



Marine Monitoring Handbook

March 2001

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Submerged or partly submerged sea caves

Definition

Caves situated under the sea or opened to it, at least at high tide, including partially submerged sea caves. Their bottoms and sides harbour communities of marine invertebrates and algae.

Introduction to the feature's interest

The UK has the most varied and extensive sea caves on the Atlantic coast of Europe, encompassing a range of structural and ecological variation. Well-developed cave systems, with extensive areas of vertical and overhanging rock, and those that extend deeply into the rock, generally support the widest range and highest diversity of plants and animals.

Cave communities vary considerably depending on the structure and extent of the cave system, their degree of submergence and of exposure to scour and surge, and the nature of their geology. Caves can vary in size, from only a few metres to more extensive systems, which may extend hundreds of metres into the rock. There may be tunnels or caverns with one or more entrances, where vertical and overhanging rock faces provide the principal marine habitat. Caves are typically colonised by encrusting animal species but may also support shade-tolerant algae near their entrances.

Physical conditions, such as inclination, wave surge, scour and shade, change rapidly from cave entrance to the inner parts of a cave and this often leads to a marked zonation in the communities present. Sites in which these zonation patterns are well developed have been favoured in selection.

A high proportion of caves is found in the intertidal or in shallow water. Caves on the shore and in the shallow sublittoral zone are frequently subject to conditions of strong wave surge and tend to have floors of coarse sediment, cobbles and boulders. These materials are often highly mobile and scour the cave walls. Caves that are subject to strong wave surge are characterised by communities of mussels *Mytilus edulis*, barnacles *Balanus crenatus*, cushion sponges, encrusting bryozoans and colonial sea-squirts, depending on the degree of water movement and scour at particular points in the cave system.

Caves that occur in deeper water are subject to less water movement from the surrounding sea, and silt may accumulate on the cave floor. The sponges *Dercitus bucklandi* and *Thymosia guernei*, the soft coral *Parerythropodium corallioides*, solitary sea-squirts, bryozoans and sessile larvae of jellyfish are characteristic of deeper cave systems. These caves, particularly where they are small, provide shelter for crabs, lobsters *Homarus gammarus*, crawfish *Palinurus elephas*, and fish, such as the leopard-spotted goby *Thorogobius ephippiatus*.

The type of rock in which the cave is formed has an important influence on its shape and qualities as substrata for plants and animals. In chalk caves in south-east England bands of microscopic algae occur, including Chrysophyceae and *Pilinia maritima*, which are highly specific to this habitat type. The UK holds a high proportion of the total area of coastal chalk, a comparatively rare habitat in Europe.

Typical attributes to define the feature's condition

Generic attributes

Table 3.7-1 lists the generic attributes for sea cave 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 improves of the factors that determine the condition of cave ecosystems.

Table 3.7-1 A summary of attributes that may define favourable condition of submerged or partly submerged sea caves

<i>Attribute</i>	<i>Measure</i>	<i>Comments</i>
<i>Extent</i>		
Extent of the feature	Number and location, measured once during reporting cycle	
<i>Physical structure</i>		
Internal dimensions of each cave within an SAC		
<i>Biotic composition</i>		
Diversity of sea cave biotopes	Number of all sea cave biotopes (or presence of specified biotopes)	This can be measured both within an individual cave where it is a representative example of that type within an SAC. It may also be evaluated throughout all sea caves in the SAC where there is a range of different types of cave in the site.
Species composition of characteristic biotopes	Presence and abundance of composite species of characteristic biotope.	The diversity and relative species-richness of representatives of cave biotopes should be assessed using a number of representative monitoring stations.
<i>Biological structure</i>		
Spatial pattern of characteristic biotopes	Identity and distribution of biotopes within a cave	The spatial arrangement of biotopes within a cave is normally a reflection of the prevailing physical condition, and thus any change may indicate other physical changes within the SAC. This should be measured both within an individual cave, and throughout all sea caves in the SAC.

Suggested techniques for monitoring attributes of sea caves

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 3.7-2). 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 3.7-2 Suggested techniques for measuring the attributes of sea caves. 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.

<i>Generic attribute</i>	<i>Feature attribute</i>	<i>Technique</i>
Extent	Intertidal	Intertidal resource mapping; <i>GIS mapping</i>
	Subtidal	Surveying sea caves; <i>GIS mapping</i>
	Biotope extent	Intertidal resource mapping; Intertidal biotope ID; Subtidal biotope ID
Physical properties	Physical dimensions	Surveying sea caves; <i>Land surveying techniques</i> ; <i>Cave exploration techniques</i>

<i>Generic attribute</i>	<i>Feature attribute</i>	<i>Technique</i>
Biotic composition	Intertidal biotope richness	Intertidal biotope ID; Intertidal ACE
	Subtidal biotope richness	Subtidal biotope ID; Diver-operated video
	Intertidal species composition/richness	Intertidal ACE; Intertidal quadrat photography; Intertidal quadrat sampling (see Subtidal quadrat sampling)
	Subtidal species composition/richness	Subtidal quadrat sampling; Subtidal biotope ID; Subtidal photography; Suction sampling; Diver-operated video
	Intertidal characteristic species	Intertidal ACE; Intertidal quadrat photography; Intertidal quadrat sampling (see Subtidal quadrat sampling)
	Subtidal characteristic species	Subtidal quadrat sampling; Subtidal biotope ID; Subtidal photography; Suction sampling (small epibiota); Diver-operated video
Biological structure	Spatial pattern of biotopes within a sea cave	Surveying sea caves; Intertidal biotope ID; Intertidal ACE; Surveying sea caves plus Subtidal biotope ID; Diver-operated video; <i>Transect surveys</i>
	Spatial pattern sea cave biotopes within a SAC	Intertidal resource mapping; Subtidal biotope ID with <i>GIS mapping</i>

Specific issues affecting the monitoring of caves

Each attribute will have its own inherent source of variability that must be addressed during data collection and subsequent interpretation of the results. Many cave attributes will be similar to *reefs* and the guidance described above should also be consulted in relation to cave monitoring. However, some generic issues 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 cave communities. Some of the more obvious visual changes occur in algal assemblages (at the entrance), and following settlements of juvenile animals such as ascidians, mussels and barnacles. Boulders present at the entrance are often seasonally stable allowing ephemeral algal communities to develop. The degree to which seasonal change will influence the monitoring of a cave 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 affects 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.

Meteorological changes

Prevailing weather conditions and tidal state will affect any monitoring study. Sites open to the prevailing wind and swell will require particularly calm conditions for effective field survey. Where a cave is adjacent to sediment habitats, excessive water movement 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, underwater visibility will improve and therefore assist sampling efficiency and reliability. Sublittoral caves located in areas with a large tidal range should be sampled during neap tides, at or near high or low water to reduce water movement. If possible, sampling exercises should avoid the equinoctial tides when the duration of low and slack water will be at their shortest.

Ambient light levels within a cave will have a significant influence on the sampling exercise. If possible given the many other constraints, sampling should be timed to maximise light levels (for instance, in bright sunny conditions at midday).

Access

Caves through their very structure pose a number of serious problems to a monitoring study. Issues pertaining to gaining access to a cave may be considered on two levels: gaining access to the site (cave entrance) and entering the cave itself.

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 (for locating caves, see below). It will be necessary to use a boat to gain access to some caves and therefore it will be necessary to consider the availability of harbours and/or launching facilities.

The relative ease of gaining access to a cave itself will depend on its physical size and structure. There are considerable health and safety issues to be considered prior to entry. Cave exploration may require staff with appropriate training and/or specialist equipment such as ladders, lighting helmets, guide ropes on reels. For caves in the intertidal zone, careful consideration must be given to the tidal cycle to ensure that staff can complete the monitoring exercise and exit before the tide rises.

Sampling issues

A monitoring programme must collect sufficient information to assess the condition of the whole feature. The complexity of such monitoring will depend on the physical dimensions of a cave and its location (in terms of time available for sampling), and the number and variety of caverns in the system. Basic techniques for surveying the physical structure were investigated for intertidal and subtidal caves in the Berwickshire & North Northumberland Coast cSAC during the *UK Marine SACs project*.^a These techniques were simple and straightforward and could be undertaken without specialist training in cave surveying, although they relied on an estimate of the internal height rather than an accurate measurement. This work recommended that:

- The level of accuracy required should be specified prior to the survey.
- The accuracy and precision of the measuring tools (e.g. compass, depth gauge) should be established at the start, and linked to the required accuracy of the survey.
- It may be necessary to measure local magnetic variation at the cave.
- Difficulties may arise when a highly accurate survey is specified, but the practical application dictates that it is only possible to estimate some distances (such as cave height). It may be necessary to incorporate two levels of accuracy in a controlled manner by specifying estimated distances and measured distances.
- Cave morphology will dictate whether there is a 'ceiling' to the cave - tall thin caves have little ceiling area. It must be made clear to recorders from the outset as to whether a separate record is required for the ceiling.
- Trigonometric methods (as opposed to using a ruler and protractor) should be used for plotting cave plans.
- Inherent differences in the way field recorders interpret the distribution of cave biotopes may be minimised by providing a survey team with previous biological records and maps from the same site.

Specialist guidance is available on cave survey techniques both on the Internet¹ and from cave exploration associations.^b There are also many sources of bespoke software for analysing and visualising the results of cave mapping surveys.²

Monitoring the biotic composition of caves is similar to monitoring reefs. There are often marked spatial patterns in cave biotopes, particularly algal dominated biotopes whose presence declines in relation to the availability of light. Transect sampling techniques are most appropriate for monitoring biotope distribution throughout a cave. Zonation patterns must be considered when planning a sampling strategy within an individual biotope to ensure that sample stations (individual quadrats) are not located in

1 For example, see: <http://rubens.its.unimelb.edu.au/~pgm/asf/stds.html>

2 For example: <http://www.survex.com/> or <http://members.aol.com/caverdave/CPHome.html>

the transition zone between biotopes. Scale drawings of cave walls and floors are useful aids for location when undertaking biological sampling. Where full diagrams are not available, for instance if they were being compiled at the same time as the biological recording, the recorders should be aware (or agree) the 'nodal' points of the cave for accurate spatial correlation (Figure 3-4). Video recording with a voice-over commentary is an extremely useful aid to cave monitoring because it provides a permanent record to support both physical and biological monitoring. Recording should be undertaken by the monitoring staff to ensure the images and sound match the attributes under investigation. Nevertheless, there are severe problems with lighting when recording video in caves, and there is a risk that a video recording could turn into a time-consuming 'production'. It is possible to use an ROV to record video in some subtidal caves, although there are severe operational problems and in practice it should only be considered for caves beyond normal safe diving depths. Furthermore, the video resolution may be insufficient to confidently identify many species.

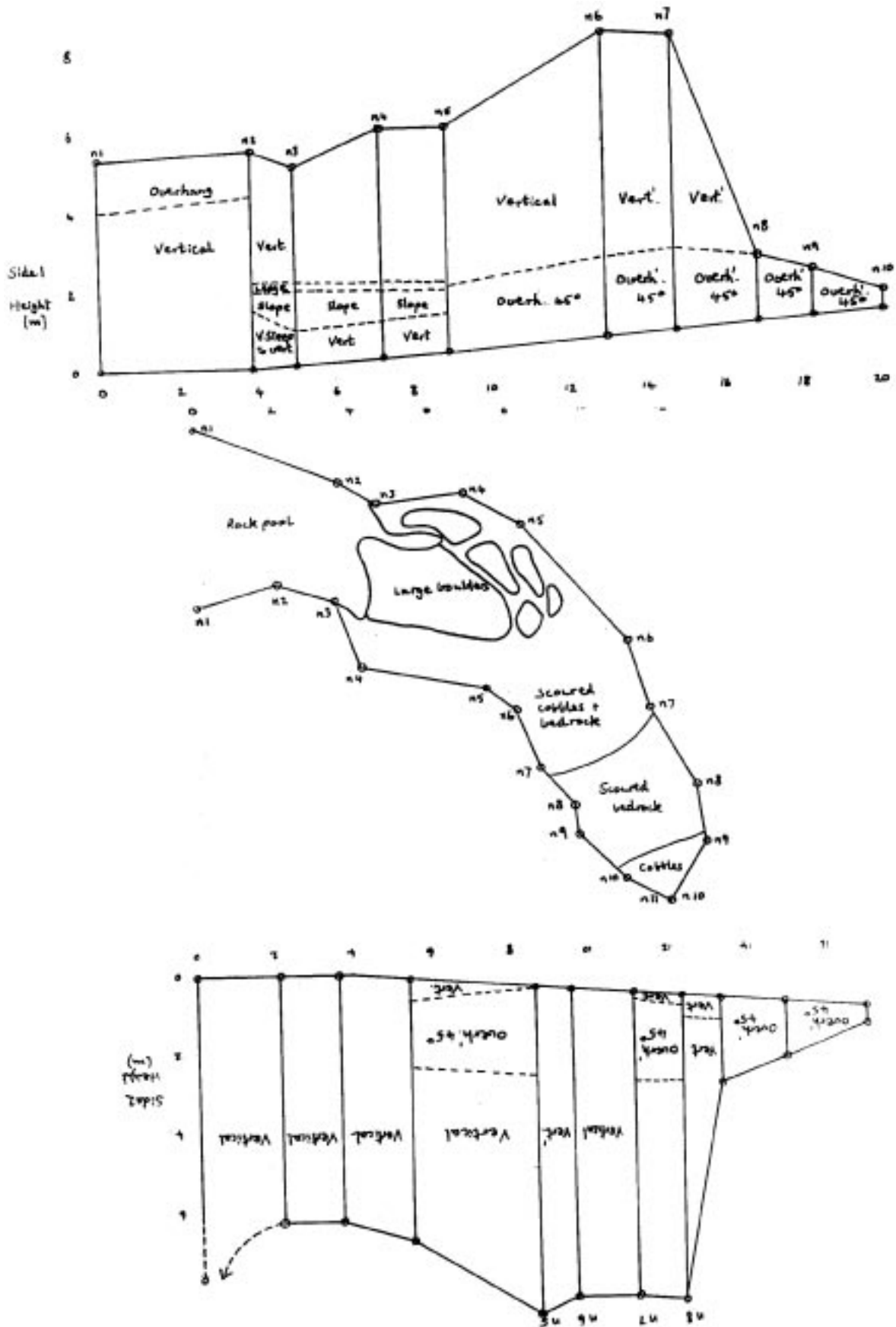


Figure 3-4 An example of a cave diagram showing the 'nodal' points of the system.^a

A recent trial encountered many difficulties in identifying cave biotopes in the field that resulted in considerable inconsistencies between field teams studying the same cave.^a Interestingly, the patterns of zonation and species compositions were similar between field teams, but diverged when assigning biotopes to the data. Two issues were identified: non-familiarity with cave-dwelling taxa, and the scale of biological changes over small distances. Clearly, the former should be addressed when selecting and training field staff. The scale issue could be addressed by directly mapping those species responsible for the observed patterns and hence not assign biotopes. Alternatively, unambiguous biotope descriptions should be derived from the baseline survey (see Section 5), possibly for individual caves, and/or the smallest biotope 'patch' size must be defined at the outset. Photographs or video recordings of the defining features and species would create an important permanent record to support future monitoring interpretations.

Site marking and relocation

Most issues relate to the location (intertidal or subtidal) and physical dimensions of a cave. For intertidal caves, there are fewer problems in relocating the entrance (except if very small), although it should be noted that dGPS may not provide an accurate fix near high cliffs. Accurate drawings of local landscape features provide an invaluable aid to relocation (Figure 3-5).

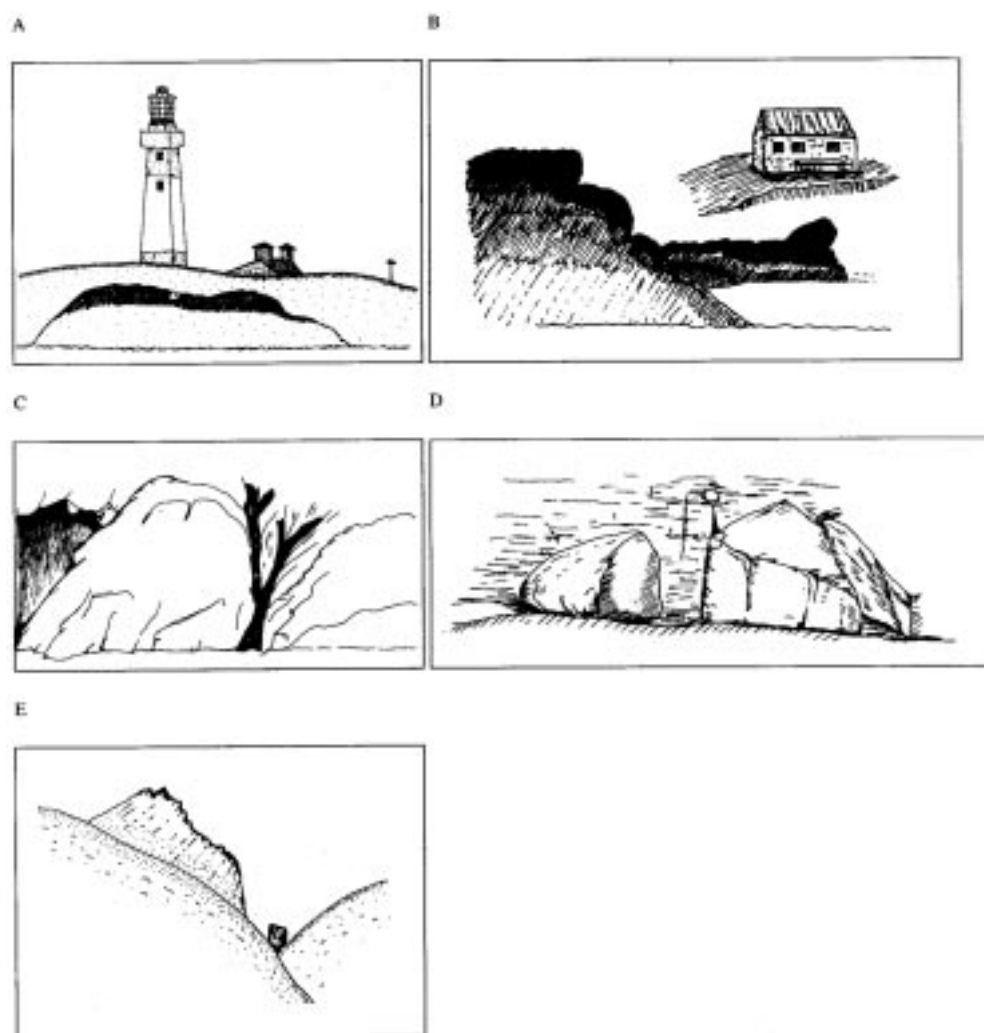


Figure 3-5 A example of the use of transits to relocate sampling stations.^{c,3} Transits are straight sight-lines between land-based features (for example in B where the prominent rock aligns with the middle of the house) which intersect over the position of the sampling station. The best accuracy is attained by having the intersecting lines close to 90° apart.

For subtidal caves, relocation may be difficult particularly in poor visibility and/or where the entrance is small. Box 3.7-1 lists a series of options for relocating a subtidal cave, in descending order of the probability success.

³ See Procedural Guideline 6-2 on site marking

Box 3.7-1 Options for relocating a subtidal cave

Installation of a permanent marker buoy (surface or subsurface)
 Installation of a permanent subsurface beacon/transponder unit^d
 Engaging a local dive guide to assist in site marking at the start of the project (e.g. an SAC warden)
 Engaging the use of non-divers with good local knowledge (e.g. boat skippers)
 Annotated site drawings or photographs (ideally at low and high water)
 Transits or bearings
 Detailed maps with locations marked
 Differential GPS co-ordinates⁴ (with datum)
 GPS (with datum)

The installation of permanent markers may require prior consent or permission and there will be an ongoing requirement for their maintenance.

Relocation of sampling stations and mapping 'nodes' requires careful consideration. Fixing pitons or bolts into the rock may damage the rock, particularly soft friable rock, and create a hazard to other visitors to the cave. Paint or fluorescent markers would avoid physical damage to the rock but may attract unwanted attention from the public and reduce the scenic value of the site. The final choice of station marking will depend on the local situation but should always consider the risk of failing to find the cave or station in future monitoring studies.

Health and safety

There are many health and safety implications for cave monitoring studies, although the degree of risk will depend on the location and dimensions of each cave. All field staff must follow approved safety procedures published by their host institution, or that of the contracting agency, whichever are the more stringent. Guidance on cave safety is published by cave exploration societies and available on the Internet (for example: <http://www.sat.dundee.ac.uk/~arb/speleo.html> or http://wasg.iinet.net.au/asf_safe.html). Field staff must be briefed on the risks associated with cave survey prior to undertaking any monitoring studies. Examples of these risks are:

- The energy from a wave entering a cave becomes more 'focused', creating a powerful surge. Waves that appear relatively innocuous at the entrance can become rather dangerous at the head of a cave.
- Long caves, particularly complex systems with many caverns, will be dark and there is a risk of disorientation and loss of bearings.
- The incoming tide may trap surveyors in intertidal caves.
- Seals often haul out at the head of caves: surveyors may inadvertently prevent a seal leaving a cave and thereby risk being attacked. This situation could be exacerbated during the breeding season when a surveyor may separate young seal pups from their mothers, or come between a bull seal and its female mate.

Subtidal sampling in caves will involve SCUBA diving techniques. All diving operations are subject to the procedures described in the Diving at Work Regulations 1997⁵ (see: <http://www.hse.gov.uk/spd/spddivex.htm>) and must follow the Scientific and Archaeological Approved Code of Practice⁶ (<http://www.hse.gov.uk/spd/spdacop.htm> - a). Divers may require specific training in cave-diving procedures to ensure their safety when surveying caves.

4 See Procedural Guideline 6-1 on dGPS guidance.

5 The Diving at Work Regulations 1997 SI 1997/2776. The Stationery Office 1997, ISBN 0 11 065170 7.

6 Scientific and Archaeological diving projects: The Diving at Work Regulations 1997. Approved Code of Practice and Guidance – L107. HSE Books 1998, ISBN 0 7176 1498 0.

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