**Biological monitoring of marine**
**Special Areas of Conservation:**
**a review of methods for detecting change.**

JNCC Report Number 284

Keith Hiscock

This report is a contribution to the development of a monitoring handbook of the UK Marine SACs Project.

Reference:

HISCOCK, K. 1998. *Biological monitoring of marine Special Areas of Conservation: a review of methods for detecting change.* Peterborough, Joint Nature Conservation Committee. (JNCC Report No. 284)

This review is derived from:

HISCOCK, K. 1998. *Biological monitoring of marine Special Areas of Conservation: a review of methods for detecting change. Part 1. Review and description of methods. Consultation draft. 27 March 1998.* Peterborough, Joint Nature Conservation Committee.

This work was undertaken with the support of the
European Commission Life Nature Programme.

*"To record change is no problem. There is too much, and it would be a remarkable investigation that showed none. The major need is to ensure that the change recorded is real and relevant."*

J.R. Lewis, 1976

# Biological monitoring of marine Special Areas of Conservation: a review of methods for detecting change.

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# Biological monitoring of marine Special Areas of Conservation: a review of methods for detecting change.

**Keith Hiscock**

## Preface

Monitoring programmes which produce quantified descriptions of real change and which are accountable in terms of their accuracy and significance of results are required for site management. It is through sound monitoring programmes that site managers can receive timely warnings of unacceptable change and see whether the measures they adopt are maintaining the interest features of a site. This review is written as a contribution to the development of a marine monitoring handbook, which will help both the scientists designing a monitoring programme and the responsible body determining the most cost-effective and appropriate means of obtaining necessary information. It also describes and illustrates results from studies of change in marine communities to inform those new to monitoring or to monitoring unfamiliar habitats.

The monitoring described here is relevant to management of protected areas and will normally be carried out to detect any change greater than that expected to occur naturally. However, the same techniques can be applied to assessment of effects of accidents or activities likely to be damaging to the marine environment.

This review focuses on biological surveillance and monitoring but including extent of habitats, whether physical or biological, and especially in relation to managing sites and features for nature conservation. The review does not consider experimental studies (except where ones, which have been undertaken help, interpret change) or the use of biomarker or physiological response techniques. The review gives practical guidance on the methods available, their deployment, accuracy and their application to management. It identifies the extent to which natural variability can be separated from change brought about by human activities.

A key aim of the review is to ensure that those designing and managing monitoring programmes understand the significance (or lack of it) which they can interpret from their results. This includes error or variability likely from the sampling strategy chosen (including worker variability) and separation of natural temporal change from change induced by human activities. The aim of this volume is to provide information on practical application rather than a review of techniques as several texts already describe sampling methods, many of which are applicable to monitoring studies.

# 1. Introduction

## 1.1 Surveys to detect change - what is 'monitoring'?

The term 'monitoring' is widely used as shorthand for studies to detect change in the context of environmental impact assessment and management to minimise adverse effects of human activities. However, the term is understood and defined in various ways. Practitioners coming from a nature conservation management background will be most used to the definition from Hellawell (1978) ("monitoring is surveillance undertaken to ensure that formulated standards are being maintained") whilst those coming from a marine ecology background will be most familiar with the general definition from GESAMP (1995) ("Observation of a variable over space and or time in order to determine the condition or state of the ecosystem"). Hellawell (1978) separately identifies 'surveillance' as "a continued programme of surveys systematically undertaken to provide a series of observations in time". GESAMP (1995) split 'monitoring' into *surveillance monitoring* which is "an attempt to detect unanticipated impacts, particularly ones that may be wide ranging, subtle or that only slowly become large and obvious" and *compliance monitoring*, that is, "survey undertaken to detect departures from agreed or predicted amounts of disturbance". However, for the rest of the review, a more precise definition of monitoring is applied and that of Hellawell (1978) preferred as it relates directly to the sort of standards used by nature conservation practitioners. For surveillance, account is taken of the discussions held by nature conservation agency staff at a workshop in 1993 and the definition of Hellawell modified slightly to: "a procedure by which a series of surveys is conducted in a sufficiently rigorous manner for changes in the attributes of a site (or species) to be detected over a period of time".

In this review, "surveillance" is considered equivalent to *surveillance monitoring* and "monitoring" to *compliance monitoring* of GESAMP (1995).

In a marine protected area, there is likely to be a background of surveillance of the features important for the designation of the site with monitoring being undertaken in relation to features which may be or are being affected by human activities. It is likely that there will be an initial requirement for survey (to identify the location of main characteristics of the area), followed by surveillance which gives a broad idea of the scale of changes taking place, followed by monitoring which uses the results of surveillance to set limits outside of which management action is likely to be taken.

A monitoring programme tests a hypothesis - usually a null hypothesis. The hypothesis most often worked to in managing for conservation in the marine environment is that:

> Change will stay within that considered normal in an environment affected only by natural events.

(Of course, "normal" has to be defined and is often very difficult to do. However, wherever possible, known natural variability will be identified and used as the initial basis from which to indicate 'change limits'.)

## 1.2 Obligations to detect change and to 'monitor' in SACs

The monitoring of European marine sites will need to encompass the following elements:

- surveillance of the conservation status of the natural habitats and species listed in Annex I, II, IV and V of the Habitats Directive (with particular regard to priority habitats / species) as part of the surveillance for the UK as a whole;
- surveillance of populations of bird species; in particular, trends and variations in species listed in Annex I of the Birds Directive and in migratory bird species, as part of this surveillance for the UK as a whole;
- monitoring the conservation status of Habitats Directive Annex I habitats and Annex II species on the site;
- monitoring to determine whether the conservation objectives for the site have been, or are in the process of being, achieved;

- monitoring to determine whether measures taken to avoid deterioration of Habitats Directive Annex I habitats and habitats of Annex II species, and significant disturbance of Annex II species, are being complied with, together with analogous monitoring of the habitats and populations of Birds Directive Annex I and migratory bird species.

Whilst the nature conservation agencies anyway have a long-standing obligation to "take account, as appropriate, of actual or possible ecological change" (Nature Conservancy Council Act 1973 perpetuated in subsequent statutes) in undertaking their statutory duties, it is the EC Habitats Directive which has given new and very significant responsibilities in the marine environment.

### 1.3 The role of monitoring in marine site management

Monitoring is not undertaken to satisfy curiosity but results have to be fed back to management of a site or development and action taken if deleterious change is suspected. An example of this sort of feedback is given, for dredging, at the site of the 'Great Belt' bridge project in Denmark (Gray & Jensen 1993) (Figure 1). Finding an example of feedback to management with a biological trigger for marine examples has not proved possible although examples must exist.

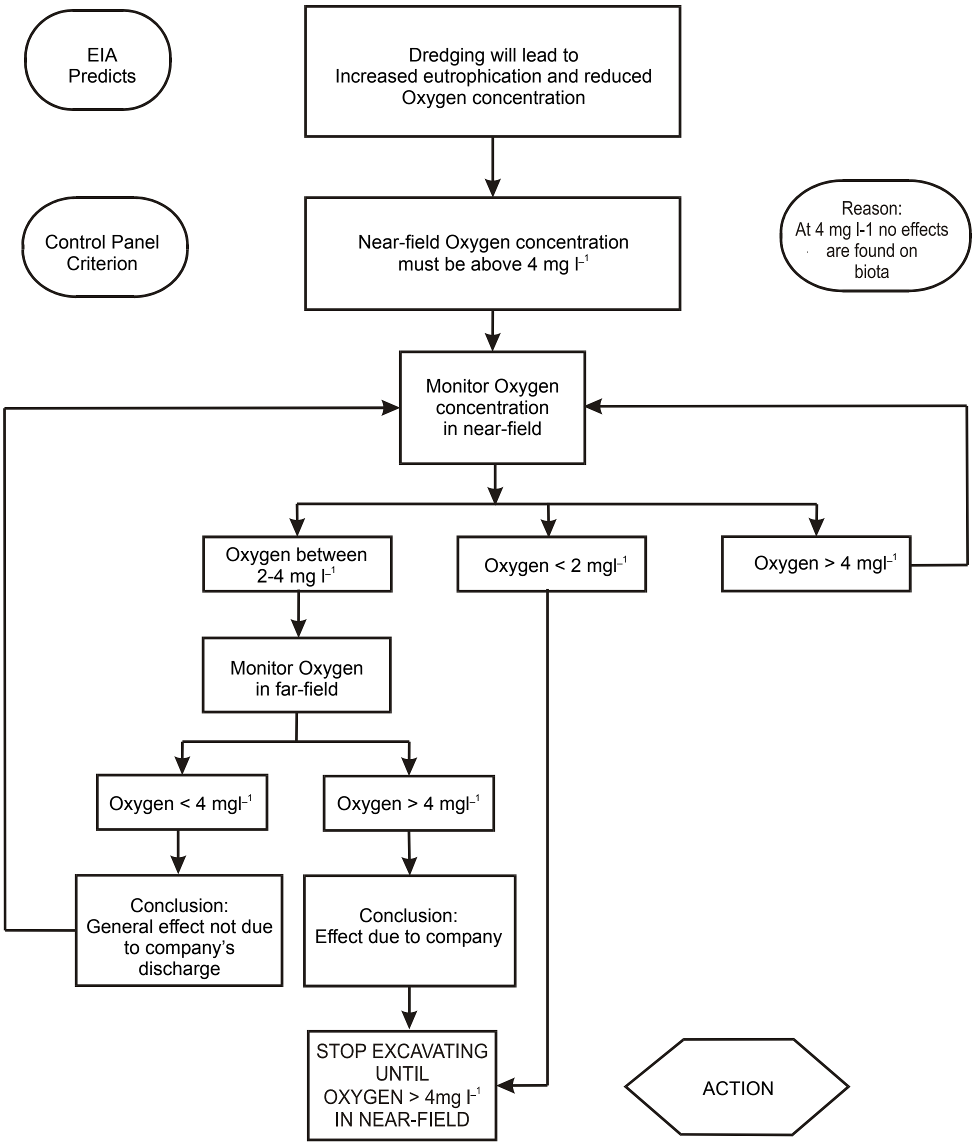


**Figure 1** Flow diagram of a feedback loop showing how a criterion from the impact assessment is used to control operations. (From Gray & Jensen 1993.)

### 1.4 The scope of this review

The background to the development of the review and parallel activities is given in Appendix 1. This volume focuses on biological surveillance and monitoring but including extent of habitats, whether physical or biological, and especially in relation to managing sites and features for nature conservation. The review does not consider experimental studies (except where ones, which have been undertaken, help interpret change) or the use of biomarker or physiological response techniques.

The review gives practical guidance on the methods available, their deployment, accuracy and their application to management. It identifies the extent to which natural variability can be separated from change brought about by human activities. The review relates to benthic habitats including littoral rock and sediments and sublittoral rock and sediments. Fish are included where they are species associated with the seabed and are not commercial species. Methods for monitoring abundance of commercial species are being developed by fisheries departments. Seals and cetaceans are included for inshore areas.

The monitoring described here is relevant to management of protected areas and will normally be carried out to detect any change greater than that expected to occur naturally. However, the same techniques can be applied to assessment of effects of accidents or activities likely to be damaging to the marine environment.

A key aim of the review is to ensure that those designing and managing monitoring programmes understand the significance (or lack of it) which they can interpret from their results. This includes error or variability likely from the sampling strategy chosen (including worker variability) and separation of natural temporal change from change induced by human activities.

Whilst the development of methods have generally been restricted to those for habitats listed in Annex I and marine species listed in Annex II of the EC Habitats Directive, the methods described here for seabed habitats can be used or adapted for monitoring of any area of the continental shelf (depths generally less than 200m) in temperate biotopes.

The aim of this volume is to provide information on practical application rather than a review of techniques. Several texts already describe sampling methods, many of which are applicable to monitoring studies. These include Holme & MacIntyre (1984) and Baker & Wolff (1987).

For the person interested in viewpoints on monitoring, they should read articles by Hartley (1982), Segar & Stamman (1986), Underwood (1992) and Elliott & de Jong (1996). For those interested in identifying 'real' change and separating it from apparent change and the consequences for management decisions, they should read Gray (1990) and Buhl-Mortensen (1996) together with Gray (1996).

Literature which helps us to understand scales of temporal change and interpret the effects of human activities is constantly growing and some of the imponderables of this text may be made more easily understood by work yet to be published.

The use of a 'decision tree' to assist in determining monitoring requirements is desirable and examples are given in Figure 2. However, it may be preferred to use a worksheet (Appendix 3) to aid the project planner. The worksheet has been developed using results from the nature conservation agencies monitoring workshop held in Beaumaris in 1993, National Research Board (1990) and Goldsmith (1991).

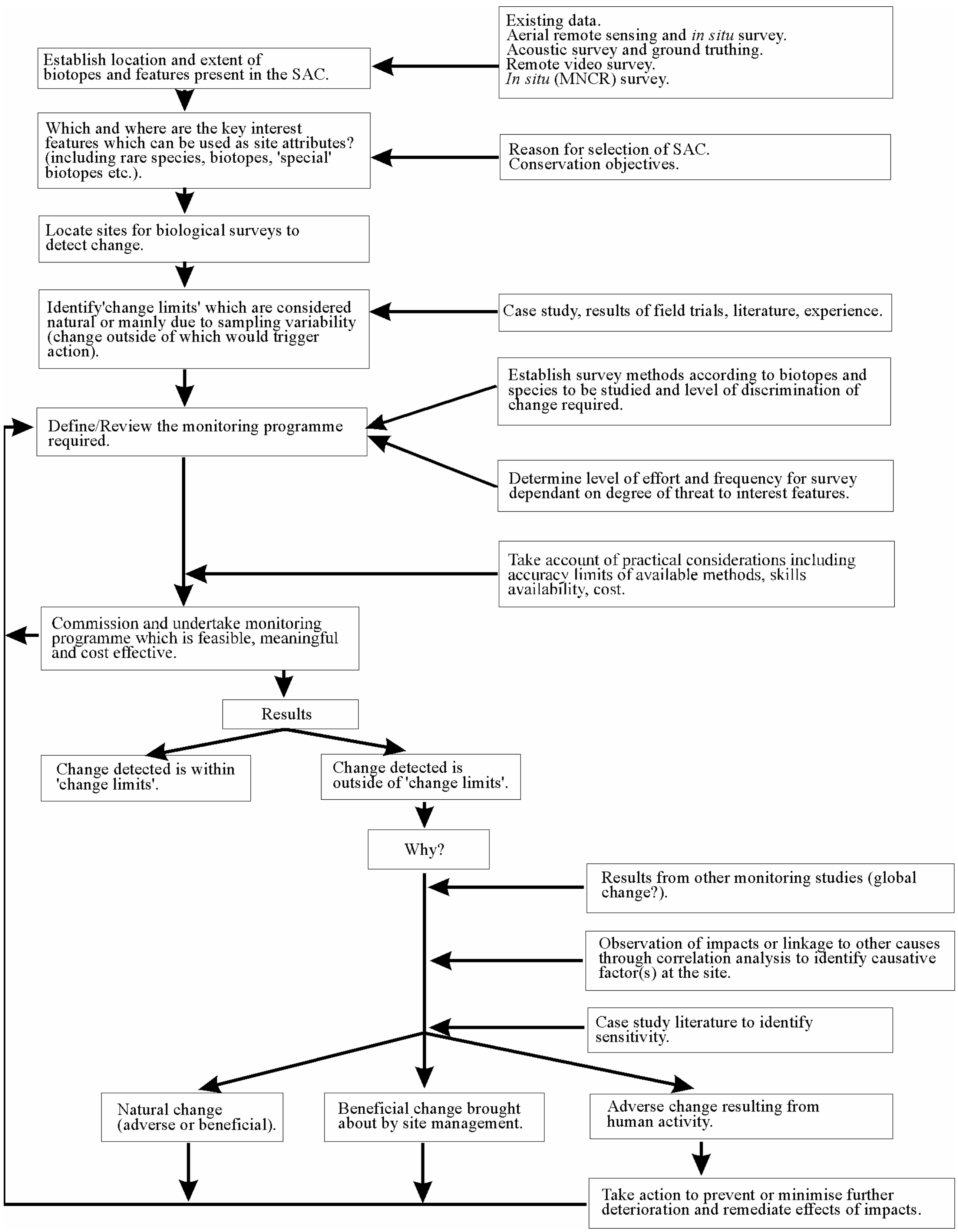


**Figure 2** A possible decision tree for SAC monitoring. Based on one developed during the workshops in spring 1997 by Roger Proudfoot, Environment Agency and Paul Brazier, Marine Nature Conservation Review and using, in part, the decision tree for ‘Marine Biological monitoring of the Durham coast for Turning the Tide’.

# 2. The development of monitoring methods for marine nature conservation management

## 2.1 'Adopt and adapt' - experience from marine biological studies

### 2.1.1 Introduction

A wide range of survey methods have been developed to detect change in marine communities and species with the aim of at least describing real changes (whether resulting from human activities or some other factor) and, in some, to provide a trigger to taking action to prevent or minimise further undesirable change. Survey methods are described in several volumes and those edited by Price, Irvine & Farnham (1980), Holme & McIntyre (1984), Baker & Wolff (1987) and Kramer, Brockmann & Warwick (1994) are especially worth referring to. Where those methods are described as 'monitoring', they have been developed usually in response to some specific activity or management need. They will have different approaches and different triggers for management action depending on the activity. A review of the literature relevant to developing monitoring programmes in marine SACs was undertaken as background to reporting on the results of the workshops held early in 1997 (Worsfold, Dyer & Howson 1997). That report is taken account of and developed here to critically review the utility of methods and the usefulness of analytical techniques for monitoring in SACs.

### 2.1.2 Rocky shore descriptive surveys

Rocky shores have been the subject of development of monitoring methods and there has been little change to sampling methods since the workshop held in 1984 (Hiscock 1985). The key conclusions reached at that workshop regarding applicability of various techniques are summarised in Table 1. More quantitative approaches to surveying rocky shores and a more objective approach to sample design allowing application of more effective data analysis are described in Underwood (1997).

The North Wales based Coastal Surveillance Unit (Jones *et al.* 1980) undertook one of the most successful exercises to identify change in rocky shore communities and provided detailed information on what can be considered the range of natural variation over a ten year period from 14 locations. Their data is held by the Countryside Council for Wales and provides important contextual information for the range of abundances of species present around Anglesey both seasonally and over the period of the project. These sorts of results inform us regarding natural ‘change limits’ to be expected in species. To some extent, the methods used on rocky shores can be developed for rocky subtidal areas but it would be unwise to simply convert using previously developed techniques. For instance, the rocky shore monitoring technique, which uses stations, placed at one tenth of the tidal range heights and an abundance scale was originally developed as a field exercise to demonstrate to students the zonation present on shores. Repeat survey to detect change need only include stations in the main zones or those communities relevant to the importance of the site. The abundance scale does not lend itself to data analysis and its use needs discipline if results are to accurately reflect change. The Coastal Surveillance Unit developed methods from scratch and their use of counts within quadrats and of cross-wire frames for algal cover provides much more accurate and repeatable results than using abundance scales. The cross-wire frame is shown in Figure 3. However, results from fixed-point quadrats or transects do not lend themselves to a range of statistical techniques which repeat random sampling at fixed levels on rocky shores would. This is particularly the case where measures of abundance of species ± confidence limits are required.

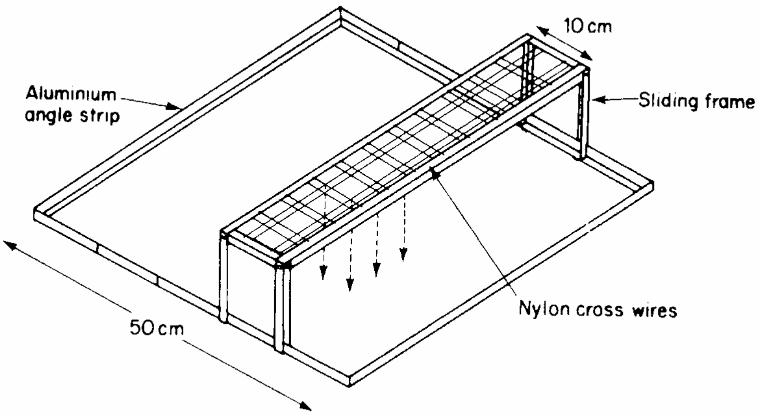


**Figure 3** The cross-wire frame developed by the Coastal Surveillance Unit to measure percentage cover of algae at rocky shore stations. The use of cross wires allowed records to be made of occurrence in the different layers. From Jones *et al.* (1980).

**Table 1.** Summary of survey techniques considered to be appropriate and practical for different monitoring objectives on different rocky shore types (from Hiscock 1987).

| OBJECTIVE | SHORE TYPE | Visual assessment | Species listing | Abundance of species at marked sites | Quantitative recording in marked areas | Quantitative recording by random sampling | Manipulative studies / settlement plates / Transplants | Morphological / physiological / cell biology / reproductive studies |
|---|---|---|---|---|---|---|---|---|
| Description of gross change | Unbroken platforms | 1 | 1 | 1 | 1 | 2* | 3 | 3 |
| | Broken rock | 1 | 1 | 1 | 1 | 3 | 3 | 3 |
| | Stable boulders | 1 | 1 | 1 | 3 | 3 | 3 | 3 |
| | Under boulders | 1 | 1 | 1 | 2 | 3 | 3 | 3 |
| | Shingle and cobbles | 1 | 1 | 1 | 1 | 2* | 3 | 3 |
| | Rock pools | 1 | 1 | 1 | 1 | 3 | 3 | 3 |
| Detection of a gradient from a point source | Unbroken platforms | 2 | 2 | 2 | 1 | 1 | 1 | 2* |
| | Broken rock | 2 | 2 | 2 | 1 | 3 | 1 | 2* |
| | Stable boulders | 2 | 2 | 1 | 3 | 3 | 1 | 2* |
| | Under boulders | 2 | 2 | 1 | 2 | 3 | 1 | 2* |
| | Shingle and cobbles | 2 | 2 | 1 | 2 | 2 | 1 | 2* |
| | Rock pools | 2 | 2 | 2 | 3 | 3 | 1 | 2* |
| Description of subtle change in populations | Unbroken platforms | 3 | 3 | 3 | 1 | 1 | 2 | 2 |
| | Broken rock | 3 | 3 | 3 | 1 | 1 | 2 | 2 |
| | Stable boulders | 3 | 3 | 2 | 3 | 3 | 2 | 2 |
| | Under boulders | 3 | 3 | 3 | 1 | 3 | 2 | 2 |
| | Shingle and cobbles | 3 | 3 | 3 | 1 | 2 | 2 | 2 |
| | Rock pools | 3 | 3 | 3 | 3 | 3 | 2 | 2 |
| Detection of sublethal effects | | 3 | 3 | 3 | 3 | 3 | 3 | 1 |

1 = Highly recommended, 2 = Applicable but not highly recommended, 3 = Not applicable, * = Over-detailed. Based on part on the conclusions of the Rocky Shore Survey and Monitoring Workshop (Hiscock, 1985).

### 2.1.3 Surveys of inshore fish populations

Demersal fishes make an important contribution to community structure in many marine biotopes and the assessment of change in this group may be indicative of wider changes in the environment (Barber *et al*. 1995; Hansson 1987). Monitoring fish numbers is more difficult than other less motile phyla and these difficulties arise particularly from:

- High natural annual variability in fish populations (Gibson *et al*. 1993; Henderson 1989; Jannson, Aneer & Nellbring. 1985; Jones & Clark 1977; Nellbring 1985; Rogers & Millner 1996; Stromberg 1997).
- Difficulty in the accurate quantification of populations as a result of factors such as the season, weather, tide and observer subjectivity (Baker, Hartley & Dicks 1987; Darwall & Dulvy 1996). Time of sampling may therefore be critical.
- Differing efficacy of various techniques precluding comparisons of population levels when using different techniques (Baker, Hartley & Dicks 1987).

These factors mean that demonstrating statistical significant change in fish communities requires the examination of a long time series (Dufour *et al*. 1995; Haage & Bengt-Owe 1970; Rogers & Millner 1996) and, to be reliable, the same techniques for assessing population should be used preferably by the same personnel (Baker, Hartley & Dicks 1987). Producing time series data is both time and resource consuming but is an obvious necessity if natural inter-annual variations are to be accounted for in population assessment. Regrettably few accurate long-term descriptions of changes in inshore fish communities exist (Dufour *et al*. 1995; Francour 1997; Henderson 1989; Jones & Clark 1977).

Suggested methods of sampling in a range of habitat types are shown in Table 2. Gear and fishing methods tend to be size and species selective and this selectivity differs between habitats. For a review of techniques see Potts & Reay (1987). When selecting a technique the following issues should be considered:

1. Fish species or group of interest
2. Fish size (proportional to species and age)
3. Habitat type (sedimentary/rocky/weedy)
4. Exposure (weather, tides - can gear be left?)
5. Security (can gear be left unguarded?)
6. Purpose (i.e. fish for mark - recapture studies need to be in good condition)
7. Destructiveness of technique (e.g. trawling in SACs)
8. Restrictions in fishing practice (by-laws etc.)
9. Safety (diving, netting)

**Table 2.** Commonly used techniques for the assessment of fish populations in temperate waters.

| | **Habitat type** | | | | |
|---|---|---|---|---|---|
| **Technique** | **Sedimentary** | | **Rocky** | | **Seagrass/** |
| | Sandy | Muddy | Subtidal | Intertidal | **Kelp** |
| **Nets** | | | | | |
| Gill/ trammel net | ** | *** | *** | ** | * |
| Beach seine | *** | x | x | x | * |
| Drop net | ** | x | ** | * | *** |
| Fyke net | ** | *** | * | * | * |
| Pop-up net | ** | * | ** | * | ** |
| Beam trawl | *** | x | * | x | x |
| Push net | *** | ** | x | x | x |
| Hand net | x | x | * | *** | x |
| **Traps** | * | ** | *** | *** | *** |
| **SCUBA** | | | | | |
| Point counts | * | x | *** | *** | x |
| Transects | * | x | *** | x | x |
| **Other** | | | | | |
| Video | ** | x | *** | * | x |
| Anaesthetics | x | x | ** | *** | ** |
| Bailing | x | x | x | ** | x |
| Manual search | * | x | * | *** | x |
| Mark recapture | ** | * | ** | ** | * |

KEY: *** - recommended and most commonly used method, **- used occasionally, * - possible, x - not possible/ impractical

For simplicity, accuracy and cost effectiveness, it is desirable to concentrate on a few indicator fish species, the choice of which will depend on habitat type and the reason for the assessment. Ideal species for detecting change are those that are common over a wide geographical range and, where applicable, resident throughout the whole year. Seasonal migrations (Gibson *et al*. 1993) and seasonal activity changes (Sayer, Gibson & Atkinson 1993) must be considered when assessing any change in the apparent fish population. Monitoring the catch on power station cooling water screens (Henderson 1989) is a very effective way of continuous sampling but requires a power station on site. Examples of where fish population changes have been assessed are shown in Table 3.

**Table 3.** Examples of fish population assessment showing temporal and spatial change using different techniques

| Habitat | Method | Purpose | Reference |
|---|---|---|---|
| Intertidal mussel bed | Visual, during low tide | Determine fish assemblage variability over a 16 year period | (Jones & Clark 1977) |
| Shallow water in non-tidal sea. | Gill netting | Determine impact of paper mill effluent (high biological oxygen demand) | (Hansson 1987) |
| Estuarine | beach seine | Determine effect of thermal effluent on community structure | (Jones *et al.* 1996) |
| Sea loch | beach seine | Evaluate fish community structure at fish farm sites | (Carss 1996) |
| Estuarine | beam trawl | Determine effect of increased sewage discharge on fish community | (Hall *et al.* 1997) |
| Various | Analysis of power station cooling water intake screens | Indicate fish variability, in differing habitats, around the UK | (Henderson 1989) |
| Seagrass and mud | SCUBA census, gill net | Compare techniques | (Jannson *et al.* 1985) |
| Shallow soft bottom | Drop trap | Evaluate seasonal and inter-annual variations | (Nellbring 1985) |
| Rocky | Visual | Compare fish assemblages inside and outside marine reserves after a 12-year interval. Examine the effect | (Dufour *et al.* 1995) |

### 2.1.4 Surveys of point-source impa

Impacts of point-source discharges (a
relatively easy to monitor across hom
sampled at distance intervals to establ
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monitoring are many and are associat
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undertaken to illustrate changes in the
following clean-up. Figure 5 shows th
shows the results of surveying using r

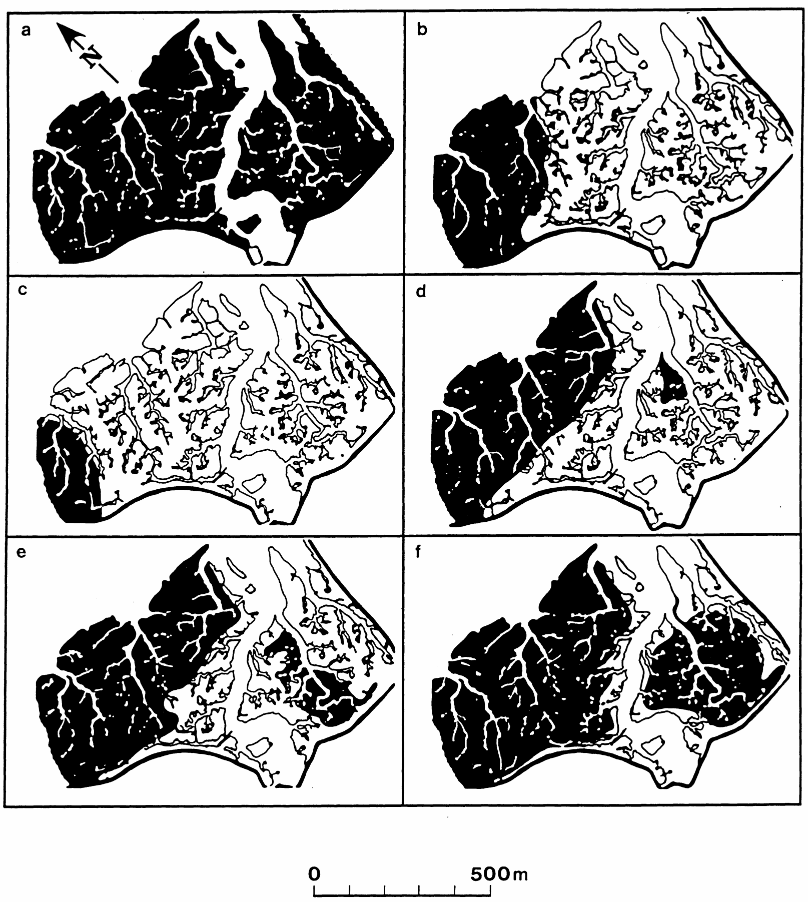


**Figure 4** Maps showing the extent of saltmarsh plants (shaded areas) adjacent to the effluent of an oil refinery discharged into creeks at centre and right of the maps. (a) 1950; (b) 1966; (c) 1970; (d) 1972; (e) 1973; (f) 1974. The maps illustrate to management the improvement following effluent clean-up. From Dicks (1976).

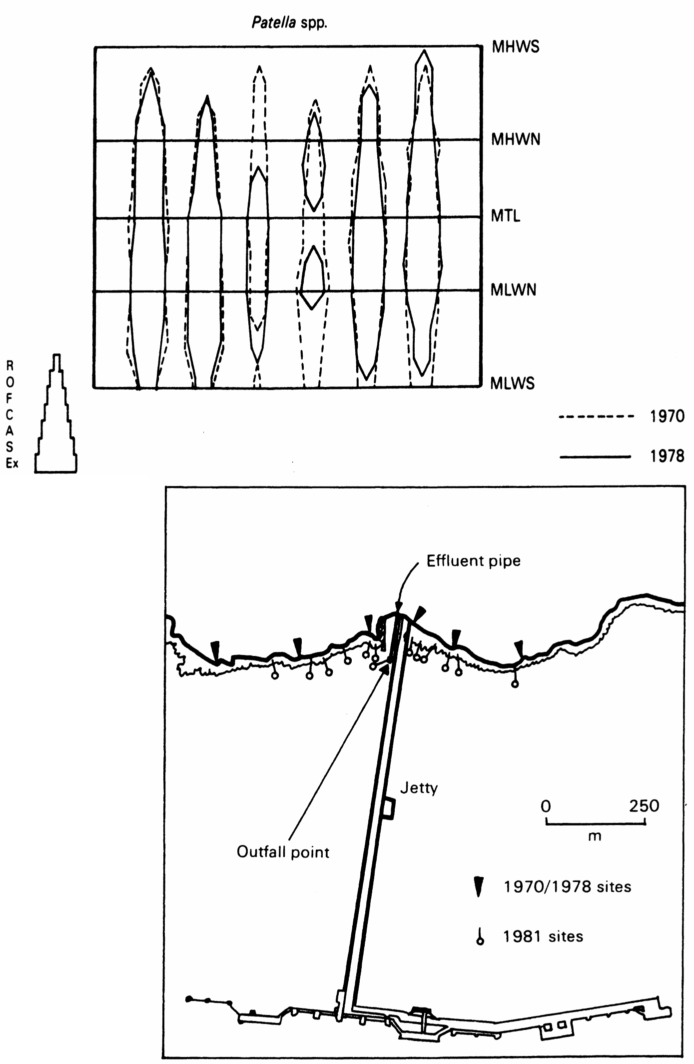



**Figure 5** Gradient of impact from an oily effluent on the shores of Milford Haven. The location of survey stations is shown on the map and the results of zonation studies of the abundance of limpets in 1971 and 1978 illustrate a gradient of effect that was particularly clear in 1978. From Petpiroon & Dicks (1982).

### 2.1.5 Surveys of effects of diffuse impacts or contamination

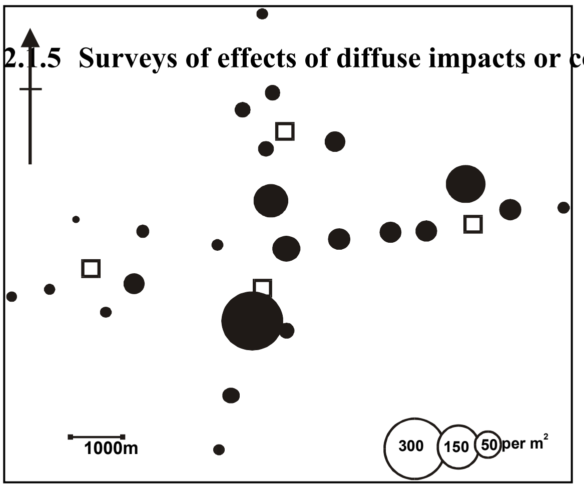
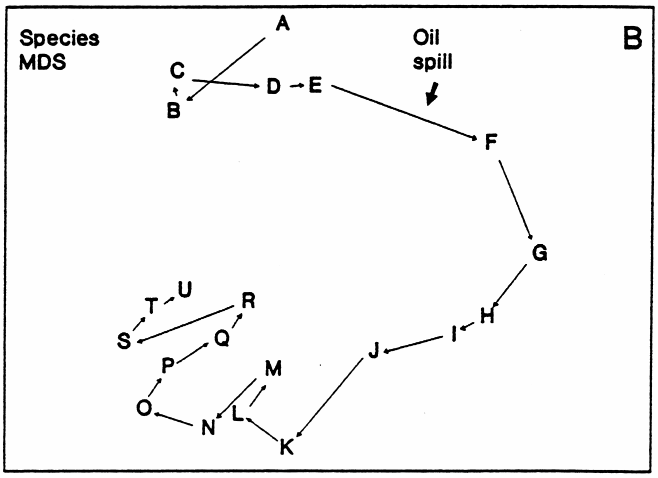



**Figure 6** Density distribution of '*Chaetozone setosa*' along a gradient of effect away from the Forties oil platform. The four platforms are shown as squares. Abundance is shown as proportional circles at each of the sampling stations. From Hartley & Ferbrache (1983).

Impacts of large scale diffuse pollutants or activities confined within a delimited area require methods which can separate change resulting from human activity (including management measures) from those which are part of the natural variability of a community or species. The approaches developed by A.J. Underwood (see, for instance, Underwood 1992) are particularly pertinent here. They rely on the application of random sampling in both location of sample sites and time of sampling at the site of impact and at reference (called "control") sites which are unaffected.




ession of change before and after the *Amoco Cadiz* oil of quarterly samples of macrobenthic communities in laix, France. A = April 1977; the oil spill was March ıary 1982. From Warwick & Clarke (1993).

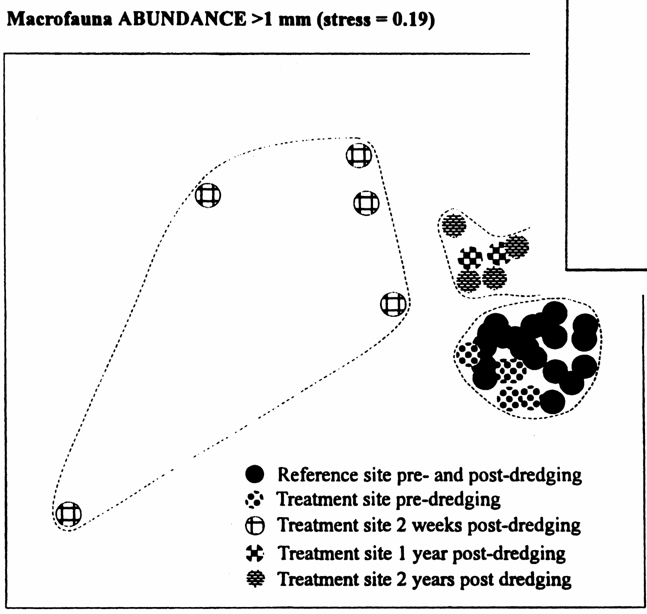



**Figure 7** Degree of recovery following aggregate dredging illustrated using indices based on quantitative sampling; each point being plotted according to scores assigned by the data analysis. Data analysis was undertaken using MDS performed on Bray-Curtis species similarities following $\log_e(x+1)$ species abundance transformations. From Kenny & Rees (1996).

Severe but potentially recoverable impacts can include those caused by, for instance, mobile fishing gear, aggregate dredging, contaminants such as anti-fouling paints or large oil spills but also natural events such as severe storms or very hot or very cold weather. Monitoring here may use measures from locations known or likely to be affected by the impact in comparison with measures from reference sites considered to be the same in character but not affected by the impact. The work undertaken in Sullom Voe since 1976 and still ongoing provides one of the longest time series of monitoring data. The work there has been in part based on the sampling of comparable sites near to and distant from the oil loading jetties and effluent diffuser. Rocky shore surveys (Moore, Taylor & Hiscock 1995) using abundance scale sampling within different zones on the shore providing an indication of year-to-year fluctuations proved to be useful only as reference data for changes on shores severely affected by oil spills and subsequent bulldozing or for the reduction of dogwhelks due to TBT impacts in the Voe. The results of localised natural fluctuations and worker variability far outweighed small-scale changes resulting from terminal operations. However, analysis of macrobenthic data from Sullom Voe collected between 1978 and1992 using Shannon-Weiner diversity indices (Simpson 1949) and non-metric multi-dimensional scaling (MDS) (Kruskal 1964) have shown changes which can be associated with the activities of the terminal near to the loading jetties where disturbance occurs (May & Pearson 1995). MDS has proved to be a particularly effective way of illustrating complex results in one figure where the plotted points show change in the character of the communities (species and their abundance) present. It has been used to illustrate the degree of change outside of that which is normal in the case of aggregate dredging in Figure 7 and for the impact of the Amoco Cadiz oil spill in Figure 8. Studying the effects of mobile bottom fishing gear has used trawls and grab sampling (Kaiser & Spencer 1996). Where studies have investigated one-off impacts, the results, illustrated as plots of the scores obtained in data analysis, often show something close to a cyclical progression from 'damaged' (with plots distant from those of reference sites) to 'recovered' and near to the hypothetical 'envelope' which encloses the scores representing natural variability (Figure 7). Ideally, studying the impact of a development will include assessing degree of natural variability before the impact occurs. Such a study was undertaken by George *et al.* (1995) revealing significant changes (Figure 9) from year to year in the subtidal cobble community but differences which were common to all of the stations placed at increasing distances from the location of the sewage effluent pipe to be constructed in future years.

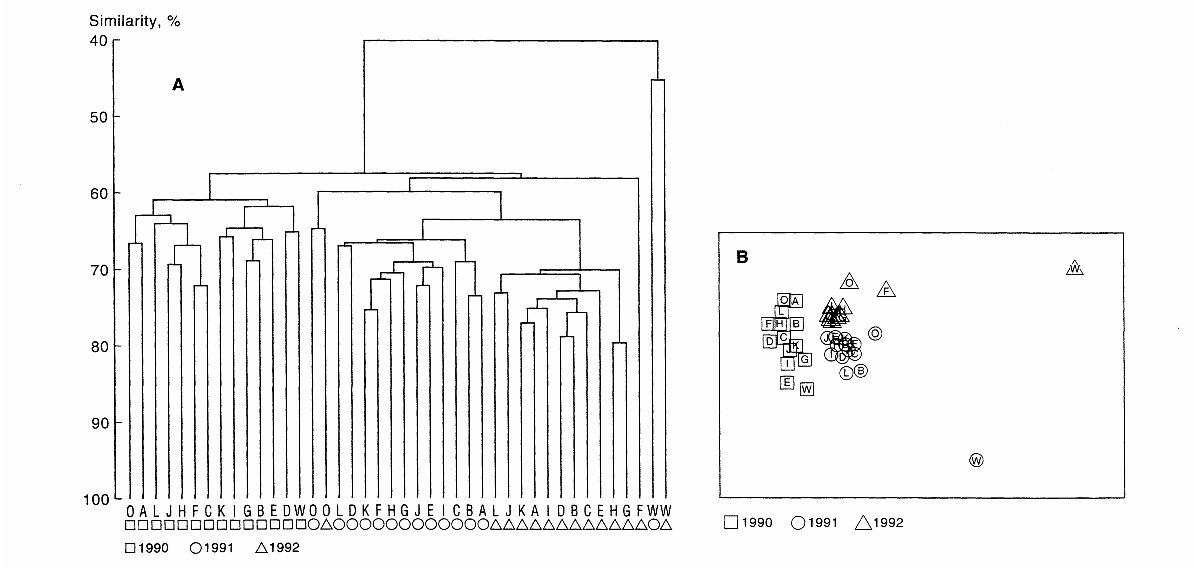



**Figure 9** Similarity and MDS dendrograms for communities on cobbles at 14 sites in 1990, 1991 and 1992 off North Norfolk. Results of a pre- impact study illustrating the presence of different communities from year to year but which are similar at different sites in each year. From George *et al.* (1995).

### 2.1.6 Monitoring studies designed for nature conservation management

Monitoring exercises related to features of marine natural heritage importance have been developed by the nature conservation agencies in Great Britain especially at Lundy, Skomer and the Isles of Scilly. Fowler & Pilley (1992) review those for Lundy and the Isles of Scilly and the work undertaken at Skomer described by Bullimore (1987) and Hiscock (1986). Those studies are specifically designed to inform conservation objectives for and management of those sites. They have especially helped us to understand aspects of the sensitivity of species including growth rates, poor recruitment/reproductive success and mortality rates. Some of the results could be triggers to management action. For instance, the measures of growth rates in the sponge *Axinella dissimilis* undertaken by photographic monitoring of the same individuals (for instance, Figure 10), illustrates their very slow growth rate and, together with no indication in viewpoint photographs of any recruitment over 13 years, the likelihood that they would not recover if lost. Sampling would therefore not be permitted. Similarly, viewpoint photography at one site on Lundy revealed a reduction by in the region of 20% in the numbers of the solitary coral *Leptopsammia pruvoti* between 1983 and 1996 (K. Hiscock, personal research) together with reductions in the abundance of several other species which are nationally rare or scarce and whose loss is therefore a matter for concern. A similar reduction in the numbers of *Leptopsammia pruvoti* together with the Devonshire cup coral *Caryophyllia smithii* and possibly other species appears to have occurred in fixed site photographic monitoring quadrats in the Isles of Scilly between 1984 and 1991 (Figure 11). Consideration of the reasons why the reduction is occurring is required.

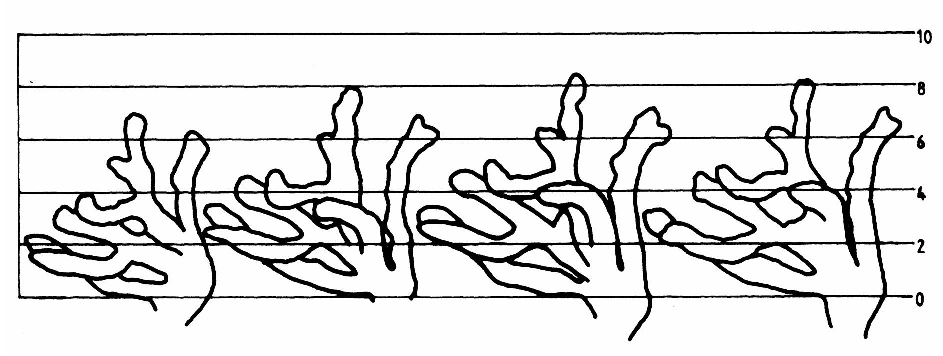



**Figure 10** Measuring growth rates to assess degree of sensitivity resulting from slow growth and longevity. Outlines of a sponge *Axinella dissimilis* drawn from photographs taken from the same angle against a scale in successive years (left to right: July 1985, 1986, 1987 and September 1988). The scale lines are 2 cm apart. (Keith Hiscock, unpublished.)

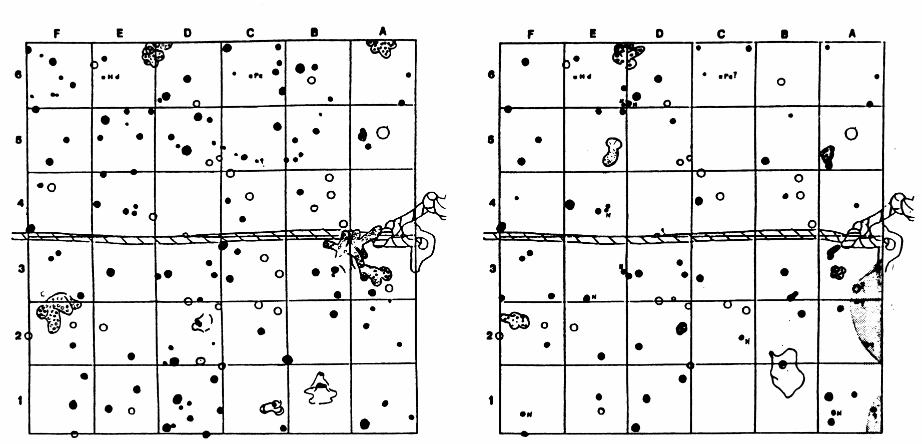



**Figure 11** Recording changes in the population of species to assess mortality and recruitment. Drawings made from photographic transparencies of the populations of cup corals *Leptopsammia pruvoti* (closed circles) and *Caryophyllia smithii* (open circles) together with other conspicuous species and a fixed quadrat location in the Isles of Scilly in 1984 (left) and 1991 (right). From Fowler & Pilley (1992).

### 2.1.7 Contextual monitoring

The UK National Monitoring Programme (NMP) was devised in response to the 1986 House of Lords Select Committee on Marine Science and Technology who recommended that a common approach to monitoring should be established to provide information required by the full range of national and international commitments. Overall responsibility for the NMP rests with the Department of Environment Transport and the Regions and is co-ordinated by the Marine Pollution Monitoring Management Group (MPMMG). Broadly, the Environment Agency in England and Wales and the Scottish Environment Protection Agency in Scotland are responsible for estuaries and coastal areas whilst the Ministry of Agriculture, Fisheries and Food, Centre for Environment, Fisheries and Aquaculture Research and the Scottish Office Marine Laboratory for offshore areas with the Department of Agriculture for Northern Ireland responsible there. Sampling is of physical, chemical and biological characteristics of each of about 90 stations around the UK made-up of three stations in each of 16 estuaries and the remainder in coastal regions and offshore. The programme has become biology-led as the biology is considered to integrate and reflect the effects of the wide range of physical and chemical conditions occurring at a site. However, a perceived weakness is the difficulty of linking cause and effect. A National Marine Biology Analytical Quality Control Scheme (NMBAQC) was established in 1992 and has undertaken various exercises and workshops involving 25 laboratories to establish quality assurance standards, thus providing a model for quality assurance measures in SAC surveys. Biological survey in the NMP is based on macrobenthic sampling using grab and core sampling of sediment biotopes. Being quantitative counts of individual organisms, the results lend themselves to the use of diversity indices and multivariate analysis to indicate 'health' and extent of change. As such, they provide a measure of the character of communities in an area and a context for assessing the significance of localised change (for instance, whether increase in the abundance of a species indicating stressed conditions is infact part of a UK-wide change). Such surveys to provide a context to localised surveys to detect pollution gradients in the region of oil production platforms are now being undertaken in Norway (J.S. Gray, pers. comm.).

### 2.1.8 World-wide developments

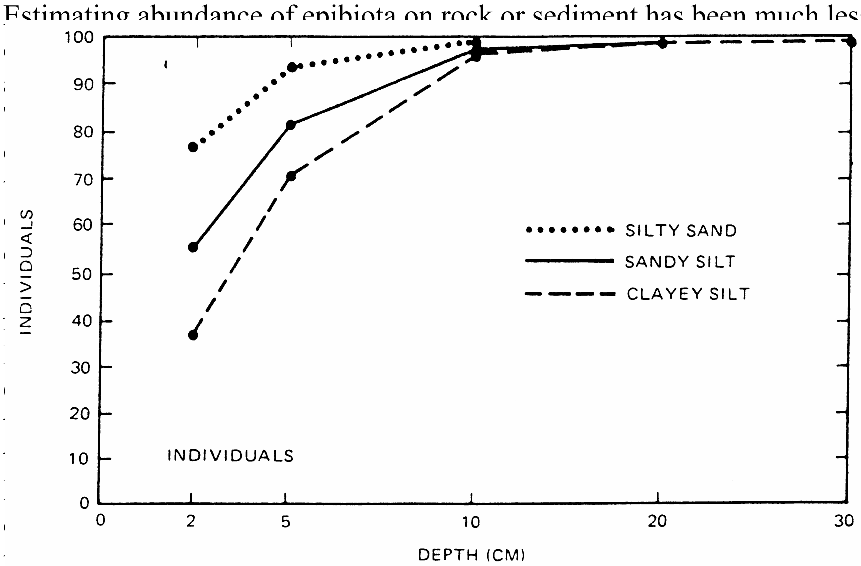
Examples of monitoring methods from other parts of the world, including of very different habitat types to those occurring in the north-east Atlantic and Mediterranean, are also relevant especially where the information they collect is used for conservation management. Thus we can learn from work being undertaken in coral reef habitats for the survey of hard bottom communities (for instance the work of Loya 1978 recommending a stratified random sampling programme; the studies of Weinberg 1981 and 1984 who concluded that quadrats in which the number of individual colonies are counted and their relative cover estimated provided the most reliable and immediate results; the ‘Standard Operational Procedure’ volumes being issued for long-term monitoring of the Great Barrier Reef), and studies of tropical fish populations (for instance, Christie *et al.* 1996).

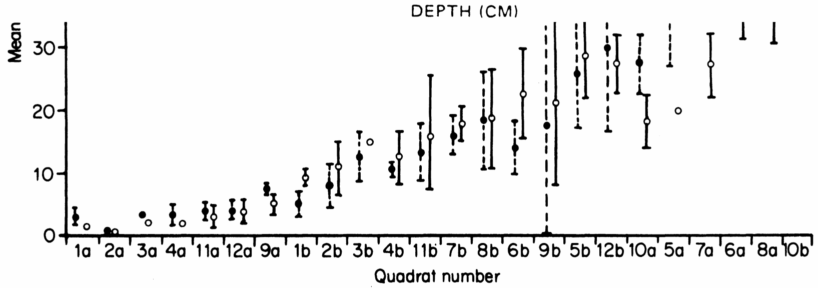
### 2.1.9 Sample and worker variability – understanding and minimising it, experience from trials

Undertaking pre-survey trials to ensure that your work will generate meaningful results about change is essential. There is much experience to benefit from published in the literature and workshops undertaken under this project have also indicated the limits of accuracy of novel techniques. The literature on sediment sampling is very extensive and has led to the sort of guidelines given in Holme and McIntyre (1984) and the sort of conclusions reached by Ferraro *et al.* (1994). Writing this section has benefited from the review of sources of variation in benthic ecological surveys undertaken by Dalkin (1995).

Assessing minimum sample area for quantifying the number of species present at a site and their density is referred to in Section 3.5.5. Sample collecting variability is most likely to happen when equipment is inconsistently or inadequately used. For instance, a grab or core needs to penetrate a minimum depth to collect a reasonable proportion, and preferably the majority, of the fauna (see Figure 12). If a minimum penetration equals about 10 litres of sediment, collecting that much must be a quality assurance requirement. Even the way in which a sieve is deployed to separate fine sediment from fauna is important and requires guidelines so that biological material is not lost by, for instance, over-enthusiastic hosing. When the sample reaches the laboratory, further scope for error is available and the percentage of fauna separated from the sample can vary greatly between workers. Such sources of error are being identified and means to minimise them established through the National Marine Biology Analytical Quality Control Scheme in the UK (see later).

Estimating abundance of epibiota on rock or sediment has been much less subject to trialling than sampling
ed techniques of recording
density of different organisms.
istance Figure 13). Often such
ating percentage cover or interprets
is to record the percentage of rock
nterprets the requirement as to
als might drive the survey planner
which case cost will rise if the same
st because the tide also rises.
es from the work of Dethier *et al.*
ements with point quadrats. The
Worsfold & Dyer 1997) especially
rding on hard and mixed substrata.
littoral rocky area recorded a total
city identified to species by another
orty-five of the species were only
divers but that leaves quite a high
a six point scale (Appendix 4) out



(for instance, records were between Occasional and Common). On a second visit with target species identified, all pairs located and recorded all target species except where they were Rare or Occasional but the range of estimates of abundance remained as much as two and even four points out. The reasons for such disparity might be due to:

- failure to observe rare or cryptic species (dedicated searching might be required);
- taxonomic confusion – a species either identified incorrectly or given a generic or Family name rather than the species and genus;
- inaccurate estimates of density or percentage cover to convert to abundance grades;
- uncertainty of what part of the abundance scale to apply – different ones chosen;
- lack of time to search thoroughly;
- the area searched was different to that searched by others.

Some of the problems above are clearly resolvable and must be addressed in procedural guidelines if such rapid and comparatively inexpensive techniques are to be used. They must also be addressed in pre-survey exercises undertaken on the first day of every survey to check between workers the reasons for any differences.

Another of the exercises undertaken during the workshops was to establish to what extent observation-based survey on rocky shores provided a measure of cryptofauna species (>0.5mm in size). *In situ* survey did not record non-sessile taxa which were smaller that 4mm and, of the 65 taxa recorded from weed washings at one site, 61 were not recorded during the *in situ* surveys (although some were lumped in categories such as ‘Amphipoda indet.’). Conversely, 26 non-sessile taxa were recorded *in situ* of which 19 were not found in the samples. These two approaches to sampling appear to provide data, which can either be considered as mutually exclusive or complimentary.

Another aspect of sample variability will be the changes over time which occur naturally or as a result of an impact. Establishing methods which will overcome confusion of results through variability with time is particularly advocated by Underwood (1992).

### 2.1.10 Site relocation and marking

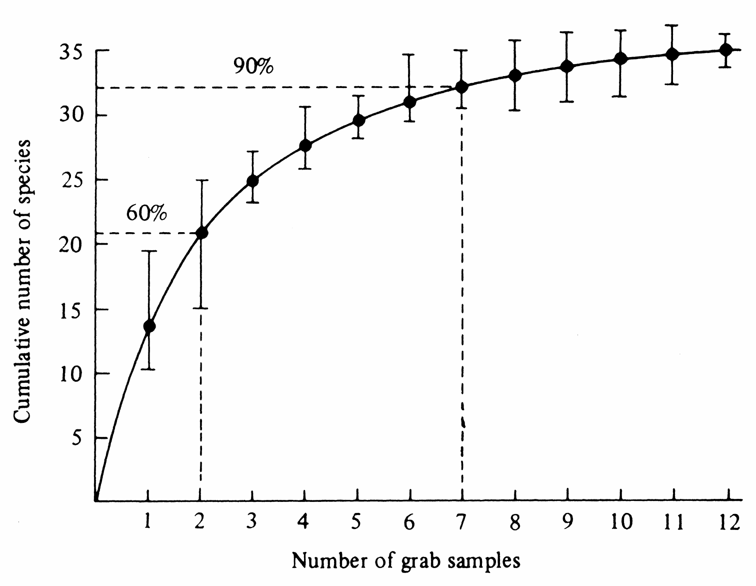
Re-location of fixed sites can be very difficult especially underwater in poor visibility or with few conspicuous features to act as navigation aids. Even over level sediment seabeds, maintaining or re-establishing the same location may be important because of patchiness (see Rees, Allen & Coppock 1994) to re-sample from exactly the same location. The Geographical Positioning System (GPS) provides accuracy to within about 30 m on the surface and Differential GPS (DGPS) to within less than one metre. Both systems are available although coverage by DGPS is not currently universal. Despite the advent of GPS, transit marks and the use of conspicuous land features to locate sites remains important and useful. On rocky shores, it is usual to use a map to locate the rough position of a marked site, a photograph (including land or seashore features which are conspicuous and preferably line-up to produce a transit) to identify where station marks are, and careful searching to identify station marks. In underwater rocky areas, confusion in poor visibility is easy and thought should be given to locating stations, which can be easily re-found. It is likely that photographs will be used to indicate where the station marks are and then careful searching perhaps aided by a metal detector to find bolts or screws.

**Figure 13** Mean estimates by two workers of barnacle percentage cover in each of 12 quadrats and 95% confidence limits of the value ($n = 4$). Quadrats are arranged in ascending order of barnacle cover. (From Jones *et al.* 1980).

Site marking can employ several approaches and may not be necessary where topographical features on rock are adequate or possible on sediments where markers are likely to be moved and may be unnecessary on level seabed. A list of site marking techniques is given in Appendix 5 but ingenuity and an appraisal of the technique best suited to such considerations as rock type, degree of wave exposure and likelihood of interference with markers in an area is required.

### 2.1.11 Look before you leap

The greatest care has to be taken in accepting established techniques. For instance, diversity indices or the results of multivariate analysis are useful for nature conservation management only if they are interpreted. Even if the score or plot stays within the range considered to reflect normal variability, inspection of the data will be required to show whether species considered of marine natural heritage importance have been lost or whether species considered indicators of stress or pollution are driving the change in numerical scores.




'Traditional' macrobenthic sampling methods, based on sampling small areas of seabed and identifying and counting all of the species which occur as individuals, should not go unchallenged in monitoring for environmental protection and management. Usually, the number of samples required to characterise the communities present is based on taking a large number of samples, identifying all of the species present and discovering where the number of additional species per additional unit sampled levels off. The number of samples above which obtaining a 10% increase in the number of species would require a 100% increase in sample area is often considered about the 'right' sample size for monitoring studies (see Section 3.5.5). Whilst such species area curves produce very useful indications of species richness in different locations or the same location with time (for instance, see Figure 14) it is often only possible to identify real change in the quantity of a species for the most abundant ones. For instance, for hard substratum epibiota on a level bottom, Hiscock & Rostron (unpublished) found that only a small number of the total of 192 species were present in sufficient quantity for statistical comparison. Of these, 26 required up to 20 0.1m² sampling units to achieve 95% probability of a standard error equal to 20% of the mean. However, for a standard error of 10% of the mean, four times as many sampling units were necessary, and in this case only four populations were described adequately by less than 20 sampling units. In apparently homogeneous sediments in the Oslofjord, Gray, Valderhaug and Ugland (1984) found that the quantity of five **common** species completing one turnover of all individuals during the course of their study were present within bounds of ± 10% between sampling intervals but rare species were "highly variable in abundance". They recognised that this was the result of the sample size being inadequate to establish mean densities or even be sure of sampling a specimen of many or most species. In conclusion, it seems that, although comparative species richness can be assessed using a reasonable number of quantitative samples, trying to establish meaningful information about changes in abundance of 'all' of the species in a community would require an almost impossibly large (and certainly financially impractical) number of samples.

Studies which sample only small areas are also unlikely to include large widely dispersed species which may be very good indicators or which, because they are scarce, have an importance for conservation. 'Traditional' methods of grab or core sampling for such species is inappropriate and *in situ* observation (whether by diver or remote operated video) or digging-over (for infauna) an area of sediment will be required for such species.

The data analysis techniques used in the majority of past monitoring or comparative studies are also difficult to apply to many of the species being sampled in nature conservation monitoring because the methods used to analyse data cannot cope with colonial species - characteristic of many of the habitat types of marine natural heritage importance. So, if the habitat to be subject to monitoring is sedimentary, it is likely that techniques for assessing diversity or supplying data for multivariate analysis are well developed.

Sampling the full range of macrobenthos is also very expensive, whether in sediments or from rock and more selective approaches might not only be less expensive but also more meaningful for conservation management.

## 2.2 'Adopt and adapt' – experience from terrestrial studies

There is not only much to learn from the terrestrial monitoring and nature conservation management scene but it is also important to ensure compatibility wherever possible so that the same 'language' is used and the marine monitoring results will contribute to general reporting. However, no attempt is made here to review terrestrial methods of survey and the reader is referred to Goldsmith (1991) and Spellenberg (1991) for recent accounts of terrestrial monitoring methods in relation to nature conservation management. Rodwell (1997) reviews how the National Vegetation Classification can be applied to monitoring especially in relation to achieving 'desired condition'.

Applying results of monitoring to reporting under the Habitats Directive is dealt with by Shaw (1997) and the integration of monitoring with management planning in the context of the Habitats Directive but in relation to terrestrial habitats is reviewed in Brown & Rowell (1997). It is useful here to consider the eight 'Principles' suggested by Brown & Rowell (1997) and to comment on their relevance to marine habitats.

1. "For most (UK) conservation sites, features (and their condition) are already well known". There is little known about the condition of most marine sites with respect to defining favourable conservation status for each feature; much work is being undertaken to improve our knowledge on this.

2. "Monitoring in the context of management planning is about drawing conclusions, making decisions and taking action". This is equally true in the marine environment.

3. "Science alone cannot make decisions for us about conservation management, or judgements about feature condition". This is particularly the case in the marine environment where the relationships between environmental conditions and change or knowledge about the biology of species are often very poor. Whilst information and existing knowledge of cause and effect are essential to use, the judgement of experienced scientists will often be required in appraising reasons for change and in making management decisions.

4. "Monitoring always involves some form of hypothesis-testing since it involves making decisions". The 'decisions' to make in marine conservation management are different to terrestrial as the environment together with the biota it supports are largely functioning as a natural system. However, in managed systems, for instance many saline lagoons, the hypothesis "if we do w, x will happen", or "if species y appears, it indicates environment condition z has changed" can be addressed. This principle needs expanding, or an additional principle is required, to address the question of triggers to action. If repeat survey to detect change is to be an effective management tool, it must identify triggers to action.

5. "The evidence required to evaluate the condition of an instance of a habitat is less than a full definition of favourable condition (or Favourable Conservation Status)". This is taken as a 'you cannot measure everything' principle which must lead to identification of both priorities for survey and those attributes which can best be used to indicate 'condition'. This principle is equally relevant for marine sites. Inevitably, the attributes chosen to represent (act as surrogates for) site condition will be less than the full picture but must in some way reflect the reason why the site was established.

6. "Attributes of a feature must be quantified but will not always require quantitative measurement". The explanation of this Principle seems to be concerned with understanding cause and effect; something which is equally difficult in the marine environment if the impact has not been observed or is not obvious. Another interpretation of the principle is that an experienced observer can often give a 'good-enough' assessment that change is occurring without undertaking an impossibly large amount of sampling to a level which will establish statistically significant measures of change. Indeed, expert judgement is often likely to be better than pseudo-science, which is also very expensive and often undertaken by inexperienced contractors.

7. "Monitoring the condition of a feature will not, in itself, explain cause and effect". Monitoring of biology, physical and chemical conditions and of human activities tell the manager that change has

occurred or an 'event' taken place: it is making the link to explain change which management requires. This is where, as in terrestrial systems, an excellent knowledge of the literature describing events and their effects linked to an understanding of the biology of key or indicator species is required. 'Expert' computer systems will help but will not replace an experienced scientist (yet). Experimental studies (including taking advantage of accidents or extreme natural conditions) may be needed.

8. "Information about habitat condition and habitat management must be treated as separate lines of evidence in evaluating whether a habitat is in favourable condition". Habitat condition will be a far more important measure in the marine environment as management is rarely undertaken to improve condition.

I identify here two other important principles:

1. Monitoring is potentially very expensive and identification of minimal methods to satisfy management objectives and reporting requirements may be important. This may be even more the case in the marine environment where environmental conditions result in the need for often very expensive equipment.

2. Monitoring requires careful targeting on those features or attributes which require it or which are capable of being surveyed effectively. There is much scope for the academically-inclined researcher to discover matters of great fascination for ecology but which do not assist management.

## 3. Determining requirements for survey, surveillance and monitoring

### 3.1 The nature of marine habitats, communities and species

A basic understanding of the nature of marine habitats, communities and species, and of ecological theory as it relates to marine ecosystems, is of fundamental importance to designing monitoring programmes which will be useful in managing marine ecosystems. Several texts will help the non-marine biologist. The volume entitled *The sea shore* (Yonge 1966) gives an excellent and highly readable introduction to seashore ecology in Great Britain. Other informative texts on the seashore are Southward (1965) and Barrett (1974). McLusky (1989) describes the ecology of estuaries. Other more recent volumes such as Fincham (1984), Meadows & Campbell (1988), Hawkins & Jones (1992), Little & Kitching (1996) and Raffaelli & Hawkins (1996) are intended as student text books for the study of marine ecology whilst a wider audience is served by volumes such as *Sea life of Britain and Ireland* (Wood 1988). Gray (1981) describes the ecology of sediments. The volume by Krebs (1994) gives an excellent background to ecological principles and interpretation of distribution patterns and to change.

Marine communities are not, overall, at an intermediate stage in ecological succession although change is occurring. Exceptions occur especially in disturbed situations such as areas subject to substratum mobility and scour during storms or where large fluctuations in physical or chemical conditions occur; for instance, in saline lagoons. The predominant impression of ecologists returning to the same site year after year or after several years is of an overall constancy in the composition of communities at particular locations within a generally small degree of seasonal change. This is described as global stability. Nevertheless stochastic events can cause large changes in what had appeared to be very constant communities or populations of species – these events are, for instance, severe gales, very cold winters, toxic algal blooms or an anchor dragging through a biogenic reef. The view that significant change is the norm stems mainly from the small-scale sampling which identifies patchy change but fails to identify that, overall, the same species in similar abundance will be present over an area of similar habitat type. Also, studies of settlement onto panels or cleared or otherwise interfered with substrata is often used to promote the idea of great changeability whereas such studies should be disregarded when considering natural variability. Unlike most terrestrial communities, many marine communities come closest to what are described as ‘climax communities’. This means that in some habitats or locations there is one stable dominant species or community which persists despite all but extreme perturbations (described as being in ‘global stability’). Such communities may have a high ‘resistance’ (the tendency to withstand perturbation) or ‘adjustment stability’ which is the ability of a perturbed (and therefore changed) population or community to return to the same equilibrium point or limit cycle (Connell & Sousa 1983). This is not to say that there is no change but, in many communities, the dominant species are constant with a variable abundance and presence of a minority of the community. In other situations, there might be different dominant species which switch between each other perhaps depending on stochastic events such as storms which clear-out one species and open-up space for the larvae

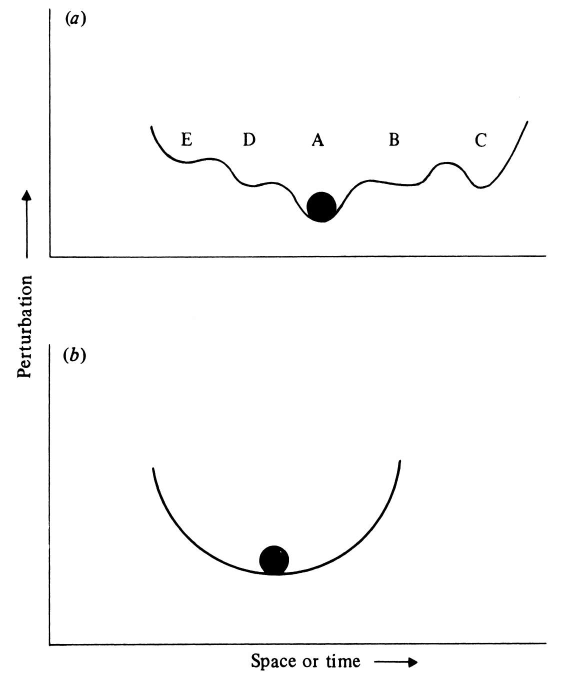



**Figure 15** Models of stability in natural systems. In neighbourhood stability (a), perturbation may result in change but the degree of perturbation required is different: to move from state E to state D, only a slight perturbation is needed but a major one would be required to move the community from state A to D or B. In global stability (b), despite perturbation, the community remains the same. (From Gray 1977.)

available to settle at the time the event occurs and which are also able to thrive in that habitat (resulting in 'neighbourhood stability'). Gray (1977) (Figure 15) describes some of the concepts of stability and examples from the UK are given in Hiscock & Mitchell (1980) and papers by Gray, Valderhaug & Ugland (1984) for the Oslofjord sediments and Christie (1983) for rocky subtidal communities in Norway are worth referring to. Cycles of change such as predators moving in, destroying a population, then moving on might also be generating temporal or spatial patches of different dominant species – another expression of neighbourhood stability sometimes described as 'mosaic cycling'.

Within an often overall stable community, seasonal change may be very large and the person planning a monitoring exercise must take account of such variations. Figure 16 shows seasonal changes in algal populations off Skomer. Clearly, in the case of algae, a decision needs to be made of the best time of year – most likely when any spring growth of ephemeral algae has settled down, perennial species have produced new fronds and before the autumn die-back. For animals, there will be times of year, usually springtime, when massive larval settlement produces very large numbers of juveniles few of which will survive. This can be clearly observed with barnacle settlement and the field worker sent out in April, May or June to survey a rocky shore may not know whether to record juveniles, knowing that few may be relevant to long term change. Similarly in sediments, very large numbers of juveniles will confuse the picture especially if a species produces overwhelming numbers which skew dominance measures – best to wait until late summer in such a situation. A recent study by Alden *et al.* (1997) demonstrated that for benthic macrofaunal communities in Chesapeake Bay, summer was the best season in which to sample and yielded the greatest power for trend detection. However, the 'ideal' time of year is probably community or species specific and depends on what aspect of the habitat it is necessary to monitor.

Several studies provide the basis for establishing degree of change especially in separate species but many have to be interpreted with caution as they were undertaken in areas small enough for patchy change to dominate the picture or species chosen for data analysis were those where change had occurred. Experimental studies may mimic natural events and may be useful for interpreting reasons for change. However, the considerable amount of work in the form of experimental manipulation studies only demonstrates

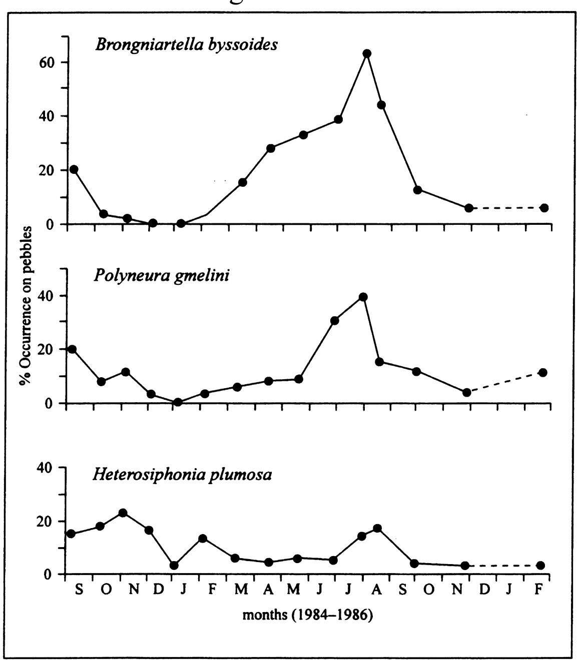



**Figure 16** Seasonal change in the percentage occurrence of sublittoral algae on pebbles at Skomer. Re-drawn from Hiscock (1986).

that major switches in community type <u>can</u> be induced (for instance, papers reviewed in Connell 1985) and must not be used to suggest that major changes occur in natural marine communities.

### 3.2 Matching survey objectives to field and analytical methods

The methods used for monitoring must be amenable to meaningful interpretation and have known precision and accuracy. If a strategic approach to determining objectives and methods to achieve those objectives is not taken, then energy time and money will be wasted. A strategic approach requires that the objectives are clearly determined and that the most cost-effective techniques which will (if any can) answer the questions being asked are identified. In all of this, the way in which the data will be compared, analysed and interpreted must be taken into account. The following notes are examples of matching survey objectives to methods.

| Survey objective | Method | Interpretation |
|---|---|---|
| Demonstrate any biologically significant change in the cover of green algae on the shore. | Photographs taken from exactly the same viewpoint. | Comparison of photographs and description of change. |
| Establish and describe quantitative changes in the number of cup corals at a site. | Photographs of marked sites using a reference frame. | Counts within the photographs expressed as total numbers in the same area. |
| Establish growth rate of the branching sponge *Axinella dissimilis.* | Identify individuals, which can be readily located and use viewpoint photographs to map them for re-location. Photograph each against a 1 x 1 cm grid marked on a black background and taken from a specified angle. Re-locate and photograph at required intervals. | Draw outline onto graph paper using appropriate manual (enlarger and angle the baseboard) or electronic ('rubber sheeting') techniques to ensure maintenance of a square grid. Compare measurements from one visit to the next to express as + or – branch lengths. |
| Establish and describe quantitative changes in the numbers of *Amphiura filiformis* adjacent to an effluent. | Collect five $0.1m^2$ grab samples (or whatever established as required minimum by tests) at each of 10 stations at 100m intervals due south (downstream) of the effluent discharge point. Samples must be minimum volume 5l sediment in each. Wash samples over a 1mm mesh, pick and count all individual *Amphiura filiformis* from each sample. | Calculate mean density of *Amphiura filiformis* at each station and illustrate as proportional circle diagrams. Calculate mean density and standard error between sample points and for different sampling events to establish if differences are significant. |
| Establish similarity of communities at a location from one sampling event with another. | Collect random or comprehensive samples within a specified area or specified number of sample units and enumerate (presence/absence, abundance, numbers of individuals of each species) all taxa to the specified level (e.g. all conspicuous species, all species held by a 1mm mesh). | Apply appropriate multivariate analysis to produce dendrogram of stations or scatter diagram for comparison of the similarity of whole community scores from different stations and in different sampling events. Assess 'closeness' of scores between impacted and reference sites or whether the scores remain similar and suggest no significant biological change. |

| | | |
|---|---|---|
| Evaluate the impact of an oil spill and subsequent clean-up on intertidal fish in a range of habitat types. | Broadly categorise areas into habitat type and exposure to oil/clean-up. Find similar unaffected habitats and match with affected areas (matched pairs). Establish transects and hand collect fish in quadrat delineated areas down transects. | Evaluate species diversity using Shannon-Wiener index. Use appropriate statistical analysis (Wilcoxon signed rank test, multiple stepwise logistic regression) comparing clean and oil/clean-up sites (Barber *et al*., 1995). |

Matching sampling methods to the analytical techniques to be used requires careful consideration of the 'requirements' of any statistical tests to be applied. Non-parametric statistics require few assumptions about data quality but allow the presentation of results only as frequencies or ranks. Parametric statistical tests, for instance, calculation of mean density with standard error require data collected to high standards and tested quality methods. Inevitably, the more detailed or carefully collected the data is, the more costly it will be to collect and serious consideration has to be given to whether stringent statistical tests will be needed or whether indicative results from whole community observations or the use of a restricted number of species will be adequate to signal that site quality is being maintained or not.

## 3.3 Location of sampling sites and sample strategy (sample design)

### 3.3.1 Location

Areas established as marine protected areas will require the preparation of an inventory of its resources so that the representative and special features are clearly known. Those features may need to be mapped to establish their extent (area covered and location) or location (for spot features such as the location of rare species).

Where monitoring is of a site-specific nature (i.e., it is not for extent of features), suitable sites will need to be identified based on:

- the location of representative habitats, species and/or communities of marine natural heritage importance identified as site attributes;
- likely sensitive sites;
- proximity to and (as reference sites) distance from potentially threatening activities;
- the presence of species or communities which require a better understanding of recruitment, growth rates and longevity;
- where there is perceived likelihood of change (or expected constancy);
- the presence of 'indicator' species which might be representative of change in the community 'early warning' of change trends;
- suitability of the site location for the techniques to be used (for instance, a flat rock surface for fixed site photographs).

### 3.3.2 Operational requirements

Operational requirements are likely to be driven by:

- practical matters such as access to sites including planning for weather windows in exposed locations or making certain that aerial photography is undertaken within one hour of low water on spring tides or agreeing that survey work underwater will not be undertaken unless horizontal visibility is better than 2 m;
- scientific requirements such as undertaking the survey at the same time of year as a previous survey, obtaining use of the same sampling equipment as used previously, obtaining the services of the same surveyors;

- financial requirements such as a survey not costing more than £15,000.

### 3.3.3 Sampling brief

A clear brief has to be completed including:

- sites and/or species to be surveyed (including specific requirements regarding extent, species to be included etc.);
- field methods to be used;
- analytical methods to be used;
- quality assurance requirements.

Pilot studies, often at the beginning of a survey, will generally be required to test sample size required to obtain statistically significant results, ensure inclusion of all species (to a certain percentage of 'real' total) in a habitat etc.

Gray (1981) advocates the following monitoring strategy for benthic [sediment] communities:

1. Thoroughly describe the species present in a given community and estimate their relative abundances; characterise the habitat by grain size, sorting coefficients, organic content etc.
2. Rationalise the species list to around 10 important species, which control the dynamics of the community. This can be done by the use of manipulation experiments where appropriate.
3. Monitor these species by intensive sampling once a year when the population densities are low and there is little chance of recording larval settlement (in boreal areas this will probably be in mid-winter). Record as many population parameters as is possible for the species studied, such as numbers, biomass, age structure, size frequencies, growth rates, etc., plus as many environmental parameters as is practicable.

The criteria used to identify species to be subject to sampling and analysis are likely to be different or additional to the simplistic ones above and will include species, which are sensitive, keystone or indicator or which may act as surrogates for the whole community.

### 3.3.4 Random or selected samples stations?

By way of introduction, I can do no better than to quote Lundälv (1985). “A basic problem in most ecological studies [and studies to detect change] is that of representativeness of samples in relation to some larger entity, e.g. population, community or geographical area. The utility of a sample differs markedly depending on what sampling strategy is employed. For most types of communities in the marine environment various strategies based on destructive random sampling have been used. This approach has the advantage of providing a standardised technique for the calculation of confidence limits or other estimates of precision. Among its disadvantages and problems, however, may be mentioned (i) that the sampling procedure in itself introduces variation (e.g. Lewis 1976), (ii) that it is often uncertain whether the basic requirements for the use of various statistical techniques are fulfilled and (iii) that the final measures obtained are often coarse, thereby offering only limited opportunities for the study of subtle or slow biological change and/or detailed analysis of population-dynamic features.”

Applying random sampling methods in extensive homogeneous sediment habitats is unlikely to present problems in undertaking repeat surveys to detect changes in SACs. However, rock habitats are more often than not architecturally complex with a consequent high level of heterogeneity in the communities present. A very large number of random samples would be required to adequately represent such a community (see next section). However, randomising sampling (done to take advantage of the wider range of statistical tests, which can then be applied) may be helped by careful stratification of the samples. Where habitats are just too broken and heterogeneous to consider random samples, there are very necessary practical advantages to using fixed sites for monitoring on rocky or mixed substratum habitats. Such fixed sites have the advantages that there is reduced variability between consecutive samples as many environmental factors are kept constant. Also, the same organisms are being studied and there are significant opportunities to add value to the data by assessing longevity and growth rates. Since fixed sites almost certainly means less sites, this is very important where time to survey is limited due to the duration of dives or to the period that the tide is out. Fixed sites have the disadvantage that they might have to be large or it might not be possible to reflect 'mosaic re-cycling' (the observation that in many rocky habitats, dominant species may be different from year to year at the same spot but, over a large area, they are present in similar abundance from year to year, e.g. Hawkins & Hartnoll 1983; Sebens 1985 and see next section).

Studies which undertake to quantify change in rocky habitats have used three basic sampling strategies: (i) fixed belt transects (for instance, Jones *et al.* 1980; Baker & Crothers 1987); (ii) fixed quadrats in selected areas (for instance, Jones *et al.* 1980; Hawkins & Hartnoll 1983; Lundälv 1985), and (iii) repeated random sampling in set areas (for instance Southward, Hawkins & Burrows 1995). The 'belt transects' established for surveys on rocky shores in Milford Haven and Sullom Voe were essentially a series of horizontal belts and, as it became clear that broken rocky surfaces made it necessary to define the precise area to be surveyed, became near to fixed quadrats. The fixed belt transects used by the Coastal Surveillance Unit in North Wales were vertical belts but, again, quadrats were relocated in exactly the same place on each visit and so were 'fixed' quadrats.

There are no general guidelines for the sampling of inshore demersal fish populations. The chosen strategy will depend on the habitat type, targeted fish species and the objective of the sampling programme (Baker, Hartley & Dicks 1987; Potts & Reay, 1987).

### 3.3.5 Sample size

How many samples of what size should be taken, how large should fixed quadrats be and how many should there be? There is significant guidance from the literature on this topic (see Section 1.2.1) although new studies to establish minimal sampling area might be required especially if they are in habitats previously little sampled to investigate change.

**Minimum sample area** Minimum sample area will depend on the objectives of a study, which must of course be clear. Some of the main likely objectives are included in Appendix 6. Sample design must take account of and, in part, be determined by the power of the analytical techniques, which will be used to detect real change (see later). Personal expertise, equipment available and cost will also be relevant.

Usually, establishing minimum sample area will require experimentation involving taking a much larger number of samples using different regimes (random versus regular stations, a few large versus many small samples, different core penetrations into sediments, different mesh sizes etc.) and the results will be specific to that location. This type of experimental study has been widely undertaken in relation to grab sampling and Figure 14 shows the results of a study in the German Bight. Ferraro *et al.* (1994) provide an excellent demonstration of an experimental study aimed at identifying the most cost effective sampling strategy for a well defined objective in a particular location. They differentiate between "faunal surveys" which are undertaken to characterise communities in terms of number of species, species composition, faunal abundance etc. and "quantitative study" which provides data adequate for statistical analysis. They found that, whilst core samples totalling 0.1 m² may be adequate to distinguish reference from impacted conditions (and therefore probably different biotopes), monitoring to identify change in structure and composition within biotopes will require a larger number of samples. In the case of the specific location studied by Ferraro *et al.* (1994), about 5 replicate small (<0.1 m²) samples were suggested as optimal for detecting important structural changes in macrobenthic communities with high species richness and abundance. Five replicate

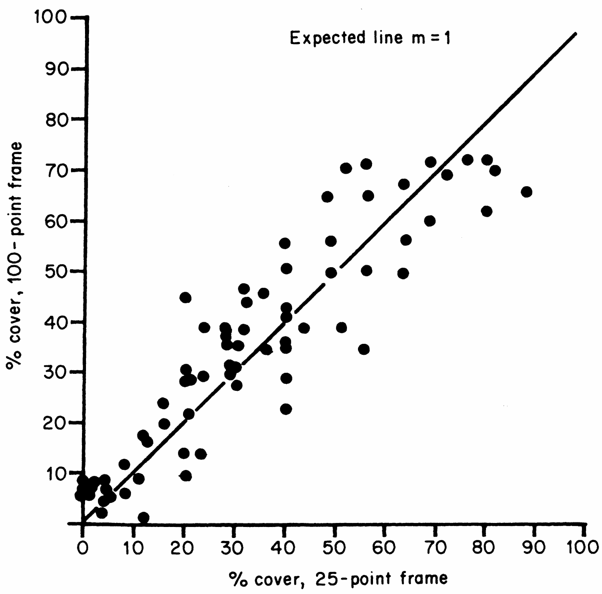



**Figure 17** Comparison of the percentage cover of barnacles measured with a 25-point and 100-point cross-wire frame plotted against each other. From Jones *et al.* (1980).

0.1 m² samples is the number advised by McIntyre, Elliott & Ellis (1984) and adopted by many subsequent workers in quantitative, including monitoring, studies.

Studies of minimum sampling areas have been little carried out for rock epibiota, whether for sampling and enumeration of the biota or for photography and subsequent analysis. Cross-wire or pin frames can be used in studying intertidal algal cover or crustose species such as barnacles (the approach does not work underwater for algae because they move too much). Jones *et al.* (1980) compare cross wire frames with 25 and 100 points (Figure 17). Boudouresque (1971) found that collecting samples of only 100 cm² was required to list all of the algae present in the shallow shaded areas whilst 250 cm² was required in the coralligenous zone of the circalittoral in the Mediterranean. Larkum, Drew and Crossett (1967) used 400 cm² as the minimum sampling area required for algal vegetation off Malta but noted that, because of patchiness within communities, the eight samples usually taken at each station may not have given a completely reliable picture of the vegetation. Maggs (1984) determined that the volume of maerl (using volume because maerl is a three-dimensional habitat) required to study seasonal changes was 300 cm³. Weinberg (1978) found that different areas were required for different animal communities in caves and on open rock surfaces but most species seemed to be collected within about (1 to 2 m²) on the open rock surfaces (Figure 18). The number of species sampled is very small in the study undertaken by Weinberg and we should look to studies in the NE Atlantic for guidance. Based on samples collected from adjacent 0.25 m² quadrats on natural sublittoral rocks at Lough Ine and at Lundy, Hiscock (1979) suggested that the total of 0.5 m² was not an adequate sampling area and that 1 m² would have been preferable to collect a reasonably high percentage of the species present. In a more systematic and thorough study taking random 0.1 m² samples from the side of a wreck (and therefore minimising heterogeneity due to surface features but hardly mimicking natural rock surfaces), Hiscock & Rostron (unpublished) identified 192 species from 1.4 m². However, the species area curve was still rising at that point and extrapolation suggested that a further 19 species would have been collected if 2.5 m² had been sampled.

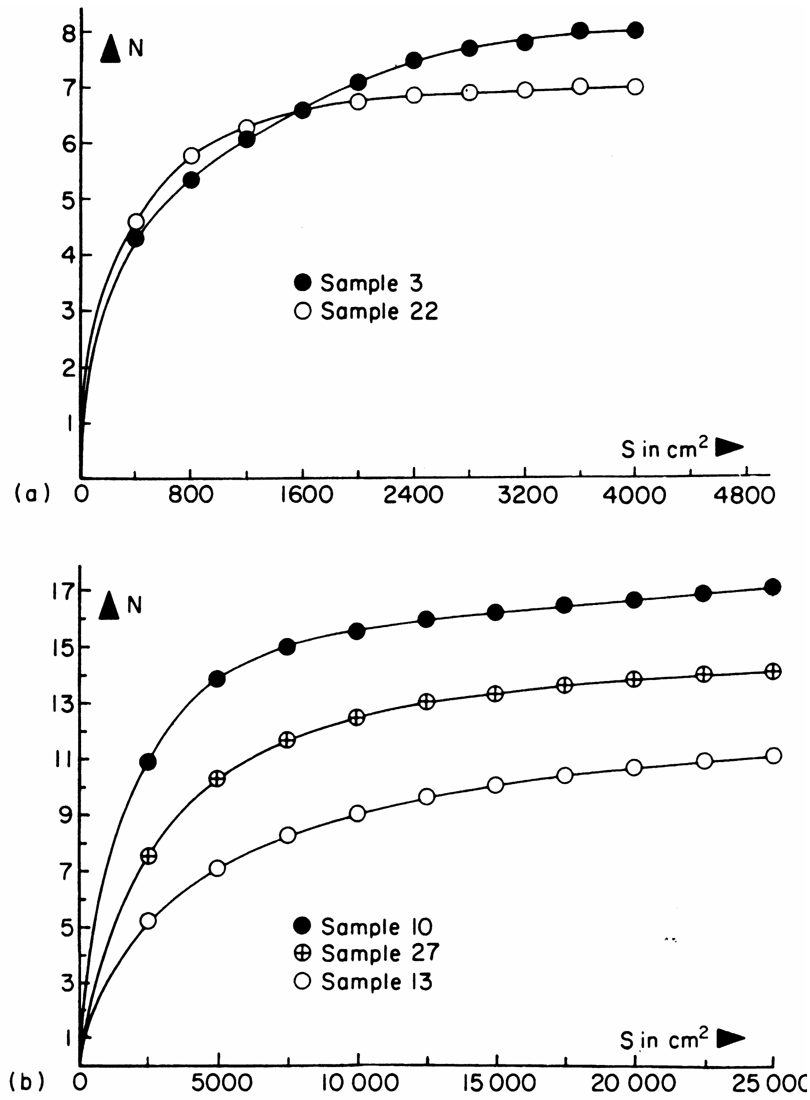



**Figure 18** Species area curves for samples from sublittoral rock surfaces in the Mediterranean. (a) dark caves; (b) open communities. N = number of species; S = sample size. (From Weinberg 1978.)

The majority (90%) of that total of 211 species was reached by taking about 13 0.1 m² samples. Although it is unwise to generalise, it seems that sampling from an area of about 1.5 m² on sublittoral rock should identify the majority of species present in the community, missing those which are large and widely dispersed or those which are rare.

Considering the cost, complexity and likely large sample size required in taking the above approach as well as the difficulty of establishing a meaningful random sampling regime on heterogeneous rock surfaces, a more pragmatic approach using marked sites recorded *in situ* without removal of samples is both possible and meaningful.

For fish populations, the optimal sample size will depend on the sampling strategy employed, the variability of data produced and the objectives of the sampling programme. If the standard error or, for example, abundance estimate is known it can be used to predict the required sample size to detect change at a given level of significance (Baker, Hartley & Dicks, 1987; Sokal & Rohlf, 1995). Pihl & Rosenberg (1982) describe pilot studies to assess the sample size required to reduce the standard error of drop trap samples to 25% of the mean abundance. The variability was inversely proportional, *inter alia*, to abundance (less abundant species showing higher variability).

Of course, the reader must remember that, as explained in Section 3.5.5, the traditional method of establishing an optimum minimum sample area using species area curves is only useful for species richness. Establishing the mean density of a species will require a very much larger sample if more than the most common species are to be included in assessment.

**Using survey 'baselines'.** Baselines for surveillance are the first full survey in a series or a one-off survey undertaken at some previous occasion. Baselines for monitoring are the results of surveillance and describe which monitoring is being undertaken. Comparing monitoring results against a baseline only demonstrate if significant change has occurred - establishing cause is a further requirement.

**Using 'reference' sites.** The term 'reference site' is preferred here to 'control site' which has been used by some marine ecologists, notably A.J. Underwood (for instance, Underwood 1981; 1992) in experimental studies. The term 'control' is derived from experimental studies where a strict procedure is used to determine and control variables. In monitoring, there is no 'control' by the investigator, there are only locations where it is likely that natural conditions will prevail.

Reference sites are locations where the activity or input being studied does not occur but where it is considered that the habitats, communities and species are similar. Using reference sites assumes that changes resulting from an activity can be detected because those changes will not have occurred at the reference site. Where this approach has been adopted, it has only succeeded where gross change has occurred. The background of natural variability has confused the picture. For instance, Jones (1995) found that changes in sediment shore macrofauna species in the region of Sullom Voe were very site specific, thus rendering the concept of 'control' sites in surveillance/monitoring highly dubious.

### 3.4 Identifying ‘sensitive’ or ‘keystone’ habitats, communities and species

Once the features important to the designation of the site have been located, further consideration might be needed of which are especially 'sensitive' in relation to particular activities or inputs and should be subject to the development of a monitoring programme. Species or habitats are likely to be sensitive if they:

- are fragile (brittle);
- are susceptible to pollution;
- are long-lived and recruit poorly;
- are slow to reach maturity;
- have poor recruitment;
- have poor larval dispersal or no larval stage;
- are unable to move away.

A species or habitat is likely to be ‘keystone’ if its presence maintains or determines the presence of a particular community or species. Removal of a keystone species leads to rapid, cascading changes in the community structure they support. For instance, sea urchins grazing algae create ‘urchin barrens’ including complete absence of the kelp forest biotope in some instances; horse mussels, *Modiolus modiolus* support a rich associated epibiota community – without their hard substratum and crevices, the species colonising the sediments on which they live would be predominantly infauna.

## 4. 'Levels' of approach

### 4.1 Habitats and biotopes

Identifying the habitats and their associated communities present at a site and their location within that site is often a precursor to identifying locations where detailed sampling will be undertaken at representative locations or within 'special' features. The classification used for marine habitats is the MNCR biotopes classification (Connor *et al.* 1997a&b; exemplified in Appendix 7). Only where remote survey techniques discriminate different categories of bottom types but ones which cannot correspond to levels in the MNCR biotopes hierarchy should any different classification be used, although this is undesirable. Preparing an inventory of biotopes does not necessarily require detailed survey as the types identified in the MNCR biotopes classification are often readily recognised by even inexperienced surveyors. Where the extent of a habitat or biotope is one of the site attributes which it is desired to maintain or increase, mapping extent will be appropriate. Here, the levels of accuracy of mapping boundaries and the discrimination between different types will be important to establish.

### 4.2 Communities

#### 4.2.1. 'All' species recorded

Data on the abundance of species or taxonomic groups in samples can be analysed and displayed using a number of well-established methods (Clarke & Warwick 1994).

Where quantitative data on all of the species countable as individuals in a sample is available, a favourite tool in presenting monitoring data is the 'diversity index'. The diversity index is a single number representing the numerical abundance and number of species present. As changes in the diversity index change, so certain impacts can be assumed. However, the change needs to be substantial for change to be clearly indicated and, anyway, management for wildlife conservation needs to know what species are involved and 'drive' any change in the index. Often there is confusion because conservationists use 'diversity' to mean species richness. It is unlikely that diversity indices will be useful in identifying small changes in overall communities and, more importantly, detecting when a species of nature conservation importance has changed in abundance.

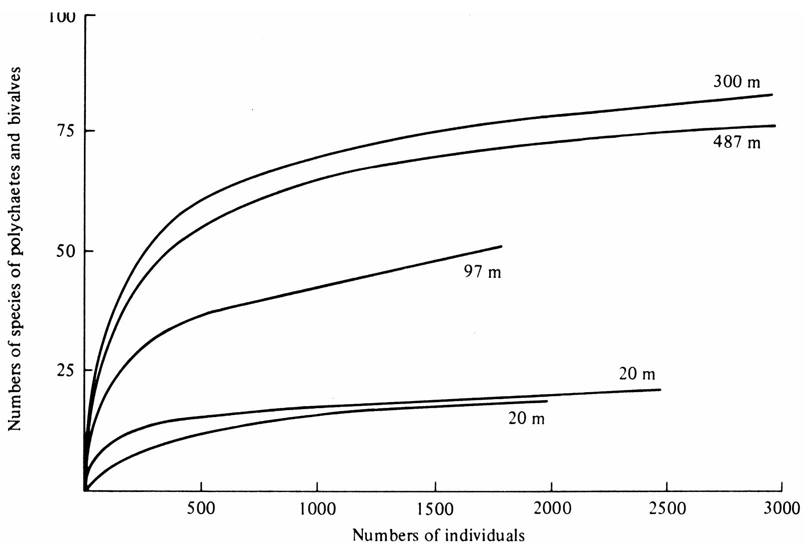



**Figure 19** 'Rarefaction curves' for molluscs from samples taken in shallow sediments (subject to variable environmental conditions and frequent to occasional perturbation) and deep sediments (subject to stable environmental conditions and very rare perturbation) (after Sanders 1968).

Rarefaction curves plot the number of individuals against the number of species and it is often the case that stressed communities have large numbers of individuals of a small number of species. However, a similar reaction in the number of species may be seen in comparing naturally stressed (by large changes in temperature, salinity changes, sediment mobility etc) to very stable environments – the stability-time hypothesis of Sanders (1968) makes eminent sense – the longer a community remains unperturbed by varying environmental conditions, the richer it is likely to be in species (Figure 19). A change from a community with lots of species but generally small numbers of each to one with few species but large numbers of each would suggest stress.

Multivariate analytical techniques are illustrated as dendrograms where the similarity between samples is identified from analysis of quantitative data or scatter plots where major 'lines' of similarity between samples are identified and each is given a score depending on its distance of fit with other samples. Several 'lines ' of similarity are identified for one sample and the position of a sample in relation to others is represented by two values plotted against each other. From sample time to sample time, the score of each sample on the two plotting axes will vary, sometimes showing a progressive change, sometimes random. Within certain boundaries on the scatter plot, variability can be considered to be caused by natural fluctuations or sample variability. However, outside of that range, effects of human activities might be suspected. Often models produced where human impact is known to have occurred are essential to interpretation (for instance, the plot shown in Figure 8). Where a marked gradient of change occurs (for instance, in relation to a point source discharge), clear difference between sampling stations along the gradient will be observed and it might be that taxonomic discrimination of samples to Class or Phylum level might be sufficient to separate stations (reviewed in Vanderklift, Ward & Jacoby 1996).

Neither diversity indices or scatter plots tell the interpreter just what has happened to create the change in scores and, since that interpretation relies on inspection of the raw data, the value of diversity indices or ordination might be questioned. Also, they traditionally rely on using only species, which occur as individuals and can therefore be enumerated, ignoring algae, colonial animals or crustose species.

### 4.2.2 Using abundance scale data and selected species

The results of surveys which collect data on the abundance of conspicuous species from biotopes can be subjected to the same sorts of analysis as described for quantitative data in Section 3.2.1 and incorporate algae, colonial animals and crustose species. The abundance scale developed by the Marine Nature Conservation Review for descriptive surveys is shown in Appendix 4. However, that scale needs considerable improvement to be used for monitoring – especially to indicate which scale to apply to the full range of species (by name, not size) likely to be encountered and to displace species to another scale or add another abundance notation if known high abundance is well beyond the top of the scale. In trials undertaken during workshops (Worsfold & Dyer 1997), it was found that the brief to "record the abundance of all conspicuous species at the site" resulted in considerable error and that it would be better to select species to be included on a check list for survey. This technique became known as "Abundance scale, Check list and Exact location (ACE)". The species selected for ACE surveys are likely to be:

- 'Important' (for nature conservation) species (e.g. key attributes of the site, nationally rare or scarce species, scheduled species, charismatic species eliciting questions from the public);
- Keystone (e.g. grazing, habitat providing) species;
- Indicator species (known to respond to changes in environment by changes in abundance);
- Ones whose life histories are well known;
- Taxa (families/genera/species) which can be identified in the field;
- At their geographical limits (climate change effects?);
- Likely 'sensitive' species (slow growing, infrequent recruitment, susceptible to impacts from human activities);
- All common, abundant or superabundant species;
- Sedentary or sessile species;
- Ones which are being studied elsewhere (global comparisons);
- Ones which represent a spread of taxa and life styles.
- Characteristic of that biotope;

- Not ephemeral;
- Not likely to be confused with a similar species.

In this type of survey, it is best to select a small number (up to 10) species for careful survey but to follow-on the careful survey with identifying the abundance of the full range of conspicuous species within the defined area. This is because, inevitably, the selection of species means that there is no record to track changes in the presence and abundance of species which may become dominant or disappear but which have not been included in the checklist. Photographic or video records (distant and close-up) taken at the same time as surveys may also provide an ‘insurance policy’ to assess presence of species not on checklists.

### 4.2.3 Comparing field data against environmental quality standards

The large amount of survey data now describing the species composition of particular biotopes is a potentially useful tool in assessing 'quality' by establishing standards of species richness or expected presence of certain species indicating clean or polluted or disturbed situations. Caution and expert interpretation is required as local differences may be due to such natural influences as geographical location or to the survey intensity or quality of recorders. However, with due caution, management objectives could include the use of community composition as a measure of desirable change through, for instance, aiming for increase in species richness, increase in abundance of 'special' species or decrease in abundance of species indicating human impact to reach a desired condition. The concept of using 'desired condition' of communities as a management guide is expanded in relation to terrestrial communities in Rodwell (1997). The large amount of field data now available from 'clean' and 'polluted' locations (for instance, in relation to organic enrichment illustrated in Figure 20) or following incidents which have changed communities and the careful collection of new data to strict standards also offers opportunities to identify and monitor against Environmental Quality Standards (EQSs).

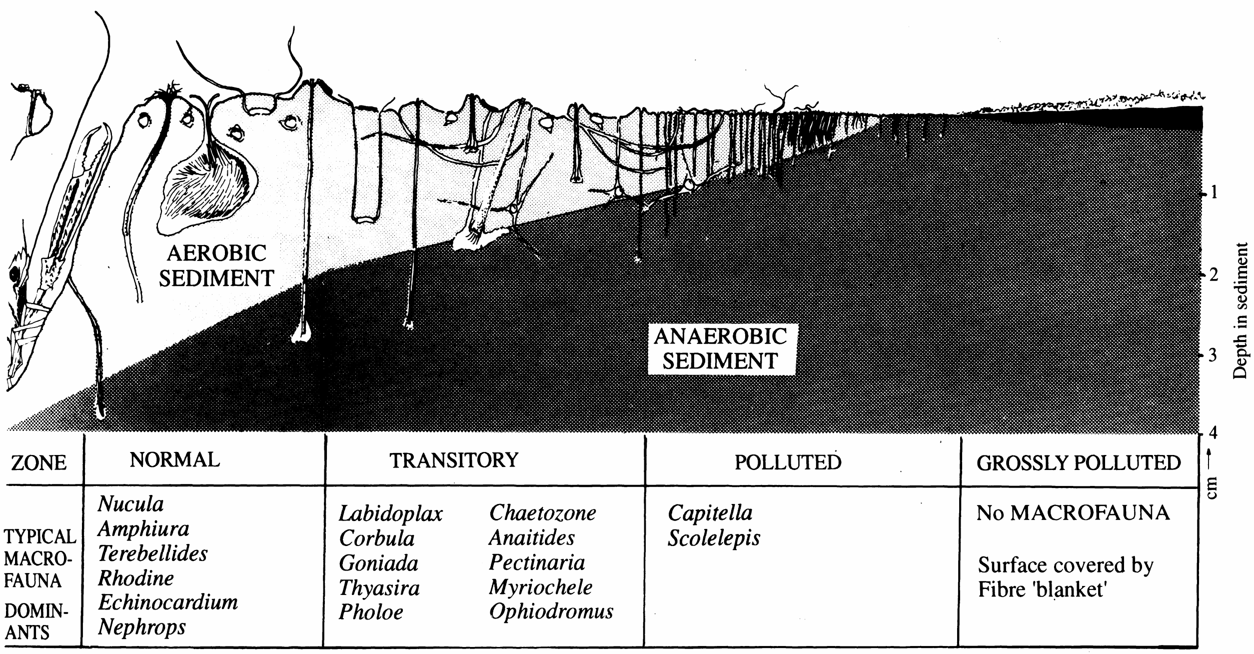



**Figure 20** Diagrammatic representation of faunal and sedimentary changes under increasing organic loading showing, from right to left, a 'fiber blanket', burrows of polychaetes, bivalves, brittlestars, a sea urchin and a Norway lobster *Nephrops* (from Pearson & Rosenberg 1976).

The concept is similar to that which has been developed for freshwater (River InVertebrate Prediction And Classification System – RIVPACS; Wright *et al.* 1997) and is considered in the context of monitoring the impact of sewage sludge dumping in Rees *et al.* (1990). For the Group Co-ordinating Sea Disposal Monitoring (GCSDM), a sub-group of the Marine Pollution Monitoring Management Group (MPMMG), their Ecological Quality Objectives (EQO) was “Protection of the ecosystem to ensure that it is typical for the type of area concerned" (MPMMG 1997). It is most likely that EQS's or EQO's will be developed further in future especially in coastal areas and in relation to the proposed EC Water Framework Directive. The OSPAR IMPACT Working Group is also considering the development of EQO's.

### 4.3 Single species studies

If the intention of a study is to follow species richness on a presence-absence basis, then establishing minimum sampling area for that will be very important and can be achieved with a reasonably small number of samples or sample area (see Section 3.5.5). However, studies aimed at establishing statistically significant change in the abundance of the species in a community may need very large sample sizes. On the other hand, change in the abundance of many solitary, sessile and conspicuous species (for instance, species of sea fan, solitary sponge or cup coral) may be measured using one fixed site - the importance here is to determine how representative that site is of the rest of the area. Lundälv (1985) suggests that 1.5 $m^2$ is an adequate area for the sort of large sessile species he was recording at fixed sites on rock walls in Sweden. Much of the monitoring undertaken already for nature conservation management in Great Britain has used fixed sites to track changes in the abundance of species and has been highly successful in identifying significant changes or, in many cases, lack of change – constancy. Photographic records may be converted to drawings to aid illustration and comparison: two such drawings from permanent quadrats on rock wall in the Isles of Scilly are shown in Figure 11. Some large species such as the sea urchin *Echinus esculentus* often occur sparsely over very large areas and may require a swim-line technique in which a line is reeled-out over the shore or seabed and the number of individuals occurring under a metre rod held at right angles to the line counted.

The size structure of a population can be measured to indicate change and possible adverse effect of activities. For instance: an exploited population of shellfish might have predominantly individuals, which are below commercial size; a long-lived species which has stopped recruiting will be of large individuals only.

Where the key attributes for a site include the presence of a certain species, then consideration should be given to monitoring that species and random sampling on homogeneous substrata or fixed sites on broken substrata or in patchy communities can be used.

### 4.4 Indicator, signpost and surrogate species

The concept that there are species which thrive in particular conditions, especially ones which are stressful, has been in existence for some time. They are called 'indicator species'. Indicator species may be sensitive to specific types of perturbation or contamination. Additionally, there are 'signpost species' which direct the observer to look for usually associated species such as Mediterranean-Atlantic species and which may be used to identify likely change in other species with similar habitat requirements. 'Surrogate species' are ones that are likely to change if the whole community is changing and therefore respond to change on behalf of the community. A gradual change or switch from communities dominated by species considered characteristic of unpolluted, undisturbed situations to ones characteristic of perturbated situations might suggest environmental degradation.

Ecological indicators of the quality of the marine environment are described by Pergent (1991) for the Mediterranean. He suggests that the sea grass *Posidonia oceanica* provides an indicator of global water quality, being particularly sensitive to pollution and aggressive human activities. *Posidonia* also indicates a degree of turbidity through the depth to which it extends. Angiosperms are identified as indicators of salinity. A further indicator of general (good) water quality is named as *Cystoseira stricta* whilst *Ulva lactuca* and *Ulva rigida* are cited as indicators of nitrification. Amphipods are cited as especially sensitive to pollution and diversity of species decreases in polluted situations on hard substrata. Organic pollution in sediments is reflected by the presence or high abundance of the polychaetes *Capitella capitata*, *Scolelepis fuliginosa* and *Nereis caudata*.

GESAMP (1995) reviewed the use of biological indicators in the measurement of the condition of the marine environment having been charged, amongst other tasks, with identifying suites of indicators of the state of marine ecosystems. Whilst identifying the theoretical basis of identifying a suite of indicators at different levels in a hierarchy (for instance, molecular and cellular change, organismal responses such as physiological changes through to mortality, changes in population structure and changes in assemblages), they did not identify species whose abundance might indicate a certain change in environmental condition. Such a list is clearly required to assist in interpreting the results of monitoring but is beyond the current scope of this review. Also, it is important not to view likely effect just in terms of adults. For instance, in the case of TBT effects in reducing abundance of oysters, it was the larval stage, which proved to be sensitive and monitoring of the presence of larvae which demonstrated that something was wrong.

The presence of some species might indicate very large-scale change. It might be that several species present in south-west Britain in the 1960's and 1970's but rarely or not observed today or which have declined in abundance since then were indicators of distinctly different water masses being present. These were edge of range species such as the sea slug *Greilada elegans*, the alga *Zanardinia prototypus*, the John Dory fish *Zeus faber* and, a species which has suffered decline, *Leptopsammia pruvoti* (K. Hiscock, personal observations). Another is the hermit crab *Clibanarius erythropus*, first found in Britain in the winter of 1959/60 but which was in decline after about 1967 and following high mortality during the clean-up of oil from the *Torrey Canyon*. Southward & Southward (1977) suggest that decline continued as a result of a reverse climatic change. All these are species to look out for as indicating a possible change in climatic conditions and possibly oceanic water currents.

In more general terms, species diversity (both as an index and as species richness) decreases significantly under stress but only under severe stress (Warwick & Clarke 1991) so that the disappearance of a particular species known to be highly sensitive or the appearance of a species known to be highly tolerant of disturbance might be more sensitive than whole community measures. Indeed, if monitoring could be directed only at such indicator species, it could be made very cost effective and may not require specialist staff.

## 5. Methods being developed under the UK Marine SACs Project

The UK Marine SACs project is developing a series of Procedural Guidelines which describe the techniques and equipment available for survey, surveillance and monitoring. The Guidelines are an aid to those commissioning work and include outline descriptions of the application, accuracy and time required for different methods. They do not provide precise details, which will vary according to location, objectives and equipment available. The initial set of Procedural Guidelines prepared in 1998 as background to undertaking monitoring studies in SACs are listed below.

**Intertidal rock and sediments**

Mapping intertidal biotopes
Fixed viewpoint photography
Abundance scale Check list surveys at Exact locations (ACE)
Cryptofaunal sampling (includes 'weed washing')

**Rock pools**

Sampling fish in rockpools

**Intertidal sediment requiring sampling**

Abundance scale Check list surveys at Exact locations (ACE)
Quantitative sampling of animal species using cores

**Sublittoral areas - seabed types and major biological features**

Acoustic survey with ground truthing

**Sublittoral areas (rock and sediment)**

Descriptive and quantitative surveys using remote operated vehicles (ROV)
*In situ* surveys of epibiota using hand-held video
*In situ* surveillance of epibiota using towed sledge video and still photography
Abundance scale Check list surveys at Exact locations (ACE) using diving
Sampling benthic and demersal fish populations in subtidal rock habitats
Recording benthic and demersal fish in dense vegetative cover

Sampling benthic and demersal fish populations on sediment
Quantitative surveillance of sublittoral biotopes and species using photographs

**Sublittoral sediment**

Abundance scale Check list surveys at Exact locations (ACE) using diving
Descriptive and quantitative surveys using remote operated vehicles (ROV)
*In situ* surveillance of epibiota using towed sledge video and still photography

**Quantitative sampling of sublittoral sediment biotopes and species**

Quantitative sampling of sublittoral sediment biotopes and species using remote-operated grabs
Quantitative sampling of subtidal sediment biotopes and species using diver operated corers

An example of a procedural guideline is given in appendix 9.

# 6 Interpreting results: establishing cause and effect

## 6.1 Introduction

There are two aims in data analysis and interpretation: one is to establish whether a change has really taken place, the other is to establish why a change has taken place. The question of 'does it matter?' is important, and will determine whether there is a need to establish 'why', but is not dealt with here.

## 6.2 Has a significant change (really) taken place?

### 6.2.1 Introduction

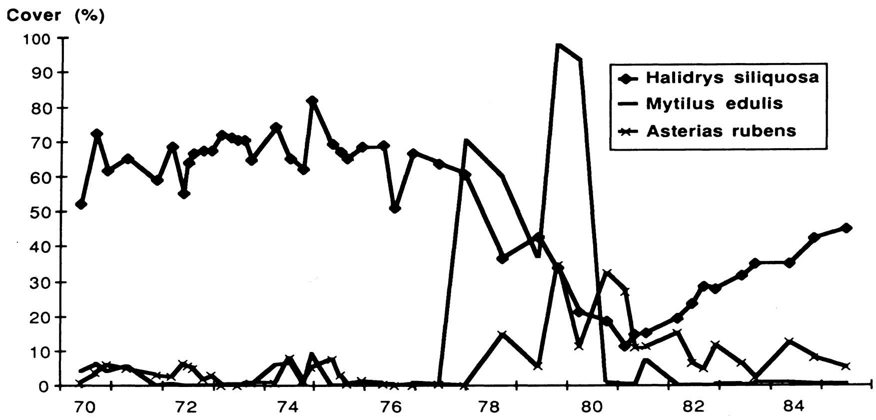



**Figure 21** Changes in the cover of dominant species at 10m depth recorded from photographic quadrats at a site on the Swedish west coast (from Lundälv, Larsson & Axelsson 1986). Change within the quadrats is clear and illustrates a 'classic' large scale variation related to the settlement of mussels in 1979. How representative of the whole Swedish west coast is that change?

What is significant? Biologically significant change can be seen by inspection of results such as the density of a species in one year compared to another and which falls outside of the errors generated by the method used and the number of samples taken. Those changes might be so great that there is no doubt they have occurred (for instance Figure 21). Another example is shown in Figure 22, for fish, where interpretation is more equivocal. Statistically significant change relies on the application of mathematical analysis to suitable data and readers are referred to Clarke & Warwick (1994).

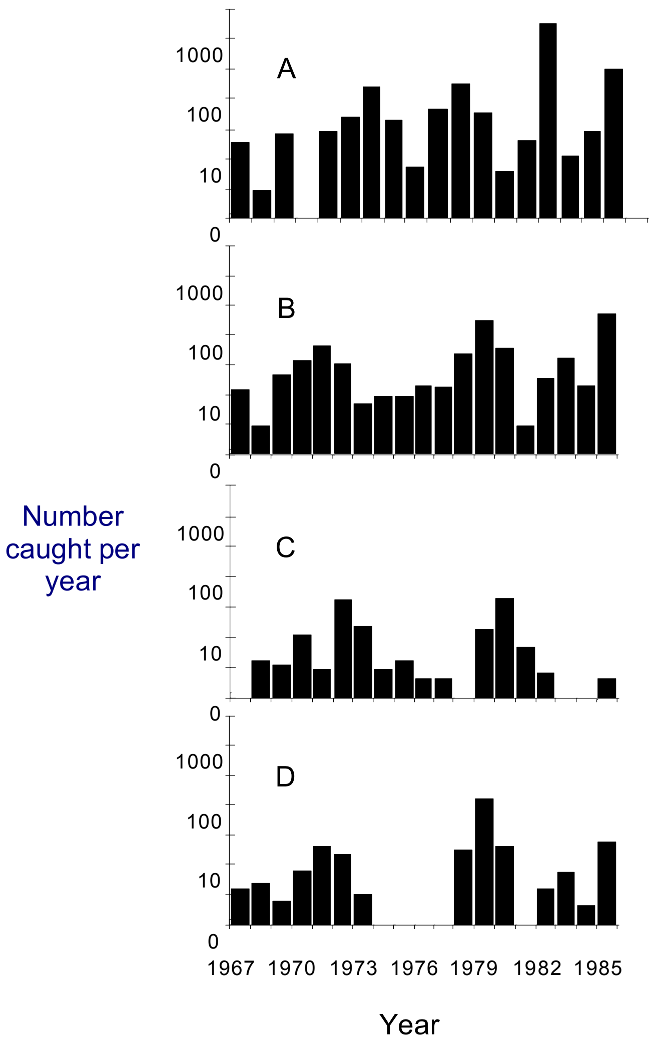



**Figure 22** Annual variation in the numbers of four dominant fish species in two New England tidepools. A. *Tautolabrus adspersus*, B. *Pholis gunnellus*, C. *Gasterosteus aculeatus*, D. *Myoxocephalus aenaeus*. Sampling, for example, *Myoxocephalus aenaeus* over the period 1972 to 1978 would indicate that it had become extinct in this area and that a decline in *Gasterosteus aculeatus* had also occurred. Linking cause and effect in such species is difficult. Note the logarithmic scale. (From data in Collette, 1986).

### 6.2.2 Fixed site monitoring – how representative?

Re-survey of epibiota at precisely located stations using methods whose accuracy is known will identify real change at those stations. However, how representative those results are of change across the site needs to be established.

### 6.2.3 Between site or between samplings - differences established by statistical tests.

Establishing the power of statistical tests to detect change at a defined level is important to the interpretation of results. This importance is emphasised in papers by Buhl-Mortensen (1996) and the associated article by Gray (1996). Establishing what sampling intensity will be used and the likelihood of obtaining meaningful results is a two way process. Often, the practicality of taking required number of samples will determine the power of analysis which can be used and therefore circumscribe the level of change or difference which will be capable of detection. As an example, Ribic & Ganio (1996) describe the specification for a monitoring programme, which includes reference to the power of the statistics being used. Their brief was to determine if there was a 20% linear decrease in beach debris over 5 years with quarterly sampling, a confidence of 0.95 (i.e. Type I error of 0.05), and power of at least 0.84. For marine benthos, van der Meer, Craeymeersch & Duin (in a paper without adequate bibliographic information) working in subtidal and intertidal habitats in the Netherlands found that, applying different sampling strategies, it appeared that the most effective way to identify change was through many stations with little sampling effort per station. Even using only the most common organisms (up to 16 species were analysed), a very large number of samples would be required to obtain a power of e.g. 0.80. For a further discussion of the power of experimental (surveys are ‘experiments’ – they test a hypothesis) design the statistically literate reader is referred to Underwood (1997).

### 6.2.4 Taking account of sample variability

The greater the amount of sediment collected in a single grab sample or the longer an observer spends searching, the more species or the larger numbers of individuals are likely to be recorded. Ensuring consistent and therefore comparable samples is a matter of discipline. Remote samples should only be accepted if they are of a minimum volume (which reflects the grab penetrating to a depth where the majority of species and individuals will have been collected). Observational studies can be time-limited but, taking account of variable experience, it is better to specify (for example) 'search within [a tightly specified area] until no more conspicuous species are being found and rough counts are not changing abundance records'.

### 6.2.5 Taking account of worker variability

There will be differences in the results generated by different workers. Just as variability between samples needs to be reduced as much as practically possible, worker variability needs to be reduced. This relies greatly on training and on comparative exercises which are analysed to discover and then minimise sources of variability between workers. It may be that 'open' briefs such as "search until all conspicuous species have been recorded" still result in significant differences between workers and an approach limited to species on a check list has to be adopted. Similarly, the brief for sorting fauna from sediments has to be well defined.

## 6.3 Why has a (real) change taken place?

### 6.3.1 Introduction

The site manager reviewing the results of monitoring studies who decides that there has been change outside of that considered natural variability (significant change), will ask what has caused the change. Sometimes the cause of change will be obvious (dredge spoil dumping causing smothering, an extremely cold winter causing mortality etc.) but often cause of change will not be known (for instance, an anchor being dragged one night through a colony of long-lived species and causing individuals of the species to just disappear).

There are five methods to interpretation of change: experience, observation, intelligence gathering, experimental study and mathematical analysis of possible links between biological change and environmental fluctuations.

One day, there will be a database which transfers the enormously diverse amount of information on natural variability, sensitivity to different impacts and results of experimental studies to a user-friendly aid to interpretation of survey results – meanwhile, sensible use of abstracting services and hard slog through the literature is required.

### 6.3.2 Experience and case study

Experience is generally taken as having experience of studying marine life both formally and informally over a considerable period and to have ‘seen that before’. The significant amount of literature describing variability under conditions apparently unaffected by human activities, the result of impact of a wide range of human activities as well as the effects of natural events can also be used to suggest possible reasons for observed changes (for instance as: ‘normal – within expected limits of natural variability’; ‘normal – the result of an unusually severe but natural impact and outside of limits of normal variability’; ‘abnormal - within the range of natural variability’; ‘abnormal - outside of the range of natural variability’). Changes on rocky shores has been thoroughly enough studied to produce some general principles. For instance, the work of Hartnoll & Hawkins (1985) investigating patchiness and fluctuations of moderately exposed rocky shores (Figure 24); the work of Beukema (1992) on 29 species in the Wadden Sea which revealed a group of 12 species which showed low densities after cold winters over a twenty-year study period. Experience and case study can also be used to predict likely sequence of change including recovery following an event likely to cause change. Such an approach has proved to be accurate time-and-time again in relation to the succession which follows a severe oil pollution incident on rocky shores. A knowledge of the biology of a species (longevity, reproductive potential, growth rates, feeding requirements) gained either from the literature or personal observation can be essential in interpreting whether a change is normal and whether recovery is likely to occur and within what time scale. Often, the 'type' of change can be linked to events (for instance:

loss of a species after a cold winter which records show had been lost following previous severe winters; loss of a species following nearby dredging shown in experimental studies to be killed by siltation).

Identifying literature to interpret the changes which have been observed as a result of monitoring is a daunting exercise without access to a guidance system based on providing key information on species and biotopes: the main units which will be used in describing change. Examples of variability in the abundance of species and the character of biotopes are given throughout this text.

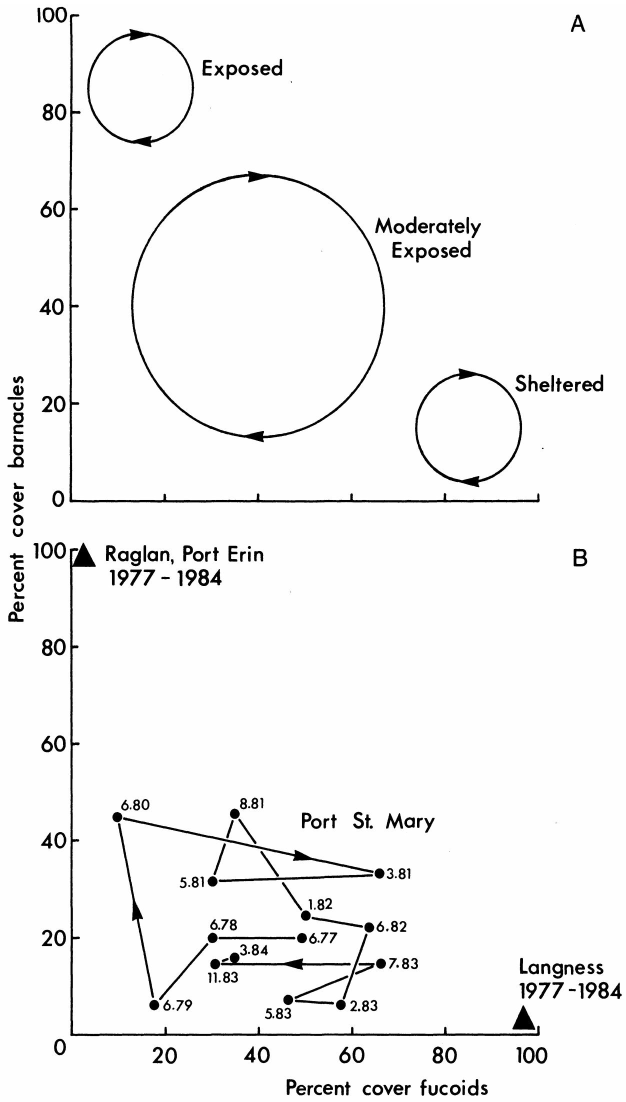



**Figure 24** Plots of barnacle cover against fucoid cover at three sites in the Isle of Man (A) interpreted to a model of the cycle (B) which suggests large scale change in semi-exposed situations but only small scale variability in exposed and sheltered situations. (From Hartnoll & Hawkins 1985.)

### 6.3.3 Observation

Observations may explain a change or at least give clues of possible reasons for change. Observation can mean just careful looking at the surroundings. For instance, seeing students turning-over boulders and not returning them might account for major changes. Sometimes explanations will be clear - for instance, in accounting for the loss of a significant number of corals at a site, the observation that many were heavily bored by worms and some were lying whole at the base of the rock but alive suggests that they have been easily knocked off (by foraging wrasse, clumsy divers?) because of weakening rather than they are being collected as curios or smashed by anchors. But such explanations might be incomplete - why is the coral tissue, which normally permeates the perforate skeleton, not preventing attack by the worms - are the corals struggling to survive in poor water quality?

### 6.3.4 Intelligence gathering

'Intelligence' can be being told by a local naturalist that the students never turn boulders back or might be simply a thorough knowledge of the literature. It might also be through networking by marine biologists - has anything similar happened at the same time which might suggest a widescale change rather than some local effect? For instance, when the conspicuous brown seaweed *Zanardinia prototypus* disappeared from Lundy, marine biologists reported that it had also disappeared from every other part of Britain where it had been recorded. Any suggestion of a local cause is therefore rejected.

### 6.3.5 Experimental study

Various experimental studies may help to interpret field results. Experimental studies may be undertaken in the field or the laboratory and may include the following types of exercises.

**Simulative studies**. These are experimental studies, which deliberately assess the impact of different activities by simulating the impact. For instance, oil spills (Howard, Baker & Hiscock 1989) and bottom trawling (Kaiser & Spencer 1996). Simulative studies may be undertaken to establish whether and on what characteristics the act of sampling has an effect. For instance, the study of Chapman & Underwood (1996) to establish to what extent and how turning boulders to record the quantity and species present affected the underboulder community.

**Manipulative studies**. Manipulative studies may include moving an organism or group of organisms from its natural location to one where it does not normally exist and then recording changes observed in relation to the new conditions it is exposed to: for instance, experiments by Muntz *et al.* (1972) revealed that the jewel anemone *Corynactis viridis* requires clean sites with low illumination and change in those conditions resulted in mortality. Their results could be used to assist interpretation of a reduction in abundance of *Corynactis viridis*.

**Settlement studies.** New surfaces are established revealing which species settle readily and the succession of species providing an indication of those species and communities, which can be considered transitory or successional: for instance, see Sutherland & Karlson (1977).

**Bioassays** are experimental procedures in which organisms are exposed to different substances or combinations of substances to determine concentrations that adversely affect them. The role of bioassay in environmental management is summarised in GESAMP (1995) where it is noted that the short-term nature of most bioassays, which only consider single species under controlled conditions, rather than many species under natural conditions, limits their predictive value as indicators of complex chemical and biological interactions.

Occasional disasters, such as major oil spills, can be used as 'field experiments' to establish effects and follow recovery; often doing much to identify sensitive species. These experimental studies help to interpret natural change but are in themselves artificial and care is required in extrapolating their results to survey results.

## 7. Unacceptable techniques

Many sampling techniques in use are destructive or cause disturbance. Destructive techniques may be acceptable in some situations (for instance, extensive sediments where core samples are a minute proportion of the total area of a biotope, where information from collected specimens is essential to interpret change; for instance reproductive status). In general, monitoring of species of nature conservation importance is unlikely to be destructive. Observation techniques therefore become of high importance and descriptions of work to establish minimum sampling areas for destructive sampling has not therefore figured largely in this review.

## 8. Using monitoring results for prediction

Prediction of likely change is the objective of environmental impact assessment (EIA) and predicting whether a change identified by monitoring is part of a trend in declining site quality will trigger management action. In managing marine areas for nature conservation, it will be necessary to use available knowledge to predict likely consequences of activities. This may not be difficult (for instance, where physical disturbance is proposed or where a point source discharge of a well-researched contaminant is planned) but more subtle effects, especially continued chronic inputs or progressive change in climate, will be subject to a host of unknown factors and interactions which make prediction uncertain.

Experimental studies can help predictability up to a point. Studies of effects of contaminants are likely to be most unreliable - but these are the very studies on organisms in the laboratory which are used to establish discharge consents. Mesocosm experiments are more likely to provide an idea of what might happen in the field if certain activities occur.

Trying to review literature which might help to predict future change or interpret present change is a daunting task not attempted here. Planned information systems linked to the biotopes classification and to species should help the manager who is overwhelmed with the complexity of literature and the integration of information necessary. Meanwhile, experienced marine biologists must advise.

## 9. Quality assurance

Use of data from monitoring studies requires confidence in its accuracy. Ensuring accuracy requires that the work is undertaken carefully (with regard to site location/relocation, sampling method, treatment of samples and analysis of samples including taxonomic accuracy) and by suitably qualified and competent personnel. It also requires a scheme to develop accurate working by personnel and to check the degree of accuracy so that interpretation of results takes account of statistical or worker variability and so that areas for improvement in accuracy can be identified. Such schemes already exist. Competency of individuals in species identification may be evidenced by qualifications obtained through, for instance, the Natural History Museum IDQ scheme. For chemical analysis, the QUASIMEME (Quality Assurance of Information in Marine Environmental Monitoring Programmes in Europe) scheme (Topping 1992) has been developed. For biological sampling, the National Marine Biological Analytical Quality Control Scheme provides for comparative exercises involving both sample analysis and taxonomic identification for those involved in the National Monitoring Programme. Such schemes provide members with an understanding of how errors occur and training which will help to avoid errors. The results of comparative exercises indicate the amount of variability which might result from sampling and worker errors and therefore limits of interpretation.

Quality assurance measures are applied to equipment specifications, survey protocols, experience and training of staff, sample processing and interpretation of results. Measures can range from the obvious such as ensuring that the same type of sampling equipment is used from survey to survey, through the less obvious like having a consistent sieving technique for separating organisms from sediments, to ones such as having your sample identifications cross-checked by someone else.

Quality standards and the use of the same techniques also ensure that, with several programmes of monitoring likely to be underway in similar habitats and including the same species, results from the same habitats and species can be compared. Some changes might be site specific but, more importantly, some might be widespread and therefore not attributable to site-specific activities.

## 10. Health and safety

Many of the techniques described in this review require physical effort often in adverse conditions or using equipment that may be a hazard. The Health & Safety at Work Act 1974 places a general duty on employers to ensure the health, safety and welfare at work of all its employees. Section 3 of this Act also places a duty of care on employers for those not in their employ, e.g. contractors, students, the public. Recent legislation generated by European directive sets out more specific duties. The Management of Health and Safety at Work Regulations, Regulation 3 requires employers and the self-employed to undertake risk assessment. It is important that a risk assessment for all operations is available and that it is reviewed in relation to the specific survey being undertaken and any recommended measures are taken. An example of such a risk assessment is given in Appendix 8.

## 11. And finally - Use experience and common sense

The design of a monitoring programme for a particular site can only be **aided** by this review. Practical experience, a knowledge of the literature and common sense will help the practitioner to develop a monitoring programme that is feasible and meaningful - or even to determine that no monitoring programme will answer the questions being asked.

In interpreting results, case study (including observation and experimentation) will often be more useful than ecological theory. Again, knowledge and experience are invaluable.

## 12. Acknowledgements

The preparation of this review has benefited especially from the contribution of ideas and the trialling of methods undertaken by over 50 individuals at the monitoring workshops held early in 1997. The workshops were organised by Martin Dyer and Tim Worsfold of Unicomarine who also prepared the report. They were assisted especially by Colin Munro (Marine Biological Surveys) and Dale Rostron (Subsea Surveys). Lists of contributors are to be found in the report of the workshop (Worsfold & Dyer 1997).

Robin Gibson and Thomas Wilding wrote Section 2.1.3 on inshore fish populations and contributed to Section 3.4.

Mike Elliott provided detailed advice on approaches to monitoring and especially the programme of work proposed under the UK Marine SACs Project.

The workshop held in November 1996 advised the structure and content of the review and participants reviewed the final draft of this publication: John Baxter, SNH; Blaise Bullimore, CCW; Bob Clarke, PML;

Roger Covey, EN; Alistair Davison, SNH; Alistair Fergusson, EA; Stephen Hawkins, Southampton University; Dan Laffoley, EN; Hubert Rees, CEFAS; Mandy Richards, CCW; Richard Warwick, PML.

Comments on the consultation draft of the 'Monitoring Handbook' (Hiscock 1998) circulated in April 1998 have been taken account of in this review. I am especially grateful to Professor Stephen Hawkins, Dr Roger Bamber and Dr Lin Baldock for their comments.

Eleanor Murray undertook the redesign and conversion of the original consultation draft into this review.

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## APPENDIX 1 The development of this review and parallel activities

**Marine monitoring developments in the UK.** There are many monitoring programmes, which have been developed or are currently in operation in the UK. Some have been short-term and aimed at identifying extent and/or degree of impact of specific developments. Others may have been underway for a long period (for instance the ongoing programme of work commenced in Sullom Voe in 1976). Studies which are particularly relevant for the nature conservation agencies are those which have a commitment to methods and quality assurance development and those whose results give a context to work on SACs; for instance by identifying global trends. The major statutory bodies, other that the nature conservation agencies, with responsibility for marine environmental protection and management (the Ministry of Agriculture, Fisheries and Food operating through the Centre for Environment, Fisheries and Aquaculture Research, The Scottish Office operating through the Scottish Office Marine Laboratory, the Department of Agriculture for Northern Ireland, the Environment Agency and the Scottish Environment Protection Agency) collaborate in the 'UK National Monitoring Programme' which includes a network of sampling stations for intertidal and subtidal sediment biology. Common standards or procedures have been developed for other monitoring activities; for instance in relation to monitoring the effects of sewage sludge disposal on benthic communities (Rees *et al.* 1990). Other statutory bodies and government departments and some non-governmental organisations (for instance the Wildlife Trusts, the Royal Society for the Protection of Birds, the National Trust) commission or undertake marine biological monitoring usually in relation to specific incidents and activities or in a broadscale way but are not involved in development of methods or quality assurance measures.

**Marine monitoring developments in Europe.** No attempt is made here to identify the full range of monitoring activities underway in marine ecosystems in Europe. However, in the context of statutory requirements, it is most important to be aware of activities being undertaken in relation to international commitments. There are a growing number of international conventions or directives, which require or might require monitoring of biological attributes of marine habitats and therefore the development of common standards for both survey and reporting. Such “international commitments” that were in mind in 1991 when the UK National Monitoring Plan was developed largely related to the Convention on the Protection of the Marine Environment of the North-east Atlantic (the OSlo and PARis Conventions for the Prevention of Marine Pollution - OSPAR). The Joint Assessment and Monitoring Programme (JAMP) of the OSPAR Commission is developing guidelines for monitoring and may generate common standards and quality assurance measures which should be taken account of in the preparation of Procedural Guidelines for different techniques. The proposed Annex V to the OSPAR Convention “On the protection and conservation of the ecosystems and biological diversity in the maritime area” would generate further requirements to identify effects of activities on ecosystems and biological diversity which most likely involves monitoring. Clearly, the major current EC Directive requiring reporting of the quality of marine habitats is the Habitats Directive but the proposed EC Water policy framework Directive also includes provision for monitoring the ecological status of coastal waters, i.e. waters within estuaries and within one nautical mile offshore of the baselines for territorial seas.

**UK Marine SACs Project monitoring workshops.** Workshops held in April and May 1997 were undertaken with the primary objective of compiling comparative information necessary to support the preparation of procedural guidelines for future surveys. That objective was addressed through presentations, field trials, discussion, a literature review and the interpretation of results. The description of the workshop results given below is drawn from the report (Worsfold & Dyer 1997) and the summary of conclusions for all of the techniques considered is included here as Appendix 2.

A variety of possible monitoring methods were selected for field trials at the workshops and the results discussed with respect to applicability to SAC monitoring, methodology, procedural guidelines and solutions to any problems identified. In addition to the field trials, opinions on all possible techniques were collected through discussions and written feedback. With this information, it was possible to create a catalogue of techniques, with discussions on their applicability, limitations, solutions to problems and some clarifications of methodology. Although there were subjective disagreements over the applicability of each technique, their actual purposes and limitations were broadly agreed.

A number of conclusions were also reached regarding approaches to a monitoring programme. Quality control and archiving of data were highlighted as major points that must be considered before commencing with SAC monitoring. Different techniques are suitable for different objectives and it was agreed that the aims of the SACs monitoring programme must be established from clearly stated conservation objectives before techniques are chosen. A related management question to be considered is the degree to which monitoring programmes should be tailored to particular SACs or co-ordinated between SACs. It was decided that questions of timing of surveys and monitoring of non-biological factors and human activities likely to cause changes should also be considered.

A review of literature concerning methods which could be applied to monitoring in SACs was also undertaken (Worsfold, Dyer & Howson 1997).

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## APPENDIX 2 Glossary of terms

The terms and definitions given below are mainly drawn from McLeod (1996) and are compatible with those being used in nature conservation agency common standards in monitoring and reporting (JNCC 1998).

**abundance scale** A scale describing the relative abundance of organisms (as numbers of individuals per unit area or as % cover), with groupings in several broad categories. In the case of the MNCR's semi-logarithmic 'SACFOR' scale, the units are Superabundant; Abundant; Common; Frequent; Occasional; Rare. (Scale from Connor & Hiscock 1996).

**acoustic mapping** A remote survey technique for identifying the 'roughness' and 'hardness' of the seafloor and thus major substrata types and erect biotic cover using SONAR signals interpreted by the use of video or diver recording of representative sites. The acoustic signal is tracked through the global positioning system and thus mapped. Cf. 'RoxAnn®'.

**adjustment stability** The ability of a perturbed population or community to return to the same equilibrium point or limit cycle (Connell & Sousa 1983). (Cf. 'stability', 'resistance', 'resilience'.)

**assessment** "The orderly process of gathering information about exposure and effect in a possibly stressed system and determining the significance and causes of any observed changes" (from Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection - GESAMP - 1995).

**association** A term used by botanists to refer to an assemblage of plants with a definite floristic composition, considered by many workers to be synonymous or very similar to the zoological concept of 'community' (from Hiscock & Connor 1991).

**attribute** A characteristic of a habitat, biotope, community or population of a species which most economically provides an indication of the condition of the interest feature to which it applies. (JNCC 1998.)

**baseline** A defined condition for a site or conservation features of a site, against which change in the condition of the site/features can be monitored, and the significance of this change assessed. (JNCC 1998.)

**bioassay** "An experimental procedure in which organisms are exposed to different substances or combinations of substances to determine concentrations that adversely affect them" (from GESAMP 1995).

**biodiversity broad habitats** A framework classification of habitats contained in *Biodiversity: The UK Steering Group Report* (as amended by the Targets Group) which can be used to describe the whole land surface of the UK, and the surrounding sea to the edge of the continental shelf in the Atlantic ocean. (JNCC 1998.)

**biomarker** "A biological response that can be specified in term of a molecular or cellular event, measured with precision and confidently yield information on either degree of exposure to a chemical and/or its effect upon the organism or both" (from GESAMP 1995).

**biotope** 1) The physical 'habitat' with its biological 'community'; a term which refers to the combination of physical environment (habitat) and its distinctive assemblage of conspicuous species. MNCR uses the biotope concept to enable description and comparison. 2) The smallest geographical unit of the biosphere or of a habitat that can be delimited by convenient boundaries and is characterised by its biota (Lincoln, Boxshall & Clark 1982).

**change limit** The degree to which the value of an attribute of a feature is allowed to fluctuate around a precisely defined target value without causing concern or requiring remedial action.

**characteristic (species)** Special to or especially abundant in a particular situation or biotope. Characteristic species should be immediately conspicuous and easily identified. (Based on Hiscock & Connor 1991.)

**community** A group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and identifiable by means of ecological survey from other groups (from Mills 1969; see Hiscock & Connor 1991 for discussion.)

**compliance monitoring** Monitoring to determine whether the management measures agreed for particular designated sites are in place and operating. (JNCC 1998.)

**condition categories** The generic term describing the categories used for judging and reporting on the condition of an interest feature. (JNCC 1998.)

**condition monitoring** Monitoring to determine the conservation status of *interest features* on statutory sites and to determine whether the *conservation objectives* for particular sites are being met. (JNCC 1998.)

**conservation objective** A statement of the nature conservation aspirations for the features of interest on a site, expressed in terms of the *favourable condition* that we wish to attain for each feature of interest. (JNCC 1998.)

**constancy** 1) The frequency of occurrence of a species in samples from the same community (based on Makins 1991). 2) The continued presence of a species or community at a particular location. Cf. ‘persistence’, ‘resilience’, ‘stability’.

**contamination** “An increase of background concentration of a chemical or radionuclide” (from Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection - GESAMP - 1995).

**dendrogram** A branching diagram in the form of a tree, used to depict degrees of relationship or resemblance (from Lincoln, Boxshall & Clark 1982).

**dependency** (conservation assessment) The reliance (of a species, community or ecological process) on a particular location (for instance, a feeding, breeding, sheltering area or a migration corridor) or structure (for instance, a kelp forest, a sea grass bed, a maerl bed) for survival.

**destroyed** The recording of the condition of an interest feature as *destroyed* will indicate that an entire interest feature has been affected to such an extent that there is no hope of recovery, perhaps because its supporting habitat or processes have been removed or irretrievably altered. (JNCC 1998.)

**disturbance** “A chemical or physical process caused by humans that may or may not lead to a response in a biological system within an organism or at the level of whole organisms or assemblages. Disturbance includes stresses” (from Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection - GESAMP - 1995).

**diversity** The state or quality of being different or varied (from Makins 1991). In relation to species, the degree to which the total number of individual organisms in a given ecosystem, area, community or trophic level is divided evenly over different species, i.e. measure of heterogeneity. Species diversity can be expressed by diversity indices, most of which take account of both the number of species and number of individuals per species (Based on Baretta-Bekker, Duursma & Kuipers 1992). Cf. “evenness”; 'richness'.

**diversity** (conservation assessment) An assessment of the richness of different types in a location (which can be large or small) including the number of different biotopes and numbers of species. The number of species present in a an example of a particular biotope.

**Environmental Assessment (EA); Environmental Impact Assessment (EIA)** A process of predicting and evaluating an action's impacts on the environment, from which the conclusions are used as a tool in decision-making. It aims to minimise environmental degradation by giving decision-makers better information about the consequences which development actions could have on the environment, although it cannot, in itself, achieve that protection (based on Pritchard 1993). An Environmental Assessment can be used to produce an Environmental Statement (ES). Cf. “Strategic Environmental Assessment”.

**Environmental Statement (ES)** A statement intended to provide all of the information needed to evaluate the likely environmental implications of a proposed development. (Adapted from Treweek 1996.)

**epibenthos** All organisms living on the surface of the seabed.

**epifauna** Animals living on the surface of the seabed.

**epilithic** Growing on the surface of rock.

**epiphytic** Growing on the surface of a living plant (but not parasitic upon it).

**epizoic** Growing or living on the exterior of a living animal (but not parasitic upon it).

**eutrophication** The over-enrichment of an aquatic environment with inorganic nutrients, especially nitrates and phosphates, often anthropogenic (e.g. sewage, fertiliser run-off), which may result in stimulation of growth of algae and bacteria, and can reduce the oxygen content of the water.

**ecotone** The zone of transition between two major ecological communities.

**favourable - maintained** An interest feature should be recorded under the condition category *favourable - maintained* when its conservation objectives were being met at the previous assessment, and are still being met. (JNCC 1998.)

**favourable – recovered** A feature of interest can be recorded in the condition category *favourable - recovered* if it has regained 'favourable condition', having been recorded as 'unfavourable' on the previous assessment. (JNCC 1998.)

**favourable condition** The target condition for an interest feature in terms of the abundance, distribution and/or quality of that feature within a site, that we aim the feature to attain. It is the site specific representation of favourable conservation status. (JNCC 1998.)

**favourable conservation status** A range of conditions for a natural habitat or species at which the sum of the influences acting upon that habitat or species are not adversely affecting its distribution, abundance, structure or function throughout the EU in the long term. The condition in which the habitat or species is capable of sustaining itself on a long-term basis. (JNCC 1998.)

**feature monitoring cycle** The period within which each individual interest feature on a site should be monitored. [Set in the Common Standards Statement as 3 years]. (JNCC 1998.)

**heavy metals** Metals often defined as having a specific gravity of greater than 5 or 4 or, alternatively, as having an affinity for sulphur. (For a discussion and list of heavy metals, see Rainbow 1985.)

**holistic** The fundamental interconnectedness of all things (Adams 1987).

**hosted feature** Features which, though they were not the original reason for notification, we may be interested in managing; for example because they are listed on the Annexes of the EC Habitats Directive. (JNCC 1998.)

**interest feature** A habitat, habitat matrix, geomorphological or geological exposure, a species or species community or assemblage which is the reason for notification of the site under the appropriate selection guidelines or, in the case of Natura 2000 and Ramsar areas, the features for which the site will be designated. (JNCC 1998.)

**indicator organisms or species** An organism whose characteristics (e.g. presence or absence, population density, dispersion, reproductive success) are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species, or environmental conditions of interest (Landres, Verner & Thomas 1988). Usually used for species which indicate the degree of pollution or other environmental conditions at a particular locality. See Rowell (1994) and GESAMP (1995) for a discussion. Cf. 'signpost species'; 'surrogate species'.

**inspection survey** A survey undertaken of a monitoring site which includes checking species abundances against baseline or previous survey results and photographs, taking reference photographs, and sampling for storage only. If there is indication of significant change (outside of defined change limits or by expert judgement) full monitoring survey may be triggered.

**introduced species** Any species which has been introduced directly or indirectly by human agency (deliberate or otherwise), to an area where it has not occurred in historical times and which is separate from and lies outside the area where natural range extension could be expected (i.e. outside its natural geographical range (q.v.)). The term includes non-established introductions ('aliens' (q.v.)) and established non-natives (q.v.), but excludes hybrid taxa derived from introductions ('derivatives').

**keystone species** A species which, through its predatory activities (for instance, grazing by sea urchins) or by mediating competition between prey species (for instance, by eating sea urchins), maintains community composition and structure. Removal of a keystone species leads to rapid, cascading changes in the structure they support (based on Raffaelli & Hawkins 1996). The term is also applied here to species which provide a distinctive habitat (for instance a bed of the horse mussel *Modiolus modiolus*, or kelp plants *Laminaria hyperborea*) and whose loss would therefore lead to the disappearance of the associated community.

**k-strategy** A life strategy optimally geared to living in a stable habitat with a high level of interspecific competition. Parental care is facilitated by low fecundity (small litters of large size offspring), by longevity and size. K-strategists are unlikely to be well adapted to recover from population densities significantly below their equilibrium level and may become extinct if depressed to such low levels. (From Baretta-Bekker, Duursma & Kuipers 1992). Cf. 'r-strategy'.

**macrobenthos** The larger organisms of the benthos, exceeding 1 mm in length (from Lincoln & Boxshall 1987); often applied to organisms > 0.5 mm. Cf. 'meiobenthos', 'microbenthos'.

**macrofauna** Animals exceeding 1 mm in length (Lincoln & Boxshall 1987) or retained on a 1 mm or 0.5 mm sieve; often applied to organisms > 0.5 mm. Cf. 'meiofauna', 'microfauna'.

**meiobenthos** Small benthic organisms which pass through a 1 mm mesh sieve, but are retained by a 0.1 mm mesh (from Lincoln & Boxshall 1987). Typically, they inhabit interstitial space in sediments. Cf. 'macrobenthos', 'microbenthos'.

**meiofauna** Small interstitial animals which pass through a 1 mm mesh sieve but are retained by a 0.1 mm mesh (from Lincoln & Boxshall 1987). Cf. 'macrofauna', 'microfauna'.

**microbenthos** Microscopic benthic organisms less than 0.1 mm in length (Lincoln & Boxshall 1987). Cf. 'macrobenthos', 'meiobenthos'.

**microfauna** Small animals less than 0.1 mm length, not visible to the naked eye (cf. 'macrofauna', 'meiofauna').

**microhabitat** A small part of the habitat which has distinct physical conditions, e.g. rock crevice.

**monitoring** "Surveillance undertaken to ensure that formulated standards are being maintained" (Hellawell 1978). "Observation of a variable over space and or time in order to determine the condition or state of the ecosystem" (from GESAMP 1995). See also 'compliance monitoring', 'surveillance', 'surveillance monitoring'.

**mosaic cycling** A cycle of dominance of one or more species over parts of a community resulting in patchiness which changes with time as one dominant switches to another (because of such factors as predation, grazing or senescence).

**multivariate analysis** In statistics, a group of techniques for the simultaneous analysis of more than one independent variable (from Lincoln, Boxshall & Clark 1982). See 'cluster analysis'; 'ordination'.

**non-native** (species) A species which has been introduced directly or indirectly by human agency (deliberate or otherwise), to an area where it has not occurred in recent times (about 5,000 years BP) and which is separate from and lies outside the area where natural range extension could be expected (i.e. outside its natural geographical range (q.v.)). The species has become established in the wild and has self-maintaining populations; the term also includes hybrid taxa derived from such introductions ('derivatives'). Cf. 'alien species'; 'introduced species'; 'recent colonist'; 'reintroduction'; 'translocation'.

**ordination** A method of statistical analysis used for summarising similarities between communities or between taxa, by representing the subjects as points in a multidimensional space in such a way that the inter-point distances are inversely related to the similarities (based on Lincoln, Boxshall & Clark 1982).

**overall monitoring cycle** The period within which all designated sites and their interest features will be monitored. [Set as 6 years in the Common Standards Statement]. (JNCC 1998.)

**parameter** Quantity constant in case considered, but varying in different cases (Fowler & Fowler 1951). An arbitrary constant, as distinguished from a fixed or absolute constant. Any desired numerical value can be given to a parameter. The term is also used to describe a definable characteristic of an item, device or system (Considine 1976). A variable in terms of which it is convenient to express other interrelated variables which may then be regarded as being dependent upon the parameter (Chambers & Chambers 1971).

**partially destroyed** It is possible to destroy sections or areas of certain interest features or to destroy parts of sites with no hope of reinstatement because the interest feature itself, or habitat or processes essential to support it, has been removed or irretrievably altered. Such cases would be recorded under the condition category *partially destroyed*. (JNCC 1998.)

**persistence** The time a variable has a particular value before it is changed to a new value (Pimm 1984).

**photogrammetry** The process of making measurements from photographs.

**pollution** (marine) **"**The introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of seawater and reduction of amenities."(Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection - GESAMP – 1995.)

**potentially damaging activities** Any activity occurring in an SSSI that has the potential to damage the interest features for which the site has been designated. (JNCC 1998.)

**power** The power of a statistical test is the probability that it will yield statistically significant results (Cohen 1977). The probability of making Type 1 and 2 errors in a given test (study or experiment) are labelled $\alpha$ and $\beta$ respectively. Power is defined as $1 - \beta$ (Gerrodette 1987). Cf. 'type 1 error'; 'type 2 error'.

**qualifying feature** Features which, though they do not appear in the designation citation could now qualify according to current guidelines.

**rarefaction curve** Plot of numbers of species against numbers of individuals in samples.

**relict (species)** A species believed to have been previously more widely distributed but is now restricted to a limited number of locations where populations are probably self-sustaining, for example, *Thyasira gouldi*, *Leptopsammia pruvoti*.

**reporting categories** The generic term which refers to the categories that will be used to report the results of SSSI/ASSI monitoring at the GB/UK level. (JNCC 1998.)

**reporting cycle** The period within which a definitive report on the condition of features protected within the SSSI/ASSI series will be produced. [Set as once in every 6 years in the Common Standards Statement.] (JNCC 1998.)

**resilience** The ability of an ecosystem to return to its original state after being disturbed (from Makins 1991) (cf. 'constancy', 'persistence', 'stability').

**resistance** The degree to which a variable is changed following perturbation (Pimm 1984). The tendency to withstand being perturbed from the equilibrium (Connell & Sousa 1983). (cf. 'Stability'; 'adjustment stability'.)

**risk assessment** An evaluation of the possibility of undesired events and the probability of harm being caused.

**r-strategy** A life strategy which allows a species to deal with the vicissitudes of climate and food supply by responding to suitable conditions with a high rate of reproduction. R-strategists are continually colonising habitats of a temporary nature. (From Baretta-Bekker, Duursma & Kuipers 1992). Cf. 'k-strategy'.

**sampling** The selection of a set of data, or the collection of a quantity of material, or of a set of individuals from a population with the purpose of measuring a given characteristic of that sample (based on Dooley & Kirkpatrick 1993).

**sedentary** Attached to a substratum but capable of movement across (or through) it (cf. 'sessile').

**semi-quantitative** Measurement based on estimates or rough counts of relative quantity (density, cover) - e.g. abundance scales (cf. 'quantitative').

**sensitivity** (conservation assessment) The intolerance of a habitat, community or individual (or individual colony) of a species to damage, or death, from an external factor. See 'fragility', 'vulnerability'.

**sessile** Permanently attached to a substratum (cf. 'sedentary').

**signpost species** species which direct the worker to look for other species or characteristics usually associated or found with that species. Cf. 'indicator species'; 'surrogate species'.

**site** As used for MNCR field surveys: the general location surveyed and at which separate stations are sampled (cf. 'station').

**site attributes** The characteristics, qualities or properties of a feature which are inherent and inseparable from the feature (Alexander 1996).

**site fabric** Any natural or semi-natural physical or biotic aspect of the site other than the *feature*, or any other physical or biotic aspect that either directly supports the *feature* or damage which is likely to be detrimental to the *feature*. (JNCC 1998.)

**Site of Special Scientific Interest (SSSI)** An area of land or water notified by the Nature Conservancy Council or its successor agencies under the Wildlife and Countryside Act 1981 as being of special nature (can include geological) conservation importance.

**special area of conservation (SAC)** A site of [European] Community importance designated by the [EU] Member States through a statutory, administrative and/or contractual act where the necessary conservation measures are applied for the maintenance or restoration, at a favourable conservation status, of the natural habitats and/or the populations of the species for which the site is designated (Commission of the European Communities 1992). (This status is achieved by sites adopted by the European Commission.)

**stability** The ability of an ecosystem to resist change (from Makins 1991) (cf. 'adjustment stability' 'constancy', 'persistence', 'resilience'). (See Connell & Sousa 1983 and Shrader-Frechette & McCoy 1993 for a discussion of the term and associated terms.)

**station** The location at which a sample is taken or an observation or record is made. 'Stations' may consist of a series of replicate samples. Cf. 'site'.

**stochastic** (statistics) (Of a random variable) Having a probability of distribution, usually with finite variance.

**Strategic Environmental Assessment (SEA)** The formalised, systematic and comprehensive process of evaluating the environmental impacts of a policy, plan or programme and its alternatives, including the preparation of a report on the evaluation and the use of the findings in publicly-accountable decision-making (Pritchard 1993) (cf. 'Environmental Assessment').

**stratified** (sampling) The selection of sample sites from situations of the same environmental character. 'Stratified random sampling' is the sampling method whereby an area is divided up into a number of blocks (strata) of the same size and samples are taken at random within each block (based on Grieg-Smith 1983). Stratified random sampling is often applied more loosely by selecting sample locations at random from all of the examples of a particular major habitat type (for instance, all of the locations where a 1 km Ordnance Survey grid intersect crosses an exposed sandy beach).

**stress** "A chemical or physical process that leads to a response within an organism, or at the levels of whole organisms or assemblages" (from Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection - GESAMP - 1995).

**succession** Sequential development of plant or animal communities through time.

**suction sampler** A benthic sampling device which uses suction to draw sediment and its fauna or biota scraped from rocks into a tube leading to some form of self-sieving collector (based on Holme & McIntyre 1984.)

**surrogate species** species which are likely to change if the whole community is changing and therefore respond to change on behalf of the community.

**Surveillance "**A procedure by which a series of surveys is conducted in a sufficiently rigorous manner for changes in the attributes of a site (or species) to be detected over a period of time" (from Marine Conservation Monitoring Workshop, January 1993, based on Hellawell 1978). See also 'compliance monitoring', 'monitoring', 'surveillance monitoring', 'survey'.

**surveillance monitoring** "An attempt to detect unanticipated impacts, particularly ones that may be wide ranging, subtle or that only slowly become large and obvious" (GESAMP 1995). See also 'compliance monitoring', 'monitoring', 'surveillance', 'survey'.

**survey** An inventory of the attributes of a site, area or region in terms of habitat and associated organisms (or of the distribution and/or autecological characteristics of selected species), usually by means of a standardised procedure. (Based on Marine Conservation Monitoring Workshop, January 1993.)

**target:** Broad targets which describe the fluctuation of the *attributes* of an *interest feature* under prevailing conditions. Because all features are subject to some change the targets may express how much change we would accept whilst still considering the feature to be in favourable condition. These will serve as a trigger mechanism so that when changes that fall outside the thresholds expressed are observed or measured some further investigation or remedial action is taken.

**transect** A defined line or strip across a site, along which observations or experiments are made or stations located.

**Type 1 error** The conclusion, following data analysis, that a significant change has occurred when it has not (based on van de Meer in press).

**Type 2 error** The conclusion, following data analysis, that a significant change has not occurred when in fact it has (based on van de Meer in press).

**unfavourable – declining** Decline is another possible consequence of a damaging activity. In this case, recovery is possible and may occur either spontaneously or if suitable management input is made. This condition category can be recorded more than once for a particular feature in relation to a single damaging activity. (JNCC 1998.)

**unfavourable - no change** An interest feature may be retained in a more-or-less steady state by repeated or continuing damage; it is unfavourable but neither declining or recovering. In rare cases, an interest feature might not be able to regain its original condition following a damaging activity, but a new, stable state might be achieved. (JNCC 1998.)

**unfavourable – recovering** A feature of interest can be recorded under the condition category *recovering* after damage if it has begun to show, or is continuing to show, a trend towards favourable condition. This category can be recorded more than once for a particular feature in relation to a single damaging activity. (JNCC 1998.)

**vagile** Clinging; sedentary (from Zibrowius 1991) (cf. 'sessile').

**vagrant (species)** Individuals of a species which, by natural means, move from one geographical region to another outside their usual range, or away from usual migratory routes, and which do not establish a self-maintaining, self-regenerating population in the new region (cf. 'alien species'; 'recent colonist').

**vulnerability** Describes the exposure of a habitat, community or individual (or individual colony) of a species to an external factor to which it is sensitive. See 'Sensitivity'.

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## APPENDIX 3 Results of the UK Marine SACs monitoring workshops.

Results are summarised as techniques and conclusions for objectives of detecting change in habitat or biotope diversity (Table A) and detecting change in species diversity (richness) and abundance (Table B).

**Summary Table A. Monitoring objective: To detect changes in habitat or biotope diversity or extent.**

| Technique | Quantitative ? | Qualitative ? | Apply to: | | | | Limitations | Solutions & suggestions for further testing | Workshop coverage | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Intertidal sedi. | Intertidal rock | Subtidal sedi. | Subtidal rock | | | Exercise | Discussion | Questionnaire |
| Satellite images | 1 | ✓ | ✓ | ✓ | 2 | 2 | Not detailed enough for most biotope recognition. | Ground truthing essential to get best matching. Test repeatability of identification of habitats, biotope complexes and biotopes from images. | | | ✓ |
| | | | | | | | Poor penetration below sea level. | Accept lack of suitability. Use other techniques. | | | |
| | | | | | | | High cost. | Use of loaned images. | | | |
| | | | | | | | Interpretation difficult (including cannot rely on classification of spectral images). | Use trained/experienced staff. | | | |
| | | | | | | | Images often not coinciding with low water or clear sky. | Future developments? | | | |
| Acoustic survey | 1 | ✓ | | | ✓ | ✓ | Not discriminatory enough for most biotope recognition. | Accept level of distinctiveness to habitat, biotope complex or biotope and adopt method if adequate. Improve technology. | | | ✓ |
| | | | | | | | Limited to deeper than 5-6m. | Use other techniques for shallower depths. | | | |
| | | | | | | | Repeatability not fully tested. | Testing/development required for boundary and biotope distinction. | | | |
| | | | | | | | Interpretation difficult. | Experienced staff only to interpret including with assistance. | | | |
| Aerial photography | 1 | ✓ | ✓ | ✓ | 2 | 2 | Lack of detail for identification of biotopes. | Improve ground-truthing. Accept level of accuracy possible. Technical improvements may help. | | | ✓ |
| | | | | | | | Unlikely to differentiate sediment biotopes. | Use other techniques. Fly lower. Try improving ground truthing. | | | |
| | | | | | | | Interpretation difficult (including cannot rely on classification of spectral images). | Use trained/experienced staff. | | | |
| | | | | | | | Poor penetration below sea level. | Accept lack of suitability. Use other techniques. | | | |
| | | | | | | | High cost. | Use of loaned images / collaborative projects. | | | |

| Technique | Quantitative ? | Qualitative ? | Apply to: Intertidal sedi. | Intertidal rock | Subtidal sedi. | Subtidal rock | Limitations | Solutions & suggestions for further testing | Workshop coverage: Exercise | Discussion | Questionnaire |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Viewpoint photography<br>(including video) | ✓ | ✓ | 3 | ✓ | 3 | ✓ | Lack of detail. | Establish camera to subject distance required for objectives. | | | |
| | | | | | | | Images taken at different times do not match. | Care to identify camera position exactly. Use previous image to match. | | | |
| | | | | | | | Overgrowth obscures encrusting or low growing organisms. | Be content to include top layer only. Use other techniques. | | | |
| | | | | | | | Interpretation of photographs difficult and time consuming. | Use trained/experienced staff. Detailed analysis for key species only. | | | |
| Detailed biotope mapping | | ✓ | ✓ | ✓ | ✓ | ✓ | Poor repeatability. | Training and care. Simplification of methods. | ✓ | ✓ | ✓ |
| | | | | | | | Boundaries inaccurate, not statistically rigorous. | Use measures with accuracy established by repeat recording. Target 'key' biotopes where area of extent is important.<br>Better standardisation of biotopes. Develop/use more accurate locational methods e.g. DGPS. | | | |
| | | | | | | | Cost of aerial photographs. | Use of loaned images / collaborative projects. | | | |
| Rapid biotope mapping | | ✓ | ✓ | ✓ | | | Lack of detail. | Accept limitation. Expand to detailed biotope mapping. | | | ✓ |
| | | | | | | | Poor repeatability. | Accept limitation. Use trained/experienced staff. | | | |
| | | | | | | | Confusion between different manuals – incomplete catalogues. | Better standardisation of biotopes. | | | |
| Biotope inventory | | ✓ | ✓ | ✓ | ✓ | ✓ | Limited scope (information restricted to a list of catalogued biotopes). | Accept limitation. Expand to mapping survey. | ✓ | ✓ | ✓ |
| | | | | | | | Poor repeatability. | Accept limitation. Use trained/experienced staff. | | | |
| | | | | | | | Confusion between different manuals – incomplete catalogues. | Better standardisation of biotope. | | | |
| Seasearch | | ✓ | | | ✓ | ✓ | Lack of detail. | Incorporation of other techniques. | | | ✓ |
| | | | | | | | Poor repeatability. | Accept limitation. Use trained/experienced staff. | | | |

| Technique | | | Apply to: | | | | Limitations | Solutions & suggestions for further testing | Workshop coverage | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantitative ? | Qualitative ? | Intertidal sedi. | Intertidal rock | Subtidal sedi. | Subtidal rock | | | Exercise | Discussion | Questionnaire |
| Divers on sledges or manta boards | 1 | ✓ | | | ✓ | ✓ | Logistically difficult due to poor visibility. | Plan survey for most likely period of good visibility. | | | ✓ |
| | | | | | | | Potentially hazardous. | Risk assessment especially important. Abandon if any significant risk. | | | |
| | | | | | | | Position fixing difficult. | Use DGPS and correct for position of sledge on seabed. | | | |
| | | | | | | | Often communication problems with surface. | Purchase reliable equipment. Train staff. | | | |
| | | | | | | | Limited area covered. | Use remote techniques to extrapolate results if relevant. | | | |
| Diver operated video | 1 | ✓ | | | ✓ | ✓ | Lack of detail. | Use mix of distance and close-up. | ✓ | ✓ | ✓ |
| | | | | | | | Cannot be used in poor visibility. | Accept limitation. Plan surveys for likely best visibility. | | | |
| | | | | | | | Limited to shallow (<50m) water. | Use other techniques for deeper water. | | | |
| Towed Video / ROV | 1 | ✓ | | | ✓ | | Limited area covered. | Use remote techniques to extrapolate results if relevant. | ✓ | | ✓ |
| | | | | | | | Peripheral vision poor to identify subjects for examination. | Accept limitation. Use in situ methods. | | | |
| | | | | | | | Cannot be used in broken rocky areas (danger of loss). | Accept limitation. Use in situ methods. | | | |
| | | | | | | | Logistical problems. | Careful planning of surveys. | | | |

**Note**

Many sampling methods, such as grabs or cores in a regular grid, could also be used for biotope mapping, with biotopes defined by cluster analysis. Problems would include difficulties in extrapolation between samples and the possible exclusion of large features.

Footnotes (numbers refer to those in columns)

1 Current techniques not fully quantitative but statistically rigorous methods could possibly be developed.

2 Applicability to subtidal habitats limited to very shallow water with good visibility.

3 Only suitable for surface fauna and flora.

**Summary Table B. Monitoring objective: To detect changes in species diversity (i.e. richness) and abundance.**

| Technique | | | Apply to: | | | | Limitations | Solutions & suggestions for further testing | Workshop coverage | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantitative ? | Qualitative ? | Intertidal sedi. | Intertidal rock | Subtidal sedi. | Subtidal rock | | | Exercise | Discussion | Questionnaire |
| In situ recording<br>Using abundance scales | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | Limited to large species, over 4mm. | Add other techniques if smaller species are to be sampled. | ✓ | ✓ | ✓ |
| | | | | | | | Poor repeatability. | Improve discipline. Undertake comparative exercises at start of surveys. | | | |
| | | | | | | | Lack of statistical rigour. | Accept limitation. | | | |
| | | | | | | | Abundance scale poorly developed or incomplete. | Improve abundance scale. | | | |
| Abundance scale, Checklist,<br>Exact location ('ACE') | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | Limited scope to detect change in diversity due to reduced checklist. | Add other techniques (e.g. full listing or sampling) if required. | ✓ | ✓ | ✓ |
| | | | | | | | Limited to large species, over 4mm. | Add other techniques if smaller species are to be sampled. | | | |
| | | | | | | | Unknown repeatability and statistical rigour. | Further testing of repeatability and statistical rigour. | | | |
| | | | | | | | Abundance scale poorly developed or incomplete. | Improve abundance scale. | | | |
| Divers on sledges or<br>Manta boards | 2 | ✓ | | | ✓ | ✓ | Logistically difficult due to poor visibility. | Plan survey for most likely period of good visibility. | | | ✓ |
| | | | | | | | Potentially hazardous. | Risk assessment especially important. Abandon if any significant risk. | | | |
| | | | | | | | Position fixing difficult (repeat location). | Use DGPS and, most effectively, fixed transit marks where possible. | | | |
| | | | | | | | Often communication problems with the surface. | Purchase reliable equipment, train staff. | | | |
| | | | | | | | Limited to a few large spp. | Accept limitation. Use other techniques if required. | | | |
| Diver operated video | 2 | ✓ | 3 | ✓ | 3 | ✓ | Lack of detail due to poor visibility. | Plan survey for likely good visibility. Use other techniques. | ✓ | ✓ | ✓ |
| | | | | | | | Lack of statistical rigour in analysing results. | Accept limitation. | | | |
| | | | | | | | Lack of definition, Inability to see under layers. | Use mix of distance and close-up, Use other techniques. | | | |
| | | | | | | | Limited to shallow (<50m) water. | Use other techniques for deeper water. | | | |

| Technique | Quantitative ? | Qualitative ? | Apply to: Intertidal sedi. | Intertidal rock | Subtidal sedi. | Subtidal rock | Limitations | Solutions & suggestions for further testing | Workshop coverage: Exercise | Discussion | Questionnaire |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Towed video / ROV | 2 | ✓ | | | 3 | ✓ | Lack of detail, limited to large spp. | Accept limitation. Use mix of distance and close-up with ROV. Supplement with stills camera mounted with video. | ✓ | | ✓ |
| | | | | | | | Logistically difficult due to poor visibility. | Plan survey for likely good visibility. Use other techniques. | | | |
| | | | | | | | Inability to see under layers. | Accept limitation. | | | |
| Photographic records<br>of marked locations<br>(Viewpoint photography<br>including video) | ✓ | ✓ | 3 | ✓ | 3 | ✓ | Lack of detail, limited to large spp. | Establish camera to subject distance required for objectives. | | ✓ | ✓ |
| | | | | | | | Images taken at different times do not match. | Care to identify camera position exactly. Use previous image to match. | | | |
| | | | | | | | Overgrowth obscures encrusting or low growing organisms. | Accept limitation - include cover organisms only. Drape aside large fronds or photograph from below canopy (kelp). | | | |
| | | | | | | | Interpretation time consuming. | Use trained and/or experienced staff. Use standardised procedural guidelines. Restrict analysis to dominant and key species only. | | | |
| | | | | | | | Underwater sites are difficult to locate. | Use sites which can easily be re-found or plan for time required. Mark sites clearly. Use aids such as metal detectors to find markers. | | | |
| Fixed quadrat photography<br>(Quantitative recording)<br>Limitations / solutions are additional to 'Photographic records' above. | ✓ | ✓ | | ✓ | | ✓ | Marking is time consuming. | Use imagination or employ navvies. | | | ✓ |
| | | | | | | | Photography at 90° essential. | Use framer attached to camera. | | | |
| | | | | | | | Shadows occur from larger organisms and obscure adjacent organisms. | Use dual flashguns. | | | |
| | | | | | | | Random stations (for statistics) would be too many to undertake and analyse. | Use sequentially placed quadrats and accept that certain stats. can't be used. | | | |

| Technique | Qua | Qua | Apply to: | Limitations | Solutions & suggestions for further testing | Workshop coverage |
|---|---|---|---|---|---|---|

| | | | Intertidal sedi. | Intertidal rock | Subtidal sedi. | Subtidal rock | | | Exercise | Discussion | Questionnaire |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Transects & quadrats(in situ) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | High cost of field time. | Accept cost. Determine minimum sampling area and best plot design. | | | ✓ |
| | | | | | | | Limited to large spp. over 4 mm. | Accept limitation. Use additional techniques (sampling). | | | |
| | | | | | | | Statistical rigour compromised in heterogeneous areas. | Accept limitation. Adopt 'stratified' sampling procedure. | | | |
| Cores & grabs | ✓ | ✓ | ✓ | | ✓ | | High sample processing cost. | Process a proportion of samples only and store others against future need. | | | ✓ |
| Dredges & trawls | 1 | ✓ | | | ✓ | | Poor statistical rigour. | Use dredge which takes quantifiable 'bite' or trawl over measured distance. | | | ✓ |
| | | | | | | | Destructive. | Use a dredge which takes a 'bite'. | | | |
| Timed searches | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Ability to observe differs between workers. | Use trained/experienced staff. Use standardised procedural guidelines. | | | ✓ |
| | | | | | | | Mobile species (e.g. fish) may be counted more than once. | Calibrate workers and establish/remove reasons for differences. | | | |
| Suction samples | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Logistically difficult. | Perception unfounded. Raise and lower sampler from boat. Use two workers. | | | ✓ |
| | | | | | | | High sample processing cost. | Process a proportion of samples only and store others against future need. | | | |
| Cryptofaunal samples | ✓ | ✓ | | ✓ | | ✓ | High sample processing cost. | Process a proportion of samples only and store others against future need. | ✓ | ✓ | ✓ |
| | | | | | | | Limited to small species. | Use other techniques for larger species. | | | |
| Artificial substrata | ✓ | ✓ | | ✓ | | ✓ | Uncertain relevance to natural biota. | Further testing of similarity to natural biota. | | ✓ | ✓ |
| | | | | | | | High sample processing cost. | Process a proportion of samples only and store others against future need. | | | |
| Sweepings & traps | 1 2 | ✓ | ✓ | ✓ | ✓ | ✓ | High sample processing cost in some cases. | Process a proportion of samples only and store others against future need. | | | ✓ |
| | | | | | | | Limited scope. | Incorporate other techniques. | | | |
| | | | | | | | Statistical rigour difficult. | Use standardised approach. | | | |
| Micro-samples (e.g. meiofauna) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | High sample processing cost. | Process a proportion of samples only and store others against future need. | | | ✓ |

Footnotes (numbers refer to those in columns)

1 Semi-quantitative

2 Quantification difficult but possible with refinement of method

3 Only suitable for surface fauna

## APPENDIX 4 Monitoring proposal worksheet

**MONITORING PROPOSAL WORKSHEET**

**Site name:**

**Reason(s) for which site is established (marine):**

**Hosted features (reasons for selection):**

**Management objectives (including change limits, if appropriate):**

**Rationale for undertaking monitoring including hypotheses being tested:**

**Monitoring objectives relevant to the specific details below:**

**Habitat(s), biotope(s) or species to be monitored:**

**Environmental data to be (or being) monitored:**

**Sources of above:**

**What is already known about likely variability in the features to be monitored?:**

**How confident are you that methods will detect significant change?:**

**Pilot studies to be undertaken:**

**Are reference sites to be established?:**

**Field methods (how sites will be located and identified for relocation, recording/sampling methods to be used including size and number of samples and collecting equipment):**

**Experience/ability level of staff or contractors:**

**Data analysis methods:**

**Quality assurance measures:**

**Linked experimental studies?:**

**Personnel required and time/cost:**

**Intervals between monitoring events, time of year/month for monitoring and end-date for monitoring:**

**Any special operational requirements? (e.g. spring tides required, minimum underwater visibility required, hovercraft needed for site access, same staff as previous to be used):**

**Financial limitations:**

**Reporting and appraisal intervals:**

**Data archiving arrangements:**

**Feedback mechanisms to management:**

**Performance indicators:**

**Plans and work to be assessed by:**

# APPENDIX 5 Abundance scale used by the MNCR. From Hiscock (1996).

| GROWTH FORM | | | SIZE OF INDIVIDUALS / COLONIES | | | | |
|---|---|---|---|---|---|---|---|
| **% COVER** | **CRUST / MEADOW** | **MASSIVE / TURF** | **< 1 cm** | **1-3 cm** | **3-15 cm** | **> 15 cm** | **DENSITY** |
| > 80% | S | | S | | | | > 1 / 0.001 $m^2$ (1x1 cm) > 10,000 / $m^2$ |
| 40-79% | A | S | A | S | | | 1-9 / 0.001 $m^2$ 1000-9999 / $m^2$ |
| 20-39% | C | A | C | A | S | | 1-9 / 0.01 $m^2$ (10 x 10 cm) 100-999 / $m^2$ |
| 10-19% | F | C | F | C | A | S | 1-9 / 0.1 $m^2$ 10-99 / $m^2$ |
| 5-9% | O | F | O | F | C | A | 1-9 / $m^2$ |
| 1-5% or density | R | O | R | O | F | C | 1-9 / 10 $m^2$ 3.16 x 3.16 m) |
| < 1% or density | | R | | R | O | F | 1-9 / 100 $m^2$ (10 x 10 m) |
| | | | | | R | O | 1-9 / 1000 $m^2$ (31.6 x 31.6 m) |
| | | | | | | R | >1 / 10,000 $m^2$ (100x100 m) <1 / 1000 $m^2$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| PORIFERA | Crusts<br>*Halichondria* | Massive spp.<br>*Pachymatisma* | | Sml solitary<br>*Grantia* | Lge solitary<br>*Stelligera* | |
| HYDROZOA | | Turf species<br>*Tubularia*<br>*Abietinaria* | | Small clumps<br>*Sarsia*<br>*Aglaophenia* | Solitary<br>*Corymorpha*<br>*Nemertesia* | |
| ANTHOZOA | *Corynactis* | *Alcyonium* | | Sml solitary<br>*Epizoanthus*<br>*Caryophyllia* | Med. solitary<br>*Virgularia*<br>*Cerianthus*<br>*Urticina* | Large solitary<br>*Eunicella*<br>*Funiculina*<br>*Pachycerianthus* |
| ANNELIDA | *Sabellaria spinulosa* | *Sabellaria alveolata* | *Spirorbis* | Scale worms<br>*Nephtys*<br>*Pomatoceros* | *Chaetopterus*<br>*Arenicola*<br>*Sabella* | |
| CRUSTACEA | Barnacles<br>Tube-dwelling amphipods | | *Semibalanus*<br>Amphipods | *B. balanus*<br>*Anapagurus*<br>*Pisidia* | *Pagurus*<br>*Galathea*<br>Small crabs | *Homarus*<br>*Nephrops*<br>*Hyas araneus* |
| MOLLUSCA | *Mytilus*<br>*Modiolus* | | Sml gastropod<br>*L. neritoides*<br>Sml bivalves<br>*Nucula* | Chitons<br>Med. gastropods<br>*Patella*<br>*L. littorea*<br>*Turritella*<br>Med. bivalves<br>*Mytilus*<br>*Pododesmus* | Lge gastropod<br>*Buccinum*<br>Lge bivalves<br>*Mya Pecten*<br>*Arctica* | |
| BRACHIOPODA | | | | *Neocrania* | | |
| BRYOZOA | Crusts | *Pentapora*<br>*Bugula Flustra* | | | *Alcyonidium*<br>*Porella* | |
| ECHINODERMATA | | | | *Echinocyamus*<br>*Ocnus* | *Antedon*<br>Sml starfish<br>Brittlestars<br>*Echinocardium*<br>*Aslia Thyone* | Large starfish<br>*Echinus*<br>*Holothuria* |
| ASCIDIACEA | Colonial<br>*Dendrodoa* | | | Sml solitary<br>*Dendrodoa* | Lge solitary<br>*Ascidia Ciona* | *Diazona* |
| PISCES | | | | | Gobies<br>Blennies | Dogfish<br>Wrasse |
| PLANTS | Crusts Maerl<br>*Audouinella*<br>Fucoids/Kelp<br>*Desmarestia* | Foliose<br>Filamentous | | | *Zostera* | Kelp<br>*Halidrys*<br>*Chorda*<br>*Himanthalia* |

Examples of groups or species for each category

## APPENDIX 6 Site marking

Comparative studies of variability between sampling teams have shown the high importance of re-surveying the same area especially in the case of rock habitats or wherever a particular feature is being mapped. The method of marking a site will depend on substratum type (for instance, pitons might be ideal for slate rock with crevices but impossible to use on granite) and available materials. Some imagination is needed and some of the suggestions below are novel and require trialling. Site marking is often best left to engineers rather than biologists.

**Photographs (and chalk)**

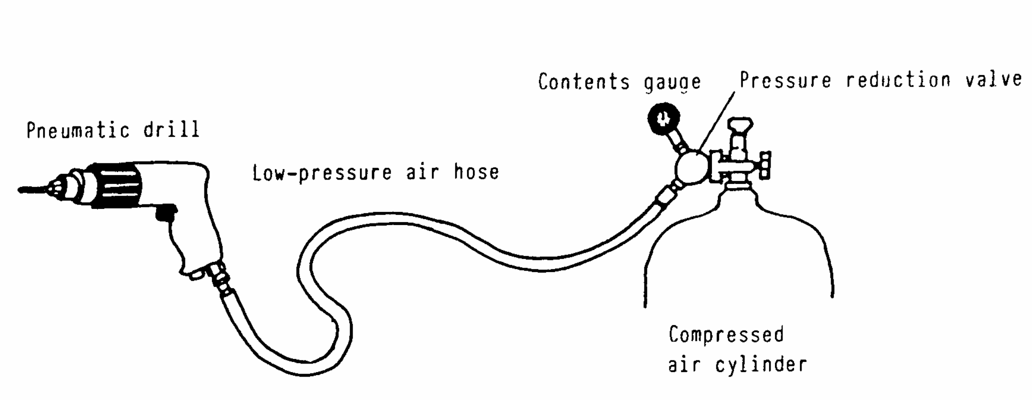
Photographs of shore sites with conspicuous features which can be re-located and preferably as transits for location or the line of a transect can be used. Chalk marks can indicate stations and, if there are enough topographical features on the rock to relate to chalk marks, it may not be necessary to mark the station permanently.

**Paint**

Paint can be used on rocky shores to mark stations. It may need touching-up from year to year.

**Pitons**

Exact location is rarely possible, unlikely to be used where quadrats or transect are to be marked but can be used to attach signpost markers (subsurface buoys, fluorescent tape) near to less conspicuous but exact marks or near to individual sessile organisms being studied. (Pitons may be dangerous if they are used on shores and likely to trip people.)




**Appendix figure 6.1** Compressed air drill used for drilling marker holes.

**Plastic plugs and bolts in holes drilled with a pneumatic drill**

Bolts including ring bolts can be used to mark quadrats or transects as holes can (usually) be drilled in exact locations. A portable generator and standard electric drill can be used on the shore. On the shore and underwater, a compressed air drill operated from a diving cylinder (Appendix Figure 7.1) can be used. On the shore, holes remain conspicuous and easily found without inserting bolts. Plastic plugs can be inserted in the holes and stainless steel or brass ring bolts or screws inserted. These may become overgrown and, although site photographs will help get near to their location, it may be necessary to use a metal detector (for instance, a 'pipe-finder') to re-find. (Protruding bolts may be dangerous if they are used on shores and likely to trip people.)

**Subsurface buoys**

These are hard floats which can be attached to a short (c. 50 cm) length of line and will be highly conspicuous from a distance. They can be tied to rock features, to pitons or to 'corkscrew' markers in sediment.

**Acoustic pingers (transponders)**

These have the potential to be useful especially where visibility is poor.

**Localised features**

Often, the local 'architecture' of rocky areas or subtidal area is sufficient, especially when aided by photographs, to indicate approximately or precisely where a site is or to provide a guide to find station marks.

**Existing man-made features (including wreckage)**

As above.

**Heavy objects**

These include concrete blocks or lumps of metal and can be used especially on sediments. A transect line or grid could be re-strung between then.

**Epoxy putty**

This has considerable potential for marking rock sites where pitons are not possible or may fracture rock and to avoid the hard labour of drilling holes for bolts.

## APPENDIX 7 Matching objectives to methods.

The following table was drafted in October 1996 and has been developed with comments made at the workshop in November 1996, at the spring 1997 workshops and subsequently. Refer to the Glossary (Appendix 1) for definitions of technical terms. Comments on the techniques are not included in this table – cross reference to Appendix 2.

| Objectives | Intertidal methods | | Subtidal methods | |
|---|---|---|---|---|
| | **Rock/hard/mixed** | **Sediment** | **Rock/hard/mixed** | **Sediment** |
| **Conservation:** Ensure that major habitat types supporting features of interest retain or restore (where damaged) their area. [This objective refers to the minority of habitats where there is a potential for human impact on extent].<br><br>**Survey:** Map/re-map extent of major substratum features including major biotope complexes. | Aerial photography at 1:10,000 + ground truthing.<br><br>Oblique aerial photography of contiguous lengths of coastline.<br><br>Ground viewpoint photography (from a fixed station) of whole shores or habitats. | Aerial photography at 1:10,000 + ground truthing.<br><br>Oblique aerial photography of contiguous lengths of coastline, whole bays.<br><br>Ground viewpoint photography (from a fixed station) of whole shore or habitats. (Usually requires high viewpoint overlooking a portion of shore.) | Aerial photography at 1:10,000 + ground truthing (very shallow only).<br><br>Oblique aerial photography of contiguous lengths of coastline (very shallow only - see 'notes').<br><br>Viewpoint photography of easily relocated stations.<br><br>Acoustic survey (RoxAnn®, QTC, sidescan with mosaicing) with ground truthing using video or divers. *Seasearch*. | Aerial photography at 1:10,000 + ground truthing(very shallow only).<br><br>Oblique aerial photography of contiguous lengths of coastline (very shallow only - see 'notes').<br><br>Viewpoint photography of easily relocated stations.<br><br>Acoustic survey (RoxAnn®, QTC, sidescan with mosaicing) with ground truthing using video or divers. *Seasearch*. |
| **Conservation:** Ensure that the range and types of biotopes or biotope complexes present in an area is maintained or restored (where damaged).<br><br>**Survey:** Inventory / reinventory biotopes or biotope complexes present in a defined area. | Rapid *in situ* survey matching habitats and characterising species present to biotopes classification. Can be undertaken from the sea for steeply sloping surfaces but some landing and inspection required. | Rapid *in situ* survey matching habitats and characterising species present to biotopes classification. Requires occasional digging and sieving to locate characterising species. | Video survey at spot locations identified by chart inspection or acoustic survey as including different habitats. Diver surveys in broken areas including caves, tunnels.<br><br>*Seasearch* for biotope complexes. | Dredge sampling at spot locations identified by chart inspection or acoustic survey as including different habitats. (Video survey may be used if epibiota sufficient to identify biotopes.)<br><br>*Seasearch* for biotope complexes. |

| Objectives | Intertidal methods | | Subtidal methods | |
|---|---|---|---|---|
| | **Rock/hard/mixed** | **Sediment** | **Rock/hard/mixed** | **Sediment** |
| **Conservation:** Ensure that the extent of the different biotopes or, for classified groups of biotopes, biotope complexes, is maintained and/or for rare, fragile, representative or rich or damaged biotopes expands at the site [without compromising other important features].<br><br>**Survey:** Map/re-map area occupied by all or selected biotopes or biotope complexes in a defined area. | **Indicative method** Viewpoint photography from fixed point. **Definitive method** Using 1:2,500 scale maps or vertical aerial photographs, overlay biotopes or biotope complexes by *in situ* survey. Or, establish boundaries of biotopes by standard surveying techniques but including enhanced GPS if appropriate. | **Indicative method** Viewpoint photography from fixed point. **Definitive method** Using 1:2,500 scale maps or vertical aerial photographs, overlay biotopes or biotope complexes by *in situ* survey. Or, establish boundaries of biotopes by standard surveying techniques but including enhanced GPS if appropriate. | ROV survey in at least fair (1m+) visibility over areas identified by chart inspection or acoustic survey as including different habitats. *Seasearch*. Especially zigzag over or follow apparent boundaries Diver surveys in broken areas including caves, tunnels.<br><br>Divers on sledges can be used in good (3m+) visibility over mixed level substrata or rocky substrata without severe breaks.<br><br>Position of video/diver plotted by GPS adjusted for tow line length. | Towed-video survey in at least fair (1m+) visibility over areas identified by chart inspection or acoustic survey as including different habitats. *Seasearch*. Especially, zigzag over or follow apparent boundaries. Dredge or grab samples of sediment for ground-truth.<br><br>Divers on sledges can be used in good (3m+) visibility.<br><br>Position of video/diver plotted by GPS adjusted for tow line length. |
| **Conservation:** Maintain the species richness in the biotope and/or abundance of key (rare, fragile, declining, representative or damaged) species in biotopes.<br><br>**Survey:** Establish/re-establish the species which are present in biotopes at a site including their abundance. | Abundance scale, Check list and Exact location surveys.<br><br>(The more precision which is required in searching for presence and recording density, the less species will be on the check list.) | Abundance scale, Check list and Exact location surveys.<br><br>(The more precision which is required in searching for presence and recording density, the less species will be on the check list.) | Abundance scale, Check list and Exact location surveys.<br><br>(The more precision which is required in searching for presence and recording density, the less species will be on the check list.) | Abundance scale, Check list and Exact location surveys.<br><br>(The more precision which is required in searching for presence and recording density, the less species will be on the check list.) |

| Objectives | Intertidal methods | | Subtidal methods | |
|---|---|---|---|---|
| | **Rock/hard/mixed** | **Sediment** | **Rock/hard/mixed** | **Sediment** |
| **Conservation:** Maintain the species richness in the biotope and/or abundance of key (rare, fragile, declining, representative) species in biotopes.<br><br>**Survey:** Establish the species present in biotopes and their density or % cover within statistical limits. | Coastal Surveillance Unit survey methods (counts of solitary species in quadrats, measures of % cover of algae using cross-wire frames at marked stations).<br><br>Collection and 'washing' of algae for associated fauna. | Box core samples, sieved and preserved for sorting, identification and enumeration. Number of cores required to sample species richness and to separate differences in quantity of individuals caused by temporal rather than spatial variability determined by pilot study. | Quantitative samples from defined rock surface (e.g. precision as above). (Can include collection of pebbles or cobbles from mixed substrata.) Number of quadrats required to sample species richness and to separate differences in quantity of individuals caused by temporal rather than spatial variability determined by pilot study.<br><br>Collection of kelp holdfasts, seagrass leaves, horse mussels etc as sampling units. Number/area/volume required has to be established as above. | Quantitative sampling using diver operated cores or grab/box core samples remotely at defined location. Samples sieved and preserved for sorting, identification and enumeration. Number of cores required to sample species richness and to separate differences in quantity of individuals caused by temporal rather than spatial variability determined by pilot study. |
| **Conservation:** Maintain the quantity of particular species of conservation importance (rare, fragile, declining species – those for which the site is 'special').<br><br>**Survey:** Record / re-record the numbers or cover of named species. | Photographic recording of marked locations to a scale suitable for the species being surveyed. (Viewpoint or quadrat.)<br><br>Counting within the same quadrat areas or transects (for widely distributed species).<br><br>Random quadrat counts or measures (using cross-wire frames or pin frames) for density or % cover of the species being surveyed.<br><br>Where the same individuals or colonies will be identified on each visit, a large enough number must be used to represent the population as a whole. | For species conspicuous on the surface: Photographic recording of relocatable stations to a scale suitable for the species being surveyed, or counting within quadrats or transects (for widely distributed species) in relocatable areas.<br><br>For buried large species: Digging to a suitable depth within quadrats at re-locatable areas and counting individuals within each quadrat.<br><br>For buried small species: Coring to a suitable depth at re-locatable areas and counting individuals from sieved samples. | Photographic recording of marked locations to a scale suitable for the species being surveyed. (Viewpoint or quadrat.)<br><br>Timed searches of precisely defined locations for widely dispersed species.<br><br>Belt transect surveys where seabed level. | For conspicuous epifauna at the surface:<br><br>1. Belt transect or circular search survey<br><br>2. Towed video or diver surveys counting individuals over a specified length of seabed and specified field of view (or drift dive).<br><br>3. Drop-down video with quadrat at defined locations. Number of sample stations determined by pilot study.<br><br>For buried large species: Digging by diver to a suitable depth within quadrats at re-locatable areas and counting individuals within each quadrat, or grab sampling followed by sieving and on-board counting.<br><br>For buried small species: Coring to a suitable depth using divers at re-locatable areas and counting individuals from sieved samples. |

| Objectives | Intertidal methods | | Subtidal methods | |
|---|---|---|---|---|
| | **Rock/hard/mixed** | **Sediment** | **Rock/hard/mixed** | **Sediment** |
| **Conservation:** Establish degree of likely sensitivity of a population through gaining an understanding of longevity and growth rate of the species.<br><br>**Survey:** Measure growth and longevity of a population. | Identify individuals of each species and ensure they can be re-identified on future occasions. This might be by tagging or, for sessile species, plotting position within a marked area.<br><br>For growth studies, measure appropriate dimensions of identified individuals or use photography against scale. | Likely to be possible for epibiota or emergent species only.<br><br>Identify individuals of each species and ensure they can be re-identified on future occasions. This might be by tagging or, for sessile species, plotting position within a marked area.<br><br>For growth studies, measure appropriate dimensions of identified individuals or use photography against scale. | Identify individuals of each species and ensure they can be re-identified on future occasions. This might be by tagging or, for sessile species, plotting position within a marked area.<br><br>For growth studies, measure appropriate dimensions of identified individuals or use photography against scale. | Likely to be possible for epibiota or emergent species only.<br><br>Identify individuals of each species and ensure they can be re-identified on future occasions. This might be by tagging or, for sessile species, plotting position within a marked area.<br><br>For growth studies, measure appropriate dimensions of identified individuals or use photography against scale. |

## APPENDIX 8 Extracts from the MNCR biotopes classification for inventory

The biotopes listed below are extracted from the full published list and include levels 1-5. From Connor *et al.* (1997a).

| Higher code | Biotope code | Biotope |
|---|---|---|
| SLR | | **Sheltered littoral rock (fucoid shores)** |
| SLR.F | | **Dense fucoids (stable rock)** |
| SLR.F | Pel | **Pelvetia canaliculata on sheltered littoral fringe rock** |
| SLR.F | Fspi | ***Fucus spiralis* on moderately exposed to very sheltered upper eulittoral rock** |
| SLR.F | Fves | ***Fucus vesiculosus* on sheltered mid eulittoral rock** |
| SLR.F | Asc | ***Ascophyllum nodosum* on very sheltered mid eulittoral rock** |
| SLR.F | Asc.Asc | Ascophyllum nodosum on full salinity mid eulittoral rock |
| SLR.F | Asc.T | *Ascophyllum nodosum*, sponges and ascidians on tide-swept mid eulittoral rock |
| SLR.F | Asc.VS | *Ascophyllum nodosum* and *Fucus vesiculosus* on variable salinity mid eulittoral rock |
| SLR.F | Fserr | ***Fucus serratus* on sheltered lower eulittoral rock** |
| SLR.F | Fserr.T | *Fucus serratus*, sponges and ascidians on tide-swept lower eulittoral rock |
| SLR.F | Fserr.VS | *Fucus serratus* and large *Mytilus edulis* on variable salinity lower eulittoral rock |
| SLR.F | Fcer | ***Fucus ceranoides* on reduced salinity eulittoral rock** |
| | | See also ELR.BPat.Sem, MLR.Fser.Fser, MLR.Ent and MLR.Rho |
| SLR.FX | | **Fucoids, barnacles or ephemeral seaweeds (mixed substrata)** |
| SLR.FX | BLlit | **Barnacles and *Littorina littorea* on unstable eulittoral mixed substrata** |
| SLR.FX | FvesX | ***Fucus vesiculosus* on mid eulittoral mixed substrata** |
| SLR.FX | AscX | ***Ascophyllum nodosum* on mid eulittoral mixed substrata** |
| SLR.FX | AscX.mac | *Ascophyllum nodosum* ecad. *mackaii* beds on extremely sheltered mid eulittoral mixed substrata |
| SLR.FX | FserX | ***Fucus serratus* on lower eulittoral mixed substrata** |
| SLR.FX | FserX.T | *Fucus serratus* with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata |
| SLR.FX | EphX | **Ephemeral green and red seaweeds on variable salinity or disturbed eulittoral mixed substrata** |
| SLR.FX | FcerX | ***Fucus ceranoides* on reduced salinity eulittoral mixed substrata** |
| | | See also SLR.Pel and SLR.Fspi |
| SLR.MX | | ***Mytilus* (mussel) beds (mixed substrata)** |
| SLR.MX | MytX | ***Mytilus edulis* beds on eulittoral mixed substrata** |

## Littoral rock (other)

| | | |
|---|---|---|
| LR.Rkp | | **Rockpools** |
| LR.Rkp | G | **Green seaweeds (*Enteromorpha* spp. and *Cladophora* spp.) in upper shore rockpools** |
| LR.Rkp | Cor | ***Corallina officinalis* and coralline crusts in shallow eulittoral rockpools** |
| LR.Rkp | Cor.Par | Coralline crusts and *Paracentrotus lividus* in shallow eulittoral rockpools |
| LR.Rkp | Cor.Bif | *Bifurcaria bifurcata* in shallow eulittoral rockpools |
| LR.Rkp | Cor.Cys | *Cystoseira* spp. in shallow eulittoral rockpools |
| LR.Rkp | FK | **Fucoids and kelps in deep eulittoral rockpools** |
| LR.Rkp | FK.Sar | *Sargassum muticum* in eulittoral rockpools |
| LR.Rkp | SwSed | **Seaweeds in sediment (sand or gravel)-floored eulittoral rockpools** |
| LR.Rkp | H | **Hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools** |
| LR.Ov | | **Overhangs and caves** |
| LR.Ov | RhoCv | ***Rhodothamniella floridula* in upper littoral fringe soft rock caves** |
| LR.Ov | SR | **Sponges and shade-tolerant red seaweeds on overhanging lower eulittoral bedrock** |
| LR.Ov | SByAs | **Sponges, bryozoans and ascidians on deeply overhanging lower shore bedrock** |

## LITTORAL SEDIMENTS

LS

## Littoral gravels and sands

LGS

| | | |
|---|---|---|
| LGS.Sh | | **Shingle (pebble) and gravel shores** |
| LGS.Sh | BarSh | **Barren shingle or gravel shores** |
| LGS.Sh | Pec | ***Pectenogammarus planicrurus* in mid shore well-sorted gravel or coarse sand** |
| LGS.S | | **Sand shores** |
| LGS.S | Tal | **Talitrid amphipods in decomposing seaweed on the strand-line** |
| LGS.S | BarSnd | **Barren coarse sand shores** |
| LGS.S | AEur | **Burrowing amphipods and *Eurydice pulchra* in well-drained clean sand shores** |

## APPENDIX 9 An example of a procedural guidelines being developed by the UK marine SACs project

# QUANTITATIVE SAMPLING OF SUBLITTORAL SEDIMENT BIOTOPES AND SPECIES USING REMOTE-OPERATED GRABS.

**Author:** Nigel S. Thomas, Emu Environmental Ltd, Hampshire Laboratory, Sparrowgrove, Otterbourne, Hampshire SO21 2SW, UK.

### Special notes

This protocol has been adapted from established benthic grab sampling methods described in Holme & McIntyre (1984) and Baker & Wolff (1987) with further consideration of sampling strategies and data analyses from recent texts (GCSDM 1993, 1997; Clarke & Warwick 1994, Ferraro *et al.* 1994) and workshops (Elliott 1997, Worsfold & Dyer 1997).

### Applicable to the following conservation objectives

At the time of writing, specific conservation objectives for marine SACs have not been prepared. However, grab sampling will be appropriate for conservation objectives concerning biotope presence (ground truthing only), quality in terms of species richness and the abundance of species and for detecting whether areas of impact away from point sources are expanding or contracting. Generic conservation objectives are:

1. Ensure that the extent of the different biotopes or, for classified groups of biotopes, biotope complexes, is maintained and/or for rare, fragile, representative or rich or damaged biotopes expands at the site [without compromising other important features]. (Sampling is for ground-truthing, not detecting change in abundance of species.)
2. Maintain or increase the species richness in the biotope and/or abundance of key (rare, fragile, declining, representative) species in biotopes.
3. Maintain or increase the quantity of particular species of conservation importance (rare, fragile, declining species - those for which the site is ‘special’).
4. Reduce the extent of impact of point source disturbance.

### Applicable to the following survey objectives:

1. Map/re-map area occupied by all or selected biotopes or biotope complexes in a defined area. (Sampling is for ground-truthing, not detecting change in abundance of species.)
2. Establish/re-establish the species which are present in biotopes at a site including their abundance and biomass within statistical limits.
3. Establish/re-establish the species which are present along a gradient of change away from a point source of disturbance including their abundance and biomass within statistical limits.

### Equipment required

**Site location.** Maps and charts to appropriate scale, Differential Geographical Positioning Systems (DGPS <5m accuracy). Survey vessel adequate for the sea conditions likely to be encountered and for the equipment to be deployed.

**Sampling.** Survey vessel should be fitted with a suitable ‘A’ frame or lifting arm and power winch. A grab suitable for the sediment at the site; both the Day Grab ($0.1m^2$) and van Veen ($0.1m^2$) are appropriate to a wide range of sand and muddy sediment types by adjusting weights. The jaws should be stainless steel. In sediments with a coarse component the most suitable grab is a Hamon ($0.29m^2$) with a stainless bucket. Landing tables are required for both the Day and Hamon Grabs. Sieves (1mm for sands and gravels, 0.5mm for muds), puddling hopper, running water via hose with a ‘shower head’, forceps, site log with pens, pre-labelled (except final site number/reference) sample buckets or sample pots, pre-labelled strong plastic bags for particle size, organic material and sediment metals samples, cable ties, other jars as appropriate for chemical analysis samples (e.g. pentane washed glass pots with aluminium foil lids for pesticides), plastic sampling scoops (for metals), stainless steel scoops for pesticides and hydrocarbons, fish boxes, water proof camera, waterproof markers, protective clothing (hard hats, gloves and safety boots in addition to normal gear).

**Storage and preservation**. 10% buffered formal saline (4% formaldehyde). Samples may be fixed on return to shore (single day surveys) to avoid exposure of personnel to spilt formalin. Preserve any samples for chemical analysis in a freezer. Biological samples are to be preserved in 70% IMS after fixing in formalin.

**Staff required**

Both the Day Grab and van Veen can be operated by two survey staff in addition to a winch operator and skipper. The optimum number of survey staff is three to include two for grab deployment and recovery with third for recording and sample processing. The third person may also operate the winch if sufficiently experienced. The Hamon grab is less easy to handle and requires a third person to assist with deployment and recovery in addition to the skipper and winch operator. At least two of the survey team should be experienced with handling grabs and have a knowledge of marine invertebrates.

**Best time of year to sample**

The optimum time for field work in inshore waters is May to September. In terms of avoiding recruitment periods the best sampling time is February to May. May is, therefore, the optimum sampling period. Practical constraints may preclude this period so the most important consideration is that repeat surveys should be completed at the same time of year.

**Survey brief**

Locate sites and collect specified number of grab samples and supporting information.

**Methods**

**Field**

1. *Site location.* Latitude and longitude for sample sites should be determined prior to commencing field work (or should be the same as for sites surveyed in the first monitoring survey). In using the Geographical Positioning System make sure that the correct datum is employed e.g. WGS84 or OSGB etc. Positioning should be by DGPS with better than 5m accuracy (offset on the vessel should always be noted) with quality control checks taken from known positions and records of signal quality during the survey.

2. *Sample collection.* The number of replicates required is subject to variation dependent on the sediment type and environmental conditions in which the samples are collected. Ideally for pilot surveys a large number of replicates should be collected (6-10) with the optimum number required for repeat surveys calculated after analysis has been completed. However, where costs are an important consideration it is recommended that, at each site, 5 replicate samples should be collected in the case of the Day Grab or van Veen. Four replicates only, may be used for the larger Hamon Grab samples (each of which may be up to 20 l in volume). Once at site the grab should be set down gently, with the winch wire remaining vertical. In the case of deep or fast moving water this may require additional weights on the grab and maintaining position by steaming into the current or, in exceptional circumstances, anchoring. Site position should be noted at the time the grab sample is taken. Additional notes should be made of the water depth, time (GMT 24hr clock) weather and sea state. On retrieval the grab should be placed on the landing table.

3. *On- board processing.* The sample should be checked for adequacy. In the case of the Day Grab and van Veen the depth of the sediment at the centre of the grab should be measured. In general a depth of greater than 7cm is required in muds and 5cm in hard sands. Anything less should be discarded. The Hamon grab sample should be emptied directly into a fish box marked with volume gradations. Anything less than 7.0l should be discarded. Records of sample size should be noted.

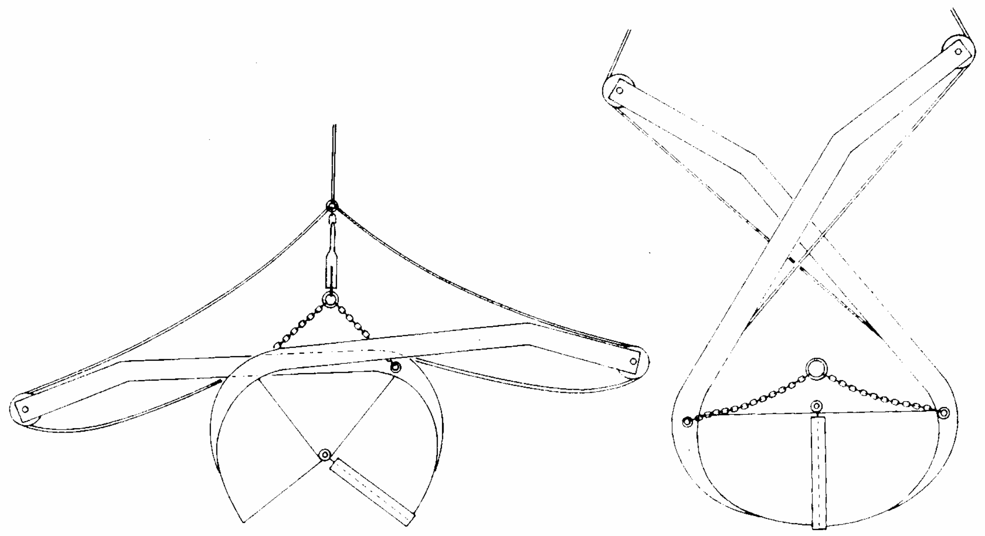


Figure 1. A van Veen grab, open and closed. From Holme & McIntyre 1984 (re-drawn from Dybern et al. 1976).

Where practical, photographic records should be made of whole samples (only possible when decanted into hoppers in many cases) along with information on surface colour, surface texture (e.g. concretions, presence of mudstone), colour change with depth, smell and presence of $H_2S$ blackened sediments. Consideration should be given to measuring Redox. (eH) with a platinum pin electrode, bearing in mind that in coarse sediments it is not possible to achieve stable values. Additional notes covering **any** aspect of the sample should be made, including dominant fauna, presence of dead shell or single large stones, etc. These additional notes can often prove invaluable in the interpretation of data.

If subsampling is required from an undisturbed sample for metals, organic matter/CHN or other chemicals, these should be collected directly from the grab bucket before the sample is decanted into the receiving hopper. Sediment particle size samples may be collected from well-mixed sediments once decanted. Appropriate scoops should be employed depending on the analysis required (metals need plastic scoops, others need stainless steel).

The faunal samples should be gently decanted into a receiving hopper; (large buckets in the case of Day and van Veen, a fish box for the Hamon). The grab is to be rinsed thoroughly before redeployment. Water should be added gently to the receiving hopper to produce a water sediment suspension. The sample is transferred in small quantities to a sieve in a separate water filled hopper. Sieving should be by puddling (no direct jetting of water on the sieve). Consideration should be given to two stage sieving for coarse sediments, to avoid specimen damage, i.e. 5mm initial sieve followed by 1mm sieve. The residue on sieve should be back washed into pre-labelled specimen containers. Containers should be marked three or four times with site and replicate number. Back washing should be undertaken over a tray or fish box to avoid accidental loss of the sample. The sieve should be checked and cleared of trapped fauna and any sediment impeding the efficiency of the sieve. A water proof label with site details should also be added to the sample container (adhere to NMBAQC requirements). Fix samples in 10% formal saline (which may be undertaken on return to the shore, but in all cases it must be done within 24 hours of collection).

**Laboratory**

Methods for the sieving, sorting , identification and biomass analysis of marine invertebrates should adhere to Environment Agency methods [reference required]. Chemical methods are not defined in this series of guidelines [reference?]. Particle size analysis should be undertaken according to the methods described by Buchanan (1984).

**Data analysis**

A range of data analyses procedures are available. These are described in Clarke & Warwick (1994), and GCSDM (1993). An initial consideration will be to define or refine the definition of the biotopes present in the survey area. This stage will most easily be achieved after an initial consideration of site groupings based on faunal similarity. Once site groups have been defined the physical conditions may be derived to provide a biotope description. The techniques most widely accepted in the UK for the definition of faunal assemblages, although by no means the only ones (see Clarke & Warwick, 1994), are Bray & Curtis similarity analysis in combination with a hierarchical clustering procedure and ordination by Multidimensional Scaling (MDS). These techniques are available in the PRIMER package (see Clarke & Warwick, 1994).

In terms of monitoring it may be necessary to provide a quantitative comparison based on only part of the faunal assemblage (e.g. infauna only). The principal reason for this constraint is finding compatibility between counts of individuals of each species for the infauna and percentage cover or abundance scale data for colonial epifauna. The degree to which manipulation will be necessary is clearly related to the substratum type. Most fine particulate sediments will be comprised almost exclusively of infauna, whereas sediments with a significant gravel component, such as those in the Solent area, have a diverse and abundant epifauna.

Having defined the faunal assemblage to be examined, the minimum data analysis should comprise a consideration of number of species, total abundance and biomass. These three ‘primary variables’ may be used to test year to year variation (in terms of percentage difference) and can in turn be used to undertake compliance monitoring according to the methods described in the GCSDM (1993). These methods were originally devised for compliance testing at sea disposal sites, and have been expanded to include wastewater discharges. They can, therefore, be employed to provide a coarse measure of deviation from the *status quo* with limits applied on a site by site basis, which may be considered as ‘Action Points’.

Where possible the analysis of primary variables should be supported by other univariate (diversity indices and graphical methods) and multivariate analysis techniques (MDS and supporting analyses such as ANOSIM), particularly where any identification from normality is noted. In all cases a broad approach to data analysis should be adopted, without losing site of the species that contribute to the data sets.

**Accuracy**

The data produced will be quantitative dependent on the heterogeneity of the environment and the number of replicates collected. Inaccuracies can arise due to a range of factors including the experience and conscientiousness of workers and their sample identification skills. The amount of error or variability likely has been established by tests undertaken under the auspices of the NMBAQC and advice given on minimising such variability.

**Time required**

**Field.** Mobilisation and demobilisation will be site dependent but will be a least one day each. On site it is possible to sample up to 40 times per day using the Day Grab or van Veen. The Hamon Grab is less easy to handle and a maximum of 30 per day is likely. In all cases sampling speed is subject to variation due to water depth, current speed, size of survey area, weather conditions, daylight, etc.

**Laboratory.** The laboratory time is usually very high. Sorting of samples is dependent on the nature of the sediment. Generally sands are very rapidly sorted (15 minutes), muds often take longer due to the large numbers of small specimens (several hours) whereas large consolidated gravel samples, with considerable amounts of retained material, may take more than a day. Similarly the identification stage will vary. Low diversity samples dominated by infauna can be identified in less than one hour, with high diversity muddy gravels containing many epifauna, taking several days. Consideration should always be given to the additional time taken to complete QC checks and reference collections.

**Data analysis.** Time taken for data analysis will depend on the extent of the analyses employed. Simple compilation of an Excel spreadsheet including classification using the MCS/Ulster Museum Species Directory codes and full QC checks may take up to two days for a 50 sample/ 400 species data set. Employing the PRIMER package is very rapid (<1 day) once the data has been adequately formatted, but a timescale for the interpretation of the outputs is dependent on the complexity of the results and may involve several reruns of the data.

**Advantages**

These methods provide quantifiable results which are open to statistical analysis and interpretation and provide a common standard between a potentially large number of data sets.

**Disadvantages**

The collection and subsequent analysis of sediment samples can be costly and time consuming.

**Quality Assurance Measures**

Quality assurance measures should focus on the following areas:

- repeatability of site positioning;
- quality and quantity of the sample,
- accuracy and traceability of the sample numbering,
- accuracy and traceability of sample registration,
- accuracy of sample sorting and species identification (participation in NMBAQC).,
- repeatability of physical and chemical analyses (NAMAS preferably) and
- accuracy of data compilation.

**Health & safety**

A comprehensive code of safe operating procedures for field work should be drawn up with particular reference to protective clothing to be worn during sampling and to operating procedures for potentially dangerous equipment. Risk assessments must be prepared for specific locations where field work is being undertaken. Laboratory safety codes of practice (COSHH approved methods) must be followed.

**References/further reading:**

Baker, J.M. & Wolff, W.J. *eds.* 1987. *Biological surveys of estuaries and coasts.* Cambridge, Cambridge University Press. (Estuarine and Brackish-Water Sciences Association Handbook, No. 3).

Clarke, K. R. & Warwick, R.M., 1994. *Changes in marine communities: an approach to statistical analysis and interpretation.* Plymouth, Natural Environmental Research Council, UK., 144pp.

Elliott, M. 1997. Benthic techniques, best practice review. Workshop at Hull University 18/9/97.

GCSDM, 1993. Analysis and interpretation of benthic community data at sewage-sludge disposal sites. Aquatic Environment Monitoring Report No. 37. Ministry of Agriculture Fisheries and Food, Lowestoft. 80 pp.

GCSDM, 1997. Comprehensive studies for the purposes of article 6 & 8.5 of the Dir 91/271 EEC, The Urban Waste Water Treatment Directive. 2nd Edition. DoE(NI), EA, SEPA and WSA.

Holme , N.A. & McIntyre, A.D. *eds.* 1984. *Methods for the study of marine benthos.* 2nd ed. Oxford, Blackwell Scientific Publications for International Biological Programme. (IBP Handbook, No. 16).

Worsfold, T.M. & Dyer, M.F. 1997. *UK Marine SACs Project. Monitoring methods workshop at Plymouth (April 1997) and Millport (May 1997). Part 1. Report.* (Contractor: Unicomarine, Letchworth). Peterborough, Joint Nature Conservation Committee.

**Reference to this Procedural guideline**

Thomas, N.S. 1998. Quantitative sampling of sublittoral sediment biotopes and species using remote-operated grabs. Version 1 of 23 March 1998. *In: Biological monitoring of marine Special Areas of Conservation: a handbook of methods for detecting change. Part 2 Procedural guidelines*, ed. by K. Hiscock, 6pp. Peterborough, Joint Nature Conservation Committee.

Version 1 of 23 March 1998

## APPENDIX 10 Example of a risk assessment for field work.

**RISK ASSESSMENT CHECK LIST AND RECORD**

**ACTIVITY: Rocky Shore Survey**

| HAZARD | RISK High | RISK Med | RISK Low | CONTROL MEASURES TO MINIMISE RISK |
|---|---|---|---|---|
| **Climate** | | | | |
| Extreme Temperatures | | * | | Obtain weather forecast to plan to avoid onshore waves. Use protective clothing including windproofs, waterproofs, sun block, hats, sun glasses as appropriate. Consider taking navigation equipment (compass, GPS). Take safety equipment including throw rope, first aid kit, VHF radio. Do not venture to lower shore where waves may sweep. |
| Rain | | | * | |
| Fog | | * | | |
| Waves | | | * | |
| Wind | | | * | |
| **Work equipment** | | | | |
| Bulk + packing of equipment | | | * | Take manageable load. |
| **Human** | | | | |
| Fitness + Fatigue | | | * | Ensure adequate fitness of participants. Do not plan journeys on foot over the capacity of individuals (bearing in mind the weather). |
| Obstruction by Landowners (access) | | | * | Plan access and obtain permission from relevant land owners. |
| **Agents** | | | | |
| Sewage effluent | | | * | Ensure current inoculations as relevant (hepatitis, tetanus). Use suitable protective clothing (gloves especially) + disinfectant if required. |

ACTION REQUIRED FOR SPECIFIC SURVEY (in priority order):

IS RESIDUAL RISK ACCEPTABLE?

ASSESSMENT MADE BY: DATE:

# APPENDIX 11 A statement on common standards for monitoring designated sites

## 1. Introduction

1.1 One of the special functions of the three country agencies (Countryside Council for Wales, English Nature and Scottish Natural Heritage) is the establishment of common standards throughout Great Britain for the monitoring of nature conservation. This information note describes the basic standards which relate to the monitoring required on statutory sites. The standards have been developed by these agencies, together with the Environment and Heritage Service in Northern Ireland and have been agreed by the Joint Nature Conservation Committee.

1.2 The standards apply to statutory sites designated as Sites of Special Scientific Interest (SSSIs) and Areas of Special Scientific Interest (ASSIs). They will also apply to areas designated as part of the Natura 2000 series, (Special Protection Areas (SPAs) under the EC Birds Directive and Special Areas of Conservation (SACs) under the EC Habitats Directive), together with Ramsar sites designated under the Convention on Wetlands of International Importance.

1.3 The standards set out below provide the basic framework required to ensure consistent monitoring throughout the UK. A glossary of the terms associated with common standards monitoring is provided in Annex I. Further guidelines are being produced by the country agencies to assist with the practical interpretation and application of these standards. Once agreed they will be published by the Joint Nature Conservation Committee. The detailed implementation of the standards is the responsibility of the individual country agencies.

## 2. The need for common standards for site monitoring

2.1 There are several benefits to be derived from having an agreed set of common standards for site monitoring:

- At a local level, staff have a framework within which they can develop their programme of site monitoring with the confidence that this is supported and being implemented throughout the country. The standards enable staff to make consistent judgements about site condition and help to ensure that judgements are comparable from one person to another and from one site to another.

- If data are collected, managed and exchanged following accepted standards the costs of data exchange are substantially reduced. Less time is spent interpreting and reconciling data from different sources and consistent data facilitates the comparison of results in time and space.

- Common standards allow individual agencies to establish procedures to ensure data is provided at the right time, in the right format. The data can then be aggregated and information produced at a range of geographical scales. This will enable obligations to report on the condition of designated sites at a country level and at a United Kingdom level to be met.

## 3. The basic approach

3.1 In developing common standards for site monitoring it is important to define what is meant by monitoring. In these standards we distinguish between surveillance and monitoring.

3.2 Surveillance relates to a continued programme of surveys systematically undertaken to provide a series of observations over time. Such programmes of repeated observations are very valuable for establishing the trends in the components of nature conservation at different geographic scales. Surveillance programmes and survey information both contribute to the national audit of wildlife which serves a range of different purposes including informing decision making, policy development and empowering individuals and groups to make wise choices about the natural environment. Surveillance programmes can benefit from agreed standards but this is not dealt with further in this paper.

3.3 Monitoring is, in contrast to surveillance, the making of an observation to establish whether a standard is being met. This can be established in a single visit or observation and does not require information collected over time.

3.4 The purpose of site monitoring is essentially to:

- Determine whether the desired condition of the feature(s) of interest for which the site was designated is being achieved. This can enable judgements to be made about whether the management of the site is appropriate, or whether changes are necessary.

- To enable managers and policy makers to determine whether the site series as a whole is achieving the required condition, and the degree to which current legal, administrative and incentive measures are proving effective.

3.5 Standards for site monitoring need to be sufficiently robust so that they can be implemented consistently across the UK by the different agencies, yet also be able to cater for the different operational practices and systems that have evolved in each country. The framework of standards ensures that the minimum requirements are defined and are able to be delivered within the resources available. The detailed operational development of these standards is the responsibility of each of the country agencies. The standards must enable us to monitor all of the habitats, species and earth science features protected within the SSSIs and ASSIs, including those of importance in the Natura 2000 network and Ramsar sites.

3.6 The bulk of the monitoring effort is likely to be undertaken by local conservation officers in the course of their day to day duties although in some situations, for example in the marine environment, other specialists may be required. The framework is designed to enable staff to undertake the assessments required bearing in mind the wide variation in types of site, interest features, knowledge of natural changes which occur and even the variation in the expertise and experience of staff. The standards facilitate quick and simple judgements but are also sufficiently robust to provide the required level of quality control and assurance that the assessments of site condition are accurate and consistent across the country.

## 4. The common standards

4.1 The basic framework of common standards for monitoring covers:

- Features to be monitored
- Conservation objectives
- Judging the condition of site features
- Recording activities and management measures
- Monitoring cycle
- Reporting arrangements

### 4.2 *Features to be monitored*

**The features to be monitored are known as the *interest feature(s)* for which the site has been notified or, in the case of Natura 2000 and Ramsar sites, the features for which the site is designated.**

In monitoring, the special interest of the site may not always be dealt with as a single entity since many sites have a complex mix of species, habitats or earth science features which provide the justification for the designation of the site. However, the individual interest features can be identified, monitored and reported separately. These interest features are described in the notification documents and are the reasons why the site was designated. In the case of SPAs and Ramsar sites the interest features which justify the designation are recorded in the site documentation. Until SACs are formally designated the interest features are those for which the site has been selected.

### 4.3 *Conservation Objectives*

**Conservation objectives will be prepared for interest features on all sites. These objectives will define what constitutes favourable condition of each feature by describing broad targets which should be met if the feature is to be judged favourable.**

Each interest feature of a site will have one or more attributes that can be used to help define favourable condition. For species these may include population size, structure, habitat requirements and distribution. Attributes of habitats may include area covered, key species, composition and structure and supporting processes. Attributes for earth science features include the Geological Conservation Review selection criteria and accessibility for education and research purposes.

Broad targets will be identified for those attributes that most economically define favourable condition of the interest feature. Because all features are subject to some degree of change the targets may express how much change we would accept while still considering the feature to be in a favourable condition. If a feature changes to the extent that it falls outside the thresholds expressed then this acts as a trigger for remedial action or further investigation.

In some cases relatively little may be known about the interest feature so it may be difficult to define favourable condition. In such circumstances we will consider using the current condition as our definition of favourable condition, in the absence of any evidence that the current condition was unfavourable.

### 4.4 *Judging the Condition of Sites*

**The condition of site features will be assessed against the following categories:**

- **Favourable - maintained.** An interest feature should be recorded as *maintained* when its conservation objectives were being met at the previous assessment, and are still being met.

- **Favourable - recovered.** A feature of interest can be recorded as having *recovered* if it has regained favourable condition, having been recorded as unfavourable on the previous assessment.

- **Unfavourable - recovering.** A feature of interest can be recorded as *recovering* after damage if it has begun to show, or is continuing to show, a trend towards favourable condition.

- **Unfavourable - no change.** An interest feature may be retained in a more-or-less steady state by repeated or continuing damage; it is unfavourable but neither declining or recovering. In rare cases, an interest feature might not be able to regain its original condition following a damaging activity, but a new stable state might be achieved.

- **Unfavourable - declining.** Decline is another possible consequence of a damaging activity. In this case, recovery is possible and may occur either spontaneously or if suitable management input is made.

- **Partially destroyed.** It is possible to destroy sections or areas of certain features or to destroy parts of sites with no hope of reinstatement because part of the feature itself, or the habitat or processes essential to support it, has been removed or irretrievably altered.

- **Destroyed.** The recording of a feature as destroyed will indicate the entire interest feature has been affected to such an extent that there is no hope of recovery, perhaps because its supporting habitat or processes have been removed or irretrievably altered.

These categories will be used to assess and report on the condition of features of interest and will replace the old loss and damage categories previously used.

Judgements on the overall condition of a feature will be influenced by a variety of factors and in some cases a feature may be assessed as being in favourable condition when only some of the targets set for it have been met.

### 4.5 *Recording Activities and Management Measures*

**Activities on, or near, the site and practical management measures affecting the condition of interest features will be included in the monitoring process. This information will be reported using a set of agreed categories.**

An important part of monitoring is the potential of relating observed changes in the condition of the interest features to the reasons for such changes. Activities being carried out on, or near, the site may be causing the feature to decline in condition, or may be constraining desired improvements. Conversely, management measures may result in improvements to the condition of features and the identification of such measures will demonstrate their value and influence future management actions. The result of such compliance monitoring will help inform views on whether existing legal, administrative, practical management and incentive measures are proving effective. Data from other sources may also provide contextual information and help inform our views on the success or otherwise of measures.

### 4.6 *Monitoring Cycle*

**The overall cycle will ensure that the interest features for all statutory sites will be monitored at least once within six years. However, for any particular site all the interest features should be monitored within a three year period.**

There is a need to monitor statutory sites and their interest features within an agreed cycle. This cycle needs to take account of the scale of monitoring required, the likely rate of change and the national and international reporting needs. As key reports on European Directives and international agreements and Conventions operate on a six year cycle this has been chosen as the overall cycle for monitoring in the UK. Within the overall monitoring cycle, it will be useful to form a view of the overall condition of the features within a proportion of the statutory sites on a more frequent basis. Each interest feature within a site should therefore be monitored, preferably within the same year, but certainly within a three year period. This will enable an interim UK wide report on a proportion of the statutory site network to be produced every three years.

### 4.7 *Reporting Arrangements*

**Information on the SSSI and ASSI series will be presented, at the UK level, on the basis of the biodiversity broad habitat types originally described in the UK Biodiversity Action Plan (1994) and on categories appropriate to the Geological Conservation Review. Reporting on species is for an agreed set of species categories. A full report will be produced once every six years with an interim report produced between full reports. The monitoring framework will generate information on the condition of features across the statutory site network as a whole, or on the status of features within individual sites, and will be used to fulfil reporting requirements under European Directives and International Conventions.**

Reports on the condition of features are required for a variety of purposes and on a variety of scales. The common standard is to allow the separate country accounts to be compared and aggregated to produce a UK account on the overall condition of features and the activities and practical management measures affecting them. The standard must also enable more specific accounts to be produced on the important habitats and species covered by the Biodiversity Action Plan, the Annex 1 habitats and Annex II species listed in the Habitats Directive, Annex I birds in the Birds Directive and species and habitats covered by the Ramsar Convention. It may also be necessary to aggregate information on features to produce site based reports. Individual country agencies may report in more detail than these categories and may wish to report on a more frequent basis.

## 5. Further information

The JNCC is a committee of the Countryside Council for Wales, English Nature and Scottish Natural Heritage, together with independent members and with representatives from the Countryside Commission and Northern Ireland. The Committee is supported by staff from the three agencies.

For further information on the programme of work associated with common standards monitoring and reporting contact:

JNCC, Monkstone House, City Road, Peterborough, PE1 1JY. Tel: 01733 562626, Fax: 01733 555948.

For further details on operational implementation in each of the four countries contacts are as follows:

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