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# Marine Monitoring Framework

## Lundy SAC: Subtidal Reef Condition Assessment and No Take Zone Benthic Monitoring Survey 2014/15

Final Report

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# 1 Executive Summary

In this document PML Applications Ltd reports the results of survey work conducted during 2014 and 2015 (August/September) to provide ecological information to allow Natural England to assess the condition of subtidal communities within the Special Area of Conservation (SAC) and No Take Zone (NTZ) at Lundy. The representative species and habitats of the SAC features that were surveyed were kelp forest communities, subtidal vertical & overhanging circalittoral rock communities and subtidal bedrock & stable boulder communities. Sessile epifauna communities were also surveyed inside and outside of the No Take Zone (NTZ).

**Kelp Forest Condition Status Summary:**
A relatively long term shift (ten years) in the relative abundance of kelp canopy forming species has occurred at Rat Island and Gannet's Bay on Lundy. A general increase in the abundance in *L. ochroleuca* (Rat Island) and to a lesser extent *S. polyschides* (Gannet's Bay) is recorded. Based on current research at other sites, the cause of this shift is likely to be temperature related, but this link is un-proven at Lundy. Current research suggests there *could* be ecological implications of this shift in terms of epiphyte abundance, grazer assemblage structure, shading and competition for space on the reef, if *L. ochroleuca* outcompetes *L. hyperborea* in future years. The current study suggests the condition of this representative habitat is **Favourable.** However, if *L. ochroleuca* outcompetes *L. hyperborea* in future years, this condition status could change relatively rapidly.

**Subtidal Bedrock and Stable Boulder Community Condition Status Summary:**
The data collected during the present study indicate that there is very little change in condition status of sessile marine invertebrates in Subtidal Bedrock and Stable Boulder Communities during the last 11 years. The current study suggests that condition of this representative habitat of the SAC circalittoral rock subfeature is **Favourable**.

***Eunicella verrucosa* Condition Status Summary:** A significant decrease in the abundance of *E. verrucosa* (85%) was measured during the present study at North Quarries compared with 2004 survey results. This reduction in density is considered likely to be an artefact of the highly variable benthos in the sampling area that included types of substratum unsuitable for *E. verrucosa*. Therefore, the decrease in abundance measured during the present study is not necessarily considered to represent a notable decrease in condition status. Indeed, the overall condition score of the individuals encountered at North Quarries (based on epiphytic growth) had increased in comparison to previous years. An increase in *E. verrucosa* density of 35% between 2010 and 2014/15 was recorded at Gull Rock, again supported by a minor increase in average condition score. The current study suggests that condition of this notable species of the SAC circalittoral rock subfeature is likely to be **Favourable**, but suggestions are provided about how to adapt the sampling methodology in order to improve the confidence behind this statement.

**Subtidal Vertical and Overhanging Rock Condition Status Summary:** The lack of previous data describing the Subtidal Vertical and Overhanging Rock habitat at Lundy prevented a robust condition assessment being reached with the exception of the *L. pruvoti*, a representative species of the SAC circalittoral rock subfeature and the sea cave SAC feature, which is discussed below. The Subtidal Vertical and Overhanging Rock habitats at Lundy were found to support slow growing species that are susceptible to physical damage suggesting minimal exposure to physical impacts at the site. The current study suggests that condition of this representative community is **Favourable**.

***Leptopsammia pruvoti* Condition Status Summary:** Where *L. pruvoti* was encountered during the present study (Knoll Pins), a general decrease in abundance of 57% was recorded compared to 2010. In two sites where *L. pruvoti* has historically been recorded, albeit in low numbers, the present study was unable to locate any individuals. There is some doubt that the present study relocated the exact monitoring sectors designated by previous surveys where *L. pruvoti* was found to be absent. Regardless of this, there was found to be a general loss of condition of the feature in terms of abundance since the previous survey. Where *L. pruvoti* was encountered, the number of associated parasitic barnacles was reduced compared with previous years. Additionally, the proportion of juveniles to adults had increased compared with 2010 data, and evidence of recruitment was found. The current study suggests that condition of this representative species is **Unfavourable and in Decline,** although some evidence of a limited potential recovery was also found in the form of new recruitment and reduced parasitic loading.

**No Take Zone Status Summary:** The data collected during the present study indicate that there is very little change in condition status of sessile marine invertebrates within the NTZ during the last 11 years. The changes observed were minor and occurred in both directions (increases and decreases within both the NTZ and control sites).

# 2 General Overview

## 2.1 Aims and Objectives

### 2.1.1 Aims

Natural England commissioned ecological survey work during the summer of 2014 and 2015 in order to obtain standardised biological information for some of the subtidal reef representative habitats and communities of the Lundy Special Area of Conservation (SAC) and No Take Zone (NTZ).

The survey work addressed two aspects of the designations, specifically:

- To survey the listed attributes (Table 1) in order to provide information for the condition assessment of the representative habitats of the infralittoral and circalittoral subfeatures of the SAC against previous survey data, namely:
    - kelp forest communities,
    - subtidal vertical & overhanging circalittoral rock communities ,
    - subtidal bedrock & stable boulder communities.

- To assess any change in the sessile epifauna communities inside and outside of the No Take Zone, as per Hoskin et al. (2009).

These two aspects are reported separately within this document.

**Key aims were to:**

- seek efficiencies between the two aspects in order to provide both SAC condition assessment information and NTZ monitoring as efficiently as possible, and to:

- pay particular attention to survey design so that quantitatively robust data are acquired which will permit rigorous statistical analysis and support robust condition assessment judgements of the SAC using a comparison with previous surveys where possible.

**The overarching objectives, aims and requirements of this work were to:**

A. Carry out a cost effective sampling strategy to allow condition of kelp forests, vertical rock and bedrock and boulders representative habitats to be assessed against the relevant attributes of the Lundy SAC which allows for comparison with previous survey data (i.e. Mercer et al., 2006 and Irving, 2011). This is in order to assess the condition of these attributes as listed in Table 1.

**Table 1.** Relevant attributes of the Lundy SAC.

| Representative community or Notable species | Attribute | Measure |
|---|---|---|
| Kelp forest communities | Distribution and range of kelp biotopes | Distribution of kelp dominated infralittoral communities measured using extent, in particular those biotopes listed at Appendix III. Measured during summer, once during reporting cycle |
| Kelp forest communities | Algal species composition | Number and composition of kelp species (and understorey algae if resources allow) from kelp zone, measured twice during reporting cycle |
| Subtidal vertical & overhanging circalittoral rock communities | Species composition of characteristic biotopes | Presence and abundance of composite characteristic and notable species (biotopes listed at Appendix III of Reg 33). |
| Subtidal bedrock & stable boulder communities | Characteristic species - density and quality of sea fans *Eunicella verrucosa* | Average density (counts in a fixed area) of *Eunicella* and average proportion of damaged tissue epiphytic growth, measured once during reporting cycle. |
| Subtidal bedrock & stable boulder communities | Species composition of characterising biotopes e.g. CR.HCR.XFa.ByErSp | Frequency and occurrence of composite characteristic and notable species, measured once during reporting cycle. |

B. Assess the Lundy NTZ sessile epifauna attribute as a repeat of the Hoskin et al. study i.e. by comparing sampling stations within two treatments, around the island (2 sites inside NTZ and 2 outside (control). Hoskin et al. (2009) assessed 12 quadrats along 6 transects at each of the four sites previously sampled.

C. Develop a single monitoring methodology to provide information for a) SAC condition assessment of the species composition attribute of subtidal bedrock and stable boulder communities and b) the changes in the sessile epifauna communities of the NTZ, by consideration of the methods and analyses used previously and efficiencies to be made by integration of these two aspects.

D. Carry out a survey, based on previous survey methods, that is practical, realistic and will generate sufficiently robust data to enable statistical analysis with data from previous datasets and the collection of compatible future data permitting quantitative long term trend analysis.

E. Ensure that newly collected data are compatible (analytically) with historical survey data, but at the very least will make reference to and utilise such historical data.

F. Provide an assessment of the direction of ecological change by the integration of previously obtained relevant data.

G. Allow anthropogenic influences, impacting on the ability of the sub-feature to achieve Favourable Condition, to be identified and where possible quantified.

H. Record any non-native (e.g. *Undaria pinnafida*, *Sargassum muticum*) or notable species (e.g. *Palinurus elephas*) and their abundances throughout the survey.

I. Produce two distinct and discrete parts within a single report. One for each aspect of this contract i.e. provision of SAC condition assessment information and NTZ monitoring update together with associated outputs i.e. raw data, GIS data, photographs, Marine Recorder etc..

J. Maintain contact and regularly liaise with NE staff and Lundy Warden to ensure effective communication throughout survey operations.

## 2.2 Background: Condition Assessment Monitoring

Condition monitoring is carried out to inform the Competent Authority's assessment of the condition of an SAC's interest features for the 6 yearly cycle of reporting to Europe. Sites may have one or several interest features (e.g. habitat or species) and conservation objectives are developed by identifying and setting targets for them. Each attribute supporting the feature (e.g. extent, quality, etc.) is then measured and compared against the target value set, or historical data. If all the targets are met, the feature is in favourable condition, otherwise it could be listed as unfavourable (recovering/declining) or destroyed. Human activities which are likely to have an impact on the site, and the conservation measures taken to maintain or restore the site, are also recorded (JNCC, 2006).

The purpose of the condition assessment is to indicate, at the site level, to what extent conservation measures already in place are providing effective achievements, and to identify any need for future actions; ultimately it enables the government to identify any areas that need implementation.

For this project the methodology for informing condition assessment of the Lundy SAC, and for monitoring any changes in the sessile epifauna communities in relation to the NTZ, followed that recommended in Irving (2011, 2008), Hoskin et al. (2009) and Mercer et al. (2006), and also align with the methodologies outlined in the JNCC's Common Standards Monitoring guidance.

## 2.3 Background

Lundy holds a unique and prestigious place in the history of marine conservation in the United Kingdom. Lundy was the first formally designated Marine Protected Area (MPA) in the U.K. which was officially established in 1973. In 2000, Lundy acquired the status of Special Area of Conservation (SAC) under the European Union's Habitats Directive based on its reefs, caves, subtidal sandbanks and grey seal population. In 2003, Lundy became the site of the first statutory No Take Zone (NTZ) established in the U.K. The history surrounding the MPA designation and a summary of previous monitoring activities around the island can be found in Hiscock & Irving (2012).

As described by Hoskin et al. (2009), the position of Lundy in the Bristol Channel (51° 10' N, 4° 40' W) provides hard granite substrate in an area otherwise dominated by soft sediments and gravel. This provision of structure combined with the strong tidal regime of the Bristol Channel enables Lundy to support a unique assemblage of marine invertebrates, with examples of sponges (*Axinella dissimilis*& *Raspalia ramosa*) and cup corals (*Leptopsammia pruvoti*) being among the most conspicuous.

## 2.4 Site Selection

The previous relevant surveys (Mercer et al., 2006, Hoskin et al., 2009, Irving, 2008; 2011) have completed field work around Lundy which largely pre-determined the location of sampling for the present study. A full list of positions for the sampling stations used in the present study is provided in Appendix 12.1 in WGS 84 format.

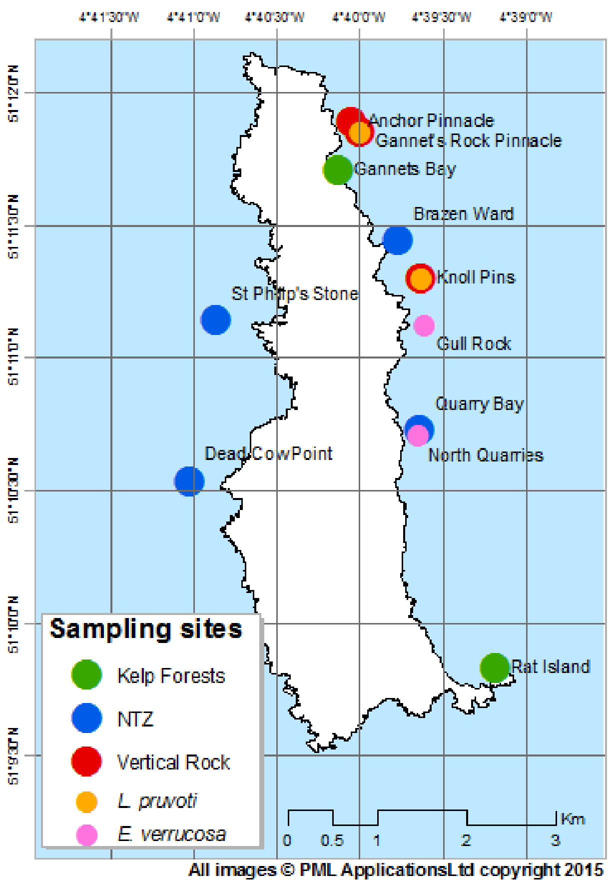



**Figure 1**. Map showing sampling site locations around Lundy.

In order to meet the objectives of this study and allow comparison with data from previous surveys, the following sites were sampled:

Kelp Forest Community Assessment

- Rat Island
- Gannet's Bay

  Algal Depth Assessment

  - Dead Cow Point
  - Knoll Pins

*Eunicella verrucosa* populations

- North Quarries
- Gull Rock
- Knoll Pins

*Leptopsammia pruvoti* population

- Knoll Pins
- Gannet's Rock Pinnacle
- Anchor Pinnacle

Subtidal bedrock and boulders – species composition, benthic fauna and NTZ comparison

- Brazen Ward and Knoll Pins (NTZ S1)
- Quarry Bay (NTZ S2)
- St Phillips Stone (Control S1)
- Dead Cow Point (Control S2).

# 3 General Methods

## 3.1 Survey Team

The scientific team consisted of six Health and Safety Executive (HSE) qualified divers working in three pairs. The scientific divers were supported by a team consisting of a dive supervisor, dressed-in standby diver, skipper and at least one member of staff for surface support in accordance with the U.K. HSE Scientific and Archaeological ACOP (http://www.hse.gov.uk/pubns/priced/l107.pdf). Dive platforms were provided by the appointed dive contractor "InDeep Diving and Marine Services" (Sea Kat), and also by "Lundy Charters" (Lundy Murrelet).

## 3.2 Diving Equipment

Diving equipment consisted of a "wing" style buoyancy control device, solid back plate and one piece webbing harness. Two 10ltr or 12ltr cylinders were bolted to the back plate and connected to each other via a manifold. This main air source was used to supply full-face AGA masks that were fitted with a through-water communication system to enable divers to talk to each other underwater and also communicate with topside. Each diver also carried a red and yellow Surface Marker Buoy to provide a failsafe pre-arranged form of communication with the dive vessel in the event of separation or equipment failure. The twin cylinder arrangement also supplied a redundant second stage regulator on a 2m hose in order to provide a backup air supply in the event of failure of the AGA mask. A completely separate 3ltr cylinder was mounted to the twin cylinder rigs that supplied gas to a manually operated 3 position bail out block. This allowed divers to manually switch to a bail-out gas supply in the event of running out of gas in the main cylinders. Nitrox gas was used on most of the dives at 32% oxygen to maximise available bottom time times.

## 3.3 Pre-survey work

Prior to the diving survey, the dive team undertook a land based identification refresher exercise. This step included communal identification of the target kelp and invertebrate species using photographs provided from the actual survey sites (provided by Dr Keith Hiscock). In addition, the team examined the data recording sheets and underwater identification guides a week before the survey, to ensure these documents were familiar during the dives.

Members of the dive team who had not completed active survey work for more than three months undertook a familiarisation dive in Plymouth prior to departing to Lundy. This exercise provided staff the chance to fine tune the unique set up of diving equipment used during this survey, and also provided an opportunity to refresh kelp identification skills with samples collected from Plymouth. Once on Lundy, all divers completed at least one familiarisation dive. During these dives species identification was confirmed, with examples of monitoring species brought to the surface to aid divers with identification where possible. This work supported consistency of identification throughout the diving operations.

## 3.4 Survey Dates

The survey sites experience strong tides and the survey times were chosen where possible to coincide with high and low tide slack water conditions in daylight hours to give the best chance of suitable underwater visibility. The survey was conducted in three separate phases. Phase 1 was between the 1-7th of September 2014. Phase 2 was conducted on the 16th -18th of August 2015 and Phase 3 was between the 6-8th of Sept 2015.

### 3.4.1 Phase 1. 1-7th of September 2014

Phase 1 was carried out with a team that was based on Lundy and was mobilised using the quay on the southeast of the island each day. The weather conditions experienced during Phase 1 made this approach challenging as described in the General Discussion Section of this report. During Phase 1, all the sampling for the NTZ zone assessment and the kelp habitat assessments was undertaken. This work was undertaken first to ensure that any assemblages that might show seasonal variation were assessed as a priority in case bad weather delayed further work. During Phase 1, winds were predominantly from an easterly direction which created calm conditions on the west of the island. As the prevailing wind direction at Lundy is usually westerly, the opportunity to sample the west of the island in calm conditions was taken and the NTZ control sites were assessed.

### 3.4.2 Phase 2 & 3. 16-18th August and 6th-8th September.

The weather deteriorated considerably after Phase 1, and there were very few periods of calm weather over the next 11 months which would enable the team to complete the remaining 5 days' work. The early summer of 2015 was noted by many of the local dive and fishing charter vessel skippers as one of the worst seasons in terms of wind for many years.

One local skipper who was able to take advantage of individual calm days and quickly mobilise from the north Devon coast reported conducting only 17 day trips between May 2015 and Sept 2015 compared to the usual 45 days. This unusual weather together with damage sustained to the dive vessel whilst in dock in Bideford resulted to a delay in completing the field work until August and September 2015.

The difficulties in accessing Lundy during easterly wind conditions as experienced during Phase 1 resulted in the team mobilising from Clovelly during Phases 2 & 3. This approach made logistics less challenging and allowed the team to take advantage of short weather windows. This approach also allowed the team to work independently of the Oldenburg Ferry which further improved the flexibility of the team to quickly respond in short favourable weather windows.

# 4 Methods for assessing the condition of the SAC representative species and habitats

## 4.1 Kelp Forest

### 4.1.1 Assemblage Species Composition

In order to enable the comparison between both previous studies undertaken on kelp habitats at Lundy (Mercer et al., 2006 and Irving, 2011), the approach used by Irving (2011) was adopted, where the abundance of a subset of 6 notable kelp species were identified namely:

- *Laminaria hyperborea,*
- *Laminaria ochroleuca*,
- *Saccharina latissima* (formerly *Laminaria saccharina*),
- *Saccorhiza polyschides*,
- *Laminaria digitata,*
- *Alaria esculenta*.

This allowed the same subset of species to be included from Mercer et al. (2006), incorporating as much data as possible for the long term trend analysis.

- Two sites (Rat Island and Gannet's Bay, see Figure 1) were sampled for kelp community condition.
- At each dive site, three pairs of divers descended down a shot line to the seabed.
- Each pair moved 5m off from the shot, along a random bearing, before undertaking algal counts in between 23-41 randomly placed 1m$^2$ quadrats.
- Counts of individual kelp stipes were recorded by divers *in situ* on underwater slates using pre-prepared recording forms (see Appendix: 12.3.1. Kelp Forest).

### 4.1.2 Algal Depth Assessment

Algal depth assessment was undertaken, using the same methodology as Irving (2011) at Knoll Pins, yet with an additional site (Dead Cow Point) incorporated. This allowed a more accurate assessment of island wide algal distribution.

- Each pair of divers descended a shot at each site to a depth of 16m. Divers then swam along and down a sloped transect to approximately a 26m depth.
- At this depth divers headed back up the slope, searching for the first occurrence of red algae and recording this with a photo of the specimen with a dive computer clearly showing depth in the frame.
- This process was then repeated further up the slope with brown algae and subsequently kelp.

## 4.2 Subtidal Vertical & Overhanging Circalittoral Rock Communities

### 4.2.1 Species Composition

For this attribute, the methodology of Mercer et al. (2006) was followed, with this habitat being surveyed using quadrat assessment along pre-determined transects. However, the location of transects was designed to follow the subdivision of the Knoll Pins, Gannet's Rock Pinnacle and Anchor Pinnacle into 9 separate sectors (as described in Irving 2011).

- Each pair of divers then marked out a 10m transect within each sector (where sector width allowed), at a predetermined depth contour.
- Divers then undertook a quadrat survey, assessing the abundance of a subset of notable species in twelve 30 x 30 $cm^2$ quadrats along each transect.
- Notable species were predetermined via consultation with Dr Keith Hiscock and Dr Miles Hoskins, as well as pre-survey orientation dives (Table 2).

**Table 2**. Notable Species assessed in Subtidal Vertical and Overhanging Rock habitats.

| | | | |
|---|---|---|---|
| **Hydroid** | *Gymnangium montagui* | **Sponges** | *Homaxinella subdola* |
| **Ascidian** | *Stolonica socialis* | | *Axinella infundibuliformis* |
| **Starfish** | *Marthasterias glacialis* | | *Axinella damicornis* |
| **Urchin** | *Echinus esculentus* | | *Axinella dissimilis* |
| **Cup Coral** | *Leptopsammia pruvoti* | | *Cliona celata* |
| **Bryozoan** | *Flustra foliacea* | | *Raspailia ramosa* |
| | *Pentapora foliacea* | | *Raspailia hispida* |
| | | | *Stelligera stuposa* |
| **Soft Coral** | *Alcyonium glomeratum* | **Anemone** | *Aiptasia mutabiis* |
| | *Alcyonium digitatum* | | *Parazoanthus cf. anguicomus* |
| | *Eunicella verrucosa* | | *Parazoanthus axinellae* |

### 4.2.2 *Leptopsammia* Sector Survey & Photographic Mosaic

- In addition, where particular concentrations of *L. pruvoti* were known to exist (following Irving 2011), a detailed photo mosaic of these sites was taken to allow counts to be made at a later date.
- At each site a pair of divers descended a marker line. One diver recorded the survey area in a raster scanning pattern using a stills camera to create a photo mosaic.
- The second diver assessed the condition of 100 randomly selected *L. pruvoti* within the site, noting size category and the presence of any colonisation by *P. hippocrepia* or *M. anglicum* (Irving 2011).

## 4.3 Subtidal bedrock & stable boulder communities

### 4.3.1 Species Composition

- Condition of this habitat was assessed exactly according to Hoskin et al. (2009).
- Four sites were sampled, with 6 transects undertaken within each site.
- The start of each transect was marked by a shot, down which a pair of divers descended.
- Divers then reeled out a 20m transect along a random bearing.
- The pair swam back towards the shot, undertaking 12 x 30cm$^2$ quadrat surveys randomly distributed along this transect.
- Divers recorded the abundance of 15 notable species from within this biotope, as determined by Hoskin et al., (2004). (See Table 3).

**Table 3.** 15 notable species, as determined by Hoskin et al. (2004).

| | | | |
|---|---|---|---|
| **Demospongiae** | | **Cnidaria** | |
| **Axinelida** | *Axinella dissimilis* | **Actiniaria** | *Anemonia viridis* |
| | *Axinella infundibuliformis* | | *Aiptasia mutabilis* |
| | *Axinella damicornis* | | |
| | *Raspailia ramosa* | | |
| **Suberitida** | *Homaxinella subdola* | **Bryozoa** | |
| **Polymastiida** | *Polymastia boletiformis* | **Cheilostomatida** | *Pentapora fascialis* |
| | *Polymastia mammilaris* | | |
| **Clionaida** | *Cliona celata* | **Chordata** | |
| **Octocorallia** | | **Stolidobranchia** | *Stolonica socialis* |
| **Alcyonacea** | *Alcyonium digitatum* | | |
| | *Alcyonium glomeratum* | | |
| | *Eunicella verrucosa* | | |

### 4.3.2 *Eunicella verrucosa* Density and Condition Assessment

- The majority of the *E. verrucosa* density survey was conducted exactly as described by Irving (2011).
- *E. verrucosa* density and condition was assessed along 10 successive transects in each of six sites, distributed between North Quarries and Gull Rock.
- Each diver photographed every *E. verrucosa* specimen they encountered within a 2m wide band along each transect, using a quadrat in each image for scaling.
- Photos were later assessed for density and condition assessment.
- As a result of unfavourable weather limiting diving activity, six transects in Quarry Bay (locations in Appendix 12.1) were conducted using drop down video camera. This method allowed density measurements to be established. However, accurate condition assessments were not possible using this technique as in many cases the

fixed angle of the drop down video camera did not allow a view of the whole organism, preventing an estimate of percentage coverage of fouling being obtained.

### 4.3.3 Additional objectives

- During all dives, any non-native species or species suspected as residing outside their normal distribution range were noted and photographed with GPS location data.

- During all dives, any anthropogenic influences such as litter, sewage outflow or suspected land runoff drainage sources (which may impact on the ability of a sub-feature to achieve favourable condition) were recorded and photographed with GIS location data.

## 4.4 GIS

Field data were transferred to excel spreadsheets using ArcGIS 9.2 (compatible with ArcGIS 10.1) for the digitisation of the maps showing the sampling sites, transects and quadrats. All maps were produced at high resolution for ease of use and are supplied as supplementary electronic files.

## 4.5 Data Analysis

### 4.5.1 Kelp Forest Representative habitat

Kelp forest data were collected and analysed in the same format as presented by Irving (2011) to allow comparison with historical data. The data collected for the present study (number of plants per species, per quadrat) were averaged by site and presented to show the ratio of each notable species in the assemblage.

### 4.5.2 –Eunicella verrucosa Notable species of circalittoral rock SAC subfeature

The present survey produced data that were again analysed and presented in the same format as the reference study (Irving, 2011) to provide a simple comparison to baseline conditions. The density data were converted into individuals per 10m$^2$ and then averaged by site and presented alongside historical data for comparison. The condition status of the individuals was also averaged across each site and for the survey year to produce an overall condition score. Condition score was calculated using the same method described in Irving (2011) (See Table 4).

**Table 4**. *E. verrucosa* condition scores: using Irving (2011) method.

| Score | Condition % fouling) |
|---|---|
| 5 | Pristine or <5% fouling (little of no epibiota) |
| 4 | 5 - 20% |
| 3 | 20 – 50% |
| 2 | 50 – 80% |
| 1 | >80% |

### 4.5.3 Subtidal Vertical and Overhanging Circalittoral Rock Communities

In the case of this habitat, the baseline data set available for comparison with data collected for the present study was minimal; therefore a robust time series analysis was not possible. Instead, the mean abundance per $m^2$ of the species common to both the present and previous surveys was presented for comparison.

In order to examine trends in the data collected during the present study, data were analysed using the multivariate statistical programme PRIMER v7 2015 (Clarke & Warwick, 2001). The abundance data obtained during the quadrat survey were checked for errors and subsequently transformed using a $4^{th}$-root transformation to reduce the differences in the overall abundances of different taxa (Clarke & Warwick, 2001).

Bray-Curtis dissimilarity values were then calculated in PRIMER and visualised on nonmetric multidimensional scaling (nMDS) plots to look for the influence of different factors on the distribution of the target species.

### 4.5.4 *L. pruvoti* Sector Survey and Photo-mosaic

The *L. pruvoti* data are presented as the total number of individuals encountered in each sector of the survey to allow direct comparison with previous surveys. Separate counts for juveniles (<5mm diameter across) and adults are presented to attempt to establish whether recruitment has occurred. These total counts are then described as percentage changes in abundance compared to baseline conditions. The photo-mosaic was constructed according to Irving (2011) and used to ascertain the condition of individual cup corals at the site.

# 5 SAC Results

## 5.1 Kelp Forest Communities

### 5.1.1 Algal Species Composition

A total of 99m$^2$ of kelp forest habitat were sampled at the Rat Island site. This produced an assessment of 2049 individual kelp plants making this the most extensive survey of its kind at the site to our knowledge. The assemblage consisted of *L. hyperborea*, *L. ochroleuca*, *S. latissima* (in very low abundance, 2 individual plants) and *S. polyschides*. *L. digitata* and *A. esculenta* were not encountered at the site, (Table 5). A total of 241 juvenile *Laminaria* species were encountered that were not developed enough to be confidently identified in the field. *L. hyperborea* and *L. ochroleuca* were the most abundant species occurring in similar proportions (41% *L. hyperborea* & 37.7% *L. ochroleuca*).

**Table 5.** Rat Island Kelp Species Composition 2014.

| Date | Recorder | No. of quadrats | *Laminaria hyperborea* | *Laminaria digitata* | *Laminaria ochroleuca* | *Saccharina latissima* | *Saccorhiza polyschides* | Juvenile *Laminaria* spp. | Total no. of plants recorded | Overall density/m$^2$ (all spp.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 03-Sep-14 | RB | 7 | 33 | 0 | 3 | 0 | 0 | 9 | 45 | 6.43 |
| 03-Sep-14 | RE | 16 | 48 | 0 | 41 | 0 | 63 | 35 | 187 | 11.69 |
| 03-Sep-14 | DS | 39 | 373 | 0 | 470 | 0 | 36 | 109 | 988 | 25.33 |
| 04-Sep-14 | DS | 37 | 390 | 0 | 260 | 2 | 89 | 88 | 829 | 22.41 |
| | | 99 | 844 | 0 | 774 | 2 | 188 | 241 | 2049 | |
| Plant density / m$^2$ | | | 8.53 | 0.00 | 7.82 | 0.02 | 1.90 | 2.43 | | 20.70 |

A total of 115m$^2$ of kelp forest habitat were sampled at the Gannet's Bay site. This produced an assessment of 1848 individual kelp plants, again, making this the most extensive survey of its kind at the site to our knowledge. The average density of plants per m$^2$ was slightly lower at Gannet's Bay than at Rat Island (20.70 per m$^2$ at Rat Island vs 16.07 per m$^2$ at Gannet's Bay). In general, Gannet's Bay is also more sheltered than Rat Island and can be subject to notable deposition of sediments which were deposited on the kelp plants.

The assemblage at Gannet's Bay consisted of *L. hyperborea*, *L. ochroleuca*, *S. latissima* (in very low abundance, 1 individual plant) *L. digitata* (in very low abundance, 4 individual plants) and *S. polyschides*. *A. esculenta* was not encountered at the site (Table 6). As also discovered at Rat Island, *L. hyperborea* and *L. ochroleuca* were the most abundant species occurring in similar proportions (56% *L. hyperborea* & 22% *L. ochroleuca*). A total of 139 juvenile *Laminaria* individuals were encountered that were not developed enough to be confidently identified in the field.

**Table 6.** Gannet's Bay Kelp Species Composition 2014.

| Date | Recorder | No. of quadrats | *Laminaria hyperborea* | *Laminaria digitata* | *Laminaria ochroleuca* | *Saccharina latissima* | *Saccorhiza polyschides* | Juvenile *Laminaria* spp. | Total no. of plants recorded | Overall density/m² (all spp.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 06-Sep-14 | RB | 20 | 178 | 0 | 69 | 0 | 8 | 4 | 259 | 12.95 |
| 06-Sep-14 | MP | 20 | 159 | 0 | 58 | 0 | 54 | 64 | 335 | 16.75 |
| 06-Sep-14 | CJ | 31 | 143 | 4 | 79 | 1 | 122 | 2 | 351 | 11.32 |
| 06-Sep-14 | DS | 44 | 571 | 0 | 213 | 0 | 50 | 69 | 903 | 20.52 |
| | | 115 | 1051 | 4 | 419 | 1 | 234 | 139 | 1848 | |
| | | Plant density / m² | 9.14 | 0.03 | 3.64 | 0.01 | 2.03 | 1.21 | | 16.07 |

## 5.1.2 Historical Algal Species Composition

Kelp forest data collected for the current study were compared with historical data collected at the same sites by Mercer et al. (2006) & Irving (2011). At Rat Island, *L. hyperborea* consistently remains the most abundant kelp species at the site over time from 2004 – 2014. The ratio of *L. hyperborea* to *S. polyschides* plants showed little variation over the previous 10 year period (Figure 2). However, the ratio of *L. hyperborea* to *L. ochroleuca* has changed considerably from 1:18 in 2004, 1:4 in 2010 and 1:1 in 2014.

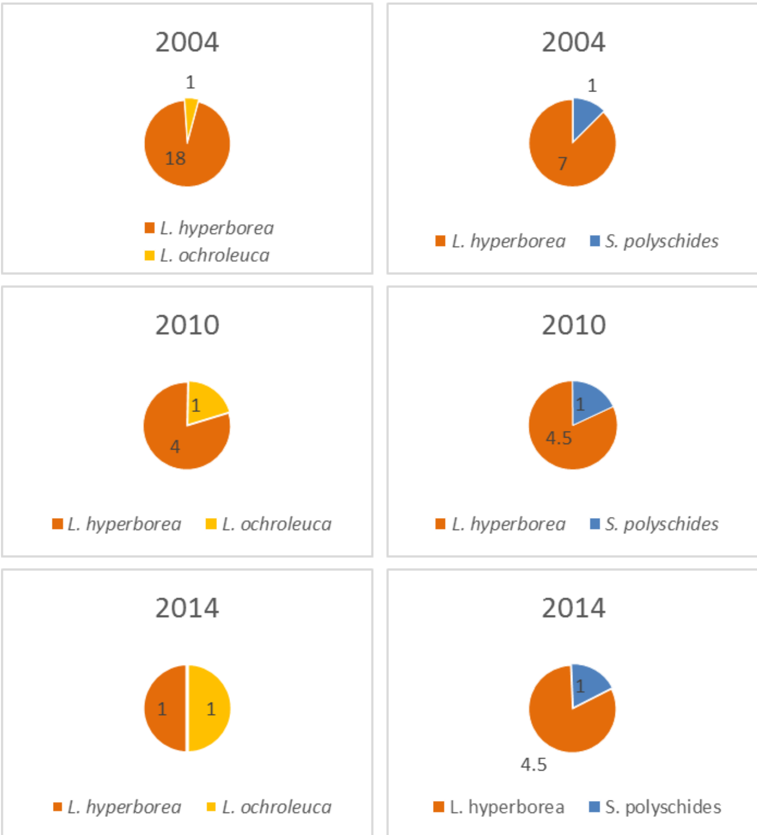



**Figure 2.** Ratio of dominant kelp species over time at Rat Island based on n= 385 in 2004, n=667 in 2010 and n=2049 in 2014.

At Gannet's Bay, *L. hyperborea* was the most abundant kelp species at the site during 2004. However, in 2010, the relative abundance of *L. ochroleuca* increased dramatically and it became the most abundant kelp species at the site. This temporary dominance declined in 2014, although the relative abundance of *L. ochroleuca* was still considerably higher than when sampling was first conducted in 2004. The proportion of *S. polyschides* plants appears to have increased and stabilised since 2004 with the relative abundance of *S. polyschides* being recorded as very similar during 2010 and 2014 (Figure 3).

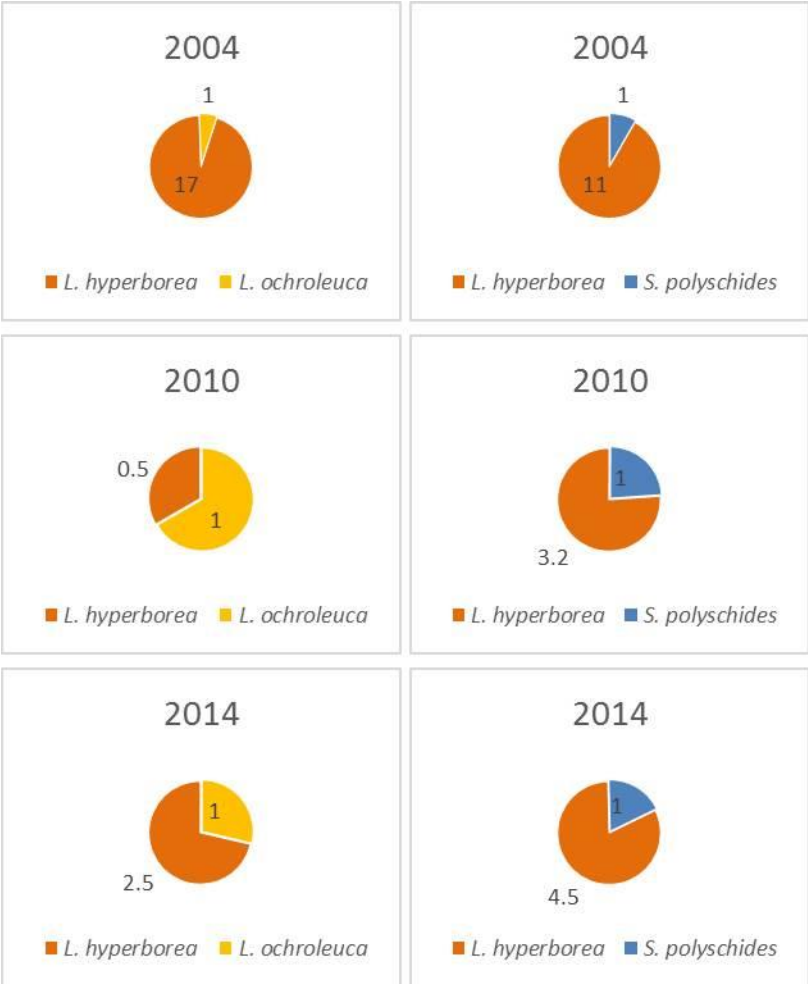



**Figure 3.** Ratio of dominant kelp species over time at Gannet's Bay based on n= 441 in 2004, n=1067 in 2010 and n=1848 in 2014.

### 5.1.3 Algal Density

The kelp forest density data collected during 2014 were compared to the historical kelp forest data in the same format as presented by Irving (2011) to enable a simple comparison of results. The number of kelp plants per species, per quadrat, were mean averaged per $m^2$ and are presented in Table 7.

The averaged algal density data unsurprisingly followed a similar pattern to the kelp ratio data. At Rat Island, the average density per $m^2$ remained consistent across the full range of species sampled from 2004 – 2014, with the exception of a marked increase in the density of *L. ochroleuca* from 0.5 to 7.82 individuals per $m^2$. The increase in *L. ochroleuca* was not accompanied with a decrease in abundance of any other species sampled in the kelp forest.

This suggests that the overall density of the kelp forest had increased at Rat Island, rather than *L. ochroleuca* out-competing another kelp forest species, a statement supported by Table 7.

Gannet's Bay also shows a pronounced increase in the density of *L. ochroleuca* in 2010. However, in contrast to Rat Island, the corresponding density of the other dominant kelp species, *L. hyperborea,* decreased over this time period. In 2014 the density of *L. ochroleuca* decreased, the density of *L. hyperborea* increased (Figure 3).

**Table 7.** Kelp Forest Survey Data Summary and Density Averages.

| Location | Measure | Year | Total no. of quadrats | *Laminaria hyperborea* | *Laminaria digitata* | *Laminaria ochroleuca* | *Saccharina latissima* | *Saccariza polyschides* | Juvenile *Laminaria* spp. |
|---|---|---|---|---|---|---|---|---|---|
| Rat Island | No. of plants | 2004 | 33 x 1m$^2$ | 295 | 6 | 17 | - | 41 | 26 |
| | | 2010 | 47 x 1m$^2$ | 382 | 0 | 100 | 3 | 84 | 98 |
| | | 2014 | 99 x 1m$^2$ | 844 | 0 | 774 | 2 | 188 | 241 |
| | Density (m$^{-2}$) | 2004 | 33 x 1m$^2$ | 8.9 | 0.2 | 0.5 | - | 1.2 | 0.8 |
| | | 2010 | 47 x 1m$^2$ | 8.13 | 0 | 2.13 | 0.06 | 1.79 | 2.09 |
| | | 2014 | 99 x 1m$^2$ | 8.53 | 0 | 7.82 | 0.02 | 1.90 | 2.43 |
| Gannets' Bay | No. of plants | 2004 | 21 x 1m$^2$ | 352 | 0 | 22 | - | 31 | 66 |
| | | 2010 | 42 x 1m$^2$ | 257 | 7 | 544 | 0 | 81 | 178 |
| | | 2014 | 115 x 1m$^2$ | 1051 | 4 | 419 | 1 | 234 | 139 |
| | Density (m$^{-2}$) | 2004 | 21 x 1m$^2$ | 16.8 | 0 | 1.00 | - | 1.50 | 3.10 |
| | | 2010 | 42 x 1m$^2$ | 6.12 | 0.17 | 12.95 | 0 | 1.93 | 4.24 |
| | | 2014 | 115 x 1m$^2$ | 9.14 | 0.03 | 3.64 | 0.01 | 2.03 | 1.21 |

### 5.1.4 Algal Depth Assessment

Algal depth assessment data were recorded at Dead Cow Point on the generally more exposed west side of the island, and also at Knoll Pins on the generally more sheltered east of the island. The depths at which each fraction of the algal community were encountered were similar between sites, but with each fraction occurring slightly deeper at Dead Cow Point than at the Knoll Pins (Tables 8 & 9).

**Table 8**. Algal Depth Assessment at Dead Cow Point.

| | Computer depths (m) | | | Average depth (m) | |
|---|---|---|---|---|---|
| | Computer model: Uwatec | Suunto | | bsl | bcd |
| **1st Red Algae** | 27.2 | 26.9 | - | 27.1 | 20.7 |
| **1st Brown Algae** | 26.7 | 26.4 | - | 26.6 | 20.2 |
| **1st Kelp** | 17.7 | 17.5 | - | 17.6 | 11.3 |
| **Kelp park** | 14.9 | 14.8 | - | 14.9 | 8.7 |
| **Kelp forest** | 13.3 | 13.2 | - | 13.3 | 7.1 |

bsl = below sea level, bcd = below chart datum

**Table 9.** Algal Depth Assessment at Knoll Pins.

| | **Computer depths (m)** | | | **Average depth (m)** | |
|---|---|---|---|---|---|
| | Computer model: a) Uwatec | b) Suunto | | bsl | bcd |
| **1st Red Algae** | 26.2 | 25.8 | - | 26.0 | 21.1 |
| **1st Brown Algae** | 21.6 | 21.2 | - | 16.9 | 12.1 |
| **1st Kelp** | 12.5 | 12.3 | - | 12.4 | 7.7 |
| **Kelp park** | 12.4 | 12.1 | - | 12.3 | 7.6 |
| **Kelp forest** | 6.7 | 6.6 | - | 6.7 | 2.1 |

bsl = below sea level, bcd = below chart datum

### 5.1.5 Historical Algal Depth Data Comparison

The historical comparison of algal depth assessment data shows little variation between maximum depths at which either the kelp plants or the foliose red algae were encountered at the Knoll Pins during the last 30 years. The greatest difference between maximum depth of kelp plants over the time series was 2.7m (+/- ~0.5m) for the red foliose algae and 3.3m (+/- ~0.5m) for the kelp plants.

**Table 10.** Maximum depth of kelp plants and red foliose algae during the last 30 years.

| **Year** | **1985[1]** | **1986[2]** | **1987[3]** | **1988[4]** | **1990[5]** | **1996[6]** | **1997[7]** | **2001[7]** | **2010[8]** | **2014[9]** |
|---|---|---|---|---|---|---|---|---|---|---|
| Max depth (m bcd) of kelp plants at Knoll Pins | 7.3 | ~7 | 10 | - | - | 9.2 | 8.1 | 8.2 | 6.7 | 7.7 |
| Max depth (m bcd) of foliose (red) algae at Knoll Pins | 21.8 | ~22 | 22 | 22.8 | 21.5 | 21.9 | - | - | 23.8 | 21.1 |

*Refs.* [1] Hiscock (1986a); [2] Hiscock (1986b); [3] Howard (1987); [4] Howard (1988); [5] Irving (1990); [6] Irving (1997); [7] Irving & Northen (2004); [8] Irving (2011); [9] Present study.

## 5.2 Subtidal Vertical & Overhanging Circalittoral Rock Communities

### 5.2.1 Assemblage Composition

The sessile invertebrate assemblages were assessed using a sector survey approach as described by Mercer et al. (2006). Twenty four 30cm$^2$ quadrats were assessed at Anchor Pinnacle and at Gannet's Pinnacle. Sixty 30cm$^2$ quadrats were assessed across 5 sectors at Knoll Pins. The abundance of notable invertebrates was recorded. These data were fourth route transformed and averaged by the factor "Sector" to reduce the noise produced by the high proportion of quadrats with very low abundances. These data are presented in an nMDS plot (Figure 4). It is evident that that there is no clear grouping of data points indicating an effect of "Site". This is confirmed by an ANOSIM result of global R = 0.007, $p<0.04$.

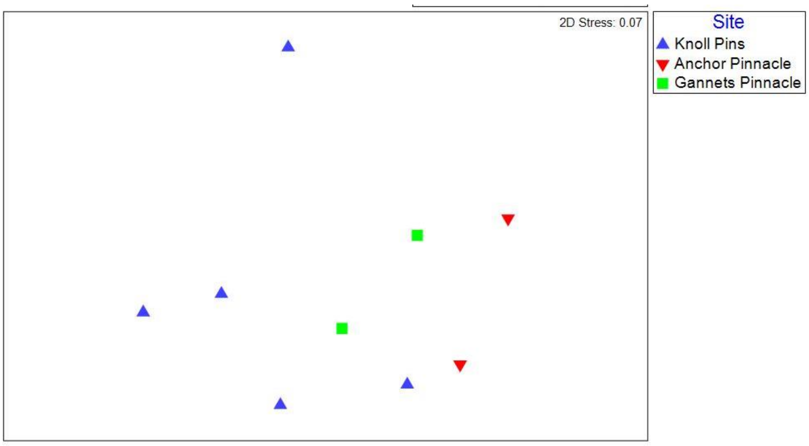



**Figure 4**. nMDS plot of Bray-Curtis dissimilarity data averaged by "Sector" representing abundance of invertebrates at the Knoll Pins, Anchor Pinnacle and Gannet's Pinnacle.

The assemblages at each site supported low abundances of the monitoring species (~3 per $m^2$ maximum) with the most abundant species across each site being the sponge *Axinella dissimilis.* The other most abundant species across all sites were the sponges *Raspailia ramosa* and *Cliona celata*. Knoll Pins appeared to support a greater diversity of target organisms compared to the other sites, yet in general the abundances were slightly lower (~1 per $m^2$), Figure 6.

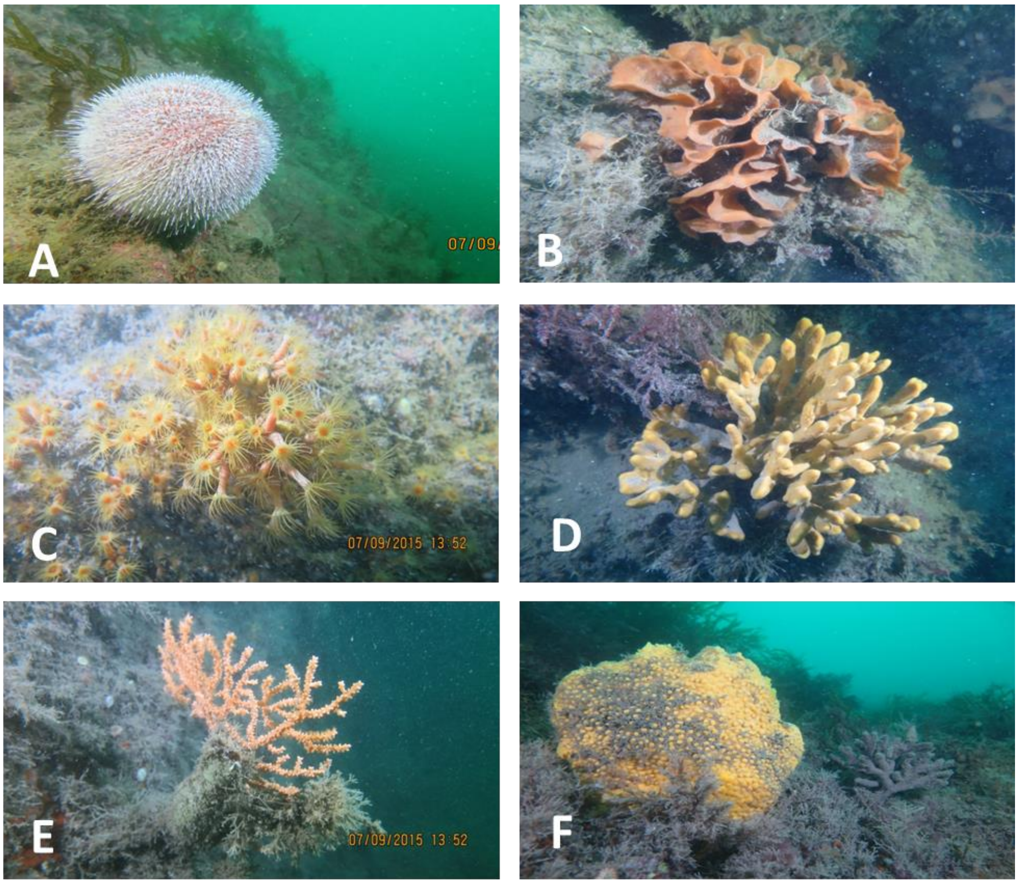



**Figure 5.**Typical appearance of monitoring species in the subtidal vertical and overhanging rock communities, A - *Echinus esculentus*, B - *Pentapora foliacea* , C - *Parazoanthus axinellae*, D - *Homaxinella subdola* , E - *Eunicella verrucosa*, F - *Cliona celata*.

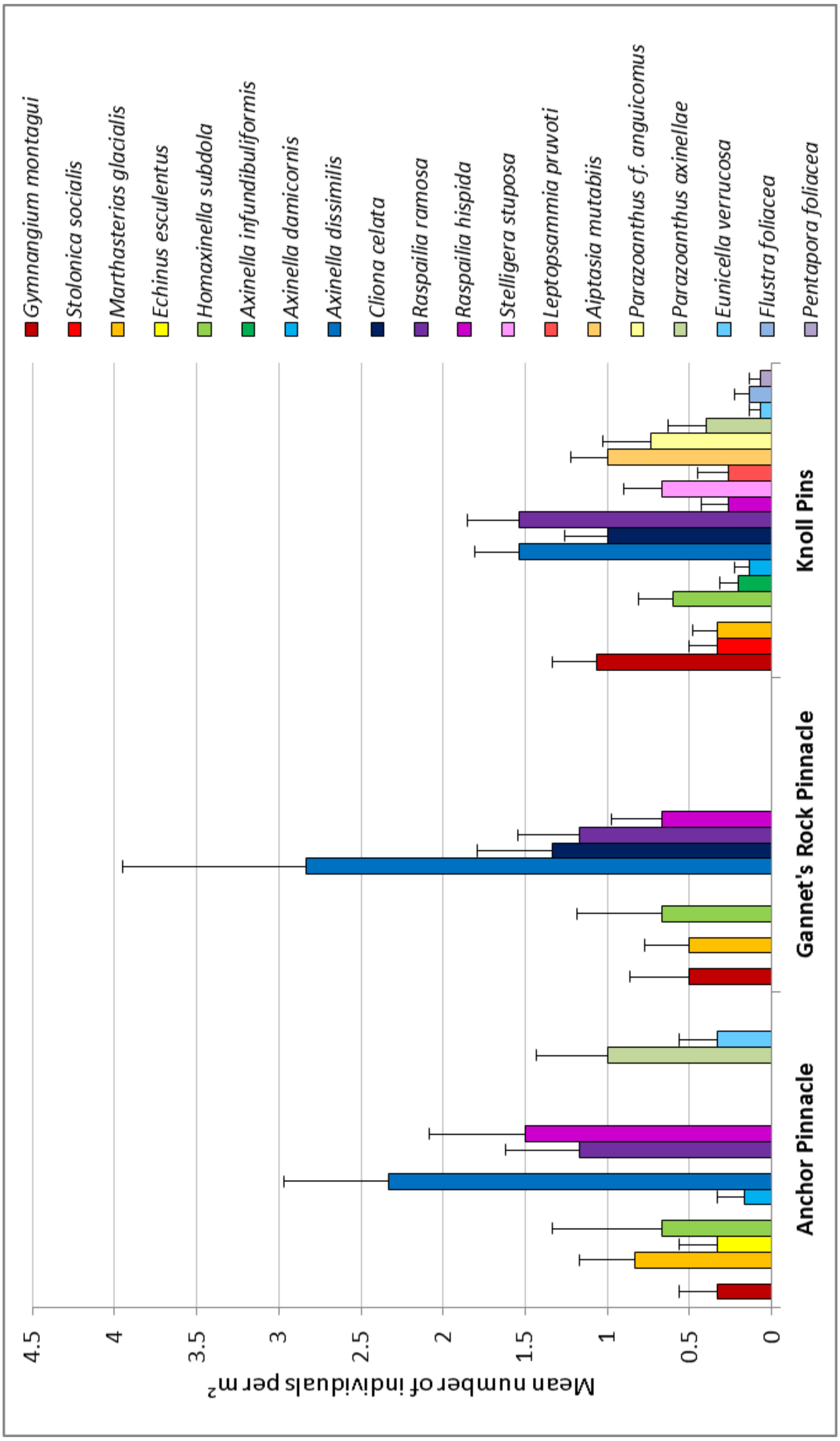



**Figure 6.** Mean number of sessile invertebrates per $m^2$ measured in 2015 at Anchor Pinnacle, Gannet's Rock Pinnacle and Knoll Pins. Error bars show standard deviation, n=60 at the Knoll Pins and n=24 at both Anchor Pinnacle and Gannet's Rock Pinnacle.

## 5.3 Historical Comparison of Circalittoral Rock Communities

The ability to compare the data collected in the present study with historical data is very limited for this attribute. The previous study that assessed similar habitats (Mercer et al., 2006) did not sample as extensively as the present survey. During the sampling that was conducted for the Mercer et al. 2006 study, only low abundances of a limited range of species were recorded at one of the three sites sampled by the present study. Only three species were sampled in common between the present study and the Mercer et al. (2006) study. In addition, one of these species was a mobile echinoderm *(Marthasterias glacialis*) which would be expected to show temporal variation in abundance as a result of their mobility.

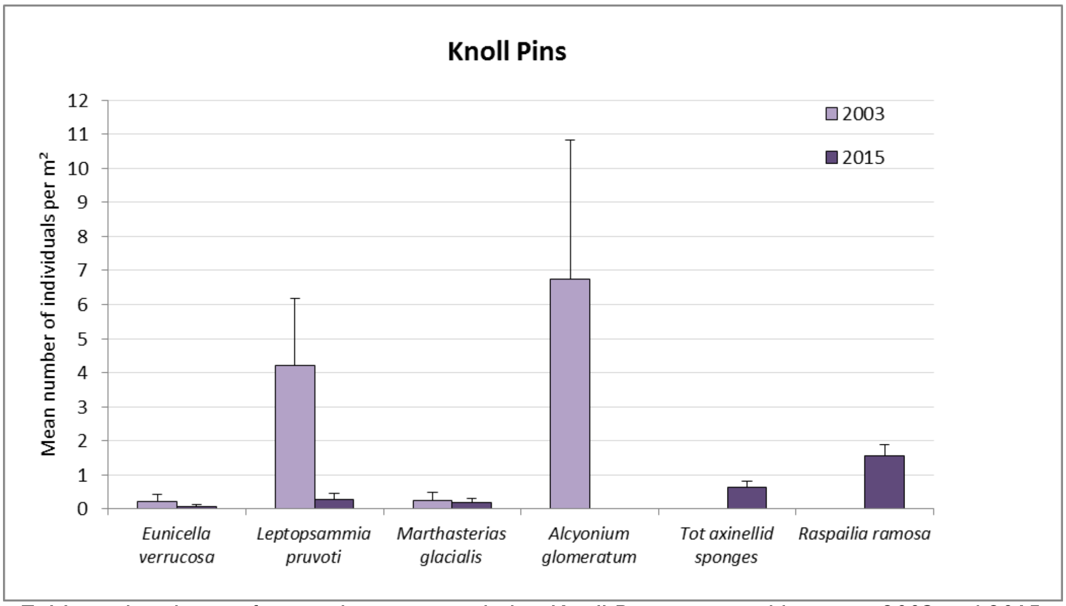



**Figure 7**. Mean abundance of invertebrates recorded at Knoll Pins compared between 2003 and 2015. n= 15 in 2003 & n=60 in 2015. Error bars show standard deviation, n=60 in 2015 and n=19 in 2003.

## 5.4 *Leptopsammia pruvoti* Sector Survey

The *L. pruvoti* sector survey conducted for the present survey produced markedly different results than have been observed previously. Focusing on the Knoll Pins site, a similar general pattern of distribution of *L. pruvoti* was observed during the present study as has been recorded previously, with the greatest concentration of individuals clustered in very discrete areas around two main features at the Knoll Pins Cave (KPC) and Knoll Pins East (KPE) (Table 11).However, the numbers of individuals encountered in the sectors between these two features was dramatically lower than has been measured in 2007 and 2010. Indeed the abundance of individuals recorded at the two main monitoring features was also lower during the present survey (94 in 2015 vs 137 in 2010 at KPC & 168 in 2015 vs 228 in 2010 at KPE) as shown in Table 11.

However, where the present study *did* encounter *L. pruvoti,* at Knoll Pins, the proportion of juveniles to adults had increased, suggesting recruitment has occurred recently (Table 12). Further evidence of recruitment is presented in Section 5.4.1.

**Table 11.** *L. pruvoti* sector survey results at Knoll Pins from 2007, 2010 & 2015.

| Site: Knoll Pins | Total Adults | | | Total Juveniles | | | Totals | | | % Change | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector | 2007 | 2010 | 2015 | 2007 | 2010 | 2015 | 2007 | 2010 | 2015 | 2010 | 2015 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | n/a | n/a |
| 2 | 44 | 96 | 4 | 1 | 13 | 0 | 45 | 109 | 4 | inc 141% | dec 97% |
| 3 | 180 | 147 | 18 | 6 | 18 | 8 | 186 | 165 | 26 | dec 11% | dec 84% |
| KPC | 121 | 129 | 72 | 7 | 8 | 22 | 128 | 137 | 94 | inc 7% | dec 32% |
| 4 | 32 | 53 | 12 | 2 | 8 | 2 | 34 | 57 | 17 | inc 66% | dec 70% |
| KPE | 219 | 196 | 121 | 49 | 32 | 47 | 268 | 228 | 168 | dec 15% | dec 27% |
| 5 | 22 | 11 | 0 | 0 | 3 | 0 | 22 | 14 | 0 | dec 36% | dec 100% |
| KPS | 12 | 0 | 0 | 4 | 0 | 0 | 16 | 0 | 0 | dec 100% | n/a |
| Totals | 633 | 632 | 227 | 70 | 82 | 79 | 699 | 714 | 309 | inc 2% | dec 57% |

In contrast to the previous studies in 2007 and 2010, the present study did not encounter any *L. pruvoti* individuals at either Anchor Pinnacle or Gannet's Rock Pinnacle.

**Table 12.** *L. pruvoti* sector survey results summary from 2007, 2010 & 2015.

| Site | Total Adults | | | Total Juveniles | | | Totals | | | % Change since previous survey | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2010 | 2015 | 2007 | 2010 | 2015 | 2007 | 2010 | 2015 | 2010 | 2015 |
| Knoll Pins | 633 | 632 | 227 | 70 | 82 | 79 | 703 | 714 | 306 | inc 2.5% | dec 56.7% |
| Anchor Pinnacle | 54 | 20 | 0 | 8 | 3 | 0 | 62 | 23 | 0 | n/a | dec 100% |
| Gannets Pinnacle | 176 | 112 | 0 | 13 | 24 | 0 | 189 | 136 | 0 | dec 28% | dec 100% |

The parasitic loading of *L. pruvoti* encountered also appeared to be reducing with no occurrences of the worm *P. hippocrepia* being recorded during the present study, as was the case in 2010 (KP site only). The percentage of *L. pruvoti* individuals hosting the barnacle *M. anglicum* was also reduced in comparison to previous years (12% in 2015 vs 21% in 2010 KP site only, see Table 14).

**Table 13.** Historical Comparison of *L. pruvoti* survey results at the "Core" sampling site at Knoll Pins East.

| Sector: Knoll Pins East "core" | | | |
|---|---|---|---|
| | 2007 | 2010 | 2015 |
| Total Adults and Juveniles | 175 | 152 | 168 |
| % Change since 2007 | n/a | ↓ 13% | ↓ 4% |

**Table 14**. *L. pruvoti* Parasitic Loading Comparison.

| Site | Total Adults with barnacle *M. anglicum* | | |
|---|---|---|---|
| | 2007 | 2010 | 2015 |
| Knoll Pins | 16.50% | 21% | 12% |
| Anchor Pinnacle | n/a | 27% | 0 |
| Gannet's Pinnacle | n/a | 23% | 0 |

### 5.4.1 *Leptopsammia pruvoti* Photographic Mosaic

Of all the *L. pruvoti* monitoring sites the Knoll Pins East was most readily re-located during the present survey due to its distinctive encrusting organisms, surrounding geological features and proliferation of *L. pruvoti* (Figure 8).

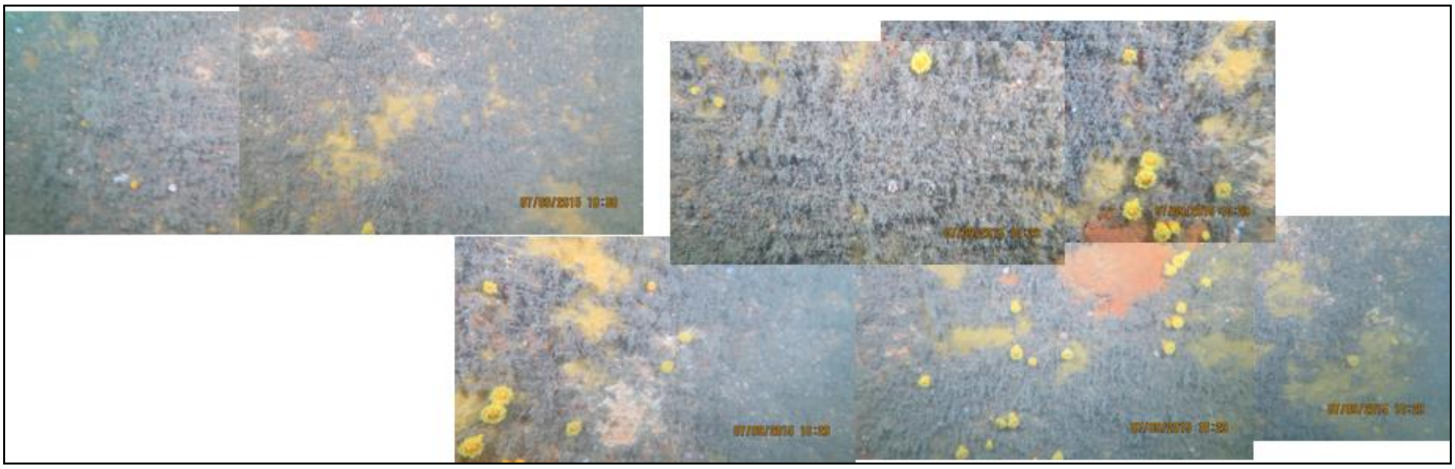


**Figure 8.** Knoll Pins East (KPE) *L. pruvoti* monitoring site.

It was challenging to make any meaningful remarks about the condition status of this representative species when examining an area greater than approximately 50cm$^2$ due to the propensity of individual cup corals to obscure each other or remain hidden from view beneath a dense turf of heavily silted bryozoans and hydroids. In order to make a useful comparison with images collected in 2010, the centre of the "Core Monitoring Zone" was considered in detail, see Figure 9.

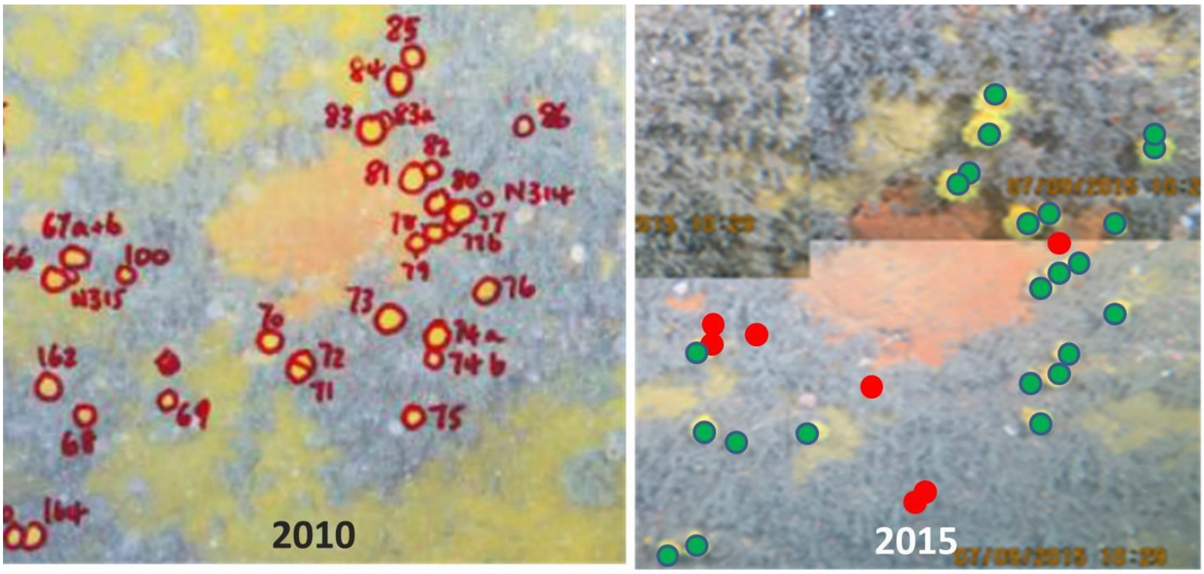
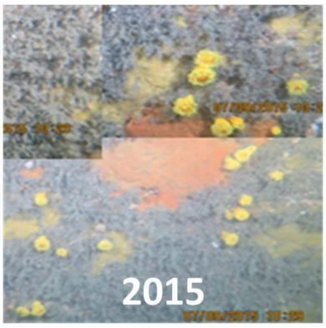



**Figure 9**. Comparison of the centre of the "Core Monitoring Zone" at KPE between 2010 and 2015. Green circles indicate individual *L. pruvoti* found during both surveys. Red circles indicate *L. pruvoti* not relocated during 2015. The smaller image in the bottom right is the same image from 2015 without coloured circles.




Examination of the centre of the "Core Monitoring Zone" in Figure 9 initially suggests that of the 30 *L. pruvoti* individuals that are visible in 2010, only 23 are relocatable with confidence from a similar image in 2015, representing a decrease in abundance of approximately 23% in this small area of approximately 50cm$^2$. However, if the 2015 image is magnified (Figure 10), at least four potential new recruits are identifiable, which were not obvious in 2010.

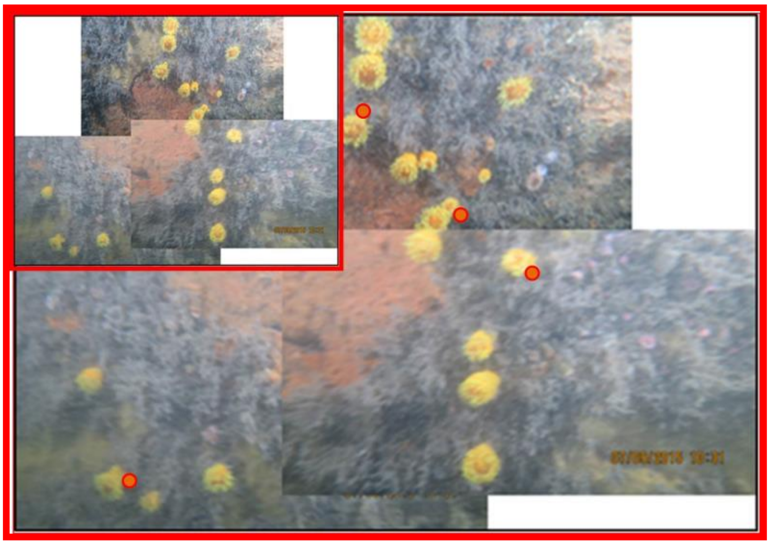


**Figure 10.** Magnified image of the part of the same "Core Monitoring Zone" from 2015 shown in Figure 9. Orange circles indicate 4 possible juvenile *L. pruvoti* that are not visible in Figure 9, and were not identified in 2010. The image in the top left shows the same area without circles.

Detailed examination of Figure 10 suggests that four new recruits are identified in 2015 that were not encountered in 2010, bringing the total number of individuals in this area to 27 in 2015, 3 less than in 2010, a decrease in abundance of 10%. These detailed observations are only possible as a result of close up images of this particular area within the monitoring site from 2015. If this level of detail is not available, as is the case for the majority of the site, it is very difficult to make definite statements about the survival of individual *L. pruvoti*.

This statement is supported by Figure 11 which compares photo mosaics of the same general area from 2010 and 2015. The same features are indicated by coloured circles, confirming relocation of the same site. However, it is clear that in many cases, individual *L. pruvoti* are not identifiable in both images. Many individuals are obvious in the 2010 image that are not identifiable in the 2015 image, and the same is true for the 2015 image vs the 2010 image.

This is considered to be a result of the slightly different angle of the image, fields of view, and most importantly, the image stitching methods used between different sampling years rather than the actual condition of the feature. This suggestion is supported by Figures 9 & 10 which show comparable numbers of *L. pruvoti* between time series sampling events.

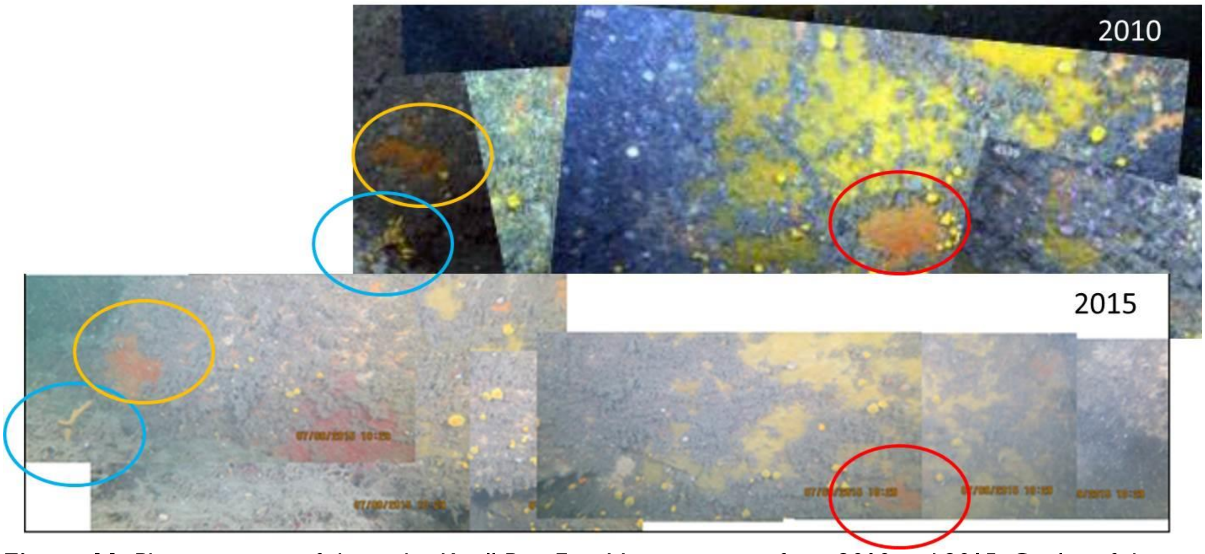



**Figure 11.** Photo mosaics of the wider Knoll Pins East Monitoring site from 2010 and 2015. Circles of the same colour indicate the same features relocated in each image.

**Figure 12.** Photo mosaic of the area above Knoll Pins East in 2015 showing very low abundances of *L. pruvoti*.

## 5.5 Subtidal Bedrock & Stable Boulder Communities SAC

### 5.5.1 Species Composition

The species composition data described in the NTZ assessment analysis (see Section 8) are the same as the data used for the Subtidal Bedrock and Stable Boulder Communities analysis. Therefore, the results described in Section 8 also represent the results which will inform the SAC interpretation. The interpretation of the condition of the representative habitats and notable species is presented in the SAC Discussion, in Section 6.

### 5.5.2 *Eunicella verrucosa* Density and Condition Assessment

The results of the *E. verrucosa* survey show that at each sampling point at the North Quarries site, significantly fewer individuals were encountered in 2014/15 than in 2004. During the present survey, approximately 6 times fewer individuals were encountered at Quarry Bay than during 2004. However, of the individuals encountered, the general condition score is slightly higher in 2014/15 than any of the previous sampling points. Caution must be exerted here as although this condition score is based on a set of fixed criteria, it is subject to individual sampling bias.

**Table 15**. Historical comparison of *Eunicella verrucosa* density and condition from 2004, 2010 and 2014/15. Note the area covered differs from the area used in the density calculation on two occasions due to unsuitable habitat being encountered during the transect.

| Site | Area Covered | | | Nunber Individuals | | | Density 10 m² | | | Av. Condition Score | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2004 | 2010 | 2014/5 | 2004 | 2010 | 2014/5 | 2004 | 2010 | 2014/5 | 2004 | 2010 | 2014/5 |
| North Quarries | 880m² | 800m² | 800m² | 117 | 63 | 18 | 1.33 | 1.57 | 0.42 | 2.93 | 3.42 | 2.1 |
| Quarry Bay | n/a | n/a | 400m² | n/a | n/a | 4 | n/a | n/a | 0.1 | n/a | n/a | n/a |
| Gull Rock | n/a | 800m² | 840m² | n/a | 45 | 61 | n/a | 0.56 | 0.72 | n/a | 2.02 | 1.91 |
| ** 2010 Density based on 800 m² of suitable habitat for North Quarries and Gull Rock* | | | | | | | | | | | | |
| ** 2014/15 Density based on 400 m² of suitable habitat for North Quarries* | | | | | | | | | | | | |

Quarry Bay was sampled during the present study, but after 400m$^2$ of seabed was surveyed, only very low numbers of *E. verrucosa* were encountered (4 individuals), largely due to a lack of suitable habitat. At Gull Rock the largest coverage of seabed to date was surveyed during the present study. The number of individual *E. verrucosa* encountered was higher than in 2010 (45 in 2010 vs 61 in 2014/15) as was the density (0.56 per 10m$^2$ in 2010 vs 0.72 per 10m$^2$ in 2014/15). As with North Quarries, the average condition score recorded during the present survey was marginally higher than at the same site in 2010, although these figures are likely to be within the range of sampling bias error.

It was noted that the occurrence of *E. verrucosa* at all of the sampling sites was patchy, with relatively high densities of individuals interspersed with comparatively sparse areas. This inherently variable distribution resulted in a low likelihood of re-sampling the exact same areas covered by previous surveys, making it challenging to accurately assess the overall condition of this notable species. This aspect is expanded on in the discussion section.

# 6 SAC Discussion

## 6.1 Kelp forest communities – Condition discussion

Based on historical data, and the data collected for the present study, there appears to be a measurable general trend in the ratio of key kelp species at Lundy. The ratio of *L. ochroleuca* to *L. hyperborea* appears to be shifting with a general increase in the abundance of *L. ochroleuca*. This general effect is more pronounced at the more exposed Rat Island site, where the ratio of *L. hyperborea* to *L. ochroleuca* has shifted from 18:1 to 1:1 respectively over a 10 year period. In all cases, the abundance of *L. hyperborea* either decreased or remained constant, and the abundance of *L. ochroleuca* has increased. The increase in abundance of *L. ochroleuca* was not always matched by a decrease in the abundance of *L. hyperborea,* with the net result of a total increase in kelp plants per unit are of reef in some cases.

If the data collected at each time point considered here (2004, 2007 & 2014) are truly representative of the general condition of the kelp forests in the wider area, this represents a shift in relative abundance of a structure forming species. It should be stressed that this pattern is based on kelp survey work at only two sites; Rat Island and Gannet's Bay. However, these two sites are physically quite different in terms of exposure and siltation based on observations made during the fieldwork, although these factors were not directly measured during the present survey.

We consider that other possible explanations of these trends such as mis-identification in the field are unlikely. This is due to the consistency of the community composition patterns over time, and the experience of the surveyors involved in the current and previous surveys.

The other kelp species measured at the sampling sites generally showed little variation in density over time, with the exception of a notable increase in the abundance of *S. polyschides* at Gannet's Bay from 2004 – 2007, a trend which appears to have stabilised and is still present in 2014.

When considering the potential causes of these kelp assemblage shifts, it is noticeable that the largest shifts at Rat Island and at Gannet's Bay appeared to have occurred between 2004 and 2010, and the same general patterns are maintained through to 2014. As both the dominant kelp species at each of the sites are considered to be affected by temperature (Smale & Vance, 2015, Smale et al., 2014), the historical temperature data logging at Lundy is presented below.

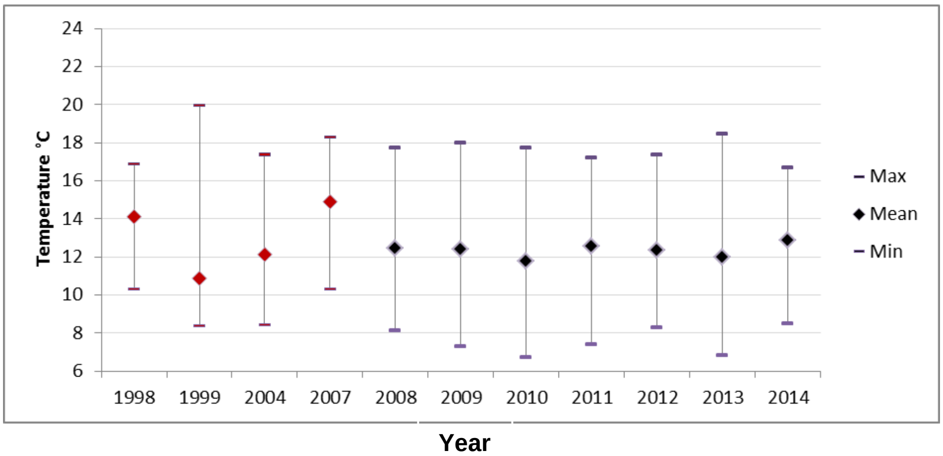



**Figure 13.** Mean temperature data from surface ocean water at Lundy. Data courtesy of The Land Mark Trust. Red icons indicate incomplete datasets with missing data for some months.

Unfortunately, the lack of temperature data immediately before and after 2004 when the assemblage shifts are believed to have occurred, does not allow much insight as to the role of temperature shifts in driving this observation. However, future monitoring of both surface water temperature and kelp species abundance at Lundy and other sites in the Southwest U.K. may help identify the driver behind the shift in abundance.

Research is currently underway at the Marine Biological Association of the U.K. to clarify the ecological implications of shifts in kelp canopy forming species in kelp habitats and any implications of these shifts on the wider marine environment to which kelp habitats are closely linked (Smale & Vance, 2015, Smale et al., 2014). Although more research is required in this area (particularly if kelp community shifts are likely to become widespread) there is already some evidence of the difference between ecological goods and services provided by *L. hyperborea* and *L. ochroleuca:* These differences may include:

- a difference in epiphyte abundance,
- a shift in the grazer assemblage the kelp plants support,
- different rates of seasonal degradation and release of biomass into the surrounding environment,
- different shading regimes on the bedrock,
- shift in holdfast invertebrate assemblage composition,
- different resilience to removal by winter storms.

Although the ecological consequences of a shift in kelp species dominance cannot be stated with certainty, the data collected during the present study suggest that the condition of this representative habitat of the infralittoral rock SAC subfeature has undergone a significant change over the last 10 years. Currently, as there has not been a considerable decrease in the abundance of *L. hyperborea,* it is likely that the overall condition of the representative habitat is favourable. If *L. ochroleuca* continues to increase in abundance and outcompetes *L. hyperborea* effectively displacing it on the reef, there is potential for the condition to decline. It is the recommendation of this study that the temperature and kelp forest assemblage structure should be monitored closely at Lundy and other kelp SAC sites.

**Kelp Forest Condition Status Summary:**
A relatively long term shift (ten years) in the relative abundance of kelp canopy forming species has occurred at Rat Island and Gannet's Bay on Lundy. A general increase in the abundance in *L. ochroleuca* (Rat Island*)* and to a lesser extent *S. polyschides* (Gannet's Bay) is recorded. Based on current research at other sites, the cause of this shift is likely to be temperature related, but this link is un-proven at Lundy. Current research suggests there *could* be ecological implications of this shift in terms of epiphyte abundance, grazer assemblage structure, shading and competition for space on the reef, if *L. ochroleuca* out competes *L. hyperborea* in future years. The current study suggests the condition of this representative habitat is **Favourable.** However, if *L. ochroleuca* out competes *L. hyperborea* in future years, this condition status could change relatively rapidly.

## 6.2 Subtidal Vertical & Overhanging Circalittoral Rock Communities – Condition Discussion

In general, it is not possible to make robust claims on the overall condition status of the Subtidal Vertical and Overhanging Rock communities at Lundy. This is due to the lack of previous data that have been collected using methods that allow robust time series analysis. Sufficient data do exist to describe the condition of the circalittoral rock representative species *L. pruvoti* which is discussed below separately (see 6.2.1).

While the subtidal sampling efforts at Lundy have been considerable, the sampling methods used, or the spatial coverage at the target Subtidal Vertical and Overhanging Rock monitoring sites have generally not been consistent with respect to the notable species sampled during the present study. Only three species were sampled in common between the present study and the Mercer et al. (2006) study, and one of these species was a mobile echinoderm *Marthasterias glacialis.* However, it is hoped that sampling methods used during the current study have contributed to a baseline understanding of condition status in these representative communities of the circalittoral rock subfeature.

The sampling method described by Irving (2011) involving quadrat surveys being conducted along pre-described sectors was found to work well in these challenging features. These methods were used to produce a data set which should allow repeated sampling efforts to generate comparable data in future years.

Although the overall abundance of notable species at these sites were low (~<2 per $m^2$) the three most abundant species encountered at the three monitoring sites were *Axinella dissimilis, Raspailia ramosa* and *Cliona celata*. *A. dissimilis* in particular is noted as being subject to physical damage in part due to its elongated and branching morphology and also due to a lack of flexibility (Moss & Ackers, 1982). In addition, this species is noted as being very slow growing and therefore could be considered vulnerable to physical disturbance. Consequently, the relative abundance of this species at the monitoring sites suggests that the representative habitat is not impacted heavily by physical disturbance. This is expected, given the occurrence of the monitoring sites within the NTZ which should prevent the frequency of physical disturbance as a result of commercial fishing activity.

**Subtidal Vertical and Overhanging Rock Condition Status Summary:** The lack of previous data describing the representative Subtidal Vertical and Overhanging Rock communities at Lundy prevented a robust assessment of condition being reached with the exception of the representative species *L. pruvoti* which is discussed below. The Subtidal Vertical and Overhanging Rock habitats at Lundy were found to support slow growing species that are susceptible to physical damage, suggesting minimal physical impact at the site. The current study suggests that condition of this representative community of the SAC circalittoral rock subfeature is **Favourable**.

### 6.2.1 *L. pruvoti* Representative species

The abundance of *L. pruvoti* during the present study was considerably reduced compared with the sampling undertaken by Irving in 2010 and 2007. The numbers of individuals encountered on all the sectors designated on the Knoll Pins monitoring site were generally substantially lower than have been previously recorded. At the two other monitoring sites (Anchor Pinnacle and Gannet's Pinnacle), no evidence of *L. pruvoti* was found at all. Although the present study did encounter *L. pruvoti* at the Knoll Pins Site, the numbers were roughly 57% lower than in 2010.

The absence of *L. pruvoti* at Anchor Pinnacle and Gannet's Pinnacle may be due to the increased difficulty in locating the sector survey areas at these sites compared with Knoll Pins. The Knoll Pins has very prominent features which enables accurate relocation of the monitoring site. Anchor Pinnacle and Gannet's Pinnacle were not found to be as easy to navigate which might explain the lack of *L. pruvoti.* However, we believe the Anchor Pinnacle and Gannet's Pinnacle sectors described by Irving (2011) were relocated with reasonable confidence, and that the numbers of *L. pruvoti* have genuinely decreased, although this cannot be confirmed outright.

Regardless of the exact location of the sectors, during the present survey, the sampling at Anchor Pinnacle and Gannet's Pinnacle was conducted at the same depth range and on the same type of habitat as where *L. pruvoti* was found during the present survey at Knoll Pins. It is therefore reasonable to assume that if *L. pruvoti* was present in 2015 in comparable numbers to 2010, it would have been encountered at some stage during the present survey.

Where the present survey did encounter *L. pruvoti,* there was a minor increase in the proportion of juveniles to adults across the site compared with previous surveys suggesting that successful recruitment had occurred in recent years. Further evidence of recruitment was found with the discovery of 4 new recruits in the core sampling area during examination of the photo mosaics of KPE. The proportion of *L. pruvoti* settled on by the barnacle *M. anglicum* had also reduced by approximately 45% compared with the previous survey in 2010. However, the 2015 proportion is based on sample size that is roughly half the 2010 sample size.

If the reduced numbers of *L. pruvoti* at Knoll Pins, and the lack of the species at Anchor Pinnacle and Gannet's Pinnacle, are a true reflection of the decline in abundance of this species, this finding could be interpreted as measurable reduction in the condition of this feature. Even at Knoll Pins, where the sectors identified by Irving (2010) were relocated with total confidence during the present survey (photographs of the same features were obtained), the numbers of *L. pruvoti* adult individuals were measurably reduced. However, the lack of certainty surrounding the exact relocation of the sectors at Anchor Pinnacle and Gannet's Pinnacle casts uncertainty on this conclusion.

Examination of the photo mosaics from Knoll Pins provided a useful method of detecting any large scale changes that might have occurred at the site. However, this method did not prove to be a reliable approach of assessing the condition of individual *L. pruvoti* due to the difficulty of obtaining comparable images and stitching them together with enough precision over several time points in order to enable accurate counts to be made.

### 6.2.2 Sampling Suggestions - *L. pruvoti*

If the assessment of individual *L. pruvoti* is to be a focus of future monitoring at Lundy, this study supports statements made by Irving (2011) that recommend the installation of fixed markers to aid relocation of the monitoring sites. Such markers would also allow a more standardised method of producing photo mosaics. For example, if markers could be installed that delineate an area equivalent to a whole field of view, and these areas were adjacent to each other, the process of photograph stitching could be achieved with enough precision to allow the identification of individuals.

Considerable care would be required when conducting such potentially disruptive operation and we suggest that a pilot trial be conducted at a nearby location with reduced *L. pruvoti* abundance before attempts were made to achieve this at the "Core Monitoring Zone" at KPE.

### 6.2.3 Ecological significance of reduced *L. pruvoti* at Lundy

When encountered underwater, *L. pruvoti* is a striking and beautiful member of the Subtidal Vertical and Overhanging Rock invertebrate assemblage. The historical association of *L. pruvoti* with Lundy has in many ways established this species as a symbol of underwater habitats of the island. However, the existence of this species at Lundy is likely to be close to the northerly limit of this species distribution (Irving, 2004).

From a pragmatic point of view, although representative of the circalittoral rock CAC subfeature, the species does not appear to provide a unique functional role in the habitat, by either providing structure, a food source or aggressively competing for space (in fact it is often over-grown (Irving, 2011)). Therefore, even if subsequent survey work confirms the decrease in numbers measured during this survey, the ecological implications of a reduction of this species are likely to be minimal. Perhaps the economic and social implications of reduced numbers of tourist divers attracted to the site to encounter this iconic species are more important than the ecological implication in this instance.

*Note: Discussion with divers who have been visiting Lundy for several decades revealed reports of populations of L. pruvoti at other rocky pinnacles around the island not surveyed by the present study (pers comms Colin Eastman of Lundy Charters). Although these reports have not been confirmed by this study, it is very likely that other established colonies of L. pruvoti exist elsewhere around the island. In addition, Gannet's Rock Pinnacle is also known locally as Gannet's Stone.*

***L. pruvoti* Summary:** Where *L. pruvoti* was encountered during the present study (Knoll Pins), a general decrease in abundance in the region of at least 57% was recorded compared to 2010. In two sites where *L. pruvoti* has historically been recorded (albeit in low numbers), the present study was unable to locate any individuals. There is some doubt over the relocation of the exact monitoring sectors designated by previous surveys at the sites where *L. pruvoti* was found to be absent, but regardless of this, there was found to be a general loss of condition of the feature since the previous survey. Where *L. pruvoti* was encountered, the number of parasitic barnacles was reduced. Additionally, the proportion of juveniles to adults had increased compared to 2010 and evidence of recruitment was found. The current study suggests that condition of *L. pruvoti* at the Lundy monitoring sites is declining in general, although some evidence of a limited potential recovery was also found.

## 6.3 Subtidal Bedrock & Stable Boulder Communities Condition Discussion

### 6.3.1 Subtidal Bedrock and Stable Boulder Communities

The condition of the Subtidal Bedrock and Stable Boulder Communities representative habitat of the circalittoral rock SAC subfeature was assessed using the same data collected to assess the status of the NTZ as both occur at the same sites around Lundy. For completeness, the interpretation of the same data set is repeated in both the NTZ and representative Subtidal Bedrock and Stable Boulder Communities SAC sections to enable each text to be used as a standalone document.

The data collected during the present survey showed a very similar pattern in terms of differences between the abundance of sessile invertebrates between the NTZ and Control Sites as discovered by Hoskin et al. (2009). Figures 15 & 16 clearly illustrate this similarity. This variation between sessile assemblages is discussed by Hoskin et al. (2009) and is very likely to be an artefact of the unavoidable nature of physical differences between the control and NTZ sites being on different sides of Lundy.

When compared to the first complete historical data set from the monitoring sites in 2005 (Hoskin et al., 2009) the data collected for the present survey do not appear to differ in response to time. When the spatial distribution of sessile invertebrates is examined within each site and between years, subtle differences are apparent between year groups. However, it should be noted that the abundance of sessile invertebrates was generally <3 individuals per $m^2$ and even the most abundant species were generally <5 individuals per $m^2$ consistently over time since 2004.

The most notable variation between 2005 data and the data collected during the present study was a decrease in the abundance of the anemone *Aiptasia mutablis* in NTZ site 1 from 0.99 $m^2$ in 2005 to 0.26 $m^2$ in 2014. Another notable difference was the decrease in the average abundance of *Alcyonium digitatum* from 0.73 $m^2$ in the Control site 1 during 2005 to not being recorded at all at the same site in 2014.

Due to the large and obvious nature of *A. digitatum,* it is unlikely that the species was present and not recorded during 2014 and therefore this variation between years is likely to represent a genuine shift in abundance. The drivers for these minor changes in distribution between years are unclear, but disturbance related to static fishing practices linked to the NTZ are unlikely to be the cause. This conclusion is suggested because the abundance of some of the species known to be susceptible to physical disturbance such as *A. dissimilis* showed minor increases in average abundance in the same site during the same time period.

As discovered by Hoskin et al. (2009), there appear to be no obvious measurable effects of the NTZ designation resulting in increased abundance of sessile marine invertebrates in Subtidal Bedrock and Stable Boulder Communities. However, the *primary* beneficiary of the NTZ designation was not intended to be the sessile marine invertebrates. In addition, this study was not able to characterise what effect the NTZ is having on sessile invertebrate populations further afield from the monitoring sites.

**Subtidal Bedrock and Stable Boulder Community Condition Discussion Summary:** The data collected during the present study indicate that there has been very little change in condition status of sessile marine invertebrates in Subtidal Bedrock and Stable Boulder Communities over the last 11 years. The current study suggests that condition of this representative community of the circalittoral rock SAC subfeature is **Favourable**.

### 6.3.2 *Eunicella verrucosa* Survey and Condition Discussion

Assessment of *E. verrucosa* in the Subtidal Bedrock and Stable Boulder Communities representative habitats indicates that there had been a sharp (85%) decline in the density of *E. verrucosa* numbers in the North Quarries area of Lundy between 2004 and 2014/15.

In contrast, the density of individual *E. verrucosa* had increased at Gull Rock from 2010 to 2014/15 by approximately 35%. In addition, in 2014/15 at both North Quarries and Gull Rock the average condition score had increased to its highest recorded level. This conflicting report of *E. verrucosa* prosperity makes it challenging to judge the overall condition of the feature. However, based on observations during the present study, we suggest the method of sampling is just as likely to produce this impression as a true site specific variation in *E. verrucosa* abundance.

The nature of the benthos at this site is highly heterogeneous, with areas of stable boulders interspaced with a mosaic of soft sediment and sandy gravel. The chances of each transect falling in an equally suitable habitat type is minimal, even taking into account the survey divers exerting discretion and only sampling in suitable habitat. Additionally, the patchy distribution of the *E. verrucosa* can easily result in two transects in very similar areas producing very different densities depending on their chance of passing through an area of particularly abundant *E. verrucosa.* In summary, repeat sampling using this method in the same general area is very likely to produce variable results, which may not accurately reflect the condition of the feature.

Given the nature of the site, the reduction in density of *E. verrucosa* at the North Quarries site observed between 2004 and 2015, although notable, is considered by the present study to be within the possible range of influence of sampling error and should not necessarily be considered to be indicative of a loss of condition. This view is supported by no obvious decrease in *E. verrucosa* abundance during the sampling undertaken for the NTZ assessment, a slight increase in abundance at Gull Rock in 2014/15, and no other obvious sign of site specific damage being observed within North Quarries. Indeed the average condition score of the individuals encountered across the site has improved in comparison to previous years, although this method is also subject to sampling error and cannot be relied upon in isolation.

### 6.3.3 Sampling Suggestions

We consider sampling methods to be a very likely contributor to the variable densities of *E. verrucosa* recently observed in Lundy. Given that Lundy is likely to benefit from repeated sampling for many years, and given the reduction of fishing activity at the site, we suggest that the introduction of fixed locators (permanent buoys) might aid the accuracy of future sampling. For example, if two fixed buoys were located in the *E. verrucosa* sampling site, this would dramatically increase the precision of future sampling efforts, increasing the likelihood of detecting representative changes in *E. verrucosa* densities.

***Eunicella verrucosa* Condition Discussion Summary:** A significant decrease in the abundance of *E. verrucosa* (85%) was measured during the present study at North Quarries compared with 2004 survey results. This reduction in density is very likely to be an artefact of the highly variable benthos in the sampling area and is not necessarily considered to represent a notable decrease in condition status. Indeed, the overall condition score of the individuals encountered at North Quarries (based on epiphytic growth) had increased in comparison to previous years. An increase in *E. verrucosa* density of 35% between 2010 and 2014/15 was recorded at Gull Rock, again supported by a minor increase in average condition score. The current study suggests that condition of the notable species *E. verrucosa* at the Lundy monitoring sites is likely to be **Favourable**, but suggestions are made about how to adapt the sampling methodology to improve the confidence behind this statement.

# 7 NTZ Assessment Methods

## 7.1 Methods

NTZ site condition was assessed exactly as described by Hoskin et al. (2009), and as described above for the assessment of subtidal bedrock and stable boulder communities.

### 7.1.1 Species Composition

- Four sites were sampled, with 6 to 10 transects undertaken within each site.
- The start of each transect was marked by a shot, down which a pair of divers descended.
- Divers then reeled out a 20m transect along a random, pre-determined bearing.
- The pair swam back towards the shot, undertaking ~12 quadrat surveys randomly distributed along this transect.
- Divers recorded the abundance of 15 notable species from within this biotope listed below, as determined by Hoskin et al. (2006).

**Table 16.** 15 notable species measured in the NTZ site.

| Demospongiae | | Cnidaria | |
|---|---|---|---|
| **Axinelida** | *Axinella dissimilis*<br>*Axinella infundibuliformis*<br>*Axinella damicornis*<br>*Raspailia ramosa* | **Actiniaria** | *Anemonia viridis*<br>*Aiptasia mutabilis* |
| **Suberitida** | *Homaxinella subdola* | **Bryozoa** | |
| **Polymastiida** | *Polymastia boletiformis*<br>*Polymastia mammilaris* | **Cheilostomatida** | *Pentapora fascialis* |
| **Clionaida** | *Cliona celata* | **Chordata** | |
| **Octocorallia** | | **Stolidobranchia** | *Stolonica socialis* |
| **Alcyonacea** | *Alcyonium digitatum*<br>*Alcyonium glomeratum*<br>*Eunicella verrucosa* | | |

### 7.1.2 Data Analysis

NTZ and the Subtidal Bedrock and Stable Boulder assemblage data were analysed using the multivariate statistical programme PRIMER v7 2015. (Clarke & Warwick, 2001). The abundance data obtained during the quadrat survey were checked for errors and then transformed using a 4$^{th}$ root transformation to reduce the differences in the overall abundances of different taxa (Clarke & Warwick, 2001).

To reduce the influence of the low abundance quadrats, and to match the style of results presented by Hoskin et al. (2009), the data were averaged by the random factor "Plot" which was nested within the fixed factor “Site”. These averaged data allowed the entire dataset to be analysed highlighting a difference between the assemblages recorded in the NTZ sites compared with the control site in 2014 (Figure 15).

Bray-Curtis dissimilarity values were then calculated in PRIMER and visualised on nonmetric multidimensional scaling (nMDS) plots to look for the influence of different factors on the distribution of the target species.

Analysis of Similarity (ANOSIM) was used to test for similarity in assemblage composition between factors. If significant differences were detected by the ANOSIM test, further analysis was conducted with Similarity Percentages (SIMPER) to determine the rank percentage contribution of the different species to the total dissimilarity.

# 8 No Take Zone Results

## 8.1 NTZ Assessment

To achieve Objectives B & C as described in the Objectives section (2.1), data collected during the present survey were analysed alongside historical time series data (2004-2007) collected from the same area by Hoskin et al. (2009). The aim was to further evaluate the effect of the NTZ on sessile invertebrates 11 years after the NTZ was established and to simultaneously asses the condition status of the circalittoral rock SAC subfeature representative community 'subtidal bedrock and stable boulder' attributes which occur in the same area. The methods used to collect these data are described in Section 7.1.

The first step in the analysis was to ascertain whether a difference existed between the assemblage structure of sessile invertebrates in the NTZ site and the control sites based on abundance data. The data were first 4$^{th}$ route transformed to reduce the influence of abundant species. However, in general the data consisted of a significant number of quadrats with very low abundance scores regardless of location either within the NTZ on the east of the island or the control sites on the west of the island. 75 out of 288 quadrats (~26%) had fewer than 2 individual species recorded per quadrat.

The frequency of low abundance quadrats in the data set masked the patterns occurring in the majority of the data where the abundance was >3 individuals per quadrat. When plotted on an nMDS plot, the result was a group of data points representing quadrats where very low abundances were measured, and a separate group of data points that were tightly grouped where there were >3 organisms per quadrat (see Figure 14). It was therefore a requirement to reduce the influence of the low abundance quadrats to discover the patterns in the higher abundance group that represented ~75% of the samples.

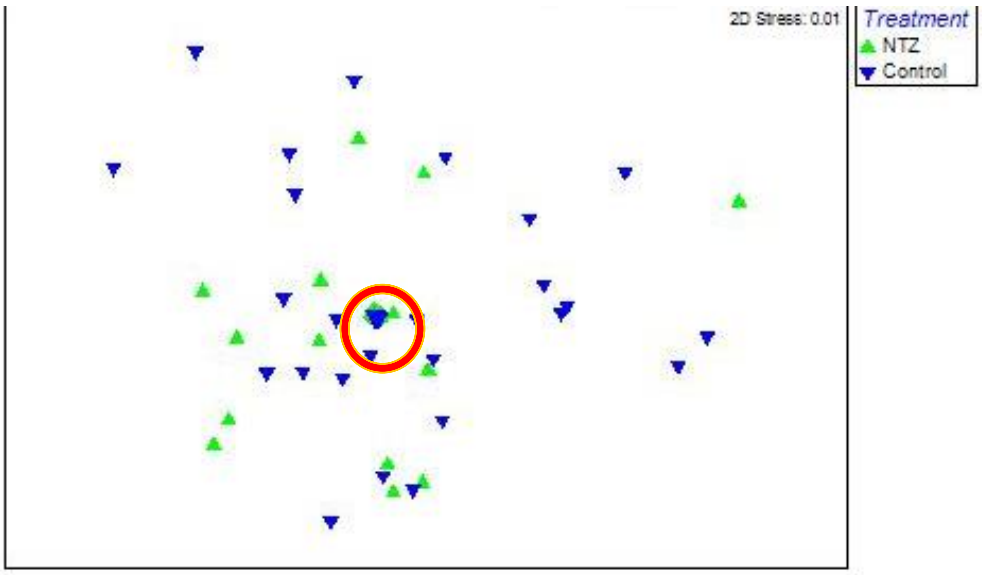



**Figure 14.** nMDS plot based on Bray-Curtis dissimilarity showing all data from 2014 labelled to show effect of treatment (NTZ or Control). The red circle shows tight clustering of data points (~75% of entire data set) representing quadrats containing 3 or more individuals.

To reduce the influence of the low abundance quadrats, and to match the style of results presented by Hoskin et al. (2009), the data were averaged by the random factor "Plot" which was nested within the fixed factor "Site". These averaged data allowed the entire data set to be compared and a difference between the assemblages recorded in the NTZ sites compared to the Control site can be observed based on the 2014 data (Figure 15). This finding was confirmed by ANOSIM (R value 0.525, p=<0.01).

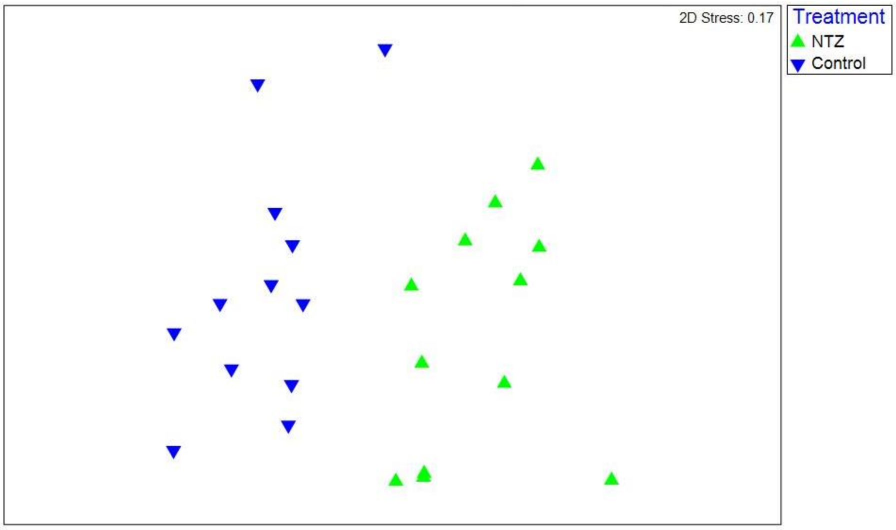



**Figure 15.** nMDS plot based on Bray-Curtis dissimilarity data from 2014 averaged by the random factor "Plot" and labelled to show effect of treatment (NTZ or Control).

The next step in the analysis was to look for any relationship between the epifuanal assemblage composition of the sites within the NTZ and the control areas. The same data shown in Figure 15 have been re-labelled and presented in Figure 16 to show which site the data originated from.

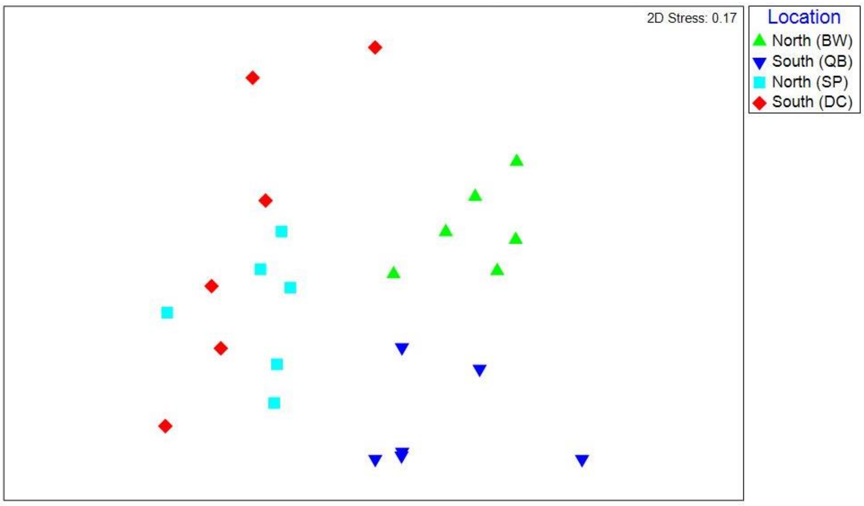



**Figure 16.** nMDS plot based on Bray-Curtis dissimilarity data from 2014 averaged by the random factor "Plot" and labelled to show effect of Site (North BW & South QB = NTZ. North SP and South DC = Control sites)

Figure 16 clearly shows a difference between the two control sites (BW & QB) which was confirmed by ANOSIM (R value 0.73, p=<0.02). The plot also shows that the two control sites (BW & QB) are different from the two NTZ sites (SP & DC) as shown in Figure 16.

The grouping of the NTZ sites indicate a similarity with the majority of points generally occurring in the same group, This pattern observed in the 2014 data (Figure 16) is very similar to the pattern described by Hoskin et al. 2009 (Figure 17) where all the previous sampling years were analysed together.

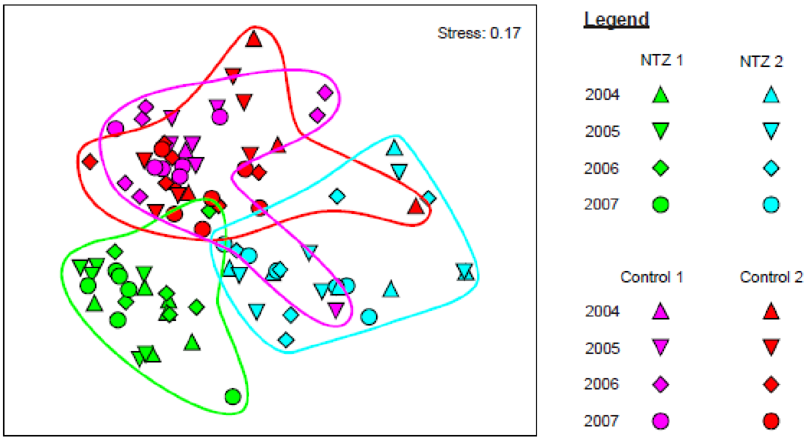



**Figure 17**. *(From Hoskin et al., 2009)* Sessile epifauna of circalittoral rocky habitats: nMDS-plot summarising differences in the composition of assemblages of sessile epifauna among sites with locations in each year.

These initial findings suggest that relative differences in sessile assemblage structure in the NTZ and control sites recorded in 2014 are very similar to the pattern that has been recorded since 2004. The next step was to examine the data from the present study in more detail against the historical data from the site and also identify whether the same species were still driving the patterns in the data.

### 8.1.1 Historical Comparison of NTZ Data

Hoskin et al. 2009 clearly demonstrate that there was very little change in sessile invertebrate assemblages during 2004 – 2007 that could be attributed to an effect of the NTZ. The data collected for the present study have been analysed against historical data collected in 2005 by Hoskin et al. in order to allow us to detect change in assemblage composition over time.

The 2005 dataset was selected because Hoskin et al. (2009) have already demonstrated that there was little difference between the 2004 – 2007 data sets, therefore pairwise analysis between the current data from all the previous years is likely to generate lots of output of little use. The 2004 data set would make an obvious comparison as this represents the maximum time difference between the historical and present data collection. However, Hoskin et al. (2009) highlight the fact that due to adverse weather conditions, the 2004 data set was incomplete. Therefore the 2005 data set provides the greatest time difference between complete historical data sets and the present study.

As described in Section 8.1, the raw data from 2005 and 2014 included a considerable proportion of quadrat samples that contained very low abundances of organisms which masked patterns in the remaining data with higher abundances. To minimise this effect, all data points from the 2005 and 2014 data sets were averaged by the random factor “Plot” which was nested within the fixed factor “Site”. All data were 4$^{th}$ root transformed prior to analysis.

Figure 18 illustrates that there is no clear grouping present in the nMDS plot when comparing data from all sites between 2005 and 2014. This lack of effect of "year" is confirmed by an ANOSIM result of global R = 0.142, p<0.04.

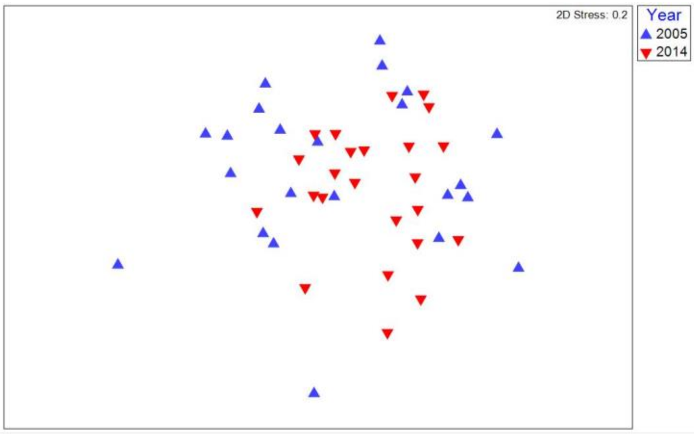



**Figure 18 .**nMDS plot showing based on Bray-Curtis dissimilarity data from 2005(blue) & 2014 (red) averaged by the random factor "Plot" and labelled to show effect of different years sampling.

When the effect of change between years 2005 and 2014 are investigated between sites there are some weak, but significant differences between year groups when tested with ANOSIM when p is accepted at <0.05, (Figure 18 & Table 17).

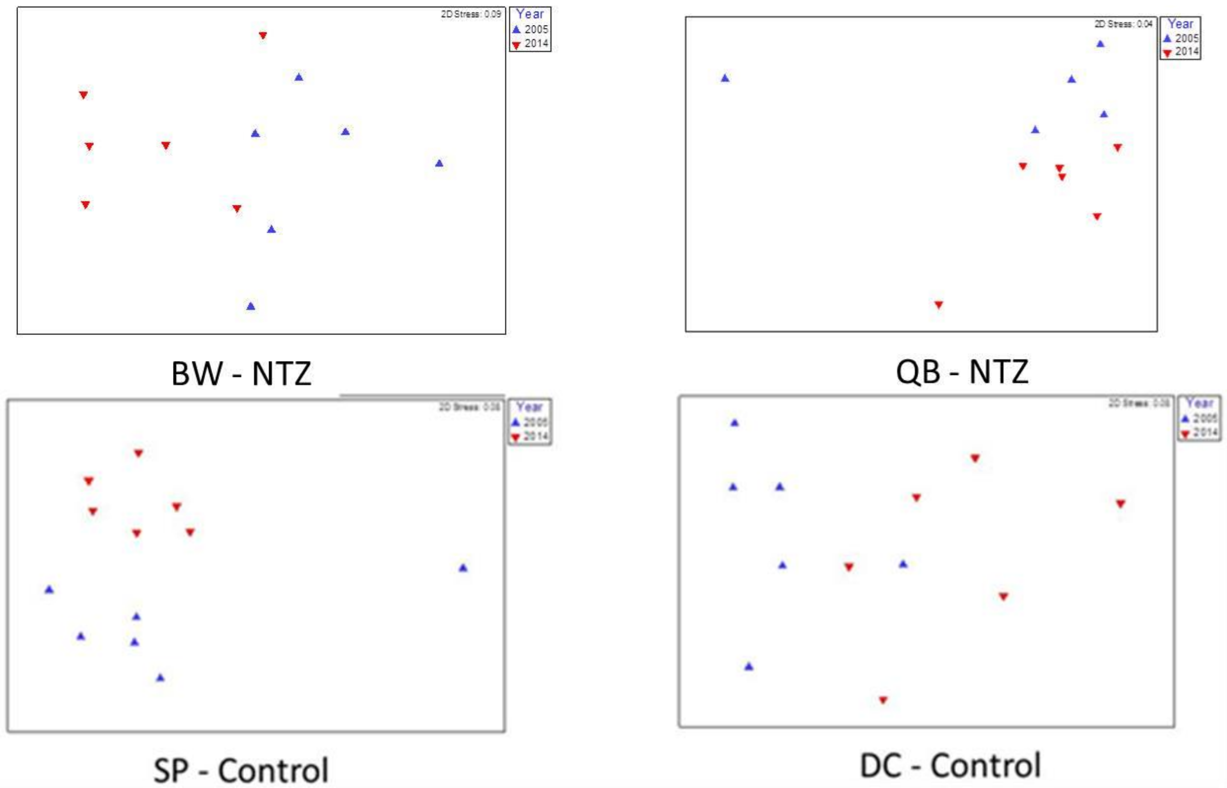



**Figure 19.**nMDS plots comparing 2005 and 2014, 4th root transformed Bray-Curtis dissimilarity data based on abundance of sessile macrofauna abundance from the two Control sites (top row) and the two NTZ sites (bottom row). 2005 data are blue and 2014 data are red.

**Table 17**. ANOSIM test results comparing 2005 and 2014 fourth root transformed Bray-Curtis dissimilarity data based on abundance of sessile macrofauna abundance from the two Control sites and two NTZ sites.

| Site | R | p value |
|---|---|---|
| BW – NTZ | 0.431 | p=<0.05 |
| QB - NTZ | 0.217 | p=<0.05 |
| SP- Control | 0.616 | p=<0.05 |
| DC- Control | 0.419 | p=<0.05 |

SIMPER analysis of the differences between years 2005 and 2014 highlights the species contributing most to the difference (Table 18). The species the SIMPER analysis suggests as being responsible for the majority of the difference between years in each site are also highlighted by Figure 20 which simply shows mean abundance of species per $m^2$ in each site over 2004 – 2014.

**Table 18.** SIMPER analysis of the difference between 2005 and 2014 $4^{th}$ root transformed Bray-Curtis dissimilarity data representing abundance of sessile macrofauna in the two NTZ sites and the two control sites.

| ***NTZ 1 Groups 2005 & 2014*** | | **Average dissimilarity =50.10** | | | | |
|---|---|---|---|---|---|---|
| | Group 2005 | Group 2014 | | | | |
| Species | Av.Abund | Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
| *A. mutabilis* | 0.99 | 0.26 | 11.06 | 1.36 | 22.07 | 22.07 |
| *A. dissimilis* | 1.01 | 0.46 | 9.88 | 1.99 | 19.73 | 41.8 |
| *H. subdola* | 0.78 | 0.52 | 6.68 | 1.41 | 13.33 | 55.13 |

| **NTZ 2** ***Groups 2005 & 2014*** | | **Average dissimilarity = 55.92** | | | | |
|---|---|---|---|---|---|---|
| | Group 2005 | Group 2014 | | | | |
| Species | Av.Abund | Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
| *A. dissimilis* | 0.74 | 0.82 | 12.66 | 0.94 | 22.64 | 22.64 |
| *A. damicornis* | 0.09 | 0.43 | 11.36 | 1.62 | 20.31 | 42.95 |
| *H. subdola* | 0 | 0.25 | 7.44 | 1.2 | 13.31 | 56.26 |

| ***Control 1. Groups 2005 & 2014*** | | **Average dissimilarity = 62.05** | | | | |
|---|---|---|---|---|---|---|
| | Group 2005 | Group 2014 | | | | |
| Species | Av.Abund | Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
| *A. digitatum* | 0.73 | 0 | 15.87 | 1.62 | 25.58 | 25.58 |
| *A. dissimilis* | 0.39 | 0.72 | 9.69 | 1.11 | 15.62 | 41.2 |
| *C. celata* | 0.51 | 0.3 | 8.85 | 1.28 | 14.26 | 55.45 |

| ***Control 2. Groups 2005 & 2014*** | | **Average dissimilarity = 57.06** | | | | |
|---|---|---|---|---|---|---|
| | Group 2005 | Group 2014 | | | | |
| Species | Av.Abund | Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
| *P. fascialis* | 0.89 | 0.25 | 14.17 | 2.35 | 24.83 | 24.83 |
| *P. boletifimis* | 0.11 | 0.53 | 9.83 | 1.29 | 17.23 | 42.06 |
| *A. dissimilis* | 0.46 | 0.33 | 7.02 | 1.67 | 12.31 | 54.37 |

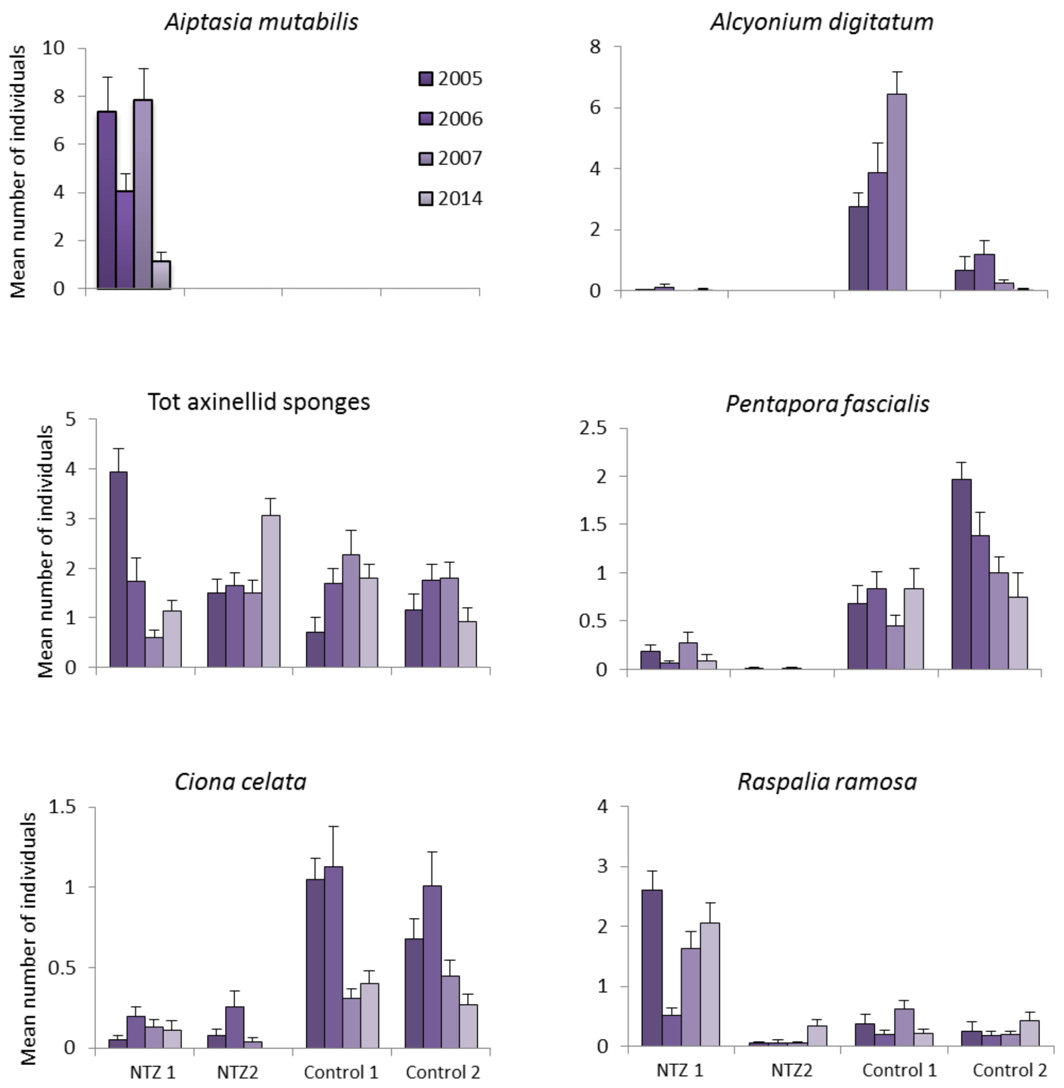



**Figure 20.** Mean abundances per m2 for the 6 epifaunal variables shown by SIMPER analysis by Hoskin et al.,, 2009 to have contributed ≥15% to significant Bray-Curtis dissimilarities for pairwise contrasts between either sites (NTZ *vs* Control) or years (all combinations of 2004, 2005, 2006 and 2007). 2014 Data are included for comparison. Each bar represents the mean of 6 plots (transects) and 72 quadrats per site. Error bars show standard deviation and n=72 at each site per year.

# 9 No Take Zone Discussion

## 9.1 No Take Zone – Status

The data collected during the present survey show a very similar pattern in terms of differences between the abundance of sessile invertebrates between the NTZ and control sites was also discovered by Hoskin et al. (2009). Figures 15 & 16 clearly illustrate this similarity. This variation between sessile assemblages is discussed by Hoskin et al. (2009) and is very likely to be an artefact of the unavoidable nature of physical differences between the control and NTZ sites being on different sides of the island.

When compared to the first complete historical data set from the monitoring sites (2005) the data collected for the present survey do not appear to differ in response to time. When the spatial distribution of sessile invertebrates is examined within each site and between years, subtle differences are apparent between year groups. However, it should be noted that in general, the abundance of sessile invertebrates was generally <3 individuals per $m^2$ and even the most abundant species were generally <5 individuals per $m^2$ consistently over time since 2004.

The most notable variation between 2005 data and the data collected during the present study was a decrease in the abundance of the anemone *Aiptasia mutabilis* in NTZ site 1 from 0.99 $m^2$ in 2005 to 0.26 $m^2$ in 2014. Another notable difference was the decrease in the average abundance of *Alcyonium digitatum* from 0.73 $m^2$ in control site 1 during 2005 to not being present at all at the same site 2014.

Due to the large and obvious nature of *A. digitatum,* it is unlikely that the species was present and not recorded during 2014 and therefore this variation between years is likely to represent a genuine shift in abundance. The drivers for these minor changes in distribution between years are unclear, but disturbance related to static fishing practices linked to the NTZ are unlikely to be the cause. This conclusion is suggested because the abundance of some of the species known to be susceptible to physical disturbance such as *A. dissimilis,* (Moss and Ackers 1982) showed minor increases in average abundance in the same site during the same time period.

As discovered by Hoskin et al. (2009), there appear to be no strong effects of the NTZ designation resulting in increased abundance of sessile marine invertebrates. However, the primary beneficiary of the NTZ designation was not intended to be the sessile marine invertebrates. In addition, this study was not able to characterise what effect the NTZ may have on sessile invertebrate populations further afield from the monitoring sites.

**NTZ Status Summary:** The data collected during the present study indicate that there is very little change in condition status of sessile marine invertebrates within the NTZ during the last 11 years. The changes observed were minor and occurred in both directions (increases and decreases within both the NTZ and control sites).

# 10 General Discussion

### 10.1.1 Diving Equipment

The present survey was challenging to execute for a number of reasons. The weather and tidal conditions associated with some of the sampling sites (Knoll Pins) were severe. Given the considerable logistical challenges of mobilising a commercial scientific diving team to Lundy, every minute of bottom time became essential in ensuring the sampling work could be delivered. This made the configuration of the diving equipment used critical to success. This was in part made possible by the large volumes of gas carried in the twin cylinder diving rigs described in Section 3.2. While there are logistical issues associated with larger, heavier diving rigs, the long bottom times these sets provided, particularly when combined with nitrox gas, played a crucial part in delivering this work.

### 10.1.2 Timing of Future Survey Work at Lundy

As discussed, the weather conditions experienced between August 2014 and September 2015 made completing the survey work at Lundy very challenging. This was, primarily due to the lack of sufficiently long high pressure weather periods in which to mobilise and complete the work, but also the unusually persistent easterly wind direction. This wind direction made access to the island and the majority of the sampling work on the east of the island very difficult.

It was noted that this time period coincided with the weather phenomenon "el Niño". It is not known to what extent this phenomenon influenced the weather patterns experienced during 2014 and 2015. However, given the challenging nature of subtidal sampling at Lundy in general, we suggest that repeated sampling is *not* scheduled during an el Niño year if at all possible in order to avoid unnecessary complications.

## 10.2 Anthropogenic Influences

There were very few occurrences of anthropogenic influences encountered during the entire subtidal sampling programme conducted for the present survey. This included an almost total lack of debris and rubbish in the subtidal habitats and a complete lack of any sign of influence from the island itself in terms of run off from land drains etc. No direct evidence of disturbance as a result of fishing or diving activity was encountered at any of the sites surveyed.

## 10.3 Species of Note

### 10.3.1 *Palinurus elephas*

Only two records of species of note were made during the present study. Both records were of the occurrence of *Palinurus elephas* which were encountered between sectors 2 & 3 of Knoll Pins at between 15 and 18m deep during low water slack tide on the 8/9/2015. The two individuals (one pictured below) had carapaces of approximately 60mm in length and appeared to be un-berried.

**Figure 21.** One of the two sightings of *Palinurus elephas* during the present study at sectors 2 & 3 of Knoll Pins on the 8/9/2015.

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# 12 Appendix

## 12.1 Coordinates for Survey Locations

| Site name | Lat | Long | Treatment |
|---|---|---|---|
| Rat Island | 51.1640 | -4.6532 | Kelp Forest |
| Gannet's Bay | 51.1965 | -4.6684 | Kelp Forest |
| Brazen Ward | 51.1907 | -4.6628 | NTZ |
| Quarry Bay | 51.1787 | -4.6607 | NTZ |
| Dead Cow Point | 51.1755 | -4.6837 | NTZ Control |
| St. Philips's Stone | 51.1856 | -4.6810 | NTZ Control |
| Gull Rock | 51.1854 | -4.6601 | *Eunicella verrucosa* |
| North Quarries | 51.1784 | -4.6608 | *Eunicella verrucosa* |
| Gannet's Rock Pinnacle | 51.1974 | -4.6666 | Vertical and overhanging rock community + *L. pruvoti* |
| Knoll Pins | 51.1883 | -4.6605 | Vertical and overhanging rock community + *L. pruvoti* |
| Anchor Pinnacle | 51.1981 | -4.6674 | Vertical and overhanging rock community |

## 12.2 Sector Maps from Irving 2011

### 12.2.1 Knoll Pins – Site overview

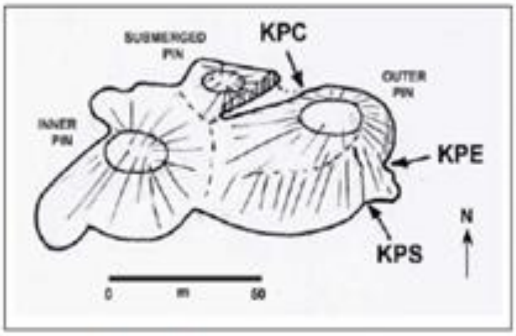


Fig. 2. Representation of the layout of the Knoll Pins (as viewed from a southern elevation), showing the three sites where overlapping photographs were taken. Scale is approximate. Circles indicate shallowest parts of each Pin, approximately. [Based on an image from the multibeam survey by Hydrosurveys Ltd., 2005].

KPC = Knoll Pins Cave KPE = Knoll Pins East KPS = Knoll Pins South

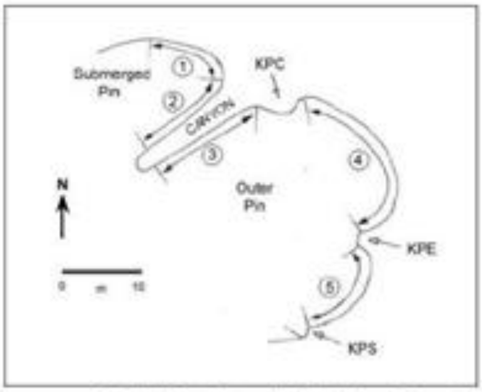


Fig. 3. Plan view sketch of part of the Knoll Pins showing the five *Leptopsammia* search sectors. The scale bar provides only an approximate indication of distance.

KPC = Knoll Pins Cave KPE = Knoll Pins East KPS = Knoll Pins South

### 12.2.2 Knoll Pins East

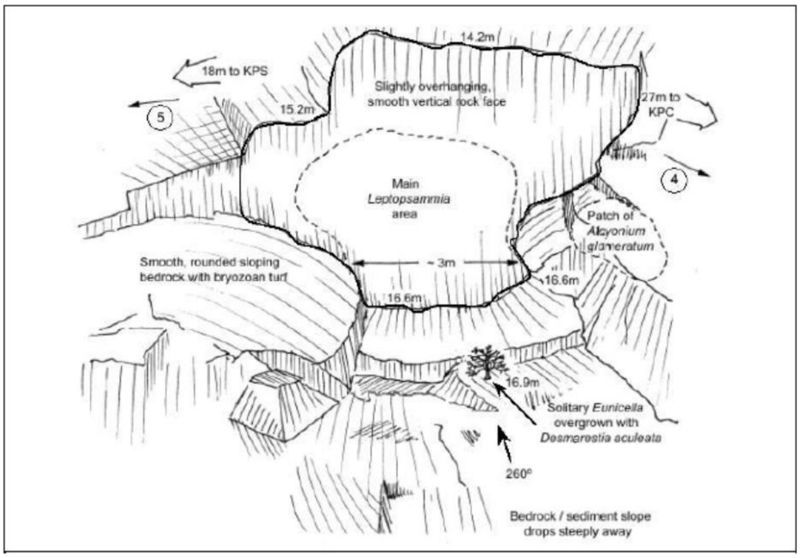


**Fig. 6.** The Knoll Pins East site on the eastern side of the Outer Pin. Overlapping photographs were taken within the area bordered by the thick black line. The start/end of search sectors 4 & 5 are marked by arrows. All marked depths are below chart datum (bcd). Scale is approximate. [Sketch reproduced from Irving, 2008].

### 12.2.3 Knoll Pins Cave

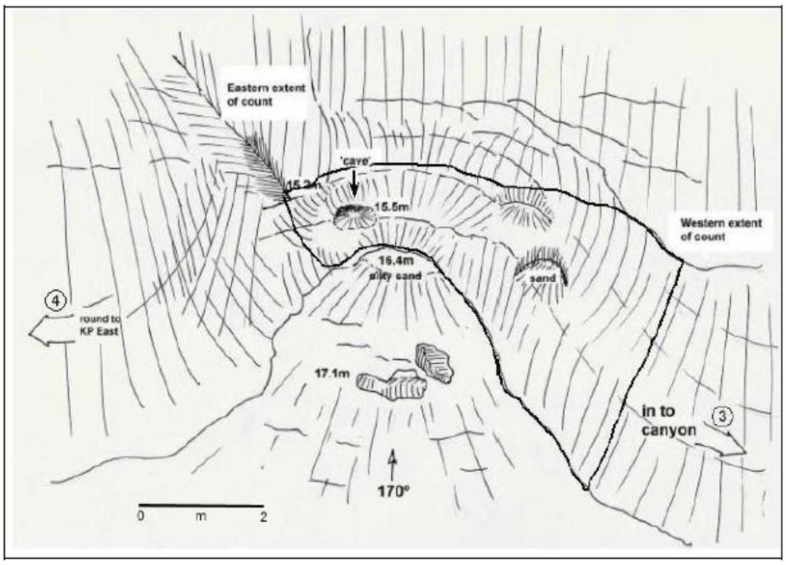


**Fig. 5.** The Knoll Pins Cave (KPC) site on the southern side of the entrance to the canyon. The 'cave' is found at 15.5 m depth (bcd) and is really a deep recess in the rock and not a cave at all. Overlapping photographs were taken within the area bordered by the thick black line (and indicated *in situ* by temporary vertical strings). The start/end of search sectors 3 & 4 are marked by arrows. All marked depths are below chart datum (bcd). Scale is approximate. [Sketch reproduced from Irving, 2008].

### 12.2.4 Gannet's Rock Pinnacle Site Overview (also known locally as Gannet's Stone).

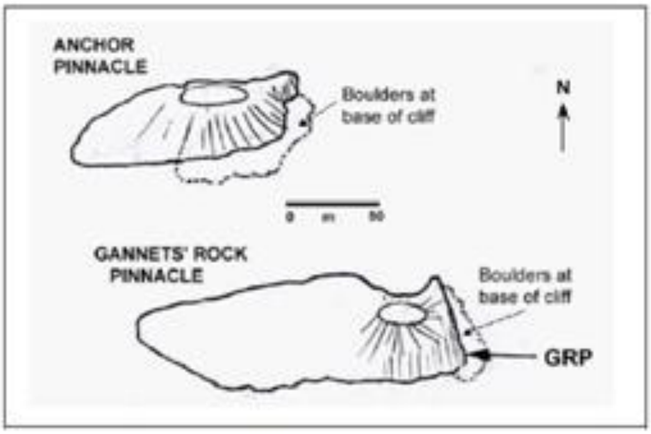


**Fig. 4.** Diagrammatic representation of the layout of Gannets' Rock Pinnacle and Anchor Pinnacle (as viewed from a southern elevation), showing the site (GRP) where overlapping photographs were taken. Scale is approximate. [Based on an image from the multibeam survey by Hydrosurveys Ltd., 2005].

### 12.2.5 Sector at Gannet's Rock Pinnacle

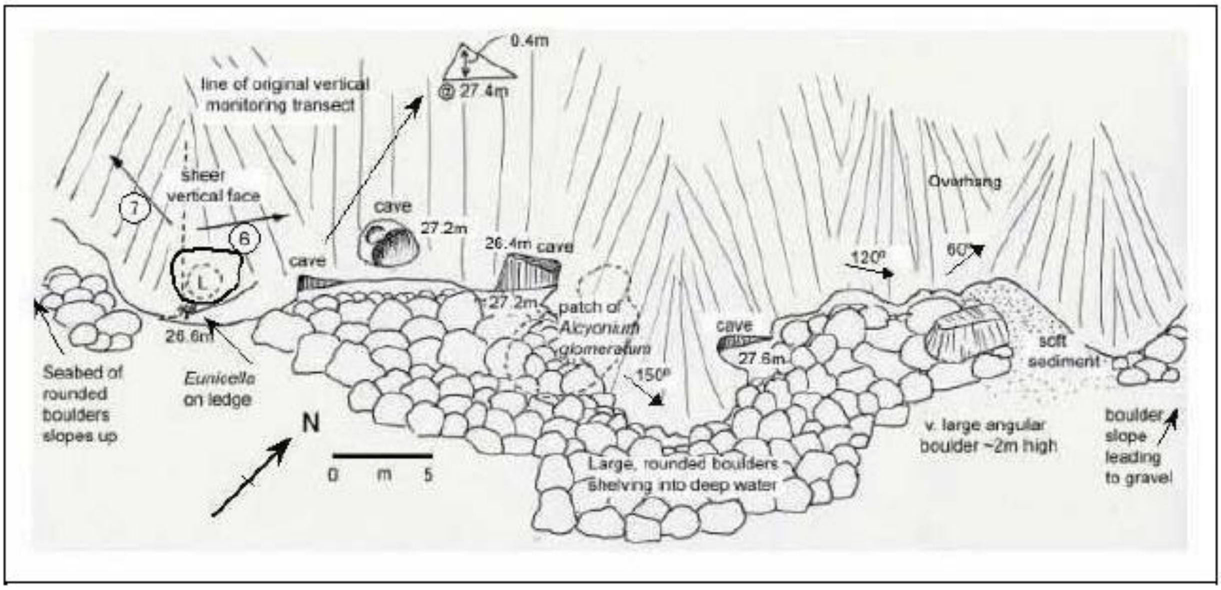


**Fig. 7.** The Gannets' Rock Pinnacle site, with the location of search sectors 6 & 7. Overlapping photographs were taken within the area marked by a thick black line. More detail is shown of the topography on the north side of the site, which produced more *Leptopsammia pruvoti* individuals, often found inside small caves, counted by divers. All marked depths are below chart datum (bcd). Scale is approximate. [Sketch reproduced from Irving, 2008].

## 12.3 Example Data Recording Sheets

### 12.3.1 Kelp Forest

**Site……………Diver………Date……Depth…..Transect bearing……..**

| Quadrat Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Notes |
|---|---|---|---|---|---|---|---|---|---|
| **Distance from Shot** | | | | | | | | | |
| **Distance from transect** | | | | | | | | | |
| ***L. hyperborea*** Rough stipe with epiphytes. Stipe oval in x-section | | | | | | | | | |
| ***L. ochroleuca*** Smooth stipe, no epiphytes (though possibly encrusting bryozoans) | | | | | | | | | |
| ***L. digitata*** flexible stipe with no epiphytes. Stipe round in x-section | | | | | | | | | |
| ***A. esculenta*** Feather like with midrib | | | | | | | | | |
| ***Saccharina latissimi*** single undivided blade with crinkly edge. Short stipe. | | | | | | | | | |
| ***Saccorhiza polyschides*** Massive lobose base with small projections. Flat stipe with wavy sides. | | | | | | | | | |
| ***Juvenile Laminaria*** *spp* small individuals or ones you are unsure about. | | | | | | | | | |
| *Red/understory* | | | | | | | | | |
| *Red/understory* | | | | | | | | | |
| *Red/understory* | | | | | | | | | |
| *Red/understory* | | | | | | | | | |
| Notes | | | | | | | | | |

### 12.3.2 *Eunicella verrucosa*

**Site…………Diver………Date………Depth……Transect bearing……**

**Condition Score:** 1: < 5% cover/pristine 2: 5% - 20% cover 3: 20% - 50% cover
4: 50% - 80% cover 5: > 80% cover

| Site description | Number of seafans in 10m | Condition score (fouling) | Notes |
|---|---|---|---|
| **1**. 10m transect<br>Depth:<br>Location: | | | |
| **2**. 10m transect<br>Depth:<br>Location: | | | |
| **3**. 10m transect<br>Depth:<br>Location: | | | |
| **4**. 10m transect<br>Depth:<br>Location: | | | |
| **5**. 10m transect<br>Depth:<br>Location: | | | |
| **6**. 10m transect<br>Depth:<br>Location: | | | |
| **7.** 10m transect<br>Depth:<br>Location: | | | |
| **8.** 10m transect<br>Depth:<br>Location: | | | |
| **9**. 10m transect<br>Depth:<br>Location: | | | |
| **10.** 10m transect<br>Depth:<br>Location: | | | |

### 12.3.3 No Take Zone and Subtidal Bedrock and Stable Boulder Communities

**Site………Sector………Diver……**

**Date……Depth……Transect bearing…….**

| Quadrat Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance from Shot | | | | | | | | | | | | |
| Distance from transect | | | | | | | | | | | | |
| *Axinella dissimilis* Yellow staghorn sponge | | | | | | | | | | | | |
| *Axinella infundibuliformis*, Spiralled sponge | | | | | | | | | | | | |
| *Axinella damicornis* Webbed sponge | | | | | | | | | | | | |
| *Homaxinella subdola* Untidy branching sponge | | | | | | | | | | | | |
| *Raspailia ramosa* Chocolate finger sponge | | | | | | | | | | | | |
| *Polymastia boletiformis* Stout sponge many tapered papillae, smooth | | | | | | | | | | | | |
| *Polymastia mammillaris* Stout sponge many straight papillae, rough | | | | | | | | | | | | |
| *Cliona celata* Yellow Boring Sponge | | | | | | | | | | | | |
| *Alcyonium digitatum* Dead man's fingers | | | | | | | | | | | | |
| *Alcyonium glomeratum* Red sea fingers | | | | | | | | | | | | |
| *Eunicella verrucosa* Sea fan | | | | | | | | | | | | |
| *Anemonia viridis* Snakelocks anemone | | | | | | | | | | | | |
| *Aiptasia mutabilis* tall anemone | | | | | | | | | | | | |
| *Pentapora fascialis* Wavy erect bryozoan | | | | | | | | | | | | |
| *Stolonica socialis* Orange sea squirt | | | | | | | | | | | | |
| Notes | | | | | | | | | | | | |

### 12.3.4 Vertical and Overhanging Rock Communities

**Site……………… Diver……….. Date……… Depth……… Transect bearing……**

| Quadrat Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Distance from Shot** | | | | | | | | | | | | |
| **Distance from transect** | | | | | | | | | | | | |
| ***Gymnangium montagui*** Yellow feathers | | | | | | | | | | | | |
| ***Stolonica socialis*** Orange sea squirt | | | | | | | | | | | | |
| ***Marthasterias glacialis*** Spiny starfish | | | | | | | | | | | | |
| ***Echinus esculentus*** Edible sea urchin | | | | | | | | | | | | |
| ***Homaxinella subdola*** Untidy branching sponge | | | | | | | | | | | | |
| ***Axinella infundibuliformis*** Spiralled sponge | | | | | | | | | | | | |
| ***Axinella damicornis*** Webbed sponge | | | | | | | | | | | | |
| ***Axinella dissimilis*** Yellow staghorn sponge | | | | | | | | | | | | |
| ***Cliona celata*** Yellow boring sponge | | | | | | | | | | | | |
| ***Raspailia ramosa*** Chocolate finger sponge | | | | | | | | | | | | |
| ***Raspailia hispida*** Yellow branching sponge | | | | | | | | | | | | |
| ***Stelligera stuposa*** Yellow branching sponge | | | | | | | | | | | | |
| ***Leptopsammia pruvoti*** Yellow sunset coral | | | | | | | | | | | | |
| ***Aiptasia mutabiis*** Tall anemone | | | | | | | | | | | | |
| ***Parazoanthus cf. anguicomus*** White cluster anemone | | | | | | | | | | | | |
| ***Parazoanthus axinellae*** Yellow cluster anemone | | | | | | | | | | | | |
| ***Alcyonium glomeratum*** Red sea fingers | | | | | | | | | | | | |
| ***Alcyonium digitatum*** Dead man's fingers | | | | | | | | | | | | |
| ***Eunicella verrucosa*** Sea fan | | | | | | | | | | | | |
| ***Flustra foliacea*** Hornwrack | | | | | | | | | | | | |
| ***Pentapora foliacea*** Wavy erect bryazoan | | | | | | | | | | | | |

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