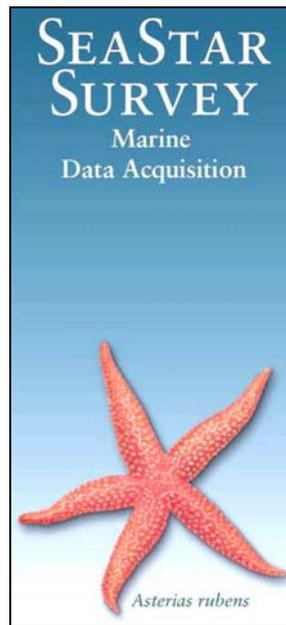


## Survey of the reef habitat around Eddystone Rocks, Plymouth

Axelsson, M., Dewey, S., Chaddock, S, and Duke, S

Seastar Survey, Ocean Quay Marine, Southampton, SO14 5QY, UK  
+44 (0)23 8063 5000, [info@seastarsurvey.co.uk](mailto:info@seastarsurvey.co.uk), [www.seastarsurvey.co.uk](http://www.seastarsurvey.co.uk)



This work will contribute to the MESH project ([www.searchmesh.net](http://www.searchmesh.net)) and received European Regional Development Funding through the INTERREG III B Community Initiative ([www.nweurope.org](http://www.nweurope.org)).

July 2006

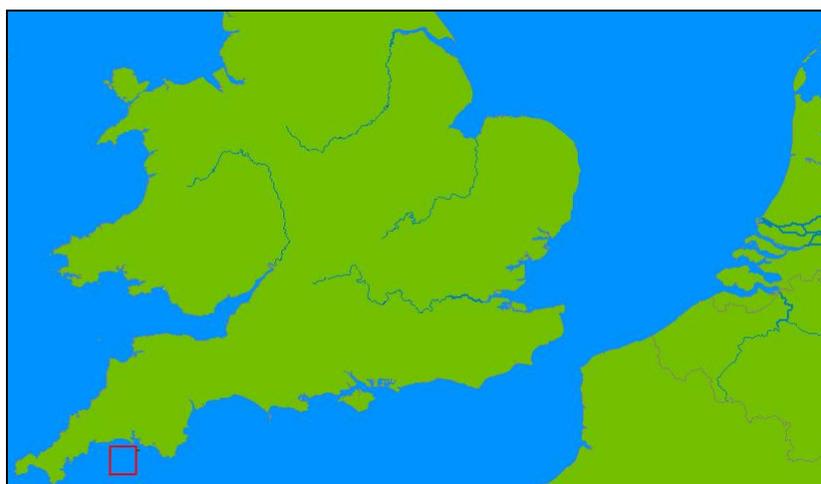
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## 1 INTRODUCTION

### 1.1 Project background

The 1992 Directive on the Conservation of natural habitats and wild fauna and flora (92/43/EEC), commonly known as the 'Habitats Directive' was implemented into law in 1994 and 1995 (Jones, 2005). One of the requirements of the Habitats Directive is the selection and subsequent designation of Special Areas of Conservation (SAC) for a range of habitats and species listed in Annex I (e.g. 'reefs' and 'sandbank' habitats) and II of the Directive (Jones, 2005). The current SACs in the seas around England are all inshore and attached to the coast but a decision in 1999 resulted in the UK being required to implement the Habitats Directive out to 200 nautical miles (Jones, 2005). Recent work commissioned by English Nature and carried out by BMT Cordah collated existing survey information for the English coast to identify possible areas of reef habitat. The information was drawn mainly from the British Geological Survey, Admiralty Charts and other existing survey data. The study showed Eddystone Reef on the South Devon Coast (figure 1) to represent a good example of a shallow offshore reef surrounded by a range of ecological habitats and therefore potentially qualify as a Special Area of Conservation (SAC).



*Figure 1. Study location situated southwest of Plymouth in Devon, UK.*

In order to record and characterise the habitats around Eddystone Rocks and potentially classify parts of the area as 'reef' habitats as described in the European Habitats Directive (92/43/EEC), SeaStar Survey undertook an acoustic and a biological survey of Eddystone Rocks and the surrounding area.

The aim of the acoustic element of the survey was to delineate the extent of the potential rocky reef habitat around the Eddystone Lighthouse as well as several areas of rocky reef to the west of the Eddystone. These reef areas occupied the central zone of the survey area, a twenty five km<sup>2</sup> area to the south-west of the Port of Plymouth (figure 2).

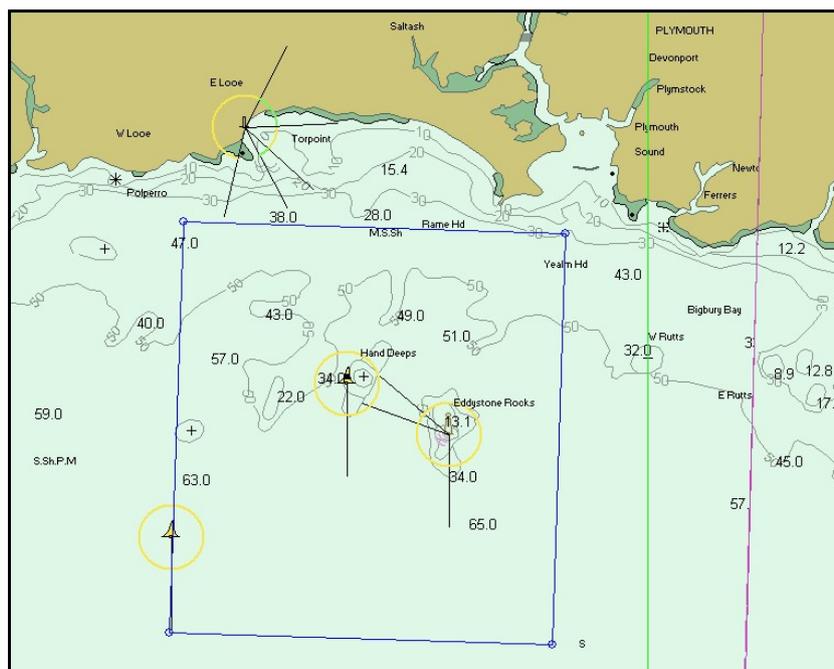


Figure 2. The Eddystone Rocks with study area (blue rectangle).

In addition, a key part of the survey was to describe and delineate the various other seabed habitat types which occurred between and around the areas of rocky reef. A digital sidescan sonar mosaic, in conjunction with single beam echo sounder derived bathymetry, provided the initial broadview to map the substrates present throughout the survey area. A certain amount of interpolation was required due to the constraints of the available budget preventing total coverage of the entire survey area.

The aim of the biological element of the survey was to provide a description of the richness and diversity of the habitats on both the rocky reef and the interspaced softer substrates. The biotope distribution and species composition was developed through interpretation of drop-down video footage and digital still photography, taken after evaluation of the sidescan mosaic.

The results of all elements of the survey were used to create a Geographical Information System (GIS) which enabled a high level of processing, interpretation and display of the sidescan sonar mosaic, bathymetry, substrata types, biotopes and the digital photography.

Running alongside and augmenting the survey was a further body of work made possible by funding from Mapping European Seabed Habitats (MESH). MESH ([www.searchmesh.net](http://www.searchmesh.net)) recognises the need for an integrated European system which will harmonise mapping in accordance with the European Nature Information System (EUNIS) and the EC Habitats Directive. Two specific projects within MESH are to generate Habitat Maps for North-west Europe and to develop Standards and Protocols for Marine Habitat Mapping. These will lead to a meta database of European mapping studies and an Interactive GIS, to be available on the Internet.

The SAC-focused survey is itself directly relevant to MESH objectives. Additional funding from the MESH project enabled the values of the survey to MESH to be enhanced. The additional work that resulted included more intense survey of a sub-area; comparison of different analyses of acoustic data; further analyses of habitat and biological data including assessing confidence; assessment of different photographic/video techniques; and extracting learning points from the survey, e.g. commenting on different survey technique protocols.

In order to contribute to the above, an area within the main English Nature survey, a rocky reef known as Hand Deep, was surveyed more intensely (referred to throughout the survey report as the 'MESH survey area' for ease of reference, although the entire survey area and associated results are relevant to the MESH project). The sidescan data were subjected to a seabed classification program developed by Quester Tangent Corporation and the biological information underwent a great deal more statistical analysis than did the survey as a whole.

The different methods of interpreting sidescan sonar were compared to investigate the consistency of interpretation along with assessment of various levels of confidence rating or value of data at different levels of collection. Similar assessment was made of the bathymetric, substrata and biotope interpretation in order to apply levels of confidence to the interpolation between the in situ sampling. It is intended that these comparisons of survey work at differing levels of intensity and utilising differing technologies will help to establish Standards and Protocols for Sidescan Sonar and Photographic Surveys for future European Seabed Mapping.

## **1.2 The environment off the Plymouth coast**

The western English Channel is in a boundary region between oceanic and neritic waters and it straddles biogeographical provinces with both boreal/cold temperature and warm temperature organisms (Southward *et al.*, 2005). Long-term research in the western English Channel started by the marine laboratories in Plymouth in the 1880s has resulted not only in a good understanding of the geological, physical and biological environment but also resulted in observations spanning significant periods of warming (1921-1961 and 1985-present) and cooling (1962-1980) with considerable fluctuations in fauna and flora (Southward *et al.*, 2005). These long time-series of data has furthermore allowed studies into the anthropological disturbances (e.g. fisheries and pollution) present in the region (Southward *et al.*, 2005).

### **1.2.1 Geology and the sedimentary environment**

The seabed sediments cover is thin in many areas off the Plymouth coast and over much of the region the sediments consist of a discontinuous cover of coarse 'lag' (i.e. winnowed) deposits less than 0.5 m thick (BGS, 1996). These deposits are mostly gravels and sandy gravels (Holme, 1966; BGS, 1996) formed of flint, chalk, sandstone, limestone and ironstone, where these gravels often are muddy as a result of the underlying clay bedrock (BGS, 1996). In some areas longitudinal gravel furrows have formed parallel to the direction of tidal currents. The lag deposits are locally overlain by mobile bodies of sand, forming ribbons, sand waves or ripples (BGS, 1996). The Eddystone Rocks that lie some 20 km south of Plymouth Sound (Davies, 1998), are Devonian in age and consist of schist, siltstone and limestone (BGS, 1996) with flat-faced, angular vertical cliffs and overhangs (Irving, 1996). The bottom deposits around Eddystone Rocks range from coarse muddy sand to fine gravel (Hiscock, 1998) but immediately around Eddystone Rocks the sediments have been reported to consist of shelly gravel (Holme, 1953). Sand is the dominant type of sediment in the area south and east of the Eddystone Rocks (Irving, 1996; Davies, 1998), while gravely sand is found immediately around the rocks with sandy gravel to the north (BGS, 1996). There is virtually no net sediment transport drift in the study area (BGS, 1996).

### 1.2.2 *The physical environment*

The water depth surrounding Eddystone Rocks ranges from 40 m to about 80 m. Immediately around Eddystone Rocks the water depth is around 15 m, or less in places, while the Eddystone Rocks are visible above water (BGS, 1996; Irving, 1996).

The prevailing winds are from the south-west with particularly strong winds occurring in winter when a series of gales often occur (BGS, 1996). Small depressions develop rapidly and move quickly eastwards causing frequent changes in wind condition but not in wind direction. North-easterly winds commonly occur during spring while south-easterly winds are less frequent (BGS, 1996). Wind speeds off the coast of Plymouth exceed 3.5 m/s 75 % of the time and reach 18 m/s 0.1 % of the time (BGS, 1996).

The south-westerly winds can generate large waves as there is a long 'fetch' from the Western Approaches of the English Channel (BGS, 1996). The wave heights can exceed 3 m for 10 % of the time during winter and a maximum wave height of more than 20 m is expected every 50 years (BGS, 1996).

The tidal range around Eddystone Rocks is approximately 4-5 m at spring tides and tidal currents reach about 1 m/s (Holme, 1961, 1966; BGS, 1996).

The salinity in this region is high, typically more than 35 g/kg, as a result of Atlantic waters moving into the English Channel and the water temperature are typically 16 °C in summer and 9 °C in winter (BGS, 1996). There is however, a distinct thermocline in the summer where bottom temperatures are several degrees below those at the surface (Holme, 1966). There are furthermore fluctuations over longer timescales as noted above as a result of changes in water circulation (Southward *et al.*, 2005).

### 1.2.3 *Biological distributions*

The environment described above, including the fact that the region straddles biogeographical provinces, combine to produce an area of considerable marine biological importance and this attracted many early naturalists to the region leading to, among other things, the establishment of the Marine Biological Association (MBA) at Plymouth in 1884 (Davies, 1998). English Nature identified six Sensitive Marine Areas (SMAs) covering a large proportion of the region's coast with the aim to highlight areas of particular marine conservation interest (Irving, 1996) and rare seabed species have been recorded from the Eddystone Rocks area including the sea fan *Eunicella verrucosa* (Sanderson, 1996). The Eddystone Rocks have been shown to be colonised by a turf of bryozoans, hydroids, anemones and extensive patches of jewel anemones *Corynactis viridis* (Irving, 1996). Southern (Mediterranean – Atlantic) species, such as the sea fan *Eunicella verrucosa*, the soft coral *Alcyonium glomeratum* and the sea cucumber *Holothuria forskali* (Irving, 1996; Sharrock, 2005a), are also present. Similar communities have been shown to occur at and off Hand Deep with the jewel anemone *Corynactis viridis* also being present (Sharrock, 2005a).

The shell gravel surrounding Eddystone Rocks are dominated by bivalves, such as *Clausinella fasciata*, *Lutraria* sp., and *Parvicardium scabrum*, and polychaetes (Irving, 1996). The communities in these coarser sediments have been characterised as a '*Spatangus-Venus*' community while the sandy substratum to the south and east of Eddystone Rocks have been characterised as an '*Echinocardium-Venus*' community (Davies, 1998).

According to Holme (1961, 1966) there are a number of species that occur throughout the English Channel including the area around Eddystone Rocks. Some of these widely distributed species include *Ophiothrix fragilis* and *Chlamys opercularis*. *Ophiothrix fragilis* is one taxa among others that prefer hard or gravel bottoms and tide-swept conditions and they have been recorded at Eddystone Rocks but they are absent in calmer waters (Holme, 1966). Some other generally distributed species include *Ensis arcuatus*, *Spatangus purpureus* and *Echinocardium cordatum* (Holme, 1966). Species recorded from the Eddystone Reef survey area include *Ophiura* spp., *Turritella communis*, *Venus* spp., *Antalis entalis*, *Ophiocolina nigra* and *Chaetopterus variopedatus* as well as crustaceans such as *Callinassa subterranea* and *Upogebia stellata* found north of Eddystone Rocks (Holme, 1966). *Marthasterias glacialis* has also been recorded from the region but is often found in the deeper water (Holme, 1966). The fluctuations of some fauna can be exemplified by *Antalis entalis* which was common around the Eddystone grounds at the end of the 20<sup>th</sup> century but was absent during some surveys in the 1960s (Holme, 1961). Hawkins *et al.* (2003) reported fluctuations in the sea surface temperatures with a warm period between 1920 and 1950, a cool period between 1962 and 1980 and a warm period again from 1980s.

#### 1.2.4 Human use and impacts

South-west England is characterised by important populations of exploited seabed species, especially crustaceans such as lobsters, crawfish, spider crabs and edible crabs (Pawson and Robson, 1996) and pot fisheries are present at the Eddystone Rocks and surrounding areas (pers. observation). There are also scallop (both *Pecten maximus* and *Aequipecten opercularis*) fisheries offshore around Eddystone Rocks but there are no exploitable quantities of brown shrimp, prawns or *Nephrops* (Pawson and Robson, 1996). There are also many fish species exploited in both the pelagic and demersal fisheries south of Plymouth including Mackerel and Dover Sole (Pawson and Robson, 1996).

## 2 METHODOLOGY

### 2.1 Acoustic survey

The acoustic survey was to be undertaken between 16<sup>th</sup> July 2005 and 14<sup>th</sup> September 2005 and the survey was started on the 16<sup>th</sup> July 2005 with the transit of the survey vessel *SV Mariner* to the Plymouth area. The survey took 61 days (including weather and technical down days). During the course of the survey detailed logs were kept recording weather conditions, navigation information, equipment configuration, survey and operational notes. Out of the 61 days data was successfully acquired on 20 days, 2 days were spent on a transit to Plymouth, 1 day for equipment mobilisation, 28 weather down days, 8 technical down days (due to sub-contractors' equipment or personnel practicalities and problems) and 2 technical down days due to vessel engine maintenance.

All survey operations were conducted from SeaStar Survey's Vessel *Mariner* based at Mayflower Marina, Plymouth during the period of the survey. *SV Mariner* is a purpose built dedicated survey vessel and is fully compliant with MCA category 2 code of practice for small work boats. The skipper of 'Mariner' was qualified to RYA/DoT Yachtmaster Offshore (Commercial) and the mate was experienced in all aspects of vessel operation.

#### 2.1.1 Horizontal control

The required geodetic parameters of the survey were Latitude / Longitude, WGS 84. The bathymetric and sidescan sonar data were collected using these geodetics, but the sidescan sonar mosaic was created using UTM (zone 30), WGS 84.

The horizontal control for the survey was achieved by using a CSI Wireless Vector Sensor, with the differential signal obtained from the Lizard lighthouse and using SBAS (satellite based augmentation systems). This was also used to acquire heading data. The Vector obtained a satellite derived position in WGS84 latitude and longitude, which was recorded using HyPack Max survey management software. The Vector Sensor contains two GPS receivers inside one enclosure, and two multipath-resistant antennas in two separate enclosures. These antennas were mounted on a bar attached to the vessels mast. During this deployment a distance of approximately 2 m separated the antennae. A known position within Mayflower Marina was obtained from the Ordnance Survey using a Superplan plot in OSGB36 grid coordinates and a surveyors steel tape measure to ascertain a stationary position of the vessel.

A navigation check was made against that known location before the start and at the end of each survey day to check the continued accuracy of the GPS signal and the functionality of equipment. This involved the vessel remaining in the known position obtained from the Superplan and GPS position data being collected for a number of minutes. The results of the GPS positional data was then compared to the position obtained from the Superplan to verify the accuracy of the GPS data. An example plot of the data obtained from the GPS can be seen in appendix 1.

There is a possible navigation error present in the data in the form of lay-back error. This could occur if the vessel and the sidescan sonar fish are not in alignment. But little or no error is expected when sidescan sonar is collecting data in a straight line. However, some error may occur on occasion during turns (moving from one survey line to another) where the sidescan sonar fish and the survey vessel were not in a straight line. To avoid this error the acoustic survey was conducted in long, straight lines as far as possible, a decision taken early in the planning stages of the survey.

### *2.1.2 Vertical control*

Vertical control for the survey was achieved by the use of a Marimatech E-Sea Sound dual frequency (33 and 200 kHz), digital echo sounder. Data from the echo sounder's high frequency (200 KHz) were recorded on paper trace and digitally using the survey management software (HyPack Max). The echo sounder transducer was pole mounted on the starboard side of the survey vessel approximately 1m below the sea surface. The pole was securely fixed to the vessel by the combined use of scaffolding poles and clamps, for and aft stays and a breast line to prevent any movement of the transducer head.

An echo sounder bar check was completed prior to the start of the survey and at regular intervals during the course of the survey in order to check the draft of the transducer below the water surface. Once the correct draft was established the depth of the transducer was entered into the echo sounder set-up programme. An example of bar check data can be seen in appendix 2. This shows the data displayed in the survey planning and data acquisition software, with a spread sheet of all collected data, a plot of the vessel position as acquired from the GPS during the bar check procedure and a plot of the single beam data collected during the course of the bar check.

The speed of sound throughout the water column was measured at the start and end of each survey day and whenever a bar check was performed to correctly calibrate the echo sounder. This was performed using a Marimatech HMS 1820-P CTD. Once the correct speed of sound was established it was entered into the echo sounder set-up programme. An example of data recorded from a CTD is presented in appendix 3. Both the sound velocity profile and the bar check were recorded on the echo sounder's paper trace as part of the quality control records.

During the course of the survey the single beam data were recorded to the echo sounder's paper trace as a backup, but primarily to the main survey computer running the survey planning and data acquisition software. The data recorded were backed up on to CD at the end of each operational day and the backup removed from the vessel and stored elsewhere.

Tidal data during the survey were taken from a pre-established, self-recording tide gauge located at Devonport. All tide data were supplied by the British Oceanographic Data Centre, Merseyside, who own and operate the tide gauge. The tidal data from Devonport were then converted to the survey site using corrections from the Admiralty Tide Tables Volume 1 (NP201-03 - appendix 2). Tide height corrections were based on observations made close to the Yealm River Entrance. The tide height data were then applied to the echo sounder results to reduce the recorded depths to Ordnance Datum Newlyn.

### *2.1.3 Vessel motion reference*

Possible errors relating to vessel motion were minimised by the use of our TSS CMS 25 Compact Motion Sensor, which allow us to account for any vessel motion to an accuracy of  $\pm 5$  cm. Corrections due to vessel motion were applied in real time within the echo sounder and displayed on the paper trace. The motion reference unit was mounted on the echo sounder transducer pole, to avoid the need for offsets in the navigation setup and minimise the risk of errors.

### *2.1.4 Sidescan sonar*

The sidescan sonar survey was carried out using a GeoAcoustics dual frequency (114/410 kHz) sidescan sonar. During this survey the unit was operated at 114 kHz (known as 100 kHz mode), with a range setting of 200 m. The system comprised of a tow fish, soft umbilical, transceiver, thermal linescan recorder and data acquisition unit.

The line spacing was in general 400 m and with a 200 m range (covering 200 m either side of the fish) allowed total coverage of the surveyed areas. In some sections there is a degree of overlap of the sidescan sonar backscatter while other sections of the survey area are only covered in part (e.g. South Area) as a result of the large survey area and limited time available. The MESH survey area was covered in more detail with a 200 m line spacing resulting in a 200 m overlap either side of the line resulting in a complete coverage of the area.

The fish was deployed with the maximum ballast available (38.6kg), due to the depths of the water in which it was to be used. In addition for deployment in the deeper areas of the survey additional weight was used to depress the fish. This action was taken to allow the vessel speed to be maintained at approximately 5 knots.

A soft tow umbilical was used for signal transmission and a winch wire attached to the fish for towing. The umbilical was 200 m long to allow for the great variation in depth across the site. The choice of soft tow rather than armoured was made as the umbilical and fish were deployed by hand rather than using the winch. The transceiver unit generates the pulses and can be used to control the sidescan operating parameters, but was not used in this manner during this survey.

A Dowty Maritime Ocean Systems 3710 thermal linescan recorder was used to record the signal to paper. A CodaOctopus 760 geophysical acquisition system was used to record the data digitally to DVD – RAM. It was through this unit that the sidescan sonar was controlled. It also provides the primary way of viewing the data in real time during collection. The data

were recorded in XTF format directly through this unit. Navigation and heading data were input to this unit from the navigation computer using the HyPack Max survey software.

### *2.1.5 Weather conditions*

The weather conditions during the acoustic survey were in general quite poor. This is reflected in the fact that during a 61 day period of mobilisation, 28 days of weather down time were encountered. During the survey the sea state was on occasion close to the maximum agreed within the contract, but below the working tolerance of the motion reference unit and sidescan sonar employed for the survey. It is felt that the weather conditions will have had no affect on the quality of the survey results within the required tolerances of the survey specifications.

### *2.1.6 Processing and charting*

Processing of the bathymetric data was undertaken using the post processing tools within the survey management software. This was undertaken with reference to the echo sounder paper trace records as part of our quality control procedures. The processing of the data involved editing out the water column, the removal of spikes and other erroneous points from the data and the reduction of the depths using corrected data acquired from the tide gauge. The data were then imported into a MapInfo GIS for display and interpretation.

The sidescan sonar data were initially processed and mosaiced by a sub-contractor. This involved trimming the edges wherever possible and appropriate as well as mosaicing the sidescan traces together to obtain a map as complete as possible with a resolution of 2 m bins (i.e. 1 pixel equals 2 m of seafloor). Paper print-outs and a GeoTiff were delivered. This data was then also imported into the MapInfo GIS, and again the GIS was used as the medium of display and ongoing data analysis and interpretation.

### *2.1.7 Quester Tangent Corporation seabed classification*

Quester Tangent Corporation (QTC) used the GeoAcoustics sidescan data from a section of the Eddystone Rocks survey area (MESH Area). The area was chosen as a result of the diverse seabed environment with both soft sediments and rocky reef with small variations in the backscatter returns in both types of substrata. The QTC sediment classification use acoustic signals alone and involves the segmentation of seabeds into discrete classes based on the characteristics of acoustic backscatter throughout a region (Preston, 2006a, 2006b). Dividing the seabed into classes is useful because seabed characteristics are relatively constant throughout a class and distinct from the characteristics of other classes even though it does not independently identify geophysical types (Preston, 2006a).

A detailed description of the QTC seabed classification methodology is given in Preston (2006a, 2006b) but in simple terms it involves extracting a large number of features from the backscatter amplitudes of the sidescan sonar data. This information is then processed which includes the use of multivariate statistical techniques (Preston, 2006a, 2006b). The final product is an ASCII comma-delimited file that can be imported into mapping software for the production of plots and 3D models (Preston, 2006a, 2006b).

As this was an unsupervised seabed classification with no prior knowledge of the seabed environment, ground-truthing was required to verify the true nature of the seafloor environment in each class. This process is carried out during the integration of the different data sets in this study (see section 3.2.below). An assessment of the overall agreements of the results of the different data sets was also carried out.

## 2.2 Drop-down camera survey methodology

During the planning stages of the camera survey, the study area was divided into three areas after careful but broad analysis of the sidescan sonar results. These areas were named the North Area, Middle Area and South Area (figure 3), where the North Area and South Area were dominated by sediments while the Middle Area was a mixture of sediments and reefs (e.g. bedrock and boulders). Within the North Area, a further two regions are present. The MESH Area forms part of the additional study for research into habitat mapping (additional seabed discrimination analysis and more intense ground-truthing) and North Mud was identified for further study as it was considered an unusual feature within the survey area.

Within the Middle Area there were a total of 6 reefs and these were given names (figure 3) based on existing names taken from charts (Eddystone Reef, Hand Deeps and Hat Rock) and unofficial names that were designed to be descriptive and help explain the results (Bed Rock, Middle Rock and South Rock).

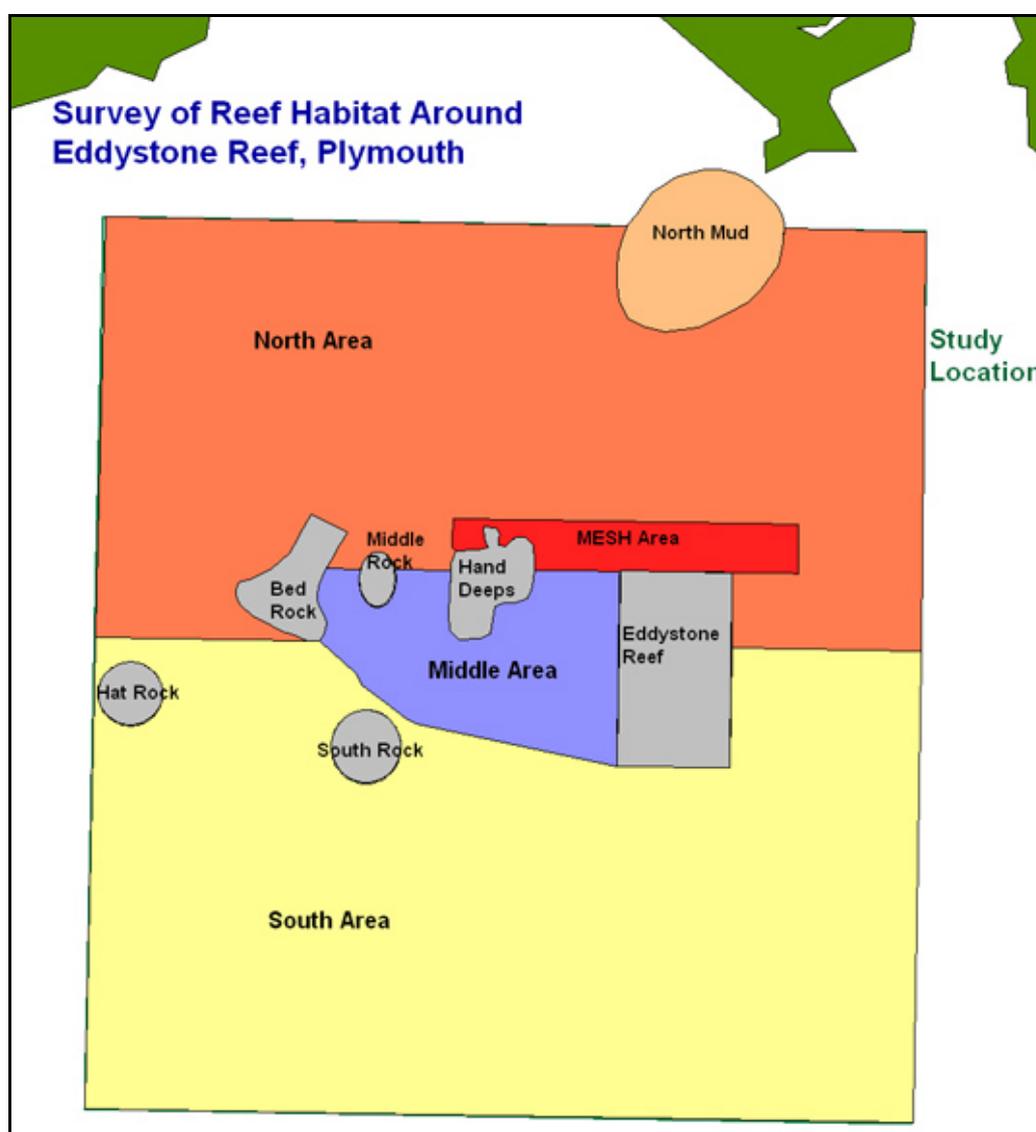


Figure 3. The drop-down video and still photography study areas.

The camera survey was planned to cover as many different areas and environments as possible within the allocated timeframe with the aims to delineate the reefs and ground-truth

the sediments and reefs as well as gather video and still photographic records to study and describe the biological distributions.

### 2.2.1 Drop-down camera system

The camera equipment used during the survey was a Kongsberg Simrad OE14-208 Digital Stills Camera System mounted obliquely on a seabed camera frame (figure 4). A flash unit and two sub-sea lights were also mounted on the frame. These units were linked to the surface with a soft umbilical cable. All controls of the camera system were kept in the wheelhouse of the survey vessel.

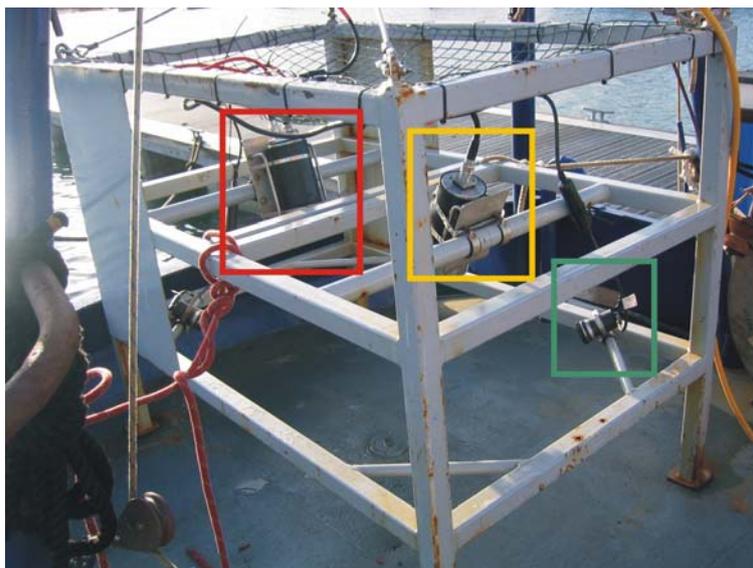


Figure 4. Camera system mounted on seabed frame (red rectangle: camera; yellow rectangle: flashgun and green rectangle: sub-sea light).

### 2.2.2 Camera operation and deployment

The drop-down camera survey was carried out during January 2006. The camera system was only deployed in suitable weather conditions by a team of experienced personnel. Before each deployment a 'clapper board' containing site name, date and weather conditions was videoed and photographed as a quality assurance (QA) record.

All camera deployments were established as transects across sites of interest, which were selected by experienced personnel after scrutinising the acoustic survey data. The vessel was positioned at one end of a transect using DGPS. The camera was then deployed and lowered to the seabed. Once the camera system was at the seabed and had time to settle, the onboard surveyors started to log navigation and the skipper was given approval to move along the transect at about 0.5 knots.

During the deployment, the control of the camera and winch were solely with the camera operator. The winch was physically controlled by a second person on deck, whilst photographs were taken using a surface trigger in the wheel house. The DTS3000 camera system sent a continuous, real-time, analogue video feed to the surface, where the deployment was monitored and the camera / winch were controlled. The analogue video feed was recorded digitally using Mini Digital Video (miniDV) tapes and backed-up using VHS tapes. The video was recorded to tape rather than DVD as the quality and life expectancy of tape is much greater. Individual still photographs were taken using a surface controlled

trigger. Photographs were taken at the discretion of the camera operator to capture interesting features and fauna – not at a set time or distance interval.

Throughout each camera deployment, navigation data was recorded. All camera deployment log keeping was synchronised to the navigation data using the time from the GPS. The log keeper recorded the time from the GPS at the start and end of each deployment and the time each photograph was taken. After each deployment the camera was removed from the frame and secured in the wheel house. The digital photographs were then uploaded from the camera to a laptop computer via a USB lead (the software used for this was Canon Zoom Browser EX). During the upload process each photograph was named with the site-name and photograph number.

### 2.2.3 Data handling

At the end of the survey the client was supplied with DVDs with mpeg video files, sets of all seabed photographs and the seabed photographs were incorporated into the MapInfo GIS. The photographs and video footage were then used for analysis in the GIS. When the camera survey was completed the miniDV tapes were taken back to Seastar Survey offices by a member of staff and the backup VHS tapes were transported to an offsite data storage facility. After the survey the digital miniDV tapes were up-loaded to a computer, edited, titled and burnt to DVD as mpeg files. All DVDs, photographs and logs were checked for errors as part of Seastar Survey's standard quality control procedures and all data supplied to the client.

### 2.2.4 Camera positioning error

There is a potential risk of a small positioning error present in the exact position of each photograph and video transect as no navigational beacon (e.g. USBL) was used during the survey as current activity and other underwater physical factors may have influenced the camera frame positions. However, the heavy photographic frame (c. 100 kg) and the placement of the GPS antennae on the A-frame are likely to minimise these errors and the maximum error is therefore estimated to approximately 10-15 m.

## 2.3 Video and photographic analysis

### 2.3.1 Analysis of the photographs and video records

The analysis of the photographs and video records was carried out 'blind', without any prior knowledge of the sites, using a personal computer and a SONY (DSR-1500P) digital videocassette recorder and a television monitor respectively. The latter system allows slow-motion, freeze-frame and standard play analysis. An initial assessment of a site was carried out by first looking through the photographs and film from the particular site quickly to get a brief understanding of the substratum, flora and fauna.

The detailed analysis consists of a general seabed description and scoring of all flora and fauna present as far as possible as well as counting and classifying the burrows present into three types (large vertical (>1 cm diameter), small vertical (<1 cm diameter) and horizontal burrows). The fauna was identified to the lowest practical level (see references in section 6.2). The abundance was recorded using the SACFOR scale (see Connor *et al.*, 2004) and a list (according to Howson and Picton, 1997) of the encountered fauna and flora was produced for each photograph and site. The photographs were subsequently classified into designated biotopes according to Connor *et al.* (2004).

### 2.3.2 Data (photographs and video) analysis

Ecological interpretation of results has been carried out by reference to the JNCC Marine Nature Conservation Review Biotope Classification (Connor *et al.* 1997), and the presence of rare or unusual species identified against the list in Sanderson (1996). All the identified and enumerated benthic macrofauna were used in the analysis and the abundance data are given in the SACFOR scale (see Connor *et al.*, 2004). Additional photographic analysis was carried out of the sites included in the MESH Area and the fauna and flora were again identified and enumerated with the abundance given as number of individuals/m<sup>2</sup>. The additional detailed faunal analysis of the MESH Area comprised both univariate and multivariate analyses all of which were calculated using Primer (Plymouth Routines in Multivariate Ecological Research) v 5.2.0 (Clarke and Warwick, 1994). The univariate analysis included the total number of individuals (N), total number of species (S), species diversity where the Shannon-Wiener (H'), Pielou's (J) and Margalef's (d) diversity indices (see e.g. Gage and Tyler, 1991; Fowler and Cohen, 1992; Clarke and Warwick, 1994) were used with the natural log (log<sub>e</sub>) being the chosen parameter in the case of the Shannon-Wiener diversity index. The multi-variate analysis was carried out using cluster analysis and ordination (non-metric multi-dimensional scaling, MDS). These data were then transformed to square root to down-weight the importance of common types of macrofauna in relation to rarer types. The transformed data were then analysed using the Bray-Curtis similarity coefficient (using Primer v.5) followed by a cluster analysis where the sites were group averaged and the resultant dendrogram plotted. Non-metric multi-dimensional scaling (MDS) was then carried out to further assess the presence of any similarities between sites (Clarke and Warwick, 1994).

### 2.3.3 Comparative assessment of video records and still photography (MESH)

The still photographs were used in the quantitative analysis in the SAC study while the videos were primarily used as reference material and quality controls (e.g. ensuring results from the still photography were correct and features such as the sediment veneer were present throughout a transect at particular sites). In this assessment three video transects were analysed fully to describe the type of substrata and identify and enumerate the fauna / flora present. These results were then compared to the results obtained in the still photography analysis. The results are descriptive, where the main differences are outlined; and numerical, where the faunal densities obtained from the two techniques are compared to assess if there is a difference between the faunal densities recorded using the two different techniques.

## 3 RESULTS

### 3.1 Acoustic analysis

The analysis of the sidescan sonar mosaic from the acoustic survey (100 kHz sidescan sonar and 200 kHz single beam echo sounder) revealed areas of different levels of backscatter, suggesting clear changes in bathymetry, sediment type and or sediment composition within the survey area (figures 5, 6, 7, 8 and 9). These clear patterns and features were used to direct the selection of deployment locations for the underwater video and still camera system (see figure 9).

#### 3.1.1 South Area

The analysis of the sidescan sonar revealed that South Area is dominated by areas of light, even backscatter returns. In the north of South Area there was a patch of darker and therefore higher backscatter that was given the name of South Rock (in the photography

planning stage). This was tentatively interpreted as a bedrock feature but the bathymetry over the exposed rock only changed by about 1 m, going from around 62.5 m on the surrounding sediment to a minimum recorded depth of 60.2 m on the rock and it was not charted at all. This site was therefore selected for further investigation using the drop-down camera. There are furthermore a number of darker returns within the South Area but due to the size of the survey area and time / weather constraints these locations were not surveyed with the camera system.

There was no evidence of trawling activity on the sidescan sonar results from the South Area, however, during the course of the survey, large otter board trawlers and beam trawlers were seen operating in the area.

### *3.1.2 Middle Area*

The Middle Area consists of areas of high backscatter surrounded by areas of lower backscatter returns. The high backscatter returns over the Middle Area were all believed to represent rocky reefs with mixed, soft sediments in between. The areas of rocky reef are clearly visible on the sidescan sonar results. These can be seen as rough areas of very bright and dark backscatter, which are very distinct from the surrounding sediments (figure 5). Three of these reefs are all relatively well-known with names shown on navigational charts (Eddystone Reef, Hand Deeps and Hat Rock) while two are areas of charted rock that were named during the survey (Bed Rock and Middle Rock) but are less well known. In fact, the precise extent of the rocks was not clearly detailed on existing charts. The total area of rocky reef mapped during the survey was approximately 1450 hectares.

The sediments in the Middle Area comprised 3 distinct returns from the sidescan sonar backscatter results: light even sediments, which were interpreted as sand (partly sand ribbons); a darker return, which was interpreted to be the mixed sediments of sand, gravel, mud and shell interpreted from the North Area; and a mid return, which was interpreted to be predominantly sand and shell.

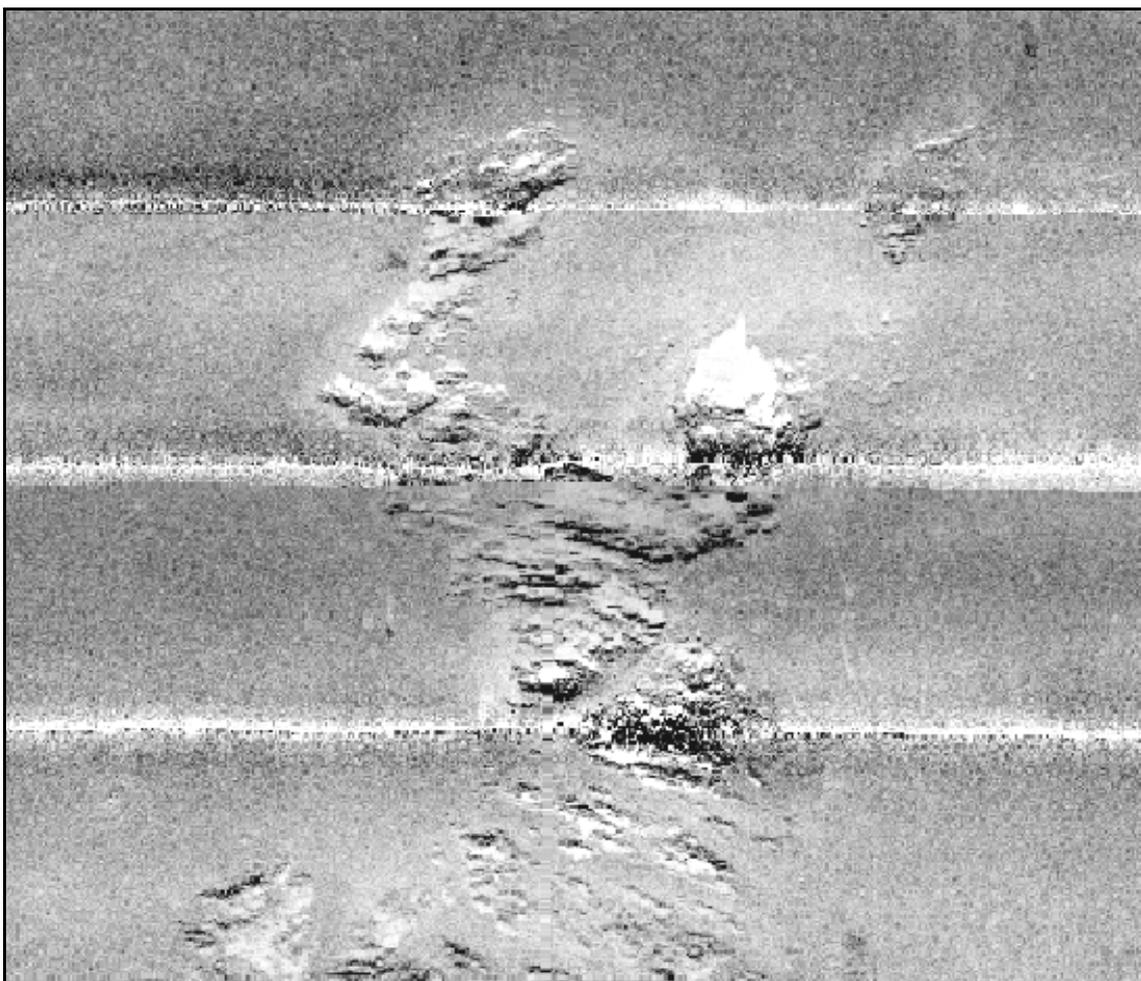


Figure 5. Sidescan sonar image of the northern part of Eddystone Reef.

### 3.1.3 North Area

North Area was made up of a variety of sidescan sonar returns including darker, mottled backscatter returns (figure 6). These returns were interpreted as very poorly sorted, mixed sediments comprising mud, sand, gravel and shell in various quantities, and are interspersed with patches of sand and gravel as well sand and shell.

Within the mixed sediments are lighter areas of backscatter return, which were interpreted as predominantly sand or sand and shell, known as sand ribbons (figure 6). In total the sand ribbons make up about 30% of the total area. To the east of North Area is a large area of sand, which is consistent with the light, even backscatter returns from South Area.

Throughout the whole of North Area there is evidence of commercial fishing activity, trawl scars from Otter Trawl doors can clearly be seen across all sediment types (figure 7). During the survey a large number of small, local, commercial fishing boats were seen operating on the mixed sediments to the north of the rocky reef areas. This suggests that the sediments are more compacted and less mobile than the sands found in South Area.

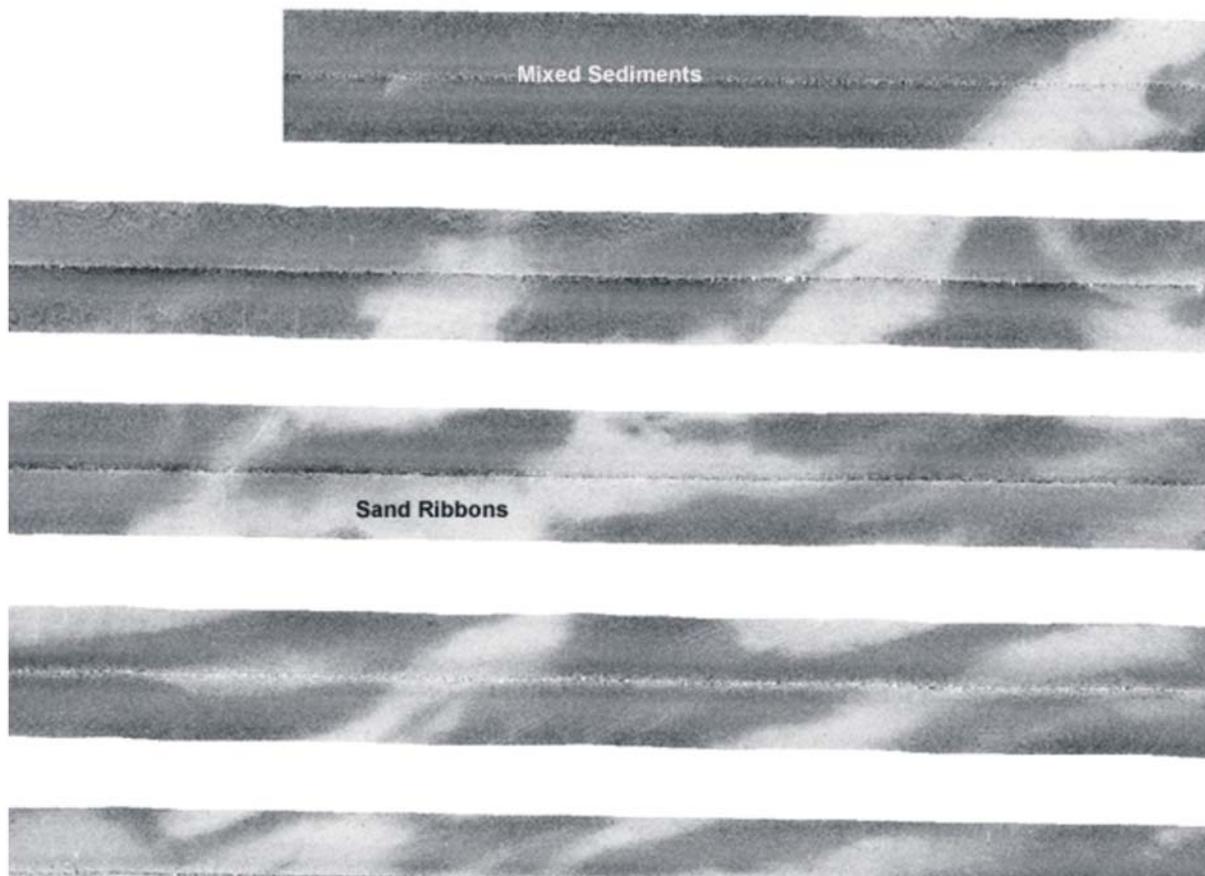


Figure 6. Sidescan sonar image of mixed sediments and sand ribbons

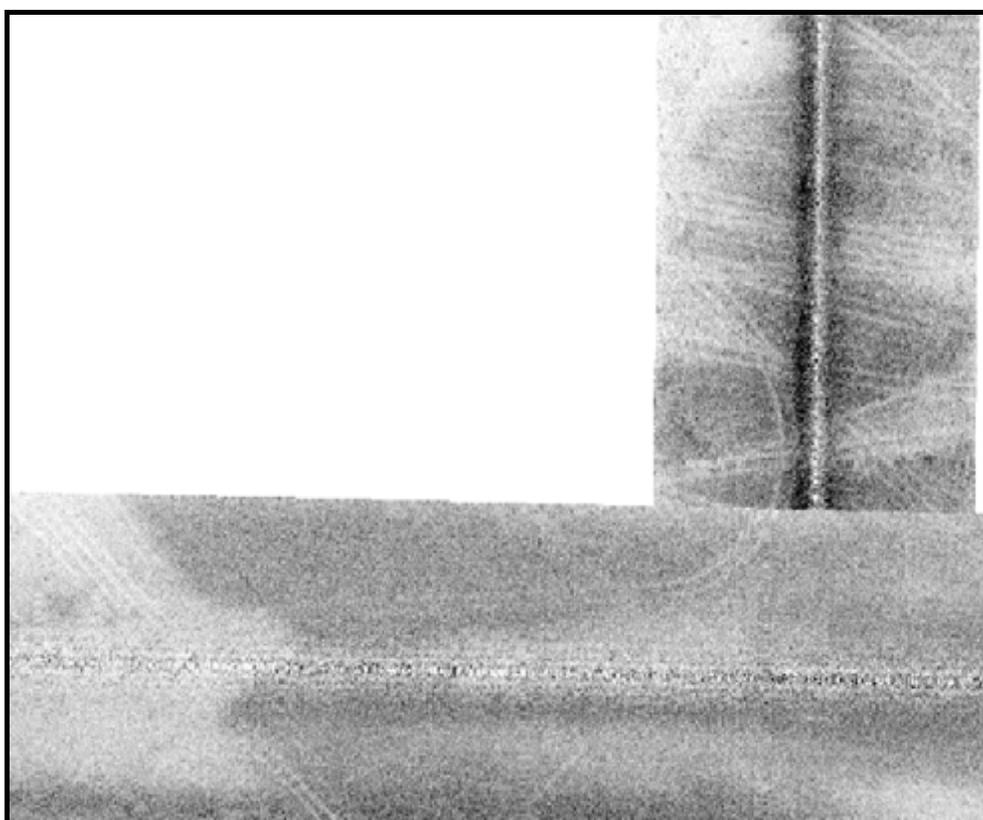


Figure 7. Sidescan sonar image of soft sediments and trawl marks.

To the north east of the survey area is North Mud. This location was named based on existing sediment information available from the British Geological Society (BGS), and was an area where muddy sediments were predominately found. The muddy sediment were not easily detectable during the interpretation of the sidescan sonar results which showed an area of even, light to mid backscatter that could very easily be to classify as sand rather than mud. Ground-truthing with the camera was required to assess these results fully.

### 3.1.4 MESH – additional survey area

The final survey sub-area was MESH, which was surveyed at shorter line spacing as part of the MESH project, whilst also forming part of the overall SAC survey area. The MESH survey area comprised a region interpreted as mixed, soft sediment to the north of Eddystone Reef and east of Hand Deeps, as well as a part of Hand Deeps rocky reef (figure 8). The eastern part of the MESH Area is dominated by sand with mixed sediments being found in patches within the sandy sediments (figure 8).

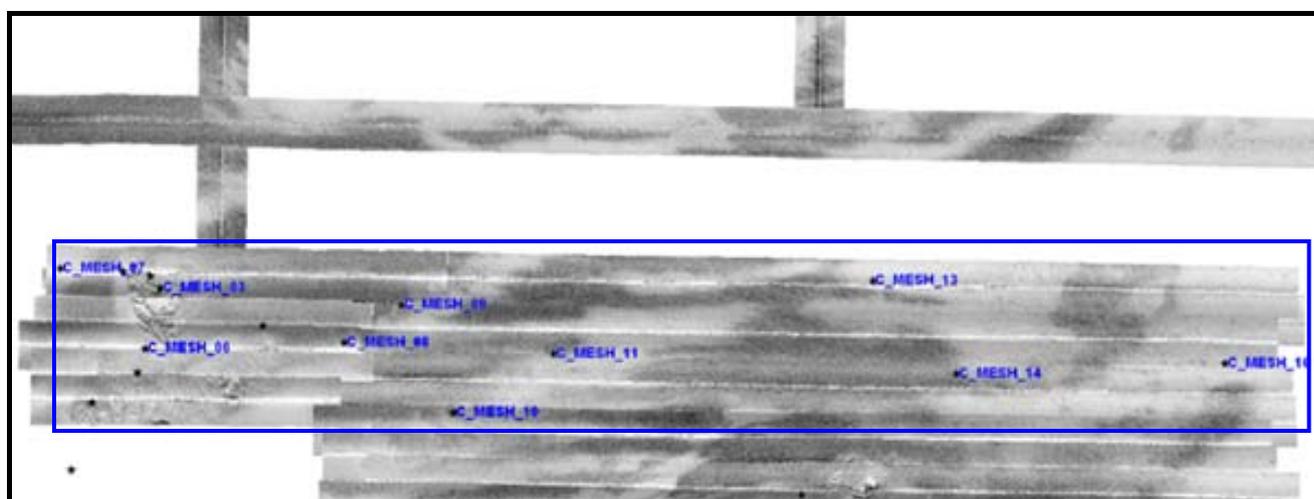


Figure 8. MESH survey area (blue rectangle) with sidescan sonar mosaic and photographic survey locations.

The Quester Tangent Corporation seabed classification was carried out on the western section of the MESH Area (figure 9). The QTC unsupervised seabed classification (no prior knowledge of the substrata) was applied to approximately 11,000 data points from three sidescan sonar survey lines resulting in a total of 10 classes (figure 9) being generated (Preston, 2006a). As it was an unsupervised classification there is no detailed information of the substrata type in each class and further analysis (ground-truthing and other comparisons) is required to assess the results further.

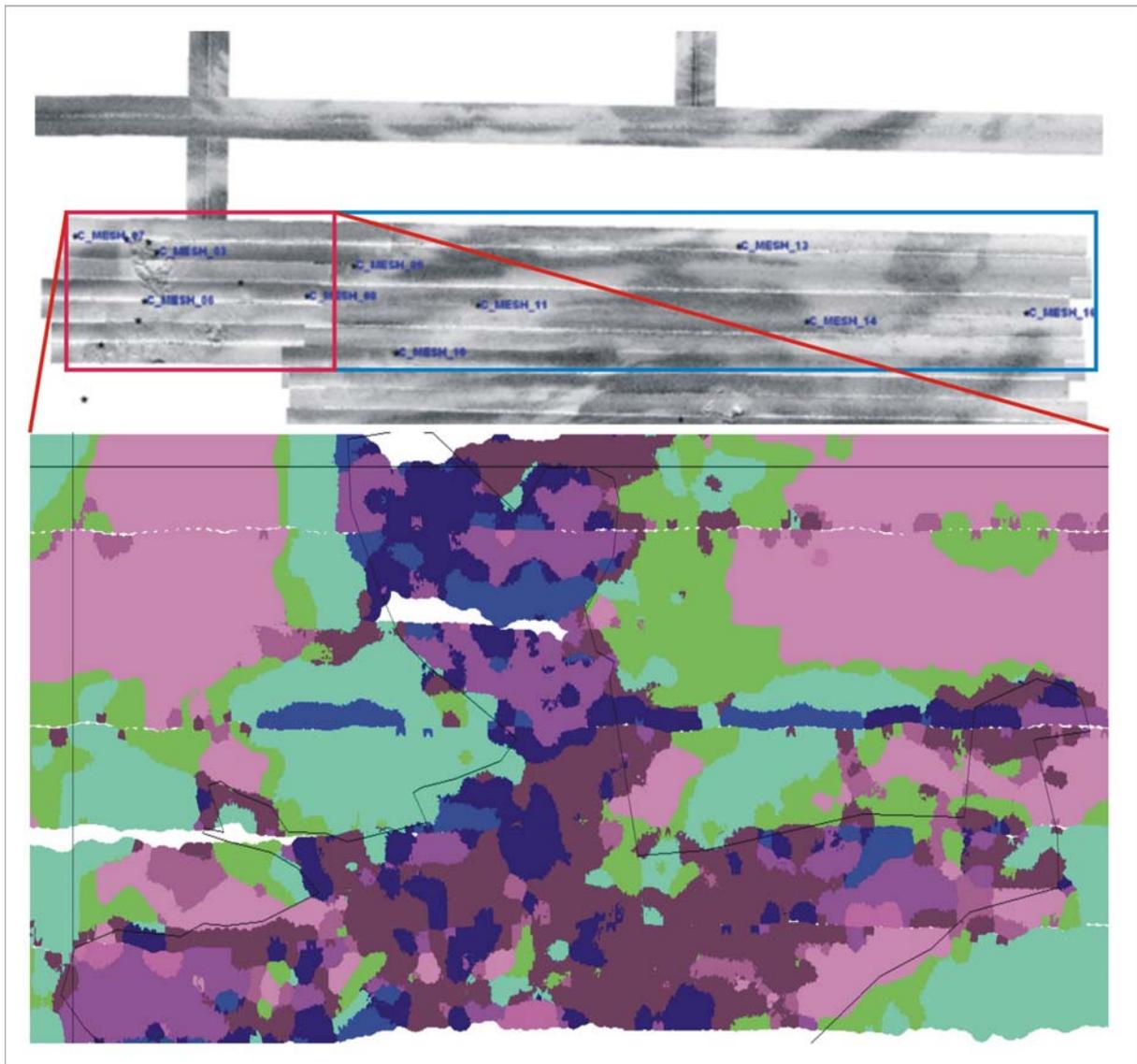


Figure 9. QTC seabed classification of the seafloor region part of MESH (the sidescan image illustrates the area (red rectangle) covered in the QTC analysis).

## 3.2 Photographic and video analysis – ground-truthing

### 3.2.1 Ground-truthing of the sidescan sonar imagery

A total of 17 miniDV tapes with over 14 hours of video footage were recorded during the drop-down camera survey and a total of 1019 still photographs were taken at 57 different sites (table 1). Figure 10 shows the sidescan sonar mosaic with the locations of the drop-down camera sites (black circles). The site names are abbreviated as follows: Eddystone Reef = ER; Hand Deepes = HD; Bed Rock = BR; South Rock = SR; Middle Rock = MR; North Area = N; North Mud = NM; and C stands for camera (not all sites are labelled to avoid confusion and to make the image as clear as possible). The numbers are simply the site numbers in each area.

Area/location	Number of sites	Video duration (miniDV) recorded	Number of still photographs
Eddystone Reef	5	01:35:02	77
North Mud	4	02:13:02	110
MESH	12	02:10:59	172
Hand Deepes	9	02:09:58	210
North Area	10	02:22:09	168
Hat Rock	4	00:57:00	73
Middle Area	3	00:27:03	33
South Rock	1	00:40:10	14
Bed Rock	6	01:25:16	114
Middle Rock	3	00:26:13	48
<b>TOTAL</b>	<b>57</b>	<b>14:26:52</b>	<b>1019</b>

Table 1. Number of sites visited and photographs taken in the different study areas during the drop-down camera survey.

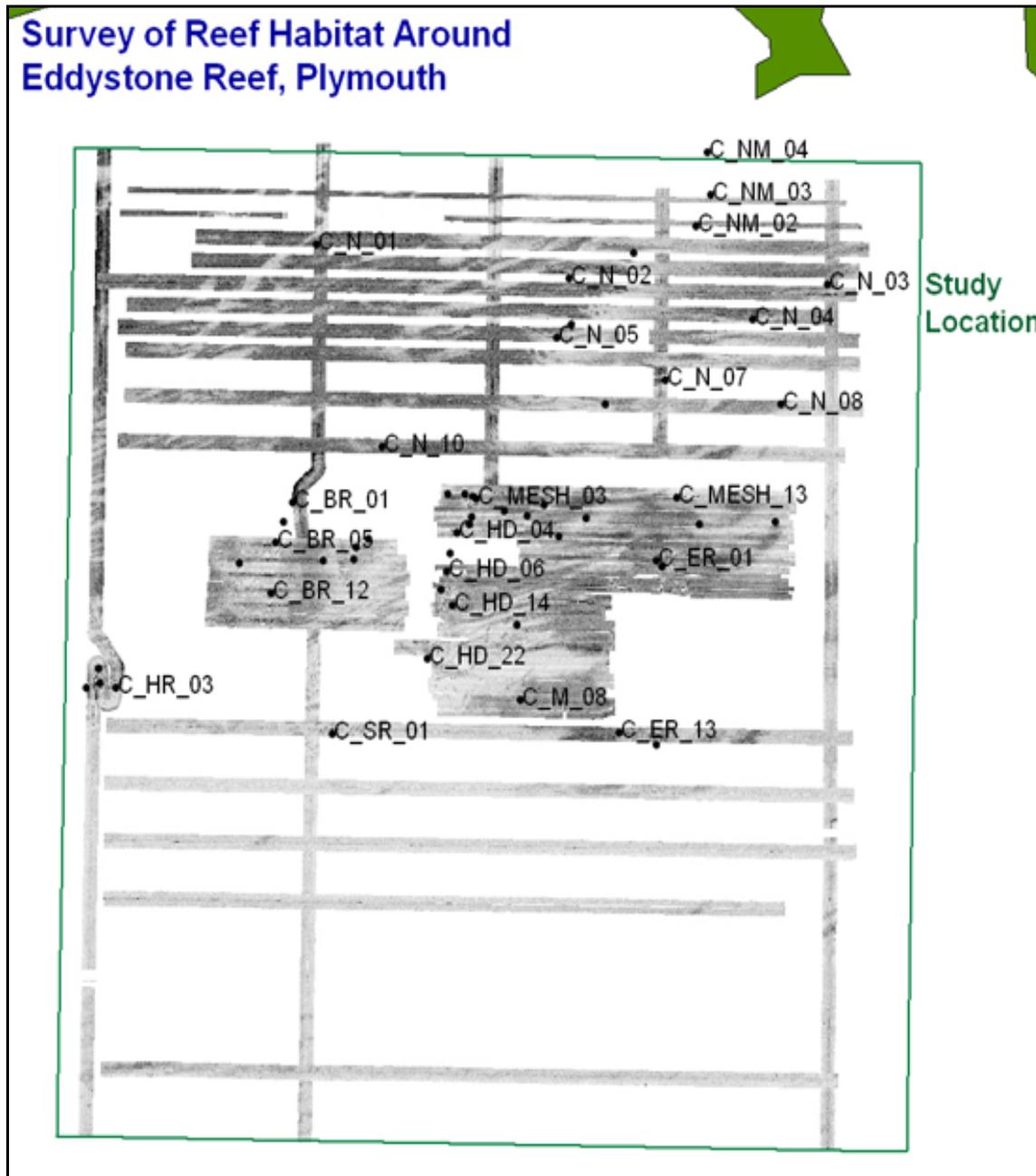


Figure 10. Drop-down camera sites (black circle) with some site names (e.g. C\_HR\_03 stands for Camera\_Hand Deeps\_site number 3) on sidescan sonar mosaic.

The analysis of the sidescan sonar mosaic together with the ground-truthing using the photography and video records allowed for a more detailed assessment of the habitats at Eddystone Rocks and the surrounding area. The interpretation of the sidescan sonar mosaic (figure 11) together with the ground-truthing (see examples of photographs in figure 12) reveals three main and distinct substrata: 1) the large area to the north (in blue) of the survey area (North Area) which has been identified through ground-truthing to predominantly be mixed sediments (gravel, sand, mud and shell); 2) the light blue area predominantly in the south (South Area) which has been identified as sand; and 3) the dark green areas (Middle Area) which are identified as rocky reefs dominated by bedrock and boulders. Within the North Area mixed sediments comprising mud, sand, gravel and shell in various quantities are dominant in the west while sandy sediments dominate the area to the east (figure 10). The mixed sediments are interspersed with patches of sand and gravel as well sand or sand and

shell, with sand ribbons also being present (figure 6). The large area of sand to the east of North Area is consistent with the light, even backscatter returns from South Area and the sediment type is confirmed using the photographic material.

In addition to these three main types of substrata, there are an additional 5 smaller features (see figure 11). Of note is a small gravel area centrally within the North Area coloured orange; North Mud which is in the north-eastern part of the North Area and is dominated by mud and burrows; and finally an area dominated by rock/sand (yellow) in the northern part of the South Area. The latter appeared as a patch of darker and coarse backscatter on the sidescan sonar image (given the name of South Rock; see figure 3) and on inspection with the camera system it was discovered that this was an area of exposed rock just braking through the surrounding sediment, which consisted of a mix of sand, gravel and broken shell.

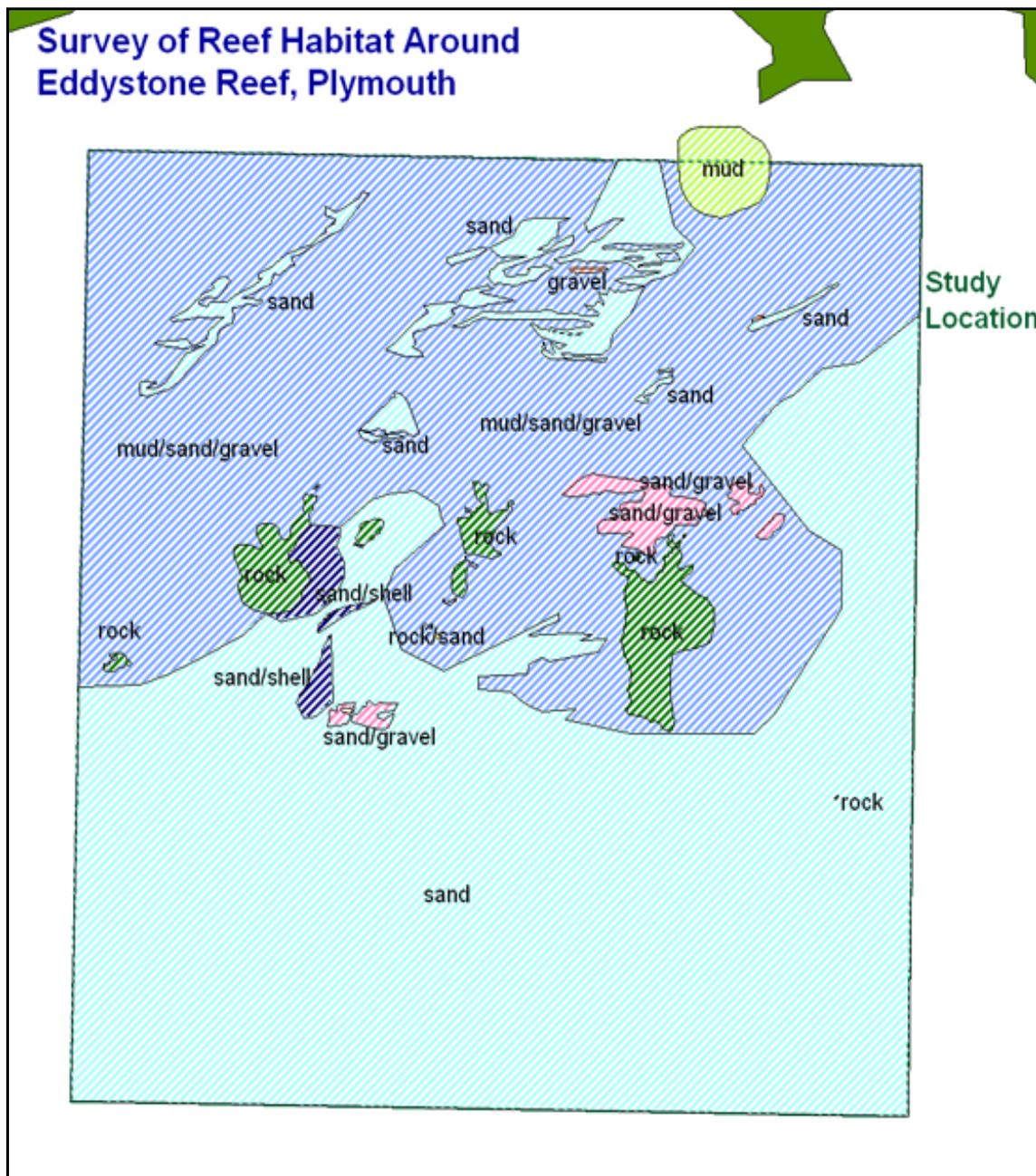


Figure 11. Interpretation of the sidescan sonar mosaic: dark blue: sand with shell; navy blue: mixed sediments of gravel, sand, mud and shell; light blue: sand; red: sand and gravel; orange: gravel; dark green: rock; light green: mud; yellow: rock/sand.

### 3.2.2 General descriptions of the biological communities at Eddystone Rocks and the surrounding areas

All the photographs were analysed and a total of 104 different taxa (appendix 4) were observed and identified (see identification keys and guides in section 6.2) and a species list produced with the SACFOR abundance scale (appendix 4). A summary of the results is given in table 2 and examples of the photographs from the different areas are given in figure 12.

Area/location	Main substrata	Main fauna	Dominant biotope
Eddystone Reef	Bedrock and boulders	<i>Alcyonium digitatum</i> , <i>Eunicella verrucosa</i> , <i>Holothuria forskali</i> , <i>Echinus esculentus</i>	CR.HCR.XFa.ByErSp.Eun
North Mud	Mud	<i>Turritella communis</i> , <i>Peachia cylindrical</i> , <i>Asterias rubens</i>	SS.SMx.CMx and SS.SSa.CFiMu
MESH	Mud, sand, gravel	Hydroids, bryozoans and polychaetes	SS.SCS.CCS and SS.SMx.CMx
Hand Deepes	Bedrock and boulders	<i>Alcyonium digitatum</i> , <i>Eunicella verrucosa</i> , <i>Holothuria forskali</i> , <i>Echinus esculentus</i>	CR.HCR.XFa.ByErSp.Eun
North Area	Mud, sand, gravel	Hydroids, polychaetes and <i>Turritella communis</i>	SS.SMx.CMx
Hat Rock	Bedrock and boulders	<i>Alcyonium digitatum</i> , <i>Eunicella verrucosa</i> , <i>Holothuria forskali</i> , <i>Echinus esculentus</i>	CR.HCR.XFa.ByErSp.Eun
Middle Area	Mud, sand, gravel	Hydroids and polychaetes	SS.SCS.CCS and SS.SMx.CMx
South Rock	Bedrock	<i>Eunicella verrucosa</i> , <i>Ophiocolina nigra</i> , hydroids and anemones	CR.HCR.XFa.ByErSp.Eun
Bed Rock	Bedrock and boulders	<i>Alcyonium digitatum</i> , <i>Eunicella verrucosa</i> , <i>Holothuria forskali</i> , <i>Echinus esculentus</i>	CR.HCR.XFa.ByErSp.Eun
Middle Rock	Bedrock and boulders	<i>Alcyonium digitatum</i> , <i>Eunicella verrucosa</i> , <i>Holothuria forskali</i> , <i>Echinus esculentus</i>	CR.HCR.XFa.ByErSp.Eun
South Area	Sand	Sparse; hydroids and sabellids	SS.SSa.CFiSa

Table 2. Summary of the video and photographic analyses with the main substrata, fauna and biotope in each area.

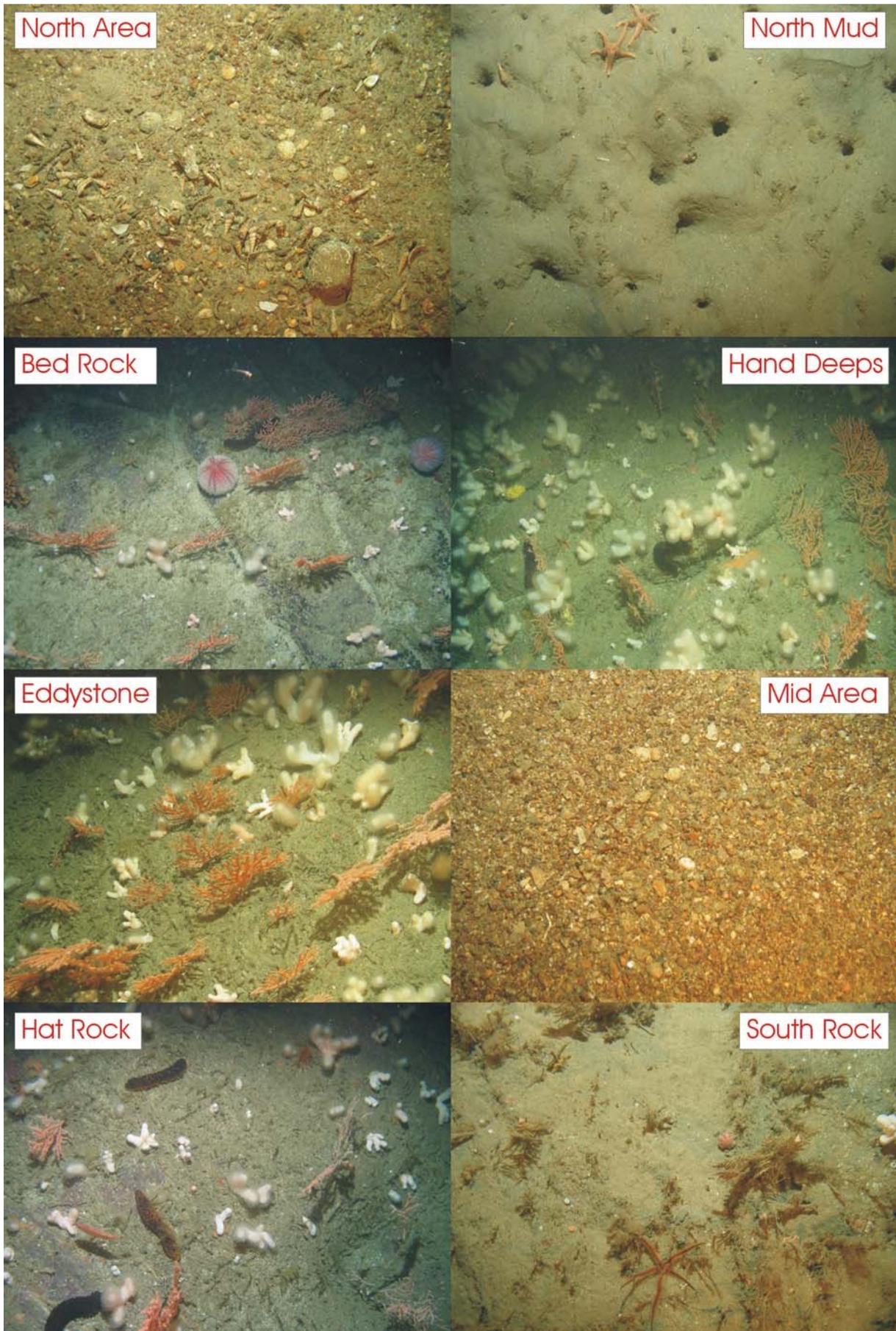


Figure 12. Photographs from the different areas of the Eddystone Reef survey.

The summary (table 2) and the photographs (figure 12) show that similar faunal communities are found on the reefs around Eddystone Rocks. Particularly characteristic fauna include the sea fan *Eunicella verrucosa*, the soft coral *Alcyonium digitatum*, the sea cucumber *Holothuria forskali*, the sea urchin *Echinus esculentus* and the sponge *Cliona celata*. Anemones such as *Corynactis viridis* and *Caryophyllia smithii* as well as hydroids such as *Nemertesia antennina* and *N. ramosa* were also common on the reef areas. Only one specimen of *Alcyonium glomeratum* was observed (C\_ER\_01\_15), although other individuals may be present.

The main reef biotope is CR.HCR.XFa.ByErSp.Eun but a kelp park biotope is found at the shallowest sites (20 to 27 m) within the survey (table 3). This biotope is designated IR.HIR.KSed.LsacSac as it is characterised by sparse populations of both *Laminaria* spp. and red foliose seaweeds (figure 13). The faunal composition is similar to that of CR.HCR.XFa.ByErSp.Eun and includes taxa such as *Nemertesia* spp., *Alcyonium digitatum*, *Holothuria forskali*, *Echinus esculentus* and *Cliona celata* but *Eunicella verrucosa* is not observed.

Area/location	Sites and photographs with kelp	Depth (m)
Eddystone Reef		
North Mud		
MESH	MESH_03_14	26 m
Hand Deeps	HD_04_30 to HD_04_36	20 – 24 m
North Area		
Hat Rock	HR_02_06 and 07	26.9 – 27.4 m
Middle Area		
South Rock		
Bed Rock		
Middle Rock		

Table 3. Sites and photographs with the kelp biotope IR.HIR.KSed.LsacSac.



Figure 13. Kelp park habitats in two locations (HR\_02\_07 and HD\_04\_32) part of the Eddystone Reef survey.

Jewel anemones are common in some parts of the reef areas contributing to the designation of the additional biotope CR.HCR.XFa.CvirCri. This biotope is present in all six reef areas (table 4) and it is characterised by dense populations of *Corynactis viridis* (figure 14) but other fauna such as *Nemertesia* spp., *Alcyonium digitatum*, *Holothuria forskali* and *Echinus esculentus* are also present. It also appears as if this biotope is particularly common on vertical bedrock walls and boulders. Depth does not, however, appear to be a main factor in the distribution of this biotope as the depth range varies considerably from around 26 m to 54 m (table 4). Note the mixed biotope in figure 14 'Eddystone' where *Corynactis viridis* is found

on the vertical wall on the right while *Eunicella verrucosa* and other fauna are present on the flat bedrock surfaces on the left side of the image.

Area/location	Sites and photographs with kelp	Depth (m)
Eddystone Reef	<i>ER_01_15, ER_13_20, ER_13_27, ER_13_28, ER_14_03, ER_14_07, ER_14_09</i>	47, 43, 41, 43, 52, 42 and 42 m
North Mud		
MESH	<i>MESH_03_13, MESH_06_10, MESH_06_11, MESH_06_12</i>	26, 41, 40 and 42 m
Hand Deeps	<i>HD_04_24, HD_04_27, HD_16_10</i>	28, 30 and 46 m
North Area		
Hat Rock	<i>HR_01_12, HR_02_05, HR_02_10, HR_03_16, HR_03_31</i>	48, 32, 37, 48 and 54 m
Middle Area		
South Rock		
Bed Rock	<i>BR_05_12 and BR_05_13</i>	36 m
Middle Rock	<i>MR_01_14, MR_01_15, MR_01_16, MR_02_03, MR_02_06</i>	44, 47, 47, 39 and 39 m

Table 4. Sites and photographs with the *CR.HCR.XFa.CvirCri* biotope or a mixture of *CR.HCR.XFa.CvirCri* and *CR.HCR.XFa.ByErSp.Eun* (mixed biotopes in italics).

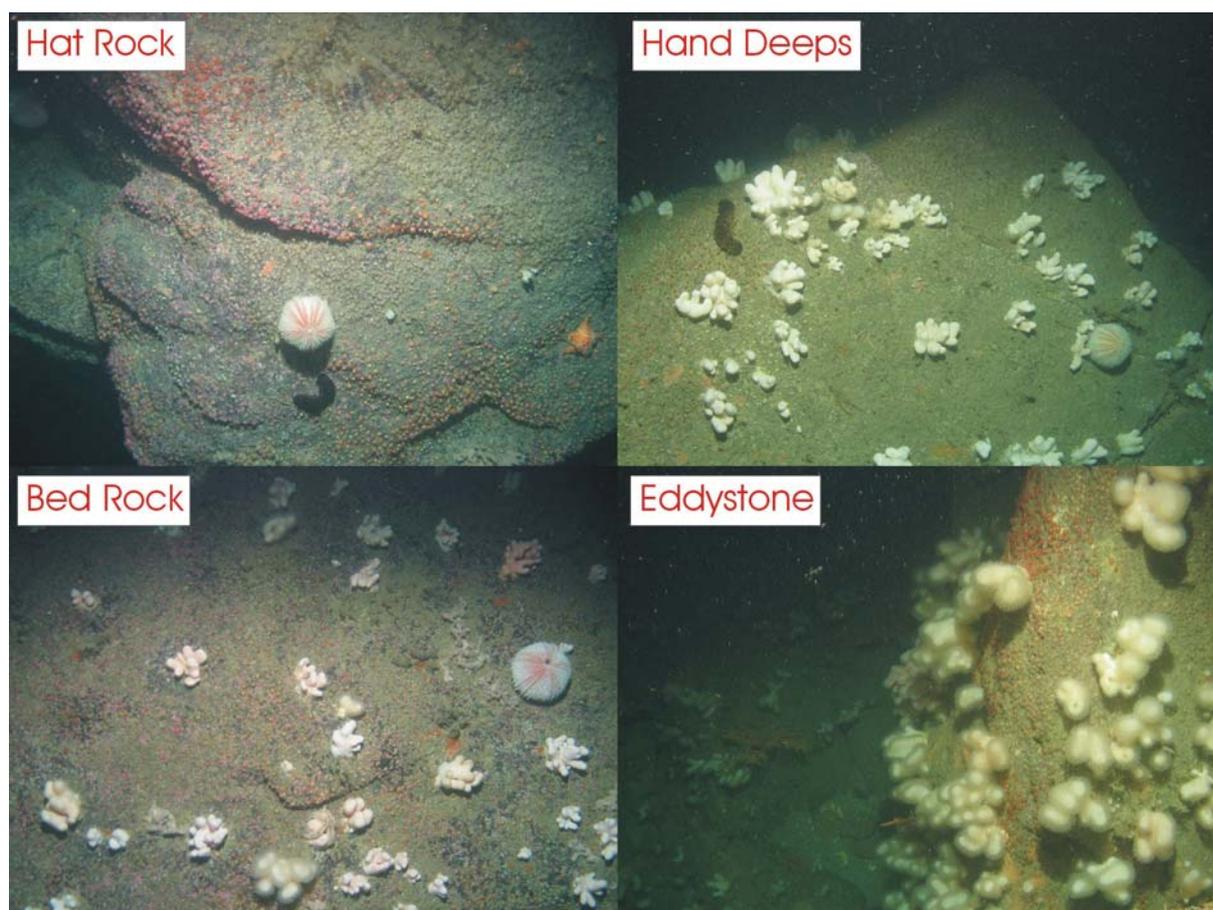


Figure 14. Jewel anemones (*Corynactis viridis*) at various sites (*HR\_02\_10, HD\_16\_10, BR\_05\_13 and ER\_01\_15*) around the Eddystone Reef survey area.

The analysis of the photographic and video material collected during the Eddystone Reef study show that both faunal distributions and the habitats appear to be very similar throughout these reef areas. This suggestion is reinforced by the designation of these habitats into three bedrock biotopes and only finer details in the faunal distributions determine the sub-biotope designation. The biotopes all represent habitats on wave-exposed, vertical or steep, circalittoral bedrock or large boulders, usually subject to moderate or strong tidal streams. These biotopes are commonly found on rocky outcrops, surrounded by coarse sediment and in the case of the kelp biotope (IR.HIR.KSed.LsacSac) these sediments restrict the floral taxa to fast-growing, opportunistic kelps *Laminaria saccharina* and/or *Saccorhiza polyschides* and prevent a longer-lived forest of *Laminaria hyperborea* from becoming established as a result of the scouring effects around the reefs (Connor *et al.*, 2004).

On the reef areas there are other faunal distributions of note including the presence of *Ophiothrix fragilis* in parts (figure 15) of Eddystone Reef. This taxon is superabundant at site ER\_01, which is on the north-western tip of Eddystone reef (figure 10), but not seen anywhere else on the reef. However, as a result of the large size of the study area and the limited time allocated for the survey, only two deployments were carried out on the northern part of Eddystone reef area. *Ophiothrix fragilis* may therefore be present in other areas of the reef but further sampling is required to assess the distribution of *Ophiothrix fragilis* further.



Figure 15. *Ophiothrix fragilis* at ER\_01 on the north-western tip of Eddystone Reef.

Other fauna of note include scallops which were observed in parts of the South, Middle and North Areas. This group may be one of the target species by fishermen in the area. Of note is also the rich sponge community at Bed Rock. *Cliona celata*, *Polymastia boletiformis*, *Stelligera* sp. and other sponges were common at several sites but particularly at BR\_09, BR\_12 and BR\_03 & 04. Most of the sites are on the northern aspect of the reef but BR\_12 is in the middle and on top of the reef. Additional sampling all around the reef is required to assess whether this rich sponge community is widely distributed on Bed Rock.

South Rock (figure 16) was a feature identified for further investigation using the drop-down camera as the sidescan sonar trace suggested South Rock to be an area of bedrock. On inspection with the camera system it was confirmed that this was an area of exposed rock covered in a thin veneer of sediment or rock just braking through from the surrounding sediment, which consisted of a mix of sand, gravel and broken shell. The bathymetry was virtually unchanged across South Rock. The fauna was dominated by hydroids but other fauna known to be characteristic from the reef areas were also present. Both the sea fan *Eunicella verrucosa* and the soft coral *Alcyonium digitatum* were present but they were both sparser in number and generally smaller in size compared to other areas around the Eddystone Rocks study area. The echinoderms that were commonly found on the other reefs

(*Holothuria forskali* and *Echinus esculentus*) were not found at South Rock but *Ophiocomina nigra* was present (c. 1 individual/m<sup>2</sup>). Of note is also the presence of *Antalis entalis* at South Rock, a species reported to have disappeared from the Eddystone Rocks area in the 1960s (Holme, 1966). As a result of the limited time available for sampling this large survey area, only one site was sampled in the South Area. *Antalis entalis* may therefore be present in other parts of the region and additional sampling programmes (e.g. photographic and biological sampling) are required to assess the distributions of this taxon fully but also to investigate whether live individuals are present (e.g. biological sampling).



Figure 16. The seabed environment at South Rock.

The features seen at South rock, where 'typical' reef fauna, such as sea fan *Eunicella verrucosa* and the soft coral *Alcyonium digitatum*, were present on soft sediments was noticed in several sections of the Eddystone Rocks area including Hand Deep (HD\_01\_32), the MESH Area (MESH\_04\_23) and Eddystone Reef (ER\_13). The latter is a particularly good example of a seabed classified as rock during the sidescan sonar analysis with high backscatter returns across the reef (see the GIS). The photographic material from areas of high backscatter (interpreted as rocky reef), however, revealed large areas of soft sediment (SS.SCS.CCS) and the bathymetry data illustrated only small variations in depth across this section. Sediment (SS.SCS.CCS) was observed in the beginning of the photographic transect until photograph number 11, at which point no photographs were taken until the reef was reached at photograph number 12. The video material does however show soft sediments across this entire section (i.e. between photograph 11 and 12) section, an area clearly generating high backscatter returns (see figure 10 or the GIS for more detail) on the sidescan sonar imagery. These backscatter returns are distinct and have been interpreted as rocky reef. These sediments are therefore most likely similar to those seen at South Rock in that a thin veneer of sediment is most likely covering a rocky outcrop and it is possible that this sediment veneer is mobile, covering the rocky outcrops during some periods but perhaps not all the time. Note, however, that although the typical reef fauna is present in these locations, the abundance is lower than that observed on the rocky reefs suggesting a transient sediment veneer or that this layer has appeared relatively recently.

North Mud (figure 17) was known from information available from the British Geological Society (BGS), to contain predominately muddy sediments but these were not easily detectable during the interpretation of the sidescan sonar images. In retrospect an area of even, light to mid backscatter can be detected, but it would be very easy to classify this area as sand rather than mud. The photographs do, however, show mixed sediments with a proportion of mud being present. Sites NM\_03 and NM\_04 are located in the North Mud while the other sites are found in the North Area slightly south of North Mud (see figure 10). The photographs from the sites in North Mud illustrate a particularly high proportion of mud with large numbers of burrows being present (see figure 12). Mud is also present in the other

sites but the concentration of burrows is lower (table 5). The originators of these burrows are unknown as no fauna was seen associated with them but the visible fauna in this area was dominated by *Turritella communis*, *Peachia cylindrical* and *Asterias rubens*. Of note is again the presence of *Antalis entalis* in North Mud but this taxon was only observed at one site (NM\_01) in this area and these individuals may be dead. However, this taxon was found at higher abundance (1-9 individuals/m<sup>2</sup>) at three other sites within the North Area (sites MESH\_16, N\_07 and N\_08) indicating that this taxon has returned to the region in recent times.

Site	Number of burrows	Burrow concentration	Depth (m)
NM_01	123	3.4	52 m
NM_02	67	3.7	49 m
NM_03	483	16.6	47 m
NM_04	332	14.4	43 m

Table 5. Burrow concentration (burrows / m<sup>2</sup> assuming 1 m<sup>2</sup> per frame) at sites in North Mud (the total number of burrows in all the photographs and depth is the approximate depth in all the photographs).

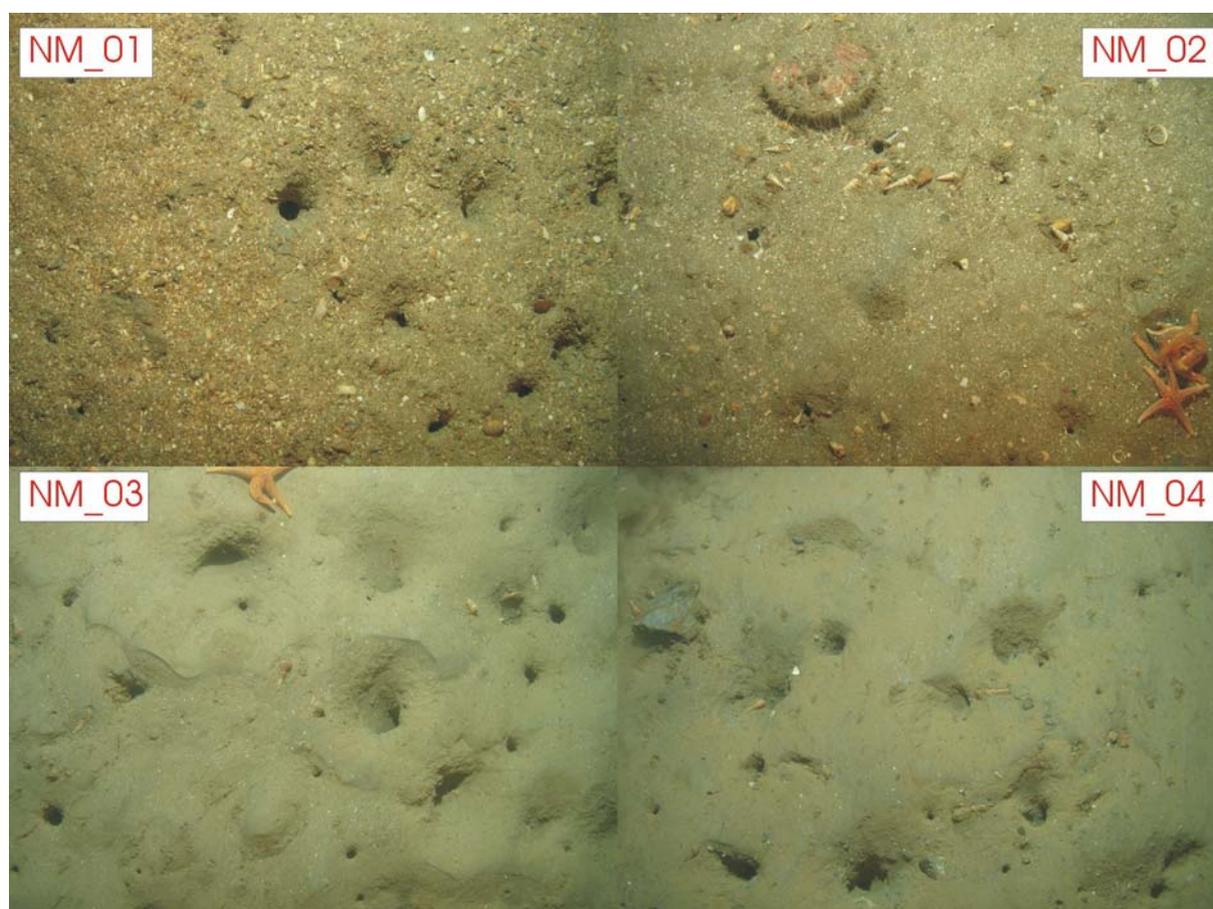


Figure 17. The seafloor environment at North Mud (NM\_01\_33, NM\_02\_05, NM\_03\_16 and NM\_04\_14).

The sidescan sonar images do not reveal any apparent physical evidence of fishing activities on the reefs or elsewhere in the study area but fishing vessels were observed operating (deploying and retrieving pots) in the area (pers. observation) during both the sidescan sonar and camera surveys. Some damage has, however, been observed (figure 18) on the reefs but whether these impacts are directly linked to fishing is difficult to verify.

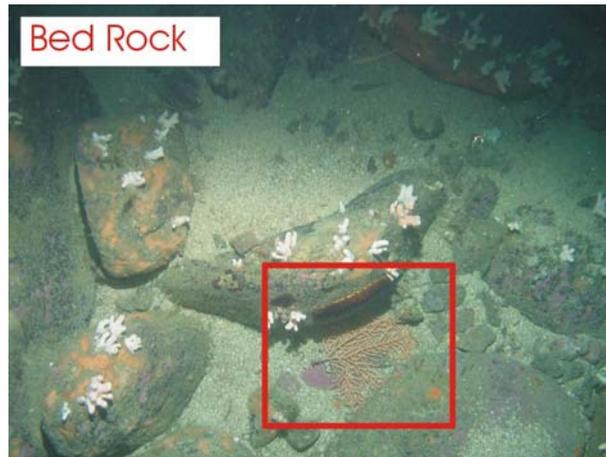


Figure 18. Broken sea fan (*Eunicella verrucosa*) on the seabed at Bed Rock (BR\_09).

The analysis of the photographs and video material and the classification of the photographs into designated biotopes have resulted in a considerable amount of detail about the habitats at Eddystone Rocks and the surrounding areas. Some of this detail is difficult to illustrate and a habitat map has therefore been produced (figure 19). This habitat map illustrates the main features identified during this survey with several rocky outcrops identified as 'reefs' and a number of sediment habits surrounding these reefs. Apart from the six main reefs described above, there are also a number of smaller rocky outcrops visible on the sidescan sonar imagery. The biological communities at these locations are unknown as no ground-truthing was carried out due to the limited time available. However, considering the similarities seen at all the other reefs, the biological communities at the smaller rocky outcrops are likely to be similar.

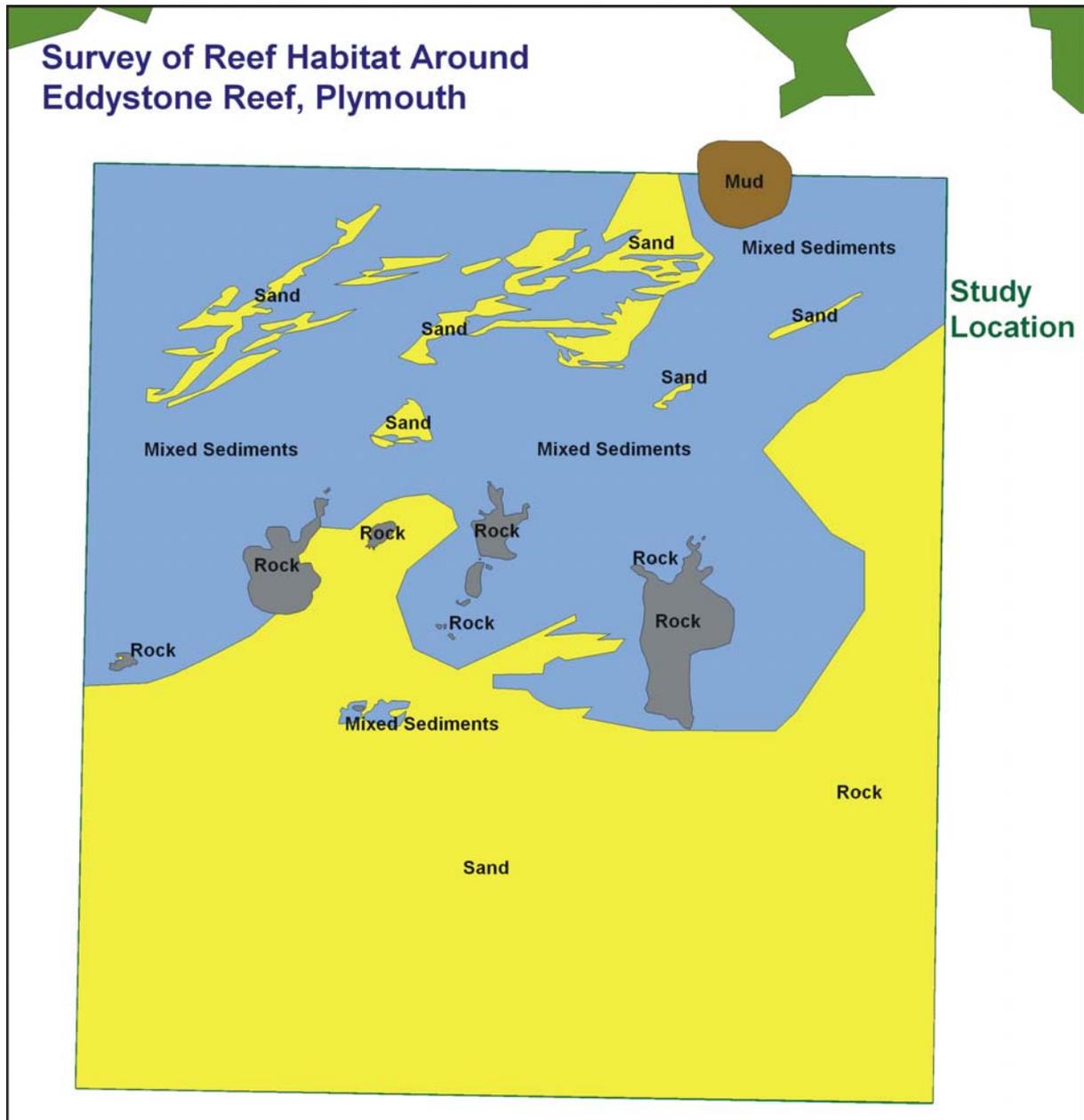


Figure 19. Habitat map of the Eddystone Reef study area.

### 3.3 MESH – additional analysis and results

The QTC seabed discrimination analysis generated 10 different classes (see figure 9) with 6 classes generated over the reef areas and 5 different classes on the sediments (one class, blue, was present across both the reef and the sediment areas). These were superimposed on the sidescan sonar imagery (figure 8) in the GIS (see GIS for more details) together with the sediment interpretations (see figure 11) and the locations of the photographs (see figure 10). A preliminary analysis of the results shows that there are some similarities between the results obtained through traditional survey techniques and those generated by QTC (figure 20). The rocky reef identified in the sidescan sonar and photographic material has been classified into three main biotopes and there appears on first inspection that some similar patterns are found within the QTC data (6 classes on the reef). The features seen in the surrounding soft sediment also appear to have some similarities where the two main

sediment types (light blue and pink) are apparent on the sidescan sonar imagery. The photographs, however, indicate that this sediment essentially is the same throughout the area (classified as SS.SCS.CCS), even where there is a photographic transect across an apparent QTC sediment boundary. To study these patterns further, some additional statistical analyses were carried out.

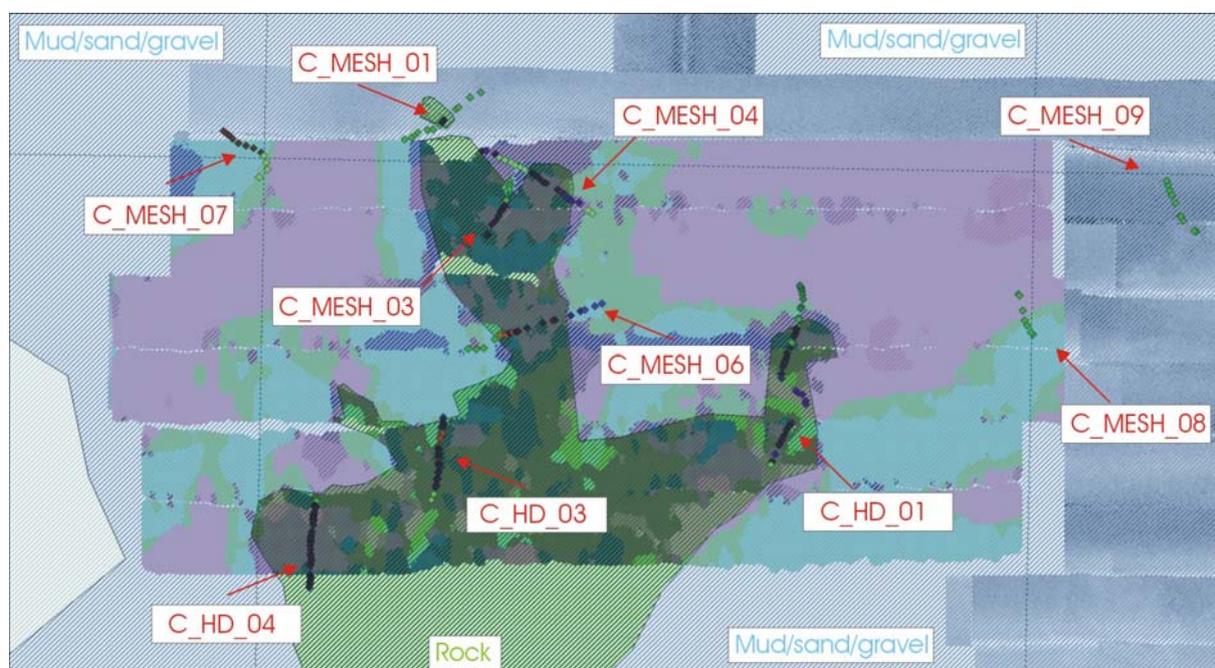


Figure 20. The seafloor region part of MESH with QTC classes, photographic sampling sites (with labels), sidescan sonar imagery and GIS classification (light green: rock and light blue: mud/sand/gravel - see GIS for more details). There is no legend for the QTC classes as these classes are generated from the sidescan sonar backscatter data and ground-truthing is required to verify the type of substratum present.

### 3.3.1 Univariate and multivariate analyses of the biological data

#### 3.3.1.1 Univariate analysis

The univariate analysis revealed an overall low species diversity among the sites included in the MESH study. The sites with the highest species diversity (table 6) were found within the rocky reef habitats although relatively high species diversity was also found on a number of photographs classified as SS.SMx.CMx and SS.SCS.CCS. The lowest species diversity was found at photographs classified as SS.SCS.CCS including sites MESH\_01, MESH\_03, MESH\_06 and MESH\_08.

Photograph	S	N	d	J	H' (log <sub>e</sub> )
C HD_03_07	12	58	2.71	0.86	2.13
C HD_03_12	10	62	2.18	0.91	2.10
C MESH_06_15	13	55	2.99	0.81	2.07
C HD_01_17	12	69	2.60	0.82	2.03
C MESH_07_04	8	11	2.92	0.97	2.02
C HD_04_35	11	76	2.31	0.81	1.94
C HD_03_03	10	89	2.01	0.81	1.86
C HD_01_25	9	68	1.90	0.85	1.86
C MESH_07_07	7	13	2.34	0.95	1.84
C MESH_07_09	8	14	2.65	0.88	1.83
C MESH_04_03	14	132	2.66	0.69	1.82
C HD_03_20	9	75	1.85	0.82	1.81
C HD_04_32	11	40	2.71	0.75	1.79
C MESH_04_13	11	179	1.93	0.74	1.78
C HD_01_42	10	86	2.02	0.76	1.74
C MESH_06_19	8	25	2.17	0.84	1.74
C MESH_07_14	6	8	2.40	0.97	1.73
C MESH_04_16	14	87	2.91	0.65	1.72
C HD_04_28	9	73	1.86	0.78	1.71
C HD_03_21	10	160	1.77	0.74	1.71
C MESH_04_04	8	34	1.99	0.82	1.70
C HD_01_35	6	34	1.42	0.95	1.69
C MESH_03_06	7	23	1.91	0.84	1.64
C HD_04_25	10	110	1.91	0.71	1.64
C MESH_01_06	6	25	1.55	0.91	1.63
C HD_04_18	9	115	1.69	0.73	1.61
C MESH_04_06	10	131	1.85	0.70	1.60
C HD_01_39	10	106	1.93	0.68	1.57
C MESH_06_20	8	21	2.30	0.75	1.56
	CR.HCR.Xfa.ByErSp.Eun				
	SS.SCS.CCS				
	IR.HIR.KSed.LsacSac				
	SS.SMx.CMx				
	Mix of SS.SMX.CMx / CR.HCR.XFa.ByErSp.Eun				
	Mix of SS.SCS.CCS / CR.HCR.XFa.ByErSp.Eun				

Table 6. Species diversity (the total number of individuals (N), total number of species (S), Shannon-Wiener species diversity (H' log<sub>e</sub>), Pielou's (J) and Margalef's (d) diversity indices) of the top 30 photographs (i.e. highest diversity) from areas within the QTC discrimination map. The biotope classification of each photograph has also been added in colour codes.

The results of the univariate analysis do not appear to give any clear divisions according to those generated by QTC and multivariate analysis is therefore required to assess these patterns further.

### 3.3.1.2 Multivariate analysis

The cluster analysis (figure 21) revealed a number of groups within the data (the ordination results support the clustering results). The first few clusters with very low similarity appear to have been grouped separately as a result of low numbers of individuals. In most cases there

are only one or two taxa present in these photographs ranging from a flatfish (HD\_03\_17), *Anseropoda placenta* (HD\_01\_44) and sabellid tubes (HD\_03\_08). Within the remaining data the main division is between photographs from the reef areas (red in figure 21) and those from the sediment areas (brown in figure 21). Within these divisions there are several sub-divisions and the soft sediment photographs (brown in figure 21) were further sub-divided into two main groups. Analysis of the data in these two groups revealed that one group (dark green) was virtually exclusively composed of photographs classified as SS.SCS.CCS (only two were not). The other group (pink) consisted of a mixture of sediments and biotopes but it was dominated by the SS.SMx.CMx biotope. SS.SCS.CCS was also present together with a number of mixed biotopes comprising SS.SCS.CCS / CR.HCR.XFa.ByErSp.Eun and SS.SSa.CFiSa / CR.HCR.XFa.ByErSp.Eun.

In the reef habitat several groups were clustered together. Some of the groups are fairly mixed but three main groups can be identified and the SIMPER analysis (table 7) revealed the dominant fauna in each group: 1) a large *Eunicella* reef group (yellow in figure 21), 2) the kelp group (group A in light green in figure 21) and 3) a jewel anemone group (group B in purple in figure 21). These three main groups were identified during the photographic analysis as there were fairly apparent differences in the fauna and flora between the groups (see above). These three groups were classified into biotopes where group 1 was classified as CR.HCR.XFa.ByErSp.Eun, group 2 was classified as IR.HIR.KSed.LsacSac and group 3 was classified as CR.HCR.XFa.CvirCri.

The large *Eunicella* group (CR.HCR.XFa.ByErSp.Eun) was further divided into several clusters (groups C – F) and the dominant fauna in each group have been identified using SIMPER (table 7). The SIMPER analysis (table 7) reveals subtle differences in the dominant fauna / flora between the groups and most of the main characteristic fauna (*Eunicella verrucosa*, *Nemertesia antennina*, *Alcyonium digitatum*, *Caryophyllia smithii*) for the CR.HCR.XFa.ByErSp.Eun biotope are present in all the groups. The main difference appears to be slightly different percentage contributions of each taxa as well as the contribution by one or two other specific taxa. Whether these subtle differences could explain the QTC results is difficult to assess. Note also that some caution is needed in the interpretation of the smaller sub-groups as described by Clarke and Warwick (1994), particularly because of the low numbers of individuals (n) present at many of the sites, and perhaps other factors are contributing to the patterns seen in the QTC results.

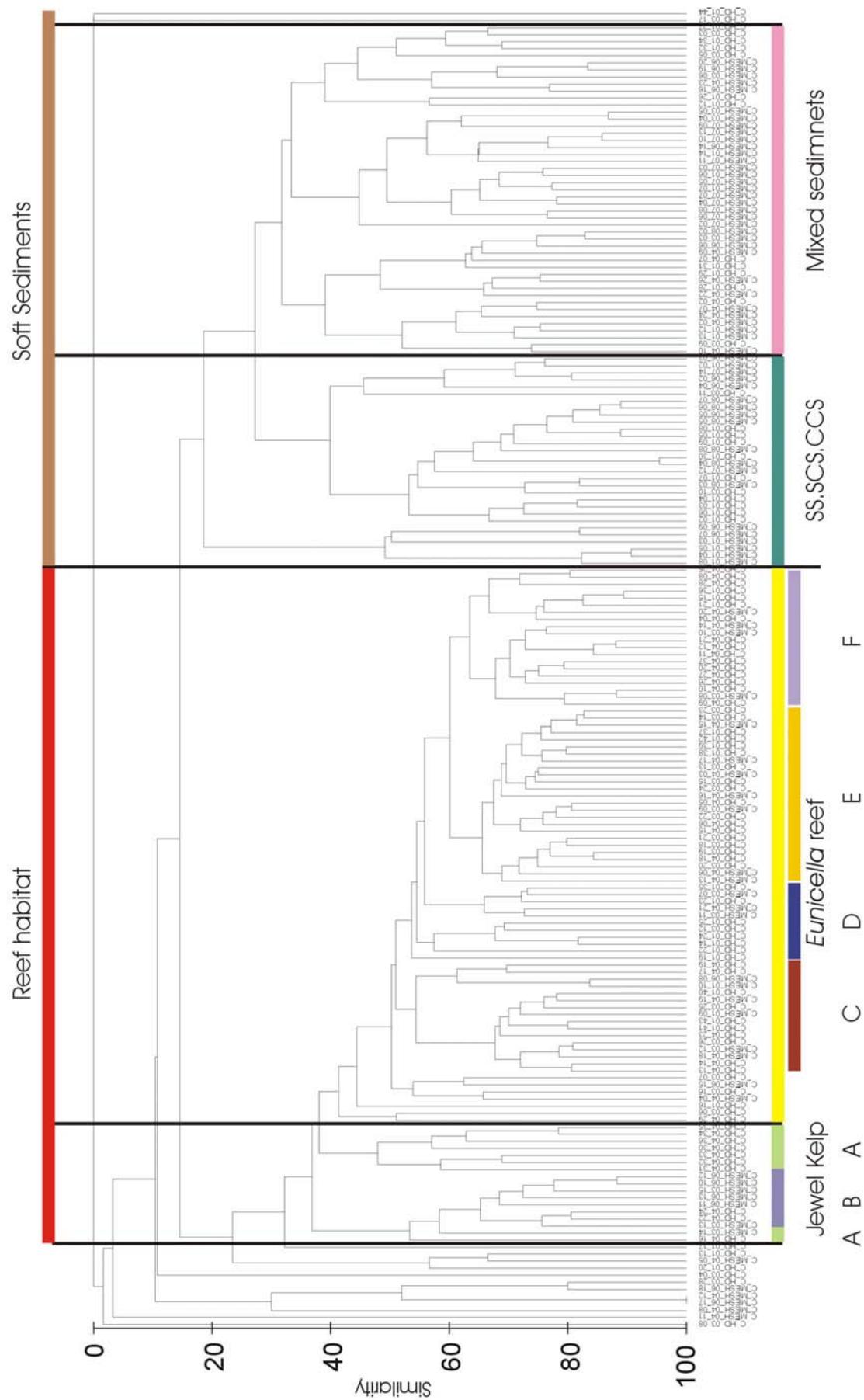


Figure 21. Cluster analysis of the photographs collected within the QTC analysis area.

Group	Taxa		% contribution	
<b>A</b>	<i>Alcyonium</i>	<i>digitatum</i>	46.9	
	<i>Caryophyllia</i>	<i>smithii</i>	19.4	
	<i>Laminaria</i>	<i>hyperborea</i>	16.3	
	<i>Nemertesia</i>	<i>antennina</i>	3.8	
	<i>Holothuria</i>	<i>forskali</i>	3.1	
	Brown algae		2.2	
	<i>Corynactis</i>	<i>viridis</i>	2.2	
	Red algae		1.5	
	PORIFERA	sp.	1.2	
	<i>Cliona</i>	<i>celata</i>	0.9	
	<i>Marthasterias</i>	<i>glacialis</i>	0.7	
	<b>B</b>	<i>Corynactis</i>	<i>viridis</i>	64.9
		<i>Alcyonium</i>	<i>digitatum</i>	31
<i>Caryophyllia</i>		<i>smithii</i>	1.1	
<i>Holothuria</i>		<i>forskali</i>	0.8	
<i>Echinus</i>		<i>esculentus</i>	0.6	
<b>C</b>		<i>Alcyonium</i>	<i>digitatum</i>	81.5
	<i>Eunicella</i>	<i>verrucosa</i>	8.2	
	Hydroid	sp.	3.5	
	<i>Holothuria</i>	<i>forskali</i>	1.4	
	PORIFERA	sp.	1.3	
	<i>Nemertesia</i>	<i>antennina</i>	1.2	
	Crisiidae	sp.	0.9	
	<i>Caryophyllia</i>	<i>smithii</i>	0.6	
	<b>D</b>	<i>Caryophyllia</i>	<i>smithii</i>	54.5
		Hydroid	sp.	16.5
<i>Alcyonium</i>		<i>digitatum</i>	8.2	
<i>Nemertesia</i>		<i>antennina</i>	7.5	
<i>Eunicella</i>		<i>verrucosa</i>	6.9	
PORIFERA		sp.	3.2	
<i>Abietinaria</i>		<i>abietina</i>	1.2	
<b>E</b>		<i>Alcyonium</i>	<i>digitatum</i>	54.7
	<i>Caryophyllia</i>	<i>smithii</i>	21.8	
	Hydroid	sp.	7.9	
	<i>Eunicella</i>	<i>verrucosa</i>	7.9	
	Crisiidae	sp.	2.1	
	PORIFERA	sp.	2.1	
	<i>Nemertesia</i>	<i>antennina</i>	2	
	<b>F</b>	<i>Caryophyllia</i>	<i>smithii</i>	63.8
<i>Alcyonium</i>		<i>digitatum</i>	18.1	
Hydroid		sp.	8.8	
<i>Nemertesia</i>		<i>antennina</i>	4.4	
<i>Eunicella</i>		<i>verrucosa</i>	3.6	

Table 7. SIMPER analysis of the 'reef habitat' clusters.

### 3.3.2 Environmental comparisons

The patterns among the classes generated by QTC do not appear to be explained by the faunal and floral distributions but an additional attempt to explain these has been carried out and the results from the cluster analysis has been compared to the environmental factors through BioEnv function in PRIMER (Clarke and Warwick, 1994). The environmental factors included type of substrata, depth and the aspect (North, South, East and West) of the photograph in relation to the reef.

Factor	Correlation (%)
Substrata	0.543
Aspect	0.159
Depth	0.108

Table 8. Results of the correlation analysis between the similarity coefficients (Bray-Curtis) and some environmental factors.

The results indicate that the type of substrata has the highest correlation with the clustering of the biological data but overall the values are low. Note, however, that there was a lack of some depth data (bathymetry) which may have affected the analysis as the logging of bathymetry unfortunately failed at some sites. In addition, there may be a need to study the aspect of every single photograph for a more complete assessment of the effects of aspect on the biological distribution.

### 3.3.3 Direct comparison between traditional survey techniques and seabed discrimination

#### 3.3.3.1 Sediment areas

There are two main photographic transects (MESH\_07 and MESH\_08) within the sediment areas and both appear to cross at least two QTC boundaries. The photographic evidence, however, indicate that there is only one type of sediment present at one site while two at the other.

The MESH\_08 photographic transect (figure 22) crosses three QTC boundaries (from light blue through light green to pink) but the photographs have all been classified as SS.SCS.CCS and there is no apparent or subtle difference between them. In the cluster analysis the photographs are all clustered together apart from C\_MESH\_08\_02. The photographs therefore indicate that there is only one type of sediment present. Note, however, that if there is a small positional inaccuracy it is possible that C\_MESH\_08\_02 is the only photograph within the 'light blue' QTC class while the others are within the purple QTC class. The purple QTC may relate to the coarse sediment (here classified through ground-truthing as SS.SCS.CCS) while the light blue class is a different sediment type not immediately evident visually. The light green QTC class is not evident visually in the photographs or the sidescan sonar.

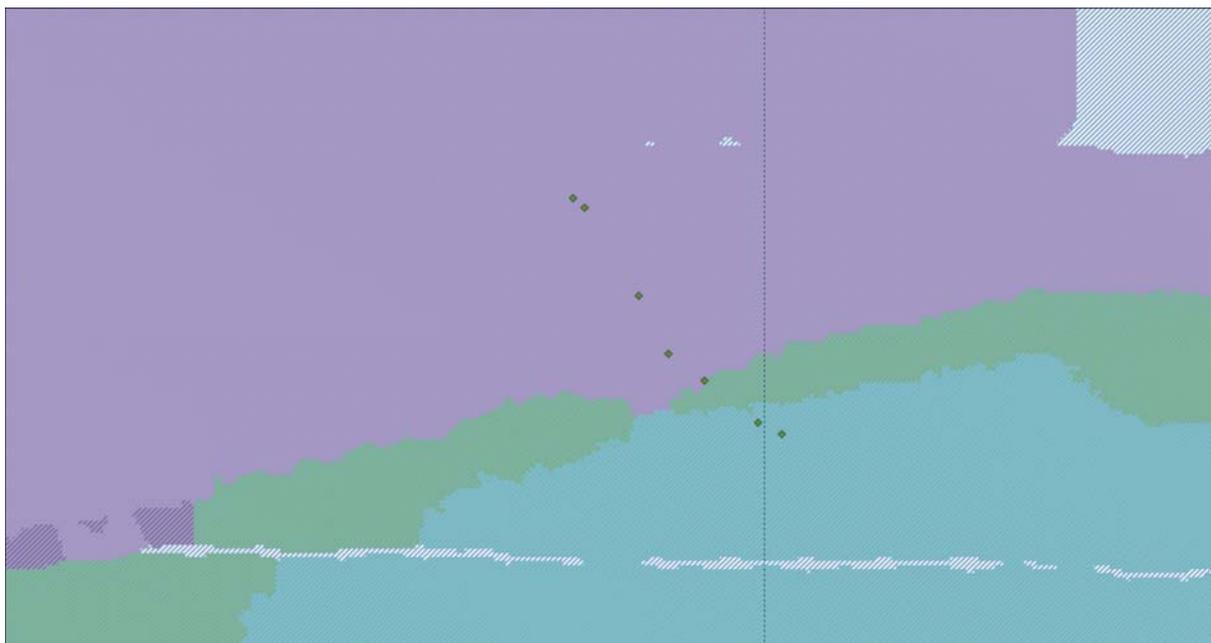


Figure 22. QTC seabed habitat boundaries and MESH\_08 photographic transect (south to north from photograph MESH\_08\_02 to MESH\_08\_08).

The second photographic transect (MESH\_07) crosses two QTC boundaries (light blue to light green in figure 23) and the photographs at MESH\_07 (figure 24) suggest that there is a subtle difference in the sediment type present. The sediment in photographs 02 to 09 are all shelly sand but the sediment in photographs 10 to 14 consist of gravely, shelly sand and there appears to be a subtle but obvious change in sediment type (figure 24). All the photographs have been classified as SS.SMx.CMx but perhaps the use of the biotope classification system is not appropriate for this type of detailed assessment. All but two (07\_12 and 07\_14) of the photographs have furthermore been clustered together within one of the three large clusters within the 'mixed sediment' group (figure 21). This group is fairly varied and subtle differences are difficult to discern but there is a clustering of almost all of the photographs together, although photograph 07\_13 does not seem to quite fit into this pattern. A detailed analysis of the sidescan sonar also suggests that there is a subtle change in backscatter across the photographic transect that seem to concur with both the photographs and the QTC class division.

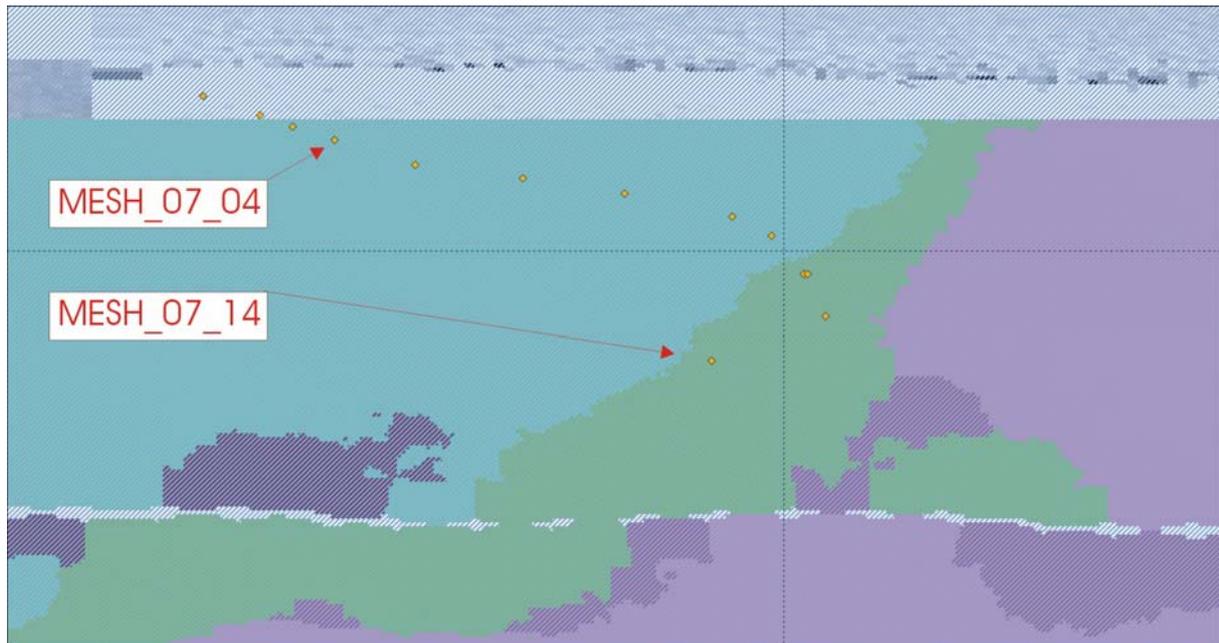


Figure 23. QTC seabed habitat boundaries and MESH\_07 photographic transect.

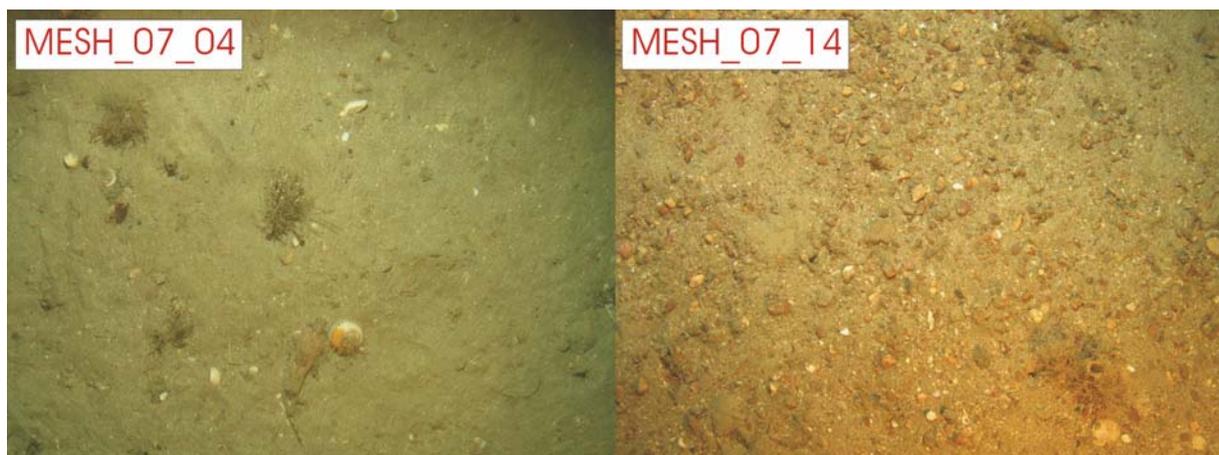


Figure 24. Photographs from MESH\_07.

It therefore appears as if there are similarities between the two methodologies (traditional vs. seabed discrimination) and at least two sediment types may be distinguished within the soft sediment with at least one boundary being evident. The QTC classification did however generate 5 classes within the sediment area while only two, or perhaps three, sediment types were evident in the photographs. The processing of the data during the QTC analysis is somewhat subjective as the number of classes is selected at one stage during the process. It is therefore possible that some of the classes seen within the data are artefacts of other factors within the data (e.g. spikes, areas left as a result of the mosaic process or other factors). These artefacts appear evident when the two results are compared it furthermore appears as if the subtle differences in the backscatter return as seen on the sidescan sonar images are evident 'by eye'. Overall it therefore appears as if traditional techniques work very well while further studies are required to assess the use of seabed discrimination techniques in areas of soft sediment. Note, however, the discussion regarding some of the problems encountered in relation to communication and technical requirements to enable the seabed discrimination to be carried out (see below).

### 3.3.3.2 Reef areas

There are six photographic transects within the QTC seabed discrimination map (see GIS and figure 20). These transects all cross at least one QTC boundary and in most cases, several QTC boundaries. One example is HD\_03 (figure 25) which crosses 4 QTC classes (from light blue through dark blue, dark pink, dark blue again and then to brown). The photographs have been classified as SS.SCS.CCS, CR.HCR.XFa.ByErSp.Eun and SS.SSa.CFiSa with the coarse sediment at either end of the run, the *Eunicella* reef biotope over virtually the whole central part of the transect and a few photographs within the *Eunicella* reef biotope that are dominated by sand. The cluster analysis has clustered these photographs in several different groups throughout the dendrogram (figure 21 and table 9) but overall there appears to be few similarities between the photographic (figure 26) and the QTC classifications (table 9). The *Eunicella* reef biotope appears in three QTC classes (dark blue, brown and light blue) and although there are subtle differences between the fauna in the photographs within these classes (e.g. Crisiidae sp. are common in some of the photographs in the beginning of the transect but this group is not present towards the end), these differences are not apparent in the clustering (figure 21 and table 9) or through the faunal identification 'by eye' (see GIS and figure 26). Even if there was a positional error it would be very difficult to find a good correlation between the photographs and the QTC classes at HD\_03. Similar results are seen at the other sites (e.g. HD\_01, HD\_04 and MESH\_03). Out of these sites, the best correlation is found at HD\_04 (figure 27) but even here there are three QTC classes along parts of the transect where there is very little discernable difference in the fauna, substrata and type of biotope (see table 9). Even photographs within the same QTC class code are clustered within the different faunal groups and for example both the brown and purple QTC classes appear in several different cluster groups (see table 9). This was the case when sites HD\_03 and HD\_04 were assessed separately in cluster analysis as well and further statistical assessments of this data were therefore difficult.

QTC class	Photographs at two sites		Cluster groups (in figure 21)
	HD_03	HD_04	
Light blue	02, 03		'Mixed sediment'
Dark blue	04-10, 12-20		Various groups including 'mixed sediment', SS.SCS.CCS, group E and D and separate cluster
Purple	11		SS.SCS.CCS
Brown	21-28		'Mixed sediment', group C, E and separate cluster
Purple		15-27	Group C, E and F
Brown		02-03	'Mixed sediment'
Pink		04-14	Group C, E, F and 'mixed sediment'
Blue		28-29	Group F and separate group

Table 9. Comparisons between QTC generated classes (from figures 25 and 27) and groups generated in the cluster analysis (from figure 21).

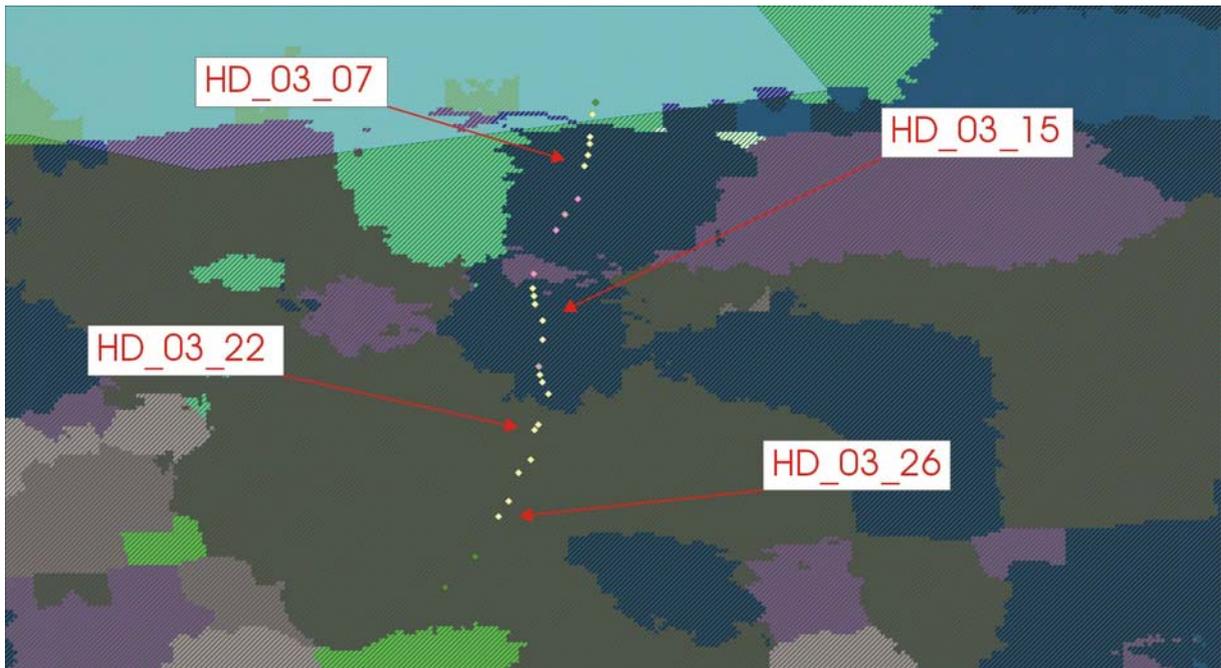


Figure 25. QTC seabed habitat boundaries and HD\_03 photographic transect (northeast to southwest – see figure 20 for exact location of the photographic transect).

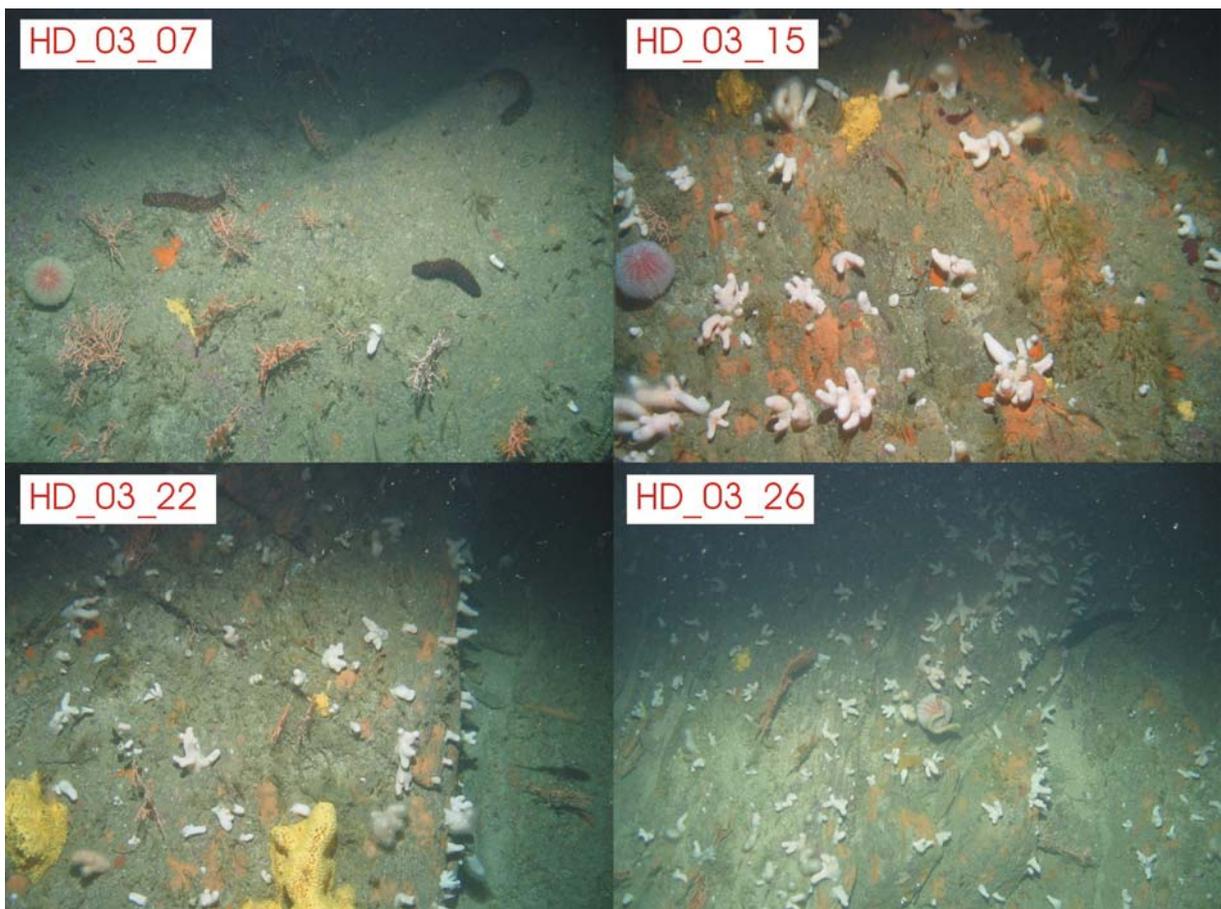


Figure 26. Photographs from HD\_03.



Figure 27. QTC seabed habitat boundaries and HD\_04 photographic transect (north to south with the green band in the lower part of the image being outside the QTC study area – see figure 20).

Overall there appears to be few convincing similarities between the QTC seabed discrimination results and those from the ground-truthing within the reef areas. In addition, there appears to be a number of QTC classes that are generated by artificial artefacts (as with the sediment areas) within the sidescan sonar backscatter. For example, the blue colour (almost everywhere) and the dark blue (on the reef areas) QTC classes seem to be present at the boundary between two survey lines or where the water column has been edited out. It would be of interest to assess the latter part of site HD\_04 as this section has been identified as a kelp biotope (see figure 21 and general descriptions above). It is possible that the faunal communities (including kelp) in this area would have generated a separate QTC class but unfortunately this part of the photographic transect was not covered within the QTC study area.

The comparison between the traditional survey techniques and the use of seabed discrimination maps do reveal some similarities but the results in this study suggest that additional work is needed. As noted above, it may be worth attempting to process this sidescan sonar data and only use 6 – 8 QTC classes for comparisons with the results of the traditional methods but the problems with regards to communication between QTC and the surveyors (see the discussion section below) should also be considered if these results were to be analysed further.

### 3.3.4 Comparative assessment of video records and still photography

The comparative assessment of the video and still photography techniques revealed a number of results but as there are many different camera systems used for video recording and still photography, it must be emphasised that these results and comments only relate to the digital system used in this study.

Both video and photography allow rapid collection of data with the ability to cover large areas quickly at a relatively low cost. The scale and size of the observation (image view) is appropriate for substrata classification, species identification and biotope designation as well

as quantitative assessments. It is also particularly suited for ground-truthing of acoustic data where a good coverage of the data will allow for successful interpretations. Video and photographic systems (particularly drop-down systems) furthermore allow low-impact, non-destructive (with regards to damage to the seabed environment including avoiding rare and fragile taxa) surveys to be carried out on all types of habitats (both rocky biotopes and in sediment areas), although additional sampling (e.g. grab sampling) may be required on the soft sediments to allow high level biotope classification to be carried out. Despite these similarities there are a number of differences (table 10):

<b>Still photography</b>	<b>Comments</b>
Positive	<ul style="list-style-type: none"> <li>• High level of faunal / floral identification possible, partly as a result of ability to zoom in on objects but also because of the use of a high resolution system.</li> <li>• Allows high level of substrata identification (as a result of zoom and high resolution as above).</li> <li>• Quantitative assessments of fauna and flora possible with relative ease.</li> <li>• Photographs can be taken randomly, selectively or on a time-basis to allow for different quantitative and qualitative assessments.</li> </ul>
Negative	<ul style="list-style-type: none"> <li>• Potentially results in undetected fauna / flora in parts of a transect not covered by the photographs.</li> <li>• System limits number of photographs taken to some extent (but this can be overcome by downloading the photographs regularly).</li> </ul>
<b>Video recordings</b>	<b>Comments</b>
Positive	<ul style="list-style-type: none"> <li>• Good overall understanding of sediment composition.</li> <li>• Able to detect sedimentological features such as sediment waves and ripples.</li> <li>• Potentially able to observe more taxa as more of the seabed is sampled (observed).</li> </ul>
Negative	<ul style="list-style-type: none"> <li>• Height above the seabed is often higher than when the photographs are taken (close up) to avoid hitting the seabed during a deployment. Therefore some fauna / flora (both identification and quantification difficult) are overlooked as the camera is too far off the seabed.</li> <li>• Analysis of video recordings is more time-consuming than photographs as the video covers a larger section of the seabed (although sub-sampling of the video record is possible as long as the video quality is high).</li> <li>• The resolution and quality of the video is lower than that of the photographs.</li> <li>• Hard to see / classify detailed sediment type (lack of zoom).</li> </ul>

Table 10. Comparative assessment of video and still photography.

Specifically the analysis of the videos in this study furthermore illustrated that some taxa were particularly difficult to detect, enumerate and identify. Hydroids, such as *Nemertesia* sp. observed on the photographs were not readily seen on the videos. Other smaller faunal such as *Peachia* sp. were also difficult to see as the video often was slightly too high above the seabed to allow identification of the smaller fauna / flora. The Crisiidae sp. (Bryozoa) was also very hard to detect among the hydroids and this taxonomic group, as well as the smaller taxa, might also have been entirely overlooked had the still photographic analysis not been carried out. Numerous fauna such as *Alcyonium digitatum* are also often difficult to quantify on the videos unless an estimate such as SACFOR is used. Taxa that are both numerous and small, such as *Corynactis viridis* and *Caryophyllia smithii*, are even harder to enumerate.

The video recordings did, however, allow a better understanding of the overall sediment distribution. The sediment veneer present at some of the sites (not detected by the sidescan sonar imagery which recorded high backscatter from the rocks underneath the thin veneer) was apparent on the video records and allowed a better overall understanding of these features compared to the results from the still photography analysis. The continuous crossing of boundaries between sediment types was also apparent on the video but not always recorded on the photographs. The fauna at the boundaries (e.g. Crisiidae sp. was often seen at the boundaries but this was not apparent from the photographs) were also recorded using the video but might have been overlooked using only the photographic material. The discovery of these types of patterns requires detailed analysis of the video records but as this is time-consuming (particularly if quantitative data is to be extracted), there is rarely sufficient time allocated to carry out all of these aspects during the video analysis.

Some of the results from the video and photographic analyses are given in table 11. These results indicate that for most taxa the faunal densities are higher using the photographs compared to the video records. Note, however, that the enumeration of taxa such as *Corynactis viridis*, *Caryophyllia smithii* and *Peachia cylindrica* using the video was virtually impossible and the values are therefore underestimates. Statistical analysis (using for example the G-test) comparing these frequencies is not possible as the frequencies must not be below 1 and no more than a fifth of the samples can be below 5 (see e.g. section 13.13 in Fowler and Cohen, 1992).

	C MESH 03		C MESH 03		C MESH 03		C MESH 07	
	<i>Eunicella verrucosa</i>	<i>Cliona celata</i>	<i>Corynactis viridis</i>	<i>Caryophyllia smithii</i>	<i>Echinus esculentus</i>	<i>Holothuria forskali</i>	<i>Peachia cylindrica</i>	Pectinidae Sp.
Photographs	3.93	0.29	19.29	30.71	0.71	0.93	0.69	0.15
Video	1.07	0.19	1.16	0.52	0.45	0.26	0.17	0.43

Table 11. Calculated faunal densities of a number of taxa using still photography and video recordings from two deployments part of the MESH study area around Eddystone Rocks.

### 3.4 Confidence assessment

The causes for navigation errors for the sidescan sonar and photographic material have been described above. The navigational errors for sidescan sonar can be estimated from the GIS produced as part of this study to a maximum of about 100 m while the maximum error for the photographs would be approximately 10-15 m. A confidence assessment of the positioning accuracies of the data has led to a division of the results, including the classification of biotopes, into three levels: 1) photographs and video transects (ground-truth points), 2) areas with the same backscatter immediately surrounding a photograph and 3) areas with the same levels of backscatter away from the photographs.

The confidence of the interpretation of the seabed environment at point source (i.e. a photograph) is estimated at 90-100 % accurate (level 1) excluding the inherent problems with

biotope classifications. These include the difficulties in assigning some biotopes as a result of lack of characterising fauna / flora; difficulties in assigning an 'energy' level to a certain habitat and difficulties in assigning biotopes in soft sediment without carrying out biological sampling (e.g. grab sampling) to collect infaunal samples. Confidence level 2 is estimated to be 70-80 % accurate while confidence level 3 is estimated to be approximately 50-60 % accurate but all of these could be even higher depending on the environment under investigation.

To achieve ground-truthing of a particular backscatter return, a total of 2 camera deployments (sampling of at least two sites/transects recording video footage and an appropriate number of still photographs) are believed to be sufficient to allow classification of the type of the substrata in homogenous environments as there is a close correlation between discrete assemblage types and acoustically discrete regions. In the Eddystone Reef survey some photographic transects were selected as boundaries between different backscatter returns. This proved to be a very useful methodology and allowed positioning of the boundary and allowed ground-truthing of the two types of substrata. To ground-truth the boundary and one other site within a homogenous area may therefore be sufficient, a strategy that potentially could allow many sites within a large area to be investigated. In areas of complex and heterogeneous sediments the relationship between acoustically detectable habitats and discrete benthic assemblages is less obvious and the number of deployments will rise depending on the environment in a particular location.

#### 4 DISCUSSION

The analysis of the sidescan sonar with the ground-truthing using the drop-down camera system has proven to be a very successful method for studying the large-scale features around Eddystone Rocks but also to investigate the finer biological and sedimentary features within the study area. Overall the sediment distributions and the positions of most of the rocky areas are similar to those previously reported (see Holme, 1953, 1966; BGS, 1996; Irving, 1996; Davies, 1998) but some changes appear to have occurred where for example the positions of the sediments appear to have shifted slightly. In addition, a large amount of new information has now been gathered about the biological communities present and the rare taxon *Eunicella verrucosa* has now been shown to be present on all the rocky outcrops (part of this study) around Eddystone Rocks. The delineation of large areas of these reefs has now been achieved and a new reef (South Rock) has been identified.

The sedimentary distribution is similar overall to that reported in previous studies (Holme, 1961, 1966; BGS, 1996) where sand was present in the south and east of Eddystone Rocks while sandy gravel was found in the north (Holme, 1961, 1966; BGS, 1996; Davies, 1998). In previous studies (BGS, 1996, Davies, 1998) clean sands were reportedly present immediately north of Eddystone Rocks (stretching as a narrow segment from the east) and this is still apparent in the present study but the size of this area may have changed slightly. Gravelly sands were reported from the areas immediately around the western section of Eddystone Rocks (BGS, 1996). Similar sediments were found in this study but more detail of these distributions are now available with narrow tongue of sand stretching up between Hand Deeps and Bedrock, covering the area around Middle Rock. Two relatively large areas of sand and shell are also found to the east and southeast of Bedrock, features not reported in previous studies (see e.g. BGS, 1996).

The sand ribbons and sand ripples were observed in the North Area have also been reported in previous studies (BGS, 1996). These bedforms were reportedly mobile and overlaid lag (winnowing) deposits consisting of gravels and sandy gravels (BGS, 1996). The sedimentary environment appears to be very similar now, although considering the mobile nature of some of the deposits and sediments, there may well have been some changes in their positions.

Sand ribbons have been reported from another part of the English Channel (Holme and Wilson, 1985) where faunal communities found on these features reportedly were at different stages of development depending on the stability of the particular sediment where they were found. These communities were generally quite different to those found in the present study (dominated by sabellids and hydroids), presumably as a result of there being a bigger proportion of sand present but also weaker tidal currents in the North Area compared to the area studied by Holme and Wilson (1985) in the middle of English Channel.

The communities in these coarser sediments have been characterised as a '*Spatangus-Venus*' community while the sandy substratum to the south and east of Eddystone Rocks have been characterised as an '*Echinocardium-Venus*' community (Holme, 1966; Davies, 1998). The '*Echinocardium-Venus*' community is characterised by molluscs and echinoderms including *Echinocardium cordatum*, *Venus striatula* and *Mactra corallina*. The sediments have been described as relatively silt-free deposits because of the distance from land as well as stronger tidal streams (Holme, 1966). The '*Spatangus-Venus*' community is characterised by *Spatangus purpureus*, *Echinocardium flavescens* and *Venus casina* found in offshore gravel sediments (Holme, 1966). *Ophiothrix fragilis* and *Ophiocolina nigra* are also known to be found in this association (Holme, 1966) and these taxa were recorded in the present study but in different parts of the survey area. The classification of the sediments seen in the current study into certain associations as described by Holme (1966) and others is, however, difficult even though the sediments appear similar as few or any of the characteristic fauna were visible on the photographic material. Biological sampling would be required to enable further classification either in the traditional associations (see Holme, 1966) or according to the recent biotope classification system by Connor *et al.* (2004).

The muddy sediment in North Mud was a relatively unusual feature in the study area but the presence of mud north of Eddystone Rocks has been reported in earlier studies (e.g. Holme, 1961, 1966). The large concentrations of burrows at North Mud were also of particular note. The originators of these burrows remain unknown as no fauna was seen associated with the burrows apart from a pair of antennae protruding from one burrow. Holme (1961, 1966) reported crustaceans such as *Upogebia stellata* and *Callianassa subterranea* from this region and it is possible that these taxa are among the species responsible for the large number of burrows seen but considering the variety of burrows present, other originators are also possible.

The presence of the rare specimen *Eunicella verrucosa* and the associated biotope (CR.HCR.XFa.ByErSp.Eun) on some of the reefs around Eddystone Rocks has been reported before (Jones, 2005; Sharrock, 2005a, 2005b) but it has now been shown that this taxon is present on all the main reefs around Eddystone Rocks. *Eunicella verrucosa* has been described as 'nationally scarce' and it is protected under the Wildlife and Countryside Act 1981 (Sanderson, 1996). It has been suggested that species such as *Eunicella verrucosa* have a poor capacity for recovery and replace their numbers slowly at the margins of their distribution. It has therefore been argued that they are particularly vulnerable to even the most minor and infrequent damage (Sanderson, 1996) but in a recent review (Lieberknecht, 2004) *Eunicella verrucosa* did not meet any of the criteria for nationally important marine species. Furthermore, it did not meet the criterion for special importance of rarity but additional data was required to assess the threat and decline of this taxon in the UK (Lieberknecht, 2004). *Eunicella verrucosa* is not included in Annex II of the Habitats Directive (92/43/EEC) and this taxon does therefore not directly qualify for protection.

Kelp taxa and the associated biotope IR.HIR.KSed.LsacSac, was shown to be present at the shallowest sites within the current survey and these communities have been shown (Sharrock, 2005a, 2005b) to be present in shallower areas around several of these reef areas (e.g. Hand Deep, Hat Rock and Eddystone Rocks) but the other algal biotope IR.HIR.KFaR.FoR.Dic reportedly present in this region (Jones, 2005) was not identified in

this survey. This biotope is described as 'dense turf of foliose red seaweeds mixed with a dense turf of the foliose brown seaweeds *Dictyota dichotoma* and/or *Dictyopteris membranacea*' (Connor *et al.*, 2004) but these characteristics were not observed in this study. These seaweeds do, however, have annual fronds which tend to die back in the autumn and regenerate again in the spring (Connor *et al.*, 2004) and as the survey took place in January, it is possible that these taxa, and therefore the IR.HIR.KFaR.FoR.Dic biotope, would be recorded had the survey been carried out at a different time of the year.

Jewel anemones (with the associated biotope CR.HCR.XFa.CvirCri) were present in sections of this survey, a distribution that appears to concur with previous information reporting that this taxon are present on vertical or steep walls (Connor *et al.*, 2004). Similar distributions have been reported from diving surveys (Sharrock, 2005a, 2005b) and jewel anemones appear to be particularly widespread at Hand Deeps and Hat Rock but additional sampling (using drop-down cameras or divers) would be required to assess this fully.

The presence of relatively large numbers of warm-water species such as *Alcyonium glomeratum* and *Holothuria forskali* together with *Eunicella verrucosa* and more typical English Channel fauna indicate that this region still span across a biogeographical boundary. Holme (1961, 1966) described the fluctuations on some faunal groups as a result of changes in the water circulation patterns and the climate. Taxa exemplified to fluctuate included *Antalis entalis*, a taxon known to be present in the Eddystone Rocks region in the late 1900s but disappeared during the 1960s. *Antalis entalis* has now evidently returned to several parts of the Eddystone Reef area (South Area, North Area) as shells were visible but additional sampling, ideally biological sampling, is required to assess whether the individuals of *Antalis entalis* are alive or whether the shells are left from previous periods when *Antalis entalis* was common in the area. This taxon is reportedly uncommon generally in the south (Hayward and Ryland, 1995) but perhaps it is more widely present along the southwest coast of England. Other West-Channel taxa including *Ophiocomina nigra* and the warm-water taxon *Marthasterias glacialis* were also observed in this study. The distribution of these 'western species' is typically limited to the area extending from the west up to around Plymouth (Holme, 1966). Whether this distribution has changed is difficult to assess in the current study but both are locally abundant around Eddystone Rocks with *Ophiocomina nigra* being present at South Rock and *Marthasterias glacialis* being abundant virtually all over the reefs. *Ophiothrix fragilis* is known to be found throughout the English Channel (Holme, 1961, 1966) but in this study this taxon was only found in a small section of Eddystone Rocks (northeast corner). *Flustra foliacea* was rare in the Eddystone Reef study area with only one record at Middle Rock (MR\_01\_09). This is an 'Eastern' species and it was not reported from this area in 1966 (Holme, 1966) although this may in part be explained by the survey methodology used in that survey (sampling around the rocky outcrops using the dredge would have been difficult). The distributions of all these different taxa suggest that there is a mixture of warm- and cold-water species present at Eddystone Rocks and the surrounding area. It therefore appears as if the suggestion that this area is straddling two biogeographical regions (Holme, 1961, 1966) still is true and the warm period is still current (see Hawkins *et al.*, 2003).

Evidence of fishing activity has been found in the North Area in particular, with trawl marks (typically long, linear marks on the seabed) being present on the sidescan sonar images. Some of the trawl marks seen on the sidescan sonar images may be old as it has even been shown that despite smothering effects by currents and other natural processes, marks made by trawl gear is known to be detectable with sidescan sonar at least several months after the event (Fish and Carr, 1990) but as fishing vessels were seen operating in both the North and South Areas during the survey, trawling is believed to occur throughout the Eddystone Rocks area. Scallops have been shown to appear in all areas in this study, a fact also reported in previous studies (e.g. Pawson and Robson, 1996) and these taxa may be the main target for fishing but other species (e.g. Dover Sole) are also known to be exploited in this region (Pawson and Robson, 1996).

Fishing activities on the rocky outcrops include both pot fisheries and angling with target species including lobsters and edible crabs (Pawson and Robson, 1996) and such vessels were present throughout the survey periods. There was some evidence of damage to fauna on the reefs and a number of sea fans (*Eunicella verrucosa*) were observed lying flat on the seabed but whether these were damaged through fishing or natural causes is difficult, if not impossible, to assess and overall these effects did not appear to be widespread. Dive surveys on parts of the reefs have also reported some damage to the fauna but as in this study, these effects appear to be limited (Sharrock, 2005a).

#### 4.1 Traditional sampling techniques versus seabed discrimination techniques

An integrated approach using a range of survey techniques to study an area of seabed has been shown to be successful in many studies and the use of sidescan sonar and photography together with traditional survey techniques (e.g. grab sampling and trawling) have become more commonly used in recent years (e.g. Bett and Masson, 1998; Brown *et al.*, 2002; Axelsson, 2003; Brown *et al.*, 2004a, b; Steven and Connolly, 2005). The use of photography in surveys has been shown to be cost-effective with large areas being covered in a relatively short time (Brown *et al.*, 2004a; Steven and Connolly, 2005), however, it is acknowledged that there is some loss in the taxonomic resolution when using photography rather than biological sampling techniques (e.g. Steven and Connolly, 2005). Most recently new techniques have been developed to potentially allow seabed discrimination using the acoustic signals from sidescan sonar and multi-beam systems with potential advantages as relatively low costs, fast surveys and allow coverage of large areas (Preston, 2006a, b). As some techniques and methods used in habitat mapping and seabed discrimination are relatively new, problems are likely to occur during at least some part of a project involving these methods. During this study some problems were encountered during the production of the Quester Tangent Corporation (QTC) seabed discrimination maps, problems largely attributed to the lack of information from QTC and the requirement to use a particular type of equipment compatible with the software used by QTC.

In order to produce the seabed classification maps, QTC required access to the sidescan sonar code. In addition, some metadata including fish altitude, fish heading and fish attitude (roll, pitch and yaw) are also required to allow typical processing of the data (Preston, 2006a). Unfortunately the requirement to have access to the metadata was not made clear during the planning stages of the survey. In addition, the sidescan sonar system used, which is a widely used system in the commercial sector, was not completely compatible with the QTC system as QTC was not able to read the standard code format produced from a Coda Octopus recorder. However, QTC would be able to use and analyse sidescan sonar data recorded as an XTF format as long as a low frequency (100 kHz) was used and the range as well as the power, or gain, was the same throughout the survey. This recommendation was therefore taken into consideration during the planning stages of the survey and followed carefully during the operations in the field. However, on receipt of the data after completion of the survey QTC were not able to read the required metadata to undertake the typical analysis. After some investigation it became clear that the metadata has been lost as the data had been recorded directly to XTF format and not the Coda Octopus standard format which would normally be used. In addition, a motion reference unit was not present in the fish as such advice was omitted during the consultation with QTC. The end product is therefore visually high quality, geo-referenced sidescan sonar data but insufficient metadata to allow typical processing of the data for the QTC classification maps and a different map could potentially have been produced had all the metadata been available. As a result of the problems during this survey, the QTC analysis may be more suited to multibeam data as the required metadata fields are more commonly available, but with a good understanding of what is required, careful survey planning and operation, and accurate positioning of the tow-fish, QTC analysis of sidescan sonar data would be useful and achievable.

The comparison between the traditional techniques (sampling and analysis) and seabed discrimination may because of the above considerations have been better had all the data been available but the conclusion of this study is that the seabed discrimination technique did not appear to allow fast habitat mapping using the sidescan sonar backscatter data alone. There appeared to be some similarities within the soft sediments but on the reefs few correlations between the two techniques were apparent. Traditional techniques are potentially slower and more expensive (Preston, 2006) but as ground-truthing still is required to generate seabed discrimination maps, one advantage of this method seems at least in part to be lost. Detailed information about the biological communities also seems to be lacking and ground-truthing appears to be essential to map the seabed and get a good understanding of the geological and biological environment, a suggestion also made by Campbell and Hewitt (2006). However, because of the presence of some similarities (particularly within the soft sediments) and possible correlations as well as the potential of applying seabed classification work over much larger areas than point data alone would allow, it would be of considerable interest to use the seabed discrimination technique in another study to assess the capability of this technique fully.

#### **4.2 Discrepancies between the sidescan sonar and photographic survey results**

The ground-truthing of the sidescan sonar data and the mapping of these results illustrated that there were some discrepancies between the data (see the results above). At a few photographic sites a sedimentary environment was evident but the sidescan sonar imagery clearly illustrated the presence of a rocky substrata. There are at least three possible explanations for these results: 1) positional inaccuracies, 2) depth of acoustic signal penetration or 3) seasonal changes in the sediment distributions.

1) As briefly discussed above, there was a potential risk for lay-back error during the sidescan sonar survey and this would most likely occur during turns from one survey line to another when the fish would not be in alignment with the survey vessel. In some sections of the survey the lay-back error may be attributed to the results seen but as the sidescan sonar survey line across the ER\_13 photographic transect was straight (see GIS), the risk of any lay-back errors are believed to be limited.

2) The depth of the acoustic signal into the sediment is, however, a possible explanation. It has been shown that some sidescan sonar frequencies (e.g. 30 kHz) penetrate into the sediment and therefore return volume backscatter rather than a backscatter signal from the uppermost sediment surface (Blondel and Murton, 1997; Axelsson, 2003; Masson *et al.*, 2003). The lower frequencies penetrate the most (Blondel and Murton, 1997) and at 30 kHz the signal could penetrate tens of centimetres (Masson *et al.*, 2003). It is therefore possible that in certain sediments, an acoustic signal at 100 kHz could penetrate the sediment to some degree and therefore generate results different to those seen on seabed photographs. The substrata at ER\_13 may therefore consist of a layer of soft sediment overlying a rocky outcrop.

3) Another possible explanation is the changes in sediment distributions within the survey area. The sidescan sonar survey was carried out during the summer of 2005 while the photographic survey was carried out in January of 2006. The Eddystone Rocks and the surrounding areas are subject to strong winds and currents as well as large waves (Holme, 1961, 1966; BGS, 1996). It is therefore possible that some sections of the sediments are moved and sections of rocky reef may at times be covered by a thin layer of soft sediment and even though it has been reported that there is no net sediment drift within the study area (BGS, 1996), small-scale movements are still possible, particularly immediately around the rocky outcrops. This potential problem could be avoided if the surveys were carried out simultaneously but as the photographic survey was planned based to the sidescan sonar

results it would be virtually impossible to carry out the two surveys at the same time. The surveys could potentially be carried out immediately after each other and this was the original survey plan but the weather conditions in 2005 were particularly poor and it was impossible to carry out the photographic survey until January 2006 as calm weather is essential to ensure a safe working environment and the collection of high quality data.

### 4.3 MESH – additional discussion

#### 4.3.1 Comparative assessment of still photography and video records

Video and still photography has successfully been used in many studies (e.g. Bett and Masson, 1998; Axelsson, 2003; Brown *et al.*, 2004a; Stevens and Connolly, 2005) including studies concluding that video and still photography are appropriate for attributes concerning the presence and extent of biotopes (Service and Golding, 2001; Sanderson and Holt, 2001) and ground-truthing of acoustic images (Brown *et al.*, 2002; Brown *et al.*, 2004a; Brown *et al.*, 2004b). Trials in northern Wales have furthermore shown that for example drop-down video is an excellent and appropriate tool for sublittoral surveys and biotopes can be assigned with high confidence (Holt *et al.*, 2001), although it has also been argued that some video records are not of a sufficient quality to allow biotope classifications to be carried out and still photography should be carried out simultaneously to supply meaningful images (Hiscock and Seeley, 2006). Even though these suggestions may reflect some of the difficulties associated with the biotope classification system, combining digital video and still photography in surveys appears to have advantages (see result section 3.3.4 above) over a single system and allows an overall higher quality assessment to be carried out. Video images can be 'frozen' (or 'grabbed') for further quantitative or qualitative analysis (Service and Golding, 2001) but the quality does often not always appear to be as good as with digital still photographs, which allow high quality data to be collected, such species identification (through for example zooming) and enumeration as well as publication of high quality images. Despite the recent developments in digital video systems, the results from the present study therefore suggest that a combination of video and still photography gives the best overall results.

#### 4.3.2 Confidence assessment

There appears to be little published material with regards to confidence assessments or ratings. In this study confidence ratings have been given to the published maps and biotope classifications (as per Connor *et al.*, 2004), where the confidence of the interpretation of the seabed environment at point source (i.e. a photograph) is estimated at 90-100 % accurate (level 1), while confidence level 2 (areas with the same backscatter immediately surrounding a photograph) is estimated to be 70-80 % accurate and confidence level 3 (areas with the same levels of backscatter away from the photographs) is estimated to be approximately 50-60 % accurate. A fourth level could potentially be produced including areas with different backscatter but such a level would be virtually impossible to classify with any certainty.

Video and still photography have been shown to be appropriate for attributes concerning the presence and extent of biotopes but the quality of the data and biotope recorded from video tapes relies heavily on the identification skills of the person scoring the tapes (Holt *et al.*, 2001). The classification of biotopes is also somewhat subjective and not all seabed environments 'fits' the biotope classification scheme resulting in some biotopes being classified to 'best fit' the communities present (Holt *et al.*, 2001). Some studies therefore develop a specific habitat or biotope classification scheme (see for example Brown *et al.*, 2004a) for that survey but long-term perhaps the biotope classification system by Connor *et al.* (2004) will be developed further and therefore more widely used. However, obtaining high level of confidence in the data still requires an experienced marine biologist, ideally with local knowledge, although a quality assurance programme including re-assessments of the tapes

can recover any lost data or mistakes in the classifications (Holt *et al.*, 2001). Training prior to any survey work can also improve the quality of the results and potentially reduce the amount of quality assurance required.

#### 4.3.3 MESH - review existing standards and protocols (action 2.1)

##### 4.3.3.1 Review of standards and protocols for sidescan sonar

The experience gained during the Eddystone Reef survey work highlighted issues also noted in another study (James *et al.*, 2004) with regards to habitat mapping.

###### 1) Towing Speed

A towing speed of 3 to 5 knots is recommended to ensure along track resolution. Slow speeds may also be necessary in deep water when deploying a sidescan system from a small vessel in order to sink the towfish to the required depth while still deploying a manageable length of cable. An armoured umbilical cable would help to depress the towfish but may not be safely deployed manually from the deck of a small vessel. In depths of 40 m or 50 m, as encountered through much of the Eddystone survey, using soft umbilical cable linked to 10 mm flexicore towing wire, it was necessary to deploy 200 m of cable from an 11.3 m vessel. Vessel speed may vary considerably in a survey area containing different depths and can have an impact on the planning, duration and cost of a survey.

###### 2) Georeferencing

In georeferencing the towfish the assumption that it is running directly behind the vessel is very much that, an assumption. The deeper the water and the longer the cable, the greater is the potential error in positioning. In shallow waters, less than 20 m for example, the system of calculating layback can be used with some confidence but this confidence becomes diluted as the tow lengthens in deeper water.

In busy waters, with leisure craft, fishing vessels and lines of lobster pots along the survey line, many alterations of course may be necessary. Extremely detailed log-keeping is required to assist in the processing, mosaicing and interpretation of the sidescan data.

It would be of great interest to investigate the possibilities of using an Ultra Short Baseline system to track the towfish during regional small scale sidescan surveys and evaluate the benefits in relation to the greater expense.

###### 3) One of the conclusions in the reviewed document is the importance of a multidisciplinary approach in the use of Sidescan, linking it with physical sampling with grabs, cores and trawls. To these should be added the utilisation of the various forms of seabed photography. The term 'ground-truthing' can be misleading in this context. It would be more realistic to say that the sidescan image directs the surveyor towards areas that need investigation by other methods.

##### 4.3.3.2 Review of standards and protocols for drop-down cameras

The experience gained during the Eddystone Reef survey work highlighted issues also noted in other studies (Coggan, 2004; Coggan and Howell, 2005; Mitchell, 2005) with regards to the use of drop-down cameras.

###### 1) The Australian Workshop on video sensing held in 2000 and referred to in the first document stated that *'there is a lot more to successfully using video than most*

*participants realised'* (Coggan, 2004). This statement can also be extended to still photography. The success of a video and stills survey is heavily dependent on the skill of the operator in the field. Experience of the strengths and limitations of a particular camera system in different conditions and surroundings is vital in bringing out the best from a deployment. Camera angles and lighting levels may need to be adjusted depending on terrain and visibility. The aims of the survey will also determine the level of quality to be strived for in the field.

- 2) Although towed underwater video sledge is a commonly used method, the problem of georeferencing without the use of an Ultra Short Baseline system can obviously affect the accuracy of habitat mapping. Potential damage to the seabed caused by a towed sledge may well be an emotive issue.

To a large extent a drop-down camera in a well designed frame can overcome these two limitations. Except in the most extreme conditions the camera should be vertically below the vessel, while 'drifting' or 'hopping' can minimise any harm done to a vulnerable seabed habitat.

- 3) The section on data processing (Mitchell, 2005) referring to video sledge, is relevant to other methods. Processing times are given as a ratio of footage time. It should be stressed that these will differ considerably depending on the equipment used, the camera operator, the vessel and crew, weather conditions, substrate and, maybe most importantly, the rationale behind the survey.

#### 4.3.3.3 The metadata sheets with reference to sidescan sonar.

Unfortunately the metadata sheets were not supplied for use during the collection of data, had this been the case the process would have been considerably easier and less time consuming. In this instance the data was entered some time after the survey was completed. The original survey logs and records were recorded in a different format. As a post survey exercise the completion was very time consuming.

General comments regarding the fields for completion:

System Table; Data processors and technicians may find this useful if technical problems are encountered especially in the data analysis stage. Fish or recording device could change if there is an equipment failure on the vessel and the system is replaced.

Survey Table; More information could be collected regarding the water depth. This may change greatly during a line, and the use of USBL beacons, if the data obtained was reliable and was used.

Operating Parameters Table; There is no need to include both range and swath width, it is suggested that range is retained. Additional configuration settings could be included, whether raw or processed data was recorded. If processed which gain, TVG gain and voltage range settings were used.

Processing Table; Additional information concerning layback would be useful as this is often changed during a line and there is no way of recording this. The fields referring to vertical parameters are not really relevant to sidescan sonar operations.

Storage; Consider adding fields regarding back-ups or multiple copies.

#### 4.3.3.4 The metadata sheets with reference to the video

The metadata sheets for the video element of the investigation were straight forward but time consuming to fill in. With up to 10 sites a day there was a lot of data to copy across and a large amount of repetition between sheets; The 'System' and 'Operating Parameters' field sections remained the same for all metadata sheets.

The 'survey' and 'weather/sea conditions' contained all the basic parameters recorded during a survey.

The 'Processing' and 'storage' sections required post processing entries detailing file names and media format for each station.

The future use of the metadata sheets as an integral part of the data collection process during the survey would prove difficult using this system due to the amount of repetition required across each sheet. As advised by Vanstean et al 2005 (TG0511 Cefas 02 paper) a database system would perhaps provide a better method for convenient standardisation of data recording.

## 5 CONCLUSIONS

The biological communities on the reefs in the Eddystone Rocks area are of particular note. Rare species such as *Eunicella verrucosa* (Sanderson, 1996) have been shown to be abundant on the reefs and distributed on the rocky reefs virtually throughout the study area. Southern (Mediterranean – Atlantic) species such as the soft coral *Alcyonium glomeratum* and the sea cucumber *Holothuria forskali*, taxa reported in previous studies (e.g. Irving, 1996; Sharrock, 2005a), have also been shown to be present in this study. The presence of *Antalis entalis* in both the North and South Areas show that the fluctuations in some taxa (see Holme, 1961, 1966) is continuing and that this region still straddles different biogeographical regions. All of these facts could potentially lead to this area being designated as a Special Area of Conservation (see Jones, 2005). Similar faunal distributions have been reported from other reefs in the south-west of England (Jones, 2005) but whether these reefs are as rich, particularly in terms of the rare species present at Eddystone, remain to be assessed.

The multi-disciplinary approach used in this study using sidescan sonar and video and still photography has proven to be very successful. The digital camera system allowed ground-truthing of the sidescan sonar data, classification of the substrata, identification of the fauna and flora as well as designation of sites into biotopes according to Connor *et al.* (2004), although additional biological sampling (e.g. grab sampling) is required to enable high level biotope classifications of the sites within the soft sediments. A total of 2 camera deployments (sampling of at least two sites/transects) are believed to be sufficient to allow classification of the type of the substrata in these relatively homogenous environments as there is a close correlation between discrete assemblage types and acoustically discrete regions.

The use of seabed discrimination techniques was an important aspect of this study. The aim was to assess whether these techniques could speed up of habitat surveys, allow large areas to be covered quickly and therefore allow data to be collected in a cost-effective manner. The results from this study illustrate that there are some similarities between the results from traditional techniques and those obtained from habitat discrimination methods. The seabed discrimination technique seems to work reasonably well within the soft sediments but less well within the reef areas where several differences were seen. Some of these differences may be attributed to technical and communication problems but further studies are required to fully assess the effectiveness of habitat discrimination.

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## **Survey Equipment Specifications**

### **Single Beam echosounder**

Marimatech E-Sea Sound 206 Dual frequency 33 / 200 KHz

Inshore survey recording and processing of 200 kHz

Operating Range (200 kHz): 15 cm – 500 m

Resolution: < 100 m = 0.01 m

### **Motion Sensor**

TSS CMS 25 Compact Motion Sensor

Heave: Range  $\pm$  100 m. Resolution 1 cm. Accuracy 5 cm or 5% of range.

Roll, Pitch: Range  $\pm$  30°. Resolution 0.01° - accuracy dynamic/static  $\pm$  0.25° RMS

### **Sound Velocity Probe**

Marimatech HMS 1820-P CTD

Range: Depth 0 - 250 m. Temperature -55 - +25° C. Salinity 01 - 60.

Resolution: Depth 1 cm, Temperature 0.01, Salinity 0.001

Accuracy: Depth 0.1% of range, Temperature  $\pm$  0.1° C. Salinity  $\pm$  0.001

### **Positioning**

CSI Wireless Vector Sensor DGPS

Type: L<sub>1</sub> frequency, C/A Code with carrier phase smoothing

12 channel parallel tracking

Positional Accuracy: <1m (DGPS)

Simrad CA42 combined chartplotter with echosounder and DGPS

DGPS Type: L<sub>1</sub> frequency, C/A Code, 14 channel continuous tracking

Positional Accuracy: 1-3 m 2D RMS

### **Sidescan Sonar**

GeoAcoustics Towfish Model 159D, Depth 0-1000m

Transceiver SS981; operating frequency 114kHz, 410kHz, Temperature -5 – 50° C

### **Thermal Linescan Recorder**

Dowty Maritime Ocean Systems 3710

### **Geophysical Acquisition System**

Coda Octopus 760 Analogue inputs, 4 independent 16 bit channels scaleable from 125mV to 5V

Navigation, 2 RS232 serial inputs for NMEA strings, Data recording DVD RAM

Recording format XTF

### **Survey Management Software**

HyPack Max

### **Details of DTS3000 Deep Water Camera System:**

Kongsberg Simrad OE14-208 Digital Stills Camera System

Flash Unit

Flex Micro PC c/w 15" TFT Monitor – camera control software

Subsea Lamps

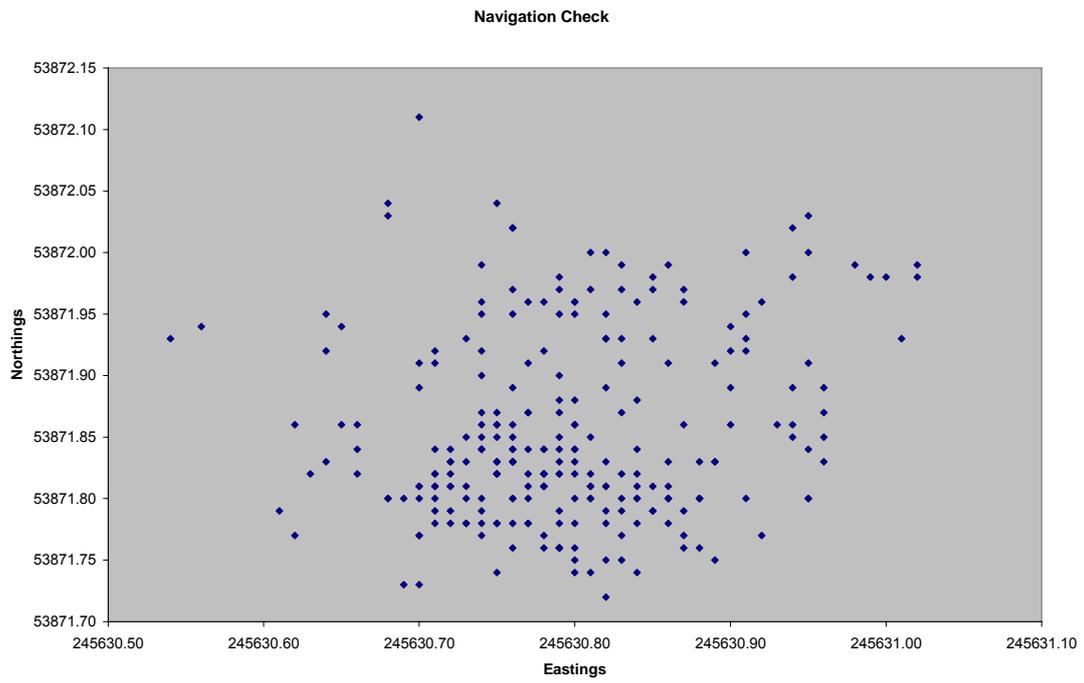
Seabed Camera Frame

JVC miniDV / VHS video cassette recorder

14" Panasonic Colour Monitor

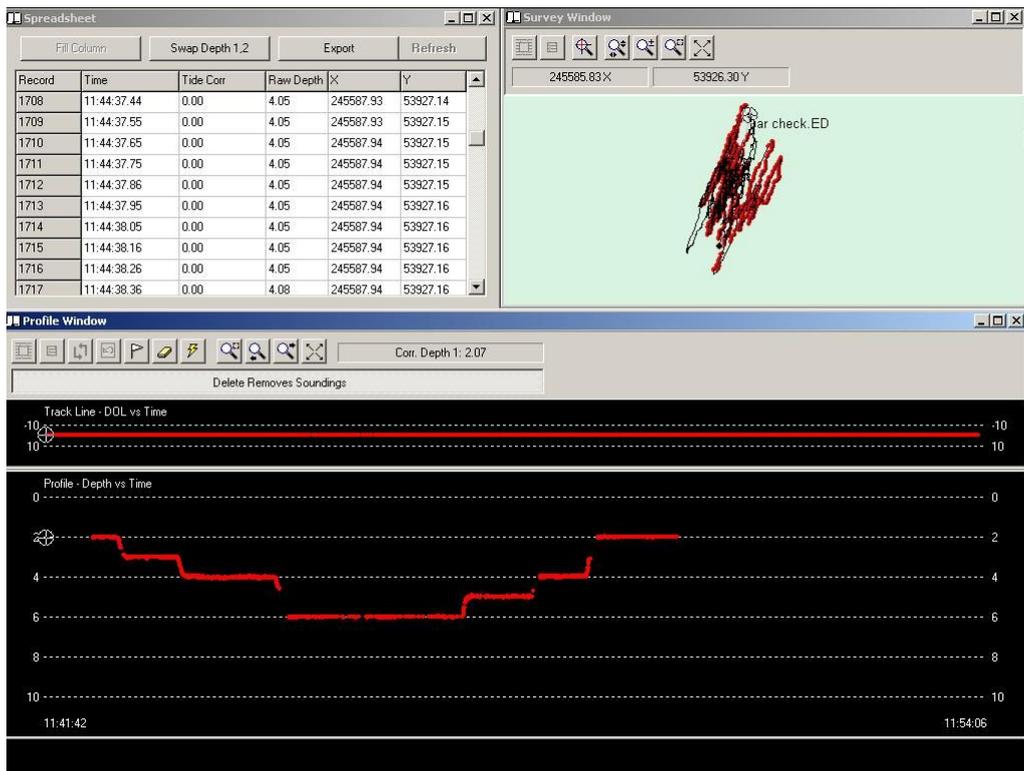
Soft umbilical

### Appendix 1



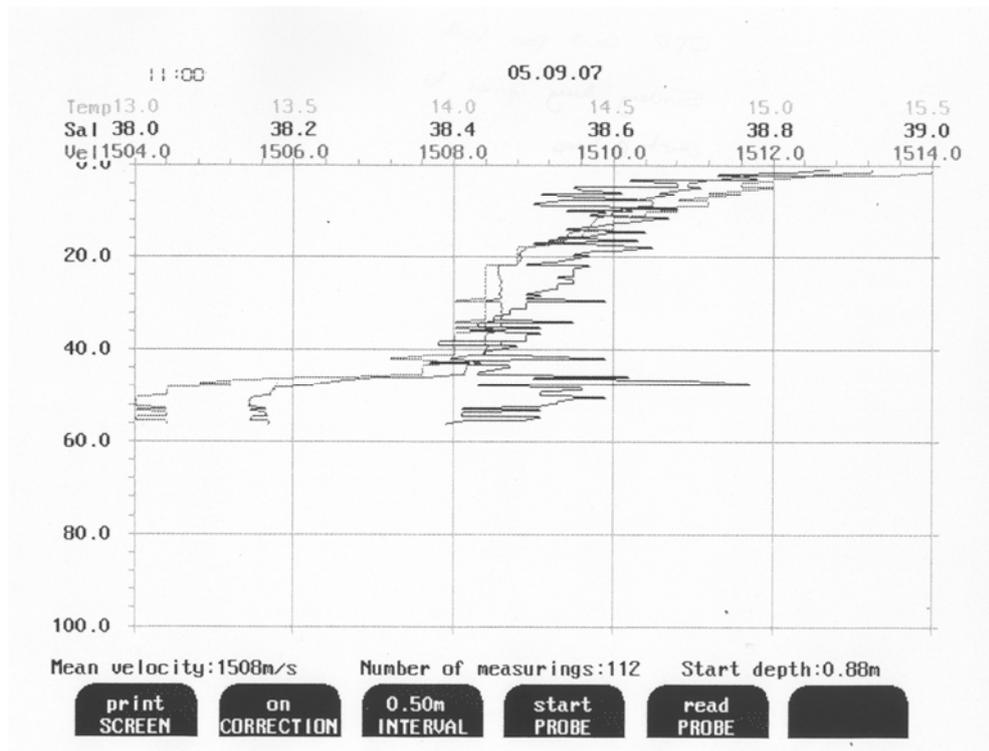
Example of navigation check scatter plot

## Appendix 2



Example Display of Bar Check Data

### Appendix 3



Example CTD cast used for sound velocity calibration in the Single Beam Echosounder

<b>Bathymetric Survey Post-Processing QA Checklist</b>	
<b>Bathymetric Data</b>	
<ol style="list-style-type: none"><li>1. Check survey log for any data not to be included in final processing e.g. re-run lines</li><li>2. Check transducer draft correction applied correctly during survey (from echosounder settings print-out)</li><li>3. Check speed of sound correction applied correctly during survey (from echosounder settings print-out)</li><li>4. Process bathymetric data using post-processing software with reference to echosounder paper rolls. Remove unwanted data (e.g. where lines re-run) and any spikes due to noise in water column.</li><li>5. Save edited depth data to new files</li></ol>	
<b>Tidal Data</b>	
<ol style="list-style-type: none"><li>1. Check tidal data recorded in same time zone as bathymetric data i.e. GMT. If different, adjust tidal data to be applied so that times correlate with survey data</li><li>2. Check vertical datum of tidal data and adjust to ODN if in ACD.</li><li>3. Check phase and amplitude of tidal curve between Devonport and Yealm River entrance and calculate difference, if any</li><li>4. Apply any phase and amplitude difference to tidal data</li><li>5. Apply tide data to bathymetric data in post-processing software to obtain reduced depths</li><li>6. Save reduced depth data to new files</li></ol>	
<b>Reduced Data</b>	
Carry out random checks at different times:	
<ol style="list-style-type: none"><li>1. Choose a time, check digital depth against paper record</li><li>2. Check correct tide applied at that time</li><li>3. Check final reduced depth</li></ol>	

## **Appendix 4: Species list with abundance of fauna given in the SACFOR scale**