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Marine Monitoring Handbook
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Contents

Procedural Guideline No. 3-12 Quantitative surveillance of sublittoral rock biotopes and species using photographs

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Background

The use of photography for quantitative survey and for the study of seasonal and long-term fluctuations in rocky sublittoral communities has been developed particularly in Sweden and Norway. Lundälv (1985) describes the results of work which followed changes on sublittoral rocks on the Swedish west coast, including providing an assessment of sample area required to describe adequately the community present and to assess change. Whilst Lundälv employed a housed medium format Hasselblad camera, systems using paired Nikonos cameras with synchronised shutter release were subsequently developed offering a less expensive and less cumbersome option. Christie, Evans and Sandness (1985) describe the equipment and methodology together with an assessment of the time and costs involved. Both systems employed in the Scandinavian studies used picture areas of $0.25m^2$ (50cm x 50cm).

In the UK, the technique was adopted and developed at Skomer (Bullimore 1983, 1986), where a long-time series of photographs is now available, and sites for photographic surveillance have also been established at Lundy and the Isles of Scilly (Fowler and Pilley 1992). The technique is routinely used as a standard data gathering tool in the Skomer MNR, using both mono and stereophotography and picture areas up to $0.7m^2$ (70cm x 100cm), and was used in candidate SACs during the LIFE monitoring trials.

Several systems have been developed for specific applications. Stereophotography offers many advantages during analysis of photographs: species are easier to separate and identify, there is increased ability to view under canopy-forming species, and more accurate measurements can be made. A highly precise anchoring and reference system has been developed independently in Ireland to meet the specific requirements of measuring growth of sponges (Picton, pers. comm.).

Purpose

Quantitative photographic sampling is suitable for measuring variables of attributes describing:

- community/biotope composition and species richness (species >2mm and not obscured by overgrowth or silt);
- numerical abundance or percentage cover of species in communities/biotopes within defined statistical limits;
- species density and distribution, size, growth rates and, for certain taxa, physical condition ('health'), presence of reproductive structures.

Data generated may also potentially contribute to increased understanding of species behaviour, recruitment and longevity and reveal subtle, unanticipated changes over time at fixed sites.

The technique is suitable for epibenthic species and communities on rock, including large boulder and stable cobble habitats. Although it is particularly suited to surveillance or monitoring of defined

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areas, there are no insurmountable reasons why it should not also be possible to collect randomised samples. However, no examples of the technique having been used for random sampling are known to the authors.

The specific purpose for which the technique is selected will determine the precise data requirements and thence the sampling locations, areas and frequency, the equipment configuration and image and data analysis requirements.

Fitness of technique for purpose

Photographic techniques offer significant advantages over other techniques for collecting quantitative data describing sublittoral species and communities. Although the photographic technique described in the present guideline has a number of limitations, several of the same limitations are applicable to other data gathering techniques and therefore limitations are not necessarily synonymous with disadvantages.

Advantages

- non destructive
- enables surveillance of marked individuals, colonies, communities etc over time
- enables collection of large volumes of data per unit time underwater
- provides a permanent record
- enables accurate quantification of organism abundance, cover, size, etc.
- facilitates inter-worker calibration
- time series enables retrospective analysis
- stereo images enable accurate identification
- relatively low cost
- divers may not need taxonomic expertise

Limitations and disadvantages

- dependency on reasonable water clarity (Lundälv 1971 suggests 3m as the limiting visibility for the Hasselblad system; experience at the Skomer MNR suggests a minimum visibility of 4 times the camera-to-subject plane distance for usable images)
- significant time requirement for laboratory analysis of photographs
- potentially unsuitable for communities dominated by tall and overhanging organisms (e.g. kelp forest)
- taxonomic voucher specimens are not acquired
- cryptic fauna are not sampled
- equipment dependency
- equipment relatively cumbersome (not heavy, but reference frames may have high drag factor)
- initial capital equipment costs

Other considerations

Taxonomic accuracy is dependent on the communities targeted and a range of other factors, and may be better or worse than *in situ* recording. Although certain taxa are difficult to identify in photographs, taxonomic accuracy may be enhanced by the use of stereo or close-up photographs.

Efficiency, cost-effectiveness and area covered will be dependent on the relationship between the specific data requirements and the prevailing physical conditions.

Logistics

Equipment

Site and station marking[3]

See Procedural Guideline 6-2 for details.

Photography

Photography to enable quantitative analysis necessitates acquisition of images of areas which are known or contain quantifiable reference points. The use of cameras mounted on reference frames enables photographs to be taken with fixed area of coverage at constant camera-to-subject plane distance. This provides the additional practical advantage of enabling the use of fixed focus, aperture and lighting, which frees the diver to concentrate on the photographic subject and accurate positioning rather than the actual photography. (*Note: the standard camera with wide-angle lens for 'viewpoint' photography is considered to be a non-quantitative indicative or illustrative technique and is not addressed in this Guideline.*[4])

Reference frames

The size of reference frame or area will be in part determined by the subject size(s), area to be photographed and underwater visibility, which determines subject area indirectly as a consequence of camera-to-subject distance. Reference frames ranging in size from 40cm x 50cm to 70cm x 100cm have been used with success in British waters. Close-up lens framers provide an additional option for work in poor visibility and for small subjects.

Aluminium box section (25mm) and 'quick fit' preformed, rigid, plastic coated, corner sections (2, 3 and 4 way) are readily available[5]. Camera/strobe mounting bars have been constructed from 40 or 50 x 5mm aluminium angle. These materials enable sturdy, appropriately sized, purpose-built reference frame/support units to be readily, economically and rapidly constructed.

Cameras and lenses

Nikonos cameras fitted with 15mm focal length lenses are ideal tools for reference frame photography. Fifteen millimetre lenses reduce camera-to-subject plane distance, minimising potential optical backscatter, with acceptably low optical distortion, and maximise potential depth of field in the photographic images. Dual cameras can be used to produce stereophotographic images.

Nikonos cameras with a 28mm or 35mm lens fitted with close-up lens and framer can be used for small areas.

Other camera systems have been and may be employed, for example the sort of housed Hasselblad system used by Lundälv (1985). Other than the larger film format of that system, there are no advantages in using a housed camera for this type of work. In the case of a medium format system the high equipment and consumables cost and the short film lengths are significant disadvantages.

Lighting

High output, rapid recycling strobe units are required to enable small lens apertures to be used to maximise depth of field (especially important when working at close range and/or with tall target species). Units with modelling lights are useful to ensure correct lighting alignment and in low light conditions. Dual strobes are strongly recommended to minimise heavy shadows which may make analysis of images difficult. If dual strobes are to be used, note that slave strobes may be unreliable and that the range of units capable of accepting dual-sync leads is limited.

Digital photography

The low cost of consumables and the ease of importing images to computers for analysis make the use of digital photographic techniques particularly attractive. Progress in the development of digital imaging has been rapid during the period of preparation of this Guideline. Housings for many digital cameras are now available. However, products designed for the general diving photographic market are not necessarily suitable for routine scientific application where simplicity and limited features, but also the highest image resolution and widest lens angles, are required. A limited number of digital cameras

3 In this guideline the term 'site' is used to denote a location at which photographic sampling events are undertaken; 'station' is used to denote a specific photographic sampling location within a site, e.g. a quadrat or cluster of quadrats.

4 See PG 1-2 for guidance on viewpoint photography.

5 For example from RS Components (indexed under 'Storage: racking' in their catalogue)

designed for specialist commercial underwater applications are beginning to become available.

At the time of writing, the lower resolution of digital systems compared to film and the relatively poor fields of view of digital cameras (compared with, for example, Nikonos 15mm) make digital still imaging not yet a viable option for this work. However, further advances in specification (e.g. high specification, but very expensive, cameras with interchangeable lenses are now available) and falling costs are likely to make digital still imaging attractive and of greater potential application in this field in the near future. However, the memory requirement for the highest resolution, true colour images and capital costs of highly specialised equipment are likely to remain high and housed cameras are less suitable for mounting on reference frames than compact cameras such as the Nikonos

Personnel

Suitably experienced and qualified divers. Site familiarity is advantageous, although it should not be essential since the relocation of a site and the sampling stations should be facilitated by detailed instructions and marks.

Meeting photographic sampling requirements

Initial planning

It is not possible to provide project-specific advice in this Guideline since requirements will vary depending on the species or communities to be monitored, the measurements to be made and the particular environment in which the monitoring project will be undertaken. The data requirement (number of samples, replicates, sample area, etc.) need to be determined prior to consideration of whether or how quantitative photography could provide that data.

Where the objective is to determine community change, or whether a target condition is being met, either:

(a) the minimum number of individual samples that needs to be taken to provide the basis for determining statistical significance needs to be established (as guidance only, Tomas Lundälv (pers. comm.) has found that about twenty 50cm x 50cm random samples are required to obtain adequate data to identify mean densities or cover of the main organisms in Swedish fjords, and that data from random samples showed the same trends as on the fixed sites); or

(b) the minimum area which is representative of the target community needs to be established and defined: Lundälv (1985) found that four 50 x 50 quadrats were required to obtain mean density or % cover in what he called a ‘dynamic minimum area’.

Other objectives may include the measurement of species size, determination of growth rates or quantification of numbers of target organisms per unit area. Sampling requirements will need to be determined for each, taking into account all the relevant variables.

Despite the availability of extreme wide-angle lenses, the necessary camera-to-subject distances may be too great for clear photography in many areas of the British Isles where water turbidity is high.

Sampling area

The area of coverage required will vary, being dependent on (at least):

- the target environment and the dynamics of the target species/biotopes
- the size of the species within the target biotopes/communities
- the heterogeneity or homogeneity of the target species/biotopes and seabed topography

Timing of photographic sampling

Timing will usually be related to ensuring the best likelihood of calm conditions and consistency in time of year to minimise seasonal effects. Summer is usually therefore best on the open coast. Consideration needs to be given to any seasonal differences in biota. Although this may lead to sampling always being undertaken at the same time of year, it might also, for example, necessitate sampling of encrusting or low-growing species when the growth of ephemeral algae is least.

Site selection

Sites selected will be dependent on the particular subject features or characteristics to be recorded, as appropriate. In addition to considering biological criteria for selecting monitoring or surveillance sites, consideration should also be given to:

- the physical ease or difficulty of marking/relocating the sites/stations
- the local topography of the seabed surface (reasonably flat surfaces are more readily photographed)
- exposure to wave and current action (will it be possible to handle and accurately reposition photographic systems in water conditions typical of the site?)

Site and station marking

The ease of location and sampling fixed sites will be dependent on the comprehensiveness with which the sites are marked. However, comprehensive clear permanent marking may not be desirable because it may attract attention or interfere with the community being monitored, or may not be feasible depending on rock type, slope, exposure and subject.

Ideally, site and sampling station location should be planned so as not to necessitate specific relocation dives and/or dives to temporarily remark sampling locations. In practice this is rarely likely to be achievable.

Sites are most reliably marked by permanent marker buoys, acoustic beacons or other fixed, robust, easily visible or relocatable features. Only where divers can reliably descend to the seabed without risk of horizontal displacement by water movement should surface site location not be supplemented by foolproof aids wherever possible. In these circumstances, precise surface positioning is vital, using dGPS, transits, bearing and distance (radar).

To enable rapid and efficient relocation, sites should be mapped, sketched or photographed as appropriate and clear, unambiguous, foolproof written instructions for locating stations should be prepared. Precise bearings and exact distances between reference points are particularly useful. This is particularly important when temporary surface markers cannot be left in place during sampling; for example, one monitoring station in Milford Haven lies immediately beneath the approach line to the Irish ferry berth.

Permanent fixed station reference attachment points to which camera frames can be rapidly and precisely attached are advantageous. Where permanent transects, lines or other station marking devices are inappropriate, long (e.g. 30m or 50m) tape measures provide robust, rapidly and easily deployed and retrieved transect lines. Deployed from diving surface marker buoy reels and fastened between permanent, regularly spaced, unobtrusive, robust markers (ring bolts, rock anchors, pitons, screw-eyes), they enable the clear and unambiguous relocation of sampling stations.

Personnel

The minimum team size will be dependent on ease of site and station relocation, the amount of temporary station marking necessary, the number of sampling stations and the sampling time available.

The absolute minimum diving team size will be two (i.e. the minimum number required to dive to collect samples; rather than the minimum team size to meet HSE requirements). The camera operator must have sufficient biological familiarity to enable the sampling to be carried out effectively. The second diver will be required to give sampling position guidance, keep a sampling record, provide safety cover and possibly assist with supporting the reference frame. Site familiarity is clearly advantageous.

Photographic equipment configurations

The photographic equipment selected will depend on several variables including:

- specific objectives
- subject size
- area of coverage required
- anticipated visibility
- predicted density of canopy forming species

Frame size and camera-to-subject distance will depend on the variables noted above. As a guide, using Nikonos cameras with 15mm lenses:

- a 400mm (vertical axis) x 500mm (horizontal axis) reference frame requires a camera (film plane) to subject plane distance of 510 mm;
- a 500mm x 700mm reference frame requires a camera (film plane) to subject plane distance of 590 mm;
- a 700mm x 1000mm reference frame requires a camera (film plane) to subject plane distance of 810 mm;

Using a Nikonos camera with (Nikonos) close-up lens:

- both 35 mm and 28 mm prime lenses require a camera (film plane) to subject plane of 325 mm, to provide useful picture areas of c. 150mm x 100mm and 225mm x 150mm respectively.

Three basic photographic configurations have been used in sublittoral monitoring in the UK:

- single (Nikonos) camera/wide-angle (15mm) lens mounted on reference frame (wide-angle monophotography): see Figure 1
- dual cameras/wide-angle (15mm) lenses mounted on reference frame (dual camera stereophotography): see Figure 2
- camera with close-up lens and reference framer (close-up photography)

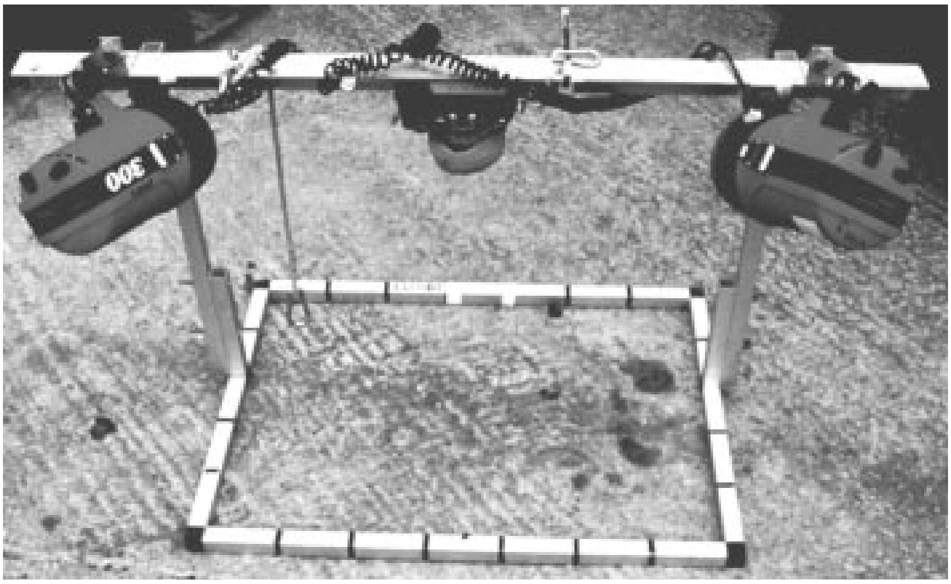

Figure 1 Configuration of wide-angle monophotography rig

Twin strobe lighting units are almost essential for both the reference frame configurations to prevent images with heavy shadow areas.

The fields of view of Nikonos cameras mounted with lens axis separation of 160mm (i.e. 80mm either side of centre) are accommodated by the frame sizes described above. The cameras must be mounted so that the optical axes are exactly parallel.

All three systems require minimal photographic expertise. Each uses fixed camera-to-subject distances and once focus and exposure requirements have been determined for any particular combination of equipment, these too can be fixed to minimise a source of operator error, leaving the operator free to concentrate on accurate location and framing.

A further medium close-up system utilising a housed 35mm camera, 28mm lens and dome port has been developed to measure sponge growth (Picton, pers. comm.). The system was designed to enable sampling of an area of c. 1.8 x 1.2m as a mosaic of 30 (6 x 5) images and employs a frame with a travelling camera support bar which is temporarily fixed to permanent mounting bolts at each sampling event. Accuracy of camera positioning is reported to be excellent, within 1cm or better.

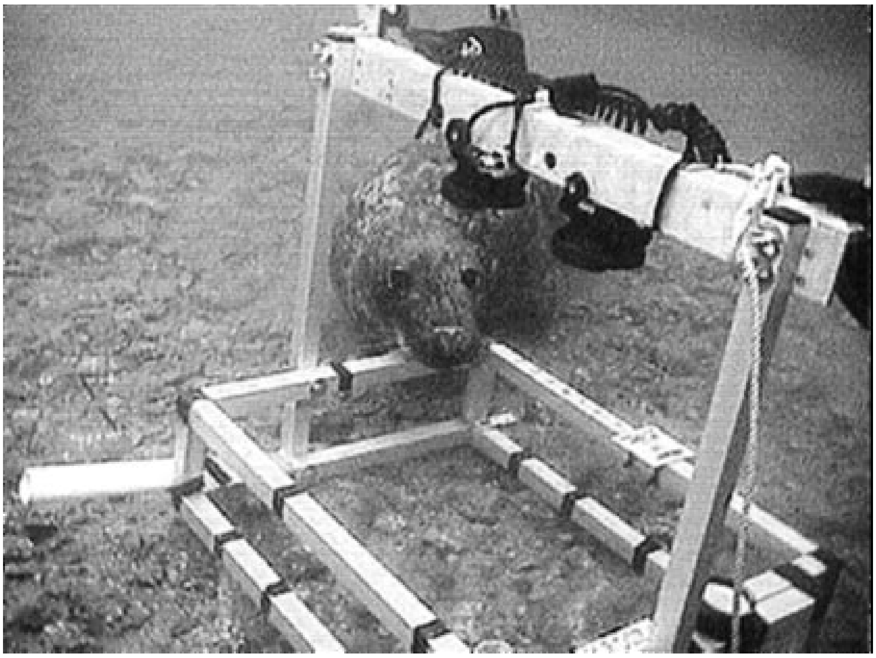

Figure 2 Configuration of a dual camera stereophotography rig (with curious bystander)

Relative advantages of mono- and stereophotography

The main justifications for using dual camera stereophotography are that:

- three-dimensional images are generated and significantly improve species identification, particularly of small and drably coloured organisms and in low-contrast images;
- the masking effect of smaller canopy-forming species is reduced (but not eliminated);
- photogrammetric measuring techniques are made possible.

The major drawback of dual camera stereophotography is that synchronisation of both cameras with the flash requires careful operation and a well practised operator;

Single camera stereophotography (i.e. moving the camera between exposures) is impractical unless the reference frame can be rigidly fixed to the seabed and the subject species will not move between exposures.

Specialised or bespoke viewing systems are necessary to see three-dimensional stereophotographic images.

Additional factors are shown in the following table.

	Single camera monophotography	*Dual camera stereophotography*
Equipment set-up and operation	simpler	more complex
Risk of equipment failure	marginally less	marginally higher
Equipment capital cost		approx. 40% higher
Consumables cost	marginally lower (negligible)	marginally higher (negligible)
Image quality	same	same
Image viewing requirements	simple – projection, printed, scanned and viewed on computer	requires specialised viewing system to view 3D images; potential to produce computer-generated 3D 'virtual' images; single images may be viewed as for monophotography

Close-up photography

The Nikonos camera system fitted with supplementary lens and frame-finder provides the simplest readily available method of photography, and is valuable for photographing small areas and species and for use in poor visibility. Advantages are ease of use and relatively low capital cost. Disadvantages are the small area included.

Methods

Station location

Following site relocation, and possible temporary marking if it is to be sampled over a period of time, station markers should be relocated using previously prepared maps or other instructions, their condition assessed and any temporary lines or other markers installed. The opportunity of maintaining the condition or visibility markers should be taken during the retrieval of lines or other temporary station markers.

Photographic procedures

Except in the simplest sampling programme, photographs should be taken following a predefined plan. A written record may be valuable to ensure that the sampling programme is completed to plan and to record errors (failures, duplications, positioning errors, photographs out of sequence, etc.).

Extreme care should be taken to ensure that photographs are taken:

- with the greatest positional precision possible;
- with the camera axis as perpendicular as possible to the rock surface;
- without causing damage or disturbance to the communities being monitored;
- without mobilising silt deposits which would reduce water clarity and consequently image quality.

Depending on the location, current exposure, slope and equipment configuration, the camera operator may be capable of positioning and supporting the reference frame unaided, though assistance in maintaining position may be useful in certain circumstances. In most programmes the assistant will provide guidance for positioning and act as recording secretary.

Additional instructions for dual camera stereophotography

The major practical difficulty of dual camera stereophotography is ensuring simultaneous exposures in both cameras. Nikonos cameras have a mechanical shutter release. Although simultaneous mechanical triggers have been used in Scandinavian systems, when they were investigated in Wales they were found to produce unreliable results because of the extremely fine tolerances required to release the shutter exactly synchronously.

The exposure technique in current use at the Skomer MNR is as follows:

(1) One camera (usually the left of the pair) is set at shutter speed ‘bulb’ (B).

(2) The other camera is set at either automatic or flash sync speed, and connected to both strobes via dual sync lead.

(3) Exposures are made in the sequence: left camera shutter released and manually held open; right shutter released; left shutter allowed to close.[6]

With practice, the actual exposure time of the left camera is estimated to be about 0.5 seconds. Whilst this is undoubtedly a long exposure time, in practice it is of minor consequence and does not result in loss of picture sharpness because, at a normal working lens aperture of f11 or f16, the only significant light that the film is exposed to (in normal conditions in UK waters below c. 5m depth) is from the strobe, which is of extremely short duration (<0.001 sec).

6 See Bullimore (1986) for further details.

Analysis

Photographic analysis

Analysis will depend on the purpose of the specific project.

Viewing images

Images may be projected onto a screen, viewed directly under low power microscopes or other low power optics, scanned and viewed on a computer monitor, or converted to photographic prints.

Stereo pairs need to be viewed, using pairs of low power microscopes, a stereo comparator or other appropriate stereo-optical viewer.

Images must be viewed at an appropriate size to discriminate the smallest organisms resolved by the images.

Data gathering from images

The best possible taxonomic accuracy is fundamental to the extraction of any data from images. Species that are most difficult to identify or discriminate from similar species may be excluded or aggregated. Keystone species or species which might act as surrogates for overall change must be recorded. Christie *et al.* (1985) suggest that organisms down to 2–3mm may be identified. It may be necessary only to record a proportion of the total number of species present.

Care is essential in counting numbers of individual organisms (per unit area) or in using point sampling to estimate cover. Measurement of absolute organism sizes or areas requires the position of the subject relative to the plane of the reference frame to be known or to be calculable (with stereopairs), or reference scales included in the images.

Computer-assisted measurements may enable more rapid measurement of certain species.

Point sampling

Determination of percentage cover is best achieved by point sampling. Depending on the viewing method, a sampling grid is overlaid on the image (e.g. digital overlay on computer, acetate underlay beneath a transparency) and the individual organisms at each point recorded. Note that it is possible for two or more organisms to be recorded at a single point (caused by overgrowth or overhanging of one species over another) and total cover to exceed 100%.

Several workers have established that there is no advantage in using random as opposed to systematically placed points. Points that are systematic make analysis much easier than wholly random points, although some workers use randomly selected points from a grid of a large number of systematically arranged.

Workers in Scandinavia have found that 100 points are adequate to describe communities dominated by reasonably large organisms. However, Bullimore (1996) concluded that this was insufficient for communities in which a significant proportion of the rock surface was dominated by small organisms and used a 320-point (20 x 16) grid.

Area and organism measurements

Stereo comparators are available which are operated with a graticule. Green (1980) suggests that size measurements of approximately 1.5mm can be made using the Nikonos system. Bullimore (1996) reports measurement from 35mm transparencies to an accuracy of ±0.05mm, equivalent to ±1.0mm in life at a camera-to-subject distance of 510mm. Gilbert (1998) made measurements from scanned digital images to a resolution of 1mm. However, it should be noted that the high measurement resolution possible with available viewing systems exceeds the positional accuracy possible during image capture and it is the latter which will usually be the limiting factor in absolute size determinations.

Analysis of digital images

Many software applications are commercially available for analysis of digital images, whether captured from digital cameras or scanned from transparencies. Gilbert (1998) investigated the suitability of several image-analysis applications for use with Skomer MNR images. She concluded that few offered the functionality required, either being highly over- or under-specified. Several applications designed specifically for medical applications were investigated. Their functionality depended heavily on high-contrast images containing clearly identifiable target objects and were expensive.

Gilbert (1998) concluded that GIS software offered most of the functionality required. The desk-top GIS application MapInfo™ was selected for its ability to easily and accurately register images (using 'non-earth' registration), ease of data handling, flexibility of measurement options and the ability to layer information over images, enabling comparison of images in time series.

The generation of 'virtual reality' 3D images from stereo-pairs using VRML software on a desk-top environment appears feasible (Pan, Cardiff University, pers. comm.). Such virtual reality images have potential application for rapid and easy visualisation and quantification of attributes of sublittoral species and habitats.

Data analysis

Analysis of numerical or other data derived from quantitative photographic sampling will be project-dependent and is not considered in this Guideline.

QA/QC

Sampling

- Precise re-location of quadrats is essential.
- Framer must be used to ensure a perpendicular angle of photography; underwater horizontal visibility must be better than minimum levels (>3m for taking 50 x 50cm quadrats using a Nikonos and 15mm lens, >1m for using the 28mm Nikonos lens and supplementary lens).
- No silt disturbed by the diver should be in the picture area.
- Film stock should be of high quality, fine grained (50–100 ASA) and in-date.
- Photographs must be accurately exposed.
- Water column discontinuities which may cause optical distortion, such as a halocline, must be avoided.
- Image capture requires careful recording, and individual images need to be precisely and promptly labelled with project, date and station to avoid misidentification of images.
- Where reference frames are employed, the date and station should be marked on frames where they will be clearly visible within captured images.

Analysis

Taxonomic accuracy is dependent on image clarity and resolution and on taxonomic skill of the analyst. Accuracy of identification of many organisms from photographs may be as high or higher than field recording by competent diving biologists if the image area and target species sizes are appropriately matched. The photographic record makes it possible to check the accuracy of taxonomic identification. Accuracy is compromised if organisms being measured are obscured by overgrowth. In analysing photographs, different workers should be able to have an error of 3–4%, but no more than 10%, in % cover and density measures if well trained (Lundälv, pers. comm.).

Measurement accuracy is dependent on the position of the subject within and relative to the plane of the reference frame. Barrel distortion caused by wide-angle lenses is greatest closest to the image edge, though the measurement errors introduced are less than c. 1%. As noted above, positional accuracy during image capture will usually be the limiting factor for size determinations rather than measurement resolution from images.

QA advantages of photographic techniques

- avoids variation due to patchiness (random sampling requires too many samples to overcome heterogeneity on broken rocky surfaces);
- detailed analysis is possible in the laboratory and the standard of accuracy is much higher than for *in situ* survey, arising in part from the pressures on available time inherent with *in situ* survey;
- stereo pairs can be used to accurately measure growth rates and calculate biomass (indirectly);
- photographs provide a permanent record so that possible errors can be checked and more detailed work can be carried out at a later date if required;
- photographs enable the distinction of smaller organisms than *in situ* survey;

- photographs can be used to demonstrate or illustrate feature change or stability;
- reasoned allowances can be made for variation in cover of tall and/or highly contractile organisms.

QA restrictions on photographic techniques

Photographs may under-record species or individuals that are obscured by overgrowth (partly overcome by stereopairs) or silt. The consequent underestimate of abundance is particularly important if seasonal changes are being studied in the species that is occasionally obscured.

High turbidity tends to increase image contrast. Image analysis is constrained by low image contrast.

It may be difficult, particularly in British waters, to locate a sufficiently extensive area of unbroken rock with the same inclination to provide an optimum sampling area or a sufficient number of replicate photographs (though this restriction is not limited to photographic techniques).

Data products

Permanent images: both original film-based material and electronic copies need to be stored in suitable, secure locations.

Numerical or other data: require storage in industry standard spreadsheets, databases, GIS data tables and map layers as appropriate.

Costs and time

The main costs arise from personnel time and the capital costs of equipment.

Site establishment

Site preparation for fixed station photographic sampling may be significant. Depending on the requirement of the project, distribution of target species, rock type, exposure and depth , the establishment of a site may take several days excluding the time required for selection of the location.

The time taken to drill holes in rock for plastic plugs or ring bolts, or to hammer pitons into suitable cracks, depends on rock type and station depth. The time required to mark hard rock sites may be considerable.

Equipment and consumable costs are not high in comparison with personnel costs.

Site relocation

Relocation time will vary with quality of relocation information, and familiarity of workers with the site. Once the site is relocated, it will take one full or part dive to mark it for photography unless permanent seabed markers have been installed

Sampling

The time required for photographic sampling is dependent on field conditions and the proximity of sample stations to each other. In optimal diving conditions completion of 36 adjacent sequential quadrats within 15 minutes is quite feasible. Consequently, depending on depth constraints and personnel availability it may be possible to complete several sample sets in a single tidal window.

Consumable costs are not high in comparison with personnel costs and capital equipment costs.

Photographic analysis

Counting of individual organisms or measurement of percentage cover, organism size and comparison of photographs can be very time-consuming. For example, point sampling analysis can take in excess of an hour per photograph whilst counting of individual organisms depends on density (Lundälv, pers. comm.). Scanning, registration and measurements from digital image scans may take several hours per image depending on the numbers of measurements being made. The time necessary for analysis is essentially a reflection of the data required.

Data analysis

Analysis of numerical or other data derived from quantitative photographic sampling will be project-dependent and is not considered in this Guideline.

Health and safety

Diving regulations must be followed. Risk assessments must be prepared for each project and location where sampling will be undertaken.

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