JOINT NATURE CONSERVATION COMMITTEE

Marine Monitoring Handbook
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UK Marine SACs Project

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Procedural Guideline No. 6-2 Relocation of intertidal and subtidal sites

Rohan Holt and Bill Sanderson, Countryside Council for Wales[1]

Background

Relocating sites on the shore or seabed can be very difficult given the nature of the marine environment in temperate waters. Underwater visibility is often restricted to a few metres and weather, sea state and other sea users can make marking a site with permanent marker buoys impractical in the long term. Hiscock (1996) outlines a selection of well-tried methods available for accurately marking and relocating sites on the shore and underwater: variations of these and others utilising recently developed technologies are described below

Purpose

This guideline deals with the following issues:

- marking and relocating shore and nearshore sites adjacent to surface features (mainland, islands and off-lying rocks)
- marking and relocating offshore sites
- documentation of monitoring sites

Applicable to the following objectives

Accurate position fixing is a fundamental choice in the design of the monitoring strategy for a given attribute. Position fixing has been used in the monitoring of population and community composition attributes as well as the integrity/structure of populations. It is also conceivable that site marking could be used directly or indirectly (as a georeference point) in the measurement of extent.

Also applicable to the following baseline survey objectives:

- subtidal rock and sediment biology requiring sampling/repeat sampling at exact locations by a variety of different methods
- establishing fixed-point monitoring stations
- locating and relocating structures/communities/species of conservation importance.

Advantages of marking sites

- Greater precision in detecting changes by being able to return to the same location.
- Ability to examine localised structures, communities or even individuals of one species.
- Accurate position fixing reduces valuable field work/dive time looking for a site.
- Possible health and safety implications – accurate information about a site allows for pre-dive planning and the whereabouts of divers on the seabed are also known.
- Time-series data are secure when anyone can use the information to return to the site (i.e. not reliant on individuals).

1 Plas Penrhos, Ffordd Penrhos, Bangor, Gwynedd, Wales, LL57 2LQ.

- Permanent site markers such as the 'pyramid' design can be used as a fixing point for other scientific equipment as necessary, such as temperature, current, light and salinity meters.

Disadvantages of marking sites

- Maintenance commitments and costs involved in the deployment and upkeep of a fixed site.
- Frequent visits to a fixed site can result in localised disturbance (e.g. trampling, silt disturbance, diver's bubbles, mechanical damage to delicate species, behavioural changes in some species of fish).
- Markers may attract unwanted attention from other sea/shore users.

Logistics

Diving operations

*All diving operations will be carried out using conventional **scuba equipment** following the procedures in the current agency diving regulations (Holt 1998).*

Equipment

Marking shore and near-shore sites

Recording facilities

Establishing accurate positions on or close to the shore can make best use of a 'low-tech' approach and still provide accurate position information down to less than one metre. The alignment of natural features ('transit marks' – see Figure 1, Figure 3, and Figure 4) will need to be recorded as sketches (*waterproof paper/slate*) supplemented with *photographs* taken with a standard or short telephoto lens (e.g. 35 to 70mm focal length zoom on a 35mm SLR camera would probably suit most situations).

Artificial markers can be used on the shore or underwater bearing in mind that human disturbance and natural weathering processes can result in their loss and therefore necessitate site maintenance.

Support vessel

A *support boat* is required for most diving operations and should be equipped with an *echo-sounder* that will allow a seabed profile to be viewed and accurate depths recorded. Current time and date should be recorded to allow for recalculation of depth relative to chart datum using an appropriate tidal correction.

Pitons and bolts

Easily recognisable natural features on the shore or the seabed can be supplemented with *pitons* (Figure 2) hammered into cracks using a 2kg lump hammer. Rock type (i.e. its friability, the availability of cracks for bolts and pitons and its softness, if drilling bolt holes) and exposure to wave action and weather (with respect to corrosion) must be taken into account. Regular replacement or maintenance should be considered perhaps every 2–3 years.

Stainless steel eye-bolts (Figure 2) fixed with rawplugs or *epoxy resin* into the rock also make suitable attachment points for marker tapes and lines. A battery- or petrol-driven portable drill (with 'hammer action') can be used on the shore to bore suitable bolt-fixing holes or making *marker holes*. Only a few tools such as a *compressed air drill* or *bolt gun* can be used underwater. A small air drill with a masonry bit, driven by compressed air from a large diving cylinder via a standard first stage of a diving regulator, will bore holes in *soft* rock. Allow approximately one 12L cylinder for 2–3 holes drilled at 10–20m water depth (Sanderson *et al.* 2000). However, very few air-powered tools available to the scientific diver will make much of an impression on hard limestone and granite and only result in the diver and the drill consuming large quantities of compressed air. Bolt guns work on the principle of driving a steel pin into the rock using a small explosive charge from a 'blank' starter pistol cartridge (M. Bates, Port Erin Marine Laboratory, pers. comm.). Again, such devices are best used on relatively soft rock and require careful use with regard to health and safety.

Small bolts and pitons can be quickly overgrown by turf-forming plants and animals. Finding them by eye can be difficult, even if the location down to the last square metre is known. *Fluorescent tape* (Figure 5) or coloured cable-ties attached to the head of a piton will clearly highlight its position although the tape itself can become detached or have a scouring effect on the flora and fauna at turbulent sites. *Submersible metal detectors* that emit an audible tone when passed over a metal object can help relocate a lost piton or bolt, although this could be very time-consuming if a large area has to be searched. Alternatively, documentation of distances from nearby highly conspicuous natural or man-made features can assist in finding bolts and pitons with a measuring tape (Figure 6).

Resins and glues

Resins and glues that set underwater (e.g. quick-setting epoxy resin) are a less labour-intensive method of fixing markers into crevices (although additional drilling may be required). On very hard flat surfaces, where drilling might be impracticable, small markers, for example to indicate where a repeat quadrat sample should be positioned, can be stuck directly to the rock surface. The rock surface must be thoroughly cleaned of any encrusting algal or animal films using an abrasive wire brush or similar to ensure a firm bond is achieved.

Figure 1 Drawings of marks and transit features. On the left, when the paint marks (P1 & P2) on a foreground boulder and background cliff face are correctly aligned will indicate the correct location in terms of position and distance offshore. On the right, the transit features are correctly aligned when the tooth-shaped rock appears in the 'V' of the hillside.

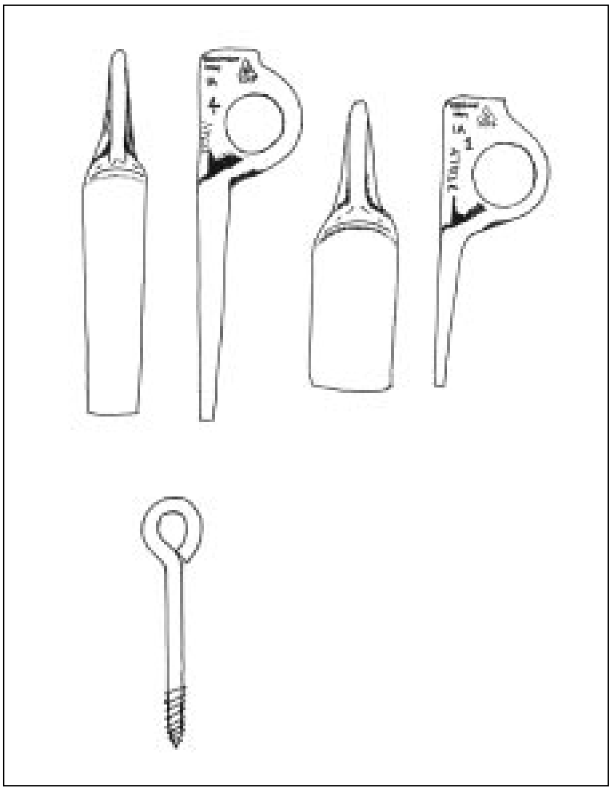

Figure 2 Examples of typical pitons and an eye bolt used to mark positions on rocky monitoring stations

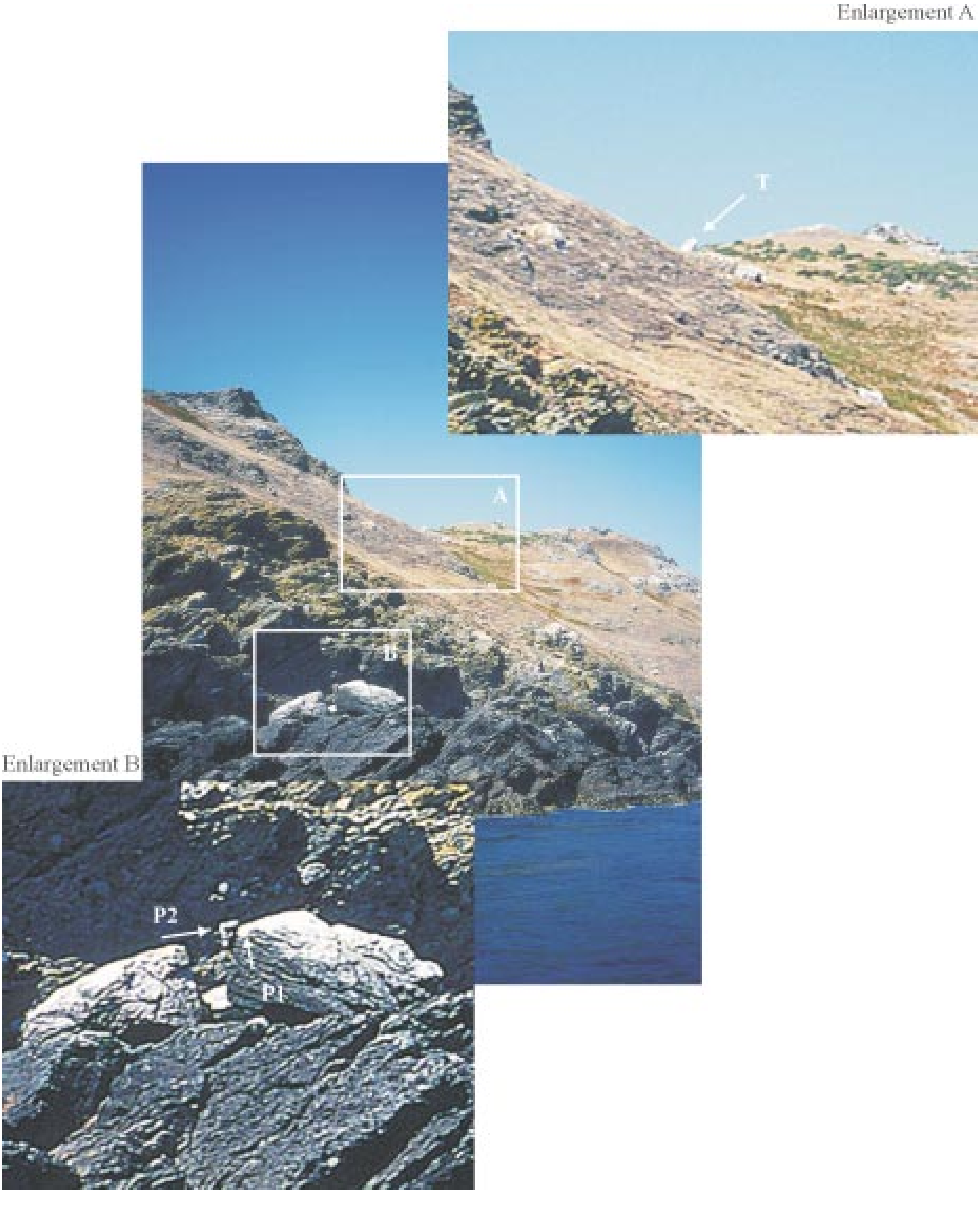

Figure 3 Photographs of the marks at Pen Cristin on the east side of Bardsey Island. Enlargement A shows the detail of the tooth-shaped rock (T). Enlargement B shows the detail of the paint mark on the boulder (P1) in alignment with the inverted 'L' shaped mark (P2) on the short cliff face.

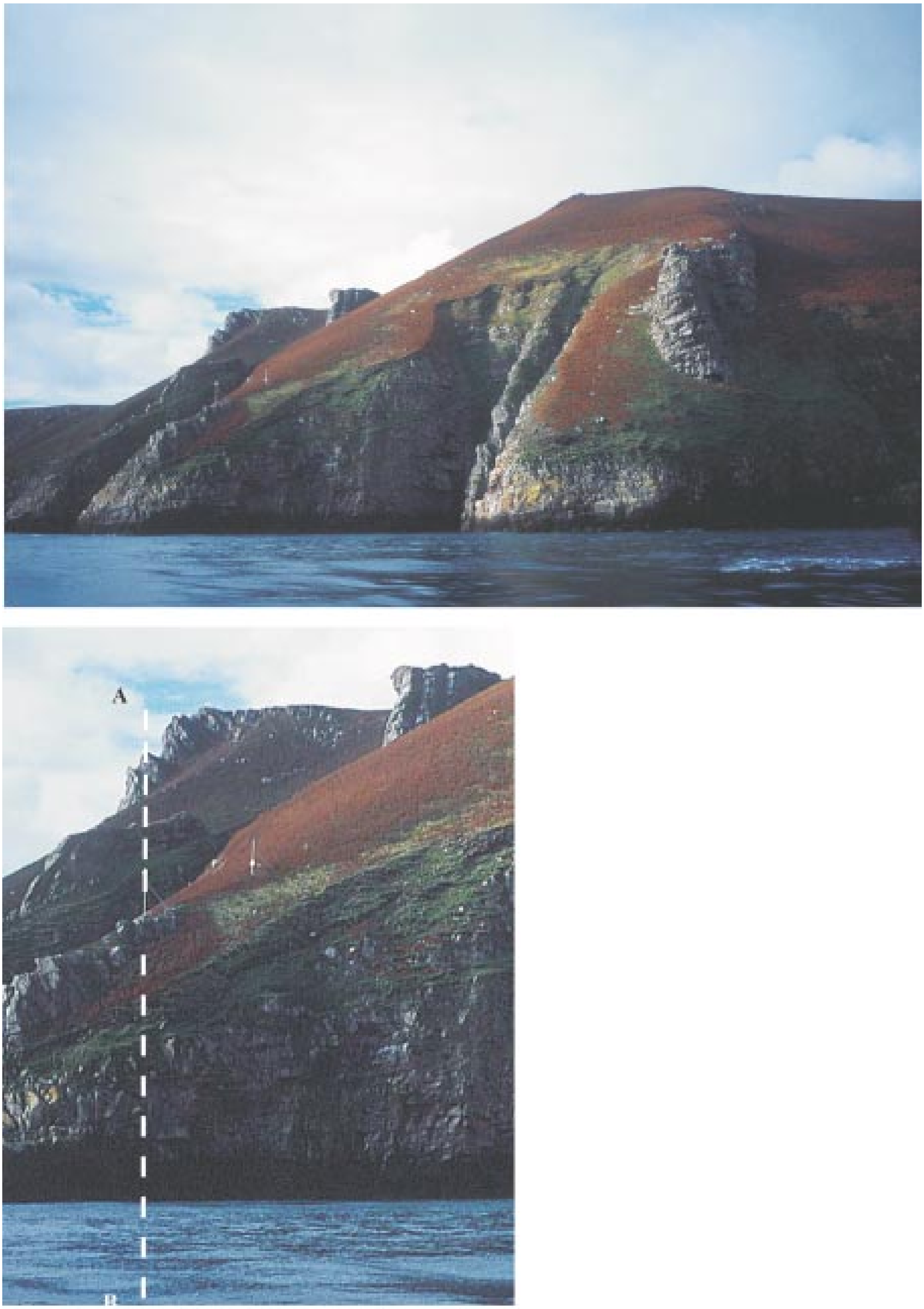

Figure 4 General view and enlarged view of features used as part of the transit marks on east Lundy at the Knoll Pins monitoring site. Line A–B shows the alignment of the cable marker with one of the peaks in the background (Photographs by W. Sanderson).

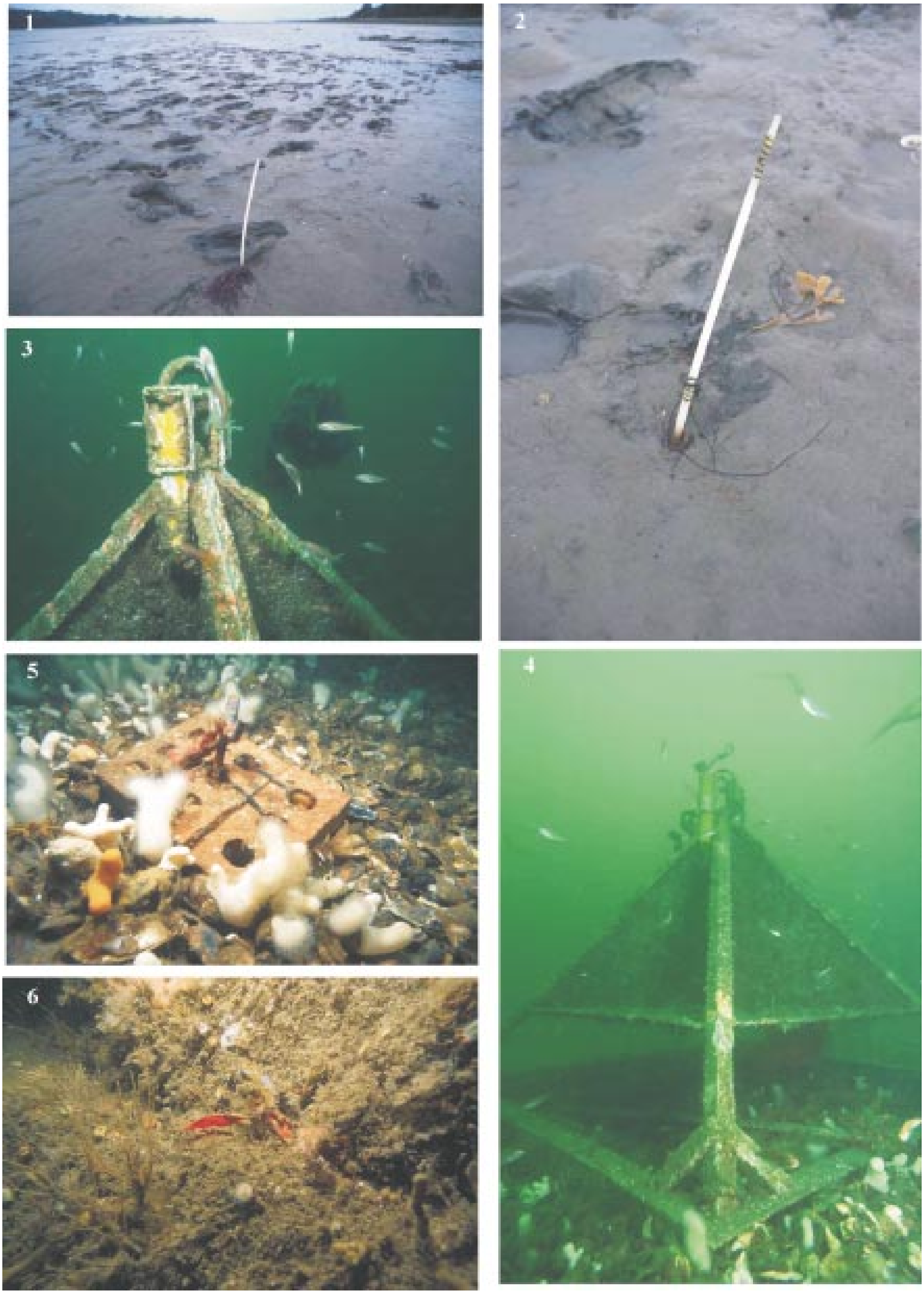

Figure 5 Images 1 and 2 show plastic whips attached to sub-sediment surface blocks or stakes to mark the perimeter of an experimental plot. Images 3 and 4 show an acoustic transponder beacon placed on the apex of a pyramid marker on a *Modiolus modiolus* bed used to guide a diver to the marker even in poor visibility. Image 5 shows a bundle of bricks tied with cable ties fastened securely to the seabed with a 'road pin' that allows for the attachment of guidelines. Image 6 shows a piton hammered into a crack in a rock face almost obscured by epibiotic turf except for its fluorescent tape to show its whereabouts. (Photographs by Rohan Holt)

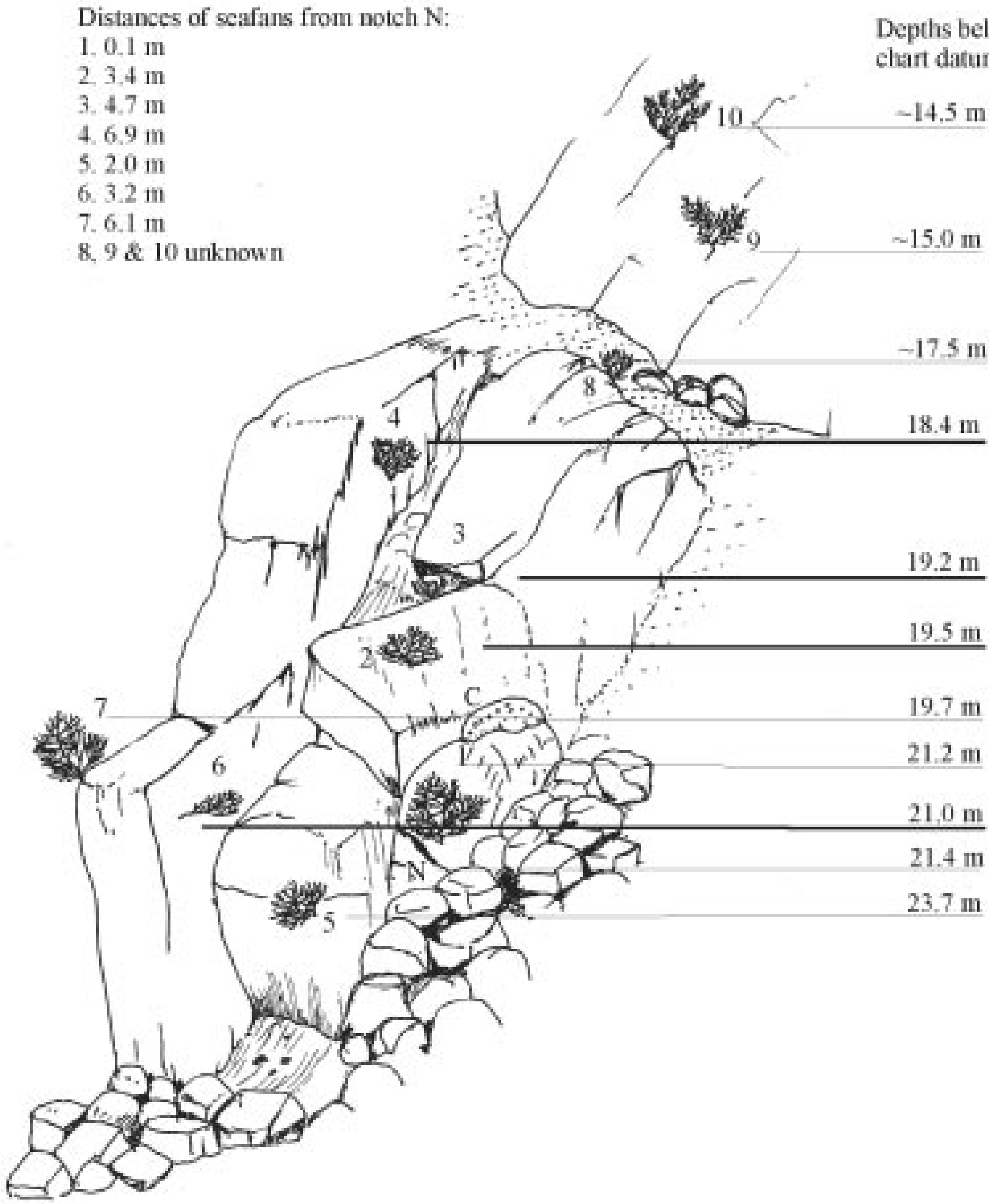

Figure 6 A diagrammatic representation of the main features at the *Eunicella verrucosa* monitoring site at North Wall, Skomer showing the layout of the seafans in relation to a distinctive notch (N), and a conspicuous colony of the sponge *Cliona celata* (C). (Drawing by Rohan Holt adapted from drawings by K. Lock, Skomer Marine Nature Reserve)

Marker posts and stakes

Sediment shore and seabed sites can be marked with a combination of *stakes*, *pegs* and '*cairns*' of boulders or bricks (Figure 5). Steel '*road pins*' can be driven into the sediment with a lump hammer and '*cork-screws*' (made from steel reinforcing rods wound round a post to make helix-shaped markers about 50cm long with an eye bent into the top section) can be screwed into sandy/muddy sediments. With such systems of marking, consideration needs to be given to the rate of corrosion of the markers or whether the habitat is sufficiently mobile to cover over the marker. In some circumstances it might be desirable to avoid having large conspicuous posts or rods protruding from the sediment surface, particularly in unstable or soft sediments where such markers are vulnerable to being pushed over or where they might attract unwanted attention. A 'whip' of *thick nylon line* or flexible plastic rod attached to an anchor point, such as a wooden stake or concrete block buried below the surface of the sediment, will adequately mark a position on, for example a sandy or muddy shore (Figure 5).

Paint marks

Rocky substrata on the shore can be marked with oil-based paint to aid location of spot-positions or transit lines (Figure 3). Fresh coats of paint will be required periodically – perhaps each year in areas where weathering has a significant effect.

Guide ropes and lines

Ropes and lines laid down on the seabed to aid diver navigation are particularly useful in the short term (e.g. during a few days of work at a site) but are prone to being snagged by fishing gear or anchors and can attract unwanted growths of fouling organisms that could influence the natural state of the site. Ropes and lines should therefore be treated as a temporary fixture which if damaged or lost will not result in losing the site. It is therefore best to consider retrieving any lines at the end of a task unless other users only rarely visit the site.

Distance measurements

A tape measure can be used to accurately record distances between features on the shore or seabed and can also serve as a guide line. Very accurate distance and approximate direction can therefore be recorded if the tape is used in conjunction with a *diver's compass*. Ideally measurements should be taken from an easily identifiable reference point such as a piton or an obvious and robust natural feature such as a crevice or well-defined bedrock outcrop. This method is perhaps the best way to record the whereabouts of and relocate small features such as bolt/piton markers or individual organisms/colonies on the seabed or on the shore. An example of using tape measurements to illustrate the layout of *Eunicella verrucosa* seafans at a monitoring station at the North Wall on Skomer is shown in Figure 6 (K. Lock, Skomer MNR, pers. comm.). Waterproof diagrams of the layout of a site such as this are essential for rapid relocation of individual colonies.

Marking and relocating offshore sites

Marking and relocating offshore sites uses many of the principles applied to inshore sites described above. The differences usually concern the increased scale of the operation due to the remoteness of the location offshore, sometimes greater depth of water and generally more exposed situations. The choice of location for an offshore site and where to place a marker depends on finding out as much as possible about the area beforehand. In water of 30–40m depth deployment of remote survey techniques (see Procedural Guideline Nos PG 1-3 for Acoustic Ground Discrimination System (AGDS), PG 1-4 sidescan sonar and PG 3-5 remote video techniques) is advisable before any expensive and time-consuming diving operations take place.

GPS or dGPS

Transit marks can be used as a rough guide to bring a vessel into an approximate area, although poor surface visibility can negate their usefulness. Global Positioning System (GPS), combined with a differential signal receiver (dGPS) can provide sub-metre accuracy (see dGPS Procedural Guideline 6-1).

Seabed positioning using dGPS

GPS radio-wave signals do not pass through water and therefore GPS/dGPS units cannot be modified for underwater use. Acoustic signals do, however, pass through water very well. By converting GPS radio signals into ultrasound frequency acoustic signals and vice-versa, divers deployed from a boat carrying the appropriate acoustic positioning system (APS) can be tracked on the seabed. Three transducers housed in one unit on the side of the support boat and one located immediately under the boat's dGPS antenna interrogate an acoustic beacon attached to the diver. The position of the diver is indicated on a screen in front of the diving supervisor who can mark on the same screen the exact co-ordinates of specific locations on the site. It is then straightforward to guide the diver to a precise feature on the seabed, even in poor visibility. The beacon can also be used to track the true position of towed fish during remote sensing operations and removes the need for layback calculations during post-processing of the data. Such systems can be accurate to as little as 10mm over a range of 100m. The drawback of such systems is that they are relatively expensive (£4K+), although valuable in-water time can be saved by not having to use multiple tape measurements over long distances.

Seabed markers: general considerations

Structures placed on the seabed can be used to mark the precise position of an area of interest or act as a reference point on areas of seabed with few distinguishing features nearby. This avoids expensive and time-consuming searches by divers looking for a particular feature. Factors to consider when placing a marker on a site are:

- How and where is it to be deployed? Very large objects (100kg or more) to be deployed several kilometres out to sea will require a substantial (15m+?) vessel with heavy lifting gear. What is the maximum physical size and weight of an object that can be lifted by the deck-mounted crane?
- Alternatively, can the object be constructed on the seabed?
- Is it large enough and/or conspicuous enough to be found by divers operating in poor visibility? If not, can acoustic beacons be used to aid relocation on the seabed?
- Can it be detected remotely by AGDS/sonar/echo-sounder?
- Will it move/be damaged by the worst sea conditions expected at the site? Will it require attaching to the seabed or will it stay in position if free-standing?
- If fishing gear, or similar, is deployed regularly in the area will this disturb/displace the object?
- Will its presence alter/affect the natural situation (physical and/or chemical) in such a way as to disturb the habitats and communities under investigation? How far away from the area of study will the marker have to be?
- Does the object require any form of regular maintenance?
- Is permission required (e.g. from the Crown Estate) before the marker is placed on site?
- Do other sea users need to be made aware of the presence of a marker/experimental site (e.g. through the Sea Fisheries Committees or the Hydrographic Office)?

Seabed marker construction

Different working groups have constructed various designs of seabed marker in the past. They have been constructed from objects as simple as scrap engine blocks, rail carriage wheels and bundles of bricks to more elaborate structures built for a specific purpose. Many use concrete poured into old tyres (from car-sized to large tractor tyres) with a steel loop embedded into the concrete to attach ropes and lines; but note that greater volumes of concrete are required to achieve the same mass as a steel structure.

Examples of seabed markers are shown in Figure 5 (images 3, 4 and 5). The Countryside Council for Wales and the School of Ocean Science, Menai Bridge (University of Wales, Bangor) used the 'pyramid' design to mark sampling stations on Sarn Badrig Reef and a *Modiolus modiolus* reef off Pen Llyn, North Wales. These heavy steel 'stations' were constructed specifically for the attachment of the two types of *acoustic relocation devices* and were also designed to investigate whether they could provide an acoustic target for sidescan sonar.

The structures were built with a 2 x 2m square base of 15 x 8cm channel bar steel upon which a pyramid-shaped, angled steel construction stood 1.75m tall. The whole structure was weighted with an old 6-inch anchor chain bolted between mountings on the square base making the overall structure weigh approximately 500kg in air. The weighting was considered necessary to prevent the object moving with tide or wave action. The stations also had mounts for two types of acoustic beacon and a surrounding 'cage' for protection. The whole structure was pyramidal in design to enable fishing gear to pass over without snagging. The nature of the base was expected to enable the structure to 'bed-in' to the partially mobile sediment.

The stations were painted using high visibility colours to assist with initial diver relocation and each side of the structure painted with a letter to facilitate orientation when in use (although the paint was soon obscured by marine life). A sacrificial zinc anode was fitted to each station in order to retard corrosion in seawater and rope loops were secured to each corner from which distance lines could later be deployed.

Acoustic position markers

Acoustic beacons (7815 Miniature Marker Transponders – Sonardyne International Ltd) were attached to the top of each of the 'pyramids' described above, although such devices could easily be attached to other structures or even pitons/bolts directly hammered into rock. Divers using the hand-held Homer-Pro *diver relocation unit* (Sonardyne International Ltd) were guided to the target beacons that emitted sound pulses in the HF frequency band from 35–55 kHz.

Once activated the Sonardyne acoustic beacons were designed to be permanently 'on' and listen for encoded 'interrogation' signals from the diver's unit. In this mode the battery life span of the beacons was estimated to be 2 years (Sonardyne technicians, pers. comm. 1998), although lithium battery packs with double this life span are now available at a greater cost (£180 as against £17). The diver unit was designed to send out an encoded interrogation signal to the specific transponder (each has its own 'address' signal) to which the beacon was designed to reply automatically. The diver unit would then calculate the distance and direction from the beacon and display this information to the diver. The manufacturers recommended that the beacons were positioned in a vertical orientation one metre off the seabed in order to improve performance by facilitating a straight-line acoustic path between the beacon and the diver. In trials the acoustic beacons were detected from the surface at over 100m away.

Using similar acoustic technology it is also possible to set up an 'acoustic net' by positioning a network of transponders on the seabed. A receiver unit carried by a diver or submersible decodes the signals from three or more transponders simultaneously several times per second to obtain a precise position on the seabed. Such systems were developed in the offshore oil and gas industry and for marine archaeologists[2] but could be applied to seabed monitoring work where spatial orientation between features is important.

Maintenance implications

The 2 kg zinc sacrificial anodes lasted only 18 months on the seabed and therefore require periodic replacement.

The transponders require periodic battery replacement. In order to avoid a situation where the marker station is left on the seabed without a transponder, and to avoid having to do more than one dive to retrieve and replace a transponder, it is important to have a fully charged spare.

Personnel

Inshore/near-shore sites

Placing marks on the shore requires only one or two people. One person can position markers on a site, although a second might be required to check the correct alignment of relevant features or help record measurements and compass bearings.

Accurate recording of subtidal site positions is normally accomplished as part of a diving or remote sampling survey. Teams of four people are usually required for diving surveys, although one person can accomplish the tasks of positioning the survey vessel over the site while another makes observations. Divers working on the seabed might have to guide the boat crew to a precise location through the use of surface marker buoys and/or underwater communication systems. Teams of four, the standard size of a diving team recommended by the Health and Safety Executive (HSE) for diving work, can co-ordinate this task.

The diver's qualifications can be an issue in this matter. Diving under the Scientific and Archaeological Approved Code of Practice (ACOP) allows for use of light tools, but heavier engineering tasks such as fixing large, heavy frameworks to the seabed might have to be carried out by divers trained to work under the Inshore Commercial Approved Code of Practice. The ACOP for commercial divers includes the requirements of suitable qualifications in the use of lifting gear and heavy engineering tasks which are not normally part of a scientific diver's training.

Offshore sites

There are a number of tasks that require specialist skills:

- Constructing the markers – the 'pyramids' described above were constructed by engineering technicians. Alternative designs, such as concrete-weighted tyres, require less technical ability to construct but are nonetheless heavy.
- A suitable vessel and crew are required for the deployment of heavy objects offshore (the survey vessel *Prince Madog*, used to deploy the pyramid markers in Wales, is 28m OAL and 182 GRT. The A-frame has a 4 tonne SWL.
- 'Heavy engineering' on the seabed requires divers working under the HSE Inshore Code of Practice. This can be avoided by deploying a completed structure from a boat.
- The diving team should comprise at least four personnel. Working at depths of 30–50m requires highly experienced divers used to carrying out tasks in deep water.

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2 The Archaeological Diving Unit internet site - **http://www.st-andrews.ac.uk/institutes/sims/Adu/adu.htm** provides information on acoustic and manual methods of surveying seabed features, including links to acoustic survey techniques.

Best time of year

Shore and near-shore sites

Calm weather is required for diving and is an important health and safety issue for personnel working on steep rocky shores and from boats. Summer weather tends to be more reliable, although there may be occasions where disturbance is best kept to a minimum by deploying markers during the winter. If bolts and pitons must be put in position during the winter months, it is important to consider whether dense algae or faunal turfs will obscure them during the summer.

Offshore sites

Calm weather is required for diving and is an important health and safety issue for boat crews working with heavy loads suspended from winches and cranes. Because there is a significant amount of work required in preparation for deployment of most large marker structures, such an event is best planned away from periods when the weather is likely to be unsettled, such as at the equinoxes when high winds and strong currents are most likely. Deployment and diving operations are best carried out during neap tides when tidal streams are at their weakest.

Survey brief

To record the layout of natural features and/or artificial markers and record positions above and below sea level as required.

The level of detail should be sufficient to determine the accurate whereabouts of sub-surface features to allow personnel with *no experience of the site* to find the exact location: a long-term monitoring strategy reliant upon the know-how of one or a few staff members is inherently flawed.

Method

Marking and relocating shore/near-shore sites

Intertidal sites

The specific requirements of a monitoring exercise and the layout of a site will largely dictate the methods used to record the exact location of features. The following summarises options that should be considered (assuming the whereabouts of a feature of interest is known from previous survey information).

(1) Relate the exact location of the feature of interest to other easily recognised and permanent features on the shore, such as rocky outcrops (preferably bedrock features), very large boulders that are unlikely to move in any weather conditions or ‘permanent’ man-made features by:
  (a) taking fixed point photographs of the shore from an identifiable and repeatable position;
  (b) recording a combination of transits, distance and compass bearing measurements of the feature from a known reference point;
  (c) drawing sketches to highlight the main features.

(2) Mark the feature with a suitable tag or marker (see above) whether on a rock or sediment shore and map/photograph its exact location using methods outlined in 1 above.

(3) Use dGPS to locate a precise location on an extensive shore where nearby natural/man-made features are too far away or indistinct to use as transit marks or where positions relate to co-ordinates chosen from a map. Combine with positioning a suitable marker if possible or necessary.

Subtidal sites

There are many specific ways of marking and relocating a subsurface site near to shore using combinations of the above equipment. In general terms the following tasks should be accomplished to record the positions of a site and then tested to ensure that the information is sufficiently accurate for someone with no experience of the site to return to the exact spot. The following scenario assumes that the approximate whereabouts of a feature of interest is known from previous survey information. If this is not the case, systematic underwater search techniques may have to be deployed.

(1) Divers, carrying a surface marker buoy, locate the feature underwater and tighten the buoy line so that the buoy is as perpendicular to the feature as possible. At a pre-arranged signal from the divers (e.g. pulling on the buoy line a specified number of times) the boat carefully moves into position and the surface support crew notes the GPS/dGPS position, echo-sounder depth, date and time.

(2) Sketches and/or photographs of two, preferably three, transit marks are made. Transit marks are straight lines adjoining land-based features that intersect over the position of the site (see Figure 1, Figure 3 and Figure 4). The greatest accuracy is obtained by having the intersecting lines between 60 and 120 degrees apart. For example, looking north a line drawn from the apex of a gable end of a house in the far background might line-up with a prominent rock in the foreground. This line intersects another line from the west where a triangulation point and a prominent tree are also in line. Transit marks can also be sufficiently accurate at close quarters to gauge distance along the line;. for example, when lining up an object with a mark on a cliff close behind it (see Figure 1 and Figure 3).

(3) Compass bearings to features on the nearby shore should also be recorded to supplement the transit marks. The effect of poor visibility on distant transit line features should be considered, particularly along areas of coast where low cloud or fog might regularly obscure such features.

(4) The divers should make sketches (e.g. Figure 5) supplemented with photographs of the layout of the seabed around the feature of interest, concentrating on distances, using a tape measure if appropriate, and compass directions between features that aid navigation in poor underwater visibility. The divers should also note the relative positions of fragile parts of the site (e.g. large sponge or seafan colonies) so that subsequent deployments of a shot line (i.e. a line just longer than the depth of water anticipated with a heavy weight at one end and a buoy at the other) will miss them.

(5) Guide ropes and lines can be deployed around the site to mark the whereabouts of various features and improve the efficiency of moving around the site underwater. Guide ropes can also be considered as safety features where divers can maintain physical contact with a reference point and with one another if working as a pair along a guideline.

(6) Once the first pair of divers has completed their dive, a shot line should be deployed at the site to test the accuracy of the transit marks and supporting information gathered so far.

(7) The next pair of divers descends the shot line and adjusts the position of the shot weight to its ideal position relative to the feature of interest. The surface crew can then adjust the transit marks and GPS/dGPS positions if necessary. The divers can affix bolts, pitons etc. tagged with fluorescent tape and/or coloured cable ties or labels to mark the positions of specific features or so that divers unfamiliar with the site can confirm that they have arrived in the right area in the future.

(8) As a supplement to, or instead of transit marks, patches of rock on the shore in positions that line up with other convenient features can be marked with a conspicuous coloured oil-based paint. A piton, bolt or marker post can further supplement this where paint marks are not expected to last long. Details should be added to the sketches of the transit marks and bearings taken to the paint marks/pitons on the shore from the buoyed site (Figure 1and Figure 2).

(9) Video recordings can also be taken of the underwater features as an aid to navigation.

Accuracy/data format

The information gathered from the above process should be presented in such a way as to provide sufficient detail so that someone with no prior knowledge of the site can return to the precise location. In general a 'zooming-in' approach is probably best, starting with a general map of the area, then GPS or dGPS positions, transit marks and photographs of surface features, and finally a set of illustrated instructions on how to reach the feature underwater and what it looks like when you get there. The final approach should be sufficiently detailed to find a feature with dimensions of a few millimetres if required (see 'Documentation' section below).

Time required

Working as a team of four, and providing the approximate position of the site is known sufficiently well to locate on one dive, most of the work can be completed in one day. Extra time should be allowed for fixing bolts and pitons and any other task that requires a moderate amount of manual work. As a rough guide, it may take more than one dive to drill holes for placing bolts in hard rock, and several (3–5?) pitons may be fixed in place in one dive if there are sufficient appropriately shaped cracks and crevices.

Marking offshore sites

The following describes the specific order of events required to deploy and relocate the 'pyramid' described above, assuming that a target position has already been determined via other survey methods. Variations of this method can be adapted to suite other situations and marker types.

(1) The vessel carrying the marker approaches the pre-determined position using dGPS with the aerial positioned as near as possible to the crane used to deploy the structure.
(2) The acoustic beacon is fixed in position on the marker and tested to ensure it responds to the homing device (in air).
(3) Once over the target position the marker is deployed on a running cable/rope to allow recovery of the rope. A dGPS position is taken as soon as the marker is set down on the seabed.
(4) With the vessel still on site the homing device and acoustic beacon are tested by holding the homer over the side of the boat to momentarily activate the beacon to obtain a distance and direction reading.
(5) At a later date the dive team return to the recorded dGPS position.
(6) The homing device is used to activate the acoustic beacon and the boat moved to find a position as near to the beacon as possible (< 80m is acceptable in 33m of water).
(7) A weighted shot line is deployed slightly off position, so as to avoid damaging the monitoring stations, and the first pair of divers descend down it to the seabed carrying a coil of rope (length equal to the depth of water plus a half) and an inflatable lifting bag/buoy.
(8) The homer is used to guide the divers to the marker. The rope is then attached to the apex of the marker and the free end sent to the surface under the inflatable marker buoy.
(9) The surface crew attach a more substantial buoy to the rope and then record an updated position for the buoy with the line pulled as taut as possible.
(10) Transit marks are recorded for the site, backed up with photographs taken with a short telephoto lens.
(11) The marker buoy is used to allow easy site access during work at the site but once the survey work has been completed at the site the buoy line is detached from the marker.

Time required

The entire process can be split into several phases:

- Manufacturing the markers can take several days to cut, weld and paint the steel sections as required. Concrete-filled tyres require at least 48 hours for the concrete to set sufficiently.
- Positioning a marker on the seabed from a suitable vessel requires travel time plus deployment time. Two ‘pyramid’ markers, as in the example above, were deployed in one day.
- The initial phase of relocating the structure by diving should take one dive. The number of dives that can be carried out during one day depends on the duration of slack water (on tide-swept sites) and the depth (with respect to decompression limits of a dive).

Accuracy testing

It is perhaps prudent to allow some time after marking the site to return with new personnel to test the accuracy of the information. This tests the accuracy of the written record rather than the short-term memory of the personnel involved.

Once the recorded information has been used once to successfully return to a site further visits should be equally problem-free. Future visits by personnel new to the area should be possible without having to carry out extensive searches unless, for example, the acoustic beacons on the offshore structures fail for any reason.

QA/QC

Documentation of monitoring sites

For condition monitoring of a designated site for management purposes the duration of the work is potentially infinite. It is therefore important to provide sufficient information for, in the worst case, a competent, unfamiliar worker to be able to locate monitoring sites and stations without the assistance of a worker who is familiar with the site. Monitoring programmes that are reliant on the knowledge of individuals are insecure and the historic investment in the gathering of previous data is potentially wasted if they cannot be continued when individuals become unavailable. At Skomer Marine Nature Reserve documentation has taken the form of a file that systematically lists all the details necessary to find a site and conduct the work at them. This model is outlined here with examples drawn from several monitoring stations throughout Wales and England.

Level 1

The first level of information for the documentation of monitoring on designated sites is a table of the different monitoring locations. At this level the table can be detail metadata such as those given in the example below (Table 1).

Table 1 Level 1 metadata for site documentation taken from Skomer MNR (SMNR staff pers. comm. 2000)

Site name	*Buoy/acoustic beacon*	*Position*	*Bearings*	*Distance from shore*	*Depth*	*Slack water times*	*Notes*
Mew-stone	None	51°43'.630N 5°17'.504W	262° – Grassholm 179° – Skokholm Lthouse	4–5m offshore	15m bcd	Slack @ LW + 2.5 or HW + 3.5–4 hours	Site first marked 1994
etc…	…	…	…	…	…	…	…

Level 2

A hard copy of the relevant chart is included showing where the monitoring station is within the designated site. Surface features and transit marks for the site are shown on drawings and photographs (e.g. Figure 1 and Figure 3).

Level 3

In CCW each monitoring project is documented with a Conservation Management System (CMS) planning code, a description of the objective for that monitoring project and the months when the monitoring should be conducted. See Table 2 below.

Table 2 An example of Level 3 details

Skomer Marine Nature Reserve ***Eunicella verrucosa*** *population monitoring RM23/01 Feature Monitoring*	
Start date	August 1993
End date	Ongoing
Frequency of data collection	Annual
Data sets collected	6 (by 2000), no data collected in 1999
Costs met by other organisations	None
Partner organisations	None
Purpose	Schedule 5 species monitoring
Coverage	Single cluster of sites
Project status	Active and ongoing
Project background	Monitor *Eunicella verrucosa* populations integrity. Since the Bunker survey in 1985, the population monitoring technique has been reassessed
Status	Six sites have been mapped in detail and are mono-photographed annually.
Site 1. Waybench (1993)	The Waybench site connects with the Sandy Seafan Gully site, although the gap between them requires mapping. This site also referred to as Waybench East in previous surveys. 12 colonies present on the Weybench monitoring route (although No. 9 missing since 1995).
Site 2. Sandy Seafan Gulley (1994)	9 colonies monitored currently numbered 13–21.
Site 3. Bernie's Rocks (1993)	Includes both the Eastern (2 *Eunicella*) and Western reefs (7 *Eunicella*).
Site 4. The Pool (1997) etc...	...

Level 3 details should also include details of changes to work practices, locations of files with images of, for example, each seafan colony and where slides or other images are stored (with a filing/CMS code).

It is also appropriate to include an equipment list (can be very specific to a particular task) and details of the protocol for each site, noting any peculiarities or difficulties, for example, in finding particular individual seafan colonies. Unfinished work, for example if a GPS position is required for a certain site or a particular seafan requires re-photographing through equipment failure, should also be noted here.

Level 4

The finest level of detail can be presented as illustrations to facilitate navigation and lay-out of transects, travel lines or other such materials for monitoring tasks as well as indicating exactly where, for example, frame-photographs should be taken.

Collectively these levels of information should be capable of guiding unfamiliar competent persons to exact locations and to perform appropriate monitoring tasks.

Health and safety

Diving health and safety issues are covered for diving activities in the joint agencies diving regulations (Holt 1998). All diving operations are subject to the procedures described in the Diving at Work Regulations 1997[3] and must follow the Scientific and Archaeological Approved Code of Practice[4].

3 The Diving at Work Regulations 1997 SI 1997/2776. The Stationery Office 1997. ISBN 0 11 065170 7 See: **http://www.hse.gov.uk/spd/spddivex.htm**

4 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. See: **http://www.hse.gov.uk/spd/spdacop.htm - a**

There are advantages of work diving on a fixed station on the seabed as mentioned above – the dives can be planned in detail as the target depth and likely duration of the dive is known. Hence appropriate breathing gas mixes (nitrox as opposed to air if working at less than 34 m) can be tailored to the target depth to improve the decompression regime. The surface support crew also knows exactly where the divers should be during the dive. Slack water times can also be easier to predict for a small fixed site rather than a general area.

Summary table

Table 3 Summary of methods used to mark and relocate positions on the shore and seabed

Marker/ method	*Substratum*	*Littoral (L)/ Sublittoral (S)*	*Effort of deployment – High, Medium, Low*	*Anticipated life-span*	*Accuracy of position fix – comments*
Piton	Rock	L and S	M	2–5 years	Exact point location, although position dictated by availability of suitable cracks.
Eye bolts (drilled)	Rock	L and S	M	2–5 years (more if stainless steel)	Exact point location, although difficult to fix in very hard rock.
Eye bolts (epoxy resin fixed)	Rock	L and S	L	2–5 years +	Exact point location dictated by availability of suitable cracks and crevices or ability to drill.
Glued-on markers	Rock	L and S	L	1–2 years	Exact point location. Prone to being dislodged.
Drilled holes	Rock	L and S	M	10 years + depending on size	Exact point location. Technically simpler on shore than underwater. Can fill up, erode or be overgrown
Paint marks	Rock	L and S	L	2–3 years	Exact point location or used as part of transit mark. Requires regular maintenance.
Wooden/ plastic/ metal Posts and ‘corkscrews’	Sediment	L and S	L	>2–3 years	Small posts can be used to mark exact location (e.g. quadrat position). Larger posts used in marking transit lines or adjacent to sampling points. Not suitable for highly mobile sediment.
Sub-sediment anchored markers	Sediment	L and S	L	? >2 years	Exact point location, but disturbance of sediment required to put in place. Mark out quadrat positions in sediment. Not suitable for highly mobile sediment.
Ropes and lines	Any	L? and S	L	Temporary Depends on battery life (2 years +)	Used for guidance to exact location.
Acoustic beacons	Need fixing in place	S	M	? >5 years with regular maintenance	Exact point location, although requires stable anchor point.
Steel seabed marker, e.g. ‘pyramid’	Best on sediment	S	H		Exact location, although sampling points best positioned away from main structure. Best used in conjunction with acoustic beacon + dGPS. Potential attachment point for other instrumentation.

Marker/ method	*Substratum*	*Littoral (L)/ Sublittoral (S)*	*Effort of deployment – High, Medium, Low*	*Anticipated life-span*	*Accuracy of position fix – comments*
Concrete blocks	Best on level seabed	S	H	? >10 years	Exact location, although sampling points best positioned away from main structure. Best used in conjunction with acoustic beacon + dGPS. Potential attachment point for other instrumentation.
Boulder/ brick cairns (may be pinned in position)	Best on level seabed	S	L	? >1 year depending on depth and disturbance	Exact location, although sampling points best positioned ~ 0.5 m away.
Transit marks	Any	L and S	L	Considerable if features used are permanent	Can be accurate to approximately 2m x 2m depending on distance from transit features
Photographs and drawings of features	Any	L and S	L	Considerable if features used are likely to stay in position.	Exact location or simply to indicate that the surveyor is in the proximity of the sampling site.
GPS	Any	L and sea surface	L	Life span of the satellite system?	Sub 15m or less for non-differential unit
dGPS	Any	L and S	L	Life span of the satellite system?	Sub 1m or less. For S, an acoustic link to submersible position finder is possible.

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