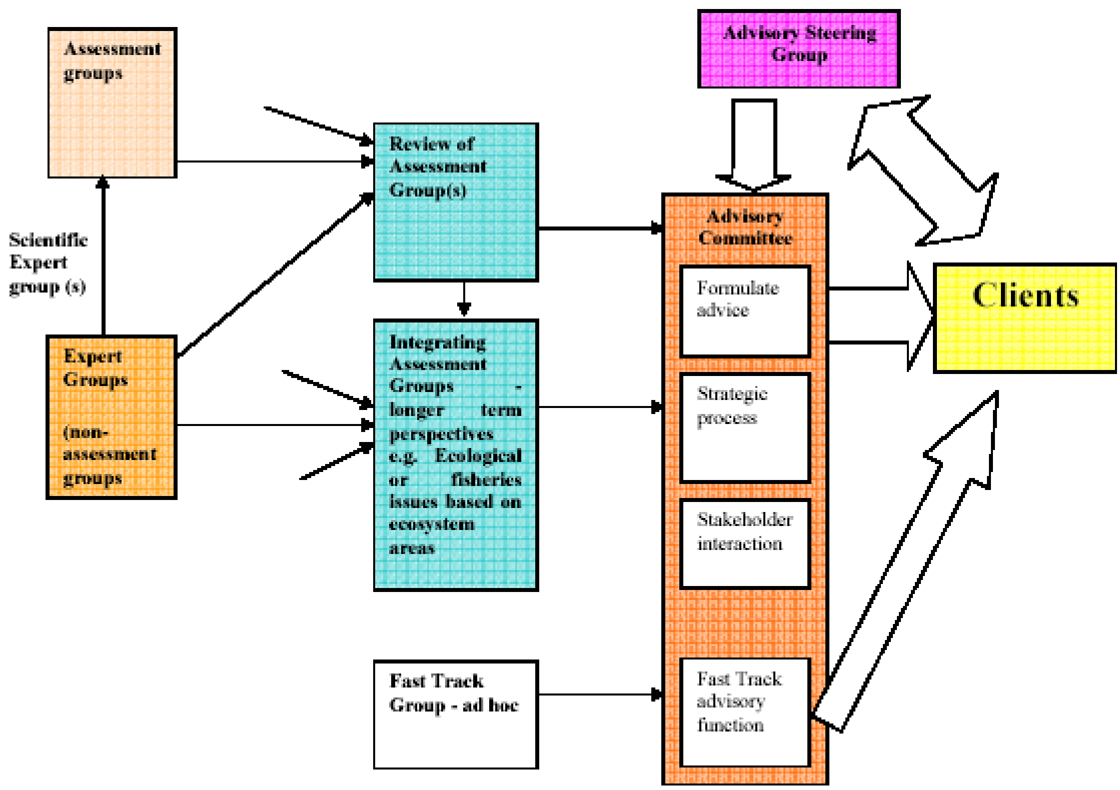

Figure 7.1. Proposed ICES Assessment and Advisory structure (from ICES 2003a).

REGNS interprets “components” in this term of reference as referring to the expert (non-assessment) groups, the output of the review of assessment groups and the Integrating Assessment Groups, bearing in mind the need(s) of the Advisory Committee(s).

REGNS consider that a global objective of Integrated Assessments is to improve management decision-taking in relation to the ecosystem as part of an ecosystem (-based) approach to marine management. At present most advice and therefore decisions are sectoral and take relatively little account of either non-controllable factors such as climate or the wider consequences on the marine environment/ecosystem of management decisions.

The advisory products required of ICES may be categorised in several ways (Table 3). Integration will differ between each of these categories and therefore the data, information, and analytical methods will vary. In general it seems that advice given on non-fisheries areas appears to be more comprehensive and integrated than that given in the fisheries area – this may be due to differing customer demands in the past.

Table 3. Examples of North Sea advisory products that are or maybe requested from ICES that will use Integrated Ecosystem Assessments

Customer	Product	Added value of integrated ecosystem products
European Commission	Fish stock advice	Evaluation of effects of environment on stocks, and of effects of fisheries on ecosystem and its components
European Commission	Advice on conservation of biota	Evaluation of effects on human activities and thereby on other components of the ecosystem
OSPAR Commission	Status of EcoQOs	Evaluation of causes of change in EcoQ metric and suggested management response

The remaining content of this section is intended to provide some guidance on 1) why such assessments are needed, 2) what we mean by an integrated assessment and how it differs from a QSR, 3) the types of data required (e.g., data attributes), 4) providing an example of output from an integrated assessment, and, finally, 5) providing summary information on the types of numerical assessment techniques which can be used to undertake integrated assessments.

7.2 RATIONALE FOR REGIONAL INTEGRATED ASSESSMENTS

The principal policy drivers behind the REGNS initiative, to establish a process within ICES to produce a Regional Integrated Ecosystem Assessment by 2006, lie within the Bergen Declaration, signed by North Sea Ministers at the Fifth North Sea Conference in 2002.

In the Declaration, Ministers agreed to implement an ecosystem approach to the management of the North Sea. The key phrases were;

- “Establishing an Ecosystem Approach to Management”

    - The Ministers recognize the need to manage all human activities that affect the North Sea, in a way that conserves biological diversity and ensures sustainable development.

    - The Ministers therefore agree to implement an ecosystem approach by identifying and taking action on influences which are critical to the health of the North Sea ecosystem. In particular, they agree that management will be guided by the conceptual framework set out in Annex 2 of the Declaration, which includes:

        - the development of general and operational environmental goals;
        - best use of available scientific and technical knowledge about the structure and function of the ecosystem;
        - best use of scientific advice;
        - **integrated expert assessment;**

- coordinated and integrated monitoring;
- involvement of all stakeholders; and
- policy decisions and control and enforcement.

The Declaration goes on to expand on these general concepts. Specific requirements of North Sea nation states include;

- To implement an ecosystem approach in line with this framework the Ministers will:

  i. recognize the need **for shared integrated expert advice and assessments of the North Sea**, including marine resources, environmental and socio-economic factors, and invite OSPAR in cooperation with EU and ICES to propose how this might be undertaken at periodic intervals involving stakeholders and to take the first steps;

  ii. improve the **coordination, harmonization and efficiency of current national and international monitoring to serve the assessment processes**, including building on the OSPAR Joint Assessment and Monitoring Programme and relevant EU monitoring programmes;

Although the Bergen Declaration can be identified as the principal driver behind REGNS, other communities have also identified the need for Regional Integrated Ecosystem Assessments. These include ICES itself through its Strategic Plan (2002), the EU through the reformed Common Fisheries Policy (2003) and the Group of Directors of Fisheries Research Organisations of the European Union (EFARO), in their Strategic Plan (2000) (See Annex 4).

Hence the European Union, ICES, all North Sea ICES Member Countries, and all North Sea Fisheries Agencies (institutes) have agreed that a Regional Integrated Ecosystem Assessment of the North Sea is required. REGNS is attempting to fulfil that need by practical action.

7.3 WHAT IS AN INTEGRATED ASSESSMENT?

An integrated assessment may mean one of two things, namely, 1) a process of actions which support ‘adaptive management and the ecosystem approach’ as described in REGNS 2003 report (ICES, 2003b) and summarised below, but it also relates to 2) the combined numerical assessment of data and information from various sources (including monitoring and R&D programmes); this can also include integrated sampling and monitoring techniques.

A base level of data and information for any integrated advice will be the Regional Integrated Ecosystem Assessments (RIEA, for the North Sea, see Section 5 of this report). An RIEA (with respect to 1), above) will go beyond a single-period QSR by:

- Evaluating current drivers and how they have shaped the present state,
- Identifying important interactions between components of the system and how these affect system behaviour,
- Evaluating wider consequences (performance) of management actions,
- Predicting consequences both of non-controllable factors, such as climate change, and of controllable factors, such as sources of pollution,
- Providing output that can be passed easily to customers (policy, public and managers) within their time frames (i.e., if annual advice is required, annual advice would be provided).

The workshop will concentrate on achieving the need for numerical (objective) integration of data sets and information from various monitoring and R&D sources with which ICES has access. The use of numerical models to predict consequences (both spatial and temporal) is beyond the present “proof of concept” integrated assessment, but what will be achieved should demonstrate the vital role that such models have in ensuring that the monitoring, R&D and provision of advice are objectively and transparently coupled.

An RIEA should review all relevant available information on the abiotic and biotic features and human uses of the areas under consideration. For abiotic features, relevant data will be those on atmospheric and hydrographical conditions that influence the state of the ocean. For biotic features, population size, distribution, and trends for species and distribution and status of habitats in their areas will be needed. Human usage data should primarily relate to the amount and distribution of the human usages having the greatest effect on the marine environment. For all features, an ideal input to the RIEA would be a long-term, comprehensive and up-to-date data set from which trends and variance in spatial and temporal trends can be evaluated. Information on either causal or correlative links between abiotic and biotic features and human uses is also required along with a statement of the certainty and/or trends in these links.

As noted in last year's REGNS report (ICES, 2003b), contributions for an integrated assessment will be required from many other working groups within ICES. The process to obtain these contributions has started and will be refined after discussion with representatives from the Working Groups leading up to the 2005 Annual Science Conference in Vigo and then further refined following the Vigo meeting.

Information will also be required on known interactions within ecosystems, both between ecosystem components and with human activities. Knowledge of trends in these interactions or in human activities would be helpful.

Plainly, if a series of indicators (with or without objectives) are available, these should be used. Indicators of all types available, e.g. within the DPSIR (Driving Force, Pressure, State, Impact and Response (by society)) framework are ideal.

7.4 DATA INPUTS

The purpose of assembling data, indicators and information is to meet the objectives which are set out in the Bergen Declaration in relation to Ecosystem Assessment and Management of the North Sea. Where the Expert Group is aware that the specific tasks in their field of expertise are already being undertaken by other groups (e.g., OSPAR), they should not duplicate this, but should provide the necessary references (and documentation) in support of their own assessments.

By way of example, REGNS has tried to specify the requirements (below) for the fisheries thematic assessment, but this should be regarded as indicative of the data, information and indicators which may be relevant to the assessment. The Expert Groups assigned to each assessment theme should use their own judgement on what is relevant (and available) and should act accordingly in providing this material. In addition to actual data, it is important to provide meta-data which will allow the material to be used correctly, including spatial coordinates and time frame of sampling. Contact information for the data originator should be included and references to websites, publications or existing databases would also be useful.

Since the primary requirement of the pilot study is to draw out relationships and trends (both spatial and temporal) between different types of data, it is most likely that data sets which are regarded as 'valuable' (owing to the time and effort made to acquire and check the data) will be used in the first instance.

For the fish stock assessment working groups, the data required should include: Standard stock assessment time series which are input to or produced by the assessment (catch numbers and weight (size) at age, maturity and fecundity at age, stock number at age, F and M at age, total and spawning stock biomass); current limit and target reference points. These data can probably be cut and pasted from the annual assessment report. They may also be available within the existing ICES fisheries database, in which case a direction to where they are held will be acceptable. These data may already have been collated by SGROMAT – so this should be checked first by the fisheries assessment facilitator (Clive Fox).

The assessment groups may also wish to develop and evaluate indicators which they regard as helpful in presenting and interpreting trends, e.g., changes in mean maximum length, changes in age/size at maturity, changes in condition, etc.

Data Attributes and Qualities

There is a considerable body of work which deals with attributes and qualities of indicators for use in Ecosystem Assessment and this will not be repeated or summarised here. An example of a scheme applied recently (Rice and Rochet, in press) is provided in Annex 6.

7.5 EXAMPLE OUTPUT OF AN INTEGRATED ASSESSMENT

Perhaps of greatest importance are how the results of an integrated assessment are disseminated. A comprehensive ecosystem assessment should comprise a huge amount of information, the challenge one faces is how to reduce this information objectively for assessment and advisory purposes. Ways of reducing this information into forms that are easier to assimilate will be useful to managers, to perceive patterns and to identify gaps in knowledge. One such tool is the ‘traffic light’ system used, for instance, in the Eastern Scotian Shelf ecosystem assessment illustrated in Figure 7.2 (DFO 2003).

Figure 7.2. Sixty-four metrics of the state of the Eastern Scotian shelf ecosystem grouped according to their similarity of changes from year to year illustrating a ‘traffic light’ system (DFO 2003, see also http://www.dfo-mpo.gc.ca/csas/Csas/status/2003/ESR2003_004_E.pdf).

In this example, the specific nature of the individual indicators is not important, the value of using such a plot is to assess the weight of evidence in observing an overall trend in the state of the ecosystem over time. In this case the weight of evidence clearly shows a state (or regime) shift sometime around the late 1980s.

A further example is a ‘dashboard’ developed to illustrate policy performance and other indicators in Italy. Figure 7.3 shows an example from the website http://esl.jrc.it/envind/db_meths.htm. The outer ring of this dashboard is composed of a series of indicators whose condition has been evaluated on a good to bad scale. The judgement of these conditions would obviously need to be defined in advance. These indicators are then grouped into categories (in the case of the example in Figure 7.3, the categories are environment, social care and economy). These categories are evaluated by weighting each of the indicators to arrive at an overall assessment of the category. Plainly the process to weight the indicators would need to be explicit, using for instance surveys among experts or the general population. Finally an overall assessment is reached by combining the assessments of each category.

In both examples the re-scaling of the indicators to a common scale of response is critical and is a procedure which can compromise the original data to the extent that it is no longer faithful to its original response. However, the scaling procedures are objective and can be modified in such a way as to maintain the greatest degree of faithfulness to the original responses. Some of the numerical techniques to explore the relationships between data which are applied when undertaking integrated assessments are described in the following section.

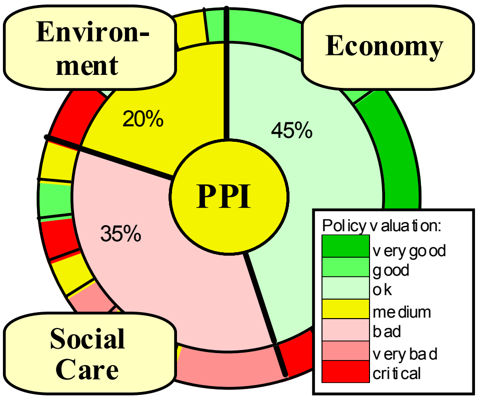

Figure 7.3. A dashboard illustration of the state of indicators building to an overall performance index (PPI) (from http://esl.jrc.it/envind/db_meths.htm)

7.6 ANALYTICAL TOOLS

There are few specific numerical techniques to conduct integrated assessments (sometimes referred to as meta-data analysis), but such techniques do exist for assessing specific ecosystem components. Numerical analysis of data and the presentation of 'model' output are closely related, since both rely on numerical computations. The close links between 'modelling' ecosystems and integrated assessments is noteworthy in that a good integrated assessment will rely on numerical techniques which will also underpin models that can predict changes in response to various management actions. To put this another way, the presentation of environmental data according to a traffic light scheme as shown in Figure 7.2 will be derived using many of the numerical techniques listed below.

A good example of where numerical assessment techniques are used and integrated with models to predict the effects of management actions are those developed to assess fish stocks; other similar tools include Population Viability Analysis that may be useful in examining risks such as by-catch on cetacean or seabird populations. Population models can help predict possible future changes in some species (but these models require much data that are not usually collected or available). Time series tools such as these are useful in forecasting. Geographic (spatial) tools can help in determining areas where interactions between human activities and the natural environment are occurring.

7.6.1 Time Series Analysis

Various methods can be used for modelling, comparing and/or forecasting, based on time series data. They can be categorized into three families: (a) regression methods, (b) time-series methods, and (c) multivariate analysis methods. An overview of relevant methods is provided in Table 4.

A distinction must be made between modelling (i.e., fitting) and short-term forecasting (i.e., operational forecasting, 1–2 years in advance). Methods that provide good fitting do not always perform well in terms of forecasting. Fitting and forecasting performances can be evaluated using a variety of accuracy measures (i.e., standard, relative and other statistical measures), each suffering from certain limitations (CIESM, 2003). For a detailed general introduction to accuracy measures, the reader is referred to Makridakis *et al.* (1983).

Many of the methods listed in Table 4 have been widely applied to marine time series (e.g., ARIMA, transfer function models, intervention analysis, decomposition and regression models), whereas others have not. Analysing time series of population abundance by non-linear time series models (also called non-linear stochastic process models) may reveal complex and chaotic dynamics, which otherwise remain undetected when using (linear) ARIMA models.

Table 4. (derived from CIESM, 2003) List of methods available for time series analysis, accompanied by underlying assumptions, suitability, and usually two references. **GAM** = Generalized additive models, **GLM** = Generalized linear models, **L** = linearity, **NL** = non-linearity, **MF** = multivariate forecasting, **N** = normality, **P** = parametric, **NP** = non-parametric, **TL** = time lags, **TS** = time series, **ST** = stationarity, **UF** = univariate forecasting.

Method	**Assumptions**	**Suitability**	**References**
Regression			
Time-varying[1]	N,L,P no TL	For TS with gaps. UF	Makridakis *et al.,* 1983
Linear regression[1]	N,L,P no TL	For TS with gaps. MF	Makridakis *et al.,* 1983
GLM[2–4]	L, P, no TL	For TS with gaps. MF	McCullagh and Nelder, 1989
GAM[3–4]	P, NP, no TL	For TS with gaps. MF	Hastie and Tibshirani, 1990
LOESS regression[4]	NP, no TL	For TS with gaps. MF	Cleveland *et al.,* 1992
Non-linear models[4-5]	NP, no TL	For TS with gaps. MF	Myers *et al.,* 1995
Time Series[6]			
Smoothing methods	P, NP	For short TS, UF	Hastie and Tibshirani, 1990
ARIMA[7]	N, ST, TL	For long TS, UF	Box and Jenkins, 1976
Decomposition methods[8]	N, STL, NP based on loess	For short TS, UF	Makridakis *et al.,* 1983
Intervention analysis[7,9]	N, ST, TL	For long TS, MF	Box and Jenkins, 1976
Transfer function models[7,10]	N, ST, TL	For long TS, MF	Box and Jenkins, 1976
Dynamic Regression[7]	N, TL	For long TS, MF	Chatfield, 1984
Vector autoregression[11]	N, TL	For long TS, MF	Chatfield, 1984
Kalman-filters		Estimations of past, present and future states	Kalman, 1960
Non-linear time series analysis	No N, No ST	MF	
Filters	P, NP		Cleveland, 1993
Multivariate Analysis[12]			
Ordination (i.e. PCA, MDS)[13]			Clarke and Warwick, 1994
Cluster[13]			Clarke and Warwick, 1994

Notes:

1. Linear relationship between a continuous response variable and continuous predictor variable(s): Normality dependent and predictor variable(s).
2. The distribution of the dependent variable can be non-Normal and does not have to be continuous: predictor response both for dependent variables and discrete distributions and for dependent variables which are non-linearly related to predictors.
3. Allows various distributions of the response variable.
4. The shape of the function is not constrained by some *a priori* model but is flexible in relation to existing data; allows simultaneous smoothing of up to three independent variables.
5. Non-linear relationships between variables.
6. Other potentially useful methods include: Mann-Kendall tests; spectral analysis; wave-length analysis; state space models; Bayesian analyses.
7. Takes into account time-lags (i.e., dynamic models). Handles all components of a time series (i.e., seasonality, trend, irregular component, cycles): strong verification of model accuracy: better forecasting power than other methods.
8. Handles seasonality and trend.
9. Detects and quantifies non-random changes (anomalies).
10. Quantifies the impact of external variables.
11. Very useful for modelling and forecasting two or more closely related variables as a system (e.g. ,predator prey or competing species).
12. Other potentially useful methods include multivariate regression and multivariate autoregression.
13. Very useful for identifying changes in species composition of assemblages with time, regime shifts, or for identifying the best-fitting/forecasting model in terms of accuracy measures.

Dealing with gaps and missing values

In all scientific fields, time series are characterized by gaps (i.e., long periods without records) or missing values (i.e., a few isolated time points without records). This is an important problem since both cases drastically restrict the application of many time series techniques. In fact, missing data imputation and handling is a rapidly evolving discipline by itself (see, for example, Little and Rubin, 1987; Allison, 2002).

Missing data and gaps can result from a variety of circumstances (e.g., logistics, equipment failure, sample loss, sample contamination, bad weather, removal of outliers, corruption of data, etc.).

The simplest way for dealing with gaps and missing values is to completely ignore them. Whereas a few simple non-parametric tests (e.g., Mann-Kendall), regression models, and many simulation models are not affected by the presence of gaps in the data, the application of time series models, which involve lags of dependent and/or independent variables, does require completeness.

Spatial analysis

There has been a recent increase in the number of books on the subject of geostatistics, but a good beginner book to read would still be "An Introduction to Applied Geostatistics" by R.M. Srivastava and E. Isaaks (Oxford University Press). For more advanced mathematical treatments, one can read "Statistics for Spatial Data" by Noel A. Cressie (Wiley-Interscience). The most commonly used methods are described in Table 5.

Table 5. List of methods available for spatial analysis, accompanied by underlying assumptions, suitability, and references.

Method	Description	References
Interpolation methods		
Kriging	Optimal interpolation using weighted distance (semi-variance) function	Isaaks and Srivastava, 1990
Inverse distance	Deterministic, weighted distance based on user-defined search radius	Isaaks and Srivastava, 1990
Delauney triangulation		
Voronoi tessellation		Gold, 1999,
Spatial structure		
Point pattern	Test for spatial randomness in point data	O'Driscoll *et al.*, 2000
Moran/Geary autocorrelation	Test for spatial autocorrelation	
Geostatistics	Test for spatial autocorrelation and structure	Isaaks and Srivastava, 1990
Density estimation	Surface creation: observations per unit area	Silverman, 1986.
Data reduction	Reducing multidimensional data into principal components	
EOF	Empirical Orthogonal Functions	
PCA	Principal Component Analysis	Clarke and Warwick, 1994
MDS	Multi-dimensional scaling	Clarke and Warwick 1994
CCA	Canonical Correspondence Analysis	
MFA	Multiple Factor Analysis	
Comparison methods		
Co-occurrence Indices	An index of the co-occurrence of species at the same site.	Bez and Rivoirard, 2000
Multivariate Correlation		
Spatial t-test		
Prediction		
Regression-based	Regression modeling of a continuous response variable based on both continuous and non-continuous (categorical) predictor variables. Model is then spatialised in GIS using spatial data for the predictors.	Guisan and Zimmermann, 2000
Index-based	Same as above but using an index of the response variable instead of a parameter estimate.	Guisan and Zimmermann, 2000

7.7 OVERALL ICES ASSESSMENT TIMETABLE

Table 6. Flow chart of work leading up to Pilot Integrated Regional Assessments and Theme Sessions in 2006 (after ICES, 2003c)

STEP	GROUP	ACTIVITY	YEAR
1	ACE/CONC	Terms of Reference to REGNS (and BSRP) and "Environmental" Expert Groups to commence preparations.	Autumn 2003
2	'Assessment' Expert Groups	General discussion of information that could be and should be provided to groups conducting integrated regional assessments. Report on opportunities and challenges.	2004 meetings
3	'Environmental' Expert Groups	Consider how to approach Terms of Reference (Step 1). Where progress can be made, report results to ACE and REGNS. Where additional effort is needed, develop intersessional workplan, and propose Terms of Reference for completion in 2005.	2004 meetings
4	REGNS and BSRP	Consider input, to the extent available from Step 2 and 3. Specify as fully as possible the information needs from all Expert Groups, especially assessment groups, to enable it to undertake pilot integrated regional assessment for the North Sea (and Baltic) in 2006. Outline as fully as possible with current knowledge, how an integrated regional assessment would actually be conducted.	April 2004
5	ACE and ACME	Review reports from REGNS (and BSRP), consider opportunities and gaps, and propose Terms of Reference for all relevant Expert Groups and Advisory Committees in 2005.	Spring 2004 and fall consultation
6	ACFM	Consolidate information from assessment Expert Groups (Step 2) and identify opportunities and challenges.	Autumn 2004 consultation
7	CONC	Consider input from ACE (ACME?) and ACFM Steps 5 and 6), and draft Terms or Reference for all relevant Expert Groups for 2005, to support pilot integrated regional assessments in North Sea (and Baltic?) in 2006.	Autumn 2004
8	Expert Groups	Fully address Terms of Reference (Step 7) to consolidate and provide input to REGNS (and BSRP) in 2006.	All 2005
9	REGNS and BSRP	Review feedback and input from Expert Groups and Advisory Committees as provided in 2004 (Steps 2, 3, 5, 6). Where information allows, experiment with testing approaches proposed in Step 4. Where feedback is not particularly encouraging, consider alternative approaches that would take account of feedback, but still produce robust and informative integrated regional assessments. Prepare for Theme Session in 2006.	Spring 2005
10	ACE	Review reports from REGNS (and BSRP), consider opportunities and gaps, and propose Terms of Reference for REGNS (BSRP?) and Advisory Committees in 2006.	Spring 2005 and consultations
11	CONC	Consider input from ACE and draft Terms of Reference for REGNS (BSRP?) and plans for Theme Session in 2006.	Autumn 2005
12	REGNS and BSRP	Conduct pilot integrated regional assessment. Prepare results for Theme Session in 2006.	Spring 2006
13	ASC (CONC)	Hold Theme Session on Integrated Regional Assessment – approaches, products, and prospects.	Autumn 2006
14	CONC	Review results of Theme Session (and Committee Report?). Plan future work.	Autumn 2006

8 CLOSURE OF THE MEETING

The meeting was officially closed at 2 p.m. on 7 April. Dr Kenny thanked all those who attended and contributed to the discussions and looked forward to meeting everyone in Spain at the ASC in Vigo later this year, and making preparations for the REGNS "Regional Integrated Ecosystem Assessment" workshop in Copenhagen, May 2005.

9 ACKNOWLEDGEMENTS

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ANNEX 2. SUMMARY OF UK (DEFRA) FUNDED R&D ENVIRONMENT AND FISHERIES PROJECTS

Summary of **Environment** (DEFRA - UK) funded R&D from 1997 highlighting those projects, which directly address the Priority Science Issues.

Projects		**Short Term Issues**		**Log Term Issues**		**Neither**	
No.	Value	No.	Value	No.	Value	No.	Value
136	**£35.5 M**	**14**	**£4.5 M**	**57**	**£21.5 M**	**65**	**9.5 M**
		R&D mainly addressing indicators issues		R&D mainly addressing transport and effects of contaminants issues		R&D mainly addressing data management issues and technique developments	

Summary of **Fisheries** (DEFRA – UK) funded R&D from 1997 indicating those which directly address the Priority Science Issues.

Projects		**Short Term Issues**		**Log Term Issues**		**Neither**	
No.	Value	No.	Value	No.	Value	No.	Value
56	**£25 M**	**7**	**£2.5 M**	**13**	**£11 M**	**36**	**11.5 M**
		R&D mainly addressing indicators, threatened & declining Species and spawning areas		R&D mainly addressing food web and life history interactions and role of benthic species richness issues		R&D mainly addressing impact assessments and technique developments (tagging)	

ANNEX 3. ECOSYSTEM MODELLING: HOW TO MAKE ADAPTIVE MANAGEMENT AND INTEGRATED ASSESSMENTS OPERATIONAL

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REGNS reported in ICES CM 2003/ACE:04 how to provide ecosystem-based advice. Figure 2.1 illustrated the conceptual framework with a strong emphasis on ecosystem models and operationality. In the following text, I will write down my experience in three-dimensional modelling of the North Sea / northwest European continental shelf (NECS). To my understanding, it will contribute mainly to task 1 of the agenda (5-7 April).

The following expertise stems from Moll, A. and Radach, G., 2003 (Review of three-dimensional ecological modelling related to the North Sea shelf system - Part 1: Models and their results. Progress in Oceanography, 57(2): 175-217.) and I tried to focus on the "Priority science issues for North Sea ecosystem management ICES REGNS 2003 Report, page3)". The scientific issue with state-of-the-art in ecosystem understanding through modelling is provided in the article itself.

SYSTEM OVERVIEW AND SELECTED MODELS

The state-of-the-art in modelling the marine ecosystem of the greater North Sea is reviewed, providing an overview especially about three-dimensional models that describe and predict how the marine ecosystem of the greater North Sea area functions and how concentrations and fluxes of biologically important elements vary in space and time, throughout the shelf and over years, in response to physical forcing. Table 1 of Moll and Radach (2003) listed the names of North Sea "ecological models", gives references to articles in the literature applying those names and shows the institutional affiliations of the modelling groups. The driving forces of the North Sea (eco)system are illustrated to provide a condensed overview:

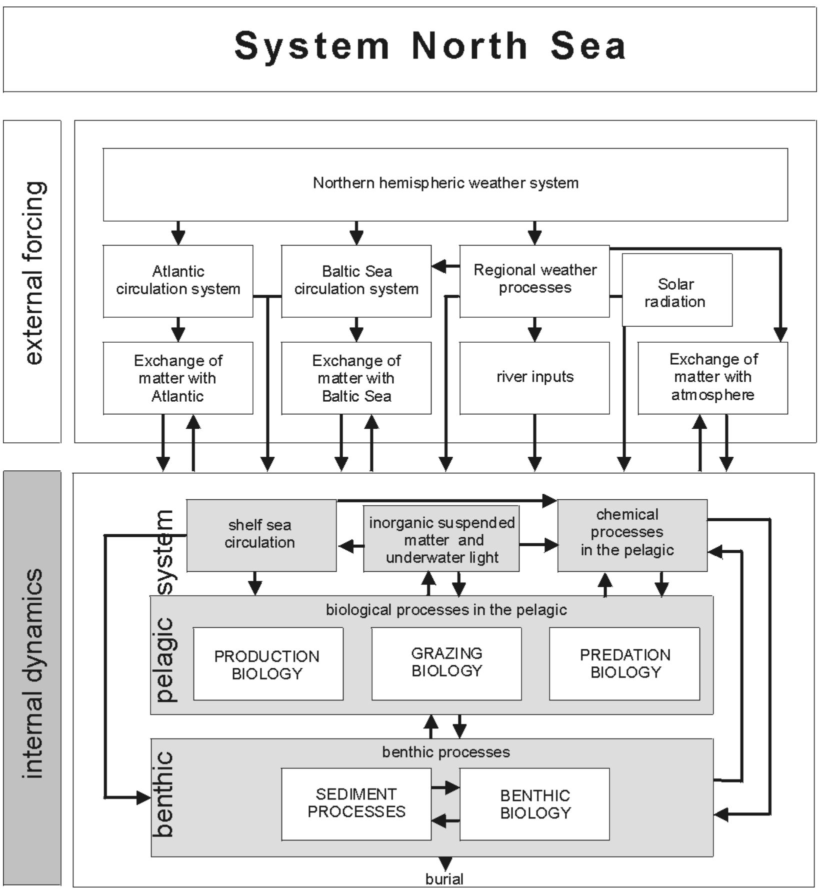

Figure 1: The North Sea ecosystem is embedded in its geological, physical and chemical environment, which modelling of its ecosystem must take this into account. The "System North Sea" is divided into internal dynamics and external forcing to illustrate the coupling of the driving forces with its pelagic and the benthic subsystems.

SPACE AND TIME SCALES OF APPLIED MODELS

To illustrate the resolution of the physical and biological scales for the selected models the numerical values of the horizontal space scales (Δh, H) and the time scales (Δt, T) are given in Table 1. For the North Sea models the finest horizontal resolutions are 7 km (COHERENS) and 12 km (POL3dERSEM); most models work with a resolution of 18 km to 20 km (GHER, ECOHAM and NORWECOM). ERSEM adopted a 1° box structure, which corresponds to a spatial resolution of about 110 km in north-south direction and 50 km in east-west direction. Except for ERSEM, all models resolve the diurnal cycle. The duration of the simulation is the annual cycle for all models. Long-term simulations of ten years' duration are available from NORWECOM and ECOHAM. For ERSEM a simulation of 39 years was performed to simulate the eutrophication of the North Sea during 1955–1993.

Table 1: Space and time scales in the selected three-dimensional North Sea models and their geographical area of model domain. (*) approximated for NORWECOM which has polar stereographic coordinates.

No	Model name	Spatial resolution Δh (km)	Longitude (degree)	Latitude (degree)	Spatial extent (km)	Temporal resolution Δt (sec)	Temporal range (years)
1	**NORWECOM(*)**	20	-12.0, 12.0	49.0, 64.0	1.600	900	1985-1994
2	**GHER**	18	-12.0, 13.0	48.0, 61.0	1.400	69	1989
3	**ECOHAM**	20	-04.5, 10.0	49.0, 61.5	1.400	900	1985-1994
4	**ERSEM**	110	-04.0, 11.0	51.0, 61.0	1.100	86400	1955-1993
5	**ELISE**	4	-06.0, 02.0	48.5, 51.0	300	1000	1978-1992
6	**COHERENS**	7	-04.0, 10.0	48.5, 57.0	900	600	1989
7	**POL3dERSEM**	12	-12.0, 14.0	48.0, 63.0	1.700	1080	1995

STATE VARIABLES IN THE MODELS

The three-dimensional models for the northwest European shelf or the North Sea system have a trophic resolution which distinguishes the main functional units (nutrients, phytoplankton, zooplankton, and detritus, dissolved organic matter and bacteria in the pelagic and diagenesis and zoobenthos for the benthic compartment). Higher trophic levels like fish, birds or mammals are not included in ecosystem models as prognostic state variables up to now. With respect to the real complexity of ecological processes, models remain relatively simple. We describe the trophic resolution of the model systems in Table 2 considering the resolved matter cycles and chosen state variables for the different functional units, for the pelagos and benthos. Except for COHERENS, all models simulate the pelagic and benthic system. ECOHAM simulates the phosphorus cycle only, while COHERENS and GHER simulate the nitrogen cycle only. Cycles of phosphorus, nitrogen and silicon are included in NORWECOM, ELISE, POL3dERSEM and ERSEM, with separate state variables for the pelagic and benthic systems. Representation of phytoplankton ranges from one bulk state variable to four: picophytoplankton (0.2 to 2 μm equivalent spherical diameter, ESD), flagellates (2 to 20 μm ESD), diatoms (20 to 200 μm ESD), and dinoflagellate-like "inedible" phytoplankton (20 to 200 μm ESD) that is not grazed by zooplankton. The state variable chlorophyll was defined as the sum of the chlorophyll content of the sub-groups. Zooplankton state variables are not included in two models; ECOHAM and COHERENS prescribed the observed biomass of mesozooplankton. GHER used a bulk formulation, and only the two ERSEM models included different size-dependent zooplankton units. Dissolved organic matter and bacteria were not represented as state variables in four models; there is a bulk representation included in GHER and POL3dERSEM, and a full representation is incorporated in ERSEM only. Except for ECOHAM all the models have resolved the detritus in the water column using one or more state variables. The benthic system was introduced to provide for nutrient remineralisation on medium and long time scales. Thus, except for COHERENS, all models have formulated the nutrient regeneration by indirect mechanisms or used up to four explicit state variables for nutrients in the benthic bottom layer. A zoobenthos compartment is resolved only by the two ERSEM models, with state variables for meiobenthos, suspension and deposit feeders.

Table 2: State variables in the selected North Sea models, sorted by the number of pelagic state variables.

No	Name	Pelagic				Benthic	
		Matter cycle	**Nutrients**	**Phytoplankton**	**Zooplankton**	**Matter cycle**	**Nutrients**
		State variables	**DOM**	**Bacteria**	**Detritus/POM**	**State variables**	**Zoobenthos**
3	**ECOHAM**	P	one bulk	one bulk	not explicit	P	not explicit
		2	no	no	no	1	no
6	**COHERENS**	N,O	two explicit	one bulk	not explicit	N,O	no
		8	no	no	two functional	0	no
1	**NORWECOM**	N,P,Si,O	three bulk	two functional	no	N,P,Si,O	not explicit
		8	no	no	two functional	5	no
4	**ELISE**	N,P,Si	three bulk	two functional	no	N,P,Si	three bulk
		10	no	no	three functional	3	no
2	**GHER**	N	two explicit	two functional	one bulk	N	not explicit
		16	one bulk	one bulk	one bulk	1	no
7	**POL3dERSEM**	N,P,Si,O	four explicit	three functional	three functional	N,P,Si,O	four explicit
		35	one bulk	one bulk	one bulk	18	three functional
4	**ERSEM II**	N,P,Si,O	four explicit	four functional	three functional	N,P,Si,O	four explicit
		43	four bulk	three functional	four functional	22	three functional

The most complex model structure was that of ERSEM, in which the trophic web was represented by four groups each of phytoplankton, zooplankton and benthic organisms (Figure 1). Particulate and dissolved organic matter contains the elements C, N, P, and Si. The sediment is layered, and anoxic or oxic layers may develop. The sediment plays a role as deposit for the elements. The cycles of these elements are represented by the prognostic nutrients nitrate, ammonium, phosphate, silicate, and carbon dioxide as state variables. POL3dERSEM used a slightly reduced trophic resolution. The trophic and chemical representation in ERSEM is by far the most complex used up to now in ecological modelling for shelf seas, as well as for oceans. The simple structure of other models is, however, sufficiently complex to estimate main processes, e.g., primary production or eutrophication as well as more complicated representations like ERSEM.

APPLICATION AS MANAGEMENT TOOLS

To build management tools for societal concerns like “eutrophication”, it is convenient to aggregate different state variables and their standard processes into "key processes" and to describe their implementation into the models (Table 3). Such “key processes” are, e.g., spring algal blooms, annual phytoplankton cycles, nutrient regeneration, eutrophication, trophic relations in the food web, recruitment of fishes, pelagic-benthic coupling, and contaminant dynamics.

Table 3: Implementation of "key process complexes" in the selected models. For each "key process complex", a short list of necessary criteria was defined, with SV=state variables, FU=functional units, SPmodel=structured population model, IBmodel=individual based model, HM=heavy metal, PCB=polychlorinated biphenyl. The evaluation of the seven models is judged due to these criteria as: first line "Yes"= necessary state variables included; second line: explanation if necessary.

No	Model Name	Algae Blooms	Nutrient Regeneration	Eutrophication	Tropic Relations	Recruit-ment	Pelagic-benthic coupling	Conta-minants
	Criteria	phytoplankton succession; nut. limitation	particulate and dissolved organic matter	nut: N/P ratio; phyto/zooplankt. bacteria / oxygen	number of FU and SV; relations	Zoo-plankton: SPmodel/ IBmodel	Processes between pelagos and benthos	HM module; PCB module; other
1	**NORWECOM**	Partly: only two groups	Partly: only POM	Partly: no microbial loop	No: only phy	No	Yes/restricted: no zoobenthos	Yes: HM / PCB modules
2	**GHER**	Partly: only two groups	Yes: one DOM	No: only N cycle	Partly: phy/zoo/bac sum param.	No	Partly: Very crude parameterisation	No
3	**ECOHAM**	No: bulk formulation	Partly: only POM	No: only P cycle	No: only phy	No	Partly: Very crude parameterisation	No
4	**ERSEM**	Yes: four groups	Yes:	Yes/restricted: coarse resolution	Yes	No	Yes/restricted: large boxes	No
5	**ELISE**	Partly: only two groups	Partly: only POM	Partly: no microbial loop	No: only phy	No	Partly: only nutrients	Partly: PCB / Cd under progress
6	**COHERENS**	No: bulk formulation	Partly: only POM	No: only N cycle	No: only phy	No	No: only SPM	No
7	**POL3d-ERSEM**	Yes: three groups	Yes: one DOM	Yes	Yes	No	Yes: nutrients, POM zoobenthos	No

To understand and analyse "algal blooms", the phytoplankton has to be separated into several distinct state variables with different parameterisations for nutrient limitation to cover the annual cycle and successions of different groups. For the simulation of "nutrient regeneration", it is necessary to differentiate several particulate and dissolved organic compartments for the regeneration of the C, N, P, and Si cycles. "Eutrophication" has by far the widest demands. It is necessary to simulate N:P nutrient ratios and to separate the microbial food web from the classical food chain for larger plankton particles. Oxygen demands have to be included. To study "trophic relations", state variables must be connected as a food web. Study of fish "recruitment" makes it necessary to simulate populations as structured size or stage classes and take individual-based species information into account. Characterizing "pelagic-benthic coupling" requires both pelagic and benthic subsystems with appropriate physical forcing at the benthic boundary layer. And finally, evaluating contaminant effects requires at least a module for heavy metals (hydrophilic particles) or organic contaminants (hydrophobic particles) including the relevant dissolved and particulate substance cycles.

The potential of the seven three-dimensional models to contribute to the understanding of the dynamics characterised by the "key processes" has been assessed; the results are given in Table 4. At the present time, the models are suited only for investigating a very restricted scope of key process complexes. No model is suited for the recruitment problem; only one model (NORWECOM) has a module incorporated that could be used for the simulation of special contaminant dynamics. ERSEM and its three-dimensional derivative POL3d-ERSEM are suitable for all the key process complexes, except for recruitment and contaminant dynamics. The spatial resolution of ERSEM is, however, too coarse in its present box-model versions.

APPLICATION TO EUTROPHICATION MANAGEMENT

To study eutrophication effects, the model ecosystem must include several different state variables of nutrients and phytoplankton and also a representation of the microbial loop. This degree of complexity was more or less implemented in NORWECOM2, ERSEM, and POL3dERSEM.

The measures to be taken against eutrophication can only be investigated by simulations of so-called "reduction scenarios". The possible effects of a 50% reduction of riverine nutrient inputs were the subject of a modelling workshop

(OSPAR *et al*., 1998). Model results from three-dimensional and two-dimensional (vertically integrated) ecological models were analysed for different amounts of P or N reduction, as well as simultaneous P and N reduction. The goal was to illustrate effects of 80%, 50%, or 10% reduction in all the rivers. Output variables of the simulations were created for ten different areas, namely the mean winter concentration of DIP and DIN, the mean summer, the mean winter and the maximum of weekly averaged chlorophyll concentration values, the annual primary production and the maximum weekly averaged production, the area having more than 10% decrease in primary production, the diatom/non-diatom ratio, and finally the area and days with oxygen depletion. Not all of the models were able to calculate all of the selected variables. Models which did not include both N and P as nutrients could not calculate the effect of P reductions or N and P reductions. Most models were unable to calculate oxygen depletion in the bottom waters.

Table 4: Effect of nutrient load reductions on primary production (gC m^2 y^{-1}) by (OSPAR *et al*., 1998) for different coastal zones (CZ) of the North Sea (NS). The column "Base Case" quantified the absolute annual primary production of the standard run. The following two columns indicate the scenario of only P reduction and N plus P reduction.

Area	**Model**	**Base Case**	**50% P reduction**		**50% NP reduction**	
			(abs)	**(%)**	**(abs)**	**(%)**
Channel	ELISE	193	176	-9	176	-9
	CSM-NZB	238	237	0	233	-2
Belgium CZ	ECOHAM1	234	200	-14		
	ERSEM	216	181	-16	177	-18
	NORWECOM	198	178	-10	175	-11
	MIRO	475	399	-16	269	-43
	CSM-NZB	294	287	-2	270	-8
Dutch CZ	ECOHAM1	307	269	-13		
	ERSEM	267	215	-19	205	-23
	NORWECOM	207	171	-17	172	-17
	MIRO	1103	841	-24	688	-39
	DCM-NZB	314	299	-5	289	-8
	CSM-NZB	359	330	-8	304	-15
German Bight	ECOHAM1	325	277	-15		
	ERSEM	290	221	-24	213	-27
	NORWECOM	197	164	-17	165	-16
	CSM-NZB	340	297	-13	264	-22
Danish CZ	ECOHAM1	225	219	-2		
	ERSEM	303	260	-14	244	-19
	NORWECOM	122	114	-2	114	-6
	CSM-NZB	292	277	-5	239	-18
UK E Coast S.	ECOHAM1	222	202	-9		
	ERSEM	113	110	-3	106	-7
	NORWECOM	137	135	-2	131	-5
	CSM-NZB	282	275	-2	252	-11
UK E Coast N.	ECOHAM1	149	149	0		
	ERSEM	129	126	-2	128	-1
	NORWECOM	182	182	0	182	0
	CSM-NZB	255	253	-1	251	-2
Skagerrak	NORWECOM	168	168	0	164	-3
Southern NS	DYMONNS[1)]	117			108	-8
	ECOHAM1	227	211	-7		
	ERSEM	193	171	-11	165	-15
	NORWECOM	139	129	-7	127	-8
	CSM-NZB	269	260	-3	247	-8
Northern NS	ECOHAM1	119	119	0		
	ERSEM	140	137	-2	137	-2
	NORWECOM	157	157	0	156	0
	CSM-NZB	207	206	-1	203	-2
French CZ	MIRO	470	363	-23	308	-34

The overall effect of riverine nutrient load reductions can be seen best from annual primary production. A reduction of N and P inputs in almost all cases led to a predicted decrease in primary production (Table 4). The extent of the predicted reduction ranges from 0–24% for P reductions only and from 0–43% for P and N reductions, depending on the model and the model area. As to be expected, the predicted reductions in primary production were of greater importance in the continental coastal region than in the central or northern North Sea, where the effects tended to zero. The simulation study demonstrated how the nitrogen and phosphorus fluxes in the trophic web change from the quasi-oligotrophic open regime towards the eutrophied coastal regime. In the reduction run all processes decrease, but the microbial loop is quantitatively more important in the reduction run, with higher mass flows relative to the net uptake by phytoplankton.

CONCLUSIONS

The model results described (by Moll and Radach, 2003) show the potential of 3D ecosystem models. Such models produce huge amounts of simulated data, which should be available for further use and analysis. Moll and Radach (2001) summarised the availability of the simulation runs to date. The simulated data were not stored regularly from all models, and when they were, the simulated data were usually not stored in public or institutional databases; they are usually available only on request from the scientist performing the simulation, and the approach is mostly by direct or e-mail contact.

Model results reviewed here have either confirmed existing knowledge derived from field work or have given new insight into the mechanisms of the North Sea system: the temporal and spatial development and magnitude of primary production, its limitation, the function of the small food web and of the benthic web, the mechanisms of nutrient regeneration, the effects of coastal eutrophication, the extent of eutrophication in the North Sea, and the budgets for phosphorus, nitrogen, and silicon.

The three-dimensional ecological models of the greater North Sea have provided consistent regional and annual distributions and dynamics of state variables representing the lower trophic levels, results which cannot be derived to this degree of coverage by observations. They have given an understanding of the quantitative dynamics of primary production, especially about its spreading from the coasts to the northwest over the open North Sea.

The review has also shown apparent deficiencies of the ecosystem models. At present, most models are suited only to investigate a very restricted scope of processes. For example, modelling of algal succession depends on detailed knowledge not yet available regarding the physiological demands of algal species or groups of species, concerning nutrients, light, and turbulence intensity. No model developed so far is suited for the recruitment problem, and only one has incorporated state variables for the simulation of specific contaminant dynamics. The complexity of all models, except perhaps of ERSEM-type models, needs to be enhanced. Sediment chemistry is not represented in a way that would enable realistic long-term simulations, since burial of organic matter and subsequent remobilisation of nutrients are not included in any model formulation. Algal growth could be much better simulated in respect to the regional effects of stratification, of currents and nutrient availability, and of the influence of light intensity as they vary with latitude, season, and depth.

The advantage of box models is their relatively small demand for computer time, which gives the possibility to perform many simulation runs, e.g., to investigate the sensitivity of the model to parameter changes. However, the resolution of the box models restricts the study of meso-scale and smaller features. From the comparisons between the models for the greater North Sea and observations, it has become clear that ecosystem models should be 3D and should be coupled with or forced by state-of-the-art circulation models. For example, scenarios of eutrophication and of reduced atmospheric and riverine inputs of nutrients have not yet been studied using finely resolved, 3D ecosystem models to confirm results from simulations with coarser resolution.

Because the Atlantic circulation influences the circulation in the North Sea, e.g., in connection with the NAO, circulation models for the North Atlantic forced by realistic atmospheric conditions could provide the necessary boundary conditions for modelling shelf seas circulation under this same forcing. This is not yet achieved.

The validation procedure of the models will be presented in Part 2, which is in preparation.

ANNEX 4. SPECIFIC DRIVERS REQUIRING REGIONAL INTEGRATED ECOSYSTEM ASSESSMENTS

ICES

ICES itself calls for the development of integrated assessments at several locations in its Strategic Plan:

Goal 1. Understand the physical, chemical, and biological functioning of marine ecosystems

Describe understand, and quantify the state and variability of the marine environment in terms of its physical, chemical, and biological processes;

Goal 4. Advise on the sustainable use of living marine resources and protection of the marine environment

Further develop practical ways of applying the ecosystem approach, including the possible use of indicators of sustainability for fisheries;

Improve the assessment of fish stocks, and design new stock-assessment methods that incorporate environmental information;

Improve the basis for assessment of environmental conditions, and the status and outlook of marine ecosystems;

EFARO

The Group of Directors of Fisheries Research Organizations of the European Union (EFARO), in their Strategic Plan published in September, 2000, also acknowledge the need for new assessment processes. Key phrases from this publication are;

Area 1 - The scientific basis of fisheries management

Objective 1.2 To improve methods for the assessment and evaluation of aquatic resources.

Key task 1.2.4 develop new methodologies for resource management which are consistent with an ecosystem approach.

Key task 1.2.5 develop simple methods for the preliminary assessment of resources for which limited knowledge is available.

EU Common Fisheries Policy

COMMUNICATION FROM THE COMMISSION - Improving scientific and technical advice for Community fisheries management (2003/C 47/06)

1. SUMMARY

The Community must base the common fisheries policy on improved and timely scientific advice, thereby affording a firmer grounding in science than has been the case in the past. This will place more demands on the scientists and the existing scientific institutions than they can meet now and urgent improvements to the science base and its organisation are needed.

The Commission has two main targets for improvements. Firstly, regional scientific organisations should maintain and strengthen their roles as forums for international science, methodological development, organisation of surveys and long-term, strategic advice on the scale of one or more years. To this end, the Community should better coordinate the contributions of Member States to regional scientific organisations.

2. THE COMMUNITY'S NEEDS FOR ADVICE IN FISHERIES

Under the proposed new Framework Regulation governing the operation of the common fisheries policy, the Commission will continue to be responsible for proposals for Community measures for the conservation and management of resources, conditions of access to waters and resources, structural policy and management of the capacity of the fleet, control and enforcement, aquaculture, common organisation of the markets, and international relations. In particular, there is an obligation to put in place a decision-making process based on sound scientific advice and delivering timely results. Because of the Commission's pivotal rôle in proposing and overseeing the execution of this policy, it is essential that it be supported by the right expertise at the right time.

The main features of the required advice foreseen by the Commission are outlined below.

2.1. Basic principles

Conservation and management measures should be based on scientific advice of high quality. The scientific advice should cover all relevant factors, and notably the interaction between fisheries, the resources and the ecosystem and should include biological, technical, environmental, economical and social factors. It should also respect the precision of the available analyses (i.e., be robust to and take account of uncertainty).

2.2. Advice of strategic or long-term nature

The common fisheries policy should move towards the adoption of an ecosystem-based approach to management. This will require advice on the long-term effects of fishing on the structure and functioning of marine ecosystems.

ANNEX 5. REPORT OF THE WORKSHOP ON THE COORDINATION OF UK RESEARCH VESSEL MONITORING PROGRAMMES, ABERDEEN 17 DECEMBER 2003

Introduction

1. At the CFRD Working Group on Research vessel activities on 9 October 2003, the need to coordinate routine monitoring programmes was identified. In particular, there was a need to manage these cruises in the context of an ecosystem monitoring programme on a UK-wide basis. In order to make progress on this subject it was agreed that a workshop be held to develop a vision of how this might be achieved. Specifically the CFRD working group concluded that:

A Workshop should be convened to examine integration of monitoring programmes. The following guidelines were provided for the Workshop:

- Produce a vision for 10/20 years hence
- Identify the short term steps required to reach the vision
- Limit vision/recommendations to Agency vessels
- Identify problems that may be encountered

2. A workshop to carry out this task was convened in Aberdeen on 17 December 2003 with the following membership:

Andrew Kenny (CEFAS)	Liam Ferdinand (CEFAS)
Robin Cook (FRS, Chair)	Richard Millner (CEFAS)
Bill Turrell (FRS)	Matt Service (DARD)
Richard Briggs (DARD)	Paul Fernandes (FRS)
Andrew Newton (FRS, Secretary)	Richard Gowen (DARD)
Ray Johnstone (FRS)	

Current research vessel activity and programming arrangements

3. It was felt that discussion of the subject of programme integration was most relevant to the larger research vessels used by UK fisheries laboratories. Discussion was therefore limited to *Scotia, Endeavour, Corystes* and the *Lough Foyle*. It was noted that while DARD had not yet secured a replacement for the *Lough Foyle*, that there was a preference for a vessel of approximately 50m which would fit the remit of the discussions at the Workshop. The only other major vessel which might be relevant was the *Clupea* but this vessel is nearing the end of its working life and, if replaced, is more likely to be succeeded by a small inshore vessel.

4. Inspection of existing cruise programmes by the three agencies shows that a high proportion of the ships' time (~60—70%) is devoted to routine monitoring of various kinds with fish surveys accounting for the largest single portion. These comprise demersal trawl surveys, acoustic surveys, under-water television surveys and egg surveys for mackerel. Remaining monitoring work includes hydrographic surveys, contaminant surveys carried out under the National Marine Monitoring Programme (NMMP), fish disease surveys and ecotoxicological work.

5. All three laboratories plan their cruise programmes on an annual cycle as part of their annual programme commissioning arrangements with their respective policy customers. While there is some coordination of the cruises themselves, this tends to take place through separate mechanisms such as ICES coordinating working groups that do not form part of national planning cycles. This means that if there is a desire to manage monitoring activity on a UK-wide basis there needs to be an inter-agency mechanism for programming the respective vessels.

The need for a UK-wide ecosystem orientated approach

6. The present national cruise programmes and planning arrangements have developed to address specific scientific and agency needs at a national level. Thus while there is much commonality between different cruise programmes, the inter-agency coordination tends to be *ad hoc*. Furthermore, most cruises are designed with scientific objectives that are limited to specific aims. Given the very high costs of research vessel operations, it is natural to ask whether multiple objectives can be addressed on single cruises with a wider range of data being collected.

7. In recent years, it has become apparent to workers in different fields of marine science that the ‘ecosystem’ concept is a unifying idea that provides a context for addressing more general questions relating to human impact on the environment, whether it is through fishing, the discharge of contaminants or nutrients, or the effects of climate change. It is also important to know how changes in the environment, whether or not this is natural, affect the productivity of fisheries and human use of the marine environment. Providing advice to policy customers on these broader questions requires analyses that use multiple data types and examine the interactions between different components of the marine environment. This means collecting data in a more coordinated way and making it more easily accessible for analysis to a wide range of scientific studies.

8. Ecosystems need to be defined on spatial scale that is relevant to the issue under consideration. In the context of the fisheries laboratories, the most common spatial scale used relates to regional seas, such as the North Sea, Irish Sea, Celtic Sea, etc. This is because most regulatory agencies manage their responsibilities at this approximate geographical scale. Hence ecosystem monitoring effectively means devising schemes that collect data on a regional sea basis. These seas transcend UK national boundaries so it would make sense to manage the data collection within these seas through a UK programme that made the most efficient use of resources. Such a system could avoid redundancy and enhance the value of data collected by individual agencies by improving consistency and geographical coverage.

A vision for the future

9. The UK has a very long coastline ands its waters encompass much of the continental shelf between Biscay in the South and Shetland in the North. The location of the three main fisheries laboratories and their respective research vessels means that it is feasible for the UK to survey much of this area on an annual basis. Currently demersal trawling surveys carried out by *Scotia, Endeavour, Corystes* and the *Lough Foyle* cover almost the entire area twice per year. Acoustic surveys cover almost as much sea area on an annual basis. In addition there are more targeted surveys which collect data on a restricted spatial scale. Most of these surveys offer an opportunity to collect information on a substantial part of the marine ecosystem. It does seem therefore that the existing infrastructure could be used as part of an ecosystem monitoring programme that covers most of the waters around the UK. The workshop participants agreed that this was a desirable aspiration to work towards. It is proposed that the three fisheries laboratories should use their research vessels to survey the waters around the UK in a coordinated fashion to monitor as many aspects of the ecosystem as is feasible, with the resources available, on an annual basis. Ultimately, this would become an integrated ecosystem monitoring programme.

10. It is important to elaborate on the meaning of ecosystem monitoring in this context. At present the various routine surveys make a variety of measurements on the ecosystem with a particular emphasis on fish, plankton, contaminants, and hydrography. These surveys already encompass both the majority of likely measurements and the area that an ecosystem monitoring programme would cover. The main difference from the present situation is that the individual surveys would be more systematically co-ordinated across laboratories and that more use would be made of ships on each survey to obtain data in addition to the primary objective. It would also mean that the management of data collected on such cruises would be better integrated both across scientific disciplines and across laboratories. This would eventually create a valuable research tool to investigate questions in an ecosystem context.

Realising the vision

11. There is both a willingness and a desire across the three principal UK fisheries agencies to work towards a UK-wide ecosystem monitoring programme as outlined above. What is lacking at present is a mechanism that would allow such a programme to develop. It is suggested that this mechanism could be achieved through a standing CFRD working group charged with:

- coordinating/integrating cruise programmes

- developing the scientific priorities of the ecosystem programme

- establishing integrated data management systems

12. In order to facilitate coordination of ship usage, it is necessary to have a process that allows the vessels to be programmed collaboratively. It is envisaged therefore that the proposed CFRD WG would collectively identify and provisionally allocate routine cruise slots that would form part of the ecosystem monitoring programme taking into account specific constraints required by national agencies. Such provisional allocation would need to be done for a number of years ahead. This would help national laboratories plan their cruise programmes while at the same time allowing the integrated programme to develop in a co-ordinated way.

13. Apart from the mechanics of cruise programming, the working group would also need to develop the scientific guidelines on which the ecosystem programme would develop. At this stage, it is envisaged that the process would be to build gradually from the existing cruises towards a more elaborate system so as to avoid undesirable disruption of time series and compromising existing scientific imperatives. It would therefore need to address issues of survey design and the incorporation of additional data requirements in a careful way sensitive to the needs of principal customer requirements.

14. Discussion at the workshop identified demersal trawl surveys for fish as the most likely candidates for coordination and integration as a first step. These cruises already cover a large area and make a variety of biological measurements related to fish with some additional hydrographic information. They offer the most obvious platform for integration and development of a more holistic approach. On the basis of progress with these cruises, other surveys would then be considered.

15. One of the main purposes of the development of the ecosystem monitoring programme is to provide scientists with a research tool that facilitates investigation of questions in an ecosystem context. It is important, therefore that data collected are done so in a consistent way across the agencies and that the data are managed so that they can be accessed easily. The CFRD working group will need to develop procedures for managing the data in this way.

Conclusion

The three UK fisheries laboratories should develop an integrated ecosystem monitoring programme making coordinated use of their respective research vessels. The programme should develop gradually from the existing monitoring programmes and concentrate on demersal trawling surveys in the first instance. It will be necessary to establish a planning mechanism for the implementation of such a system and it is proposed that this is done through a CFRD working group.

ANNEX 6. AN EXAMPLE OF CRITERIA USED TO EVALUATE INDICATORS (RICE AND ROCHET, IN PRESS)

Criteria	Questions	Components
<u>Concreteness</u>	Is the indicator a concrete property of the physical/biological world, or is it an abstract concept?	Is it a concrete property of the physical/biological world (High), or an abstract concept (Low)?
		Are the units of measurement something that can be demonstrated in the real world (High), or an arbitrary scaling factor (Low)?
		To estimate the indicator, can observations be used directly (High), or <u>must</u> they be interpreted through a model (Low)?
Theoretical basis	Is there a sound basis in ecological theory to expect the indicator to have a systematic relationship with fishing?	If the indicator comes from theoretical reasoning: i) the theory is generally not contested among professionnals (High), ii) the theory is considered credible, but debated, and it accounts for patterns observed in many data sets (High to Fair, depending on how other models also fit the same data), iii) The theory is considered credible, but competing theories also have adherents and empirical support (Moderate), iv) The theory has adherents, but key components are considered untested or not established by many peers (Moderate to Low)
		If the indicator comes from empirical observations, the concepts behind it i) are readily reconciled with established theory (High)**, ii) are not inconsistent with current ecological theory, although theory cannot account for the empirical performance (Moderate), iii) are difficult to reconcile with components of current ecological theory (Low)
		The underlying theory allows to calculate the value of a reference point associated with serious harm that is serious or difficult to reverse
Public awareness	Has the public heard of the indicator?	Is it a property with a high (High) or low (Low) public awareness outside the use as an indicator?
		If there is high public awareness of the indicator, does the public understanding of the indicator correspond well (High) or poorly (low) with the technical meaning? *
		If there is high public awareness of the indicator, is the public likely to demand action that is: i) proportional to the value of the indicator as determined by experts (High), ii) disproportionately severe proportional to the value of the indicator as determined by experts (Moderate), iii) largely indifferent to the indicator (Low)

Criteria	Questions	Components
		Does the nature of what constitutes "serious harm" (used to define a reference point) depend on values that are shared among interest groups (High) or vary widely across interest groups (Low)?
	Is there any legal requirement to monitor or report on this indicator?	International binding agreements, national or regional legislation require that an indicator be reported on at regular intervals (High), to no such requirements (Low)
Cost	What is needed to estimate the indicator?	Uses measurement tools that are widely available and inexpensive to use (High), to needs new, costly, dedicated, and complex instrumentation (Low)
Measurement	How accurate can the indicator be measured?	Can the variance and bias of the indicator be estimated? Yes (High) No (Low) **
		If it can be estimated, is the variance of the indicator low (High) or high (Low)
		If it can be estimated, is the bias in the indicator low (High) or high (low)?
		If the indicator is likely to be biased, is the direction of the bias usually in the direction of over-estimating the risk to the species/community/ecosystem (High) or towards underestimating the risk (low) *
		If they can be estimated, have the variance and bias been consistent over time (High), or varied substantially over time (Low)
		The probability that the current value of the indicator is at or beyond a given reference point can be estimated with accuracy and precision (High) to very coarsely or not at all (Low)**
	Are the measurement errors known?	Indicator measured using tools whose accuracy and precision are known and consistent (High), to uses measurement tools whose accuracy and precision are either unknown or known to be poor/inconsistent
	Does the indicator depend on the sampling gear used in measurement?	Value obtained for indicator unaffected by sampling gear (High) to sampling methods can be and are calibrated (Moderate) to calibration difficult or not done (Low) *
	How far beyond the exact time and place where the data for an indicator were collected does an indicator apply?	Seasonal representativeness: Season variation: from unlikely or highly sytematic (High) to irregular (Low)

Criteria	Questions	Components
		Geographic representativeness: geographic variation: from irrelevant or stable and well quantified (High) through random (Moderate) to systematic on scales inconsistent with feasible sampling (Low)**
		Taxonomic representativeness: Indicator reflects the status of: from all taxa sampled/modelled (High), through known and ecologically predictable subset of species (Moderate), to only specific species with no identifiable pattern of representativeness (Low)
Availability of historic data	Is a frame of reference available to interpret current values and recent trends, set reference points, test robustness and sensitivity, etc.	Necessary data are available for: periods of several decades (High), to only relatively recent period (moderate), to opportunistic or none available (Low)
		Necessary data are: from the full area of interest (High), to consistent and representative but restricted sampling sites (moderate) to opportunistic and inconsistent sources or none (Low)**
		Necessary data have high contrast, including periods of harm and recovery (High), to variable but without known periods of harm and recovery, (Moderate) to uninformative about range of variation expected (Low)
		The quality of the data and archiving is known and good (High) to data scattered with reliability not systematically certified, and archives not maintained (Low)**
		Data sets are freely available to research community (High) to in private or commercial holdings (Low)
Sensitivity	Is the indicator going to change in an informative and reliable way in response to fishing?	The value of the indicator responds to fishing in ways that are i) smooth, monotonic and high slope of response (High)** ii) smooth, monotonic and low slope (Moderate) iii) smooth, monotonic over a restricted range of fishing effort characteristics (Mod. to Fair) iv)unreliable (Mod. to Fair, depending on when it fails to inform about fishing effects) v) insensitive or irregular: magnitude of response does not depend on magnitude of signal in effort (Low)**
Responsiveness	Will the indicator give reliable feedback on effects of management measures (or changes in the fishery) on time frames that are relevant to those of management?	Indicator changes value within one-three years of implementation of effective measures (High) to indicator will only reflect system responses on decadal scales or longer (Low)

Criteria	Questions	Components
Specificity	If an indicator changes value, how much does it tell us about fishing (or other specified forcing factor of concern)?	Is the impact of environmental forcing on the indicator known to be small (High) or strong (Low)?
		If environmental forcing does affect the indicator, is the effect systematic and known (High) to irregular or poorly understood (Low)**
		Relative to other factors the indicator: i) is known to be unresponsive (High), ii) responds to specific known factors in known ways (Moderate), iii) is thought to be unresponsive (Fair), iv) responds to many factors in only partly understood ways (Low)**