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Review of current and historical seabed biological time-series studies in the UK and near Europe

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Executive summary

1. Ninety-two seabed biological surveys that include time-series data have been identified, reports and papers inspected, relevant persons questioned and a description of each study entered to a Microsoft® Access database.

2. All of the 92 datasets reviewed and detailed in the database include some information that is useful in interpreting temporal change and 36 datasets that include(d) data collected in a systematic manner over many years are identified that could form a part of a network of surveillance sites in the UK.

3. Many data sets indicate a high degree of constancy in the biotopes and species present at a location against a background of change in some component species. That change is often not synchronous between sites that are similar in character, making identification of 'reference' sites where natural change can be compared against change due to human activities difficult.

4. A further series of studies identified in the text but not generally included in the database are resurveys of locations sampled more than 50 years ago. Some of these surveys reveal changes most likely brought about by fishing and eutrophication.

5. Several datasets from single surveys are identified that might be repeated to indicate long-term change.

6. Many of the surveys undertaken to study effects of perturbation, usually pollution, provide information that is useful in identifying potential indicator species. Such information is needed to support work being undertaken towards implementation of the Water Framework Directive.

7. Where change has been described and interpreted, a short summary is included in the notes in the database. More work is required to catalogue those interpretations and to make them widely available.

8. The evidence collected suggests that some time-series studies may need to be undertaken over a period of fifty years or more if some natural fluctuations are to be identified.

9. It is inevitable that existing time-series studies will not provide the full network of sites that might be appropriate to monitoring change and obtaining contextual information to interpret change in SACs etc.

10. The authors are aware that the survey of time-series studies is not complete and encourage the continued input of information to the database.

1. Introduction to the review

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. The review described here was undertaken for the UK Joint Nature Conservation Committee to identify organisations that are carrying out or have carried out time-series studies that may contribute to a network of relevant observations. The study incidentally identified studies that might establish some general principles about stability and change in seabed communities and some of the species that may respond to particular perturbations.

To provide access to the all products of the review, further copies of this report are available for download. The metadata catalogue database is also presented through a series of searchable, dynamic web pages to allow the user to find the metadata of the studies described, assess the relevance of that study to their own requirements and contact the appropriate organisation for more information if necessary.

We also encourage feedback on any further studies to be added to this metadata catalogue. Please inform us of these through the appropriate form on the *MarLIN* web site.

http://www.marlin.ac.uk/time_series_metadata

2. Methods

2.1 Information sources

Studies were identified initially by:

1. Knowledge of project staff (especially Professor Steve Hawkins, Dr Keith Hiscock, Dr Nick Hardman-Mountford).
2. Studies referred to in the MNCR Benthic Marine Ecosystems volume (Hiscock, ed. 1998).
3. Studies listed in the UK Marine Environmental Database (UKMED; www.oceannet.org).
4. Web-based sources including: Aquatic & Fisheries Science Abstracts; Web of Science; BioMare review of biodiversity (monitoring) studies; National Marine Biological Library catalogue; Google search.

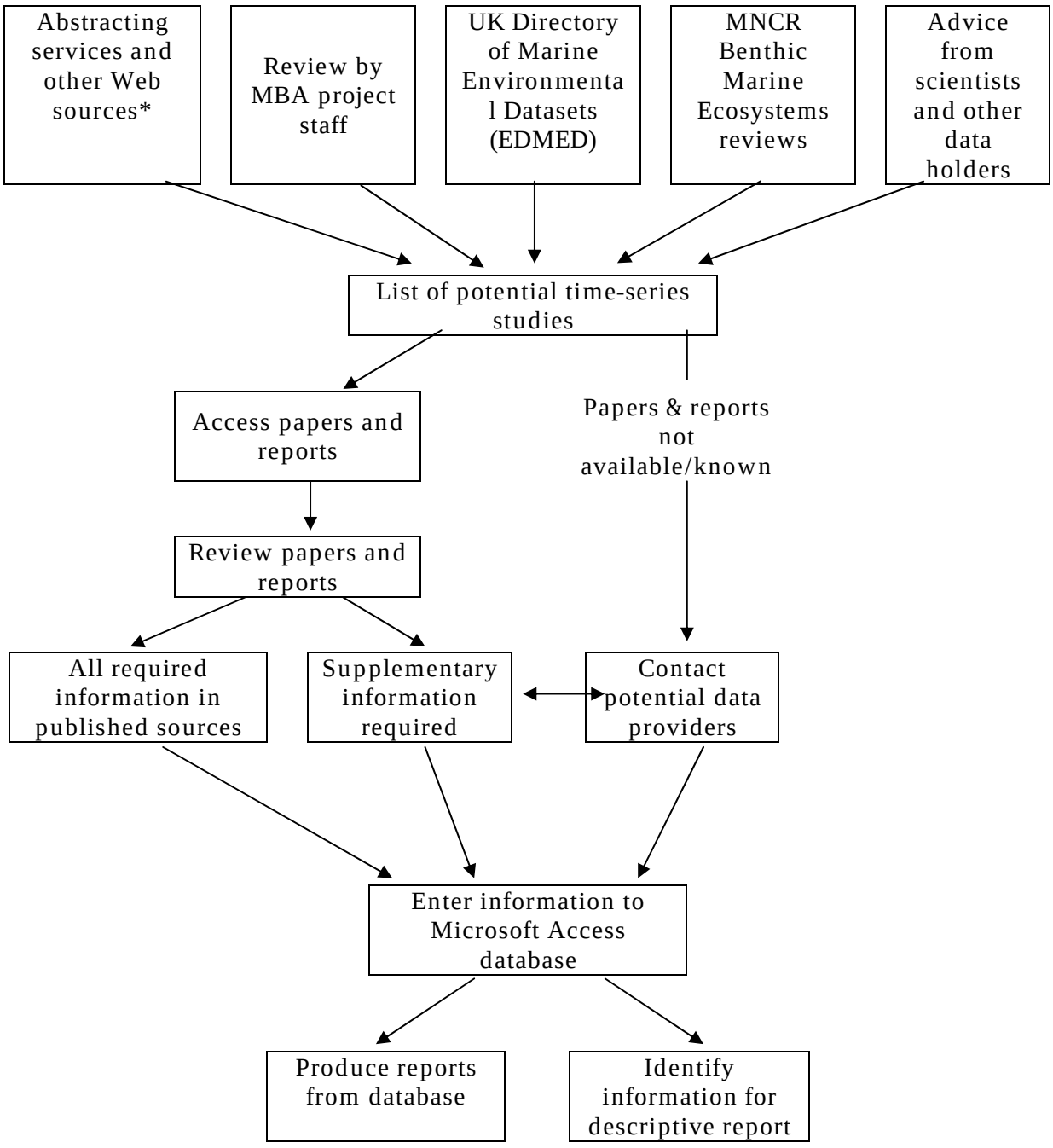
Further studies were identified as the project progressed especially through discussion with data holders. The UK Marine SACs Project series 'An overview of dynamic and sensitivity characteristics for conservation and management of marine SACs' also proved an authoritative source of information and reports in the series also review likely reasons for change in the selected habitats and species.

The process of obtaining and utilizing information sources is illustrated in Figure 1.

A more detailed review of a wide range of marine monitoring studies in Northern Ireland has been undertaken at the same time as this review for the Environment and Heritage Service (NI) by Posford Haskoning.

2.2 Information researched

The fields to be included in the database were ones that identified data holders, the status of the data, ones that were defined by the Joint Nature Conservation Committee in the contract specification, and others that were felt useful in describing the data set. Care was taken to use terminology and to ensure inclusion of fields that would make the information compatible with that being collected as part of the UK Marine Environmental Database (see: www.oceannet.org).



*Aquatic & Fisheries Science Abstracts; Web of Science; BioMare review of biodiversity studies; National Marine Biological Library catalogue; Google search

Figure 1. Process of accessing and utilizing data sources

A database was developed in Microsoft® Access to hold the information collected. The fields included in the database are listed in Appendix 1, which can also be used to create new records on paper prior to entry to the database. As much information as possible was obtained and entered to the database from published sources including limited circulation reports. Interviews were then held with data holders to complete fields for which published information was insufficient and to identify unpublished information. Studies were recorded as:

1. Current and suitable with data available in electronic format;
2. Current, suitable, data in report format;
3. Historical and possible to start again with all data available in electronic format;
4. Possibly suitable but not all data are available;
5. Unsuitable;
6. Other (name in 'Notes').

The database was used to generate information for the summary tables included in this report.

Information researched was restricted to that needed to complete database entries including a brief description of findings of time-series studies included in the 'Notes' section of the database. Some conclusions regarding the utility of datasets are given below but results of studies and reasons for change are not reviewed; the reader should refer to Clark and Frid (2001) for a recent review of long-term changes relevant to the North Sea.

2.3 Types of studies included

Studies to be included in the database were of seabed macrofauna and flora and have been selected using the following criteria:

- time-series studies undertaken over a long (>10 year) period usually at regular intervals (even if now terminated) (UK and Europe general);
- time-series studies undertaken sporadically but on-going (UK and Europe general);
- time-series studies undertaken for only a few years but where results are sufficiently detailed to identify significant change (UK).

Additionally, studies that were reviewed for mention in the report but not usually entered to the database, especially:

- studies that were repeat surveys from long-ago surveys (UK and Europe);
- studies that were one-off but where methods were well defined and the results could be used as a reference point and survey repeated (UK only).

Studies not included in the review were:

- surveys (even if declared as monitoring) where relocation would be impossible or difficult;
- studies of point source discharges or human impacts but where there was no element of repeat survey;
- descriptive surveys not designed to detect change and where methods (sampling, position fixing) were not rigorous enough to undertake resurvey.

2.4 The Microsoft® Access database

A database was designed to make entry of information as rapid as possible in a standardized entry format. The database provides a starting point for the production of customised reports depending on the requirements of the user. However, italics and emboldening as well as characters such as degrees (°), superscripts (e.g. ²) or accented letters (e.g. ö) will not be reproduced in reports from the Access database and, to facilitate any Web-based use, html tags were used in database entry.

The latitude and longitude entered are for the approximate centre of the survey area and separate positions for different survey sites have not been included.

In some cases, there are multiple limited circulation reports for the same project. As far as possible, the most recent report has been referenced and reference is given to any readily available publication in a journal or conference proceedings.

3. Results

3.1 Introduction

Appendix 1 summarizes the information accessed and entered to the database using selected fields from the database. The database has been copied to JNCC together with an electronic copy of this report. Figures illustrating change with time extracted from the reviewed studies are not included here but the reader is referred to Hiscock (1998) where examples of results of monitoring studies are illustrated.

Table 1. Number of time-series studies identified for each habitat listed in marine environmental protection imperatives. Some categories have been subdivided so that the types of habitats included in time-series studies match with habitats listed (for instance, Habitats Directive 'Reefs' is separated to intertidal and subtidal). Some studies were for more than one habitat type. Table 3 identifies datasets for each habitat category that may be suitable as part of a surveillance network.

Habitat	Habitat included in:			Number of time-series studies in database	Notes
	Habitats Directive	UK BAP Priority Habitat	OSPAR Threatened Habitat		
Mudflats and sandflats not covered by seawater at low tide / Mudflats / Intertidal mudflats	+	+	+	27	
Seagrass beds (intertidal) (*Zostera noltii)*	-	+	+	3	Occurs on Habitats Directive 'mud or sand flats'
Seagrass beds/*Zostera* beds (subtidal)(*Zostera marina*)	-	+	+	3	May occur on Habitats Directive 'sandbanks'
Estuaries	+	+	-	20	Usually overlaps with 'Mud or sand flats'
Large shallow inlets and bays	+	-	-	21	Will also include reefs, sand and mudflats etc.
Sheltered muddy gravels	-	+	-	1	
(Saline) Lagoons	+	+	-	1	
Reefs (intertidal)	+	-	-	15	Part of Habitats Directive 'Reef'
Littoral chalk (communities)	-	+	+	2	Part of Habitats Directive 'Reef'
Sabellaria alveolata reefs	-	+	-	1	Part of Habitats Directive 'Reef'
Ostrea edulis flat oyster beds	-	-	+	0	

Habitat	Habitat included in:			Number of time-series studies in database	Notes
	Habitats Directive	UK BAP Priority Habitat	OSPAR Threatened Habitat		
Reefs (subtidal)	+	-	-	17	
Sublittoral chalk (part of littoral and sublittoral chalk)	-	+	-	3	Part of Habitats Directive 'Reef'
Modiolus modiolus beds	-	+	-	3	Part of Habitats Directive 'Reef'
Sabellaria spinulosa reefs	-	+	-	2	Part of Habitats Directive 'Reef'
Serpulid reefs	-	+	-	0	Part of Habitats Directive 'Reef'
Tidal rapids	-	+	-	0	
Submerged or partially submerged sea caves	+	-	-	0	
Sandbanks which are slightly covered by seawater all the time	+	-	-	6	
Sublittoral sands and gravels	-	+	-	22	
Maerl beds	+	+	-	0	Part of Habitats Directive 'Sandbank'. See note on page 13
Mud habitats in deep waters	-	+	-	1	Possibly analogous to 'Seapen & burrowing megafauna' next
Seapen & burrowing megafauna	-	-	+	3	None listed but see comment on Irish Sea trawl surveys
Carbonate mounds	-	-	+	0	
Deep sea sponge aggregations	-	-	+	0	
Lophelia pertusa reefs	-	-	+	1	
Hydrothermal vents/fields	-	-	+	0	
Seamounts	-	-	+	0	
Submarine structures made by leaking gases	+	-	-	0	Analagous to 'Carbonate mounds' above?

Table 2. Environment Agency (England and Wales) time-series studies (non-NMMP) that include benthos. These studies are not separately included in the database.

Survey Title	Number of sites	Number of samples	Frequency per annum	Notes
Deben Benthic Quinquennial	8	40	1	Rolling programme
Great Ouse Benthic	8	40	1	1 survey day, every 5 years
HEC Benthic - Humber	11	55	1	
TiO2 Benthic - SCM Minigrid	13	65	1	
TiO2 Benthic - Tioxide Minigrid	20	100	1	
Wash Embayment Benthic Study	66	330	1	1991 and 2002
Wash Estuaries Benthic	11	55	1	
Boulby Benthic	72	360	1	Long-term dataset
TiO2 Directive - Tees Benthic	8	40	1	Long-term dataset
Mersey Estuary Benthic	18	90	1	One-off survey in 2002
DSD Sediments - Thames (Autumn)	12	12	1	
Thames Benthic Programme (Autumn)	6	30	1	
Thames Benthic Programme (Spring)	5	25	1	

3.2 Datasets included

The database includes the most significant studies that were identified and some minor studies. Several studies were not entered to the database because reports could not be obtained, personnel could not be contacted or they were considered minor. Those studies are included in the reference list.

The number of studies included in the database for each of the major categories used in the Habitats Directive, OSPAR 'Threatened habitats' and UK Biodiversity Action Plans are shown in Table 1.

The Environment Agency undertakes many of the National Marine Monitoring Programme surveys (which are not included in this review) and additionally a wide range of other time-series studies. Those studies which include sampling and identification of benthos are listed in Table 2 but are not separately included in the database.

3.3 UK datasets identified as candidates for a surveillance network

Taking account of the nature of each dataset in terms of availability of data, time-series already covered and relevance to the categories of habitat that are being identified for conservation action, Table 3 has been prepared.

Table 3. Time-series studies that could form a part of a network of surveillance sites in the UK. Studies are identified against the habitat types for which information is required. Specifically pollution studies are not generally included. The most recent or accessible reference is given. Contact details are for owners or custodians of data. For details of each study, reference to the database is essential.

Habitat	*Relevant studies*	*Notes*
Mudflats and sandflats not covered by seawater at low tide / Mudflats / Intertidal mudflats	Firth of Forth - long-term studies on an estuarine mudflat	**Reference:** McLusky *et al.* (1978). **Contact:** Dr Donald McLusky, University of Stirling (d.s.mclusky@stir.ac.uk)
	Kames Bay and Hunterston, Firth of Clyde	**Reference:** Barnett and Watson (1986) **Contact:** Dr Peter Barnett, University Marine Biological Station,Millport KA28 0EG
	Orkney sandy shores	**Reference:** Atkins *et al.* (1989). **Contact:** Environmental Unit Department of Harbours Orkney (eileen.summers@gwise.orkney.gov.uk)
	Wash and North Norfolk SAC - Littoral sediments	**Reference:** Yates *et al.* (2002). **Contact:** Marine Monitoring Officer, English Nature Peterborough.
Seagrass beds (intertidal) (*Zostera noltii)*	Moray Firth intertidal plants	**Reference:** University of Aberdeen (1981). **Contact:** None currently.

Habitat	*Relevant studies*	*Notes*
Seagrass beds/*Zostera* beds (subtidal)(*Zostera marina*)	North Haven, Skomer – monitoring the distribution and abundance of *Zostera marina*	**Contact:** Phil Newman (skomer.mnr@ccw.gov.uk)
	Fleet lagoon - seagrass and other species	**Reference:** Holmes (1993); Dyrynda (1997). **Contact:** Dr Peter Dyrynda, University of Wales Swansea (p.dyrynda@swan.ac.uk)
	Isles of Scilly sublittoral monitoring	**Reference:** Fowler and Pilley (1992). **Contact:** Marine Officer, English Nature Cornwall Office (roger.covey@english-nature.org.uk)
Estuaries	Great Ouse estuary - long-term biological monitoring	**Reference:** Bailey *et al.* (1999) **Contact:** Mike Bailey, Ecomaris Ltd. (mike@ecomaris.co.uk)
	Firth of Forth - long-term studies on an estuarine mudflat	**Reference:** McLusky *et al.* (1978). **Contact:** Dr Donald McLusky (d.s.mclusky@stir.ac.uk)
	The Wash - subtidal Benthic Surveys in the 1990's	**Reference:** Bailey *et al.* (2001) **Contact:** Mike Bailey, Ecomaris Ltd. (mike@ecomaris.co.uk)
	Northern Ireland Estuarine Classification	**Contact:** DoE(NI) Water Management Unit Lisburn (tim.mackie@doeni.gov.uk)

Habitat	*Relevant studies*	*Notes*
Large shallow inlets and bays	Milford Haven sublittoral sediments	**Reference:** Rostron *et al*, (1983). **Contact:** Milford Haven Waterway Environmental Monitoring Steering Group*
	Firth of Forth spatial study – taxonomic problems associated with long-term monitoring	**Reference:** Elliot and Kingston (1987). **Contact:** Susan Hamilton, Heriot Watt University (s.m.hamilton@hw.ac.uk) The Firth of Forth sublittoral surveys are being continued as a long-term study.
	Sullom Voe – subtidal sediment macrobenthos	**Reference:** May and Pearson (1995). **Contact:** The Secretary, Sullom Voe Oil Terminal Advisory Group (l.kingham@abdn.ac.uk)
	Strangford Lough benthic recovery time-series	**Reference:** Magorrian *et al.* (1995). **Contact:** Aquatic Service, Department of Agriculture and Rural Development NI (matt.service@dardni.gov.uk)
Sheltered muddy gravels	Lundy	**Reference:** Fowler and Pilley (1992). **Contact:** Marine Officer, English Nature, Exeter (chris.davis@english-nature.org.uk). Only time-series is for *Cepola rubescens*
(Saline) Lagoons	Fleet lagoon – seagrass and other species	**Reference:** Dyrynda (1997). **Contact:** Dr Peter Dyrynda, University of Wales Swansea (p.dyrynda@swan.ac.uk)

Habitat	*Relevant studies*	*Notes*
Reefs (intertidal)	Milford Haven rocky shore transects	**Reference:** Little (1983). **Contact:** Milford Haven Waterway Environmental Steering Group*
	South west England intertidal rocky shores survey (1954-1987)	**Reference:** Southward (1967). **Contact:** MarClim team (marclim@mba.ac.uk)
	Moray Firth – rocky shores	**Reference:** Terry and Sell (1986). **Contact:** Jan Russin, Talisman Energy (UK) Ltd., 163 Holborn Street Aberdeen, AB10 6BZ
	Lundy littoral monitoring	**Reference:** Fowler and Pilley (1992). **Contact:** Marine Officer, English Nature, Exeter (chris.davis@english-nature.org.uk)
	Sullom Voe – rocky shores	**Reference:** Moore *et al.* (1995). **Contact:** The Secretary, Sullom Voe Oil Terminal Advisory Group (l.kingham@abdn.ac.uk)
	Orkney - rocky shores	**Reference:** Baxter *et al.* (1985). **Contact:** Environmental Unit Department of Harbours Orkney (eileen.summers@gwise.orkney.gov.uk)
	Anglesey – rocky shores (Coastal Surveillance Unit)	**Reference:** Nobles *et al.* (1993). **Contact:** Marine Monitoring Officer, Countryside Council for Wales, Bangor (b.sanderson@ccw.gov.uk).
Littoral chalk (communities) (part of littoral and sublittoral chalk)		No time-series studies identified in the UK.
Sabellaria alveolata reefs		The surveys at Duckpool (Wilson 1971) could be re-started but would be considered a 'fresh start'.
Ostrea edulis beds		(Further investigations required especially shellfish surveys and surveys in the Fal.)

Habitat	*Relevant studies*	*Notes*
Reefs (subtidal)	Skomer Marine Reserve - photographic monitoring of subtidal epibenthic communities	**Contact:** Phil Newman (skomer.mnr@ccw.gov.uk)
	North Norfolk, England - fluctuations in the macrobenthos of a shallow-water cobble habitat	**Reference:** Chiminoides *et al*. (1995). **Contact:** Roger Bamber, Natural History Museum (r.bamber@nhm.ac.uk)
	Lundy sublittoral monitoring	**Reference:** Fowler and Pilley (1992). **Contact:** Marine Officer, English Nature, Exeter (chris.davis@english-nature.org.uk)
	Isles of Scilly sublittoral monitoring	**Reference:** Fowler and Pilley (1992). **Contact:** Marine Officer, English Nature Cornwall Office (roger.covey@english-nature.org.uk)
Sublittoral chalk (part of littoral and sublittoral chalk)		No time-series studies identified in the UK.
Modiolus modiolus beds	Shetland: channel between Calback Ness and Little Roe Island	**Reference:** ERT (Scotland) Ltd (2002) **Contact:** Environment Officer, Sullom Voe Oil Terminal (smithtj@bp.com)
Sabellaria spinulosa reefs		No time-series studies identified in the UK.
Serpulid reefs		No time-series studies identified in the UK.
Tidal rapids	Menai suspension bridge, telephone cable transect	No time-series studies identified in the UK. Repeat survey has been undertaken in the Menai Strait (Hoare and Peattie 1979).
Submerged or partially submerged sea caves		No time-series studies identified in the UK.
Sandbanks which are slightly covered by seawater all the time	Skomer Marine Nature Reserve - infauna of sediment	**Reference:** Barfield (1996). **Contact:** Phil Newman, skomer.mnr@ccw.gov.uk
	Red Wharf Bay sediment infauna surveys	**Reference:** Rees and Walker (1983). **Contact:** Ivor Rees, University of Wales Bangor (e.i.s.rees@bangor.ac.uk)

Habitat	*Relevant studies*	*Notes*
Sublittoral sands and gravels (Open coast/Offshore studies only included here – see other sediment time-series studies in estuaries and shallow inlets and bays)	Liverpool Bay benthic studies at dredged material disposal sites	**Reference:** Norton *et al.* (1984). **Contact:** CEFAS Burnham Laboratory (h.l.rees@cefas.co.uk). Selected sites, unaffected by dredge spoil disposal.
	Liverpool Bay sludge disposal benthos surveys	**Reference:** Rees and Walker (1991). **Contact:** Ivor Rees, University of Wales Bangor (e.i.s.rees@bangor.ac.uk) Selected sites, unaffected by sludge disposal.
	St Abbs sewage-sludge disposal grounds	**Reference:** Webster (1991a). **Contact:** SEPA Stirling (info@sepa.org.uk) Selected sites, unaffected by sludge disposal.
	Bell Rock sewage disposal ground	**Reference:** Webster (1991b) **Contact:** SEPA Stirling (info@sepa.org.uk) Selected sites, unaffected by sludge disposal.
	Northumberland – offshore subtidal sediments	**Reference:** Buchanan and Moore (1986). **Contact:** Dr Chris Frid, Dove Marine Laboratory University of Newcastle (c.l.j.frid@ncl.ac.uk)
Maerl beds		No time-series studies identified in the UK.
Mud habitats in deep waters		Possibly analogous to 'Seapen & burrowing megafauna' next
Seapen & burrowing megafauna		No time-series studies identified in the UK.
Carbonate mounds		No time-series studies identified in the UK.
Deep sea sponge aggregations		No time-series studies identified in the UK.
Lophelia pertusa reefs		No time-series studies identified in the UK.
Hydrothermal vents/fields		No time-series studies identified in the UK.
Seamounts		No time-series studies identified in the UK.
Submarine structures made by leaking gases		No time-series studies identified in the UK.

* Additionally, Milford Haven datasets collected by the Field Studies Council Oil Pollution Research Unit were transferred to BMT Cordah Ltd and may be available from their Aberdeen office. Copies of data are also maintained by Jon Moore (Coastal Assessment, Liaison & Monitoring: CALM, Pembroke Dock).

3.4 Review of current and historical initiatives

Review of current and historical initiatives

Overview. The review undertaken has identified a wide range of studies, few of which are part of a countrywide or European-wide programme. Most have developed methods appropriate to the questions being asked at a particular location but will still have produced results that illustrate general principles of change and stability of species and communities in various habitats. However, attention is drawn to the COST 647 programme of 'Long-term changes in coastal benthic communities' and the volume of *Hydrobiologia* (Heip *et al*. 1986) that describes results from a range of studies. With funding from the European Commission, it was possible, for five years from 1979, to bring together workers from different countries to agree on common approaches to undertaking time-series studies for specified communities in subtidal rock, intertidal rock, subtidal sediment and intertidal sediment habitats. Each country had to fund its own research and, in the event, few projects were really 'joined-up'. Nevertheless, some common changes with time were identified, for example, in subtidal rock habitats in Sweden and Norway (Lundälv and Christie 1986).
Bearing in mind that most interest in contextual information on change will be for habitats and species for which there are legally or politically based reporting requirements, the following points are made:

1. **'Mudflats and sandflats not covered by seawater at low tide'/ 'Mudflats'/ 'Intertidal mudflats'** including those that would fall into the categories '**Estuaries**' and '**Large shallow inlets and bays**' and include intertidal '**Seagrass beds'**, are surveyed at a large number of sites. Many studies have been undertaken to identify impacts of pollution but have also documented change with time at unpolluted sites. They include the Firth Of Forth studies (for instance, McLusky *et al*. 1978) and the Orkney studies, Jones 1985).The unpublished datasets collected from sandy beaches at Kames Bay, Isle of Cumbrae and on the opposite mainland shore at Hunterston are worth more attention (see Barnett and Watson 1986). Studies undertaken in the Wash (Yates *et al*. 2002) could become a significant data set if undertaken on a regular basis. Some of the longest-running studies have been undertaken in continental Europe. They include valuable long-term data sets and analysis of data published by Dörjes *et al.* 1986) and Beukema (1992) from the Wadden Sea. There are also unpublished long-term data sets collected by Dr Karsten Reise and colleagues for the Island of Sylt that would be worth further enquiry.

   Intertidal '**Seagrass beds**' (*Zostera noltii* mainly) have been surveyed and resurveyed in the early 1980's in the Moray Firth (University of Aberdeen Department of Geography, 1981) but no recent surveys are known. Intertidal areas of *Zostera marina* have been surveyed on-and-off since the early 1980's in the Helford (Sutton and Thomsett 2000) but detailed information on the study has not been entered to the database.
   Whilst we feel that major surveys have been identified, there are so many limited duration surveys including ones that have been undertaken locally and may not be documented at the national sources visited, that more studies will doubtless be discovered. Also, the very large number of surveys undertaken locally by the Environment Agency were not possible to document fully, although JNCC have been provided with a copy of the survey catalogue.

2. **'Inshore sublittoral sediments'** including those that would fall into the categories **'Estuaries'** and **'Large shallow inlets and bays'** and include **'Sandbanks which are slightly covered by seawater all the time', 'Sheltered muddy gravel'** and subtidal **'Seagrass beds'** are surveyed at a large number of sites with, perhaps, the most long-term being in Sullom Voe (see May and Pearson 1995). Information collected from Liverpool Bay during surveys of impacts of dredge spoil and sewage sludge disposal could be a particularly useful dataset but little material is published (see Norton *et al.* 1984 and Rees and Walker 1991) and sites apparently unaffected by dumping would need to be identified. The Tees estuary dataset is another significant one (Tapp *et al.* 1993) and the work being undertaken at Skomer (various unpublished reports, contact CCW, Skomer) will become a significant dataset if surveys are undertaken regularly. The National Marine Monitoring Programme includes the widest geographical spread of sites with many in estuaries. However, there is low correspondence between NMMP locations and cSACs. Many of the surveys identified were undertaken in relation to environmental impact assessments especially in the vicinity of outfalls (sewage and industrial). Whilst the studies undertaken in the Crouch Estuary by Rees *et al.* (1999) and Waldock *et al.* (1999) following banning of TBT anti-fouling paints provide valuable information of the impact of contaminants on infaunal and epifaunal species there, at present we have not included them as 'time-series' studies in the database, as they are not aimed at detecting natural fluctuations.

   'Seagrass beds' have been mapped, surveyed and in some areas subjected to time-series studies. Not all studies are included in this review and, for a more complete review for the UK, refer to Davison and Hughes (1998).
   Whilst we feel that major surveys have been identified, there are so many limited duration surveys including ones that have been undertaken locally and may not be documented at the national sources visited, that more studies will doubtless be discovered. Also, the very large number of surveys undertaken locally by the Environment Agency were not possible to document fully although JNCC have been provided with a copy of the survey catalogue.

3. **'Sheltered muddy gravel'** habitats may be amongst the richest intertidal and subtidal habitats but no studies have been found that specifically include time-series observations for the communities present. The muddy gravel off the east coast of Lundy has been resurveyed to assess status of the red band fish, *Cepola rubescens*, populations but not for other species.

4. **'Lagoon'** habitats have been revisited by experienced workers from time-to-time, but only in the Fleet (see Dyrynda 1997) is research considered to be systematic 'time-series' studies (Dr Richard Barnes, University of Cambridge, personal communication). Nevertheless, information in reports such as Bamber (1998) often includes observations on change and survey data that could be subject to repeat survey.

5. Intertidal **'Reef'** habitats have been surveyed at several locations and some studies are very detailed. The outstanding study is that undertaken between 1973 and 1983 by the Coastal Surveillance Unit in North Wales: Nobles *et al.* (1993). The Coastal Surveillance Unit visited sites at monthly intervals. Other long-term studies have been undertaken annually (see Moore *et al.* 1995 for Sullom Voe and Baxter 1985 for Orkney) and are continuing. Many others (for instance in Milford Haven: Little 1983) are undertaken every-so-often whilst others, for instance in the Moray Firth (Terry and Sell 1986) were only undertaken for a few years and are no more. There are also long-term studies stretching back 40 years or so on barnacle assemblages including four species and documenting changes in northern and southern species in relation to climate change (see, most recently, Southward 1991; the studies are being continued as a part of the MarClim project). Time-series studies on rocky shores, together with experimental

studies, provide significant information about scale of change that occurs there and degree of synchrony of change.

6. **'*Sabellaria alveolata* reefs'** have been extensively studied (Caline in Larsonneur 1994 and l'Homer and Larsonneur in Larsonneur 1994) in the Bay of Mont-St-Michel in France and include time-series studies on the formation and duration of reefs reported by Wilson (1971). The surveys and synthesis of old data undertaken by Cunningham *et al.* (1984) provide a starting point for surveys of distribution and abundance throughout Britain

7. **'*Ostrea edulis* beds'.** It is widely known that oyster beds have declined greatly in abundance and many beds that existed in the 1920's have disappeared. Surveys have been undertaken in the Solent (every year since 1970) and in the Fal (every year from 1971 to 1984, in 1986 and 1988 and in 2001 and 2002) by the Centre for Environment Fisheries and Aquaculture Science (CEFAS). Oysters and other commercial species and pest species are surveyed and notes made on the occurrence of some other species. There are no public-domain publications and no entry has been made to the database. (Dr Peter Walker, CEFAS, Lowestoft, personal communication).

8. Subtidal (rocky) **'Reef'** habitats have been surveyed between 1984 and 1991 at Lundy and Scilly (see Fowler and Pilley (1992) but have been set-aside before data sets became long-term. The studies at Skomer (Bullimore 1986) are long-term, results are being analysed at present and the studies continue. The most significant studies are from Scandinavia but have had limited analysis and publication (see, for instance, Lundälv 1986).

9. Horse mussel **('*Modiolus modiolus*')** beds are a significant type of reef with high biodiversity and very high sensitivity to certain factors. One very significant study (ERT Scotland Ltd 2002) of a horse mussel reef at Calback Ness in Shetland is currently being prepared for publication in a scientific journal. Studies in Strangford Lough (see Magorrian *et al.*, 1995) are notable but require further analysis of samples and data.

10. **'*Sabellaria spinulosa* reefs'**, whether as true reefs (domed structures rising above the seabed) or as crusts, have been little studied as time-series. The papers by Reisen and Reise (1982) and Reise and Schubert (1987) indicate a significant decline in reefs in the Wadden Sea and suggest, from resurveys of locations sampled in the 1920's, that shrimp trawling caused loss of the reefs. However, attention is drawn to the experimental studies undertaken by Vorberg (2000) which suggested that trawling was unlikely to destroy the reefs.

11. **'Serpulid reefs'.** Whilst there is evidence of loss of serpulid reefs from Loch Sween (Holt *et al.*, 1998; Dr Colin Moore, Heriot Watt University, personal communication) time-series studies have not been undertaken in the only known UK location for live reefs, Loch Creran, although methodologies are currently being investigated (Dr Colin Moore, personal communication).

12. **'Tidal rapids'** and **'Submerged or partially submerged sea caves'.** No time-series studies have been found except the resurvey after 20 years of the tidal sound communities in the Menai Strait by Hoare and Peattie (1979).

13. **'Sublittoral sands and gravels'** (a Biodiversity Action Plan Habitat) are those that are within the six nautical mile limit of territorial seas for the purpose of the BAP. They will include the Habitats Directive category '**Sandbanks which are slightly covered by**

seawater all the time' although maerl is considered separately as a BAP. There are many studies (see 2. **Inshore sublittoral sediments**) that will provide information on temporal change in this habitat including ones that point to sensitive and tolerant species in relation to changing environmental conditions and perturbations. Other notable studies in addition to those recorded in 2. are the ones studying sewage sludge dumping at St Abbs and Bell Rock (Hull and Webster 1991) which ceased in 1991 and the long-term data set from off Northumberland (Buchanan and Moore 1986). More short-term studies including sampling from reference sites over several years have been undertaken in relation to aggregate extraction (Kenny and Rees 1996). Survey is being continued at some aggregate extraction sites as time-series study although extraction has ceased (Dr Hubert Rees, CEFAS, Burnham, personal communication).

14. **'Maerl beds'** substrata and associated communities have few long-term studies. However, seasonal changes have been studied by Cabioch (1969) and by Maggs (1983). A 10-year time-series study of species composition and biomass of maerl beds in the Bay of Brest which has a reference point from 30 years ago is being prepared for publication (Jacques Grall, University of Brest, France, personal communication).

15. **'Mud habitat in deep water'** and **'Sea pen and burrowing decapods'** habitats are typically areas where the prawn *Nethrops norvegicus* occurs and those areas are therefore subject to fisheries. Repeat surveys being undertaken in Northern Ireland and off the Cumbrian coast will identify changes in species that are sampled using fine mesh trawls (Dr Matt Service, Department of Agriculture and Rural Development Northern Ireland, personal communication; Briggs and Service 2002). There may be other studies being undertaken by fisheries laboratories that we have not identified.

16. Offshore sediments are not included in the categories within the directives, statutes and conventions that generate the need for time-series studies in relation to monitoring obligations, except where habitats can be regarded as '**Sandbanks which are slightly covered by seawater all the time'**. Nevertheless, a great deal of useful information about widespread species and about biotopes resides in these offshore datasets.

    The United Kingdom Offshore Operators Association (UKOOA) database of offshore data includes information from 472 reports from 511 surveys known to have taken place between 1975 and 1998. The data is incorporated into a database that is generally available on CD-ROM (see: www.ukooa.co.uk/issues/ukbenthos). In view of the large number of datasets available, the database prepared to support the current study has only one entry to refer to the entire dataset. Kingston *et al.* (2001) undertook analysis of the datasets and report that 20 'cases' from the UKOOA dataset were surveyed more than once and the fauna recorded. Appendix 16 of the report identifies the area of 19 different platforms where data was analyzed for time-series information. However, the type of analysis undertaken (see below) does not translate into information on levels of change in species or biotopes with time. Multiple pre-operational surveys are reported for Forties, Maureen, Murchison and Hutton oil fields. The report does not identify long-term changes in fauna but concentrates on extent of possible impact by oil industry activity and identifying areas of contamination by hydrocarbons. The report identified a need for an "industry agreed standard for monitoring surveys that ensures that the data obtained can be used for a wider, more integrated approach to assessing environmental impact".

    Extensive surveys of sediment benthos have also been undertaken in the Norwegian oilfields (see Olsgard and Gray 1995) and analysis of the data is being continued.
    For most surveys of offshore sedimentary benthos, analysis of the data is undertaken to provide indices of diversity (the index is not of species richness) and, using multivariate statistical procedures, to demonstrate trends in data. However, the most useful interpretations in relation to nature conservation studies are ones where changes

in species abundance are described, especially drawing attention to those species that are highly variable and those that are highly constant in their presence and abundance. Olsgard and Gray (1995) identify several species that appear to have been adversely affected or are tolerant of discharges from oil production platforms.

17. **'Carbonate mounds', 'Deep-sea sponge aggregations', '*Lophelia pertusa* reefs', 'Seamounts'** and **'Hydrothermal vents/fields'.** These are all deep-water habitats that have been little studied and where time-series observations will be difficult to undertake. One study of *Lophelia pertusa* structures off Sweden includes time-series observations (Thomas Lundälv, Tjaernoe Marine Biological Laboratory, Sweden, personal communication). The BioMare review of monitoring studies suggests that there is a time-series study of a seamount off the Azores. Hydrothermal vent communities are subject to some time series observations including growth rate studies at marked locations off the Azores (Lynda Dixon, Marine Biological Association, personal communication) and further information can be obtained from Dr David Dixon and Professor Paul Tyler, Southampton Oceanography Centre.

3.5 Datasets that are available for analysis and suitable to include in a UK-wide surveillance programme

Existing datasets from locations that could contribute to a network of sites for surveillance of change in habitats that are included in directives and conventions are listed from the database in Appendix 2. However, some datasets may only prove suitable or may prove unsuitable when the raw data is inspected (there has been no significant inspection of raw datasets in this project). Overall, there are a small number of datasets immediately available and obviously suitable. These datasets are listed in Table 3.

Whilst it might seem attractive to continue existing or recent studies, it may be far more useful to see those existing or recent studies as providing context to interpreting the results obtained from a customized network of surveillance sites being surveyed in the same way at the same time of year and concentrating effort in marine protected areas. Nevertheless, it is notable that many NMMP sites 'took-over' from surveillance sites existing when the NMMP was commenced over 10 years ago.

3.6 Datasets and other information sources not included

The UK National Marine Monitoring Programme

The National Monitoring Plan (now called the National Marine Monitoring Programme) was initiated in the late 1980s to co-ordinate marine monitoring in the United Kingdom between a number of organizations. The NMMP aims to detect long-term trends in the quality of the marine environment, to ensure consistent standards in monitoring, to establish appropriate protective regulatory measures, to co-ordinate and optimize marine monitoring in the UK, and to provide a high quality dataset for key variables.

Stations, methods and reports are well documented and JNCC is a member of the National Marine Monitoring Programme Working Group. The separate survey locations sampled as a part of NMMP are not therefore catalogued in the database developed for this study. Information on the NMMP can most readily be found on www.marlab.ac.uk.

FEPA (Food And Environmental Protection Act) Monitoring

There are approximately 100 licenced sites where dumping or modification to the seabed is permitted under FEPA (Food and Environment Protection Act) licence. The responsibility for monitoring sites is undertaken by the Centre for Fisheries and Aquaculture Science (CEFAS). Surveys are highly focused on assessing impact and the approach adopted at each site is often pragmatic so that, following clarification of the nature of FEPA surveys with CEFAS staff, it was decided not to investigate the surveys as potential sources of time-series data.

Determination of the Ecological Consequences of Dredged Material Emplacement (DECODE)

Attention is drawn to the above project which commenced in 2000 as significant monitoring studies are undertaken in association with the work. DECODE is aimed at identifying the beneficial use of maintenance dredged material. More information can be found on http://www.cefas.co.uk/decode.

Studies of single species

There are several studies that have sampled occurrence, abundance, size-frequency and reproductive status of populations of a species or small group of similar organisms either at a particular location or at a large number of locations over several years. Such detailed attention is needed for species that require expert identification (for instance, to differentiate between the two species of *Chthamalus* or the three species of *Patella*). Results from the following studies provide significant information on change with time in species:

Tellina tenuis	Barnett and Watson (1986)
Patella species	Bowman and Lewis (1986)
Gibbula umbilicalis	Kendall and Lewis (1986).
Barnacle species	Southward (1991), Southward *et al.* (1995)

There is significant information on changes in the proportions of different *Patella* species especially from south-west England which is being prepared for publication (Dr Rebecca Leaper, MarClim project MBA Plymouth, personal communication).

Datasets and information identified but not accessed

Access to some information that might be useful time-series data was not possible within the time available to produce this report. Attention is drawn particularly to Dan and Mulder (2000) for studies in the Dutch North Sea and to studies in the Ythan Estuary (see, for instance, Raffaelli *et al.* 1989, 1999).

3.7 Recently started studies and datasets not yet available

The Forth Estuary Environmental Assessment Programme (FEEAP) will undertake benthic sampling over the period 2000-2010. The Marine Biological Association will re-sample some of the locations sampled in the 1920's and 1950's by MBA staff, a contribution to the resurvey of historical sample locations. The trawl surveys of bycatch from *Nephrops* grounds off Cumbria and Northern Ireland (Briggs and Service 2002) are noted but data is not yet sufficiently available to include a record in the database. Whilst sites in the German Bight have been sampled regularly since 1969, little information has been published. However, in a symposium 'Food for thought: structuring factors of shallow marine coastal communities' held in November 2001, a paper was presented (Schroeder *et al.* in press) on community dynamics in the German Bight and publication is expected in the Journal of Sea Research.

CEFAS are continuing studies of aggregate extraction sites where aggregate extraction is no longer carried out. The aim is to ensure time-series data for coarse sediments as NMMP sampling is biased towards fine sediments. The data is required as a background to assessing impact of dredged areas. (Dr Hubert Rees, personal communication.)

3.8 Resurvey of historical sample locations

Studies undertaken once but in a systematic quantitative way more than 30 years ago may provide opportunities to identify significant changes or degree of constancy in seabed communities. Some such resurveys have been undertaken and provide valuable information on the degree to which historical data can be used to identify constancy or change. Such studies have not been included in the database as they are 'repeat surveys' rather than 'time-series' but they are highly relevant to understanding the "but is it still the same today?" question.

For the chalk coasts of Thanet, Tittley *et al.* (1998) refer back to records made at Margate in 1632, to surveys of chalk cliff and sea cave flora from the 1930's and to recent surveys to suggest long-term stability in the key features of marine vegetation at Margate. Boalch *et al.* (1974) undertook a resurvey of a rocky shore transect at Wembury in south Devon after 40 years. Other examples include resurveys of the sites surveyed by Gislén (1930) in the Gullmar Fjord (Svane and Gröndahl 1988), intertidal areas of the Wadden Sea after 55 years (Reisen and Reise 1982), of subtidal areas of the Wadden Sea after 60 years (Reise and Schubert 1987), Loch Riddon after 53 years (McLusky and Hunter 1985) and of St John's Lake in the Plymouth Sound and Estuaries cSAC first described by Spooner and Moore (1940) and resurveyed in 1988 (see Warwick *et al.* 1991). The recent resurvey of Irish Sea benthic communities first surveyed in 1938 to 1950 (Bradshaw *et al.* 2002) and surveys at the entrance to the Baltic (Rex 1975; Pearson *et al.* 1985; Göransson 2002) have revealed significant change almost certainly brought about by human activities (fishing in the Irish Sea and eutrophication at the entrance to the Baltic). However, resurveys by Kaiser and Spence (2002) in 1998 of sites sampled by Norman Holme in the 1950's suggests that areas of seabed exist that have a similar community composition to those found prior to the general increase in bottom-fishing disturbance. The rocky shore sites surveyed by Crisp and Southward (1958) especially for prosobranchs and cirripedes are currently being resurveyed as part of the MarClim (Marine Biodiversity and Climate Change) study being undertaken at the MBA. The resurveys are enhanced by access to information from the field notebooks of the late Denis Crisp which have been 'rescued' and interpreted by the Countryside Council for Wales (Nobles *et al.*1993).

Locations such as Kitchings Gulley (Kitching *et al.* 1934) near to Wembury in South Devon, which were sampled quantitatively in locations that could be precisely re-established, would lend themselves to re-sampling. Other more descriptive surveys such as those undertaken in the 1950's by Forster (for instance, Forster 1955) can be re-described, most likely demonstrating that similar conspicuous characterizing and dominant species still occur in those locations (Keith Hiscock, own observations). Resources such as the Plymouth Marine Fauna (Marine Biological Association 1957), the Isles of Scilly Marine Fauna (a series published in the Journal of Natural History introduced by Harvey 1969), Lundy (a series published in the Report of the Lundy Field Society introduced by Hiscock 1974) are useful 'touchstones' for the past occurrences of species, often include natural history observations that help to interpret current change and may be precise enough in locational information to enable searches to be made for rare and scarce species where they were previously recorded. Check lists such as Boswarva (1862) who published *A catalogue of the marine algae of Plymouth*, are less useful but some extant marine biologists can still indicate where special features are that may be worth revisiting. The value of historical

check lists of algae has been demonstrated by Hardy *et al.* (1993) for north-east coast estuaries where some species could no longer be found, almost certainly due to pollution. Some specialist surveys such as of the distribution of the honeycomb worm *Sabellaria alveolata* (Cunningham *et al.* 1984*)* could form the basis of a time-series study aimed at identifying changes in distribution. Wide ranging surveys such as those of molluscs and echinoderms in the English Channel (Holme 1966) and the towed photographic sledge surveys in the English Channel undertaken by Norman Holme (unpublished, data and images held by the MBA) could be repeated.

3.9 Interpretation of information in datasets

Where change has been described and interpreted, a short summary is included in the notes in the database. More work is required to catalogue those interpretations and to make them widely available. Change that is linked to species or biotopes might best be included in *MarLIN* information reviews (a new field would be required in species pages). Other accounts of change are more descriptive. The following information was supplied by Ivor Rees for Red Wharf Bay (quoted from Hiscock *et al.* 2002) and gives a 'flavour' of the sort of explanation that can be produced by experienced scientists.

> "Red Wharf Bay on the east coast of Anglesey has a 35+ year history of sampling. Many of the species there, for instance the *Lagis koreni* and the *Abra alba* are short lived species prone to great temporal variations in abundance (Rees *et al.* 1977; Rees and Walker, 1983). On the other hand, species such as the bivalve *Nucula* spp. are longer-lived and less prone to wild swings in their abundance.
>
> Two sorts of trends have been apparent in Red Wharf Bay over the 20 and 35 years to 1997. Firstly, there have been long-term changes, which were reflected most clearly in increases of about an order of magnitude in the abundances of both *Nucula nitidosa* and *Amphiura brachiata.* Though less abundant overall, *Pharus legumen* and *Echinocardium cordatum* also became somewhat more abundant over the mid 1960s to mid 1990s period. It appeared therefore that there was a tendency towards increased stability over time in the composition of the fauna in this part of Red Wharf Bay. In addition to periodic outbursts of *Lagis koreni* and *Abra alba* there were other less expected and short lived events in the relative abundance of particular benthic species. This included two separate occasions when there were abnormally large numbers of *Lanice conchilega* present. The sediment remained as the familiar muddy sand, but with very large numbers of the sandy tubes of *Lanice* protruding from it. Eagle (1973;1975) found similar periodic increases of *Lanice conchilega* in a generally muddy sand location off the North Wirral coast, between the Dee and Mersey Estuaries.
>
> The other, even less familiar, short lived outburst event was of the tube dwelling amphipods *Ampelisca brevicornis* and *A. tenuicornis.* For just two years in the early 1980s these two species, accompanied by abnormally high numbers of another amphipod, *Photis longicaudata*, were found in large quantities.
>
> *Spisula subtruncata* has nearly always been present in samples from the Red Wharf Bay and Conwy Bay muddy sands. …. In Red Wharf Bay in 1973 a substantial number of *Spisula subtruncata* from a single cohort survived to the second and third winters, reaching shell lengths of about 10-15mm. Temporarily *Spisula subtruncata* became the biomass dominant in the middle of Red Wharf Bay. Indeed when samples were spread out in trays of about the same dimensions as the 0.1 m^2 area sampled by the grab, they covered about 80% of the bottom of the trays. At this particular time there were abnormally large numbers (>2000) of Common Scoters *Melanitta nigra* in Red Wharf Bay. The birds were seen to concentrate their diving in just the part of the bay where the 1+ to 2 year old *Spisula subtruncata* had been

found in abundance in grabs. A similar short-lived event, with a single cohort of *Spisula subtruncata* surviving for 2 years and being a significant part of the total biomass, was also observed in Conwy Bay in 1994. *Spisula subtruncata* is well known for its intermittent occurrence in single age cohort patches.

It appears, that using the MNCR (1997) codes, the same place in the southeast corner of Red Wharf Bay, might have been allocated to at least four different biotopes at various times if there had been no appreciation of the temporal variability. Moreover there are anomalies in fitting the muddy sand assemblage here to any one of the MNCR biotopes."

Some time-series studies have been undertaken especially to test important ecological principles concerned with stability, competition and succession. These studies which are often experimental, have not been included in the database but may provide important information to interpret results of monitoring. For instance, the work of Gray *et al*. (1984) sampling deep sediments in a Norwegian fjord, demonstrated a high degree of stability in the most abundant species over two years but with different scales of fluctuations in different species and, not surprisingly, high recorded variability in rare species where likelihood of being sampled may have been small. Manipulative studies may help to interpret the reasons for change in communities when they occur; for instance, the rocky shore studies of Hawkins and co-workers (e.g. Hawkins and Hartnoll 1983; Hartnoll and Hawkins 1985; Burrows and Hawkins 1998; Johnson *et al*. 1998).

3.10 'Value' of the studies

The studies reviewed can be characterized as:

1. **Studies of widespread species and communities over significant time periods.** Such studies are extremely useful for illustrating scale of change over many years. Examples include the several studies in Sullom Voe (see Dunnet and McIntyre 1995) and in Orkney (Jones 1985) for whole communities and such as those of barnacles for certain species (see, for instance, Southward 1991). However, studies may have to be undertaken for many decades to identify the influence of oceanographic conditions or impact of climate change. For instance, the rocky subtidal communities of rare and scarce species at Lundy have declined since monitoring studies commenced in 1983 and it may be necessary to wait some further time before recovery is recorded (Hiscock 2000). Pearson and Barnett (1987) reviewed time-series studies existing at that time and concluded that "some of the changes documented appear to have been relatively slow processes occurring over a 50- to 70-yr period". Since larval recruitment is important in determining constancy of species numbers in the benthos, it is also relevant to mention the observation by Russell (1973) that the postlarval stages of teleostean fishes (and larvae of other species especially decapods) were very abundant in the plankton off Plymouth in the 1920's, declined in the 1930's, and stayed low until somewhere around 1965 when a marked increase in the macroplankton, including fish larvae occurred. The numbers stayed high to the early 1970's. (Alan Southward, in the Cooper Memorial Lecture on 31 March 1998, suggested that what is now known as the 'Russell cycle' returned to its 1920's peak between 1965 and 1979). The work off Plymouth has been reviewed recently by Hawkins *et al*. (in press). Observations of changes (high abundance to/from low abundance) in some species lasting several decades have also been documented for the Firth of Clyde by Elmhurst (1936). Time-series studies may

therefore need to be undertaken over a period of fifty years or more if some natural fluctuations are to be identified.

2. **Seasonal studies**, possibly for short periods. Studies such as those of seagrass communities in the Fleet (Dyrynda 1997), at Skomer of algae on pebbles (Hiscock, 1986) off Chesil beach of epifaunal animals (Warner 1985) and of infauna amongst seagrass beds in the Netherlands (Jacobs 1983) give contextual information on the scale of change that might occur seasonally and emphasize the importance of undertaking annual surveys at the same time of year when rapid change is not occurring. The rocky shore dataset from the Coastal Surveillance Unit studies around Anglesey (Jones *et al.* 1980; Nobles 1993) is outstanding. An initial reading of the papers reviewed in the study reported here suggests that seasonal change is especially marked in epifaunal communities whilst, in deeper subtidal sediment communities at least there may be little seasonal change (for instance, see O'Connor *et al.* 1986 for an *Amphiura filiformis* community in Galway Bay).

3. **Repeat surveys undertaken after many decades**. In communities that might be expected to have a high degree of constancy in species present, a major change, including one to a different biotope or biotopes, may suggest some overwhelming change in environmental factors in the region. Examples of such changes detected by repeat surveys after several decades are the studies at the entrance to the Baltic (Göransson 2002; Pearson *et al.* 1985) revealing major change most likely resulting from eutrophication, and the changes in seabed communities in the Irish Sea (Bradshaw *et al.* 2002), most likely resulting from fisheries using heavy bottom-fishing gear.

4. **Infrequent surveys but along a gradient of perturbation or following an event**. These studies are most valuable in identifying sensitive species and recovery rates following perturbation. They are also the studies that will identify 'indicator' species – species that are tolerant of or sensitive to particular factors. Observations made following oil spills, after dredging or following natural extremes such as cold winters provide extremely valuable information. Often, such observations are descriptive rather than quantitative and may not be 'time-series' *sensu stricto*.

4. Conclusions – using time-series studies for interpretation of monitoring results

Many of the studies reviewed provide information that can be used to indicate the scale of change already recorded (and therefore that might be expected) in particular species and communities with time (for instance the rocky shore surveys by the Coastal Surveillance Unit in North Wales - Nobles 1993; the various studies in Sullom Voe –Dunnet and McIntyre 1995). The reviewed studies also reveal that some species and communities may remain largely constant with time – but that there may be a switch after years of stability to different dominants (for instance: the work of Buchanan and Moore 1986, off Northumberland showing a loss of stability in a subtidal sediment community between about 1980 and 1981; the disappearance of certain community dominants in sediments in the Bay of Biscay between 1964 and 1974 recorded by Glémarec *et al.* 1986; the observation by Ivor Rees of species becoming biomass dominants for a few years in Red Wharf Bay).

Several reviewed studies include important information on the synchrony of change in species at different locations. Whilst those looking for 'reference' sites against which locations subject to perturbation by human activity can be compared will be comforted by the synchrony seen in at least some of the changes occurring on subtidal rock walls in Sweden and Norway (Lundälv and Christie 1986) and of intertidal sediment species in the Wadden Sea (Beukema *et al.* 1996), they will be dismayed at the poor synchrony of changes in some rock and sediment shore species in Shetland (Burrows *et al.* 2002; Jones 1995) or in sediments in the Scheldt Estuary (Ysebaert and Herman 2002).

Nature conservation agency staff wishing to understand the scale and types of changes recorded in time-series studies for different seabed habitats might wish to have the most useful studies to read identified. The following are therefore recommended:

Intertidal rock. Baxter *et al.* (1985); Hartnoll and Hawkins (1985); Jones *et al.* (1980); Moore *et al.* (1995);

Intertidal sediments. Beukema (1989); Burrows and Hawkins (1998); Jones (1995); Krönke *et al.* (1998);

Subtidal rock. Lundälv and Christie (1986); Fowler and Pilley (1992); George *et al.* (1995)

Subtidal sediments. Buchanan and Moore (1986); Dauvin (2000); Glemarec *et al.* (1986); Pearson *et al.* (1985); Rees and Walker (1991);

Lagoons. Dyrynda (1997).

If a 'one-stop-shop' is required, the volume edited by Heip *et al.* (1986) as an outcome of the COST 647 programme is recommended.

The above studies represent results clearly as graphs and histograms for particular species and sometimes as diagrams illustrating change in communities. A point is made by the authors that studies using ordination diagrams or diversity indices alone to represent change in communities fail to identify the species that are causing the change and therefore fail to inform managers of impacts of change on species and biotopes that they are charged with managing. Recent advances in multivariate analysis particularly the PRIMER set of routines does, however, allow species contributing most to patterns to be identified.

5. Future development

5.1 Maintaining and populating the database

The database developed and populated as a part of the project described in this report is not comprehensive but we have tried to ensure that major sources and a range of different types of time-series information are included in the Review. The Review should be disseminated to allow attention to be drawn to additional studies that should be included but informers should be invited to complete the form included in Appendix 1 or an on-line form could be developed. The database should be maintained and enhanced especially if the report is made widely available and updates, corrections and new records are obtained.

5.2 Making information available to managers

Whilst we have summarized some key findings from the datasets identified, a systematic and careful cataloguing of findings of time-series studies by species and biotopes would be the most useful point of access for a manager or advisor interpreting monitoring results or events that change habitats or species. The *MarLIN* database already contains a field for entry of seasonal and temporal change information for biotopes (and could for species) and could be the most useful and accessible source of information on scale and character of change with time.

5.3 Identifying indicator species

Whilst undertaking the study, it was clear that at least some of the reports identified species that might be indicators, through decline or increase in abundance, of particular perturbations. With increasing interest in producing biotic indices that can support implementation of the Water Framework Directive, reports could be re-visited to identify potential indicator species. Some data could be re-analysed to identify the species that 'drive' variability currently indicated in reports only by change in an index of diversity or scores on an ordination axis. Whilst a comprehensive assessment of potential sources of information has not been undertaken, the following reports and papers of time-series studies are identified here as having significant information to identify potential indicator species:

Beukema (1989) – cold winters and eutrophication on intertidal sediment communities;

Bradshaw *et al.* (2002) – fisheries impacts on subtidal sediment communities;

Dauvin (1998) – long-term impacts of oil spill subtidal sediment communities;

Göransson (2002) – eutrophication on sediment subtidal communities;

Hardy *et al.* (1993) – impacts of industrial pollution on macroalgae;

Kenny and Rees (1996) – gravel extraction on subtidal sediment communities;

Olsgard and Gray (1995) – discharges from oil platforms on offshore sediment communities;

Pearson *et al.* (1985) – eutrophication on subtidal sediment communities;

Rex (1975) – eutrophication on rocky subtidal vegetation;

Southward (1991) – ratios of southern and northern barnacles in relation to climate change.

5.4 Importance of maintaining datasets

Finally, attention is drawn to the importance of maintaining historical datasets and ensuring that they are available to help interpret degree of change in the future. Such datasets come in many forms – from field notebooks to photographs to electronic databases of detailed sample analyses. It is important that workers indicate where their data is held in perpetuity. Whilst some institutes have arrangements for archiving information, workers should have some national repository to default to if required. Organisations that contract studies should define where their contractors should lodge raw data.

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Appendix 1. Database fields

Fields included in the Microsoft Access database. This appendix can be used to create new records on paper prior to entry to the database.

1. **Dataset name**: Name of programme/title of paper or report.*
2. **Short reference**: (e.g. Hull and Webster 1991).
3. **References**: Reference to published sources of information (JNCC house style).
4. **Originator**: Organisation(s) or person(s) having primary responsibility for the intellectual content of the data set.
5. **Originator address**: (added automatically in database when known organisation field is entered).
6. **Originator website**: (as above).
7. **Geographic coverage**: Geographical location of monitoring/surveillance programme (name of region).*
8. **Country**: England, Scotland, Wales, Northern Ireland, non-UK.
9. **Latitude**: ° · N
10. **Longitude**: ° · W / E
11. **Survey time period**: Date of first and, where applicable, last survey (dd/mm/yy, or free text).*
12. **Habitats sampled**: habitats (as biotopes where possible) included (free text).
13. **Target species**: Species targeted for specific counts (free text).
14. **Habitats Directive** Interest features and sub-features of cSACs included by the programme (drop-down multi-choice list: Mudflats and sandflats not covered by seawater at low tide; Estuaries; Intertidal Reefs (part of 'Reefs'); Subtidal Reefs (part of 'Reefs'); Submerged or partly submerged sea caves; Sandbanks which are slightly covered by sea water all the time; Large shallow inlets and bays; Coastal Lagoons; Submarine structures made by leaking gases; non-specific habitat; none of the above).*
15. **BAP Priority Habitat**: (drop-down multi-choice list: Mudflats; Sheltered muddy gravels; Littoral seagrass beds (part of 'Seagrass beds'); Sublittoral seagrass beds (part of 'Seagrass beds'); Littoral chalk (part of 'Littoral and sublittoral chalk'); Sublittoral chalk (part of 'Littoral and sublittoral chalk'); *Sabellaria alveolata* reefs; Tidal rapids; *Modiolus modiolus* beds; *Sabellaria spinulosa* reefs; Sublittoral sands and gravels; Maerl beds; *Lophelia pertusa* reefs; Saline Lagoons; Mud habitats in deep waters; Serpulid reefs; non-specific habitat; none of the above).*
16. **OSPAR Threatened Habitats**: (drop-down multi-choice list: Intertidal mudflats; *Ostrea edulis* beds; *Zostera* [*noltii*] bed (part of '*Zostera* beds'); *Zostera* [*marina*] bed (part of '*Zostera* beds'); Littoral chalk communities; Seapen and burrowing megafauna; Carbonate mounds; Deep sea sponge aggregations;

Lophelia pertusa reefs; Hydrothermal vents/fields; Seamounts; non-specific habitats; none of the above).*

17. **Methods/instruments**: Method(s) used (free text).*
18. **QA**: QA procedures/qualifications (free text).
19. **Other measurements**: Ancillary measurements taken of environmental factors (aka “parameters”) (Drop-down multi-choice list: temperature, salinity; wave exposure; tidal stream exposure; substratum type; sediment particle size analysis, heavy metals; xenobiotic chemicals concs; Redox potential; depth; organic matter; other (name in ‘Notes’)).
20. **Sampling**: Predominant frequency of sampling: (drop-down list: Each day; weekly; monthly; quarterly; annual; longer than annual; as-and-when; other (name in ‘Notes’).*
21. **Number of sites**: Free text.
22. **Reason for study**: (academic or name statutes, directives, conventions, site status driving the work – free text).
23. **Is study ongoing?**: (Yes; No).
24. **Type of data**: (drop down list: quantitative counts of individuals; abundance scale; descriptive; other (name in ‘Notes’).
25. **Data storage**: Method of storing data (Notebooks; tabulated typed; tabulated electronic; spreadsheet; database (name); report(s)).
26. **JNCC suitability**: Suitability for surveillance studies (JNCC 5-point scale + “Other” as drop-down: Current, suitable, data electronic; Current, suitable, data in report format; Historical, data electronic, could start again; Possibly suitable, not all data available; Unsuitable; Other (name in ‘Notes’).*
27. **Data availability**: (drop-down list: All raw data published and freely available; All raw data available on request; Data available on request; Meta data only; Full data or analysis available commercially; Data confidential; Some restrictions; Other (see notes)).
28. **Contact (for access to data)**: Contact person or title of post (where still relevant) to deal with enquiries/requests for access to data.
29. **Contact address**: (added automatically when known contact field is entered).
30. **Contact email**: (as above).
31. **Contact telephone number**: Free text.
32. **Analysis of data**: Has there been any analysis of data? / Publications (including limited circulation reports).
33. **Notes**.*
34. **Completed by**: name of the person who undertook the review.
35. **Currency date**: (yyyy-mm-dd). The date the description was checked for accuracy and approved for dissemination.
36. **Revised by**: Name of the person who undertook revision.
37. **Revise date**: (yyyy-mm-dd). Date revised.

* = Obligatory fields.

Appendix 2. Summary of information held in the database

Dataset name and geographic coverage	*Habitats sampled*	*Habitats Directive*	*BAP Priority Habitats*	*OSPAR Threat-ened Habitats*	*Sampling Freq-uency*	*Survey dates*	*Short Reference*
Albright and Wilson effluent studies, Whitehaven, Cumbria. Dredge and Trawl survey 1970-1973	Predominantly fine sandy bottom, but some silt/clay	Inlets and Bays	Sublittoral sands and gravels	None	Other (see 'Notes')	1970 to 1973	Greenwell and Perkins (1979)
Albright and Wilson, Whitehaven, Cumbria. Biological impact of the effluent	Intertidal	Intertidal reefs	None	*Zostera* (*noltii*) bed	Each day	1970 to 1977	Perkins (1981)
Anglesey rocky shores (Coastal Surveillance Unit)	Rocky shores	Intertidal reefs	None	None	Monthly	1974	Jones *et al.* (1980)
Baie de Somme (France)	Megatidal estuarine soft substrata	Estuaries Intertidal mudflats and sandflats	Mudflats	Intertidal mudflats	Quarterly	1981 to 1992	Ducrotoy and Ibanez (2002)
Bay of Morlaix - sublittoral sediments	Fine sand and mud sediments	Inlets and Bays	None	None	Quarterly	1977 to 1996	Dauvin (2000) Dauvin (1998)
Bay of Morlaix - sublittoral sediments	Fine sand and mud sediments	Inlets and Bays	None	None	Quarterly	1977 to 1996	Dauvin (2000) Dauvin (1998)
Bell Rock sewage disposal ground	Muddy fine sand	None	Sublittoral sands and gravels	None	Annual	1978 to 1991	Webster (1991)
CEFAS - monitoring anthropogenic effects on marine benthos around England and Wales	Benthos	Subtidal sandbanks	Sublittoral sands and gravels	None	Other (see 'Notes')	1986 onwards	[Various]
Channel Tunnel sublittoral monitoring	Kelp forest and animal dominated rock	Subtidal reefs	Sublittoral chalk	None	Annual	1986 to 1990	Wood (1991)

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
Chesil Beach cobbles and wreck	Cobbles Artificial (wreck) substrata	Subtidal reefs	None	None	Quarterly	October 1977 to July 1979	Warner (1985)
Cleveland Coast, NE England	Subtidal sediments	None	Sublittoral sands and gravels	None	Annual	1970 to 2002	Brown and Shillabeer (1996)
Dogger Bank macrofauna 1950's versus 1980's	Fine sand and muddy fine sand	Subtidal sandbanks	Sublittoral sands and gravels	None	As-and – when	1950-54 and 1985-87	Krönke (1992)
Dublin Bay intertidal sediments	Muddy sand and sand	Intertidal mudflats and sandflats Inlets and Bays	None	None	Other (see 'Notes')	1977 and 1989 to 2000	Wilson and Emblow (2002)
English Channel rocky shores.	Intertidal	Intertidal reefs	None	None	Annual	2001 to present	Crisp and Southward (1958)
Environment Agency non-NMMP surveys	Mostly intertidal mud and sandflats, some subtidal	Intertidal mudflats and sandflats Estuaries Inlets and Bays	Mudflats	Intertidal mudflats	[Various, mostly annual]	[Various]	[No references
Estuary and Firth of Forth	Coarse sandy to mud sediments	Estuaries	Sublittoral sands and gravels	None	Annual	Mid 1970's to 1991	Forth River Purification Board (1993a)
Firth of Forth – long-term studies on an estuarine mudflat	Intertidal mudflat	Intertidal mudflats and sandflats Estuaries	Mudflats	Intertidal mudflats	Annual	1976 to 1996	[None]
Firth of Forth spatial study – taxonomic problems associated with long-term monitoring	Subtidal benthos and sediments	Estuaries	Sublittoral sands and gravels	None	Other (see 'Notes')	Initial survey 1976 to 1977, repeat survey 2000	Elliot and Kingston (1987)
Firth of Forth, Kincardine Bridge to Kinneil	Intertidal and subtidal sediments	Intertidal mudflats and sandflats Estuaries	Mudflat *Sabellaria spinulosa* reef	Intertidal mudflats	Annual	1972 to 2001	Ashman and Shillabeer (1993) Riddle (1997)

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
Firth of Forth, Kincardine Bridge to Kinneil	Intertidal and subtidal sediments	Intertidal mudflats and sandflats Estuaries	Mudflat *Sabellaria spinulosa* reef	Intertidal mudflats	Annual	1972 to 2001	Ashman and Shillabeer (1993) Riddle (1997)
Fleet lagoon, Dorset	Sea grass bed on sediment	Coastal lagoons	Sublittoral seagrass beds Sublittoral sands and gravels	*Zostera* (*marina*) bed	Quarterly	1995 to 1996	Dyrynda (1997)
Galloway Creamery Outfall, Loch Ryan, south west Scotland - biological survey of the beach and seabed	Subtidal and intertidal	Subtidal reefs Subtidal sandbanks			Annual	1987 onwards	SEPA (various, unpublished)
Galway Bay *Amphiura filiformis* assemblage	Fine sand at depth 18m	Subtidal sandbanks Inlets and Bays	Sublittoral sands and gravels	None	Quarterly	1974 to 1985 (1980 to 1985 in the cited paper)	O'Connor *et al.* (1986)
Garroch Head Survey (environmental monitoring), Firth of Clyde (1979-)	Benthos	None	Sublittoral sands and gravels	None	Annual	1979 onwards	Pearson (1987)
Great Ouse estuary - long-term biological monitoring	Estuary and sandbanks	Estuaries Subtidal sandbanks	Mudflats Sublittoral sands and gravels	None	Annual	1973 to 2001	Bailey *et al.* (1999)
Inner Solway Firth beaches - biological and trace metal survey	Intertidal	Intertidal mudflats and sandflats	Mudflats	Intertidal mudflats	Annual	1987 onwards	SEPA (various, unpublished)
Irish Sea – re-analysis of historical benthic data set (Isle of Man, southern offshore)	Offshore gravel, offshore fine sand, offshore muddy sand, and offshore mud	None	Sublittoral sands and gravels	Sublittoral mud - Sea pens and burrowing megafauna	As-and - when	1946 to 1953	Pennington *et al.* (1998)
Irvine Bay, Scotland	Intertidal and subtidal sediments	Intertidal mudflats and sandflats	Sublittoral sands and gravels	None	Annual	1970 to 1996	Brown *et al.* (1996)

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
Isle of Man rocky shores	Moderately wave exposed rocky shore	Intertidal reefs	None	None	Quarterly	1977-1984	Hartnoll and Hawkins (1985)
Isles of Scilly sublittoral monitoring	Sublittoral rock	Subtidal reefs	None	None	As-and - when	1984 onwards	Fowler and Pilley (1992)
Kames Bay and Hunterston, Firth of Clyde.	Intertidal sand	Intertidal mudflats and sandflats	None	None	Monthly	1973-1985	Barnett and Watson (1986)
Kattegat Petersen resurvey	Subtidal sediments	Inlets and Bays	Sublittoral sands and gravels	None	As-and - when	1911 to 1984	Pearson *et al.* (1985)
Kimmeridge Underwater Nature Trail	Sublittoral rock reef	Subtidal reefs	None	None	As-and - when	1988	Collins and Mallinson (1990)
Kingsnorth Power Station, Medway - survey of the marine infauna	Benthic mud	Intertidal mudflats and sandflats Estuaries	Estuarine mudflat	Mudflats	As-and - when	1984 to 1989	
Lafan Sands pipeline surveys	Sand and mud	Intertidal mudflats and sandflats	None	None	Annual	1973 to 1977	Rees (1978)
Liverpool Bay benthic studies at dredged material disposal sites	Estuary, soft sand/mud sediments	Subtidal sandbanks Inlets and bays	Sublittoral sands and gravels	None	Other (see 'Notes')	1974 to 1988	Norton *et al.* (1984) Rowlatt *et al.* (1986)
Liverpool Bay sludge disposal benthos surveys	Offshore stations mainly on heterogeneous muddy gravelly sand, other areas with unstable sand waves, inshore fine sands and in certain channels, cohesive muddy sands	Subtidal sandbanks Inlets and Bays	Sublittoral sands and gravels	None	Annual	1970 to 1995	Rees and Walker (1991)
Lophelia site in the Kosterfjord, Sweden	Small *Lophelia pertusa* reef	Subtidal Reefs	*Lophelia pertusa* and other cold water coral reefs	*Lophelia pertusa* reefs	As-and - when	1998 onwards	Lundälv and Jonsson (2000)

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
Lundy littoral monitoring	Rockpools, cave	Intertidal reefs	None	None	Longer than annual	1984 onwards	Fowler and Pilley (1992)
Lundy sublittoral monitoring	Circalittoral cliffs, boulders and muddy gravel plain	Subtidal reefs	Sheltered muddy gravel	None	Longer than annual	1983 onwards	Fowler and Pilley (1992)
MASCONS (Managing fisheries to conserve groundfish and benthic species diversity)	All	None specific habitat	None specific habitat	None specific habitat	Annual	08/2001 in North Sea, 11/2001 on west coast	
Milford Haven resurvey of rocky shore transects in April-May 1982	Intertidal rocky shore	Intertidal reefs	None	None	Other (see 'Notes')	April to May 1982	Little (1983)
Milford Haven sublittoral sediments	Littoral and sublittoral sediments (silt to medium sand)	Intertidal mudflats and sandflats Estuaries Inlets and Bays	Mudflat	Intertidal mudflats	As-and - when	1975, 1982, 1993, 1996, 1997	Rostron *et al.* (1983)
Montrose coast, Lunan Firth to St Cyrus	Intertidal and subtidal sediments	Intertidal mudflats and sandflats	Sublittoral sands and gravels	None	Longer than annual	1993 to 2003	
Moray Firth - rocky shores	Rocky shores	Intertidal reefs	None	None	As-and - when	1981 to 1987	Terry and Sell (1986)
Moray Firth intertidal plants	Intertidal muddy sediments	Intertidal mudflats and sandflats Inlets and Bays	Mudflats Littoral Seagrass beds	Intertidal mudflats *Zostera* (*noltii*) bed	Annual	1978 to 1981	University of Aberdeen Department of Geography (1981)
Norderney (Wadden Sea) - intertidal and shallow subtidal sediments	Fine and medium sand	Intertidal mudflats and sandflats Estuaries Inlets and Bays	Mudflats Sublittoral sands and gravels	Intertidal mudflats	Quarterly	1977-1988	Dörjes *et al.* (1986) Dörjes (1992) Krönke *et al.* (1998)

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
North Haven, Skomer - monitoring the distribution and abundance of *Zostera marina*	*Zostera* beds	Subtidal sandbanks	Sub-littoral Seagrass beds	*Zostera* (*marina*) bed	Other (see 'Notes')	1997 to 2002	Hunnam (1976) Jones *et al.* (1983) Lock (1998)
North Norfolk - medium to long-term studies on the rocky shore vegetation	Rcky intertidal and subtidal macrobenthos	Intertidal reef Subtidal reef	Littoral chalk Sublittoral chalk	Littoral chalk	Annual	1989 to 1998	Tittley (1998)
North Norfolk, England - fluctuations in the macrobenthos of a shallow-water cobble habitat	Intertidal and subtidal chalk cobble	Subtidal reef	Sublittoral chalk	None	Annual	1989 to 1992	Chimonides *et al.* (1995)
Northern Ireland Estuarine Classification	Estuarine sediments	Intertidal mudflats and sandflats Estuaries Inlets and Bays	Mudflat Sublittoral sands and gravels	Intertidal mudflats	Annual	1992-	[None available]
Northumberland - offshore subtidal sediments	Muddy sand corresponding to Petersen's *Amphiura filiformis* community	None	Sublittoral sand and gravel	None	Other (see 'Notes')	1974 onwards	Buchanan and Moore (1986) Frid *et al.* (1999)
Norwegian Sector offshore datasets	Sublittoral sediments	None	Sublittoral sands and gravels	None	Other (see 'Notes')	1975 to 1993	Olsgard and Gray (1995)
Orkney - rocky shores	Rocky shores	Intertidal reefs Inlets and Bays	None	None	Annual	1974 to 1983	Baxter *et al.* (1985)
Orkney sandy shores	Intertidal sandy sediment	Intertidal mudflats and sandflats Inlets and Bays	None	None	Monthly	1974-1986	Atkins *et al.* (1989)
Outer Leven Estuary, Morecambe Bay	Intertidal sediments	Intertidal mudflats and sandflats	None	None	Longer than annual	1989 to 2001	Brown *et al.* (2001)

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
Petersen's benthic macrofauna stations revisited in the Öresund area (southern Sweden)	Soft-bottom benthos	None	Sublittoral sand and gravel	None	One-off study	1990	Göransson (2002)
Red Wharf Bay sediment infauna surveys	Mainly inshore cohesive muddy Sand broadly Petersen *Syndosmya* (*Abra*) community	Subtidal sandbanks Inlets and Bays	Sublittoral sands and gravels	None	Annual	1965 to 1997	Rees and Walker (1983) Rees *et al.* (1977)
Severn estuary, Sheperdine to Goldcliff	Intertidal sediments	Intertidal mudflats and sandflats Estuary	Mudflats *Sabellaria alveolata* reef	Intertidal mudflats	Annual	1977 to 2002	[Internal reports only]
Shetland - long-term observations on the subtidal flora	Subtidal shingle, soft mud and sand	Subtidal reefs Inlets and Bays	*Modiolus modiolus* beds Sublittoral sands and gravels Mud habitat in deep water	Seapens and burrowing megafauna	Longer than annual	1973 to 1993	Tittley *et al.* (1985)
Shetland - sediment shores	Fine to medium sand sediment shores	Intertidal mudflats and sandflats Inlets and Bays	None	None	Annual	1977 to 1984	Jones (1995)
Skomer Marine Nature Reserve - epifaunal of sediment	None specified	Subtidal sandbanks	Sublittoral sands and gravels	None	Other (see 'Notes')	1995 to 2001	Moore (2001) Rostron (1996)

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
Skomer Marine Nature Reserve - infauna of sediment	Non-specific	Subtidal sandbanks	Sublittoral sands and gravels	None	Other (see 'Notes')	1993 to 1998	Barfield (1998) Rostron (1994) Rostron (1996)
Skomer Marine Nature Reserve - nudibranch surveys	Sublittoral habitat	Subtidal reefs	None	None	Other (see 'Notes')	1975 to 2002	Bunker *et al.* (1982) Luddington (2002)
Skomer Marine Nature Reserve - scallop surveys	Benthic	Subtidal sandbans	Sublittoral sands and gravels	None	Other (see 'Notes')	1979 to 2000	Bullimore (1985) Jones (1990) Lock (2001)
Skomer Marine Nature Reserve - territorial fish survey	Not specified	Non-specific habitat	Non-specific habitat	Non-specific habitat	Other (see 'Notes')	2001 to 2002	(No reference)
Skomer Marine Nature Reserve community and species monitoring: algal communities	Littoral rock	Reef (subtidal)	None	None	Longer than annual	1999	Hiscock (1983) Hiscock (1986) Scott (1994) Brodie and Watson (1999) Brodie and Bunker (2000)
Skomer Marine Nature Reserve littoral monitoring project (permanent quadrats)	Rocky shore communities	Intertidal reefs	None	None	Annual	1992 to 2002	Adams (1979) Bunker (1983) Crump (1993) Crump (1996) Hudson (1996)
Skomer Marine Reserve - photographic monitoring of subtidal epibenthic communities	Subtidal epibenthos	Subtidal reefs	None	None	Annual	1982 to 2002	Bullimore (1986, 1986/87) Bunker and Mercer (1988) Gilbert (1998)

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
Solway Firth, SW Scotland	Intertidal sediments	Intertidal mudflats and sandflats	Mudflats	Intertidal mudflats	Longer than annual	1973 to 2002	Craig and Ashman (1998)
South west England intertidal rocky shores survey (1954-1987)	Intertidal rocky shores	Intertidal reefs	None	None	Annual	1954 to 1987	Southward (1967) Southward *et al.* (1975) Southward and Southward (1978) Southward (1991)
Southern Brittany sediment communities	Muddy and fine sands	Inlets and Bays	Sublittoral sands and gravels	None	Other (see 'Notes')	1964 to 1983 (ongoing?)	Glemarec *et al.* (1986)
St Abbs sewage-sludge disposal grounds	Muddy fine sand	None	Sublittoral sands and gravels	None	Annual	1978 to 1991	Webster (1991a)
Stanswood Bay, Calshott - survey for application for new power station	Intertidal	Estuaries Intertidal mudflats and sandflats Intertidal reefs	None	None	As-and - when	1987	[None published]
Sullom Voe - rocky shore surveys	Rocky shores	Intertidal reefs	None	None	Annual	1976 onwards	Moore *et al.* (1995) Burrows *et al.* (2002)
Sullom Voe – subtidal sediment macrobenthos	Sublittoral sediments	Inlets and Bays	Sublittoral sands and gravels	None	Annual	1974 to present	May and Pearson (1995)
Sullom Voe oil terminal effluent discharge site chemical and biological monitoring	*Modiolus modiolus* beds	Subtidal reefs	*Modiolus modiolus* beds	*None*	Annual	1975 to 2001	

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
Swedish west coast stereophotographic monitoring (and comparisons with results from Norway)	Sublittoral cliffs	Subtidal reefs	None	None	Quarterly	1970 to 1982 (some ongoing)	Lundälv (1985) Lundälv and Christie (1986) Lundälv *et al.* (1986) Lundälv (1990)
Tees Estuary, NE England	Subtidal sediments Intertidal macroalgae	Intertidal mudflats and sandflats Estuaries	Sublittoral sands and gravels	None	Annual	1979 to 1999 (Tees Estuary) 1973 to 1996 (Tees Bay)	Tapp *et al.* (1993) Shillabeer and Tapp (1990) Warwick *et al.* (2002)
Thames estuary - marine algae	Not specified	Not specified	Not specified	Not specified	Other (see 'Notes')	1977 to 2000	
The Wash - subtidal benthic surveys in the 1990's	Benthos	Estuaries Subtidal reefs	Sublittoral sands and gravels Sheltered muddy gravel	None	Other (see 'Notes')	Original surveys in 1991 and 1993, resurveyed in 1999	Bailey *et al.* (2001)
The Wash, east coast of England cockle survey	Commercial cockle beds	Intertidal mudflats and sandflats	None	None	Annual	1989 onwards	Walker and Palmer (1990) Walker and Nicholson (1989)
The Wash, east coast of England, mussel survey (1983-1989)	Intertidal mussel beds	Intertidal reefs	Non-specific habitat	Non-specific habitat	Other (see 'Notes')	1983 to 1989	Walker and Nicholson (1986)
Torrey Canyon rocky shore recovery (Porthleven, Cornwall)	Rocky shore	Intertidal reefs	None	None	Annual	1968-1990	Hawkins *et al.* (1994)
Wash and North Norfolk SAC - Littoral sediments	Intertidal sediments	Intertidal mudflats and sandflats Estuaries Inlets and Bays	Mudflats	Intertidal mudflats	As-and - when	1986, 1998 and 1999	Yates *et al.* (2002)
West coast of Scotland Loch Linnhe/Loch Eil benthic ecology surveys (1963-1980)	Fjordic benthos	Inlets and Bays	None	Seapen and burrowing megafauna	Other (see 'Notes')	1963 to 1980	Pearson (1982)

Dataset name and geographic coverage	***Habitats sampled***	***Habitats Directive***	***BAP Priority Habitats***	***OSPAR Threat-ened Habitats***	***Sampling Freq-uency***	***Survey dates***	***Short Reference***
Western English Channel macrobenthos (echinoderms and molluscs) (1947-1986)	Benthos	Non-specific habitat	Non-specific habitat	Non-specific habitat	Other (see 'Notes')	1947 to 1986	Holme (1983)
Wyre Estuary, Shard Bridge to Fleetwood	Intertidal sand and mud	Estuaries Intertidal mudflats and sandflats	Mudflats	Intertidal mudflats	Longer than annual	1975 to 2002	[Internal reports only]

- *Intertidal mudflats and sandflats is a shortened version of the Annex 1 habitat Mudflats and sandflats not covered by seawater at low tide
- **Intertidal reefs and Subtidal reefs are divided versions of the broad Annex 1 habitat Reefs
- ***Subtidal Sandbank is a shortened version of the Annex 1 habitat Sandbanks which are slightly covered by sea water all the time
- ****Inlets and Bays is a shortened version of the Annex 1 habitat Large shallow inlets and bays