JOINT NATURE CONSERVATION COMMITTEE

Marine Monitoring Handbook
March 2001

Edited by Jon Davies (senior editor), John Baxter, Martin Bradley, David Connor, Janet Khan, Eleanor Murray, William Sanderson, Caroline Turnbull and Malcolm Vincent

UK Marine SACs Project

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Reefs

Definition

Submarine, or exposed at low tide, rocky substrates and biogenic concretions, which arise from the seafloor in the sublittoral zone but may extend into the littoral zone where there is an uninterrupted zonation of plant and animal communities. These reefs generally support a zonation of benthic communities of algae and animal species including concretions, encrustations and corallogenic concretions.

Introduction to the feature's interest

Reefs are widespread in northern and southern Europe and occur widely around the UK coast. They are very variable in form and in the communities that they support. Sites have been chosen to represent the main geographical and ecological range in the UK of this extremely variable habitat type. Selection has favoured extensive examples with diverse community structure. The selection process has taken account of the UK's special EC responsibility for reef types in conditions of extreme wave and tidal stream exposure. A large proportion of the chalk reefs of Europe occurs in the UK and selection of this type of reef was emphasised in recognition of the UK's special responsibility.

Reefs are rocky marine habitats or biological concretions that rise from the seabed. They are generally subtidal but may extend as an unbroken transition to the intertidal zone, where they are exposed to the air at low tide. Two main types of reef can be recognised, those where structure is created by the animals themselves (biogenic reefs) and those where animal and plant communities grow on raised or protruding rock. Only a few invertebrate species are able to develop biogenic reefs, which are therefore restricted in distribution and extent.

There is a far greater range and extent of rocky reefs than biogenic concretions in the UK. Rocky reef types are extremely variable, both in structure and in the communities they support. A wide range of topological reef forms meet the EC definition of this habitat type. These range from vertical rock walls to horizontal ledges, broken rock and boulder fields. The common feature between these different forms is the type of animal and plant community that grows on the rock. The species assemblage is characterised by attached algae and invertebrates, usually associated with a range of mobile animals, including invertebrates and fish. The specific communities that occur vary according to a number of factors. For example, rock type is important, with particularly distinct communities associated with chalk and limestone rock. These have a restricted distribution in accordance with the distribution of the rock type on which they grow. There may be further variety associated with topographical features such as vertical rock walls, gully and canyon systems, outcrops from sediment and rock pools on the shore. The greatest variety of communities is typically found where coastal topography is highly varied, with a wide range of exposures to wave action and tidal streams.

Exposure to wave action has a major effect on community structure, with extremely exposed habitats dominated by a robust turf of sponges, anemones and foliose red seaweeds, while reefs in the most sheltered sea lochs and rias[1] support delicate or silt-tolerant filamentous algae, fan worms, ascidians and brachiopods. The presence of enhanced tidal streams often significantly increases species diversity, although some communities require very still conditions. The strength of tidal streams varies considerably, from negligible currents in many sea loch basins to very strong tidal currents of 8–10 knots (4–5 m/s) or more through tidal rapids or in sounds. In strong currents there are communities of barnacles, the soft coral *Alcyonium digitatum*, massive sponges and hydroids.

In addition, in the UK there is a marked biogeographical trend in species composition related to temperature, with warm, temperate species such as the sea fan *Eunicella verrucosa* and the corals *Leptopsammia pruvoti* and *Balanophyllia regia* occurring in the south, and cold-water species such as the anemone *Bolocera tuediae* and the red seaweed *Ptilota plumosa* in the north. A major factor affecting reef communities is the turbidity of the water. In turbid waters, light penetration is low and algae can occur only in shallow depths or in the intertidal zone. However, in such conditions animals have a plentiful supply of suspended food and filter-feeding species may be abundant. Salinity is also impor-

1 A ria is a drowned river valley.

tant. Although most reefs are fully marine, rocky habitats in certain marine inlets are subject to variable or permanently reduced salinity and have their own distinctive communities.

Where reefs extend from the seabed into the intertidal zone, a strong vertical zonation of communities is apparent. Lichens occur at the top of the shore, with communities characterised by barnacles, mussels or species of fucoid (wrack) seaweeds in the intertidal zone.

Typical attributes to define the feature's condition

Generic attributes

Table 3.2-1 lists the generic attributes for reef features and presents examples of the measures proposed for some of the candidate SACs in the UK. This list is not exhaustive and will be further developed as our knowledge of the factors that determine the condition of reef ecosystems improves.

Table 3.2-1 A summary of attributes that may define favourable condition of reefs

Attribute	*Measure*	*Comments*
Extent		
Extent of the feature	Area (ha) measured periodically	Extent of the feature is a reporting requirement of the Habitats Directive. The extent of (non-biogenic) reef is unlikely to change significantly over time unless due to some human activity but nevertheless needs to be measured periodically. The extent of a biogenic reef is an important attribute in relation to the viability of the reef.
Extent of a specific biotope	Area and distribution of a typical or notable biotope from the site	The extent of a biotope that is a key structural component of the reef, and is particularly important due to it being: *a typical biotope for the biological zone; notable for its nature conservation importance due to its rarity/scarcity, regional importance, species richness; and/or an extensive example; sensitive to non-native species or changes in supporting processes*
Extent of a biogenic reef	Extent of the horse mussel *Modiolus modiolus* biogenic reef	
Physical properties		
Water clarity	Average light attenuation measured periodically throughout the reporting cycle	Water clarity is a key process influencing algal/plant growth, density and extent and thereby algal/plant dominated biotopes. Changes in water clarity could be caused, for example, by an increase in suspended material due to organic enrichment. Siltation causes smothering of substrata and organisms affecting feeding efficiency or feeding mechanisms, and colonisation.
Water density Water temperature Salinity	Regular measurement of water temperature and/or salinity periodically throughout the reporting cycle	Temperature and salinity are characteristic of the overall hydrography of the area. Changes in temperature and salinity may influence the presence and distribution of species (along with recruitment processes and spawning behaviour), particularly those species at the edge of their geographic ranges.

Attribute	*Measure*	*Comments*
Biotic composition		
Biotope composition	Number and occurrence/ frequency of all biotopes or a range of specified biotopes	The number and occurrence/frequency of specified biotopes is an important structural aspect of the site. It is important to establish the finest level in the national classification to which the biotopes will be discriminated. The biotopes specified should reflect both the biological and regional/local character of site
	Overall biotope richness (number of biotopes)	The target value is likely to be the total number of biotopes known from the SAC. The lower limit for a single monitoring cycle may be less than 100% of the biotopes to take account of the likelihood of not recording a biotope with a given level of effort. It may be necessary to ensure that 100% of the biotopes present are recorded over, for example, three monitoring cycles.
Species composition of a specific biotope	Frequency and occurrence of composite species (total or sub-set) from a biotope	Species composition is an important contributor to the structure of a biotope and therefore the reef as a whole. The presence and relative abundance of all characterising species gives an indication of the quality of a biotope and any change in composition may indicate a cyclic change or trend in reef communities.
Characteristic species	Estimate population size from a measure of the abundance/occurrence/ frequency/biomass of a specified species Record a relevant population structure measure such as age structure of a specified species	The species selected should be an important structural element of the biotope, and is indicative of the structure of the particular biotope; for example kelp, *Modiolus modiolus* in biogenic reef. Change in the species may indicate cyclic change/trend in host biotope and/or reef communities as a whole.
Notable species	Occurrence and frequency of a species	A notable species may: have nature conservation importance due to such factors such as its rarity/scarcity; contribute to reef structure; be used as an indicator of environmental stress (e.g. green algae), or changes in water circulation patterns (e.g. edge of range species) or sensitivity to pollutants (e.g. molluscan sensitivity to TBT).
Biological structure		
Productivity – algal biomass	Algal biomass measured in late summer through the depth zone	Algal productivity, such as in a kelp forest, plays an important functional role within the food chain both directly and through detrital supply.
Distribution of all or a range of biotopes	Relative distribution of important communities throughout the feature	The relative distribution of biotopes, for instance kelp biotopes, is an important structural aspect of the site. Changes in the extent and distribution may indicate long-term changes in the prevailing physical conditions at the site.
Structural integrity of selected biotopes	Actual measures will depend on the specific aspects of structural integrity chosen for each selected biotope	For example, in Pen Llyn a'r Sarnau cSAC, three aspects of structural integrity were identified for the horse mussel *Modiolus modiolus* reef: continuity and area to periphery ratio of the reef/incidence of scaring; density/area covered by live *M. modiolus;* age structure of the *M. modiolus*

Suggested techniques for monitoring reef attributes

For each of the attributes likely to be selected to monitor the condition of a feature, there are many techniques available to measure its value. To help implement the UK's Common Standards for Monitoring programme, it is necessary to recommend a small number of techniques that are likely to provide comparable measures (Table 3.2-2). The UK Marine SACs project evaluated the inter-comparability of some of these techniques (recording biotope richness, species counts), but further work is required on other techniques (such as measuring extent with remote sensing techniques). The advice presented below will be updated when new information becomes available.

Table 3.2-2 Suggested techniques for measuring reef attributes. The terms under *Technique* appear under the heading *Summary title* in the procedural guidelines provided in Section 6. Guidance will be developed for the techniques in italics.

Generic Attribute	*Feature-specific attribute*	*Technique*
Extent	Intertidal	*Air photo interpretation; Remote imaging*; Intertidal resource mapping
	Subtidal	AGDS; Side scan sonar; Point sample mapping; (for shallow areas: *Air photo interpretation; Remote imaging)*
	Subtidal biogenic reefs	AGDS; Side scan sonar; Mosaicing sonar images; Point sample mapping
Physical properties	Water clarity	Measuring water quality; *Water chemistry data loggers; Secchi disk*
	Water chemistry (including salinity, temperature)	Measuring water quality; *Water chemistry data loggers*
	Substratum	Drop-down video; ROV; AGDS; Side scan sonar
Biotic composition	Intertidal biotope richness	Intertidal resource mapping; Intertidal biotope ID; Intertidal ACE; Viewpoint photography
	Subtidal biotope richness	Subtidal biotope ID; Drop-down video; ROV; Diver-operated video; Towed video (limited by topography and/or risk of damage)
	Intertidal species composition/richness	Intertidal ACE; Intertidal quadrat photography; Intertidal quadrat sampling (see Subtidal quadrat sampling); Fish in rockpools;
	Subtidal species composition/richness	Subtidal quadrat sampling; Subtidal biotope ID; Subtidal photography; Suction sampling; Fish in subtidal rock habitats; ROV; Drop-down video; Diver-operated video
	Intertidal characteristic species	Intertidal ACE; Intertidal quadrat photography; Intertidal quadrat sampling (see Subtidal quadrat sampling); Fish in rockpools
	Subtidal characteristic species	Subtidal quadrat sampling; Subtidal biotope ID; Subtidal photography; Suction sampling (small epibiota); Fish in subtidal rock habitats; Fish in vegetative cover; ROV ('large' conspicuous species only); Drop-down video ('large' conspicuous species only); Diver-operated video

Generic Attribute	*Feature-specific attribute*	*Technique*
Biological structure	Intertidal zonation	Intertidal resource mapping; Intertidal biotope ID; Intertidal ACE; *Transect survey; Shore profiling*
	Subtidal zonation	Subtidal biotope ID; Diver-operated video; Subtidal quadrat sampling; ROV; Towed video (limited by topography and/or risk of damage)
	Spatial pattern of intertidal biotopes	Intertidal resource mapping; Intertidal biotope ID; Viewpoint photography; *Air photo interpretation; Remote imaging*
	Spatial pattern of subtidal biotopes	AGDS; Side scan sonar (with mosaicing); Point sample mapping (from ROV or Drop-down video data)

Specific issues affecting the monitoring of reefs

All attributes will have their own inherent sources of variability that must be addressed during data collection and subsequent interpretation of the results. There are, however, some generic issues that should be considered when planning the whole monitoring study.

Seasonal effects

Marine communities exhibit seasonal change, although the precise effects are poorly understood for many communities. Some of the more obvious visual changes occur in algal assemblages, and following massive settlements of juvenile animals such as mussels and barnacles. In Loch Maddy cSAC, a recent study concluded that the largest changes observed in shallow communities between autumn 1998 and summer 1999 were due to an increase in diversity and abundance of algae.[a] Similarly, in Plymouth Sound cSAC, most of the changes observed between 1998 and 1999 were attributed to real changes in populations, rather than variability in recording methods or behavioural factors.[b] The degree to which seasonal change will influence the monitoring of a reef attribute will depend on the community under investigation. Where possible, a community should be investigated either directly or via a literature review to gather information on the likelihood of seasonal change affecting an attribute. In general, algal assemblages should be studied during the summer months. Where seasonal effects are not fully understood, it is vital that a monitoring strategy explicitly states that data collection must always be undertaken at the same time of year.[2]

Whilst seasonal variation strictly relates to changes within a year, reef communities may change over a longer time period (many years) as a consequence of ecological processes affecting community dynamics. Physical and biotic processes can cause wholescale changes in community composition on a reef. Community dynamics of rock shores have been extensively investigated and many authors report cyclical changes in the community composition over time.[c,d] Clearly, not considering such changes when interpreting the results of a monitoring exercise would lead to incorrect conclusions. Similarly, and perhaps more importantly, over-specificity when setting an attribute – such as the presence of biotope x – would be a recipe for disaster if 'biotope x' was only one of a suite of possible biotopes in a natural cycle.

Meteorological changes

Prevailing weather conditions and tidal state will affect any monitoring study. Sites open to the prevailing wind and swell will require calm conditions for effective field survey. Where a reef is adjacent to sediment habitats, excessive water movement (from strong winds or spring tides) will mobilise fine sediment into the water column, thereby reducing underwater visibility. Conversely, calm conditions will cause suspended sediment to deposit out of the water column, visibility will improve but reef assemblages may then become smothered with sediment obscuring some species from view.

Periods of extreme cold coinciding with low water can result in mass mortality of kelp plants.[e]

When establishing a monitoring strategy, meteorological effects must be integrated with seasonal effects to ensure that sites can be monitored reliably through time.

2 See comments in Section 2: What is the most appropriate method?

Access

To gain access to the site, the surveyor must consider the issues of permission (intertidal sites), tidal state (high or low water/slack water), prevailing wind/wave/swell conditions and underwater visibility. Access to intertidal habitats would be gained from the land, except for islands and offshore banks or remote sites where boat access will be necessary. It will be necessary to use a boat to gain access to many subtidal reefs and therefore it will be necessary to consider the availability of harbours and/or launching facilities. Land access would be possible for those subtidal habitats immediately adjacent to the shore.

Sampling issues

Reefs are topographically complex features, and may comprise a wide range of biotopes, particularly where a reef extends from the top of the intertidal zone through to the deep circalittoral zone. Such complexity within a single reef, and between reefs, poses considerable obstacles to achieving a consistent monitoring strategy within an SAC. Consequently, it is not possible to consider all aspects of reef sampling in the current report and what follows will consist of some basic advice in relation to common standards monitoring.

It should be emphasised that the aim of monitoring is to assess the condition of the *whole* feature within an SAC, and therefore the sampling programme must ensure samples are recorded throughout the entire site. A stratified approach may be adopted for extensive sites where the available resources only permit a few locations to be investigated in detail, and the results must be extrapolated to the whole site. Nevertheless, the sampling strategy should include a series of 'spot checks' throughout the site to ensure that the extrapolated results are in fact representative of the condition of the entire site. Using a 'top-down' approach to stratify sampling can result in significant cost-savings by linking techniques to address multiple attributes in a single monitoring exercise. For example, a remote sensing campaign could map the extent of a feature (or more likely sub-features). The imagery could then stratify a detailed ground validation campaign, and the results could be used to measure *biotope richness*. If an ROV was used for the sampling, it would be possible to record additional information, such as counts of a conspicuous *characteristic species*.

It is vital that a standardised approach is adopted when measuring attributes of the number of species (species richness) or biotopes (biotope richness) because the number recorded is directly linked to the sampling effort. All techniques must be 'effort limited' – for example by restricting the search area or search time.[3]

The characterising species of many reef biotopes have a huge range in body size: for example in kelp biotopes, body size will range from metres (kelp plants) to millimetres (fine hydroids, small bivalves). The dimensions and scale of occurrence of the target organism is an important factor when selecting the size of the sampling unit such as a quadrat, and the enumeration technique – counts, frequency or percentage cover. The choice has a significant effect on the time required for field survey and, more importantly, the reliability (accuracy and precision) of the results. It may be possible to improve sampling efficiency through a nested approach where a large quadrat is sub-divided into smaller units[4] (Figure 3-1). Large organisms are enumerated in the entire quadrat, but small organisms are only enumerated for a proportion of the smaller units (quadrats in their own right). For monitoring of an individual species, a scale of variance analysis can help to determine the appropriate sampling unit.

3 Effort limitation was addressed by Sanderson, W G, Holt, R H F, Kay, L (2000) Efficacy of deployment of divers. In: Sanderson, W G, Holt, R H F, Kay, L, Wyn, G and McMath, A J (eds.) (2000) *The establishment of an appropriate programme of monitoring for the condition of SAC features on Pen Llyn a'r Sarnau: 1998–-1999 trials*, pp. 29–36. Contract Science Report No: 380, pp. 29-36. Countryside Council for Wales, Bangor.

4 For a description of this approach see Chapter 3.4 and Appendix 2 in: Ecoscope (2000) *A species and habitats monitoring handbook. Volume 2: Habitat monitoring*. Research, Survey and Monitoring Review No. [XX]. Scottish Natural Heritage, Edinburgh.

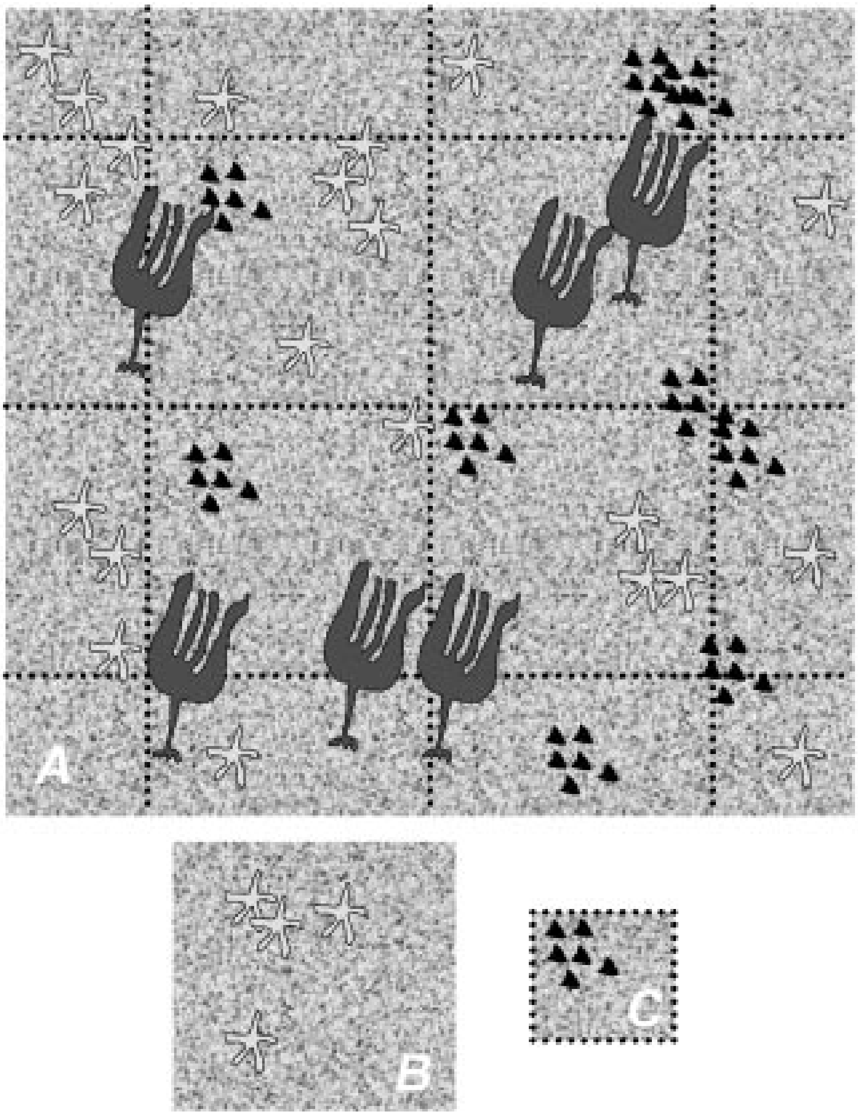

Figure 3-1 Illustration of a nested quadrat to record different sized organisms occurring at different spatial scales. Quadrat A is subdivided into 9 quadrats of size B and 36 quadrats of size C. Quadrat size will affect frequency estimates: 'starfish' frequency is 8/9 = 0.89 for quadrat B, but 15/36 = 0.42 for quadrat C.

Trials undertaken by the UK Marine SACs project demonstrated that the species composition of reef biotopes is subject to considerable temporal fluctuation.[a,b] Determining an appropriate sampling strategy, and in particular, ensuring the sampling intensity provides sufficient *statistical power* to detect any change, is critical to the success of a monitoring programme (see Section 2).

Site marking and relocation

Site marking techniques will depend on the environment (intertidal or subtidal), the rock type (hard, soft, and friable), degree of wave exposure and the likelihood of anthropogenic interference with fixed markers. Hiscock (1998)[g] lists site-marking techniques in Appendix 6. Holt et al. (2000)[h] investigated specific issues relating to site marking on a vertical, circalittoral bedrock reef. In Pen Llyn a'r Sarnau cSAC, acoustic beacons were also used to mark a horse mussel (*Modiolus modiolus*) reef, and an algal-dominated cobble reef at an offshore site.[i]

Relocation of fixed sites can be very difficult, especially underwater in poor visibility or with few conspicuous features to act as navigation aids. Global Positioning Systems (GPS) now offer the possibility of accurate site relocation to ± 15m using a standard receiver, or ± 1m if combined with an additional receiver to gather a correction signal - differential GPS (dGPS)[5]. If necessary, there are specialised GPS systems available, called Real Time Kinematic (RTK) GPS, which can achieve centimetre level accuracy, offering the possibility of returning to a very precise location. Without GPS technology, it is usual to use a map to locate the approximate position of a sampling station on intertidal reefs. Maps should be supplemented by photographs and/or diagrams of characteristic topographical features to find the precise location of a site marker. For subtidal sites, the approximate position can be located using conspicuous land features, preferably lined up to create transits. Photographs and/or diagrams should be used underwater to find the precise sample location although poor visibility creates severe problems (Figure 3-2).

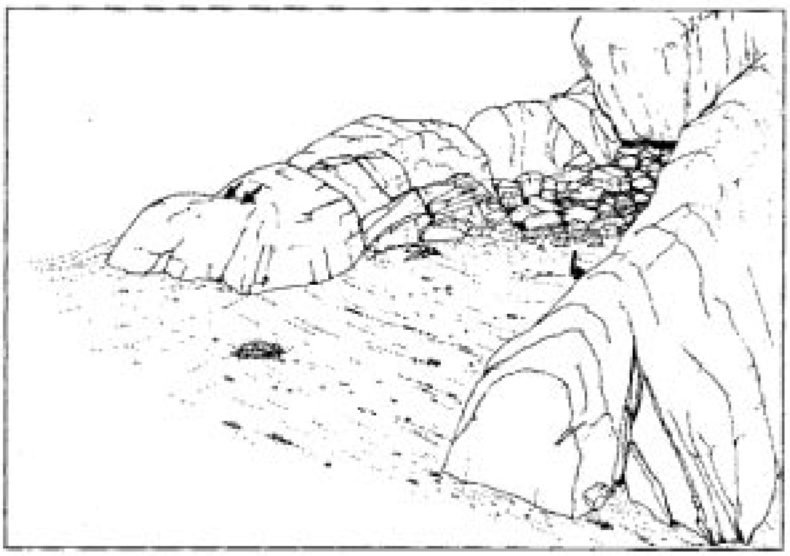

Figure 3-2 A drawing of the conspicuous underwater scenery to aid the relocation of a sample station[h]

Health and safety

All field staff must follow approved safety procedures published by their host institution, or that of the contracting agency, whichever are the more stringent.

Intertidal reefs often have complex topography that, when combined with a covering of algae, create an uneven slippery surface. Considerable care must be taken to reduce the risk of staff slipping or falling, particularly in remote areas where tidal immersion could occur before emergency assistance arrives. Field staff should carry a radio or mobile telephone to ensure the emergency services are notified promptly.

Some subtidal sampling on reefs will involve SCUBA diving techniques. All diving operations are subject to the procedures described in the Diving at Work Regulations 1997[6] (see: **http://www.hse.gov.uk/spd/spddivex.htm**) and must follow the Scientific and Archaeological Approved Code of Practice[7] (**http://www.hse.gov.uk/spd/spdacop.htm - a**).

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5 See Section 6: Procedural Guideline Number 6-1 for dGPS guidance.

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