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Lundy Marine Nature Reserve sublittoral monitoring site assessment

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Colin Munro

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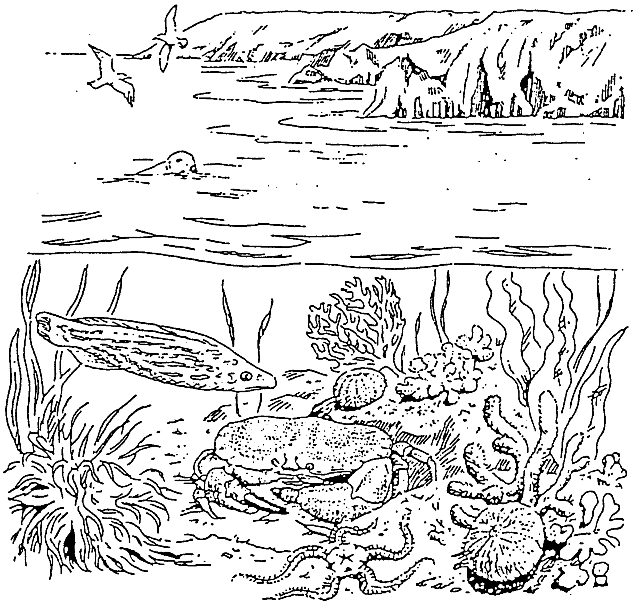
Maritime Team



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LUNDY MARINE NATURE RESERVE
SUBLITTORAL MONITORING SITE ASSESSMENT

The findings of a survey of original Lundy monitoring sites and a discussion of options for future monitoring

SURVEY TEAM

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SUMMARY

Sublittoral, biological monitoring was conducted around Lundy between 1984 and 1990. No monitoring visits have been made since the summer of 1990. This report describes a survey, conducted during the summer of 1995, of three of the original monitoring areas: Quarry Bay, Outer Knoll Pin and Gannets Rock Pinnacle. The observations of these survey dives are described. The aims and results of earlier sublittoral monitoring, and the problems encountered are also summarized. Ways of advancing the monitoring programme are suggested, taking account of the following considerations: i) the results of the earlier monitoring programme; ii) the problems encountered during this and previous survey visits, iii) general observations concerning the monitoring sites derived from this survey and iv) the potential advantages that recent technological developments, such as image analysis and environmental data logging, may bring. The logistics of future monitoring, and ways of improving efficiency during fieldwork, are also discussed and a number of recommendations are made.

1. INTRODUCTION

The waters around Lundy were designated as the U.K.'s first statutory Marine Nature Reserve in 1986. Interest in the marine life around Lundy predates this by many years; consequently intertidal and sublittoral monitoring of marine species and communities within the reserve area had begun two years earlier, and continued intermittently until 1990. Following the production of a report summarizing and analyzing the results of the Lundy and the Scillies monitoring programmes (Fowler and Pilley, 1992), interest in these programmes was rekindled. It was not, however, until the summer of 1995 that the Lundy sublittoral sites could be re-visited. Re-location of monitoring stations had been a persistent problem on previous visits, and locating pitons and ringbolts were considered likely to have been lost through corrosion or completely overgrown during the intervening years. Thus a survey and assessment of the stations was viewed as a prerequisite before attempting to re-instate monitoring. An additional consideration was that there had been many technological and conceptual developments pertinent to marine monitoring during the 11 years since this programme was first initiated, and that a fresh appraisal of the sites might identify areas where a change in emphasis or modification to the original methodology would prove advantageous .

2. SURVEY WORK CONDUCTED

The pre-monitoring survey and assessment was conducted between the 23rd and 27th of August 1995. A team of four divers conducted thirteen dives in the area of three of the original monitoring stations. These were:

i) the Outer Knoll Pin (Knoll Pins (circalittoral) monitoring transect);

ii) a submerged ridge running offshore north of Gannets Rock (Gannets Rock Pinnacle monitoring transect) and

iii) the boulder-sediment interface, Quarry Bay (Quarry Bay monitoring transect).

The above sites were dived after studying the available site relocation aids and it was attempted to identify the original monitoring transects or colonies. Where transects were positively identified but no marking pitons found, a limited amount of time was devoted to re-marking them. The sites were visually assessed (or by echo sounder, where appropriate) so that the methodology used on previous visits, the data recorded and the data analysis used could be correlated with a mental image of the physical conditions and community structure present. This could then be constructively compared with other techniques, and the practicality of either re-instating the original systems or instigating additional/alternative monitoring could be assessed.

3. MONITORING STATIONS

3.1 Overview of sites

Sublittoral monitoring of hard substrate communities and species was conducted between 1984 and 1990 at Quarry Bay, Knoll Pins and Gannets Rock Pinnacle. Monitoring of *Cepola rubescens* (red band-fish) populations was also conducted over a large area of soft sediment between Quarry Bay and Halfway Bay. The results of this monitoring programme are detailed in Hiscock (1984; 1986a; 1986b), Howard (1987; 1988) and Irving (1990). They are also summarized, analyzed and discussed by Fowler and Pilley (1992).

3.2 Site relocation methods

The prime aids to site relocation were a series of drawings of transits and of the path of the transect showing rock relief and conspicuous epibiota. These are contained in Volume II of the Report on the Lundy and Isles of Scilly marine monitoring programmes (Fowler and Pilley, 1992) and reproduced on laminated sheets for use at sea or to be taken underwater by divers (Lundy MNR, Location of Marine Biological Monitoring Sites sheets). A series of standard or wide angle photographs depicting the location of the ends of transects and the location of pitons and ringbolts were also sealed in laminated sheets, and could be referred to by divers underwater.

3.3 Quarry Bay

3.3.1 Description

Quarry Bay monitoring transect runs along the lower edge of the boulder slope at the boulder-sediment interface, parallel to the shore. It lies at approximately 14m below chart datum (bcd). *Eunicella verrucosa* (pink seafan) and axinellid sponge colonies growing on boulders close to the transect line were the subjects of monitoring at this site.

3.3.2 Relocation aids

The laminated relocation sheets hold sketches of relocation transits; wide angle photographs showing the relative positions of colonies on boulders and close up photographs of individual colonies. Quarry Bay site is relocated using one transit (the right hand edge of a boulder due west (270 degrees.) of the site in line with a closer cliff face) and one bearing (the highest point (the bow) of the wreck of the *Kaaksberg* north west (310 degrees.) from the site).

3.3.3 Survey observations

The wreck has the *Kaaksberg* has been shifted by wave action, the bow falling, since the marks were prepared. Using the west transit, the assumed position of the wreck when upright, and depth soundings, a shot was dropped approximately 15m out from the boulder slope. Two dives were undertaken, extensively covering the sediment-boulder interface north and south of the shot. It is considered probable that the transect site was covered during these dives. However, no ringbolts were found, nor did it prove possible to identify individual colonies or clusters of colonies on boulders from the laminated photographs.

It was considered worthwhile fixing a robust marker at this site (the reasoning is explained in section 4.2). An area supporting a reasonable number of *Eunicella* and axinellid sponges was identified during the second dive. This site was temporarily marked and a third dive conducted during which a sub-surface marker buoy was fixed in place. A 23cm diameter orange fishing float spliced onto 1.5 m of 14mm polypropylene line was used as the subsurface buoy. This was spliced around a plastic thimble shackled to 4m of 12mm diameter (40mm link) galvanised steel chain, in turn shackled around a large boulder. The area of numerous *Eunicella* and axinellid sponges begins approximately 5m south of the buoy.

3.4 Knoll Pins

3.4.1 Description

The Knoll Pins are two granite pinnacles that rise into the intertidal north west of Tibbets Point (approximately two thirds along the east coast of Lundy). Two monitoring sites were located on the outer pin:

i) the algal limits transect,
ii) a circalittoral transect

3.4.2 Algal Limits Transect

This site consisted of a series of line transects running down the pin from a point 6m bcd to 23.5m bcd. The prime objective of this aspect of the monitoring programme was to identify the lower limits of different groupings of algae: kelp, very dense foloise algae, fairly dense foliose algae, all foliose algae (Fowler and Pilley, 1992).

3.4.2i Relocation aids

The algal limits transect was identified by drawings of the rock relief and conspicuous animal colonies, and by photographs of the path of the transect lines. No permanent markers (eg pitons or ringbolts) had previously been fixed into the rock, the transect line being held in position by 4lb diving weights during surveys.

3.4.2ii Observations

Only the general location of the top of the transect (the eastern end of the Outer Pin) was known. No features of relief or epibiota, that team members felt could be identified underwater, could be discerned from the photographs or drawings. The photographs of the top of the transect were extremely poor, with only the dive weight and transect line discernible (relocation sheet 33, photograph LSM/232/86). It was therefore decided that to search for this transect would not be a constructive use of the available dive time and so it was omitted from the survey.

3.4.3 Circalittoral transect

This monitoring site was a horizontal transect running around the face of the pin at 15m bcd. In previous years the objective during monitoring visits has been to photograph a belt straddling the entire length of the of the transect, allowing a photo-mosaic of the area to be produced. The main subjects of this monitoring were the anthozoans *Leptopsammia*, *Caryophyllia smithii* and *C. inornata*, *Hoplangia durotrix* and *Parerythropodium coralloides*

3.4.3i Relocation aids

The location of the circalittoral monitoring transect was identified by drawings of the rock relief around the transect, including the relative position of a large gully separating the outer pin from a smaller, submerged pin to the north. The sketches also show the rock features and conspicuous animal colonies along the transect. The transect line was fixed by five ringbolts imbedded in the rock along its length. Photographs show the location of these relative to animal colonies and rock features.

3.4.3ii Survey observations

The circalittoral transect site proved relatively easy to locate. The gully between the outer pin and the submerged pin is very obvious; there are several flat boulders at the base of the gully however and neither the animal colonies not the rock relief at the west end of the transect could be positively correlated with the drawings. By following the 15m bcd contour, the cave (a depression approximately 1.5m deep and 2m high), the concentration of *Leptopsammia* and the cluster of *Alcyonium glomeratum* depicted in the transect drawing were found approximately 20-25m around the rock face, away from the canyon. These are quite distinctive features. It should, however, be noted that a second, slightly larger and deeper cave lies 2-3m lower and about 3m further east. This can be differentiated from the correct cave by carefully calculating the correct depth for the tidal height; the *Leptopsammia* west of this (deeper) cave are also considerably sparser than those west of the correct cave. This deeper cave was initially thought, during this survey, to be the eastern end of the monitoring transect. Consequently a ringscrew has been fastened into the rock just east of this cave.

The area above and to the east of the monitoring transect cave was thoroughly searched for the remains of pitons and ringbolts but none were found. It was then attempted to hammer a steel ringbolt into a crevice near the cave; however most crevices in the granite appeared to be very shallow and this attempt resulted in the ringbolt shattering. Eventually a piton was secured into a crevice approximately 1m west of the cave. A buoy was not attached as there was some doubt about the security of the rock around the piton and a buoy continually tugging on the piton might work it free. A further dive was conducted, during which the practicality of using the UT-8830 h.p. pneumatic drill, supplied to drill locating holes, was tested. This was powered by a 15l cylinder containing 100bar. At the working depth of 18m, this lasted approximately 6 minutes, during which only a small indentation in the rock was achieved.

3.5 Gannets Rock Pinnacle

3.5.1 Description

Gannets Rock is a large granite pinnacle rising some 24m above mean high water springs (MHWS). The monitoring site consists of a transect running down the face (from 18.5m to 25.5m bcd) of a submerged rock outcrop some distance north and east of Gannets Rock itself. The objective of previous monitoring visits had been to photograph a belt straddling the entire length of the transect line.

3.5.2 Relocation aids

The location of this monitoring transect was identified by drawings of three transits: two transits aligning the apex and the southern edge of Gannets Rock with features on the coastline behind, and a further transit, slightly north of first two, aligning the tip of a rock outcrop on the main island with the edge of an 'earthscar' behind.

A drawing was also available of the path of the transect down the rock face, showing the location of pitons and prominent animal colonies near the transect line. A number of standard or wide angle photographs show pitons and surrounding epibiota. (It should be noted that the numbering of pitons in the photographs and drawings does not correlate: piton 2 in the photograph appears to be the upper additional piton on the drawing; piton 3 in the photograph is piton 2 in the drawing; piton 4 in the photograph is the lower additional piton and piton 5 in the photograph is piton 3 in drawing.)

3.5.3 Survey observations

The three transits given have a rather narrow spread (all WNW of site), which is not conducive with great accuracy. Additionally, the 'earth scar' of the northernmost transect is a landslip, which appears to have slipped further during the intervening years. This transit could not be made to align with the other two and so was not used for positioning. Taking soundings while running across the transit marks showed that the pinnacle forms a ridge, running roughly WNW-ESE, dropping steeply on the north face (where the monitoring site was shown to be located) and forming a more gradual slope on the south face. The top of the ridge also falls away seaward (ESE). A shot was dropped on the top of the ridge as close to the alignment of the two transits as possible; the top of the ridge at this point was a narrow plateau approximately 9m bcd. An initial dive found that the north side, at this point, sloped steeply down to around 14m bcd, then dropped almost vertically to 27m bcd, where the rock face ran into a steep boulder slope. A short traverse west along the 25-26m bcd contour was conducted but no colony groupings corresponding to those photographed by the bottom piton were seen. The divers returned to the start point at the bottom of the cliff and ascended slowly; no pitons or colony groupings correlating with those shown on the relocation sheets were seen. The buoy originally attached to the topmost piton was known to have been lost (Irving, 1990), and no distinctive features near the upper pitons could be discerned from the photographs of the marker buoy (compare photographs LSM/121/86 and LSM/44/87, on relocation sheets 26 and 27a) or the drawings (although *Cliona*, *Pentapora*, *Parazoanthus* and *Alcyonium glomeratum* colonies are visible in the photographs, these appeared common around the 18m bcd depth band and they do not all appear in one photograph thus their relative positions are difficult to determine). The main features for the mid-transect pitons are patches of *Alcyonium glomeratum*, *Corynactis viridis* or *Caryophyllia*, all of which were common on the vertical face. No large clusters of *Leptopsammia* had been seen during the first dive, so it was thought that this might be a distinctive feature for the lower end of the transect. It was therefore decided to attempt to locate the lower end of the transect by descending directly down the north face from the shot line and following the 25-26m bcd contours WNW and ESE along the face until the *Leptopsammia* cluster and single *Eunicella* marking the base of the transect, and the correct rock, sediment interface features could be identified (see Location sheet 27).

Approximately 140m was covered during the WNW swim, during which the rock-sediment-boulder interface rose from 27m bcd to around 7-8m bcd. Occasional *Eunicella* were seen and a few individual *Leptopsammia*, but no distinctive groupings resembling those in the photographs or drawing. A dive ESE along the lower part of the face could not be completed; slightly ESE of the start point, the top of the cliff face overhung the lower part by 2-3m, snagging the smb line. This, combined with a strong current sweeping WNW along the face, make progress impossible. The dive pair therefore ascended above the overhang to the 18m bcd contour and proceeded east around the face. After a short distance was covered. the rock face was found to curve south, then west where near vertical bedrock gave way to a bedrock and boulder slope of approximately 45 degrees, indicating that the divers had come around the end of the ridge at that depth. One cluster of large *Pentapora* colonies was seen on the eastern end of the ridge, and numerous large *Cliona* colonies were also seen along this contour but none with *Parazoanthus* immediately below as in photograph LSM/101/86 (relocation sheet 26). Thus no positive correlation with photographs of the upper part of the transect could be made nor were any pitons found.

3.5.4 Description of site.

An impression of the sublittoral ridge, based on the dives conducted during this survey, is shown in figure 2. The top of the ridge, at the point surveyed, consisted of a narrow plateau covered in dense kelp. This sloped away steeply on the north side, the kelp giving way to *Dictyopteris* and *Dictyota* at on the upper parts of the slope, in turn replaced by a red algal turf and *Pentapora* colonies along lower edge of the slope. The vertical face supported expanses of *Corynactis* with patches of *Alcyonium glomeratum* and a few *Eunicella*. Large clusters of *Alcyonium glomeratum* occurred on some of the boulders at the base of the cliff.

A series of almost parallel runs along fixed bearings perpendicular to the line of the ridge were made in the survey inflatable, using an echo sounder to record the seabed depth and profile around Gannets Rock Pinnacle. These runs indicated that the seabed falls away rapidly north and east of Gannets Rock; a maximum depth of 58m (52m bcd) being recorded approximately 370m due east of North East Point. The slope is interrupted by a number of ridges and/or pinnacles, many rising abruptly by 10-20m. In places the crests of these ridges/pinnacles appear to be separated by less than 50m, with steep walls forming deep 'canyons'. The ridge on which the monitoring transect is thought to be located appears to extend out of the northern edge of Gannets Rock, the crest falling away from just a few metres bcd close to Gannets Rock, to about 25m bcd approximately 200m ENE of Gannets Rock (where the surrounding seabed lies at 40-43m bcd).

3.6 *Cepola* monitoring areas

The *Cepola rubescens* population along the east coast of Lundy, principally between Gannets Bay and Halfway Bay, was estimated at around 14,000 in 1977 (Pullin and Atkinson, 1978). A dramatic decline appears to have occurred between 1977 and 1981, when only a few groups were seen (Hiscock, 1984). Fewer were found during 1982 during extensive searching, and none in 1983. During surveys in 1984, no *Cepola* were seen and only a few possible burrows (Hiscock 1984). No *Cepola* and only one possible burrow were seen during 1985 surveys (Hiscock, 1986a) and no burrows or *Cepola* were seen in 1986 (Hiscock, 1986b). Six *Cepola* and 15 burrows were found some 200m offshore from VC Quarry (north of Quarry Beach) in 1987 Howard, 1987), none were found in 1988 (Howard, 1988) and one *Cepola* and 12 burrows were approximately 400m offshore and slightly further north in from VC Quarry 1990 (Irving, 1990).

From the paucity of sightings during survey visits, it would appear that there had been no recovery from the decline in the nearshore *Cepola* population during the 1984 - 1990 monitoring period. Additionally, no discrete site had been identified for *Cepola* monitoring. Sightings were recorded at different locations on successive years, covering a stretch of coastline over 2km in length. It was considered that three or four spot or drift dives during this survey (the maximum time would permit) would do little to establish the presence or abundance of *Cepola* in the area unless a dramatic increase had occurred. It was therefore decided that *Cepola* searches would not be conducted during this survey.

4 DISCUSSION

4.1 General observations on monitoring strategy

Before a sublittoral monitoring strategy can be developed, the information that one wishes to derive from the study and how one intends to analyze the data in order to reach meaningful conclusions should be established. (Hiscock, 1984, recommended that aspects of analysis needed testing and methods to be used to analyze photographic survey results were developed before subsequent fieldwork was undertaken. Presumably constraints on finance and time prevented this happening.) In turn, the data and analysis selection process requires the purpose(s) of monitoring to be identified. It is considered that the underlying rationale for monitoring at Lundy needs to be explained or developed in greater detail before initiating further monitoring.

One reason for monitoring biotic communities is to detect cycles, shifts in equilibrium, or trends which may be linked to other physical or biotic changes. This can give warning of adverse human impacts or facilitate detection of natural cycles or long-term changes. By detecting correlations between physical or biotic events, monitoring also allows glimpses of the mechanisms responsible for structuring these communities. Such correlations can only be drawn with confidence if the physical or biotic conditions likely to influence community structure have also been monitored. Physical conditions are generally the simplest to monitor. Given its location downstream from a large, industrial estuary, and the general concerns that have been expressed in recent years regarding the effects of activities such as mineral extraction on water clarity and sedimentation rates (and the concomitant effects on hard substrate biota), the installation of sediment traps and light intensity data loggers would seem a useful measure. It would also seem sensible to install temperature data loggers, and to position current meters at monitoring stations, for a complete tidal cycle (neaps to springs), in order to build up as complete a picture of physical environmental conditions as possible. These are, however, only general observations. Although some more specific proposals are made further in the discussion, it is strongly suggested that a range of specialists are consulted in order to achieve a balanced overall structure and the most appropriate methodology for any future monitoring programme

The original aims of the monitoring programme, as described by Hiscock, 1984, were to collect data that would increase understanding of the dynamics of the communities present and to collect data on the longevity and population changes of a number of selected species. It would appear, partly due to the difficulties of precise relocation and the limitations imposed on analysis by the methodology, that collation and interpretation of community-orientated data has subsequently been rather side-lined, with only limited, qualitative data described. The prime emphasis has been on the selected species, mainly sponges and anthozoans, considered to be of 'high scientific interest' (Hiscock, 1984) or 'high conservation value' (Fowler and Pilley, 1992). The main factors in the selection of these species appears to be their relative rarity (in British waters) and the fact that comparatively little was known about their life histories. The initial questions addressed by these programmes concerned the degree of stability of populations, and the longevity of individuals or colonies, of these species, about which very little was known at that time. As primarily qualitative studies, they have succeeded in providing qualitative answers to many of these questions. Whether significantly more useful data can be gained by continuing with this methodology is considered doubtful. More quantitative data collection and larger sample sizes (thus allowing analysis to be conducted with greater confidence), plus a shift in emphasis to recording data on community structure are the main changes in general methodology that are felt would significantly advance these programmes. It is thought unlikely that all the original monitoring sites can be successfully relocated; however, ignoring this problem for the moment it is worthwhile discussing individually the results and methodology and value of continuing at each monitoring site.

4.2 Quarry Bay monitoring transect

Data on growth rates of *Eunicella* and axinellid sponges has been collected at this site. Due to initially small sample sizes, further reduced by colony loss or mis-identification, the data sets available from this study are considered too small to make further effort expended on searches for the original colonies worthwhile. (A review of data in previous reports indicates that photographs for two consecutive years (ie one years growth) are available for only five *Eunicella* colonies, and that for only two colonies are three years growth data available. This needs to be considered in the context that gorgonian growth rates have been found to vary considerably between branches of individual colonies; between colonies and within colonies over time [eg Grigg, 1974; Mistri and Ceccherelli, 1993; Velimirov, 1975; Weinberg and Weinberg, 1974]. The data set for axinellid sponge monitoring appears to be of similar size.).

If *Eunicella* or axinellid sponge growth monitoring is to be continued, considerably larger sample sizes are required in order for statistically significant conclusions to be drawn. To attempt this for both *Eunicella* and axinellid sponges would be very time consuming. There are considerable problems in interpreting axinellid sponge data, given the problems of *in situ* identification, the current uncertainty regarding sponge taxonomy and the difficulties of measuring sponge growth due to many colonies branching in three planes. It is therefore felt that, if such studies are to continue, more useful data could be gained on *Eunicella* populations, particularly if this could be correlated with other parallel studies.

As stated above, growth has been found to vary between branches of individual colonies within gorgonians; it is therefore suggested that increase in two dimensional area (which will more closely correlate to increasing mass and number of polyps), is a better measure of growth than increase in length of selected branch tips. Additionally, growth monitoring of individual colonies is, on its own, not a particularly useful indicator of population dynamics. Recording of recruitment and mortality rates per unit area is suggested if the aim is to describe population trends within the study area. An additional useful measure would be to record size class intervals. This, in conjunction with growth monitoring, would help identify age classes and so trends in the population size. It may also help determine whether the population is capable of sustaining itself (studies by Grigg, 1977, show that in slow growing Californian gorgonians, sexual maturity occurs late and reproductive capacity is minimal below a certain colony size). However, the above programme could not be established, and data collected within one or two days fieldwork every year. One to two weeks annual fieldwork would probably be required, suggesting this is perhaps best tackled as a collaborative study with a university or other research institute. If only basic monitoring, to regularly check the status of the Quarry Bay seafan population, is required then annual or biennial monitoring of density would be a useful indicator (perhaps also recording the percentage of colonies in small size classes).

Given its proximity to the Landing Bay, the relatively shallow depth and the ease with which monitoring devices could be weighted or tied between boulders for short periods, Quarry Bay would seem the ideal site for installing monitoring equipment. It was with this option in mind that the sub-surface marker buoy was installed during this survey, the other reasons being that it would provide a reference for future biological monitoring work. As is discussed in section 4.7, Quarry Bay would seem a suitable site for locating a surface buoy and this would considerably assist deployment, recovery and servicing of monitoring equipment.

4.3 Knoll Pins transects

Analysis of monitoring data from the circalittoral transect has allowed the density of *Leptopsammia* and *Caryophyllia*, and annual changes in this parameter, to be recorded. Subjective observations on changes in abundance of bryozoa and hydroid turf species have also been noted and observations on changes in individual colonies of *Parethropodium coralloides, Alcyonium glomeratum, Parazoanthus axinellae* and *Stolonica socialis* have been recorded. From this data, the main conclusions to be drawn are that the densities of both *Leptopsammia* and *Caryophyllia* samples have declined slightly in within the sample area. This may have implications for the entire Lundy populations of these species, or indeed those for the populations around Southwest Britain, given that similar results have been recorded from the Scillies monitoring programme. There is, however, the problem that the individuals and colonies monitored are not random samples of the population (whether the population to be considered is all the individuals around Southwest Britain or only those around the Knoll Pins). They are, by definition, unrepresentative as the areas for study have been selected on the basis of the high density of individuals of the subject species and/or the presence of other selected species. As has been pointed out by Fowler and Pilley (1992), deliberate site selection invalidates most forms of statistical analysis. It also means that one must exercise extreme caution when extrapolating to other sites or drawing general conclusions about characteristics of the population as a whole.

As the monitoring at this site has collected photographs of set areas of bedrock along the transects, it may be possible to extract additional quantitative data from the 1984 - 1990 photographs on the dynamics of the community present within these photographs (in addition to the qualitative observations already made). Although all the photographs have not been viewed, it is suspected from the results and comments in the monitoring reports and in the report analyzing these results (Fowler and Pilley, 1992), that the gaps in the data combined with changes in viewpoint or photographed area may make this difficult.

The depth penetration of individual species of algae is believed strongly linked to the quality and quantity of light reaching that depth. Thus the algal limits monitoring transect can provide useful data on the ecological effects of changes in turbidity levels. For data to be comparable between years, the algal limits monitoring transect requires permanent marking, both to ensure accurate relocation and to enable precise depth calibration. There would seem little reason why this couldn't be conducted close to the circalittoral monitoring transect. A marker located 5 - 10m east of the eastern end of the circalittoral transect could be used as the lower marker of the algal limits transect. To cover the full distance to the top of the pin would probably require 5 - 7 permanent markers for the transect line. Estimating the values such as the lower limit of fairly dense foliose algae and very dense foliose algae is highly subjective and rather negates the value of precise depth recording. A better method might be to estimate (or better still, photograph and calculate) the percentage cover within quadrats at fixed set depths. An alternative, or complementary form of data recording and analysis would be to video the transect and, using a frame-grabber and image analysis software, compare depths at set transition points (eg the point where algal cover falls below 30%) from year to year. It would also be useful if algal species composition was recorded *in situ* at set points (perhaps within three quadrats at points along the transect) and temperature and light intensity data loggers were located by the transect. Logging of surface light levels, eg by daily logging of cloud cover, situating a light intensity data logger on top of the Marisco Tavern or simply taking a light meter reading off a grey surface every day at mid-day, would help differentiate between changes in turbidity levels and flucuations in mean cloud cover between years.

4.4 Gannets Rock Pinnacle monitoring transect

Monitoring here also consisted of a series of sequential photographs of known area along a fixed transect. No quantitative analysis of data on individual species appears to have been attempted for this transect, nor can many references to subjective observations of change along this transect be found in the monitoring results report (Fowler and Pilley, 1992). It would therefore seem that the value of the data, so far extracted from this monitoring site, is low. As was discussed regarding the Knoll Pins circalittoral transect, the possibilities of quantitative analysis of changes in community structure from the annual photographs, 1984 - 1990, would seem a possibility. Again, whether this is feasible will depend on the quality of photographs and the degree to which photographs from successive years correlate. Whether this has been attempted is not known. If this can be done, then the data so far collected may prove to be of considerable value and building on this record could be a worthwhile exercise. If not, then there would seem to be little to be gained by attempting to relocate the original transect or establishing another in the area and monitoring using similar methodology.

It was noted during this survey of Gannets Rock Pinnacle that the pinnacle appears to be regularly potted. During one dive a pot line was strung along the crest of the ridge. As the ridge drops steeply to the east, this results in the line being drawn tight across ledges. At one point the line, under tension from the weight of pots below, was seen to lie within inches of a large cluster of *Pentapora*. Presumably the lower pots can end up hanging free and swinging in the considerable current that occurs here. Potting is not prohibited (but is discouraged) around Gannets Rock. It would seem likely that potting will result in significant damage to more stable circalittoral communities. It is therefore suggested that some form of monitoring of the potting activity is instigated here, to try and determine the fishing effort and level of disturbance, and thought is given to the feasibility of instigating comparative studies to determine how significant the effects of potting at this site are.

4.5 Suggestions for circalittoral community monitoring

A major factor in the choice of Lundy as a statutory Marine Nature Reserve was the perceived diversity of its epilithic biota, in particular the circalittoral epifauna. Analysis of monitoring data from these epilithic communities has, so far, concentrated on selected species of high nature conservation or scientific interest. As many of these appear to be slow growing and late or infrequently reproducing species (ie exhibiting typical *K* strategist features) it seems likely that recovery following a sharp decline in their numbers would be slow; equally, increased frequency of disturbance to the community may result in long-term reductions in their abundance as they are replaced by opportunists. However, there is little to suggest that these species act as 'keystone' species (ie that they play any pivotal role within their biotic community or that their loss would lead to significant further species loss). Relatively little is known of the factors producing and maintaining this diversity. It is therefore felt that greater emphasis should be placed on describing the dynamics within epilithic communities as a whole.

The Knoll Pins circalittoral site appears to support a more diverse epibiota than Gannets Rock Pinnacle; it is also easier to relocate. Given constraints on funding, it may, therefore, be more constructive to concentrate energies on extracting good data from one or more sites on the Knoll Pins than to re-instate detailed monitoring in both areas. (This would, however, have the disadvantage of reducing the number of comparative sites.)

Ideally, data should be quantitative, preferably for sites of known area and of sufficiently large sample size; randomly selected, fixed position quadrats are recommended as this method would allow a considerable range of analysis techniques to be applied. One method that could be used to achieve this at Knoll Pins would be to use a horizontal transect line, say 15m long, as a datum, and subdividing (as a paper exercise) the rock above and below into numbered squares. A proportion of these could then be randomly selected for monitoring. Grids could then be established by deploying the transect line, measuring the correct distance along the transect and vertically from that point, then drilling two locating holes for the camera framer. Monitoring of change in species coverage (as absolute area or percentage cover), species replacement and changes in overall diversity could then be recorded simply by photographing each grid square annually or biennially, with a limited amount of *in situ* identification to ground truth photographic identification. (A metre square quadrat is easily covered by a 15mm Nikonos or 20mm housed camera lens at around 0.7m distance, although a slightly smaller quadrat size would make for more manageable framer dimensions.) Photographic images could be analyzed either by super-imposing a grid over the slide or print and counting boxes filled by colonies or by importing the images onto CD and calculating area of coverage of colonies using a relatively simple image analysis package. The original Knoll Pins circalittoral monitoring transect could be used as a datum (extending it slightly); the area is easy to re-locate and there is no (apparent) profound differences in community type along this transect or in the few metres above and below. Dividing the area 3m above and 2m below the transect into 1m squares would create 75 squares from which 10-20 could be randomly selected for monitoring. Although the initial establishment would be considerably more time consuming than re-establishing the original methodology, the actual data collection would not and the results could be extrapolated to the rest of the Outer Knoll Pins circalittoral community, or population of a particular species, with greater confidence.

4.6 Photographic recording

Extracting information from photographs has been a problem in the past. Suspended particles have caused high degrees of backscatter in some photgraphs, sometimes making it impossible to discern the subjects of the photograph. If the water is very turbid then it will always be difficult to get acceptable photographs. However, quality can usually be markedly improved by careful positioning of the flash(es) and making the camera to subject distance as short as possible. In shallow waters, where light levels are high, using long exposures and available light (and faster film if necessary) can create an improvement. In extremely poor conditions it may be worth considering using video without lights.

Stereo-photography has been used in other sublittoral monitoring studies, and its use has been recommended for monitoring around Lundy. As a technique only, the data to be collected and the way in which it needs to be analyzed has to be established before deciding whether stereo photography will significantly improve data quality.

The advantages of stereo-photography have been described by various authors; these are summarized below:

i) the three dimensional image created aids species identification (Bullimore, 1983)
ii) it is often possible to 'see' behind large or overhanging organisms since objects obscured from one angle may be visible from the other (Bullimore, 1983)
iii) it produces data far more suitable for image analysis (Fowler and Pilley, 1992)
iv) by duplicating images it provides a back up in case of camera failure (Fowler and Pilley, 1992).

Additionally, stereo-photographs can be analyzed to extract measurements perpendicular to the focal plane, thus facilitating measurements in three dimensions. This may be useful for recording growth in massive species such as *Cliona* or *Pentapora*.

The advantages of this need to be weighed up against the additional cost, the additional bulk of the equipment and the additional analysis of photographs required to extract three dimensional measurements.

The claim of greater suitability of stereo-photography for image analysis needs to be qualified. Image analysis is a broad field and the suitability of stereo-photographs will ultimately depend on the ability of the particular system to utilise stereo images; currently there are a number of software packages that cannot.

If the analysis proposed requires consecutive photographs along a transect to match up, then a large degree of overlap in the consecutive photographs obviously aids this process (ie negating the need for 'rubber sheeting', as described by Fowler and Pilley, 1992). If the overlap of images between the left and right camera of the stereo-pair is less than 100%, then the combined width of both images will be greater than that of one frame alone. However, where there is 100% overlap in stereo images (ie true stereo images), then the total area photographed will be no greater than that photographed by a single camera fitted with the same lens. Thus exactly the same number of stereo-pair or single camera images would be required to give the same degree of overlap between consecutive photographs along a transect. The problems with matching up the existing photographs for some of the belt transects is that: a) there was often insufficient overlap, and b) the angles at which the photographs were taken varied (both these problems seem to refer to occasions when a framer was not used with the camera). It would therefore appear that this problem could be simply overcome by using a framer and ensuring a large overlap in photographs along the transect. However, this only applies if the analysis requires accurate mapping of the transect. If instead, quadrats along the transect are analyzed independently (eg for area covered by each species within a number of fixed or random quadrats along the transect) then no overlap is necessary. More important would be insuring that the angle of acceptance of the camera lens is sufficient to cover the entire quadrat at a short camera to subject distance and that a high quality lens, minimising peripheral distortion, is used.

There is a case for having a backup in case of camera system failure; however the most common system failure is for the flash not to fire rather than camera itself to fail.

Whatever the system used, it should produce as high quality photographs as possible while requiring as little decision making (and potential for error) by the operator as possible. The author's personal preference would be to use a single, housed camera (a good quality *Nikon, Canon* or *Pentax* system in a robust aluminium housing, with TTL metering) and one powerful, wide-angle flash (underwater GN of around 10-11m at ISO 100; 100 degrees coverage) and possibly a small slave flash to allow more even lighting without losing relief-creating shadows completely. A *Nikonos V* with similar flash arrangement would also produce consistently good quality photographs. Either system would require a framer to ensure accurate re-positioning of the camera.

4.7 Site relocation and marking

Site relocation proved to be a major problem during this survey; the eastern end of the Knoll Pins circalittoral monitoring transect was the only part of the three sites visited that was positively identified. The fact that none of the personnel involved in this survey had participated in previous years monitoring, and so was not familiar with the subtle details of relief and patterns of epibiota around the transects, was probably a contributory factor. However, this has been a persistent problem even when some or all the team had worked at the site before. Inability to re-locate either the monitoring sites or individual colonies, and failure to accurately re-position cameras for repeat annual photography has resulted in large gaps in the data record, and large amounts of unusable data, between 1984 and 1990 (to give some examples: Howard ,1988, and Irving ,1990, note that difficulties were encountered in identifying seafans and sponge colonies at Quarry Bay; Howard, 1987, notes that photographs taken in 1986 and 1987 along the algal monitoring transect 'did not match at all'; Irving, 1990, notes 'considerable difficulty in locating', and that there was some doubt as to the eventual alignment of the algal limits transect with that laid previously; Fowler and Pilley, 1992, note that complete mosaics of the Knoll Pins cup coral populations could not be constructed due to lack of overlap). In the light of these problems, any proposed programme must fully address this problem before initiating monitoring. It is felt that time and money spent on installing the most robust and visible markers at the outset will very quickly pay for itself in time saved on subsequent visits and more complete data records.

Given the five year gap since monitoring and servicing of these sites was last conducted it is considered highly unlikely that any of the original pitons or ringbolts are still visible, corrosion and overgrowth removing all traces. It also seems clear that it is not possible for divers unfamiliar with the transect sites to positively identify transect paths solely by correlating natural features with those depicted on the relocation aids (the eastern end of Knoll Pins circalittoral transect excepted). Whether divers who have visited the sites previously would be able to achieve this is also open to question given that a degree of change will have occurred at each site. In view of this the benefit gained from re-locating the old Quarry Bay, algal limits and Gannets Rock Pinnacle transects needs to be weighed up against the fact that a considerable investment in time spent searching could be made with no successful outcome.

The monitoring sites have all been located close to the shore (except for the *Cepola* monitoring which has not used one fixed site), and the coastline of Lundy is extremely rugged, with small pinnacles and large rocky outcrops all along the coast. Thus transits are a very good way of re-locating the approximate position of sites (certainly more accurate than Decca or GPS, excepting differential GPS). When selecting transits or bearings, care needs to be taken to ensure that the transit marks are stable, permanent features. If a subsurface marker is to be relied upon to relocate the site underwater, then this ought to be a buoy of some sort that will be seen at the limit of visibility in relatively clear conditions (eg 8-10m). It also needs to be very securely fixed to the seabed, either chained or firmly pinned into the seabed, depending on which is most appropriate. Over and above this it still needs to be visited regularly and serviced as lines will still fray and buoys accumulate fouling organisms and sink. Careful consideration should also be given to installing a surface buoy at some sites. This would eliminate time wasted searching for underwater markers and remove the necessity for dropping potentially damaging shots. Furthermore it would allow the warden, perhaps in conjunction with visiting amateur divers or diving assistants, to quickly and easily deploy, check and retrieve monitoring equipment, eg current meters, sediment traps etc. and to organise quick dives to check and clean sub-surface markers. Quarry Bay site is considered particularly suitable for installing a surface buoy. The large boulders and relatively level seabed make anchoring such a buoy a relatively simple affair. Given its proximity to the Landing Bay, the relatively shallow depth and the ease with which monitoring devices could be weighted or tied between boulders for short periods, Quarry Bay would also seem the ideal site for installing monitoring equipment.

Irrespective of whether stereo or mono- photography is used, it is considered important that fixing points allowing cameras to photograph precisely the same area from the same angle are installed. Steel pitons or ringbolts wedged into crevices are not appropriate for this. Both will corrode with time, and crevices do not allow fixing points for the camera framer to be situated at pre-selected points and set distances apart. Holes drilled into the rock with plastic rawlplugs inserted and brass pins or eyebolts for locating a camera framer would seem a better option. Drilling large numbers of holes into granite using an high pressure air supply would require large numbers of dives to be conducted, given the very limited duration of even a 15l ,drill supply, cylinder at depth. The UT-8830 pneumatic drill formerly used for this purpose is not considered powerful enough either. A larger and more powerful hammer drill is needed. One option is a surface supplied pneumatic drill. This would eliminate the problem of limited duration and the need to balance a 15l cylinder mid-water while drilling. However, low pressure pneumatic tools do not work well at this depth (due to back pressure) unless an exhaust return hose is fitted. It would also be necessary to install a low pressure compressor (rotary vane, road compressor type) aboard the dive vessel, although this is a minor problem. A second alternative is to use a hydraulic hammer drill. Hydraulic tools are generally more powerful than pneumatic, and this could be run of the hydraulic take-off of a suitable dive/workboat. The disadvantage is that hydraulic hosepipe is considerably more expensive than air hose and chicago couplings.

4.8 Monitoring visits and site maintenance

Maintenance of the monitoring sites and deployment, inspection and retrieval of monitoring instruments would seem tasks best undertaken by the resident warden rather than visiting teams. However, it would seem, from observations during this survey visit, that the time of the warden is already very fully occupied with meeting ferries, looking after dive parties and terrestrial conservation matters. Additionally, it is obviously not possible for one person to undertake diving work. The RIB that will be available to the warden soon may allow inspection of surface buoys and deployment/retrieval of instrumentation suspended from buoys but, if other competent personnel are not available to accompany her, the safety aspects of one person going to sea in an open boat must be considered extremely carefully. One solution would seem to be to accommodate volunteer assistants with suitable diving qualifications during the summer. There are Health and Safety problems involved in paid staff diving with volunteers, however it may be that the warden could operate in an overseeing role.

Thought should also be given to employing a hardboat for monitoring work, possibly a live-aboard. Given the high cost of accommodation on Lundy, and the ferry and air fills costs, the total price costs may not be significantly different to those for living on the island. On the plus side, the efficiency of the operation would improve markedly; cylinders could be filled between dives and all equipment would be on-site. The wisdom of conducting two deep dives then climbing several hundred feet up a steep hill every day, as happens when living on the island, must also be questioned.

5. CONCLUSIONS AND RECOMMENDATIONS

1. Improved marking of sites is required to ensure accurate relocation of transects and positioning of cameras. If this cannot be achieved, the value of the data collected is greatly reduced. Thus the methods for relocation and marking must be a prime consideration when designing future monitoring programmes.

2. When specific monitoring programmes are being designed, thought must be given to the proposed methods of data analysis *at that stage*. Care needs to be taken to ensure that the sample size is sufficiently large, the selection process suitable for the intended extrapolation and the form in which the data is collected is appropriate for the intended analysis.

3. It is felt that the priorities for monitoring need to be more clearly identified; only then can individual monitoring programmes designed to fulfil these priorities.

4. It is suggested that greater emphasis is placed on collecting quantitative data on circalittoral community structure rather than concentrating on individual species.

5. To collect the quality of data that will allow robust interpretation, it is felt that the number of sites and different aspects to the monitoring needs to be scaled down. It is also suggested that routine maintenance and data logging could be undertaken by, or under the supervision of the island warden.

6. Studies on the autecology of individual species generally require large amounts of data collection in order to interpret observations with confidence. Such studies may best be tackled by student research programmes or collaborative ventures with research establishments.

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APPENDICES

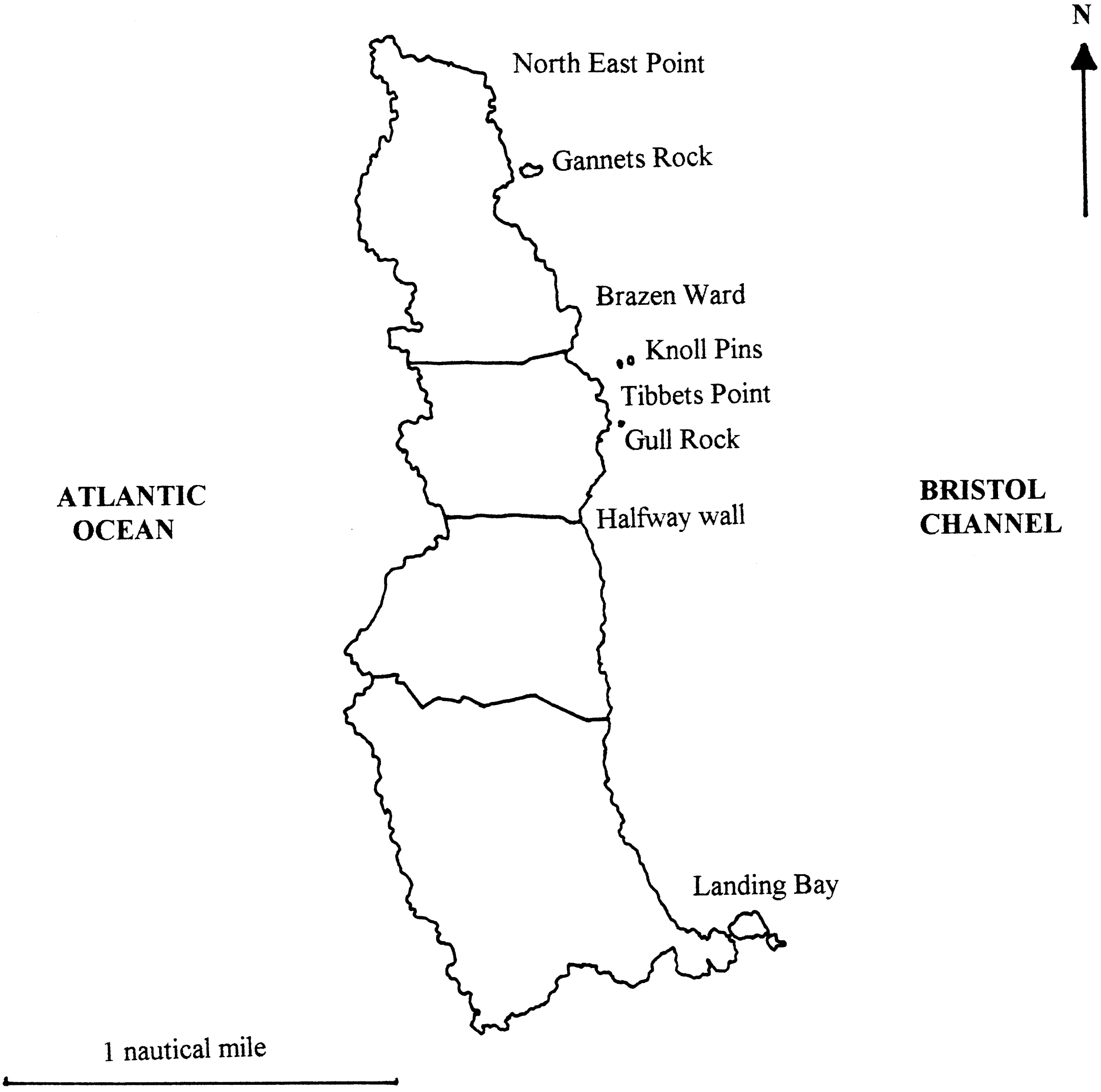

Figure 1. Lundy Island showing areas mentioned in text

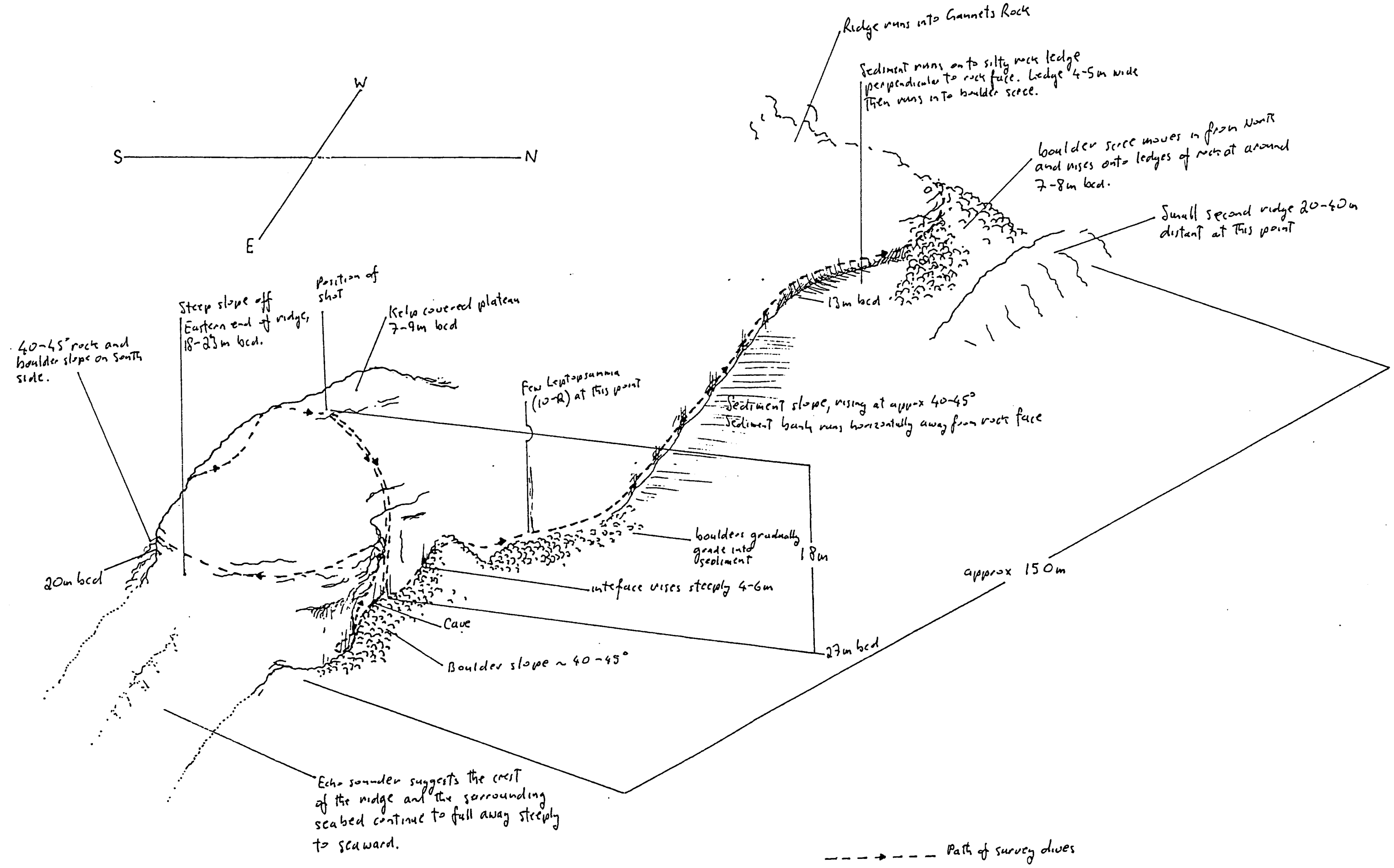

Figure 2. Sublittoral ridge, north east of Gannets Rock: impression from survey dives and echo sounder runs.