Marine Environmental Change Network

MECN

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Department for Environment Food and Rural Affairs

The evaluation of time series: their scientific value and contribution to policy needs.

Report from a Workshop held at the Marine Biological Association of the United Kingdom, December 1st & 2nd, 2005.

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THE MARINE BIOLOGICAL ASSOCIATION

Plymouth Marine Laboratory

NATURAL ENVIRONMENT RESEARCH COUNCIL

CONTINUOUS PLANKTON RECORDER SURVEY

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Reference:

Frost, M. T, Jefferson, R. & Hawkins, S. J. (Editors). (2006). The evaluation of time series: their scientific value and contribution to policy needs. Report prepared by the Marine Environmental Change Network (MECN) for the Department for Environment, Food and Rural Affairs (DEFRA). Marine Biological Association, Plymouth. Contract CDEP 84/5/311. Marine Biological Association Occasional Publications No. 22. 94pp.

Executive Summary

- In 2000 a Review of Current Marine Observations in relation to present and future needs was undertaken by the Inter-Agency Committee for Marine Science and Technology (IACMST). The Marine Environmental Change Network (MECN) was initiated in 2002 as a direct response to the recommendations of the report.

- A key part of the current phase of the MECN is to ensure that information from the network is provided to policy makers and other end-users to enable them to produce more accurate assessments of ecosystem state and gain a clearer understanding of factors influencing change in marine ecosystems.

- The MECN holds workshops on an annual basis, bringing together partners maintaining time-series and long-term datasets as well as end-users interested in outputs from the network. It was decided that the first workshop of the MECN continuation phase should consist of an evaluation of the time series and data sets maintained by partners in the MECN with regard to their 'fit for purpose' for answering key science questions and informing policy development. This report is based on the outcomes of the workshop.

- **Section one** of the report contains a brief introduction to monitoring, time series and long-term datasets. The various terms are defined and the need for MECN type data to complement compliance monitoring programmes is discussed. Outlines are also given of initiatives such as the United Kingdom Marine Monitoring and Assessment Strategy (UKMMAS) and Oceans 2025.

- **Section two** contains detailed information for each of the MECN time series / long-term datasets including information on scientific outputs and current objectives. This information is mainly based on the presentations given at the workshop and therefore follows a format whereby the following headings are addressed: Origin of time series including original objectives; current objectives; policy relevance; products (advice, publications, science and society).

- **Section three** consists of comments made by the review panel concerning all the time series and the network. Needs or issues highlighted by the panel with regard to the future of long-term datasets and time-series in the UK are shown along with advice and potential solutions where offered. The recommendations are divided into 4 categories; 'The MECN and end-user requirements'; 'Procedures & protocols'; 'Securing data series' and 'Future developments'.

- Ever since marine environmental protection issues really came to the fore in the 1960s, it has been recognised that there is a requirement for a suitable evidence base on environmental change in order to support policy and management for UK waters. **Section four** gives a brief summary of the development of marine policy in the UK along with comments on the availability and necessity of long-term marine observations for the implementation of this policy. Policy relating to three main areas is discussed; Marine Conservation (protecting biodiversity and marine ecosystems); Marine Pollution and Fisheries. The conclusion of this section is that there has always been a specific requirement for information on long-term change in marine ecosystems around the UK in order to address concerns over pollution, fishing and general conservation. It is now imperative that this need is addressed in order for the UK to be able to fulfil its policy commitments and manage marine ecosystems in the light of climate change and other factors.

List of Contents

1. Introduction

M. T. Frost, R. Jefferson. & S. J. Hawkins

1.1 Background and aims

1.1.1 MECN background

In 2000 a Review of Current Marine Observations in relation to present and future needs was undertaken by the Inter-Agency Committee for Marine Science and Technology (IACMST).[1] This review recognised that for UK waters there was an urgent need for the continuation, restoration and enhancement of marine observations and the establishment of a network of parties involved in this work. The Marine Environmental Change Network (MECN) was initiated in 2002 as a direct response to this need with funding being provided by the Department for Environment, Food and Rural Affairs (Defra). The funding supported coordination of the network by the Marine Biological Association (MBA) plus targeted restart of discontinued time-series in Plymouth, continuation funding for the Dove Marine Laboratory and workshops and networking to facilitate coordination.

The MECN was established with the aim of using long-term marine environmental data from around the British Isles and Ireland to separate global, regional and local anthropogenic impacts from natural fluctuations. The MECN also aims to provide contextual information (spatial and temporal) to aid the interpretation of current trends or events observed as a result of more localised or short term monitoring programmes.

The MECN has developed links with other networks coordinating long-term data collection and time series. These networks include the Environmental Change Network (ECN) which coordinates long-term monitoring for terrestrial and freshwater ecosystems and the Marine Biodiversity and Ecosystem Functioning EU Network of Excellence (MarBEF) which coordinates long-term marine biodiversity monitoring at a European level.

In June 2005 the MECN completed its pilot phase, with funding being provided for the continuance of the network up to March 2007 at which time it will be subject to a funding renewal bid. Full details regarding the background and history of the MECN, as well as the aims and achievements of the initial phase can be found in MECN pilot phase final report[2] (Executive Summary in Annex 1).

A key part of the current phase of the MECN is to ensure that information from the network is provided to policy makers and other end-users to enable them to produce more accurate assessments of ecosystem state and gain a clearer understanding of factors influencing change in marine ecosystems. This information is provided through reports, workshops and direct engagement with policy makers through contributions to meetings and discussions. Currently, the main method by which the MECN is intending to provide information on long-term change is the Annual Report Card (ARC) Scheme being

[1] Portmann, J. E. (2000) Review of Current Marine Observations in relation to present and future needs. Inter-Agency Committee on Marine Science and Technology (IACMST) Information Document No. 7, 32pp, Southampton.
[2] M. T. Frost , C. L. J. Frid, C. Griffiths, N. J. Hardman-Mountford , S. J. Hawkins, I. Joint, K. Kennington, (Ed. M. T. Frost). Defra Contract Report No. 06. (2005). Final Report of the pilot phase of the Marine Environmental Change Network. (Deliverable 8). Defra contract CDEP 84/5/311.

trialled in November 2006 by the Marine Climate Change Impacts Partnership (MCCIP). The MECN, therefore, acts as a knowledge transfer mechanism, allowing information from strategic long-term observations and research programmes to be utilised by policy bodies and organisations with a responsibility for the management of UK Seas.

1.1.2 Workshop background

The MECN holds workshops on an annual basis, bringing together partners maintaining time-series and long-term datasets as well as end-users interested in outputs from the network. Previous workshops have focused on issues such as enhancing the usefulness of time series measurements by undertaking quality control exercises and inter-comparability assessments and on providing a forum for MECN members to identify areas for collaborative research. It was decided that the first workshop of the MECN continuation phase should consist of an evaluation of the time series and data sets maintained by partners in the MECN with regard to their 'fit for purpose' for answering key science questions and informing policy development. This was felt to be particularly useful at the current time due to two key initiatives relating to UK Marine Science: the development of a United Kingdom Marine Monitoring and assessment Strategy (UKMMAS) and the Natural Environment Research Council's (NERC) Oceans 2025 strategy for marine science (See Box 1). The involvement of the MECN with both these initiatives makes it ideally placed to provide an evaluation of time series 'fit for purpose' for Defra's and other organisations policy requirements and NERC's scientific objectives under Oceans 2025.

In addition to the initiatives outlined in Box 1, there are number of other issues that are informed by policy-relevant work carried out by the MECN. A review of UK Marine Policy and how it is informed by science from long-term observations can be found in Section 4 of this report.

BOX 1: Two key UK marine science initiatives related to monitoring and sustained observations

United Kingdom Marine Monitoring and Assessment Strategy

The development of a United Kingdom Marine Monitoring Strategy (UKMMAS) is being undertaken by Defra in response to recommendations arising from the State of the Seas report (2005)[3]. It is expected that the review and revision of current monitoring regimes (due for completion in 2007) will lead to the improved coordination of UK monitoring in order to target resources more efficiently as well as the establishment of a monitoring regime more suited to an ecosystem-based approach. Specifically, this improvement is being brought about by firstly identifying gaps or deficiencies in current UK monitoring and then ensuring better use of existing data (e.g. improved data sharing) and the redirection of resources and / or adaptation of monitoring programmes where appropriate. The main issue being addressed is how an assessment of marine ecosystem state and trends can be made relative to the vision of having 'clean, healthy, safe, productive and biologically diverse oceans and seas within one generation'[4]. *It is important, therefore, that the MECN is able to provide a clear understanding of how its long-term data sets and time series fit into and/or complement the monitoring framework currently being developed in order to allow the relevant policy questions to be addressed.*

Oceans 2025

Oceans 2025 is an initiative of the Natural Environment Research Council (NERC) funded Marine Research Centres as an integrated science strategy for the next cycle of funding. The strategic marine science programme will be used to address areas of present or anticipated national need with particular emphasis on looking at environmental issues that require sustained long-term observations. A key component of this strategy is ensuring that data from satellite systems, *in situ* observing systems, long-term research and other monitoring studies is used to improve predictive capabilities via calibration and validation of models and increased understanding and provide an evidence base for policy guidance[5]. This element of Oceans 2025 is currently encompassed within Theme 10 (Integration of Sustained Observations in the Marine Environment). The MECN includes all of the NERC marine research centres as members and is already co-ordinating many of the long-term observations through the network. NERC is also strongly committed to making sure that UK marine policy is informed by NERC science output[6]. *It is important, therefore, that the MECN is able to provide information on the scientific value of the long-term observations being incorporated into the Oceans 2025 strategy and inform how NERC scientific output can inform UK policy requirements. MECN can also provide a link with other sectors undertaking sustained observations (i.e. Government Laboratories; Cefas, AFBI, FRS and the universities; e.g. Liverpool, Newcastle, UCW, Bangor).*

[3] Defra (2005). Charting Progress: An Integrated Assessment of the State of UK Seas. Defra, 2005. 120pp
[4] Defra (2002). Safeguarding our Seas: A Strategy for the Conservation and Sustainable Development of our Marine Environment. Defra Report. ISBN 0-85521-005-2
[5] Oceans 2025: Overview of the NERC marine centres' proposed Strategic Research Programme 2007-2012. Consultation Draft (November, 2005)
[6] NERC (2005). Science into Policy: Taking part in the process.

1.1.3 EU Network of Excellence Marine Biodiversity and Ecosystem Functioning (MarBEF)

The workshop was run as a joint activity with the Marine Biodiversity and Ecosystem Functioning EU Network of Excellence (MarBef). MarBEF is a large network consisting of 82 European marine institutes and operates as 'a platform to integrate and disseminate knowledge and expertise on marine biodiversity to a wide variety of end-users, with links to researchers, industry, stakeholders and the general public'[7]. MarBEF has a particular commitment to long-term observations through its 'Large scale and long term Networking on the observation of Global Change and its impact on Marine Biodiversity' (LargeNet) responsive mode project which forms part of the major theme 'Global Patterns of Marine Biodiversity Across Ecosystems'. The LargeNET project brings together long-term datasets on marine biodiversity in order to identify key aspects of change and relate these changes to the variability and trends of the hydro-climatic environment. Other aspects of the project include the development of tools for analysis at a range of scales, the formulation of hypotheses on the causes and consequences of environmental change, and the application of new experimental approaches for hypothesis testing and for detecting and comparing similar global change driven trends in different regions of Europe.

The MECN has developed links with MarBEF due to the recognition that long-term observations being coordinated through the MECN at the UK level need to be placed within the context of long-term research being coordinated at the European level.

1.1.4 Workshop aims and objectives

The title of the workshop was '*The evaluation of time series: their scientific value and contribution to policy needs*'.

The theme of the workshop meant that it was important that representatives from policy end-users could attend as well as marine scientists. Workshop funding from Defra allowed the MECN to host a wide range of stakeholders, end-users and MECN members. The workshop was organised by the Marine Biological Association of the United Kingdom in liaison with Plymouth Marine Laboratory (PML) and the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) and was run as a joint activity with MarBEF.

Specifically the objectives of the workshop were:

a) To provide an independent evaluation of UK time series and their present 'fit for purpose' for future scientific and policy needs.

b) To provide an overview of long-term observations in UK waters with regard to their location, history and present status that can be used to inform NERC's next funding cycle (Oceans 2025).

c) To encourage knowledge transfer from scientists/research community to policy makers/end users and discuss mechanisms by which this can be achieved (e.g. ARC scheme via MCCIP)

d) To encourage knowledge transfer and collaboration between institutions and individuals maintaining time series.

[7] http://www.marbef.org/index.php.

1.1.5 Workshop: Evaluation Process

The first stage in evaluating 'fit for purpose' as regards the time series and long-term data sets is to identify what data is available and make sure that the different sectors and institutions are fully aware of what is being collected. Other important issues as regards the evaluation, such as current purpose of monitoring, scientific outputs and policy relevance can then be addressed.

The MECN, therefore, invited all members maintaining time-series or holding long-term data to attend the workshop and present their time series and long-term data collections for this evaluation process. In order to facilitate the evaluation process, workshop participants were asked to use (as close as possible) the following format for their presentations:

1. Origin of time series including original objectives
2. Current objectives
3. Policy relevance
4. Products
    a. Advice
    b. Publications
    c. Science and Society

Another aim of the workshop was to inform NERC's next cycle of funding by highlighting the importance of the datasets along with information regarding the funding status. The precarious nature of the funding status of marine time series has been a subject of concern for some time. For example, in November 2003 SAHFOS hosted a meeting for IACMST's Global Ocean Observing System Action Group (GOOSAG) that looked at technologies available for taking measurements in the marine environment. A key point raised from this meeting was that many long-term observations were not funded properly and relied on research funds which were usually short term (whereas satellite-based observation measurements were usually better funded). The minutes from the IACMST GOOSAG meeting recorded that policy makers recognise the importance of long term observations but are not often sure what observations are important to continue.[8] By providing details of the times series and long-term datasets with an evaluation of their importance, the MECN workshop aimed to address this issue.

It is important to note that the evaluation carried out through the workshop was *developmental and advisory* rather than *judgemental*. No 'ranking' of the time series observations occurred. There have been numerous comments made on the value of long-term time series in papers reports and workshops, partly due to the paucity of long-term data available for scientists and policy makers. As it was, therefore, obvious that all marine long-term data sets and time series have some intrinsic value due to their uniqueness and rarity (the reason the MECN was set up in the first place), the emphasis was placed on developing the time series and the network: specifically, could the time series enhance their 'fit for purpose' and could the network be further developed to maximise the value of the information being collected.

In order to function as a proper review process, the evaluation of long-term observations needed to be carried out on an independent basis and for this reason a number of scientists were invited to form an external review panel. The members of this panel represented marine scientists and end-users from

[8] The minutes from this meeting are available at:
http://www.oceannet.org/goosag/meetings/open_meetings/before_2004/openmtgrep25Nov03.pdf

organisations in Britain and mainland Europe and were given the responsibility of carrying out the evaluation process and producing a set of recommendations (see Section 3).

1.1.6 Structure of Workshop Report

This report constitutes the main output from the workshop and is supplied to Defra under the terms of the MECN workshop contract. Copies of the report are also to be provided to NERC and it is hoped that the report will be a useful resource for other parties interested in what long-term data and time series information is available and its relevance to UK marine science and policy.

The remainder of Section one of this report consists of a brief introduction to monitoring, time series and long-term datasets. The various terms are defined and the need for MECN type data to complement compliance monitoring programmes is discussed.

Section two contains detailed information for each of the MECN time series / long-term datasets including information on scientific outputs and current objectives. This information is mainly based on the presentations given at the workshop and the presentation authors are therefore shown.

Section three contains the comments made by the review panel concerning all the time series and the network.

Section four concludes the report with a brief review of UK marine policy, its development and the associated requirement for information on long-term environmental change to support this policy.

1.2 MECN Monitoring: definitions and policy context

Before discussing the type of monitoring programmes coordinated by the MECN, it is necessary to agree definitions for the terms used when discussing the various monitoring activities. This is important since there is no agreed set of definitions and this can lead to confusion[9].

1.2.1 Monitoring

The term 'monitoring' is usually only defined relative to the framework in which the monitoring is being carried out. So, as a great deal of environmental monitoring is focussed on pollution issues, the current definition of monitoring given by, for example, the European Environment Information and Observation Network (EIONET), is:

"The assessment of marine pollution by an integrated chemical, ecological and toxicological survey[10]*"*

Within the context of the broader aim of assessing marine environmental quality (not just pollution) by measuring a range of parameters, the definition of monitoring given by the OSPAR Convention (Annex

[9] Reid, P. C. & Portmann, J. (2006). Marine Monitoring in the United Kingdom. A report to the Global Ocean Observing System Action Group (GOOS AG) of the Inter Agency Committee on Marine Science and Technology (IACMST).
[10] http://www.eionet.eu.int/gemet/concept?cp=5042&langcode=en

IV, Article 1) and adopted by OSPAR's Joint Assessment and Monitoring Programme (JAMP) is "*the repeated measurement of*:

a. *the quality of the marine environment and each of its compartments, i.e. water, sediments and biota;*

b. *activities or natural and anthropogenic inputs which may affect the quality of the marine environment; and*

c. *the effects of such activities and inputs".*

Both the above definitions have in common the fact that the monitoring being referred to is that carried out against specific targets or objectives, as opposed to the type of monitoring that seeks only to identify trends or patterns or document change. Target related monitoring includes 'compliance' monitoring, which is monitoring "*designed to demonstrate compliance with the requirements of current national and international regulation"*[11] as well as monitoring against targets set by conventions or treaties such as OSPAR or the Convention on Biological Diversity (CBD)[12]. Long-term observation that only seeks to establish baselines or document change is sometimes not considered as monitoring at all and is often conducted as part of long-term research programmes. For example, the Joint Nature Conservation Committee (JNCC) distinguishes 'monitoring' ("*surveillance undertaken to ensure that formulated standards are met"*) from 'surveillance' ("*a continued programme of biological surveys systematically undertaken to provide a series of observations in time"*)[13]. The Water Framework Directive (WFD), however, retains the term monitoring for all its programmes but separates it into 'surveillance monitoring' (which includes the determination of long-term change); 'operational monitoring' (used to determine the status of water bodies identified as being at risk and how this changes as result of the programme of measures) and 'investigative monitoring' (used to establish reasons for failure).[14]

The MECN time series and datasets should, therefore, be classed as 'surveillance' or 'surveillance type monitoring', although many of them stem from long-term research programmes, often stemming from a desire to test hypotheses or to measure natural variability on various spatial and temporal scales.

1.2.2 'Long-term' observations

A key element of all MECN surveillance monitoring is that it involves the *long-term* collection of data (either as a time series or as data collected on a more intermittent basis – see below). The definition of 'long-term' is rarely made explicit so, for example, the Oceans 2025 Strategy document[5] refers to 'Long-term observations' and 'sustained observations' without actually defining either term. There are some definitions, however, that are useful in order to describe the type of observations coordinated by the MECN. When applied to research, 'long-term' can be defined as:

[11] http://www.defra.gov.uk/environment/water/marine/uk/science/monitoring.htm
[12] United Nations (1992) Convention on Biological Diversity, UN, New York, 31pp
[13] Jon Davies (senior editor), John Baxter, Martin Bradley, David Connor, Janet Khan, Eleanor Murray, William Sanderson, Caroline Turnbull and Malcolm Vincent. (2001) Marine Monitoring Handbook. Joint Nature Conservation Committee.
[14] http://www.euwfd.com/html/monitoring_requirements.html

"*..research occurring over decades or longer"*[15].

Within the context of monitoring, however, Parr et al.[16] suggest a useful scientific definition of 'long-term' as:

"*…the time scale which enables signals of environmental change to be distinguished from background noise*"

and a practical definition where 'long-term' covers:

"*..any sites where there is a commitment to maintain scientific and monitoring programmes beyond the usual length of a scientific research programme*".

The latter definition can be adapted to:

"*..any sites where there is a commitment to maintain scientific and monitoring programmes beyond the usual length of a scientific research programme, typically three to five years*".

All of these definitions can be applied to the type of sampling being undertaken by MECN partners, as even where measurements have started only relatively recently such as some of the new Ferrybox initiatives, data are collected with the view that they will form the basis of a long-term programme of data collection.

1.2.3 Time Series

Finally, it is noted that the term 'time series' is used to describe many of the data sets collected via the MECN. Although sometimes the term 'time series' is simply defined as any dataset that allows "*the comparison of data from two periods"*[17], it may be more useful to make a distinction between 'time series' as data collected on a regular or consistent basis, albeit with gaps occasionally occurring, and 'long-term data sets' which are observations made over long periods of time but without ever achieving any kind of consistency or regularity over the period of their collection. An example of this would be much of the data collected by the Marine Biodiversity and Climate Change Project (MarClim). MarClim data is available over large spatial scales and over a large temporal range (1930s to present) but only achieves any kind of regularity in sampling for certain periods within this range. The exceptions are the barnacle and limpet datasets on Northern and Southern Species collected between 1950 and 1987 by Southward and continued by Hawkins from 1997 to date.

The term 'time series' is, therefore, here restricted to those datasets where a degree of consistency is achieved in sampling over the lifespan of the sampling programme. The MarClim resurvey data and similar datasets are referred to as 'long-term datasets'. However, the observations (1950s to 1987, over

[15] Risser, P. G., Melillo, J. M. & Gosz, J. R. (1991). Current status and future of Long-term Ecological Research. In: Long-term Ecological Research: An International Perspective. 1991, Ed: P. G. Risser, Wiley, UK

[16] Parr, T. W., Ferretti, M., Simpson, I. C., Forsius, M. & Kovàcs-Làng, E. (2002). Towards a long-term integrated monitoring programme in Europe: Network design in theory and practice. *Environmental Monitoring and assessment*. 78:253-290

[17] See discussion in: Clark, R.A. and C.L.J. Frid. (2001). Long-term changes in the North Sea ecosystem. *Environmental Reviews*. 9: 131-187.

40 years) on barnacles restarted in 1997 and continued under MarClim and the limpet datasets collected since 1980 are 'time series'.

1.2.4 Summary: MECN

To summarise, all the MECN datasets are 'time series' or 'long-term datasets' that contribute to 'long-term' research programmes based on sustained observations. Their status as regards UK monitoring is that of 'surveillance' or 'surveillance monitoring' programmes and all MECN time series and datasets fall within the definition of monitoring given by Portmann[1] where monitoring is defined as:

> "*The taking, on a reasonably regular basis, of any form of observations relative to the (long-term) status of the marine environment, regardless of the frequency of, or purpose for which, the observations are made*."

For a comprehensive review of all UK marine monitoring programmes, reference should be made to the review carried out by Reid and Portmann for the Global Ocean Observing System Action Group (GOOS AG) of the Inter Agency Committee on Marine Science and Technology (IACMST)[9]. A comprehensive review of biological time-series in the UK (and Europe) can be found in Hiscock and Kimmance (2003)[18].

1.3 Relationship between compliance monitoring and long-term observations

The majority of UK monitoring programmes are those set against targets or policy objectives rather than pure surveillance monitoring (see Section 1.2.1). Some of this monitoring is designed to produce absolute values that can be compared spatially or with pre-agreed threshold values but the identification of 'change' or 'trends' in the monitoring data is often thought to be more useful. The direction of any observed change can then be examined relative to the target or objective. For example, the identification of trends in monitoring data from OSPAR's Joint Assessment Monitoring Programme (JAMP) is used to assess the *development* of quality status locally and across the OSPAR maritime area[19]. The purpose of this type of monitoring, ultimately, is to inform those responsible for implementing the various objectives agreed within the framework of UK marine environmental policy. Basically, trends observed in the parameters measured (a number of which are used as target or state indicators[20]) enable environmental managers and policy makers to know if targets are being met or a desired direction of change is being achieved. The management regime can then be adapted accordingly, assuming that the driver of the change can be identified and controlled. Traditionally, the various marine sectors and organisations have instituted their own monitoring programmes which are tailored to meet specific needs or targets (statutory or other). There is now a call, however, for greater

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[18] Hiscock, K. & Kimmance, S. (2003) Review of current and historical seabed biological time-series studies in the UK and near Europe. Report from the Marine Biological Association to the Joint Nature Conservation Committee. (JNCC Contract: F90-01-563)

[19] Strategy for a Joint Assessment and Monitoring Programme (JAMP) (2005 revision). http://www.ospar.org/eng/html/sap/jamp.htm

[20] N.J. Hardman-Mountford, J.I. Allen, M.T. Frost, S.J. Hawkins, M.A. Kendall, N. Mieszkowska, K.A. Richardson & P.J. Somerfield. (2005). Diagnostic monitoring of a changing environment: An alternative UK perspective. *Marine Pollution Bulletin* 50: 1463–1471

synergy between the different monitoring strands, especially where considerable spatial overlap in sampling occurs[19].

The surveillance and long-term research programmes in the MECN fall outside of this traditional monitoring framework. These programmes have been started for various reasons such as providing baseline environmental data to help interpret research studies or to address specific scientific questions. Sometimes sampling has been carried out as part of a specific research project but was also or subsequently recognised as being a potential baseline by which future environmental change could be measured. This prescience can be seen, for example, in comments made by Norman Holmes who carried out large-scale benthic surveys throughout the English Channel between the 1950s and 1980s:

"The biomass figures……are intended to provide basic data for following changes in the bottom fauna in the future."[21]

Another main difference, therefore, between compliance and surveillance monitoring is that compliance type monitoring is generally only able to detect change over relatively short periods with no indication as to the wider implications or long-term effects of that change. The MECN, however, is concerned mainly with 'ecological change' which is defined by Frid and Clark (2001) as:

"any observed change that implies a consistent change in the underlying functionality of the ecosystem. As such, this could be exhibited in a time series as not only a change in the direction of the trend but also a change in the gradient of the series with time."[22]

An example of this type of ecological change can be seen in the 'regime shift' that occurred in plankton communities in UK waters in the 1980s revealed by analysis of long-term data sets from the Continuous Plankton Recorder (CPR) programme[23], [24]. This change is now recognised as having major implications for the pelagic ecosystem as a whole from plankton communities through to knock-on effects to fish populations[25]. This type of change may also have major implications for the consideration of ecosystem resilience.

It is now widely recognised that evidence on environmental change from long-term observations is vital for complementing existing compliance programmes. For example, the Joint Nature Conservation Committee (JNCC) has devised a set of common standards for monitoring sites to assess whether various statutory and/or management objectives have been achieved. The advice for interpreting results from marine monitoring programmes emphasises the need for data from long-term surveillance monitoring to aid interpretation of data from condition monitoring:

"The interpretation of evidence from the condition monitoring activity may require access to contextual information, perhaps from a wider geographical area, or over longer time scales. It is important to ascertain that an observed change is a local phenomenon resulting from an activity on

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[21] Holme, N.A. (1953). The biomass of the bottom fauna in the English Channel off Plymouth. *Journal of the Marine Biological Association of the UK*. 32:1-49

[22] Clark, R.A. and C.L.J. Frid. (2001). Long-term changes in the North Sea ecosystem. *Environmental Reviews*. 9: 131-187.

[23] Reid, P. C., M. F. De Borges, et al. (2001). A regime shift in the North Sea circa 1988 linked to changes in the North Sea horse mackerel fishery. *Fisheries Research* 50 (1/2): 163-171

[24] Beaugrand, G., P. C. Reid, et al. (2002a). Major reorganisation of North Atlantic pelagic ecosystems linked to climate change. *GLOBEC International Newsletter* 8 (2): 30-33

[25] Beaugrand, G., K. M. Brander, J. A. Lindley, S. Souissi and P. C. Reid (2003). Plankton effect on cod recruitment in the North Sea. *Nature* 426 (6967): 661-664.

a site, and not inherent variability or a nation-wide trend due to some other factor."[26]

Another reason that the surveillance monitoring is needed is that increasingly results from compliance monitoring have to take into account the effects of climate change. The analysis of change in response to long-term variation in climatic variables requires datasets over much longer periods than traditional compliance monitoring. If climate change is having an effect on the marine environment (and there is now a general consensus that this is the case) then long-term data and time series can also be used to try to understand and predict responses. For example, Platt et al.[27] working in Canada stated that the rapid decline of Herring on the Nova Scotia Shelf could only be understood once long-term data from *in situ* and satellite monitoring became available; it then became clear that it was due to larval survival which could be predicted based on algal bloom timing linked to variation in Sea Surface Temperature (SST)[27]. Another example is where long-term data from rocky shore surveys going back to the late 1930s has enabled the MarClim project to develop models to predict range extensions of rocky shore species in response to increasing SST. These models are seen as crucial in complementing and informing results from traditional compliance monitoring to enable policy objectives to be met.[28] Both of these examples also show how predictive models based on climate scenarios are only feasible when long-term data is made available.

Climate is clearly not the only factor influencing marine ecosystems, however, and long-term observations are also vital in order to be able to disentangle the relative effects of factors such as climate, fishing and eutrophication thus enabling effective management to be carried out. For instance, long-term data from the North Sea, English Channel and Bristol Channel is being used to address the highly contentious issue of the relative effects of climate and fishing on fish populations[29]. For all these reasons, it is clear that data from long-term observations must be used to complement compliance and other monitoring programmes.

[26] JNCC (2004). *Common Standards Monitoring Guidance for Marine*, Version August 2004, ISSN 1743-8160

[27] Platt T., Fuentes-Yaco, C. & Frank, K. T. (2003). Spring algal bloom and larval fish survival. (2003). *Nature*. 423: 398-399

[28] Mieszkowska, N., Leaper, L., Moore, P., Kendall, M. A., Burrows, M. T., Lear, D., Poloczanska, E., Hiscock, K., Moschella, P. S., Thompson, R. C., Herbert, R. J., Laffoley, D., Baxter, J., Southward, A. J. & Hawkins, S. J. (2005) Marine Biodiversity and Climate Change Assessing and Predicting the Influence of Climatic Change Using Intertidal Rocky Shore Biota. Final Report for United Kingdom Funders. *Marine Biological Association Occasional Publications No. 20*

[29] See: Genner, M.J., Sims, D.W., Wearmouth, V.J., Southall, E.J., Southward, A.J., Henderson, P.A., Hawkins, S.J. (2004) Regional climate warming drives long-term community changes of British marine fish. *Proceedings of the Royal Society of London B*, 271: 655-661; and case study in Footnote Reference (2).

2. Time Series / long term datasets

Ten organisations presented time series / data sets for evaluation at the workshop:

a) Centre for Environment, Fisheries and Aquaculture Science (CEFAS)
b) Dove Marine Laboratory (presented by Liverpool University)
c) Liverpool University (Port Erin Marine Laboratory)
d) Marine Biological Association of the United Kingdom (MBA)
e) National Oceanography Centre, Southampton (NOCS)
f) Plymouth Marine Laboratory (PML)
g) Proudman Oceanographic Laboratory (POL)
h) Sir Alister Hardy Foundation for Ocean Science (SAHFOS)
i) Scottish Association for Marine Science (SAMS)
j) University College of Wales (UCW), Bangor

Two more organisations presented information on time series but not for evaluation purposes:

The Agri-food and Biosciences Institute of Northern Ireland (AFBI) is currently subject to a review process and was, therefore, not able to be subject to an another external evaluation.

The Alfred Wegener Institute for Polar and Marine Research (AWI) presented a talk as part of the MarBEF contribution in order to provide an example of a non-UK time series.

A map showing key locations of time series and long-term datasets is shown in figure 2, with more detailed maps provided in the relevant sections. Summary details for time series and long-term datasets are given in table 2. It should be noted that the Fisheries Research Service (FRS) maintains a number of time series that contribute to the MECN but was unable to contribute to the workshop.

The following section provides summaries of the time-series and long-term datasets maintained by MECN partners using the criteria given for the presentations (see Section 1.1.5). The summaries are based mainly on the presentations given at the workshop and should therefore function as an overview providing a clear outline of the work being undertaken in terms of the aforementioned criteria (origin, policy applications etc). The summaries here are not intended to provide a comprehensive review of all time series (methodologies etc) as these details are readily available from a number of sources to which the reader is referred. Selected publications are shown for each time series if supplied. Also, detailed information on all the time series, in addition to information on monitoring programmes not included in the MECN can be found in the review by Reid & Portmann (2006)[9].

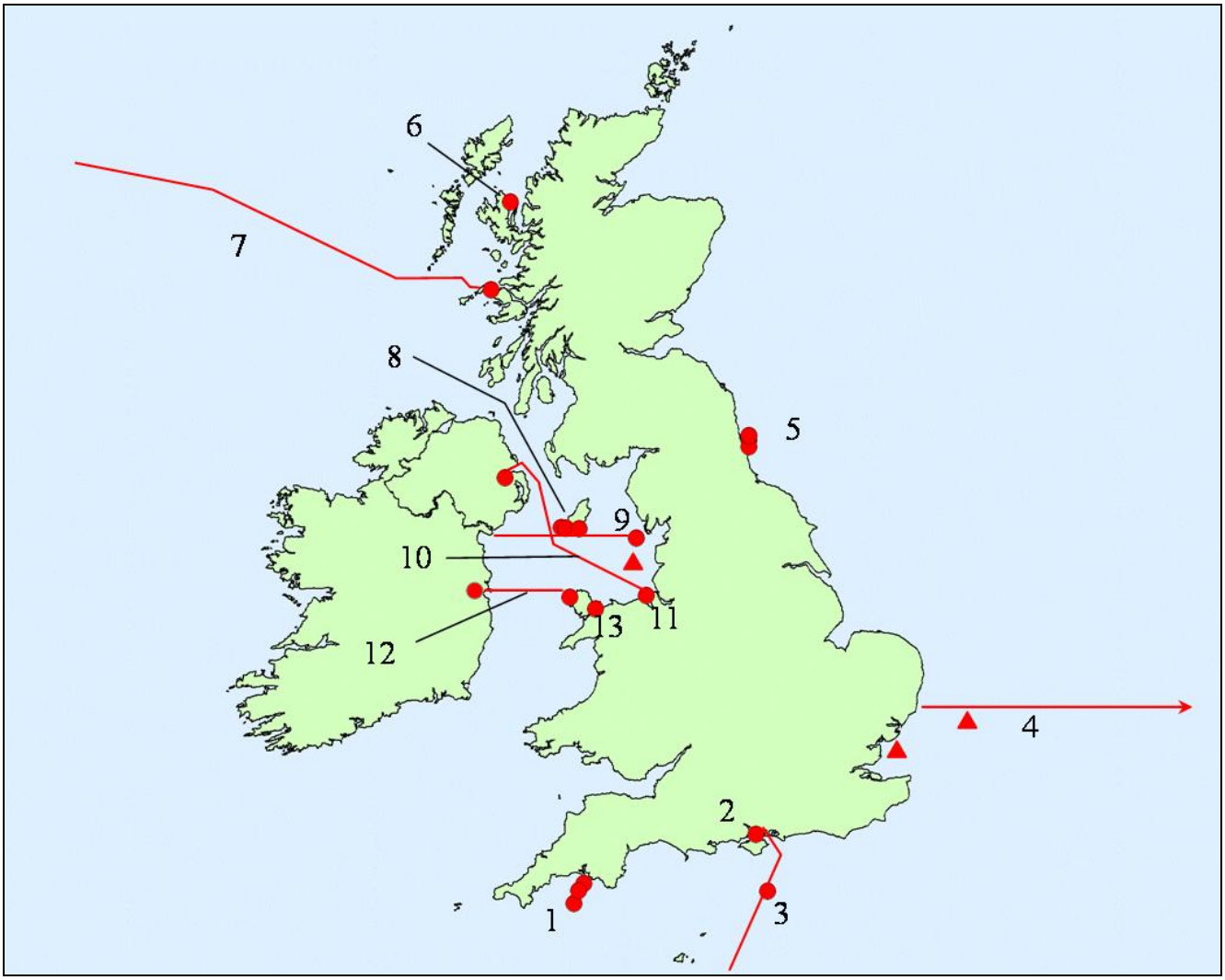


Figure 2. Map showing key locations of time series and long-term datasets. 1 = MBA/PML sampling sites; 2 = Solent and Southampton Water (NOCS); 3 = Portsmouth-Bilbao FerryBox (NOCS); 4 = Southern North Sea Ferry (CEFAS); 5 = Dove Marine Laboratory sampling sites; 6 = Tiree Passage (SAMS); 7 = Ellett Line (SAMS); 8 = Port Erin Marine Laboratory (PEML) Sites; 9 = 54° Parallel (PEML); 10 = Liverpool to Belfast FerryBox (POL); 11 = Dee Estuary Buoy (POL); 12 = Dublin to Holyhead FerryBox, (UCW, Bangor); 13 = Menai Strait, (UCW, Bangor); ▲ = CEFAS Smartbuoys. Note: for presentation purposes, projects with a wide spatial coverage, namely SAHFOS, MarClim and some CEFAS programmes are not shown on this map. Also, for a comprehensive map of POL's Liverpool Bay Coastal Observatory sites see section 2.1

Organisation	Time Series	Length of time series (years)	Parameter type	Habitat details	Temporal Resolution
MBA/ PML	L5	93	Biological	0-60m	Monthly
	L4	18	Physical Biological Nutrients	0-55m	Weekly
		110 (intermittent)		L4 environs: benthos	Variable
	E1	104 (intermittent)	Physical Biological Nutrients	0-70m	Monthly
	MarClim	Intermittent ~50	Biological	Intertidal rocky shore	Variable
SAHFOS	Various	60	Biological	Surface	Variable
NOCS	Southampton and Solent	~20	Physical Biological Nutrients	0-12m	Weekly
	Portsmouth to Bilbao Ferrybox	4	Physical	Surface	5 times per week
CEFAS	Southern North Sea Ferry	35	Physical	Surface	Weekly
	Denmark Strait	20	Physical	1500-2500m	Hourly
	Coastal Temperature Network	~ 40	Physical	Surface	Daily - weekly
	WaveNet	3	Physical	Surface	Half-hourly
	Smartbuoys	6	Physical Biological Nutrients	~5m	Variable
Dove Marine Laboratory	Benthic Station M	34	Biological	55m	Bi-annual
	Benthic Station P	35	Biological	80m	Annual
	Station Z	38	Biological Physical	54m	Monthly
SAMS	Ellett Line	26	Physical	0-2300m	Annual
	Tiree Passage	21	Physical	20-48m	Daily
PEML	Port Erin	98	Physical	Surface	Daily
	Cypris	Up to 48	Physical Nutrients	Water column	Monthly, often weekly
	Breakwater	102	Physical	Surface	Daily
	Baynargh	42	Physical Nutrients	Water column	Monthly
	54 degree parallel	12 + 1950s data	Physical Nutrients	Water column	Bi-annually
POL*	Liverpool to Belfast Ferrybox	3	Physical	Surface	Continuous
	Coastal tide gauges	13	Physical	Surface	Continuous
	Dee Estuary Buoy	Redeployed -2006	Physical	Surface	Continuous
UCW, Bangor	Dublin to Holyhead Ferrybox	2	Physical	Surface	Twice daily
	Menai Strait	39	Physical	Surface	Daily

Table 2. Summary details of time series and long-term data sets. *The POL observatory incorporates measurements from various networks and only examples are shown. For full details see section 2.1.

2.1 Liverpool Bay Coastal Observatory (Proudman Oceanographic Laboratory)

J. Howarth et al.

Details

The Liverpool Bay Coastal Observatory integrates data from a number of time series, with all outputs and products from the observatory accessible via a web interface (http://cobs.pol.ac.uk/).

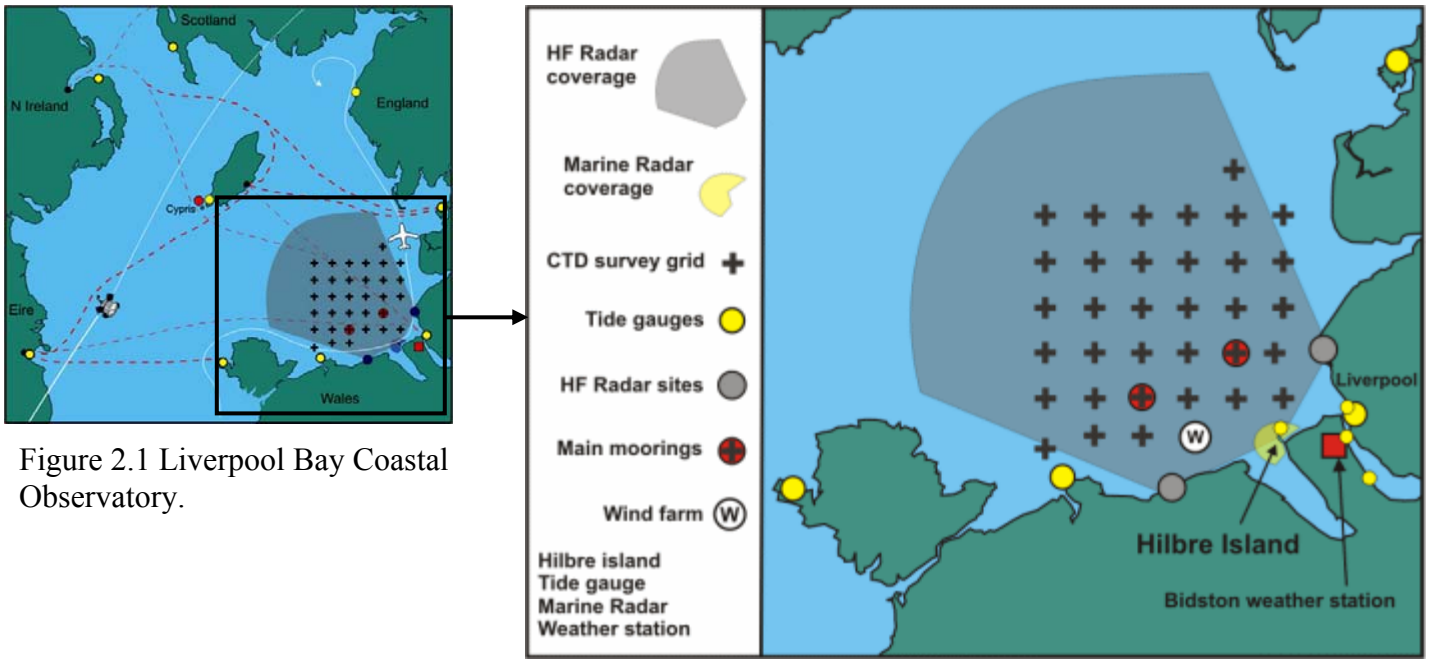


Figure 2.1 Liverpool Bay Coastal Observatory.

Coastal Tide Gauges: Near real-time observations of coastal sea level are taken from selected ports and locations in the Irish Sea and Liverpool Bay. The National Tidal & Sea Level Facility network (NTSLF) takes measurements at Workington, Heysham, Liverpool - Gladstone Lock, Llandudno and Holyhead. Mersey Docks & Harbour Company (MDHC) records tidal elevations from Eastham Lock, Alfred Lock, Gladstone Lock and Hilbre Island. The MDHC elevations are relayed via VHF transmissions in real time.

Liverpool to Belfast Ferry: Data have been collected from the surface waters of the Irish Sea between 53.4°N, 3.01°W and 54.6°N, 5.92°W. Proudman Oceanographic Laboratory (POL) has been maintaining this time series since December 2003 with temperature, conductivity, chlorophyll, salinity and turbidity being measured on a continuous basis.

Fixed moorings: Data are collected from a number of sites with two main mooring sites being maintained at Site A at 53° 32'N 3° 21.8'W and Site B at 53° 27'N 3° 38.6'W.

Measurements at Site A began in August 2002. An Acoustic Doppler Current Profiler (ADCP) attached to a bottom frame at this mooring site gives a current profile (values for currents throughout the water column) and also records pressure, directional waves, conductivity, temperature and turbidity. Another

ADCP was redeployed to Site B in March 2006. Also at Site A, a CEFAS surface SmartBuoy records surface fluorescence, turbidity, Photosynthetically Active Radiation (PAR), salinity, conductivity, temperature and oxygen saturation. Other measurements include nitrate and silicate concentration, phytoplankton biomass and suspended particulate. There is a directional wave buoy, part of WaveNet, at Site A.

A buoy is deployed in the Dee Estuary (re-deployed in February 2006) which measures waves in the Hilbre Channel at position 53° 23.6'N 03° 14.21'W.

Surveys are conducted as part of maintenance cruises nine times a year at approximately four to six week intervals. A CTD/LISST (Laser *In Situ* Scattering and Transmissometry) and water sample survey is taken of 34 sites on a five nautical mile grid in the Eastern Irish Sea. Various other measurements are taken on these surveys including zooplankton vertical net hauls at mooring Site A.

Met Station: Comprehensive meteorological measurements are taken by the Hilbre Island weather station situated at the outer part of the Dee Estuary.

Radar: A high-frequency (HF) radar system has been deployed since March 2004 at two sites in Liverpool Bay (Llanddulas in Colwyn Bay and Formby) to observe sea surface currents and waves.

River flow: The Environment Agency provide data on river flow (daily) in to Liverpool Bay and the Irish Sea.

Satellite: The Remote Sensing Data Analysis Service (RSDAS) provides weekly composite data on SST, chlorophyll and suspended sediment.

Origin of time series including original objectives

The Liverpool Bay Coastal Observatory is being developed as a proof of concept by POL to provide near real–time measurements and modelling capability accessible via a web interface. Anyone can join the observatory and the individual time series included within the framework of the observatory have come from a variety of organisations including CEFAS, Environment Agency (EA) and the Met Office. The origins of many of the individual time series are, therefore, diverse depending on which organisation maintains the time series and the original requirements of that organisation.

Current Objectives

The main objective is to use measurements of horizontal and vertical gradients at a variety of scales for the development and testing of models. Another objective is the establishment of key long-term time series that can be used to address issues such as seasonality, inter-annual variability, events versus mean condition and distinguishing between natural physical and biological variation and that caused by anthropogenic factors including climate change. This knowledge can then provide the underpinning science for an ecosystem-based approach to marine management.

Specific science questions being addressed include the impact of storms on shelf seas and shores, the influence of river discharge on sea contaminant and nutrient levels and a greater understanding of the timing, cause and effects of eutrophication events and Harmful Algal Blooms (HABs).

Policy relevance

The integration of a wide variety of physical and biological measurements from the Irish Sea provides the underpinning science for an ecosystem-based approach to marine and coastal zone management. The provision of information to the government on the status and changes in Liverpool bay regarding eutrophication and HABs is directly relevant to various water quality directives including the Urban Waste Water Treatment Directive (UWWTD) and the Water Framework Directive (WFD).

Products

The outputs from the observatory can all be viewed at http://cobs.pol.ac.uk/. Integrated near real-time measurements are available at a variety of space and time scales and are multi-disciplinary in nature. The models available include daily nowcasts/forecasts of physical state (T, S, ζ, U,V, waves) as well as nutrients, biology and suspended particulate matter. Up to December 2005, the observatory had over 500 users registered through the website including a wide public audience (55%), researchers from the scientific community (20%), coastal managers (10%), teachers (10%) and other end users (5%). Data from the observatory and details of its operation have been outlined at a number of conferences and workshops. Although the observatory is a fairly recent development, a number of scientific papers are currently in preparation. Data collected by the observatory is managed by the British Oceanographic Data Centre (BODC) with all basic data and modelling output freely available.

2.2 Port Erin Marine Laboratory time series (University of Liverpool)

T. Shammon & K. Kennington

Details

The time series maintained by the University of Liverpool's Port Erin Marine Laboratory on the Isle of Man are some of the longest time series in UK marine waters with measurements going back over 100 years. Unfortunately, due to the imminent closure of the laboratory, the time series here are under severe threat and sampling has already ceased at one of the locations (see below). Negotiations are under way to find alternative sources of funding for all the time series but nothing has been decided at the present time[30].

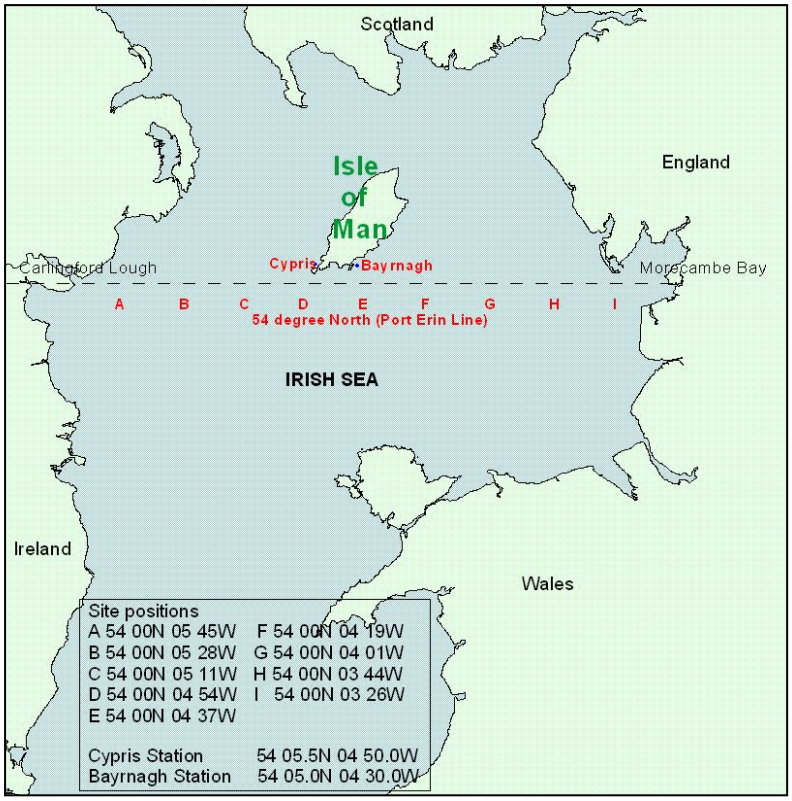


Figure 2.2. Locations of University of Liverpool time series: Cypris, Bayrnagh and 54° North Parallel (Port Erin Breakwater site not shown). Source: Shammon, T.M., & Hartnoll, R.G. (2002)[31].

Port Erin Breakwater: This is the oldest of the time series with basic routine daily hydrographic measurements of SST being instigated in 1904. Daily salinity measurements were added to the series in 1965.

[30] Since the workshop, PEML has formally closed and responsibility for monitoring has transferred to DLGE Government Laboratory. As part of the work there it is the intention to continue with the 'Cypris' and Port Erin Breakwater timeseries.
[31] Shammon, T.M., & Hartnoll, R.G. (2002). Long Term Studies of the Irish Sea: Environmental monitoring and contamination. Summary of results for the years 2000 and 2001. Reports to the Department of Local Government and the Environment, Isle of Man Government. (Port Erin Marine Laboratory).

Cypris: The Cypris Station, five km west of Port Erin has been sampled at least once a month (weekly during spring and summer) since 1954. Originally, temperature, salinity, phosphate and dissolved oxygen were measured with measurements being added for silicates in 1958, for nitrate and nitrite in 1960 and chlorophyll since 1966, for total dissolved nitrogen in 1992 and total dissolved phosphorous in 1996.

Bayrnagh: The Bayrnagh (Resa) Station, situated five km to east of Isle of Man was sampled from 1994 to 2003 using identical protocols as for Cypris. Unfortunately, lack of funding means that no samples were taken after 2003.

54° North Parallel: Nine stations from outside Carlingford Lough to Morecambe Bay along the 54° North Parallel (The Port Erin Line) were sampled in winter and summer on an intermittent basis during 1950s and regularly from 1992 to 2004. The same measurements are taken as for the Cypris Station. Between 2001 and 2004 the 54° North Parallel was monitored at approximately monthly intervals between late-winter and autumn. Funding for this time series then ceased and an alternative funding source has not been located.

Origin of time series including original objectives

The time series maintained by PEML were originally instigated in order to provide a basic understanding of the local hydrography and to provide baseline environmental data for the interpretation of biological investigations conducted at the Port Erin Marine Biological Station (it became PEML in 1988). The time series were therefore seen purely as a service activity providing support for the scientific investigations underway at the laboratory and consequently had a fairly low scientific profile. However, the potential value of the long-term observations was recognised at an early stage:

> "*The motor boat Cypris has, however, been used for making weekly observations on salinity, temperature and phosphate off Port Erin, and it is hoped to continue these more or less in perpetuity, since their cumulative value increases continuously with time*"[32]

By 1991 the time series were indicating distinct trends for sea temperature and also, at Cypris, inorganic nitrogen, phosphorus and spring chlorophyll. The importance of these observations was recognised and the Department of Local Government and the Environment of the Isle of Man were persuaded of the advantages of continued environmental monitoring in Manx territorial waters. Since 1990 the time series have therefore formed the basis of the 'Long Term Studies of the Irish Sea project' looking at environmental monitoring and contamination supported by the Manx Government (Reiltys Ellan Vannin) as part of its commitment to the aims of the Irish Sea Study Group which reported in 1990.

Current Objectives

Since 1992 the time series have been utilised with the following specific aims:

- to provide a strategic overview of key water quality variables in Manx territorial waters

[32] Colman, J.S. 1955. Directors report for 1954. *Annual report of the Marine Biological Station*. 67: 5-24

- to provide an empirical overview of the local impact of environmental and climate change
- to provide a strategic overview of key water quality variables in waters of adjacent Irish Sea jurisdictions i.e. to place the Manx data into a wider Irish Sea context

This work, along with additional data from Liverpool Bay became the basis for wider studies in the north-east Irish Sea funded from 1995 by The Environment Agency. The objectives of this work are:

- to examine spatial trends in nutrient concentrations and associated phytoplankton communities in the north east Irish Sea with regard to the UWWTD
- to identify areas potentially at risk from the adverse effects of excessive nutrient discharges from sewage and industrial outfalls

Analysis of time series data is undertaken by staff at PEML and included in a series of technical reports to the Environment Agency and also the Department of Local Government and the Environment of the Isle of Man Government (see Products).

Policy relevance

The work undertaken using the PEML time series is relevant to a number of UK and Isle of Man Government policy areas including:

- OSPAR – strategy to combat eutrophication
- EU Water Framework Directive
- EU Urban Waste Water Treatment Directive
- EU Nitrate Directive
- EU Habitats Directive
- EU Shellfish Hygiene Directives
- Response to environmental & climate change
- Forthcoming UK Marine Bill

Irish Sea Infraction under the UWWTD (Jan 2006): Data gathered by PEML and also by MECN co-members DARDNI, SAHFOS, School of Ocean Sciences, Bangor (SOS) & CEFAS, have been instrumental in allowing Defra to build a strong case against the forthcoming litigation for non-compliance with EC UWWTD, 1990 (Irish Sea Infraction under the UWWTD, Jan 2006).

Products

Data and publications: PEML time series data have been used to provide advice and produce various publications and some examples are given below.

Data from the PEML time series have been a major component for a recent major study on disturbance and eutrophication published as:

Anon (2004a). Understanding of undesirable disturbance in the context of eutrophication, and development of UK assessment methodology for coastal and marine waters: Stage 1 Report: what is undesirable disturbance? Prepared (March 2004) for the Department for Environment, Food and Rural

Affairs by: Napier University, Edinburgh; Centre for Environmental, Fisheries and Aquacultural Science, Lowestoft; Department of Agriculture and Rural Development, Belfast; Heriot-Watt University, Edinburgh; and Liverpool University, Port Erin Marine Laboratory, Isle of Man. Available from Defra.

Anon (2004b). Understanding of undesirable disturbance in the context of eutrophication, and development of UK assessment methodology for coastal and marine waters: Stage 2 Report: measuring undesirable disturbance. Prepared (July 2004) for the Department for Environment, Food and Rural Affairs by: Napier University, Edinburgh; Centre for Environmental, Fisheries and Aquacultural Science, Lowestoft; Department of Agriculture and Rural Development, Belfast; Heriot-Watt University, Edinburgh; and Liverpool University, Port Erin Marine Laboratory, Isle of Man. Available from Defra.

As part of its MECN activities data from the time series has been supplied to Defra as:

Scientific Report No. 02. 17th November, 2003. Long-term environmental studies in the Irish Sea: a review. Evans, G.L., Hardman-Mountford, N. J., Hartnoll, R. G., Kennington, K., Mitchelson-Jacob, E.G., Shammon, T. & Williams, P.J. le B. Defra Contract CDEP 84/5/311. Available from MECN.

Scientific Report No. 09**.** 30th April, 2005. IRISH SEA: Final report of Port Erin Marine Laboratory: Review of PEML long-term monitoring activities 2001-2004. Kev Kennington. Contract CDEP 84/5/311. Available from MECN.

A series of R&D technical reports, 'The distribution of nutrients and phytoplankton in the northern Irish Sea' have been provided to the Environment Agency:

Kennington, K., Shammon, T.M., Wither, A. Kraberg, A, Jones, P., Harrison, A. & Hartnoll, R.G. (2004). The distribution of nutrients and phytoplankton in the northern Irish Sea during 2002. Environment Agency Technical Report. E –1049/TR6

Kennington, K., Shammon, T.M., Wither, A. Kraberg, A, Jones, P., Harrison, A. & Hartnoll, R.G. (2005). The distribution of nutrients and phytoplankton in the northern Irish Sea during 2003. Environment Agency Technical Report. E –1049/TR7

Kennington, K., Wither, A., Shammon, T.M. Jones, P. Kraberg A.C. & R.G. Hartnoll. (2003). The distribution of phytoplankton and nutrients in the North East Irish Sea during 2001. Environment Agency of the U.K. R & D Technical Report E1-049/TR5. 23pp.

Shammon, T.M., & Hartnoll, R.G. (2002). Long Term Studies of the Irish Sea: Environmental monitoring and contamination. Summary of results for the years 2000 and 2001. Report to the Department of Local Government and the Environment, Isle of Man Government. (Port Erin Marine Laboratory).

Shammon, T.M. & R.G. Hartnoll. (2003). Long term studies of the Irish Sea: Environmental monitoring and contamination. Summary of results for years 2000 and 2001. Report to Department of Local Government and Environment, Isle of Man. No 9 & 10, 76 pp.

Shammon, T.M., Kennington, K. & Hartnoll, R.G. (2004). Long Term Studies of the Irish Sea: Environmental monitoring and contamination. Eleventh Report. Summary of results for the years 2002 and 2003. Report to the Department of Local Government and the Environment, Isle of Man Government. (Port Erin Marine Laboratory). 91 pp.

Shammon, T.M., Kennington, K. & Hartnoll, R.G. (2005). Long Term Studies of the Irish Sea: Environmental monitoring and contamination. Twelfth Report. Summary of results for the year 2004. Report to the Department of Local Government and the Environment, Isle of Man Government. (Port Erin Marine Laboratory). 68 pp.

Shammon, T.M., & Hartnoll, R.G. (in prep^{n}). Long Term Studies of the Irish Sea: Environmental monitoring and contamination. Thirteenth & Final Report. Summary of results for the year 2005 & January to March 2006. Report to the Department of Local Government and the Environment, Isle of Man Government. (Port Erin Marine Laboratory). 68 pp.

The time series data were also used to produce a Strategic Environmental Assessment for the Department of Trade and Industry:

Kennington, K. & Rowlands W.L. (2005). Strategic Environmental Assessment of SEA area 6 (Irish Sea). 1) Plankton. Report to the DTI.

Data from PEML long term time series data have also been included in the reports of other institutions including:

Alcock, G., & Rickards, L. (Eds). (2001). Climate of UK Waters at the Millennium: Status and Trends. Inter-Agency Committee on Marine Science and Technology (IACMST).

Inter-Agency Committee for Marine Science and Technology (2005), Marine Processes and Climate, Report 2 of 5 contributions to Charting Progress: an Integrated Assessment of the State of UK Seas, 132pp

The following is a selection of papers using PEML time series data that have been published since 1995:

Allen, J.R., Slinn, J., Shammon, T.M., Hartnoll, R.G., & Hawkins, S.J. (1998). Evidence for eutrophication of the Irish Sea over four decades. *Limnology and Oceanography*. 43(8):1970-1974.

Evans, G.L., Williams, P.J. le B and Mitchelson-Jacob, E.B. (2003) Physical and anthrogenic effects on long-term nutrient changes in the Irish Sea. *Estuarine and Coastal Shelf Science.* 57:1159-1168

Gowan, R.J., Hydes, D.J., Mills, D.K., Stewart, B.M., Brown, J., Gibson, C. E., Shammon, T.M., Allen, M., & Malcolm, S.J. (2002) Assessing trends in nutrient concentrations in coastal shelf seas: a case study in the Irish Sea. *Estuarine and Coastal Shelf Science.* 54:927-939.

Hartnoll, R.G., (2000) The Irish Sea. In Sheppard, C.R.C. (ed.), Seas At the Millennium: an Environmental Evaluation. Volume 1. Regional Chapters: Europe, the Americas and West Africa. Pergamon, Amsterdam. Pp 83 – 98.

Hartnoll, R.G., Kennington, K., & Shammon, T.M. (2001) Eutrophication of the Irish Sea - a threat to biodiversity? In Nunn, J.D. (editor) Marine biodiversity in Ireland and adjacent waters. *Proceedings of a conference 26 -27 April 2001*. MAGNI Ulster Museum. pp 121 – 131

Hydes, D.J., Gowen, R.J., Holliday, N.P., Shammon, T.M. & Mills, D. (2004) External and internal control of winter concentrations (N, P, Si) in north-west European shelf seas. *Estuarine and Coastal Shelf Science.* 59:151-161.

Kennington, K., Allen, J.R., Wither, A., Shammon, T.M., & Hartnoll, R.G. (1999). Phytoplankton and nutrient dynamics in the north-east Irish Sea. *Hydrobiologia.* 393:57-67.

Kennington, K., Wither, A., Shammon, T.M., Jones, P., & Hartnoll, R.G. (2002). Nutrient inputs into the Irish Sea: Temporal and spatial perspectives. *Hydrobiologia*. 475/476:29-38.

Laane, R.W.P.M., Southward, A.J., Slinn, D.J., Allen, J., Groenvald, G., & de Vries, A. (1996). Changes and causes of variability in salinity and dissolved inorganic phosphate in the Irish Sea, English Channel and Dutch Coastal Zones. *ICES Journal of Marine Science*. 53:933-944.

Montagnes, D.J.S., Poulton, A.J., & Shammon, T.M. (1999). Mesoscale, finescale and microscale distribution of micro- and nanoplankton in the Irish Sea with emphasis on ciliates and their prey. *Marine Biology*. 134:167-179.

Slinn, D.J., Allen, J.R., Jones, E.G., Shammon, T.M., & Hawkins, S.J. (1995). What is Eutrophication? In The Irish Sea, Eutrophication, Seminar Report 10, The Irish Sea Forum, University of Liverpool.

Shammon, T.M., & Hartnoll, R.G. (2002) The winter and summer partitioning of dissolved nitrogen and phosphorus. Observations across the Irish Sea during 1997 and 1998. *Hydrobiologia*. 475/476:173-184.

Science and Society: Contributions to science and the wider society have been made in a variety of ways:

- Participation in QUASIMEME Laboratory Performance Studies and developmental workshops
- Lectures and talks to the general public, schools and fisherman
- Presence and demonstrations at local 'Marine Days'
- Interviews for local press and radio
- Participation in the Irish Sea Forum
- Periodic local response and public reassurance regarding, for example, local pollution events, nuisance algal blooms and mass mortalities of organisms
- Attendance and presentations at relevant international conferences

2.3 Bangor Menai Straits time series (University of Wales, Bangor)

K. Ellis, G. Mitchelson-Jacob, G. L. Evans, P. J. le B. Williams

Details

Menai Straits Database (MSD): This database contains 35 years of data collected in the Menai Straits, between NW Wales and Anglesey. Over 100 parameters are included in the database including physical (salinity, turbidity), inorganic (nitrate, phosphate), and organic (chlorophyll-a, P*haeocystis pouchetii*) measurements.

Full details of this project can be found at http://www.sos.bangor.ac.uk/research/msd/index.htm.

Origin of time series including original objectives

The MSD has incorporated data from a range of student projects (MSc and PhD) subject to a rigid quality audit. There is also a system for ensuring that the same methods are used between projects so a consistency in measuring parameters is achieved. The data has allowed a time series / long-term dataset to be developed on an ad-hoc basis particularly as regards those parameters which are measured routinely as part of many research projects (e.g. temperature, salinity, chlorophyll). Data is also taken from stations sampled regularly by the Environment Agency. There is therefore, a range of parameters sampled at a range of frequencies (from weekly to sporadic).

Current Objectives

The School of Ocean Science website states that the aim of the Menai Strait database is to:

"*concentrate data, both historical and current, preventing the loss of valuable information and creating time series for a variety of parameters in a unique marine environment. The hope is that more measurements are made and will be included, enabling some insight into the possible long-term changes in the Menai Strait".*

Much of the regular sampling, however, is currently in abeyance due to funding ending in 2003. A small amount of weekly sampling (unfunded) occurs in order to maintain the time series. A CTD linked to the website is also in place but with limited funding.

Policy relevance

Comparison with data from Cypris Station on the Isle of Man has shown that the time series / long-term datasets are representative of conditions in the Irish Sea. Work on monitoring and turbidity is directly relevant to the Water Framework Directive. Analysis of temperature data (see products below) and turbidity and phytoplankton monitoring is also revealing effects of climate change in the Irish Sea and other UK waters.

Products

The database is freely available on the University of Wales, Bangor website http://www.sos.bangor.ac.uk/research/msd/index.htm. Up to now the database has been using published work as sources for data. Large-scale analysis is now underway, however and there are a number of publications based on the long-term information.

There has also been recent investigations comparing the Menai Straits temperature data with data from the North Sea and English Channel. This work has shown temperature rise as a combination of effects:

- a progressive rise in Temperature over 35 years
    - 2 °C in spring and summer
    - 1 °C in winter and no change in autumn

- seasonal variations in Temperature (not constant in the year)
    - Spring comes 2-3 weeks earlier
    - Autumn timing shows no change

- greater rates of change in
    - April-May and August for all 3 areas, with change starting earlier (March) for the English Channel

2.4 Bangor Ferry box Project (University College of Wales, Bangor)

G. Mitchelson-Jacob, D. Doxaran, C. Binding, D. Bowers, & K. Ellis

Details

Ferrybox Project: The ferrybox samples a Dublin to Holyhead transect (ship route). Two transects are taken per day with 35 measurements per transect. A number or parameters are measured including *in situ* Suspended Particulate Matter (SPM), chlorophyll and colored dissolved organic matter (CDOM), radiometer derived SPM, chlorophyll and remote sensing reflectance.

Origin of time series including original objectives

The Ferrybox project was started in 2004 with the following main aims:

- to calibrate measurements from TriOS radiometers against water quality parameters (algal blooms, sediment loading, water clarity)
- to install & commission the optical instruments on the Dublin to Holyhead ferry (the Ulysses – Irish Sea)
- to acquire a long time series of water quality measurements
- to ascertain the feasibility of using these methods for long-term water quality monitoring in the Irish Sea

Current Objectives

In addition to the above aims, a small amount of funding is being sought to enable the ferrybox measurements to be linked to a web portal. The data download could be automated to download daily rather than weekly and be available on the website the following day.

Policy relevance

The use of the data to assess water quality in the Irish Sea is directly relevant to the Water Framework Directive.

Products

As this project has only recently started, outputs in the form of journal publications, reports etc are being prepared or are in press. Some analysis of the data has already been carried out, however, on monthly variations in turbidity. The initial outputs from the project are:

- Instrument setup completed and working well giving a year long continuous dataset with twice daily transects across the Irish Sea

- Scope, as the dataset continues to grow, for developing and refining the data processing techniques for deriving ocean colour algorithms and extracting water quality parameters from the above-water signal (suspended matter & chlorophyll)

- Potential for a long term, detailed investigation into other environmental / physical parameters (wind fetch / duration, sea surface temperature and tidal currents) in the Irish Sea study area

- Interest from the Environmental Protection Agency and the Environment Agency (U.K.) for autonomous water quality monitoring in the Irish Sea

- The possibility of incorporating the ferrybox on other ferries e.g. associated with the Coastal Observatory in the Eastern Irish Sea

2.5 Ellett Line and Tiree Passage Moorings (SAMS)

C. Griffiths & M. Inall

a) b)

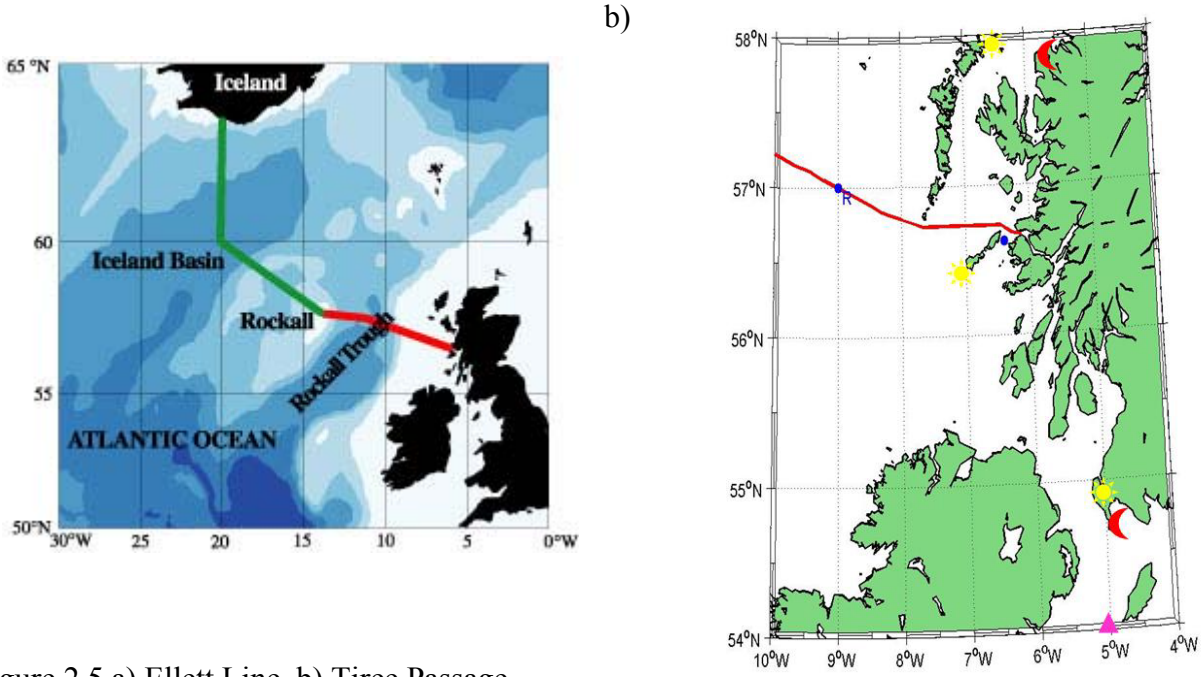


Figure 2.5 a) Ellett Line, b) Tiree Passage

Details

The Scottish Association for Marine Science (SAMS – formerly the Scottish Marine Biological Association, SMBA) maintains the following time-series:

Ellett Line: The Ellett Line has been occupied 75 times since 1975. It was maintained by the Scottish Marine Biological Association until 1996 at which point the Southampton Oceanography Centre (now the National Oceanography Centre, Southampton (NOCS)) took over and the line was extended to run to Iceland (figure 2.5a) to form the 'Extended Ellett Line'. From 1998 to present, the time series has been maintained as a joint operation between SAMS and NOCS. There were gaps in sampling in 1986 and 2002.

The main data being collected is physical (CTD). A very detailed overview of the Extended Ellett Line along with the latest results from the time series can be found at:
http://www.noc.soton.ac.uk/GDD/hydro/nph/ellett/index.php.

Tiree Passage: A mooring has been maintained in the Tiree Passage since 1981 at 56° 37.409 N 6° 24.013 W. At this mooring, in 48m of water, various physical parameters (including temperature, currents, salinity) are measured from near surface and near bottom. In 2005, real-time telemetry of temperature and salinity data was added, connected directly to an unrestricted access graphical web portal. Further details can be found at: http://www.sams.ac.uk/research/marine%20physics/tiree.htm

Origin of time series including original objectives

The Ellett Line was originally proposed in response to the success of the Marine Laboratory in Aberdeen in maintaining the Faeroe-Shetland Channel and the recognition that up to the 1960s, the deep water of Western Scotland was poorly known. The time series was, therefore, proposed to provide basic oceanographic information from an area for which little information was available. The line is named after D. J. Ellett who proposed that sampling be undertaken regularly from the SMBA (now SAMS). Full details of the origin of the Ellett Line can be found in Alcock and Rickards[33].

The Tiree Passage mooring was instituted originally as a conventional mechanical current meter to provide information on currents in an area for which no information was previously available. The Tiree Passage is now the longest time series of flow and temperature on the NW European continental shelf.

Current Objectives

The Ellett Line and Tiree Passage are in the perfect position to answer questions regarding the shelf and coastal waters to the west of the UK and how they are impacted upon by the Atlantic Ocean. Specific questions include:

- What drives the coastal flow?
- How frequent are Atlantic water intrusions?
- Do NAO signals appear on the shelf?

Policy relevance

Analysis of data from the Ellett Line and Tiree Passage is providing crucial insights into climate effects as the warm water flowing through the Rockall Trough moderates the climate of the UK and NW Atlantic region. The time series are likely to be key sources of data needed by the MCCIP.

The data has also been also compared with data collected by PEML (see Section 2.2) to provide a greater understanding of shelf response to climatic change and oceanic exchange. Understanding the relative influence of Irish Sea waters versus NE Atlantic water is essential in order to be able to discriminate natural changes in coastal productivity from enrichment and eutrophication arising from increased urbanization and aquaculture development in coastal regions[34]. This has relevance to EU directives such as the WFD.

Products

All data is archived with the British Oceanographic Data Centre and live data is available via a web interface (http://www.noc.soton.ac.uk/GDD/hydro/nph/ellett/index.php).

[33] Alcock, G. & Rickards, L. (2001) Climate of UK Waters at the Millenium: Status and Trends. IACMST Information Document No. 9.
[34] See Reference Footnote (2)

The data has been discussed at various conferences including:

Griffiths, C. R., Inall, M. E. and Ribeiro, C. Intrusions of Slope Current Water onto the NW European Shelf. Oral presentation, European Geophysical Society, April 2003, Nice.

The data was used as a key information source for:

Alcock, G. & Rickards, L. (2001) Climate of UK Waters at the Millenium: Status and Trends. IACMST Information Document No. 9.

A number of papers have been produced using the Ellett Line data.

2.6 Continuous Plankton Recorder Survey (SAHFOS)

D. Johns

Details

The Continuous Plankton Recorder (CPR) survey operated by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) is one of the best known long-term datasets, being the longest and spatially extensive marine survey in the world. Between 1946 and 2003 over 5 million miles of ocean were sampled with over 200000 samples being collected. Areas covered include the North Atlantic, North west Atlantic, Mediterranean, Gulf of Guinea, South Atlantic, Baltic and Pacific. Measurements are made of Phytoplankton Colour, Phytoplankton and Zooplankton.

Full details of the CPR survey can be viewed at the website: http://www.sahfos.ac.uk/index.htm. The history and methodology of the CPR is also discussed in detail in a special issue of Progress in Oceanography[35].

Origin of time series including original objectives

The original objectives and the evolving aims of the CPR are discussed in Reid et al[35] from which the following information is taken. The original CPR objectives are described as follows:

"*Alister Hardy conceived the Continuous Plankton Recorder (CPR) survey in the 1920s as a means of mapping near-surface plankton in space and time, interpreting the changing fortunes of the fisheries and relating plankton changes to hydrometereology and climatic change*."

The herring fishery in the 1920's was a major fishery and Hardy's main aim was really to improve the efficiency of the fishery. Much of the period up to the war was then spent refining techniques and methods, Hardy's 'Pioneer Period'. Since the war (i.e. 1946 onwards) there was an increasing emphasis on indicator species and patterns of distribution (biogeographical patterns) coupled with an expansion of coverage and the introduction of new techniques such as computerisation. NERC's decision to close the survey in 1988 led to an international rescue operation that led to the creation of SAHFOS.

Current Objectives

Current research themes include:

- Climate change (biogeographical changes, seasonality & phenological changes)
- Eutrophication
- Monitoring of non-indigenous and toxic species
- Fisheries

[35] Reid, P.C., Colebrook, J.M., Matthews, J.B.L., Aiken, J. & The Continuous Plankton Recorder Survey Team. (2003). The Continuous Plankton Recorder: concepts and history, from Plankton Indicators to undulating recorders. *Progress in Oceanography (Special Issue)*. 58 (2-4): 117-173

- North Atlantic Oscillation
- Plankton Ecology

Recent additions to the sampling include monitoring for eight new species of potentially toxic *Dinophysis.* Marine pollution issues are also being addressed with the amount of plastic found in samples being monitored as a contribution to a larger study[36].

In light of the large range of issues being addressed by the CPR, a key objective is to continue to ensure consistency of methodology which has been crucial in allowing issues of long-term change to be addressed. Archive samples are also retained allowing other issues to be addressed in the future as the need arises.

Policy relevance

The CPR dataset has a long history of being applied to management and policy issues and, as already stated, was used to inform fisheries management from an early stage. Fisheries issues continue to be informed, particularly in the light of the adoption of the ecosystem-based approach to marine management. In particular, the difficult issue of the influence of climate on fisheries has being addressed through numerous studies. For example, the data has been used to look at how climate affects pelagic ecosystems as regards the plankton[37] and also how changes in plankton can then affect fish populations (e.g. North Sea Cod[25]). Other work relevant to fisheries includes that looking at climate change and trophic mismatch[38].

As well as the work relevant to fisheries management, other issues regarding the impact of climate change on the marine environment have been addressed. The implications of climate change for the marine environment at regional sea scales, for example, have been documented in the work undertaken by SAHFOS staff who identified a 'regime shift' that occurred in the North Sea plankton community in the 1980s[39]. The vast amount of work and experience SAHFOS has in climate research led to the organisation being asked by Defra to take the first step in launching the Marine Climate Impacts Change Partnership (MCCIP, now hosted by CEFAS).

Data from the CPR has also been used to develop an ecosystem-based approach to monitoring in the marine environment[40, 41] and look at the issue of ecosystem modelling which is crucial to enable policy

[36] Thompson, R. C., Y. Olsen, R. P. Mitchell, A. Davis, S. J. Rowland, A. W. G. John, D. McGonigle and A. E. Russell (2004). Lost at sea: where is all the plastic? *Science.* 304 (5672): 838.
[37] E.g. Richardson, A. J. and D. S. Schoeman (2004). Climate impact on plankton ecosystems in the Northeast Atlantic. *Science* 305(5690): 1609-1612.
[38] E.g. Edwards, M. and A. J. Richardson (2004). Impact of climate change on marine pelagic phenology and trophic mismatch. *Nature.* 430 (7002): 881-884.
[39] E.g. Beaugrand, G., P. C. Reid, F. Ibanez, J. A. Lindley and M. Edwards (2002). Reorganization of North Atlantic marine copepod biodiversity and climate. *Science*. 296 (5573): 1692-1694.
[40] Beaugrand, G. (2004). Monitoring marine plankton ecosystems. 1: Description of an ecosystem approach based on plankton indicators. *Marine ecology progress series*. 269: 69-81
[41] Beaugrand, G. (2005). Monitoring pelagic ecosystems using plankton indicators. *ICES Journal of Marine Science.* 62 (3): 333-338.

makers to make decisions based on accurate models[42]. Other areas of research that have policy relevance include studies on eutrophication[43] (relevant to WFD) and biodiversity. There are currently trials being held to see if CPRs can be used in shallow waters to measure plankton variability in shallow waters for the EU WFD and EC Habitats Directive, which if successful could be developed throughout Europe for coastal WFD monitoring[9].

Products

In terms of scientific output, there are over 900 papers from the CPR survey work. Lists of all publications can be found at www.sahfos.org/publications.

A vast amount of scientific information is also available to researchers and the public including monthly means for standard areas for some taxa via the website. Raw data is available for use by visiting researchers and data requests can be registered to SAHFOS (over 100 current registered users not including WinCPR requests). As part of its work developing the MCCIP, SAHFOS has also developed a Marine Climate Change Encyclopaedia available as a CD-ROM or online at (http://www.sahfos.org/climate encyclopaedia/index2.html).

Services provided include report preparation and data manipulation for commercial groups, WinCPR and broad-knowledge based advice. SAHFOS is also engaged in numerous public outreach activities.

[42] E.g. De Young, B., M. R. Heath, F. Werner, F. Chai, B. Megrey and P. Monfay (2004). Challenges of modelling of ocean basin ecosystems. *Science*. 304: 1463-1466.
[43] Edwards et al. (2006 - In Press).

2.7 L4 and E1/L5 time series (PML, MBA)

R. Harris, D. Bonnet & I. Joint

Details

L4: This sampling station is situated c.10 nautical miles southwest of Plymouth in approximately 55m of water at 50º15'N 04º13'W. Sampling started here in 1988 and has been carried out on a weekly basis. Parameters measured include; zooplankton species abundance (vertical haul from 50m to surface); meso-zooplankton; copepod egg production; phytoplankton species and biomass (10m depth); chlorophyll; particulate carbon and nitrogen; and temperature and salinity (CTD to 50m). Measurements of optics and of pigments by High Pressure Liquid Chromatography (HPLC) were added in 2000 and funding from the MECN allowed a selection of nutrients to be added in 2002. There is also additional temperature and chlorophyll information available for the area from satellite data.

Full details of the sampling regime and a comprehensive list of all parameters measured at L4 can be found on the website www.pml.ac.uk/L4.

E1/L5: ICES station E1 is situated c.22 nautical miles SW of Plymouth at 50° 02.0'N 04° 22.0'W in approximately 72 m of water. It has been sampled since 1903 but with gaps occurring in the time series (most notably between 1987 and 2001). Sampling is carried out on a monthly basis with temperature and salinity profiles being taken along with phytoplankton, nutrients and optical properties. However, not all of these parameters have been measured over the whole period that the time series has been maintained. Station L5 is situated c.two nautical miles west of Eddystone Reef at 50° 10.9'N 04° 18.0'W and monthly sampling occurs here of zooplankton and macro-zooplankton (young fish larvae).

Origin of time series including original objectives

Sampling originally started at E1 and L5 over 100 years ago when the MBA undertook the English share of the work carried out for the International Council for the Exploration of the Seas (ICES)[44]. Sampling was continued at E1 and L5 due to the early interest shown by scientists such as Allen[45] in establishing time series in order to observe 'natural fluctuations' in the marine environment. The time series were continued (with some gaps) until 1987 when NERC's reassessment of its funding priorities led to the withdrawal of funding for many long-term observations including those at E1/L5.

L4 was started after sampling at E1 and L5 was terminated in 1987. This time series developed initially out of a number of research projects and components of international programmes such as Land-Ocean Interaction Study (LOIS) and Global Ocean Ecosystem Dynamics (GLOBEC).

Full details regarding the origin and history of all long-term observations in the Western English Channel can be found in Southward et al[44] from which this information was taken.

[44] Southward et al, (2005). Long-Term Oceanographic and Ecological Research in the Western English Channel. *Advances in Marine Biology*. 471:1-105.
[45] Allen, E. J. (1922) The Progression of life in the sea. *Nature*. 110: 448-453.

Current Objectives

The time series at E1 and L5 were restarted in 2002 as part of the MECN programme. Additional parameters were added to L4 (see above). Continued funding for the time series is being sought via NERC's Oceans 2025 strategy as the time series are integral elements of the proposed Western Channel Observatory. The time series represent key sustained observations that can provide underpinning capability for UK science. A number of research questions are currently being addressed.

Zooplankton: Zooplankton data at L4 is being used by itself and also in conjunction with the young-fish trawls at L5 and CPR data to address issues regarding:

- The effects of climate on the pelagic system[46]
- Investigation into seasonal cycles of copepod abundance: comparing CPR with L4[47]
- Methodological comparisons: Nets comparison of L4 (WP-2) with historical MBA series (YFT)
- Ecology of zooplankton (contribution to ICES working group 2003, 2004)
- Monitoring zooplankton (contribution to ICES report)[48]
- Climate and the autecology of *Calanus helgolandicus* [49]
- Long term changes in *Calanus helgolandicus* adult abundance at fixed stations[49]
- Population dynamics, egg production, mortality
- Other uses of the data include research into population genetics; investigations of dietary acquisition of photoprotective compounds in marine zooplankton (direct and indirect responses to UV); the SARDYN project (Sardine egg seasonality).

Historical data from E1 and L5 have been used for numerous research projects over the years. The restart data from 2002 is now being used in conjunction with data from L4 and historical data to investigate:

- Long-term changes in the nitrate to phosphate ratio (Redfield Ratio)
- Long-term variation in seasonal nutrient concentrations
- The use of phytoplankton pigments as 'markers' to detect diatom blooms.

Policy relevance

The data from L4 is relevant to the EU Water Framework Directive and has also been used for the Integrated Regional Assessment (Region 4: Western English Channel, Celtic Seas and South West Approaches).[50]

[46] Irigoien, X., Harris, R.P., Head, R.N. and Harbour, D. (2000). North Atlantic Oscillation and spring bloom phytoplankton composition in the English Channel. *Journal of Plankton Research*. 22: 2367-2371

[47] John, E.H., Batten, S.D., Harris, R.P. and Hays, G.C. (2001).Comparison between zooplankton data collected by the Continuous Plankton Recorder survey in the English Channel and by WP-2 nets at station L4, Plymouth (UK*). Journal of Sea Research*. 46, 223-232

[48] ICES CRR No 276: Zooplankton monitoring results in the ICES area, Summary Status Report

[49] Bonnet, D. et al (2005). An overview of *Calanus helgolandicus* ecology in European waters*. Progress in Oceanography* 65:1–53

[50]Integrated Regional Assessments (IRA). Portmann, J. E. (2005), Integrated Regional Assessment, Report 5 of 5 contributions to Charting Progress: an Integrated Assessment of the State of UK Seas, 175pp

Phytoplankton data from E1 has been supplied to the Environment Agency for work being carried out under the EU Water Framework Directive.

Products

Data: All the data from L4 is available on the L4 website at www.pml.ac.uk/L4.
All historical data from E1 and L5 has been archived onto a modern database format and can be requested from the MECN coordinator (mecn@mba.ac.uk).

Publications:

There have been a large number of publications utilising the data from L4 and only a small selection is shown below; the full list can be found on the L4 website publications page. There is a long history of publications using the historical data from E1 and L5 and these can be found in the reference list of Southward et al[44]. A small selection of more recent publications using E1 and L5 data is shown.

Delphine Bonnet, Anthony Richardson, Roger Harris, Andrew Hirst, Gregory Beaugrand, Martin Edwards, Sara Ceballos, Rabea Diekman, Angel Lo´pez-Urrutia, Luis Valdes, Francois Carlotti, Juan Carlos Molinero, Horst Weikert, Wulf Greve, Davor Lucic, Aitor Albaina, Nejib Daly Yahia, Serena Fonda Umani, Ana Miranda, Antonina dos Santos, Kathryn Cook, Susan Robinson, Marie Luz Fernandez de Puelles. (2005). An overview of *Calanus helgolandicus* ecology in European waters. *Progress in Oceanography.* 65:1–53

Coombs, S.H., Halliday, N.C., Southward, A.J. & Hawkins, S.J. (2005). Distribution and abundance of sardine (*Sardina pilchardus*) eggs in the English Channel from Continuous Plankton Recorder sampling, 1958-1980. *Journal of the Marine Biological Association of the United Kingdom*. 85: 1243-1247.

Hawkins, S. J., Southward, A. J. & Genner, M. J. (2003). Detection of environmental change in a marine ecosystem – evidence from the western English Channel. *Science of the Total Environment*. 310: 245-256.

ICES CRR No 276: Zooplankton monitoring results in the ICES area, Summary Status Report

Irigoien, X., Harris, R.P., Head, R.N. and Harbour, D. (2000). North Atlantic Oscillation and spring bloom phytoplankton composition in the English Channel. *Journal of Plankton Research*. 22: 2367-2371

John, E.H., Batten, S.D., Harris, R.P. and Hays, G.C. (2001).Comparison between zooplankton data collected by the Continuous Plankton Recorder survey in the English Channel and by WP-2 nets at station L4, Plymouth (UK). *Journal of Sea Research*. 46: 223-232

Southward, A. J., Langmead, O., Hardman-Mountford, N. J., Aiken, J., Boalch, G. T., Dando, P. R., Genner, M. J., Joint, I., Kendall, M. A., Halliday, N. C., Harris, R. P., Leaper, R., Mieskowska, N., Pingree, R. D., Richardson, A. J., Sims, D. W., Smith, T., Walne, A. W., Hawkins, S. J. (2005). Long-Term Oceanographic and Ecological Research in the Western English Channel. *Advances in Marine Biology*. 471:1-105

Science and Society: There have been numerous PhD and student projects based on the data from L4 as well as numerous scientific collaborations. The web-site provides open access for researchers, end-users and the public to all data and information on the L4 time series.

2.8 Long-term sampling of fish in the Western English Channel (MBA)

D. W. Sims, M. T. Frost, G. Budd, M. Genner, R. Jefferson & A. J. Southward & S. J. Hawkins

Details

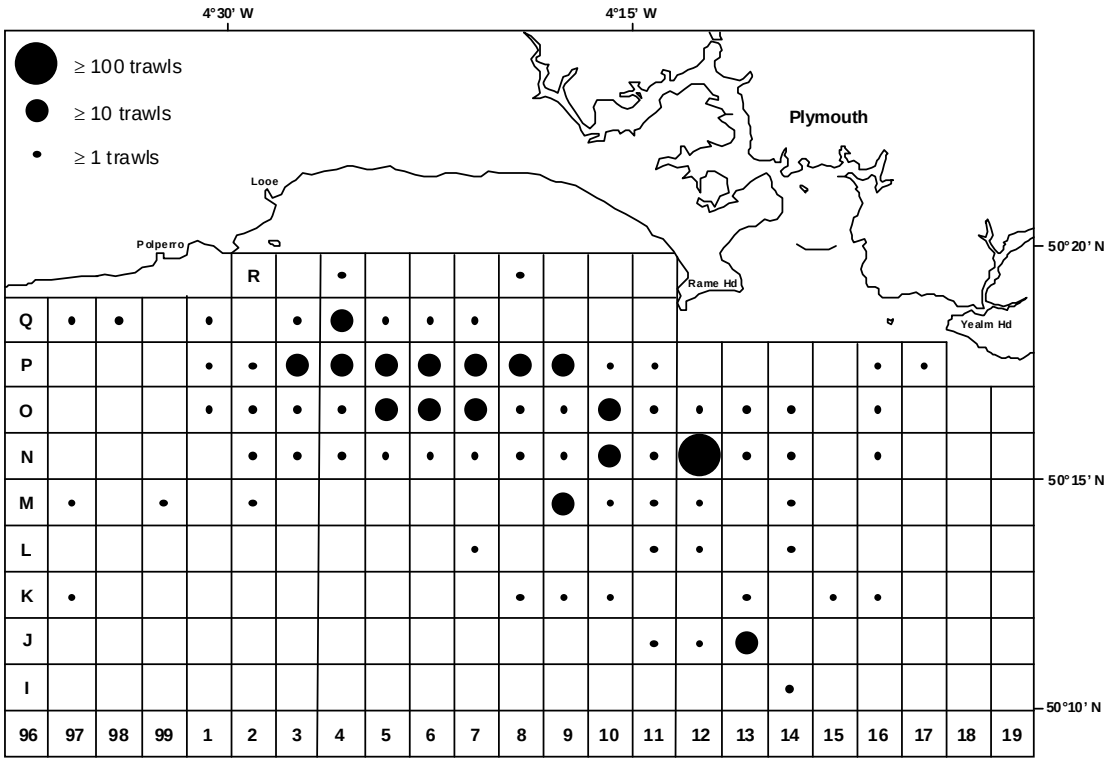


Figure 2.8. Location of demersal fish samples. N12=ICES Station L4 (Source: Southward et al, 2005[44])

Demersal fish assemblages off Plymouth have been sampled over a number of periods: 1913-1914 and 1919-1922 (cold), 1950-1958 (warm), 1967-1979 (cold), 1983-1986 (cold), and 2001 ongoing (warm) and this intermittent sampling now constitutes a long-term dataset spanning nearly 100 years. 92 species have so far been recorded with 820 otter trawls taken at 30-50m depth. Samples have been taken at 130 'fishing marks' with the majority concentrated around ICES station L4 (figure 2.8).

Between 1976 and 2005, an intermittent sampling programme has been underway in the form of the 'Standard Haul' time series which has now been turned into a regular time series (ship time permitting since 2001). There is also a standardised dataset available of 1550 trawls that were undertaken between 1953 and1972 as part of the 'Sarsia' high resolution time series.

Origin of time series including original objectives

The surveys were originally carried out as part of the Marine Biological Associations investigations into the fisheries of the SW English Channel. These early surveys carried out in 1913-14 and 1921-22 provided baselines for subsequent re-surveys giving intermittent series of observations.

Current Objectives

The regular demersal fish sampling (Standard Haul time series) is continuing at L4 with funding being sought for its continuance. The long history of sampling off Plymouth makes the region ideal for the basis of a long term time series to separate fishing impacts from climate change and also inform bioresource management. It also enables linkages with the pelagic data collected at L4 to give a comprehensive picture of the ecosystem as a whole.

Scientific questions currently being addressed using the long-term fish data include:

- How does the interaction between fishing impacts and climate change shape demersal fish assemblages?[29]
- Do long-term trends in demersal fish assemblages provide evidence of restructuring trophic interactions in conjunction with benthic observations?[51, 52]
- Is phenology of species such as flounder and squid linked being driven by trends in sea temperature?[53, 54]

Policy relevance

As most available fisheries data are from commercial operations, whole assemblage time series such as the L4 Standard Hauls (with covered cod end) are rare and useful in both revealing long-term patterns in fish communities and allowing the relative effects of anthropogenic activities and natural variation to be assessed[52]. The demersal fish time series is relevant to a number of directives, treaties and conventions including: the Reformed Common Fisheries Policy (CFP); the EC Habitats Directive; the European Marine Strategy; OSPAR; CBD (implemented nationally by Biodiversity Action Plan (BAP)), the Bern convention (implemented in UK law by the Wildlife and Countryside Act (1981)) and the UK Marine Bill (stewardship including Marine Protected Areas (MPAs) and offshore Special Areas of Conservation (SACs)).

[51] Southward, A. J. (1980). The Western English Channel. An inconstant Ecosystem? *Nature*. 285:361-366;
[52] Araujo, J.N., Mackinson, S., Stanford, R.J., Sims, D.W., Southward, A.J., Hawkins, S.J., Ellis, J.R., Hart, P.J.B. (2006) Analysing the effects of food web interactions, climate change and fisheries on the western English Channel ecosystem. *Marine Ecology Progress Series.* 309: 175-187
[53]Sims, D.W., Genner, M.J., Southward, A.J., Hawkins, S.J. (2001) Timing of squid migration reflects North Atlantic climate variability. *Proceedings of the Royal Society of London B* 268: 2607-2611
[54] Sims, D.W., Wearmouth, V.J., Genner, M.J., Southward, A.J. & Hawkins, S.J. (2004). Low-temperature-driven early spawning migration of a temperate marine fish. *Journal of Animal Ecology.* 73: 333-341

Understanding fish-benthos interactions is essential for implementing the ecosystem approach to marine stewardship and sustainable bio-resource management.

Products

Data: All data on species composition and size structure per standard fishing unit from 1913 to present (with some gaps) is held at the MBA and available for use to researchers[52].

Example Publications:

Araujo, J.N., Mackinson, S., Stanford, R.J., Sims, D.W., Southward, A.J., Hawkins, S.J., Ellis, J.R., Hart, P.J.B. (2006) Analysing the effects of food web interactions, climate change and fisheries on the western English Channel ecosystem. *Marine Ecology Progress Series.* 309: 175-187

Genner, M. J., Sims, D. W., Wearmouth, V. J., Southall, E. J., Southward, A. J., Henderson, P. A.& Hawkins, S. J. (2004). Regional climatic warming drives long-term community changes of British Marine Fish. *Proceedings of the Royal Society of London, B*. 271:655-661.

Hawkins, S. J., Southward, A. J. & Genner, M. J. (2003). Detection of environmental change in a marine ecosystem – evidence from the western English Channel. *Science of the Total Environment*. 310: 245-256.

Sims, D.W., Genner, M.J., Southward, A.J., Hawkins, S.J. (2001). Timing of squid migration reflects North Atlantic climate variability. *Proceedings of the Royal Society B*. 268:2607-2611.

Sims, D. W., Wearmouth, V. J., Genner, M. J., Southward, A. J. & Hawkins, S. J. (2004). Low-temperature-driven early spawning migration of a temperate marine fish. *Journal of Animal Ecology*. 73: 333-341.

Southward, A. J., Langmead, O., Hardman-Mountford, N. J., Aiken, J., Boalch, G. T., Dando, P. R., Genner, M. J., Joint, I., Kendall, M. A., Halliday, N. C., Harris, R. P., Leaper, R., Mieskowska, N., Pingree, R. D., Richardson, A. J., Sims, D. W., Smith, T., Walne, A. W., Hawkins, S. J. (2005). Long-Term Oceanographic and Ecological Research in the Western English Channel. *Advances in Marine Biology*. 47: 1-105

Science and society: Fish represent one of the best known components of marine ecosystems. Scientific studies on fish populations and communities can have social, economic and political implications and are, therefore, of great interest to wider society.

2.9 Long-term sampling of benthos in the Western English Channel (MBA)

S. Jenkins, M. T. Frost, H. Hinz, K. Hiscock, M. Kendall, H. Vaughan & S. J. Hawkins

Details

Benthic samples have been taken at various locations throughout the English Channel since 1895 as part of numerous MBA research projects (table 2.9). Benthic data exists for approximately 110 sites occurring just off Plymouth (within 40km of station L4) (figure 2.9) and for more than 700 sites as part of broad-scale surveys of the English Channel.

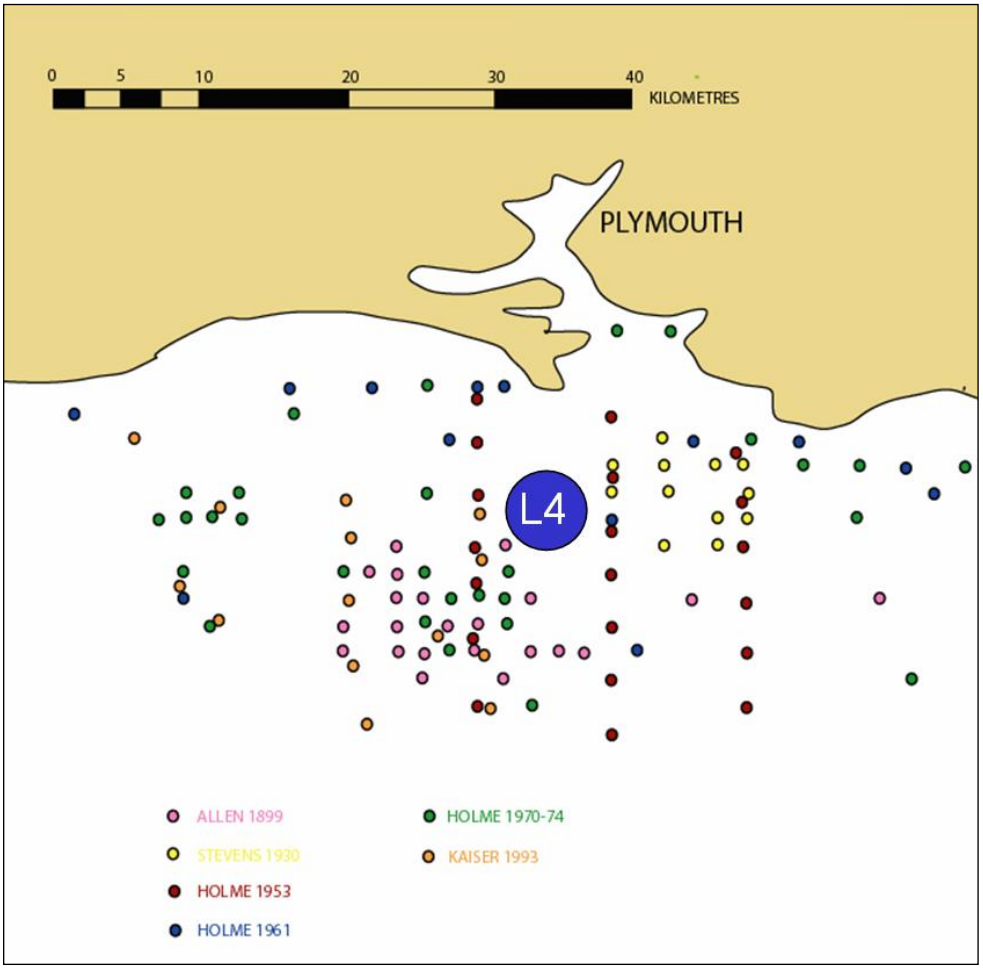


Figure 2.9. Historic benthic sampling sites off Plymouth

1895-1898	Eddystone grounds	Dredge; trawl	Allen, 1899
1906	Outside Eddystone	Dredge; trawl	Crawshay, 1912
1922-1923	Plymouth area	Grab	Ford, 1923
1928-1929	Inside Eddystone	Grab; trawl	Steven, 1930
1931	Eddystone gravels	Conical dredge	Smith, 1932
1939	Rame mud	Corer; grab	Mare, 1942
1949-1951	Plymouth area	Camera	Vevers, 1951, 1952
1950	Plymouth area	Grab	Holme, 1953
1958-1962	English Channel	Anchor dredge	Holme, 1961, 1966a
1970-1981	W English Channel	Dredge	Holme, 1984
1972-1982	Lizard-Start Point	TV sledge	Wilson *et al.*, 1977; Franklin *et al.*, 1980
1997-2002	Fowey-Eddystone	Scallop dredge; Anchor dredge	Kaiser et al., 1998 Kaiser and Spence, 2002

Table 2.9 Summary of benthic surveys taken at L4 and environs[55]

Origin of time series including original objectives

Although the aims of each survey differed, it was recognised by Holme[21] that many of these large-scale surveys provided the basis for long-term temporal comparisons:

"*The biomass figures ……. are intended to provide basic data for following changes in the bottom fauna in the future*"

Therefore, although the surveys were undertaken using a variety of methodologies for a wide range of purposes, a number of factors mean that a valuable long-term dataset can be collated and analysed to provide information on long-term change . These factors include accurate recording of methodologies, archive storage of samples and the retaining of all raw data both in database format and in original notebooks.

Current Objectives

A number of questions have recently or are currently being addressed using the long-term benthic data. These questions include:

- How constant are marine ecosystems?[51]
- Has the megabenthos of the English Channel altered over the last few decades (1950s to 1998) in response to increased disturbance[56]?
- How can we unravel effects of fishing on benthic communities from climate change impacts?[57]
- What seabed biotopes are represented where in the English Channel?[58]

[55] For original references see Footnote Reference (44)
[56] Kaiser, M. J. & Spence, F. E. (2002). Inconsistent temporal changes in the megabenthos of the English Channel. *Marine Biology.* 141:321-331.
[57] MF0727 (Defra/MAFF) (2001). Archiving and analysis of the MBA bottom trawl and benthic survey data: Unravelling fishing efforts from climate change (grant awarded to Hawkins, S. J. & Southward, A. J.)
[58] Hiscock, K. & Oakley, J. (2005). English Channel towed sledge seabed images. Phase 2: Analysis of selected tow images.

- Is long term change in benthic infaunal composition and biomass consistent with increased physical disturbance from demersal fishing[59]?

A grant has also been recently awarded to analyse long term trends in the distribution and abundance of benthic organisms in the English Channel in order to provide an environmental context for studying impacts of aggregate dredging[60].

Funding is currently being sought for regular benthic sampling at L4 in order to have a fully standardised long-term benthic dataset available. The wealth of historical data available for Plymouth makes the region ideal for such a long-term benthic programme. Also, physical measurements of the water column along with data on the pelagic ecosystem and fish trawls are also collected regularly at L4. Therefore, a benthic sampling programme would provide valuable information on interactions between benthic and pelagic systems.

Policy relevance

Recent assessments of the state of UK waters identified the lack of long-term offshore benthic data as a key 'gap' in UK monitoring[61]. The lack of 'context' in which to identify change in offshore benthos is a difficulty when carrying out assessments under various policy directives, conventions and treaties including the EC Habitats Directive (offshore SACs are in the process of being identified); European Marine Strategy; OSPAR; CBD (implemented nationally by BAPS) and the Bern convention (implemented in UK law by the Wildlife and Countryside Act (1981)).

Environmental Impact Assessments (EIAs) carried out to look at aggregate dredging are also hampered by the lack of information regarding long-term change in benthic communities and the impact of other factors including fisheries and climate change. This situation is being addressed via the retrieval and analysis of archived benthic data held at the MBA along with new sampling[61].

Understanding fish-benthos interactions is essential for implementing the ecosystem approach to marine stewardship and sustainable bio-resource management (see also Section 2.8)

Products

Data: Data from 1896 onwards is held in archives (new Data Archive Seabed Species and Habitats - DASSH) and disseminated via various publications. Species information for 673 sites sampled by Holmes (1961, 1966, 1984) throughout the English Channel are currently being made available to the wider scientific community through the National Biodiversity Network (NBN).

Publications: a number of publications have used the long-term benthic data held at the MBA to look at aspects of change, including:

[59] Jenkins, S. & Vaughan, H. (2006 – In Prep) Long term change in benthic infaunal composition and biomass consistent with increased physical disturbance from demersal fishing.
[60] MAL0022 Aggregate Levy Sustainability Fund. An environmental context to aggregate dredging (2005). (grant awarded to Jenkins, S. J. & Frost, M. T.).
[61] Marine Habitats and Species (MHS). Joint Nature Conservation Committee (2005), Marine Habitats and Species, Report 3 of 5 contributions to Charting Progress: an Integrated Assessment of the State of UK Seas, 188pp

Kaiser, M. J. & Spence, F. E. (2002). Inconsistent temporal changes in the megabenthos of the English Channel. *Marine Biology*. 141 (2):321-331.

Southward, A. J. (1980). The Western English Channel. An inconstant Ecosystem? *Nature*. 285:361-366.

Southward, A. J., Langmead, O., Hardman-Mountford, N. J., Aiken, J., Boalch, G. T., Dando, P. R., Genner, M. J., Joint, I., Kendall, M. A., Halliday, N. C., Harris, R. P., Leaper, R., Mieskowska, N., Pingree, R. D., Richardson, A. J., Sims, D. W., Smith, T., Walne, A. W., Hawkins, S. J. (2005). Long-Term Oceanographic and Ecological Research in the Western English Channel. *Advances in Marine Biology*. 47:1-105.

Science and Society: The UK has the widest variety of seabed habitats of any European state. The seabed and the species that colonise marine habitats provide important goods and services to society. The desire to have '*clean healthy, productive and diverse seas'*[4] can only be achieved if we understand how marine ecosystems are structured, how they function and how spatially changeable they are. The long term studies undertaken by the MBA are informing stewardship of our seas.

2.10 Rocky Shore datasets – Marine Biodiversity and Climate Change Project (Marclim)

M. T. Burrows, S. J. Hawkins, A. J. Southward, M. A. Kendall, R. C. Thompson & R. O'Riordan

Details

The Marine Biological Association of the United Kingdom has a large amount of data collected over many years from rocky shores in the Southwest and wider UK and some shores in Ireland and mainland Europe. The datasets are summarised in table 2.10.

Geographic distribution	**Original collector**	**Data archived**	**Data Range**
UK, France & Portugal	A.J. Southward D.J. Crisp S.J. Hawkins	(1) Quantitative barnacles, limpets & trochids; semi-quantitative broadscale surveys	1950-1987 1947-1967 1980-2001
UK, N. France	Rocky Shore Surveillance Group (J.R. Lewis et al)	(2) Trochids	1964-1987
Southern England	R. Herbert	(3) Quantitative barnacles & trochids; semi-quantitative broadscale surveys	1987-2001
Shetland	Shetland Oil Terminal Advisory Group	(4) Broadscale and transects	1978-2001
UK, Ireland & France	MarClim Project	(5) Quantitative Barnacles, limpets & trochids; semi-quantitative broadscale surveys	2001-2005

Table 2.10. Rocky Shore datasets utilised by the MarClim project.

Full details of all the rocky shore datasets can be found in the final report of the MarClim project[28].

Origin of time series including original objectives

(1) The original aims of the broad-scale surveys are described in the MarClim final report[28] as being:

- to ascertain, as precisely as possible in the field, the environmental requirements of the species chosen

- to relate the distribution of each species directly to the physical environment and by looking for a common basis in the various distributions find the major factors responsible

- to provide a reference against which any future changes in distribution might be shown.

(1 & 3) The quantitative surveys (barnacles and limpets) were started for similar reasons and their continued sampling was due to the fact that their potential importance for indicating climate effects was recognised at an early stage.

(2) The Trochid dataset (1970s-1980s) originated from detailed comparisons of their population structure and abundance carried out by the NERC Rocky Shore Surveillance Group.

(4) Further broad-scale surveys were started in the 1970s by Shetland Oil Terminal Advisory Group in response to concerns about pollution related to the growth of the oil industry. The surveys were undertaken because it was recognised that background variability had to be taken into account.

Current Objectives

(5) The main aim of the MarClim Project (2001-2005) is, 'Assessing and predicting the influence of climatic change using intertidal rocky shore biota and its implications for the conservation, management and protection of the marine environment in Britain and Ireland'. The specific objectives can be summarised as follows:

- To assemble, rescue, collate and archive existing data sets
- To do an extensive biogeographic re-survey of the distribution of intertidal species for comparison with past records
- Make projections in close collaboration with UKCIP, using their climate change scenarios, on species range shifts
- Interpret results within existing policies and frameworks to address the implications of responses to climate change to inform policies and provide a framework for the conservation, management, protection and utilization of marine biota.

The MarClim project has recently come to an end and a final report published[28]. MarClim is, however, continuing under the auspices of the MECN and funding is being sought to undertake the following:

- Continue analysis of the quantitative barnacle, limpet and trochid data and the semi-quantitative broadscale data.

- Annual broadscale survey at range edges.

- Extreme weather events (eg forecast cold winter 2005/06): Targeted surveys at species range edges to look for changes in range size and population structure.

- To secure funding to continue the intertidal long-term data series in order to put in place a monitoring network.

Policy relevance

The MarClim project has contributed significantly to UK many areas of UK marine environmental policy and a report has been published that summarises the key policy implications:

- "*The MarClim Project, key messages for decision makers and policy advisors, and recommendations for future administrative arrangements and management measures"* (Laffoley et al. 2005)[62].

The project has been instrumental in raising awareness of climate issues and has stimulated the creation of the Marine Climate Change Impact Partnership (MCCIP) which was formally launched by Elliot Morley in 2005.

MarClim has also provided general contextual time series data to support reporting on:

- Marine aspects of Biodiversity Action Plans, European structures including the Habitats, Birds and Water Framework Directives

- Management and monitoring of marine activities and resources, including fisheries and SACs, Sites of Special Scientific Interest (SSSIs), RAMSAR.

Products

The MarClim final report[28] contains a full list of all the outputs from the project but a summary of outputs including a selection of publications is given below:

Data: The project has led to the creation of the MarClim Data Archive that acts as a central repository for all historical and resurvey data records over a 60 year period. The data is all held in a standardised electronic format and original data records have undergone extensive quality assurance checks. The dataset will expand over time with repeat surveys and monitoring and all data has been made available via the National Biodiversity Network at www.searchnbn.net.

There is also an electronic MarClim database with data for 4400 site visits at over 1000 locations. This data can be requested by contacting the Marine Environmental Change Network (MECN) co-ordinator at www.mba.ac.uk/MECN.

Publications:

Refereed publications:

Burrows, M.T., Moore, J., & James, B. (2002). Spatial scale synchrony of population changes in rocky shore communities in Shetland: implications for monitoring. *Marine Ecology Progress Series.* 240: 39-48.

[62] Laffoley, D.d'A., Baxter, J., O'Sullivan, G., Greenaway, B., Colley, M., Naylor, L. and Hamer, J. (2005). The MarClim Project. Key messages for decision makers and policy advisors, and recommendations for future administrative arrangements and management measures. English Nature Research Reports, No. 671.

Coombs, S.H., Halliday, N.C., Southward, A.J. & Hawkins, S.J. (2005). Distribution and abundance of sardine (*Sardina pilchardus*) eggs in the English Channel from Continuous Plankton Recorder sampling, 1958-1980. *Journal of the Marine Biological Association of the UK*. 85: 1243-1247

Genner, M.J., Sims, D.W., Wearmouth, V.J., Southall, E.J., Southward, A.J., Henderson, P.A. & Hawkins, S.J. (2004). Regional climatic warming drives long-term community changes of British marine fish. *Proceedings of the Royal Society of London, Biological Sciences*. 271: 655-661.

Hardman-Mountford, N.J., Allen, J.I., Frost, M.T., Hawkins, S.J., Kendall, M.A., Mieszkowska, N., Richardson, K.A. & Somerfield, P.J. (2005). Diagnostic monitoring of a changing environment: An alternative U.K. perspective. *Marine Pollution Bulletin*. 50: 1463-1471

Hawkins, SJ, Southward, A.J. & Genner M.J. (2003). Detection of environmental change in a marine ecosystem-evidence from the western English Channel. *Science of the Total Environment*. 310: 245-56.

Hawkins, S.J., Gibbs, P.E., Pope, N.D. Burt, G.R., Chesman, B.S., Bray, S., Proud, S.V., Spence, S.K., Southward, A. J. & Langston, W.J. (2002). Recovery of polluted ecosystems: the case for long-term studies. *Marine Environmental Research.* 54: 215-222.

Herbert, R.J.H., Hawkins, S.J., Sheader, M. & Southward, A.J. (2003). Range extension and reproduction of the barnacle *Balanus perforatus* in the eastern English Channel*. Journal of the Marine Biological Association of the UK*. 83: 73-82.

Hiscock, K., Southward, A. J., Tittley, I. & Hawkins, S. J. (2004). Effect of changing temperature on benthic marine life in Britain and Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems.* 14: 333-362.

Kendall, M. A., Hawkins, S. J., Burrows, M.T. & Southward, A. J. (2004). Predicting the effects of marine climate change on the invertebrate prey of the birds of rocky shores. *Ibis (Special Edition).* 146: 40-47.

Mieszkowska, N, Kendall, M. A., Hawkins, S. J., Leaper, R., Williamson, P., Hardman-Mountford, N. J. & Southward, A. J. (2006). Changes in the range of some common rocky shore species in Britain - a response to climate change? *Hydrobiologia.* 555: 241-251.

Simkanin, C. S., Power, A. M., Davenport, J., Myers, A. A. & McGrath, D. (2003). Monitoring intertidal community change in a warming world. The Irish Scientist 2003 Yearbook May 2003. Samton Limited.

Simkanin, C., Power, Power, A., Myers, A., McGrath, D.,Southward, A., Mieszkowska, M., Leaper, R. & O'Riordan, R. (2005). Using historical data to detect temporal changes in the abundances of intertidal species on Irish shores. *Journal of the Marine Biological association of the UK*. 85: 1329-1340.

Southward, A .J., Langmead, O., Hardman-Mountford, N. J., Aiken, J., Boalch, G. T., Dando, P. R., Genner, M. J., Joint, I., Kendall, M. A., Halliday, N. C., Harris, R. P., Leaper, R., Mieszkowska, N., Pingree, R. D., Richardson, A. J., Sims, D. W., Smith, T., Walne, A. W. & Hawkins, S. J. (2005).

Long-term oceanographic and ecological research in the western English Channel. *Advances in Marine Biology.* 47: 1-105.

Thompson R.C., Crowe, T.P, & Hawkins, S.J. (2002). Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years. *Environmental Conservation*. 29 (2): 168-191.

In addition to the refereed publications there have also been a number of reports and semi-popular publications:

Cannell, M., Brown, T., Sparks, T., Marsh, T., Parr, T., George, G., Palutikof, J., Lister, D., Dockerty, T. & Leaper, R. (2003). Review of UK Climate Change Indicators. DEFRA Contract Report No. EPG 1/1/158.

Frost, M. T., Leaper, R., Mieszkowska, N., Moschella, P., Murua, J., Smyth, C. & Hawkins, S. J. (2004). Recovery of a Biodiversity Action Plan species in northwest England: possible role of climate change, artificial habitat and water quality amelioration. *Marine Biological Association Occasional Publication No. 16*

Kendall, M. A. (2002). MarClim – Marine Biodiversity and Climate Change. Report to BIOMARE Newsletter, p10, Autumn 2002 Issue.

Laffoley, D., Baxter, J., O'Sullivan, G., Greenaway, B., Colley, M., Naylor, L. & Hamer, J. (2005). The MarClim Project: Key messages for decision makers and policy advisors, and recommendations for future administrative arrangements and management measures. English Nature Research Reports, No. 671.

Leaper, R. (2003). Intertidal species as indicators responses of biodiversity to rapid climate change in UK marine ecosystems. Report to the Marine Biological Association Newsletter, p8, April 2003

Science and Society

There have been a large number of conference and workshop presentations on the MarClim work both to professional scientists and members of the public. Professor S. J. Hawkins also sits on two international working groups in his capacity as MarClim Principal Investigator.

2.11 The Centre for Environment, Fisheries and Aquaculture Science (CEFAS): Time-series observations in the marine ecosystem

S. Dye

Details

Cefas maintain a wide variety of observation points and networks throughout UK waters. Some of these are time series with a long history whilst others are more recent additions to UK monitoring.

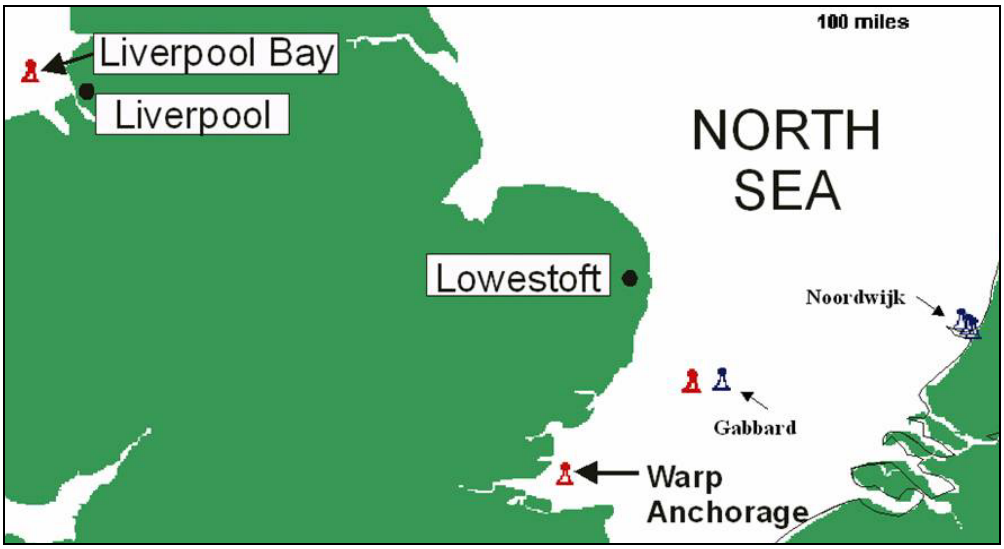


Figure 2.11a . Crown Copyright http://www.cefas.co.uk/data.htm

- **Smartbuoys** (figure 2.11a): The Smartbuoys are Defra funded and have been maintained in the southern North Sea since 2000 and in the Irish Sea since November 2002. A Smartbuoy was also deployed in Dutch coastal waters between March 2000 and April 2002. The Smartbuoys are single point moorings taking near-surface measurements (1-2.5 m) (frequency: 1 Hz – 1 day). A number of instruments are used to measure a variety of parameters; CT sensors (salinity, temperature); PAR irradiance sensors (Ed at 1 and 2 m depth); optical backscatter sensor (turbidity – suspended particle concentration); chlorophyll fluorometer (chlorophyll fluorescence); oxygen sensor (dissolved oxygen); *In situ* nutrient analysers (Total Oxidised Nitrogen (TOxN), nitrate & nitrite); Automated Water Sampler (phytoplankton and Total Oxidised Nitrogen (TOxN) . Full details can be found at www.cefas.co.uk/monitoring.

- **Southern Bight Ferry Route**: This route, maintained since 1971 consists of nine stations along 52°N (Harwich to Rotterdam) in the southern bight of the North Sea. An approximately weekly salinity bottle sample and measurement of sea surface temperature is made by the crew of a ferry leading to a >30 year time series that is mainly used in a monthly mean form.

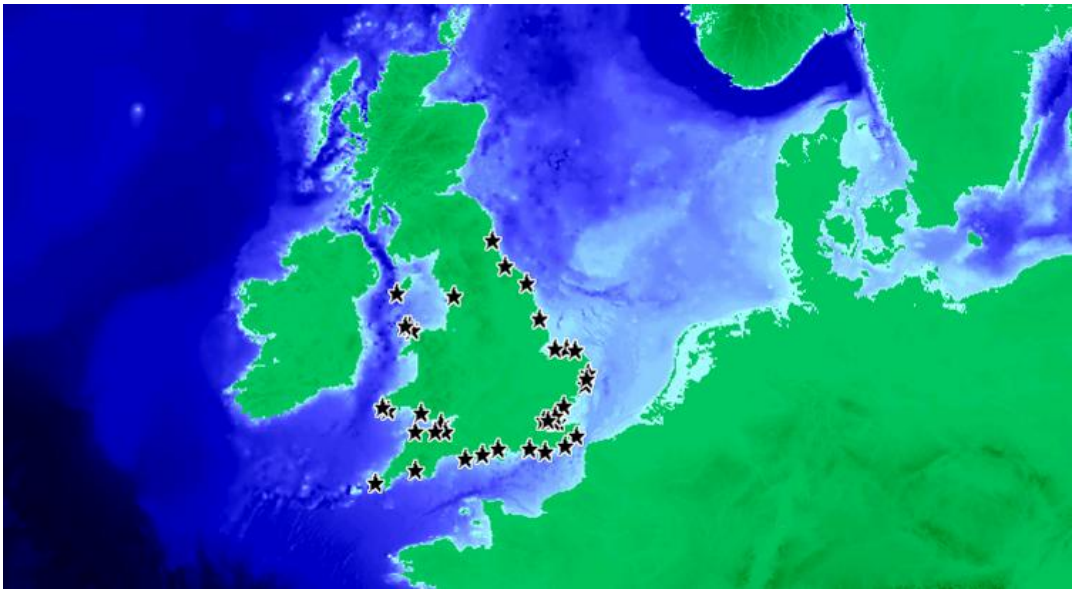


Figure 2.11b. Image: Crown Copyright http://www.cefas.co.uk/data.htm.
Bathymetry data taken from the General Bathymetric Chart of the Oceans (GEBCO) One Minute Grid BODC/GDA Licence No: 2003/4

- **Coastal Temperature Network sites** (figure 2.11b): Near surface coastal sea temperature is measured by a network of observers including councils, laboratories, companies and volunteers. 38 coastal stations around the English and Welsh coast were initially maintained although this decreased to 25 in 2004. Measurements have been taken on a daily to weekly basis mainly from the mid-1960s although some measurements go further back such as the Eastbourne station that has measurements going back to 1892.

- **Wavenet**: Wavenet is a national wave monitoring network for England and Wales (full details can be found at www.cefas.co.uk/wavenet). Real-time wave measurements have been taken at half-hour intervals since January 2003.

- **Other Cefas time series include**:

    - **Denmark Strait overflow Current Meter Array**: since1986
    - **Bury Inlet cockle survey**: 46 years
    - **63°N Freshwater Flux Array**: Since 2000
    - **Nephrops TV survey, Farn Deeps**: Nine years
    - **National Marine Monitoring Programme**: Since 1998
    - **Radionuclide concentration in water, sediments, biota**: Since 1959. Over 100 locations in England & Wales (UK coastal waters and shelf).
    - **Salmonid catch statistics**: 1952 to present but with some sites with 100 years of data. 70 rivers monitored in England and Wales (with EA).
    - **Solent oyster survey**: 30 years
    - **Young Fish Surveys**: Since 1981. All finfish species, commercial and otherwise. Since 2000 epi-benthos has been identified and quantified. Mainly English east-coast and eastern channel.

Origin of time series including original objectives

The Smartbuoys are funded by Defra in order to contribute to a robust evidence base on which to base future assessments of eutrophication around the UK.

Defra also fund the Southern Bight Ferry Route and the coastal temperature network. Although the sampling points in these networks were started for various reasons, they are maintained for the use of fisheries and environmental scientists as an aspect of their investigation into marine ecosystem variability.

The WaveNet monitoring is again funded by Defra managed via the EA in order to enable the use of real-time and archive wave data around the UK for flood defence purposes, climate change studies and auxiliary uses.

The other various time series maintained by Defra were started for numerous reasons but were either targeted to answering specific questions or part of larger monitoring programmes such as the National Marine Monitoring Programme (NMMP).

Current Objectives

As above.

Policy relevance

Cefas provides a wide variety of policy and legislative advice as a result of its data collection programmes. Much of the monitoring undertaken by Cefas is concerned with pollution (e.g. Smartbuoys) and is therefore relevant to EU directives (e.g. WFD), EU infraction proceedings and other policy drivers such as the OSPAR Comprehensive Procedure. By supplying data to various bodies such as ICES working groups (PGNSP, Regional Ecosystem Study Group for the North Sea (REGNS), WGOH, see below) , Cefas monitoring programmes also help governments and other bodies to assess impacts from fishing and climate change.

The WaveNet monitoring provides information to coastal managers on the potential risk of flooding and coastal erosion thus informing coastal defence strategies.

Products

Data from the Southern Bight Ferry Route is supplied to the ICES Working Group on Oceanic Hydrography (ICES-WGOH) which provides advice to governments and other bodies on issues such as fishing and pollution[63]. This data is also supplied to ICES for the ICES Annual Ocean Climate Status Summaries and to ICES-PGNSP (Planning Group on the North Sea Pilot Project) for its North Sea Quarterly Status Report. Coastal temperature data is also supplied to ICES-WGOH. Fisheries data is supplied for ICES procedures and stock assessments.

[63] See http://www.soc.soton.ac.uk/JRD/ICES_WGOH/index.php

The data from various time series is available at http://www.cefas.co.uk/data.htm.

A large number of reports and papers have been produced as a result of the various Cefas monitoring programmes. The full list can be searched at http://www.cefas.co.uk/Publications/default.aspx.

2.12 Time series measurements in the Solent and Southampton Water (NOCS)

D. Purdie, S. Hartman, D. Hydes, A. Iriarte et al.

Details

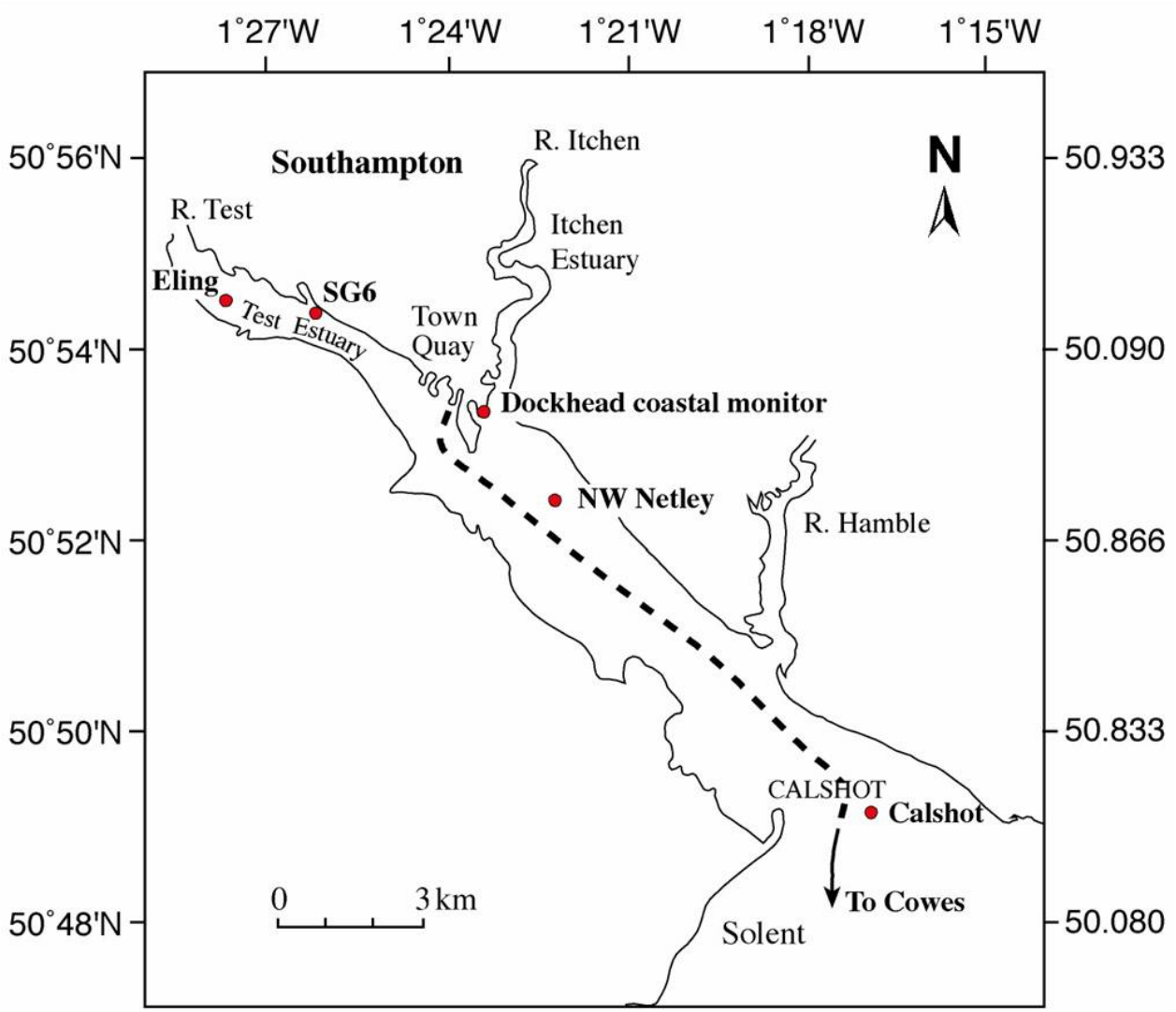


Figure 2.12. Location of time series maintained by NOCS in Southampton Water and Solent.

There are two locations where sampling has occurred frequently since the 1980s. The first of these, situated in mid-estuary is the NW Netley buoy and the second is the Calshot buoy situated in the outer estuary/coastal waters (figure 2.12).

There are also a number of other datasets and continuous monitoring sites being maintained:

- **1988-2003 several PhD projects**:
  - Sampling at several discrete stations in estuary

    - Nutrients, chlorophyll, phytoplankton enumeration. Temperature, Salinity
    - Some zooplankton surveys

- **1995-97 SONUS Project** (Department of Environment funded)
    - Surface nutrient distribution and inputs to Southampton Water

- **1998-2004 Ferry Box deployed on Red Falcon** (DETR, NERC, EA, EU funded)
    - Southampton to Cowes Ferry (up to 18 crossings per day)
    - Continuous temperature, salinity, chlorophyll fluorescence, turbidity, GPS position
    - Some discrete sampling for calibration (intensive in 2004)

- **2001, 2002, 2003 HABES** (Harmful Algal Bloom Expert System, EU funded)
    - Regular sampling (weekly) at NW Netley buoy and Calshot buoy
    - Nutrients, chlorophyll and other pigments, phytoplankton enumeration

Origin of time series including original objectives

Originally the Calshot and Netley time series were instituted in order to investigate seasonal changes in phytoplankton abundance. This included the investigation of summer red tides of *Mesodinium rubrum* in a macrotidal estuary with reference to nutrient concentrations and flushing. Several PhD projects were based around data from the time series.

Most of the other monitoring programmes were funded by UK government and European agencies (see above) to investigate water quality issues.

Current Objectives

The data from the Calshot and Netley Buoy time series have since been used:

- To determine the eutrophication status of Southampton Water and the Solent

- To investigate factors influencing the timing of spring and summer phytoplankton blooms in the estuary

- To investigate factors influencing the occurrence of spring *Phaeocystis* blooms in the estuary

The objectives for the other monitoring programmes are those mentioned above.

Policy relevance

The time series data are relevant to a number of EU directives including the:

- Urban Waste Water Treatment Directive (91/271/EEC) and
- Nitrate Directive (91/676/EEC)

Both of these require eutrophication status assessment of controlled waters to be reviewed every four years. The time series is able to provide useful measurements of the frequency, magnitude and duration of phytoplankton blooms (>10mg/m3). In recent years data has been provided data to local the Environment Agency for their review of Sensitive Areas/Polluted Water Status of Southampton Water.

Products

Data and advice has been made available to organisations including the Environment Agency and Department of the Environment Transport and the Regions (now Defra). Various publications have been produced using the data.

2.13 Ships of Opportunity and the EU FerryBox project (NOCS)

D. Hydes

Details

Ships of Opportunity (SOO): Staff at NOC are working with the University of East Anglia (UEA) on the Carbon Variability Studies by Ships of Opportunity project (CAVASSOO). Seawater and atmospheric pCO_2, temperature and salinity is measured along four transects in the North Atlantic (see map of locations at http://tracer.env.uea.ac.uk/e072/welcome.htm). These measurements have been taken on a monthly basis since April 2002.

EU FerryBox project: This project involves measuring a number of parameters using FerryBox sensors installed on ferries operating in waters of different character. Eight areas are currently measured using ferryboxes; the Baltic Sea, Skagerrak, North Sea, Wadden Sea, Baltic Sea, Irish Sea, English Channel, Bay of Biscay and the Aegean Sea. The NOC is responsible for the Bay of Bisacy monitoring which is carried out from the ship the 'Pride of Bilbao' that operates between Portsmouth (UK) and Bilbao (Spain). Parameters measured include conductivity, temperature and chlorophyll-fluorescence (measured at 1Hz frequency and then every 30 seconds from December 2004) with pCO_2 measurements being added in June 2005 and nutrients in 2006. Monthly measurements include NO_3, Si, PO_4, Chl a, salinity, and O_2. Funding is provided by the EU and by NERC.

For full details see http://www.soc.soton.ac.uk/ops/ferrybox_index.php.

Origin of time series including original objectives

The SOO project is an EC funded project initiated in 1999 that brought together all the research groups measuring CO_2 in the North Atlantic Ocean. The objective is to:

"*….provide reliable estimates of the uptake of CO_2 by the North Atlantic, and how this varies from season to season and year to year. These will in turn assist in constraining estimates of European and North American terrestrial (vegetation) sinks, using atmospheric inverse modelling techniques*[64]".

The EU FerryBox project was designed with the following objectives in mind:

- To provide the opportunity to compare different systems and different types of seas (enclosed, coastal, shelf, oceanic, oligotrophic, eutrophic).
- To provide data for the calibration and checking of existing oceanographical models for the various sea areas.
- To provide a cost-effective monitoring programme that can be used to deliver background data for the European Water Framework Directive[65].

[64]taken from: http://tracer.env.uea.ac.uk/e072/welcome.htm

Current Objectives

SOO: In addition to the above objectives outlined for the SOO project, the data is also being used to address the question: 'what controls ocean nutrient concentrations before the spring bloom'. The detail available from SOO systems should also enable better understanding of the controls of biological production, gas exchange and routine measurement of production.

EU FerryBox: In addition to the above objectives, one of the key questions currently being addressed regards the issue of Eutrophication, namely "Is it possible to derive an "indicator" to link plankton bloom intensity and nutrient load across contrasting physical environments?"

The data are also being used to provide understanding of the occurrence of *Karenia mikimotoi* blooms in the English Channel.

It is hoped that other parameters can be added including alkalinity, pH, and HPLC. PH is particularly important as there is much talk at present concerning the acidification of the ocean and yet little *in situ* data actually exists.

Policy relevance

As already mentioned, one of the aims of the EU FerryBox project was to deliver background data for the European Water Framework Directive. It will also inform the European Marine Strategy and the monitoring is also relevant to the Ecological Quality Objectives with regard to Nutrient and Eutrophication effects developed by the OSPAR commission 2005.

Crucial information is also being delivered as regards climate change on issues such as the capacity for the ocean shelf to take up CO_2.

Products

All the FerryBox data is made available through BODC and there are various publications in press or being prepared.

Data is also available on websites and it is hoped that data transfer will be improved to provide real-time access in 2006.

[65] http://www.ices.dk/marineworld/ferries.asp

2.14 North Sea time series (Dove Marine Laboratory)

C. L. J. Frid

Details

Sampling at the time series maintained by Dove Marine Laboratory is now coordinated via the University of Liverpool rather than the University of Newcastle due to the relocation of the staff member funded through the MECN to coordinate the North Sea sampling.

Benthic Stations (M1 & P): Benthic Station M1 has been sampled twice yearly in March and September since 1972. This station is located approximately ten km offshore at 55° 07'N 01°20'W in 55m of water. Benthic station P has been sampled annually since 1971. This station is located approximately 22km offshore at 55° 07'N 01°15'W in water of 80m depth on a major fishing ground for *Nephrops*. Station P is sampled on an annual basis.

Zooplankton Station (Z): This station is adjacent to benthic station M1 approximately ten km offshore at 55° 07'N 01° 20'W. Vertical zooplankton net hauls have been taken on a monthly basis since 1969 (with a gap in 1989). Water quality sampling (temperature, salinity, and chlorophyll a) was also carried out monthly between 1996 and 1998.

Origin of time series including original objectives

Originally, a number of benthic stations and the zooplankton station were established to investigate the productivity of the area. The benthic programme was then extended in response to proposals to designate the area a sewage dump site. The focus also shifted from just looking at productivity, to looking at natural fluctuations in the benthos and seeking to elucidate the mechanisms driving the observed variation. M1 and P are the benthic stations that have continued to be sampled and now constitute the time series.

Current Objectives

The time series now represent some of the only multi-decadal offshore benthic datasets available and are being used to investigate long-term change to the North Sea Ecosystem[22]. The datasets are also providing valuable information on how different ecosystem components respond to extrinsic drivers (e.g. climate and fishing).

Unfortunately, funding for the zooplankton time series has now ceased and funding for the benthic time series is only for sample collection, not for data analysis. This funding is only guaranteed up to 2007. There are also plans to reinstitute the Water Quality time series if funding can be made available.

Policy relevance

The Dove benthic time series represent the only multi-decadal offshore benthic dataset for the North Sea. As such, it was one of the only sources of information for the State of the Seas report where the lack of offshore benthic data was noted[61]. This issue is crucial for the establishment and monitoring of SACs in UK offshore waters as part of the work being carried out under the Habitats Directive. Data from the time series is also being used to inform our understanding of climate effects on marine ecosystem dynamics and the impacts of fishing.

The combined datasets are invaluable in advancing our understanding of how ecosystem-based marine management can be carried out. This was highlighted in the review undertaken by Frid et al. (2005)[66] concerning the extent to which current science is able to inform and support the aim of delivering ecosystem-based fisheries management under the reformed CFP. One key gap is the paucity of data series that allow the role of long term, extrinsic drivers to be understood and the lack of knowledge of dynamics and interactions between all major ecosystem components.

Products

A large number of publications have resulted from the work carried out on the various time series. A selection of these is shown below:

Clark, R.A., C.L.J. Frid & K.R. Nicholas (2003). Long term, predation based control of a central-west North Sea zooplankton community. *ICES Journal of Marine Science*. 60:187-197.

Bremner, J., C.L.J. Frid & S.I. Rogers (2003). Assessing Marine Ecosystem Health: The long-term effects of fishing on functional biodiversity in North Sea benthos. *Aquatic Ecosystem Health & Management*. 6:131-137.

Bustos-Baez, S. & C.L.J. Frid (2003). Using indicator species to assess the state of macrobenthic communities. *Hydrobiologia.* 496: 299-309.

Bremner, J., S.I. Rogers & C.L.J. Frid (2003). Assessing functional diversity in marine benthic ecosystems: A comparison of approaches. *Marine ecology progress series.* 254:11-25.

Bonnet, D. & C.L.J. Frid. (2004). Seven copepod species considered as indicators of water-mass influence and changes: results from a Northumberland coastal station. *ICES Journal of Marine Science* 61: 485-491

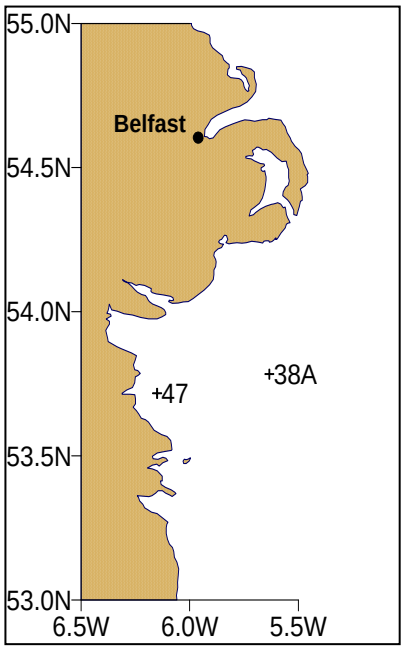
Data and analysis from the time-series has also been presented at a number of conferences and workshops.

[66] Frid, C., Paramor, O. & Scott, C. (2005). Ecosystem-based fisheries management: progress in the NE Atlantic. *Marine Policy*. 29: 461-469.

MECN Time series not included for evaluation

2.15 The Agri-food and Biosciences Institute of Northern Ireland (AFBI)

R. Gowen



AFBI maintains time series at two locations in the Irish Sea as part of its long-term monitoring programme that began in 1995 (figure 2.15). The first of these is Coastal Station 47 which is in water of 20m depth and the second is Offshore Station 38A in 95m depth. Station 38A is located in an area that forms part of the *Nephrops* fishery. The water at the offshore station becomes seasonally stratified and is within the western Irish Sea gyre.

The stations are being used to investigate short-term variability and long-term change with a number of variables being measured including temperature and salinity, dissolved nutrients, plankton and fish. This long-term surveillance programme is part of the marine environment and fisheries programme being undertaken by AFBI to provide key information to support DARD (Department of Agriculture and Rural Development in Northern Ireland) in formulating an ecosystem-based approach to fisheries management and for informing quality status assessments of the Irish Sea.

Figure 2.15. AFBI's Irish Sea mooring sites.

AFBI's programme is subject to a separate review process, which is why it was not included for evaluation at the workshop. Note AFBI was created on 1st April 2006 as the amalgamation of DARD Science Service and the Agricultural Research Institute of Northern Ireland.

2.16 Alfred Wegener Institute for Polar and Marine Research (AWI) – Helgoland Time Series

K. Wiltshire

The time series being maintained by the Alfred Wegener Institute for Polar and Marine Research (AWI) on Helgoland were presented as examples of the type of long-term observations being identified by MarBEF as part of the LargeNet project (see Section 1.1.3). The oldest of the AWI regular time series is the Helgoland Roads pelagic station (54° 11'N 7° 54'E) which has been sampled 5 times a week since 1962. The parameters measured are temperature, salinity, Secci-depth, nutrients (silicates, phosphates and nitrates) and phytoplankton counts. Zooplankton data is also available from 1975 onwards and benthic data from 1988. There is also long-term data available from the 19th century on benthic macro-algae that allows some long-term comparisons to be made.

Analysis of the long-term data from the marine environment around Helgoland is yielding interesting insights into long-term ecosystem change and the influence of factors such as eutrophication and climate change[67]. This information is vital for the European Water Framework Directive.

[67] Wirtz, K. W. & Wiltshire, K. (2005). Long-term shifts in marine ecosystem functioning detected by inverse modelling of the Helgoland Roads time-series. *Journal of Marine Systems*. 56: 262-282.

3. Evaluation

K. Philippart, E. Murphy, K. Wiltshire, & A. Wither.

3.1 Panels comments

The members of the panel were Katja Philipart (Chair) of the Royal Netherlands Institute for Sea Research (NIOZ), Netherlands; Eugene Murphy of the British Antarctic Survey (BAS), UK; Karen Wiltshire of the Alfred Wegener Institute for Polar and Marine Research (AWI), Germany; and Andrew Wither of the Environmental Agency (EA), UK.

The following section is an outline of the key recommendations and comments made by the evaluation panel in response to the workshop presentations on time series and long-term datasets. Needs or issues (●) highlighted by the panel with regard to the future of long-term datasets and time-series in the UK are shown along with advice and potential solutions (○) where offered. The recommendations are divided into 4 categories; 'The MECN and end-user requirements'; 'Procedures & protocols'; 'Securing data series' and 'Future developments'.

3.1.1 The MECN and end-user requirements

- Information is required regarding the current information status i.e. what are the end-user requirements and how does this match what information is available? It is important that end-users specify what information is required for scientific or policy purposes and what type of information is currently 'missing'. This enables partners with long-term observations to be fully aware of end-user needs when the opportunity is there for additional measurements (i.e. extra parameters added or increased frequency of sampling). Those responsible for data collection can then also consider what the best way is to obtain the required information with the tools available i.e. what is most efficient and cost-effective?

- Another important issue to address is how each time series/dataset fits into the bigger picture. This means looking at how information from time-series is being used to inform other research projects or key policy areas and how the data is contributing to other national, European or global networks. Data from individual time-series and datasets has 'added value' when it is used not just to provide information at the scale of sampling (e.g. regional sea) but is integrated with other data to inform larger scales of investigation.

3.1.2 Procedures & protocols

- There is a clear requirement to establish a set of procedures and protocols and general principles that should be adopted by those with a responsibility for time series and long-term datasets. The panel advises that :

- Clear identification should be made of what elements of the observations relate to monitoring (i.e. surveillance and underpinning capabilities) and what elements are core science components related to immediate research needs.

- There should be clear identification at a regional level of the minimum sampling effort required to provide adequate monitoring capability for that region. It is also important that regions are based on the hydrodynamics and ecology of the area rather than boundaries that lack ecological integrity such as political and geographical.

- When the location of *new* sampling sites is being decided, careful consideration should be given to potential links to remote sensing programmes. This linkage between *in situ* data from sampling and data from remote sensing is crucial for optimising modelling capability.

- For sampling sites already established it is important that sampling programmes are not stopped or relocated. Long-term time series are so valuable and rare that any benefit in relocating the sampling would be far outweighed by the loss of long-term temporal data. Long-running sampling programmes should, if necessary, be enhanced at their present locations rather than moved or stopped.

- Every effort should be made to standardise methods as much as possible. This entails making sure that parameters are measured in the same way at different locations but can also mean standardisation of parameters measured and frequency of measurement where possible. The main way of approaching these issues should be through collaboration with national and international networks.

- It will be necessary on occasions to enhance sampling procedures due to improved or newly available technology. The issue of technology transfer should be carefully considered so that improvements can be made without losing the continuity of the data stream. This can be done for example, by maintaining an accurate 'technology audit trail' so that data sampled using the old technology can be recalibrated according to the new technology or sampling procedure.

- Data recovery must be made a priority in order to make use of all the data. There is a great deal of data that has still not been made available, often stored as hard copies in drawers/cabinets or archived in inaccessible forms such old software programmes. Many standard running cruises and surveys have built up backlogs of data (hydrodynamics, depths, sediment types) that are not yet accessible to the wider scientific community and other end-users.

3.1.3 Securing data series

- The issue of funding for long-term observations needs to be addressed urgently in order to secure the future of valuable long-term data sets. Many of the time series are extremely vulnerable with threats to their current funding status. Some have already ceased and some are running on an ad-hoc basis with just enough funding being found to 'keep things ticking over'. A lot of time is also being spent in the constant battle to try and secure funds to continue sampling programmes. The panel made the following observations:

- One approach is for time series to be 'adopted' by higher organisational levels, either national or European. This alleviates the pressure on individuals or smaller institutions to seek funding for what is seen as local work. The adoption at a higher level recognises that the time series are national and/or international assets and should be funded accordingly. It would also help in making all the data publicly available.

- A minimum priority for potential funding bodies should be to secure time series in the separate regions (some regions currently only have one time series and some are as yet unrepresented).

- In order to help potential funding bodies, the MECN should ascertain the *minimum* sampling effort required to address the pertinent scientific and policy questions. This can be done, for example, by using modelling to carry out sensitivity analyses. Funding bodies can provide higher levels of funding but are at least made aware of the minimum funding required to effectively maintain a time series 'fit for purpose'.

- There are some new developments such as the FerryBox initiatives that are providing cost-effective ways of collecting high quality data. It is vital that funds are secured for the FerryBox projects once the trial periods have ended. The high quality modelling capability developed as part of the trials should be linked to *in situ* time series measurements.

3.1.4 Future developments

- There is a requirement for the MECN, end-users and potential funding bodies to consider what actions are the *priorities* for the immediate future. The panel, therefore, suggest the following:

  - Funding needs to be obtained for the time series and long-term datasets. Without funding for the existing sampling programmes, the network cannot continue.

  - Linkages need to be strengthened both within the network (i.e. between network partners) and between the MECN and other national and international networks.

  - The MECN should oversee development of all the sampling programmes (enhancement, standardisation etc) and push forward with the recommendations made at this workshop.

  - Regional views should be developed so that outputs from the network and end-user needs can be understood at regional levels.

  - Once funding is secured for the present set of time series, then a series of additions should be made to the network. The first of these is to add marine stations in areas not yet sampled. For example, Aberdeen, St Andrews and Shetland in Scottish waters and some Irish locations. Where some observations are already underway that could form the basis of a future time-series then these should be encouraged. The other major addition to the work already carried out by MECN partners should be the sampling of a wider range of ecosystem components such as birds, sea mammals and fish (only sampled at a couple locations). This is crucial in order to underpin and provide information on the ecosystem-based approach to marine management.

- NERC's new funding strategy (Oceans 2025) recognises the fundamental importance of long-term observations and provides an excellent opportunity to develop MECN as part of the NERC strategy in marine science.

- As not all MECN partners are NERC centres, a key challenge is for the NERC marine institutes, DEFRA (for England and Wales), Scottish Executive Environment and Rural Affairs Department (SEERAD) (for Scotland), DARD (for Northern Ireland) to develop a joint strategy for securing long-term series. MECN partners will need to be proactive in communicating the scientific and strategic value of maintaining and developing MECN to these, and other, key stakeholders.

4. UK marine policy and long-term marine monitoring programmes

M. T. Frost & S. J. Hawkins

Ever since marine environmental protection issues really came to the fore in the 1960s[68], it has been recognised that there is a requirement for a suitable evidence base on environmental change in order to support policy and management for UK waters. The following section gives a brief summary of the development of marine policy in the UK[69] along with comments on the availability and necessity of long-term marine observations for the implementation of this policy. The initial focus is on marine conservation as regards biodiversity and integrity of marine ecosystems. Marine pollution and fisheries are then briefly discussed in separate sections, as although in terms of impacts on the marine environment these areas are strongly interlinked, there has been some difference in how policy has developed for each area and, therefore, this policy has been supported by scientific research and monitoring. Finally, a summary of the current status regarding long-term data is given.

4.1 Marine Conservation: protecting biodiversity and marine ecosystems

The need for information on long-term change in marine ecosystems was identified at the very beginning of the development of marine conservation policy in the UK[70]. The first report on a formal marine policy for UK waters, 'Conservation Policy in the Shallow Seas'[71] was produced as a result of a meeting between the Nature Conservancy (which became part of Natural Environment Research Council (NERC) in 1965) and marine scientists in 1969. It was noted, however, that little could be done in response to the report due to the absence at that time of evidence relating to impacts on the marine environment.[70] There was an increasing concern at this time, however, over impacts on the marine environment exacerbated by incidents such as the Torrey Canyon oil spill and, in 1971, a Working Party on Marine Wildlife Conservation was established to report on the case for establishing marine nature reserves. In order to produce this report[72], key areas identified for consideration related to "*the problem of measuring changes*" and "*distinguishing between natural and artificial factors"* influencing change in marine ecosystems. Again, despite various recommendations being made, no immediate progress was made in response to this work. The real impetus towards the development of a formal marine conservation policy for the UK came from the recommendations from an NCC[73]/NERC working party initially convened in 1975. Once more, evidence on marine environmental change was

[68] Bell, S. & McGillivray. (2006). Environmental Law. Oxford University Press. (Chapter 1, p7).
[69] 'UK policy' here includes policy implemented by both UK government and the devolved administrations.
[70] A useful overview of the development of UK marine conservation policy can be found in: Hiscock, K. (ed.) (1996). *Marine Nature Conservation Review: rationale and methods*. Peterborough, Joint Nature Conservation Committee. (Coasts and seas of the United Kingdom. MNCR series).
[71] Natural Environment Research Council and Nature Conservancy (1969). *Conservation Policy in shallow seas*. Joint action meeting with the committee for Wales, Scottish Committee, the Scientific Policy Committee, Committee for England.
[72] Natural Environmental Research Council (1973). *Marine wildlife conservation: an assessment of evidence of a threat to marine wildlife and the need for conservation measures.* London, Natural Environment Research Council (Publication Series 'B', No. 5).
[73] The Nature Conservancy Council (NCC) was established as a separate entity in 1973.

identified as essential, with a key recommendation of the working party's 1979 report[74] being that "*a study of the many factors regulating the natural fluctuations in marine communities should be seen as a basic and continuing contribution to a marine conservation programme*"[75] (our underlining).

Despite this early acknowledgement of the requirement for data on measuring change and natural fluctuations in marine ecosystems, the more pressing need, in light of an increasing environmental awareness and new legislation enabling the establishment of marine reserves,[76] was for basic data on the distribution of habitats and species. The need for this type of data was particularly emphasised in the Nature Conservancy Council's report produced in 1984[77] and led to a vast expansion in data gathering activities in the 1980s through projects such as the Marine Nature Conservation Review (MNCR),[78] which carried out littoral and sublittoral surveys between 1987 and 1998. Other projects such as Coastwatch and SeaSearch were also started in this period. Laffolley (2000)[79] states that,

> "*by the turn of the century these surveys culminated in the UK having a greater knowledge of its marine environment and its conservation values than most other countries in the world*".

However, at the same time as huge efforts were being made to gather basic baseline information on the marine environment through habitat and species surveys, funding for many long-term marine observation programmes was being withdrawn. Surveys commissioned by the NCC began surveying habitat and species distributions around the UK intensively in the mid 1980s – the same time that funding was stopped for the type of long-term marine monitoring programmes (i.e. the MBA's offshore time-series, the NERC rocky shore surveillance unit at Robin Hoods Bay) now recognised as vital in order to provide the context in which to interpret and understand MNCR type survey data. The Continuous Plankton Recorder (CPR) unit was also made redundant by NERC in 1988. Fortunately, the CPR survey was rescued as the Sir Alister Hardy Foundation for Ocean Science (SAHFOS). In Europe as a whole about 40% of all long-term monitoring programmes were terminated in the late 1980s[80].

Throughout the 1990s the emphasis as regards the marine environment was on collecting data on impacts (e.g. Eno, 1991[81]; MCS, 1999[82]), species and habitat sensitivities to those impacts (e.g. Holt et al.[83], 1995; McDonald et al., 1996[84]) and broad-scale habitat and species information, particularly with regard to the various legislative and statutory drivers that were appearing at this time. These drivers

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[74] Nature Conservancy Council and Natural Environment Research Council (1979). *Nature conservation in the marine environment. Report of the NCC/NERC joint working party on marine wildlife conservation*. London, Nature Conservancy Council.

[75] Note: when parts of quotations are underlined, it is to identify relevant text to this review.

[76] Legislation supporting statutory marine reserves was included in the Wildlife and Countryside Act, 1981.

[77] Nature Conservancy Council. (1984). Nature Conservation in Great Britain. Shrewsbury: Nature Conservancy Council.

[78] Hiscock, K. (ed.) (1996). *Marine Nature Conservation Review: rationale and methods*. Peterborough, Joint Nature Conservation Committee. (Coasts and seas of the United Kingdom. MNCR series).

[79] Laffoley, D. d'A. (2000). *Historical perspective and selective review of the literature on human impacts on the UK's marine environment*. Prepared by English Nature for the DETR Working Group on the Review of Marine Nature Conservation. Peterborough. English Nature Research report 391. 20pp

[80] Duarte, C. M, Cebrian, J. & Marba, N. (1992) Uncertainty of detecting sea change. *Nature*. 356: 190.

[81] Eno, C. (1991). *Marine Conservation Handbook*. Peterborough. English Nature.

[82] Marine Conservation Society. (1999). Marine Conservation: the UK action guide. Ross-on-Wye. Marine Conservation Society.

[83] Holt, T. J., Jones, D. R., Hawkins, S. J. & Hartnoll, R. G. (1995). *The sensitivity of marine communities to man-induced change – a scoping report*. Countryside Council for Wales. Contract Science Report 65.

[84] Macdonald, D. S., Little, M., Eno, N. C. & Hiscock, K. (1996). *Disturbance of benthic species by fishing activities: a sensitivity index*. Aquatic Conservation. 6:257-268.

included the Convention on Biological Diversity (CBD)[12] which requires the identification and monitoring of components of biological diversity under article 7 and is implemented at a national level through the UK Biodiversity Action Plan (BAP)[85]. In the UK, there has been some monitoring of UK BAP species and habitats but it has been generally uneven and often ceased after a few years. An exception is the work undertaken by the Countryside Council for Wales (CCW) at Skomer Marine Nature Reserve (MNR)[86]. At the European level the CBD is being implemented through the Strategic Plan of the CBD adopted at the 6th Conference of Parties (COP6) in The Hague in 2002, which includes the target of '*significantly reducing the rate of biodiversity loss by 2010*'[87]. This target has also been endorsed by the world leaders at the 2002 World Summit on Sustainable Development in Johannesburg and adopted as part of the EU's Sustainable Development Strategy, endorsed at the Gothenburg Summit in 2001.

Another key piece of legislation at this time was the 1992 EC Habitats Directive.[88] This was transposed into UK law in 1994[89] and required the protection of species listed in the Annexes, a programme of surveillance of habitats and species, the establishment of a network of sites known as Natura 2000 and the production of a report every six years on the implementation of the Directive. The Habitats Directive was again a major stimulus for more surveys and data collection in order to be able to provide the information necessary to fulfil the aims of the Directive. It is only now, after a large body of basic information has been gathered and monitoring programmes established that attention is focusing on the *long-term data needed to enable adequate assessments to be made*. Indeed, it is now accepted as being an area that urgently needs addressing and in 2003 the Joint Nature Conservation Committee (JNCC) commissioned a review of biological time series[18] to identify potential information sources on long-term change. The review states:

> "*In assessing the status (condition) of features on protected sites, it is important to separate natural fluctuations from anthropogenic impacts. It is therefore imperative that the results of monitoring studies aimed at assessing status are interpreted in the context of long-term trends and, wherever possible, over a broad spatial scale*".[18] (our underlining)

The point was again emphasised in the 2005 State of UK Seas Report, particularly in the assessment of marine habitats and species. The Marine Habitats and Species report[61] identified the lack of long-term data as the biggest hindrance to an efficient Common Standards Monitoring Programme needed in order to meet the requirements of the Habitats Directive.

Additional important legislation for marine conservation policy at this time was the 1997 EC Directive Council Directive (97/11/EC)[90] on the Assessment of the Effects of Certain Plans and Programmes on the Environment. This Directive required Environmental Impact Assessments (EIAs) to be carried out for any activity likely to significantly affect the environment. Sectors affected by this legislation include the oil and gas industries and the marine aggregate industry. EIAs are also generally required

[85] http://www.ukbap.org.uk/default.aspx
[86] Lock, K. Burton, M., Luddington, L. & Newman, P. (2006). Skomer Marine Nature Reserve Project Status Report 2005/06. CCW Regional Report CCW/WW/05/9.
[87] Danish Presidency (2002) *Presidency conclusions of the meeting towards a strategy to protect and conserve the marine environment*. Eu2002.dk
[88] Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora
[89] Conservation (Natural Habitats, & c.) Regulations 1994 (as amended), and the Conservation (Natural Habitats, & c.) Regulations (Northern Ireland) 1995.
[90] Council Directive 97/11/EC of 3 March 1997 amending Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment. http://ec.europa.eu/environment/eia/full-legal-text/9711.htm

for offshore wind farms with respect to the requirements of the Food and Environmental Protection Act 1985 (FEPA) and Coast Protection Act 1949 (CPA). Although these sectors have accumulated a large body of data on the marine environment through their assessments, it again became increasingly obvious that surveys undertaken to examine impacts at a local level need to be interpreted within the context of the wider marine environment and long-term environmental change. This was highlighted, for example, in a 2001 review of the impacts of aggregate extraction where it was clearly stated that "*the impacts of aggregate extraction must be considered against the background of natural changes in our seas and coasts"*[91]. This issue of background change is now a main focus of interest and was again highlighted in a 2003 report[92] looking at aggregate extraction and biodiversity issues. This report recognised that although a large amount of data had been collected through numerous studies:

"...there are major shortcomings in the extent and detail available to provide a comprehensive baseline against which to judge the effects of the activities of sea users on marine biodiversity"

This comment clearly refers to all sectors requiring EIAs, not just the aggregate industry. In fact, it has been noted that a key weakness of most EIAs is that they are poorly undertaken due to "*inadequate historical baseline data*"[93]. Measures are now being taken to address this issue for the aggregates industry. For example, funding has recently been provided by the Aggregates Levy Sustainability Fund (ALSF) for the collation and analysis of historical benthic data sets collected by the MBA with the aim of providing evidence on long-term environmental change (i.e. a 'baseline'). These datasets are being analysed to show potential long-term change in response to factors such as climate in order to inform assessments of more localised short-term impacts. Also, the fundamental flaws in the EIA approach are now partly addressed by the recent Strategic Environmental Assessment (SEA) Directive (2001/42/EC) which was transposed into UK law in 2004. The SEA complements the EIA Directive and unlike EIAs provides a mechanism for ecosystem-scale considerations and a consideration of in-combination impacts. The information required for SEAs goes beyond the short term local studies carried out as EIAs:

"A fundamental part of the effective SEA is comprehensive, baseline assessment of the environment, preferably over several years to take annual variations into account, and development of a comprehensive monitoring programme.[94]*"* (our underlining)

This statement re-emphasises the fact that basic survey data on habitats and species collected initially to support marine conservation objectives arising from policy commitments, can only really be interpreted and understood in the context of wider changes in the marine environment via long-term programmes.

Whilst the various legislative developments were providing the impetus for numerous marine surveys and impact assessments in the 1980s and 1990s, there were also important policy developments that clearly pointed to the urgent need for information from wider temporal and spatial scales. These issues

[91] Posford Duvivier Environment & Hill, M. I. (2001). Guidelines on the impact of aggregate extraction on European Marine Sites. Countryside Council for Wales (UK Marine SACs project)
[92] Gubbay, S. (2003) *Marine aggregate extraction and biodiversity: information, issues and gaps in understanding.* Report to the Joint Marine Programme of The Wildlife Trusts and WWF-UK.
[93] Select Committee on Environment, Food and Rural Affairs Minutes of evidence. (2004) Memorandum submitted by The Wildlife Trusts. UK Parliament Copyright 2004.
[94] The Wildlife trusts / WWF-UK (2003) *Discussion paper on Strategic Environmental Assessment*. The Wildlife Trusts / WWF-UK Joint Marine Programme.

would eventually lead to the decision being made that it was essential to continue, restart or initiate long-term marine monitoring programmes[1].

One of the most important of these developments was the increasing awareness of climate change (and, although more poorly recognised, the arrival of non-native species) as a potentially important environmental issue, which would need to be taken into account when investigating shorter term impacts. Thus, the Environmental Change Network (ECN) was set up in 1992 for terrestrial and aquatic systems for the purpose of being able to "*distinguish man-made change from natural variations and trends*"[95] precisely the information identified as crucial for marine conservation 20 years before (see above). The ECN was established because of the recognition of the "*scientific and policy value of data collected systematically from networks of monitoring sites*"[96] and because for terrestrial systems there was a "*wealth of long-term datasets…used to quantify the effects of environmental and ecological change"*[95]. This situation was in direct contrast to that for the marine environment where, as previously noted, funding for the few long-term datasets that did exist around the UK was being withdrawn and their scientific and policy value largely unrecognised.

At a global level, however, the response to climate becoming an increasingly important scientific and policy issue for the marine environment led to the creation, also in 1992, of the Global Oceans Observing System (GOOS). Whereas GOOS now encompasses all aspects of ocean management, not just climate, it was originally set up because "*understanding and forecasting climate change would require something more than the time-limited experiments of the WCRP* [World Climate Research Programme]"[97] In other words, long-term monitoring rather than short term data collection exercises were vital in order to understand and predict climate effects on marine ecosystems. GOOS, therefore, proceeded with the development and promotion of a global network of open ocean observations. The UK Global Ocean Observing System Action Group (GOOSAG) would eventually provide the guidance for the review leading to the formation of the MECN. Now, at the time of writing, with climate change high on the scientific and political agenda (the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) came into force February 2005), there is an even greater call for data from long-term marine observations in order to assess and predict the potential impacts on marine ecosystems.

The second major policy development in the 1990s, which had a significant affect on the type of data and monitoring programmes which would eventually be required, was the move towards an ecosystem-based approach. The original CBD in 1992 merely gave a definition of an ecosystem (under article 2 of the convention) as "*a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit*"[12]. The concept of the 'Ecosystem Approach' was then further developed and promoted through the 1995 Jakarta Mandate on Marine and Coastal Biodiversity and was eventually adopted formally by the CBD in May 2000[98]. Policy commitments to implement the ecosystem approach are now included in the reformed Common Fisheries Policy (CFP)[99]; the Bergen Declaration following the North Sea Ministers Conferences[100] and the Convention

[95] Parr, T. W. (1998). The UK Environmental Change Network. http://www.internet.edu/ilter_book/uk/ .
[96] Parr, T. W & Lane, A. M. (2000). United Kingdom: Environmental Change Network. http://www.ilternet.edu/ilter_book_2000/unitedkingdom.html
[97] A brief history of the Global Ocean Observing System (GOOS). http://www.ioc-goos.org/documents/GOOShistory.pdf
[98] Laffoley, D. d'A. et al (2004). *The Ecosystem Approach. Coherent Actions for marine and coastal environments*. A report to UK Government. Peterborough, English Nature. 65pp
[99] http://ec.europa.eu/comm/fisheries/reform/index_en.htm
[100] NSC(2002). Bergen Declaration. Fifth International Conference on the Protection of the North Sea 20–21 March 2002, Bergen, Norway. Ministry of Environment, Oslo, 170pp.

for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) where it is being advanced mainly via the development of Ecological Quality Objectives.[101] The European Water Framework Directive (WFD) (2000/60/EC) has also been developed to be highly compatible with the ecosystem approach[102] and more recently in 2005 the European Thematic Strategy (to be implemented through the proposed Marine Strategy Directive[103]) states clearly that "*the principle underpinning the strategy is the ecosystem-based approach*"'.[104] At a national level, the ecosystem-based approach has been adopted in the UK government's marine conservation policy agenda as developed in a series of reports from Defra's 'Safeguarding Our Seas'[4] in 2002 through to the current proposals in 2006 for a Marine Bill[105]. The Ecosystem Approach has, therefore, become fundamental to the formulation of marine policy at the global, European and national level.

As with all the previous policy initiatives discussed, information on *environmental change over wide spatial and temporal scales* has been highlighted as a prerequisite for the successful implementation of an ecosystem-based approach and for supporting ecosystem-based management. For example, the proposed European Marine Strategy Directive[103], for which the ecosystem-based approach is central, is proposing that 'good environmental status' is achieved for the marine regions by 2021. The definition of 'good environmental status' is recognised, however, as being "*dynamic and flexible"* due to the "*dynamic nature of marine ecosystems and their natural variability*"[106]. Basically, data from long-term monitoring programmes enables the setting of realistic targets for marine ecosystem status, as natural changes occurring in marine ecosystems can to be taken into account alongside those caused by anthropogenic impacts (which will be the target of management and mitigation efforts). This issue has also been highlighted by Hardman-Mountford et al.[20] with regard to the aims of the European WFD which aims for all aquatic ecosystems to achieve 'high status' or 'good status' by 2015. Once again, Hardman-Mountford et al.[20] point out that this can only be achieved by using long-term data to establish ecosystem baselines (and their inherent variation) against which disturbance can be measured (see Box 2). It is this 'context' that is provided by long-term data and is vital to underpin an ecosystem-based approach as clearly stated by NERC in its response to the Governments Sea of Change Consultation in 2002:[107]

"One area that might be strengthened is that such an [ecosystem-based] approach necessarily requires greater "contextual information", for example to define the ecosystem in question and its natural variability.[108]"

[101] OSPAR (2002) Background Document on the development of Ecological Quality Objectives (EcoQOs) for the North Sea. Ospar Commission ASMO 02/7/info.
[102] Laffoley, D. d'A. et al (2004). *The Ecosystem Approach. Coherent Actions for marine and coastal environments*. A report to UK Government. Peterborough, English Nature. 65pp
[103] EC (2005) Proposal for a Directive of the European Parliament and of the council establishing a framework for community in the field of Marine Environmental Policy (Marine Strategy Directive). COM (2005) 505 Final. SEC(2005) 1290)
[104] EC (2005) Annex to the communication from the commission to the Council and the European Parliament: Impact assessment. SEC (2005) 1290.
[105] Defra (2006) A Marine Bill: a consultation document of the Department for Environment, Food and Rural Affairs. March, 2006.
[106] EC (2005) Proposal for a Directive of the European Parliament and of the council establishing a framework for community in the field of Marine Environmental Policy (Marine Strategy Directive). COM (2005) 505 Final. SEC(2005) 1290)
[107] Defra (2002) Seas of Change. The Government's consultation paper to help deliver our vision for the marine environment. Defra, London.
[108] Comments from the Natural Environment Research Council on Defra's consultation: Seas of Change. See http://www.nerc.ac.uk/aboutus/consult/documents/SEERADResearch.pdf

The most recent development in UK marine policy and management is the move away from a sectoral approach where legislation and policy is developed in a piecemeal and *ad hoc* manner, to a more holistic approach[109]. Towards the end of the 1990s it was recognised that marine conservation policy with its reliance on the creation of a network of Marine Nature Reserves (MNRs) was not working,[110] so in 1999 the Review of Marine Nature Conservation (RMNC) was set up to report on this issue and suggest a better way forward. This report was delivered in 2004[111] and recommended a number of measures for improving marine conservation such as the implementation of Marine Spatial Planning and the creation of an ecologically coherent network of Marine Protected Areas (MPAs). It also identified some of the key issues that needed to be addressed regarding marine conservation, with the lack of baseline information from long-term observation programmes again being highlighted. For example, the RMNC report[111] examined information on status and trends in UK biodiversity and concluded that:

"*for the majority of species groups an assessment of population status and trends is problematic because of gaps in systematic surveillance.*" (our underlining)

The UK government agreed with the reports recommendations on improving marine environmental policy but also saw the reports statements on the *lack of baseline knowledge on ecosystems* as a major factor to be addressed. In a communication from the Parliamentary Office of Science and Technology (POST) that outlined some of the RMNC recommendations it was stated that:

"*For most marine species, it is difficult to assess the size of their populations or any trends because, with the exception of plankton and commercial fish stocks, there are few systematic sampling programmes. The lack of information is particularly acute for deep waters far from shore because of the very high cost of conducting biological surveys there. Long-term changes, such as those of climate change, can best be understood using long-term data sets, which can be costly and require long-term investment.*"[112] (our underlining)

As key recommendations of the RMNC such as the use of Marine Spatial Planning and the development of MPAs are now integral aspects of the proposal for a UK Marine Bill, it is of the utmost importance that the issues highlighted regarding the need for the monitoring of long-term change are addressed. Indeed, the Marine Bill consultation document[105] is explicit in the need for flexibility in both Marine Spatial Plans and MPA development due to the potential for long-term change in marine ecosystems in response to factors such as climate change (see Annex 2). It is clear, therefore, that information regarding long-term change is crucial in order to successfully implement key aspects of the work proposed as part of the Marine Bill. It is also important to note that even though the Marine Bill is still at an early stage as regards its development, the ecosystem-based approach along with adaptive management that can respond to the dynamic nature of marine ecosystems over long and short time-scales will continue to be integral to UK marine policy.

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[109] Boyes, S., Warren, L. & Elliot, M. (2003) Summary of Current Legislation Relevant to Nature Conservation in the Marine Environment in the United Kingdom. Report to JNCC from the Institute of Estuarine & Coastal Studies (IECS). Report ZBB604-F12-2003.

[110] DETR (1998) Sites of Special Scientific Interest: Better Protection and Management. DETR, London. See: http://www.defra.gov.uk/wildlife-countryside/consult/sssi/index.htm

[111] Defra (2004). *Review of Marine Nature Conservation. Working Group Report to Government*. Defra, 2004. 139pp.

[112] Parliamentary Office of Science and Technology. (2004) *Postnote: Marine Nature Conservation.* Number 234. December, 2004.

4.2 Marine Pollution

The previous section centred mainly on the need for long-term ecological data required in the light of policy and legislative drivers relating to marine biodiversity. Another major area of policy that needs to be considered, however, is that relating primarily to concerns over marine pollution. This is obviously of direct relevance to marine conservation but a large body of policy has developed that specifically addresses pollution issues. The relevance to marine environmental data and long-term observations is that in order to assess the UK's progress against the various targets arising from pollution policy and legislation, a number of monitoring programmes have been instigated that have resulted in a significant amount of data being collected[113].

Much of the legislation relating to pollution originated from the necessity, in the first instance, to establish greater control over potential pollution sources in UK waters such as ships and pipelines. There was also a need to create greater accountability when pollution incidents occur which led eventually to the 'Polluter Pays Principle' being fully incorporated into EU legislation. Early developments relating specifically to pollution included the International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL), which was agreed in 1954 even though at this time the potential danger to the marine environment from marine pollution was still not fully appreciated[114]. Once again, the Torrey Canyon disaster in 1967 was a major turning point and policy was further developed over the next three decades through the International Convention for the Prevention of Pollution from Shipping (MARPOL 73/78)[115] and through various Oil Pollution and Merchant Shipping Acts[116]. The United Nations Convention on the Law of the Sea (UNCLOS) in 1982 was also important in providing a framework for action on pollution from land-based activities, shipping and offshore installations.[78] This particular strand of legislation and policy on marine pollution mainly concerns prevention, however, and as it does not act as a significant driver for marine observations will not be considered further.

Of more relevance, as drivers for the need for marine environmental data and long-term observations, are the conventions and legislative drivers directly addressing marine environmental quality and for which assessments against various targets are required. Unlike the marine nature conservation sector which was initially driven by the need for broad-scale information on marine habitats and species (see Section 4.1), those concerned with pollution effects tended to focus survey and monitoring efforts on measuring specific impacts (e.g. contaminant levels in sediments, effects of sewage sludge dumping on biological diversity) and specific areas (mainly estuarine and coastal sites at and near affected sites). In 1974, the Department for the Environment (DoE) set up a Marine Pollution Monitoring Management Group (MPMMG) which oversaw much of the monitoring which was, at the time, being carried out on a fairly piecemeal basis. The MPMMG addressed issues of common standards and quality control and developed subgroups such as the Coordinating Group on Monitoring of Sewage-Sludge Disposal Sites (CGMSD) which was formed in 1987. The type of data collected were either measurements of certain parameters such as metal concentrations in waters for which predefined legal limits had been set, or biological and physical data which could be compared against an agreed set of targets such as

[113] For details of all monitoring programmes see: Footnote Reference (9)
[114] See 'History of MarPol (73/78)' at: http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258
[115] International Convention for the Prevention of Pollution from Shipping (MARPOL 73/78) http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258
[116] Details of the legislation can be obtained from various sources such as the UK Coastal Zone Law Website at http://web.uct.ac.za/depts/pbl/jgibson/iczm/notes/index.htm

Ecological Quality Objectives (EcoQOs)[117]. For example, for marine benthos at sludge sites, the objective of monitoring and data collection was merely to analyse the degree to which benthic diversity deviated from nearby control sites:[117] there was very little emphasis on environmental trends in the wider environment. The MPMMG was also involved in commissioning or advising on various other projects relating to pollution including monitoring of radioactivity, nutrients and fish farms.[118] Again, marine environmental data collected including contaminants tended to be specific to the project or area under study with no overall coordination of activities or reference to natural long-term change in the wider marine environment.

This *ad hoc* and piecemeal approach to monitoring was recognised as being unsatisfactory, however, and in 1987/88 the MPMMG carried out an assessment of monitoring in estuaries and coastal waters,[119] concluding that the best approach to UK monitoring would be to establish a network of regular sampling sites. The DoE in its formal response[120] accepted the need for a core programme of monitoring and this led in 1991-1995 to the development of a National Marine Monitoring Programme (NMMP, initially called the National Monitoring Plan (NMP)) in order to bring together previously patchy co-ordination of monitoring. Phase 1 of the NMMP was largely executed between 1993 and 1995 with further gaps being filled in 1996-1998;[121] Phase 2 began in 1999 and is ongoing. The sites chosen for Phase 1 of the NMMP generally corresponded to those established under the Oslo and Paris Commission's (OSPARCOM)[122] Joint Monitoring Group whilst offshore reference sites corresponded to those established by the North Sea Task Force[118]. The NMMP was an important development as, in addition to addressing issues of standardisation and quality control, there was for the first time an explicit aim to interpret data gathered for pollution monitoring purposes within the context of wider changes in the marine environment. For example, the first MPMMG report in 1991[119] stated that offshore reference sites, as well as acting as control sites for pollution assessment would:

"*also provide data on the natural variability of the marine environment, which could be used to give a clearer definition of contamination trends in affected areas*". (underline ours)

A key objective of the NMMP, therefore, was:

"*to measure long-term natural trends in physical, biological and chemical parameters in selected areas.*"[119] (underline ours)

Initially, however, the NMMP in its first phase focused largely on spatial trends but with sites being identified as suitable for long-term monitoring of temporal trends for NMMP Phase 2[121] as required by the International Convention for the Protection of the Marine Environment of the North East Atlantic

[117] MAFF (1989) First Report of the Marine Pollution Monitoring Management Group's Co-ordinating Group on Monitoring of Sewage-Sludge Disposal Sites. Aquatic Environment Monitoring Report No. 20. Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research. ISSN-0953-4466.
[118] MPMMG (1998) Towards 2000: Marine Monitoring in the 1990s. The 5th Report of the UK Marine Pollution Monitoring Management Group. Cefas, Lowestoft.
[119] MPMMG (1991) The Principles and Practice of Monitoring in UK Coastal Waters. A report from the Marine Pollution Monitoring Management Group. Cited in: NMMP (2003) UK National Marine Monitoring Programme: Green Book. www.marlab.ac.uk
[120] See: MEMG. (2004) UK National Marine Monitoring Programme. 2nd Report (Marine Environmental Monitoring Group).
[121] NMMP. (2003) UK National Marine Monitoring Programme: Green Book. www.marlab.ac.uk
[122] The 1972 Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (the OSLO convention) and the 1974 Convention for the prevention of Marine Pollution from land-based sources (the Paris Convention) were known as OSPARCOM from 1984, OSPAR from 1992.

(OSPAR Convention) 1992 (ratified 1998). The main driver for the NMMP monitoring was OSPAR's Joint Assessment and Monitoring Programme (JAMP)[123] but there was also overlap with some of the statutory monitoring required to support EC Directives. As stated in its second report,[120] the NMMP *"was designed to fulfil the UK's mandatory monitoring requirements under the OSPAR JAMP and provides data in support of EC Directives".* Regarding the various EC Directives, the main responsibility for monitoring and data collection fell to the National Rivers Authority (NRA) which was created as a result of the Water Act 1989 and subsequently incorporated into the Environment Agency (EA) as a result of the Environment Act 1995 (the same act led to the formation of the Scottish Environment Protection Agency (SEPA) for Scotland). EC Directives relating to water and environmental quality included the 1976 Bathing Waters Directive (76/160/EEC), the 1991 Urban Waste-Water Treatment Directive (91/271/EEC), the Nitrates Directive (91/676/EEC) and the Shellfish Directive (91/492/EEC).

As observed in the development of policy relating to marine biodiversity (see Section 4.1) pollution policy has also become more holistic in nature with the ecosystem-based approach being adopted. For example, many of the EC Directives relating to water quality and pollution are now integrated in to the Water Framework Directive (2000/60/EC). Other drivers concern requirements under the Birds Directive (79/409/EEC) and Habitats Directive (94/43/EEC) to ensure there are no adverse affects on designated SACs and SPAs from contaminants or other pressures. The importance of a more integrated strategy incorporating chemical, ecological and novel monitoring approaches is the preferred way forward[124]. This means it is no longer suitable to just collect data on a piecemeal basis, as in addition to pollution controls and setting emission limit values, the WFD requires a new monitoring and data collection approach (set out in Annex V of the Directive) suited to the aim of assessing progress towards 'good ecological status' and this will require the establishment of ecosystem baselines for the wider environment[20]. As with biodiversity monitoring, long-term data on contaminants, preferably integrated with biological observations, are needed to enable adequate assessments to be made.

This progression from basic pollution monitoring to a wider ecosystem-based approach can also be seen in the way that the OSPAR Convention has developed, with new targets for marine environmental quality again requiring a different approach to monitoring and data collection. In 1998 the Annex V addition on the 'Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area'[125] (ratified by the UK in 2000) gave prominence to an ecosystem-based approach. In 2003 OSPAR revised its strategies for JAMP (revised again 2005) including changing the approach to general marine environmental assessment and monitoring pollution impacts such as eutrophication and hazardous substances [126]. As a result of these changes, data from long-term marine observations will be crucial for the success of OSPAR's JAMP. This can be seen in the Environmental Assessment and Monitoring Committee's (ASMO) identification of a number of areas that need addressing as part of the ongoing JAMP including the necessity to take into account the effects of climate change (thus requiring long-term observations). The Quality Status Reports produced by OSPAR (2000) provided a valuable overview of the status of North-East Atlantic Regions as regards various pressures on the marine environment including pollution impacts such as eutrophication and input of radioactive

[123] Oslo and Paris Commission. 1995 (1997). The Joint Assessment and Monitoring Programme: as amended by ASMO 1997
[124] Langston, W. J., Chesman, B. S., Burt, G. R. Hawkins, S. J., Readman, J., and Worsfold, P. (2003). Characterisation of the South West European Marine Sites: Summary Report. Marine Biological association of the UK. Occasional Publication No. 14. pp112.
[125] http://www.ospar.org/eng/html/convention/ospar_conv10.htm
[126] http://www.ospar.org/eng/html/sap/jamp.htm

substances and metals.[127] A recurrent theme, however, particularly in the overall assessments was that there were major gaps in knowledge, for example, the contaminant time-series were unable to show any statistical trend due to "*imperfections in the nature of the data"*[128] and it was noted that for various assessments more detail on background / reference conditions was required. For the future, the JAMP strategy explicitly states that the information required for the success of JAMP includes:

"*establishing links between anthropogenic pressures and observed impacts and other changes in the marine environment"*[126]

with a key element in being able to achieve this understanding, being outlined in Section E of the strategy (Relationship between the JAMP and marine research), which states the need for research into:

"*the causes of long-term changes identified by monitoring programmes"*[126]. (underline ours)

It can be seen, therefore, that with regards to pollution monitoring, there has been a move from marine environmental data being collected on an *ad hoc* and piecemeal basis towards a more integrated and coordinated approach. Local pollution impacts can no longer be studied in isolation and as the rate of environmental change accelerates in response to factors such as climate change, there is a vital need for data from long-term observations. An example demonstrating the practical requirement of long-term data to establish baselines against which to measure pollution (in this case undesirable disturbance due to eutrophication) is given in Box 2.

Long-term studies also allow monitoring of rates of recovery and hence the efficacy of legislation and clean-up campaigns. Good examples are the recovery from contamination of Organotin based antifouling paints[129,130, 131, 132] and the recovery of estuaries following clean-up campaigns such as in the Mersey Basin[133] and also the Thames[134].

[127] http://www.ospar.org/eng/html/welcome.html
[128] OSPAR (2000) Quality Status Report 2000 for the North-East Atlantic. Chapter 6: Overall Assessment. http://www.ospar.org/eng/html/welcome.html
[129] Spence, S.K.; Bryan, G.W.; Gibbs, P.E.; Masters, D.; Morris, L.; Hawkins, S.J. (1990) Effects of TBT contamination on *Nucella* populations. *Functional Ecology*. 4 (3): 425-432
[130] Langston, W. J., Bryan, G. W., Burt, G. R. & Pope, N. D. (1994) Effects of sediment metals on estuarine benthic organisms. R&D Note 203. National Rivers Authority, 141pp
[131] Santillo, D, Johnson, P and Langston, W. J. (2001). Tributyltin (TBT) antifoulants: a tale of ships, snails and imposex. In: Late lessons from early warnings: The precautionary Principle 1896-2000, European Environment Agency, Environmental Issue Report No 22, Luxembourg: Office for Official Publications of the European Communities, 147-162. ISBN 92-9167-323-4
[132] Hawkins, S.J., Gibbs, P.E., Pope, N. D., Burt, G. R., Chesman, B. S., Bray, S., Proud, S. V., Spence, S. K., Southward, A. J. & Langston, W. J. (2002) Recovery of polluted ecosystems: the case for long-term studies. *Marine Environmental Research*. 54:215-222;
[133] Pope, N.D. Langston, W.J., Burt, G.R. & Chesman, B.S. (1998). A Survey of Trace Metals in Biota of the Mersey Estuary – 1997. *MBA Miscellaneous Publications*. 122pp.
[134] Langston, W. J., Pope, N. D., Chesman, B. S. & Burt, G. R. (2004) Bioaccumulation of Metals in the Thames Estuary-2001. Thames Estuary Environmental Quality Series No 10, 131pp

BOX 2: Example demonstrating the requirement for long-term monitoring programmes to establish environmental baselines

A useful example demonstrating the practical requirement for environmental baselines against which policy targets can be measured, and how long-term monitoring programmes enable these baselines to be established, concerns the specific policy commitment to prevent 'undesirable disturbance' produced by eutrophication. The main policy instruments addressing this are the EU Urban Waste Water Treatment Directive (UWWTD), Nitrates Directive, Habitats and Birds Directive, the WFD and OSPAR's 'Strategy to Combat Eutrophication' which all require measures to reduce these events. In order to identify 'undesirable disturbance' a major study was conducted by a consortium led by Herriot Watt University[135]. This study identified two difficulties in identifying eutrophication effects:

"recognising an undesirable disturbance against the background of great natural variability in plankton and benthos which appears to be characteristic of all those waters that have been studied in detail"[136] (our underlining)

and

"identifying the main cause of a disturbance which might result from nutrient enrichment, climate change, fisheries effects on nekton, fishing gear impact on the sea-bed, or toxic pollution"[136]

The study used examples of where these problems were being addressed by using information from a number of long-term time series. Examples used included the North Sea time series collected by the Dove Marine Laboratory (see section 2.14) and the Helgoland Bight time series (see section 2.16) both of which enabled the relative effects of long-term drivers such as climate change to be separated from other factors such as anthropogenic inputs and fisheries.

The conclusion of the study regarding the problem outlined above was that:

"the solution to both difficulties consists of long-term monitoring at a variety of sites covering a variety of ecohydrodynamic regimes and levels of pressure."[136] (our underlining)

This need for more parameters measured at more sites and over longer periods of time is being consistently emphasised by those with a responsibility to understand and manage impacts on the marine environment.

Another long-term time series, L4 at Plymouth (see section 2.7) monitors plankton and is used in the study to examine concepts related to a Plankton Trophic Index (PTI)[137]. This index quantifies the three-way balance between primary producers, protozoan consumers and metazoan consumers and can indicate a disturbance in the link between producers and consumers.

[135] Anon (2002) *Defra-funded study of Undesirable Disturbance*. See: http://www.lifesciences.napier.ac.uk/research/Envbiofiles/EUD.htm
[136] Anon (2002) *Defra-funded study of Undesirable Disturbance. Stage 1. Chapter 7: Pressures and Trends*. See: http://www.lifesciences.napier.ac.uk/research/Envbiofiles/EUD.htm
[137] Anon (2002) *Defra-funded study of Undesirable Disturbance. Stage 2. Chapter 2: Pelagos*. See: http://www.lifesciences.napier.ac.uk/research/Envbiofiles/EUD.htm

BOX 2: ……..continued

Data from L4 were used to determine 'normal envelopes of variation' for comparison with nutrient enriched waters of the same ecohydrodynamic type. This is only possible because the data from L4 are of sufficient temporal extent and resolution to allow reference conditions to be determined that take full account of natural variation at a range of scales. The report comments on how useful the time series are for establishing baselines:

"These data are extremely valuable. They exemplify what we suggest a long-term monitoring strategy should aim to measure at reference and perturbed stations in each major ecohydrodynamic type in UK salt waters"[137]

The report also comments on the precarious nature of the time series with regard to funding:

"Despite the insight that can be gained from a long-term data set, the L4 time-series has had to be maintained without a continuing source of funding"[137]

The issue of funding for long-term time series is particularly highlighted by the Undesirable Disturbance study because other key datasets used include the Port Erin time series in the Irish Sea, all of which are threatened due to problems with funding. This study provides a good practical example of why long-term time series are needed to address problems in establishing environmental baselines in order to measure undesirable disturbance. This is just one example, however, and there are numerous other examples arguing the case for long-term observations, particularly those concerning chemical and biological approaches[130, 132, 134, 138].

[138] Pope, N. D., Langston, W. J. & Burt, G. R. (1999) Trace metals in littoral biota from north west England – 1998. *PML Miscellaneous Publications*. 84pp.

4.3 Fisheries

Fisheries policy and legislation has developed, foremost, in line with concerns over the viability of maintaining productive fisheries. Advances in technology and the increasing ability of ships to travel long distances to fish meant that one of the first issues requiring legislation was that of access to fishing grounds. Disagreements over access, such as those between the UK and Iceland in the early 1970s, resulted in the formation of a number of Fisheries Limits Acts to establish access rights for UK waters.[139] Once limits were established, the actual management of fisheries in all European waters became the exclusive competence of the European Community (EC) with policy being developed, since 1983 through the Common Fisheries Policy (CFP). This policy is enforced in UK territorial waters through legislation developed at a national level with enforcement powers being provided by a number of acts including the Sea Fish (Conservation) Act 1967 and Sea Fisheries Act 1968 (both amended by Fisheries Act 1981).[140] As a result of the Sea Fisheries Act 1966, the responsibility for enforcement in inshore waters up to 6 miles falls to the Sea Fisheries Committees (SFCs), of which there are twelve for England and Wales.[141] Defra's Sea Fishery Inspectorate (SFI) is responsible for enforcement between six and twelve miles. Management and enforcement for Scottish and Northern Ireland inshore waters is undertaken by the Scottish Executive Environment and Rural Affairs Department (SEERAD) the Department of Agriculture and Rural Development (DARD) respectively.

As, therefore, the main objective of fisheries management and policy has been the conservation of fish stocks,[142] the requirement in terms of marine data and monitoring has largely been for information on the status of commercial fish populations. Data are required that can be used for stock assessments and the setting of annual Total Allowable Catches (TACs); namely, catch and effort data supplied to the International Council for the Exploration of the Seas (ICES). This data is of limited value as it has been observed that much of the data is of a very poor quality, with models developed using this data having a high range of uncertainty[143]. Extra data is supplied, however, from research surveys undertaken annually by CEFAS for England and Wales, the Fisheries Research Services (FRS) for Scotland and DARD for Northern Ireland. These surveys are important in providing fisheries independent data that yield extra information such as the abundance of young fish and the structure of fish stocks. Data from these research surveys, along with additional information from a number of scientific research projects were used for establishing baseline descriptions for regional fish assemblages (i.e. all fish, not just commercial species) for the 2005 State of UK Seas Report.[144] Holistic assessments of fish communities have, however, generally been lacking so OSPAR have proposed that Ecological Quality Objectives (EcoQOs) are established for fish communities using various metrics such as the proportion of large fish in a population.[144] This would give a useful approximation of the overall environmental status of fish communities (rather than just information on specific populations) but the difficulty with this approach is that changes in the proposed metrics may not be noticeable in the short term and that

[139] The Fisheries limits Act 1976 extended UK fisheries limits to 200 miles. This was subsequently amended by Fisheries Limits Order 1996 (SI 1997/1750) when Britain acceded to Law of the Sea Convention (August 1997) and Fisheries Limits Order 1999 (SI 1999/1741). Currently, British vessels have exclusive rights up to 6 miles offshore, all EC states have rights from 12-200 miles offshore and the 6-12 mile limit of UK waters is open to countries with historic rights of access including Belgium, France, Germany, Republic of Ireland and The Netherlands.
[140] UK Coastal Zone Law Notes at: http://web.uct.ac.za/depts/pbl/jgibson/iczm/notes/note9.htm
[141] Responsibility for enforcement in Scotland and Northern Ireland falls, respectively, to the Scottish Executive Environment and Rural Affairs Department (SEERAD) and the Department of Agriculture and Rural Development (DARD).
[142] King, M. (1995) Fisheries biology, assessment and management. Fishing News Books. Blackwell Science, London.
[143] Cabinet Office (2004) Net Benefits: A sustainable and profitable future for UK fishing. (Prime Ministers Strategy Unit).
[144] Defra (2005) Marine Fish and Fisheries: The Fisheries Agencies contributuion to Charting Progress – an Integrated Assessment of the State of UK Seas (The 4th of 5 Reports).

"*existing time series are generally too short to establish meaningful reference levels*"[144]. There are additional difficulties in separating changes in these metrics due to fishing effects from those linked to environmental factors and long-term time series are also required to address this[144].

One of the main difficulties in assessing status and trends for fish is that there has been an overwhelming focus on surveys and data collection relating to commercial fish stocks but with less attention being paid to non-commercial species and on integrating the monitoring of commercial fish stocks with changes in and impacts on the wider marine ecosystem. It was not until the 1990s that there was real movement towards integrating modern UK fisheries management with wider marine environmental concerns. Although there was nothing new in recognising the potentially adverse affects of fishing on the environment,[145] fisheries policy up to the 1990s had not generally included considerations of impacts on the wider marine environment. The key piece of legislation addressing this oversight was the Environment Act 1995 which enabled byelaws to be created specifically for marine environmental purposes. The Environment Act also expanded the role of SFCs to take on responsibilities linked to marine environmental initiatives on marine conservation. However, this was still only a small step in the right direction; no extra data collection or monitoring was needed in the light of these changes and fisheries policy and its supporting science was still focussed on fish populations rather than the ecosystem as a whole. There have of course been a number of scientific studies by those in the scientific community looking at the effects of different types of fishing on the environment and on regional biogeographic patterns[146] but as far as European fisheries policy[147] only the EC data collection Regulation (EC 1639/2001) directly addressed anything other than the target fisheries by requiring monitoring of discards. This was already being carried out in Scotland and Northern Ireland[144] and at least gave some additional information on impacts on the wider community.

It became increasingly obvious to policy makers and scientists that there needed to be further progress towards integrating fisheries with wider ecosystem considerations, as fishing by the end of the 1990s was "*increasingly regarded as an activity interacting with ecosystems*".[148] Therefore, in 2002 the first CFP (Regulation (EEC) 3760/92) was repealed and replaced by the reformed CFP ((EC) Regulation 2371/2002) for which the ecosystem-based approach is a fundamental component. Although a significant improvement, the reformed CFP is, at the time of writing, still at an early stage and in order to implement an ecosystem approach much more data will be required than is currently available, as "*the science needs of an ecosystem approach are much broader that those of fisheries science*".[66] Conservation organisations have also emphasised the need for a proper evidence base to support ecosystem-based management. For example, a recent report on inshore fisheries states:

[145] See early examples in : Mitchell, R & Hiscock, K. (1996) Historical perspective. In: H Hiscock, K. (ed.) (1996). *Marine Nature Conservation Review: rationale and methods*. Peterborough, Joint Nature Conservation Committee. (Coasts and seas of the United Kingdom. MNCR series)

[146] e.g. Rogers, S. I., Maxwell, D., Rijnsdorp, A. D., Damm, U. & Vanhee, W. (1999) Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. IV. Can comparisons of species diversity be used to assess human impacts on demersal fish faunas. *Fisheries Research*. 40:135-152.

[147] i.e. as opposed to general environmental policy. There is general EC environmental policy such as that relating to the Habitats Directive, which requires, for example, monitoring of fisheries for by-catch of cetaceans (Annex IV). Fisheries and environmental policy is not well integrated and in the UK, an additional problem that has been cited is the fact that fisheries policy is the exclusive competence of the EU whilst environmental policy is a mixture of policy developed at the International, European and National level.

[148] Mardle, S. et al. (2002) Objectives of fisheries management: case studies from the UK, France, Spain and Denmark. *Marine Policy*. 26: 415-428.

"*If the ecosystem approach* [to fisheries] *is to be successfully adopted, resources will be required for monitoring and scientific research capabilities, to provide data and information for evidence-based management*".[149]

Although progress has been made toward a more ecosystem-based approach, with the adoption of multi-species approaches and consideration of ecologically dependent species,[66] more data are needed to address key gaps in the knowledge of the dynamics and interactions between all major ecosystem components and the role of long term, extrinsic drivers such as climate change. Once again, long-term data series measuring a range of ecosystem components will be vital in addressing these questions and in helping to place fisheries into the context of changes in the wider marine environment. At a UK level, the issue of environmental integration is a key government objective as outlined in the 2004 report Net Benefits,[143] which stated the importance of better integration of environmental issues into fisheries management. The importance of environmental integration with fisheries has also been identified as a key area to be addressed by scientists and policymakers in Scotland[150] and Northern Ireland[151]. The Net Benefits report[141] suggested the way forward should include the fisheries sector incorporating adaptive management practices based on the use of EIAs and SEAs and that consideration should be given to MPAs as a tool for management. Most importantly in terms of data requirements, it is again noted that this will require understanding of environmental interactions that will have to be identified by broader marine scientific research:

"*Achieving better marine management will require closer co-ordination of fisheries and marine science, and a greater focus on broader marine environmental interactions.*"[143]

It is quite clear, therefore, that there is an urgent need for research into and long-term monitoring of marine ecosystems to inform fisheries management and to also allow scientists to better understand the impacts of fishing on different components of the ecosystem[152]. There must also be a long-term commitment to monitoring and data collection in order to be able to support a reformed CFP that aims to take into account 'fluctuations' by adopting a 'long-term approach' to managing fisheries.[153]

As noted in the Sections 4.1 and 4.2 of this report, the issue of climate change is currently the main factor driving the need for data from long-term datasets and time series. Climate has long been known to have an influence on fish distribution and abundance[154] but this factor can only be investigated through analysis of long-term data sets.[27] For example, long-term data from the Western English Channel combined with historical records have revealed shifts in distributions of species in warm and cold-water periods[155] and recent analysis of long-term data in the North Sea has revealed fish species

[149] Wildlife and Countryside Link (2005) Marine Bill Working Paper: The Future Management of Inshore Fisheries in England. September 2005. http://www.wcl.org.uk/downloads/2005/WCL07_Fisheries_WP2_13Sept_final.pdf
[150] Symes, D and Ridgway, S (2003) Inshore fisheries regulation and management in Scotland: meeting the challenge of environmental. Integration. Scottish Natural Heritage Commissioned Report F02AA405.
[151] Robinson, J. (2006) Achieving environmental integration for inshore fisheries in Northern Ireland: A short paper for consideration by the Review of Inshore Fisheries in Northern Ireland.
[152] Frid, C. L. J., Harwood, K. G., Hall, S. J. & Hall, J. A. (2000) Long-term changes in the benthic communities on North Sea fishing grounds. *ICES Journal of Marine Science*. 57 (5): 1303-1309.
[153] European Commission. Fisheries: Reform of the CFP. http://ec.europa.eu/fisheries/cfp/2002_reform_en.htm
[154] e.g. Southward, A. J. (1963) The distribution of some plankton animals in the English Channel Approaches. iii. Theories about long-term biological changes, including fish. *Journal of the Marine Biological Association of the United Kingdom*. 43: 1-29.
[155] E.g. Southward, A. J., Boalch, G. T. & Maddock, L. (1988) Fluctuations in the Herring and Pilchard fisheries of Devon and Cornwall linked to change in climate since the 16th Century. *Journal of the Marine Biological Association of the United Kingdom*. 68: 423-445.

moving northwards in response to increasing SST.[156] Climate, therefore, is an additional factor for policy makers and managers concerned with fisheries to take into account and being able to discriminate between the direct effects of climate on fish,[156] indirect ecosystem effects[25] and fisheries impacts is a major challenge as well as being politically sensitive.[157] It is notable that all current research into fish in relation to climate is based on *good quality long-term data sets* that measure a wider range of parameters than usually measured for fisheries assessments. Key examples are the work showing long-term changes in benthic and fish communities in the North Sea in relation to fisheries impacts and climate[22] (see Section 2.14) and work in the Bristol Channel and Western English Channel using long-term data sets (Section 2.8) to elucidate the effects of fisheries and climate on fish communities.[29] This ability to understand the relative affects of the various impacts and drivers is the real benefit of having fishery-independent long-term datasets. As stated in the State of UK Seas Fisheries and Habitats Report:

"*The use of long-term data sets to monitor changes, natural variation and cycles in marine ecosystems has attracted increased attention……with several long-term studies of fisheries data undertaken in recent years. Such data are useful for determining the effects of anthropogenic activities (e.g. fishing) and/or environmental characteristics (e.g. climate change) on fish demography*"[144].

More recently, the long-term data sets from the Western English Channel were used along with other fish time series in advanced ecosystem models to explore the effects of interactions between ecosystem components and the relative effects of fishing impacts and climate change on various trophic levels[52]. This is precisely the type of science that needs to be incorporated into wider fisheries management but there is concern that this type of information is still not being utilised for the development of fisheries policy[158].

As regards policy development, the aim of having a CFP that delivers a successful management strategy based on an ecosystem-based approach depends on the degree to which it can incorporate scientific research from the wider environment. As regards science and monitoring strategies, research into ecosystem interactions that allows anthropogenic and other drivers to be identified is only able to proceed if high quality long-term fisheries independent data sets are available. In essence, long-term ecosystem monitoring will be needed to answer questions regarding fisheries impacts on the environment (top-down), and how changes in the environment are affecting fisheries (bottom-up). Such an approach can also measure recovery of impacted areas following technical measures (e.g. reducing fishing effort or banning types of gear) and evolving policy on MPAs and inform restoration targets. Ultimately, assessment of whether the rate of biodiversity loss is being reduced and ecosystem functioning and provision of goods and services sustained can only be achieved by sustained observations of the whole ecosystem..

4.4 Summary: current status

So what is the current situation with long-term observations in the light of the urgent necessity for information on long-term change? The MECN clearly represents the beginnings of a "*long-term*

[156] Perry, A. L., Low, P. J., Ellis, J. R & Reynolds, J. D. (2005). Climate Change and Distribution Shifts in Marine Fishes. *Science*. 308: 1912-1915.
[157] Schiermeier, Q. (2004) Climate findings let fishermen off the hook. *Nature*. 428: 4
[158] This is not just a UK or European concern but concerns fisheries worldwide. See : Clark, B. M. (2006) Climate change: A looming challenge for fisheries management in southern Africa. *Marine Policy*. 30: 84-95.

investment"[112] in long-term marine observations. The need for information relating to long-term change in response to climate and other factors is, however, likely to become more urgent and gaps identified as a result of previous reviews will have to be addressed. Key recommendations regarding the future of long-term monitoring for the UK have already been outlined (see Section 3). It is likely that for financial reasons there may need to be a trade-off, so that the implementation of Marine Spatial Plans (MSPs) and MPAs is facilitated by a broad-scale network of long-term monitoring stations at a few selected sites from around the UK (i.e. well-funded, long-term time series at a few sites rather than many sites that are poorly resourced). This would appear the best way for the Government to achieve its aim set out in the Marine Stewardship Report (2002)[4]:

"*we will seek to provide support for both broad-based longer-term science and research to inform specific policy questions".* (our underlining)

To summarise, the 1980s and 1990s have seen vast amounts of marine environmental data being gathered, stimulated by concerns over the state of the marine ecosystem and in response to various policy developments. It has been demonstrated that there has always been a specific requirement for information on long-term change in marine ecosystems around the UK in order to address concerns over pollution, fishing and general conservation. It is now imperative that this need is addressed in order for the UK to be able to fulfil its policy commitments and manage marine ecosystems in the light of climate change and other factors.

ANNEX 1: MECN Pilot Phase Final Report: Executive Summary

Executive Summary

The recognition of the importance of long-term time series has been a fairly recent development. In 2002, the Inter-Agency Committee on Marine Science and Technology (IACMST) identified an urgent need for the continuation, restoration and enhancement of marine observations around the UK and, in response to this, the Marine Environmental Change Network (MECN) was established. This report outlines the findings of the pilot phase of the MECN from 2002 to 2005. The report outlines the original objectives and then shows how each of these objectives has been achieved.

The distinct role of the MECN is important in providing 'contextual monitoring' that informs 'compliance monitoring' and unique in that the time series being maintained by MECN partners are some of the longest of any marine time series in the world (decadal to multi-decadal). Through the network, these time series can be compared over a wide geographical range.

The MECN has grown significantly from 6 original members to a total of 17. Details of data collected by MECN members have been used to construct a metadata catalogue that is accessible through the MECN website (www.mecn.org.uk), which also provides a comprehensive search facility for the catalogue. Quality assurance of the data series has been reviewed to assess the accuracy of measurements and the comparability between different time series.

Annual monitoring reports have been prepared for the West Coast region by the Scottish Association for Marine Science (SAMS); for the Irish Sea by Port Erin Marine Laboratory (PEML); for the North Sea by Dove Marine laboratory and for the Western English Channel by Plymouth Marine Laboratory (PML) and Marine Biological Association (MBA). These reports are available as separate documents but a summary of key findings as a result of monitoring in each of the areas is provided.

Data from PEML have revealed a potential modification to the Irish Sea ecosystem as a result of long-term nutrient enrichment of the Irish Sea which, if confirmed, will be relevant to transitional and coastal waters covered under the Water Framework Directive.

The pilot phase of the MECN has highlighted the importance of long term time series and the need for allocation of more resources for long-term data collection if we are not to miss important changes in the marine environment, such as the rapid rise in sea surface temperature from the late 1980s onwards (particularly evident in the Irish Sea and English Channel) and the two regime shifts seen in the plankton (1988, 1997). It is now vital that the MECN continues to develop and expand as a network, making sure links are maintained and developed between the research community and other initiatives such as the terrestrial Environmental Change Network (ECN) and the Marine Climate Change Impacts Partnership (MCCIP). Continuation of the MECN will contribute to forecasts of future ecosystem changes and development of an Ecosystem approach to marine environmental management.

ANNEX 2. Marine Bill Consultation document[105]. Comments demonstrating the need for information on environmental change (particularly that which may occur in response to climate) to inform key proposals being made as part of a UK Marine Bill.

Chapter Title	Reference	
Planning in the marine area	P30: 8.3	'It [Marine Spatial Planning] should enable decision making to take account of the marine area as a whole and as far as possible, of the **unique and dynamic nature of that environment and factors affecting it, such as climate change'**.
	P37: 8.30b	'the need to apply marine spatial planning in a flexible way that recognises the uncertainties of future use requirements and **environmental responses and change'**
	P57: 8.96	'Plans are useful as long as they are relevant. They would need to be monitored, reviewed and revised at appropriate regular intervals. They would need to be sufficiently flexible to take account, as far as possible, of **environmental and other changes**, both anticipated and unanticipated. **Issues such as climate change which may result in alterations to the environment over time, would need to be considered** during the preparation of marine spatial plans to build in processes to enable the plan to adapt to those changes.
Improving marine nature conservation	P101: 10.63	'In recognition of our current levels of knowledge about marine ecosystems, the **mobile nature of the marine environment and the possibility of changes brought about by climate change**, we are considering how to build flexibility into the site designation process so that networks can adapt to changes in the features for which sites are designated.'
	P101: 10.66a	'a flexible mechanism [for marine protected areas] …would also make it easier to change the levels of protection within a site in response to improvements in scientific understanding or **changes in the protected features, such as those caused by climate change**.'
Annex 5C: Initial Regulatory Impact Assessment – Improving marine nature conservation	P220: 2.4	'The proposals [for new conservation measures] are also designed to provide measures that can help to ensure that marine ecosystems are sufficiently resilient to adapt to the **significant predicted scale of marine climate change which is likely to occur in the next few decades**'

ANNEX 3. Acronyms and abbreviations.

ADCP	Acoustic Doppler Current Profiler
AFBI	Agri-food and Biosciences Institute of Northern Ireland
ALSF	Aggregates Levy Sustainability Fund
ARC	Annual Report Card
ASMO	Environmental Assessment and Monitoring Committee
AWI	Alfred Wegener Institute for Polar and Marine Research
BAP	Biodiversity Action Plan
BODC	British Oceanographic Data Centre
BAS	British Antarctic Survey
CAVASSOO	Carbon Variability Studies by Ships of Opportunity
CBD	Convention on Biological Diversity
CCW	Countryside Council for Wales
CDOM	Coloured Dissolved Organic Matter
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CFP	Common Fisheries Policy
CGMSD	Coordinating Group on Monitoring of Sewage Sludge Disposal Sites
CPA	Coast Protection Act
CPR	Continuous Plankton Recorder
CTD	Conductivity-Temperature-Depth
HABES	Harmful Algal Bloom Expert System
DARD or DARDNI	Department of Agriculture and Rural Development in Northern Ireland
DASSH	Data Archive Seabed Species and Habitats
Defra	Department for Environment, Food and Rural Affairs
DETR	Department for Environment, Transport and the Regions
DoE	Department of the Environment (DETR after mid 1997)
EA	Environment Agency
EC	1) European Commission 2) European Community (archaic)
ECN	Environmental Change Network
EIONET	European Environment Information and Observation Network
EIA	Environmental Impact Assessment
EcoQO	Ecological Quality Objective
FEPA	Food and Environment Protection Act
FRS	Fisheries Research service
GEBCO	General Bathymetric Chart of the Oceans
GLOBEC	Global Ocean Ecosystem Dynamics
GOOS	Global Oceans Observing System
GOOSAG	Global Ocean Observing System Action Group
HAB	Harmful Algal Bloom
HF	High-Frequency
HPLC	High Pressure Liquid Chromatography
IACMST	Inter-Agency Committee for Marine Science and Technology
ICES	International Council for the Exploration of the Seas
JAMP	Joint Assessment and Monitoring Programme (OSPAR)
JNCC	Joint Nature Conservation Committee

Annex 3: ….continued

LargeNet	Large scale and long term Networking on the observation of Global Change and its impact on Marine Biodiversity
LISST	Laser *In Situ* Scattering and Transmissometry
LOIS	Land-Ocean Interaction Study
MarBEF	Marine Biodiversity and Ecosystem Functioning EU Network of Excellence
MarClim	Marine Biodiversity and Climate Change Project
MARPOL	International Convention for the Prevention of Pollution from Shipping
MBA	Marine Biological Association of the United Kingdom
MCCIP	Marine Climate Change Impacts Partnership
MECN	Marine Environmental Change Network
MDHC	Mersey Docks & Harbour Company
MNCR	Marine Nature Conservation Review
MNR	Marine Nature Reserve
MPA	Marine Protected Area
MPMMG	Marine Pollution Monitoring Management Group
MSP	Marine Spatial Plan
NMMP	National Marine Monitoring Programme
NMP	National Monitoring Plan
NBN	National Biodiversity Network
NCC	Nature Conservancy Council
NIOZ	Royal Netherlands Institute for Sea Research
NTSLF	National Tidal & Sea Level Facility network
NERC	Natural Environment Research Council
NOCS	National Oceanography Centre, Southampton
NRA	National Rivers Authority (Now Environment Agency)
OILPOL	International Convention for the Prevention of Pollution by the Sea
OSPAR	Convention for the Protection of the Marine Environment of the North East Atlantic
PAR	Photosynthetically Active Radiation
PEML	Port Erin Marine Laboratory
PGNSP	Planning Group on the North Sea Pilot Project (ICES)
PML	Plymouth Marine Laboratory
POL	Proudman Oceanographic Laboratory
POST	Parliamentary Office of Science and Technology
PTI	Plankton Trophic Index
QUASIMEME	Quality Assurance of Information for Marine Environmental Monitoring in Europe
REGNS	Regional Ecosystem Study Group for the North Sea
RMNC	Review of Marine Nature Conservation
RSDAS	Remote Sensing Data Analysis Service
SAC	Special Area of Conservation
SAHFOS	Sir Alister Hardy Foundation for Ocean Science
SAMS	Scottish Association for Marine Science (formerly the Scottish Marine Biological Association – SMBA)
SARDYN	Sardine dynamics and stock structure in the North-East Atlantic
SEA	Strategic Environmental Assessment
SEERAD	Scottish Executive Environment and Rural Affairs Department

Annex 3: ….continued

SEPA	Scottish Environment protection Agency
SFC	Sea Fisheries Committee
SFI	Sea Fisheries Inspectorate
SOS	School of Ocean Sciences, Bangor
SOO	Ships of Opportunity
SPA	Special Protection Area
SPM	Suspended Particulate Matter
SSSI	Sites of Special Scientific Interest
SST	Sea Surface Temperature
TAC	Total Allowable Catch
TOxN	Total Oxidised Nitrogen
UCW	University College of Wales
UEA	University of East Anglia
UKMMAS	United Kingdom Marine Monitoring and Assessment Strategy
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
UWWTD	Urban Waste Water Treatment Directive
WFD	Water Framework Directive
WGOH	Working Group on Oceanic Hydrography (ICES)
WCRP	World Climate Research Programme