Natural England Commissioned Report NECR220

Lyme Bay - A case study

Response of the benthos to the zoned exclusion of towed demersal fishing gear in Lyme Bay; 6 years after the closure

First published 15 September 2016

www.gov.uk/natural-england

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

In July 2008 the Department for Environment, Food and Rural Affairs (Defra) closed a 60 nm^2 area to bottom towed fishing gear. The main reason for this was to protect the benthic biodiversity in the bay, eg the species at the bottom, in particular to maintain the structure of the reef system and to enable the recovery of the bottom living invertebrates.

The closure was specific to the use of bottom towed fishing gear and the area remained open to sea anglers, scuba divers, other recreational users and fishers using static gear such as pots and nets.

From 2008-2011 the monitoring of the ecological and socio-economic changes that occurred following the closure was undertaken by a consortium led by Plymouth University and funded by Defra.

From 2012 to 2014 Natural England and Plymouth University jointly supported the continuation of the ecological component of the monitoring, enabling it to be done annually for a 4th, 5th and 6th year.

Natural England will use the findings from this study as part of our work to monitor the recovery of the Lyme Bay site and where appropriate to guide site management.

This case study may also be of interest to other relevant stakeholders such as the Association of Inshore Fisheries and Conservation Authorities (IFCAs), Cefas, Wildlife Trusts, Seasearch, local authorities and fisheries.

This report should be cited as:

SHEEHAN, E.V., COUSENS, S.L., GALL, S.C., BRIDGER, D.R., COCKS, S. & ATTRILL, M.J. 2016. *Lyme Bay - A case study: Response of the benthos to the zoned exclusion of towed demersal fishing gear in Lyme Bay; 6 years after the closure*. Natural England Commissioned Reports, Number 219.

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Keywords - Condition Assessment, monitoring, recovery, reef, Special Area of Conservation (SAC), European Marine Site (EMS), Lyme Bay, bottom towed fishing gear

Further information
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ISBN 978-1-78354-361-8

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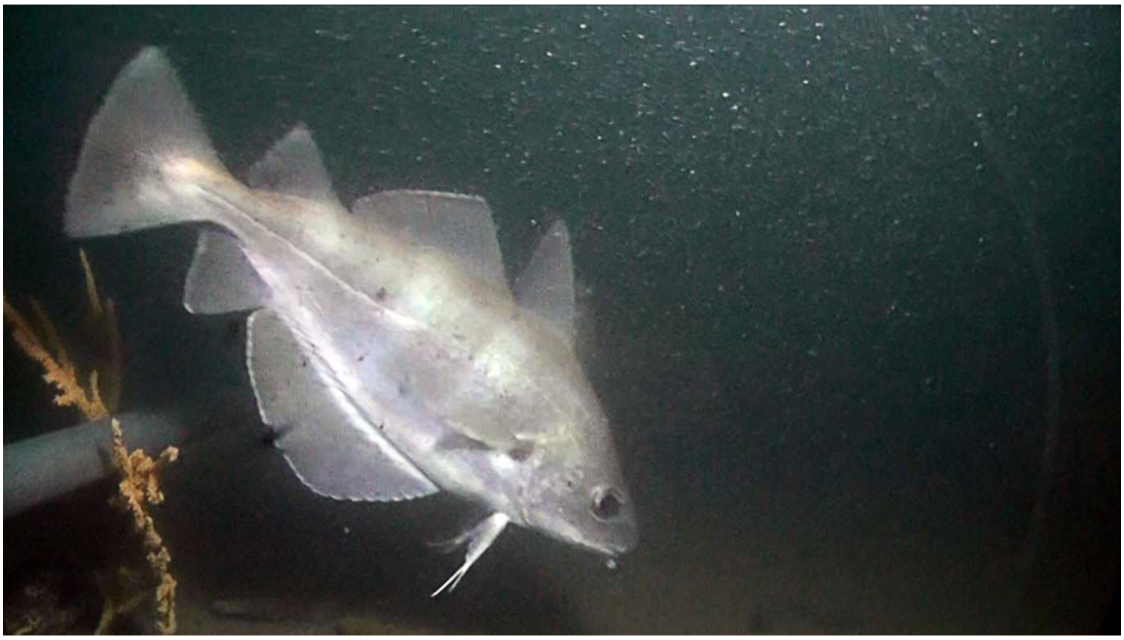

March 2015

Project Title: Lyme Bay - A case study: Response of the benthos to the zoned exclusion of towed demersal fishing gear in Lyme Bay; 6 years after the closure

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Executive Summary

In July 2008 the Department for Environment, Food and Rural Affairs (Defra) closed a 60 nm^2 area to bottom towed fishing gear through a Statutory Instrument (SI) (The Lyme Bay Designated Area (Fishing Restrictions) Order 2008). The primary aim of the closure was the protection of benthic biodiversity, namely to ensure the structure of the reef system was maintained and to aid the recovery of the benthos. This closure was specific to the use of bottom towed fishing gear; however, the area inside the closure remained open to sea anglers, scuba divers, other recreational users and fishers using static gear such as pots and nets. In addition, the bay was put forward as a candidate Special Area of Conservation (cSAC) by Natural England in August 2010 under the EC Habitats Directive (92/43/EEC) (Natural England, 2010; The Council of the European Communities, 1992).

Monitoring the ecological and socio-economic changes that occurred following the closure was undertaken by a Plymouth University led consortium and was funded by Defra from 2008-2011 (see Attrill et al., 2011; Mangi et al., 2011). Natural England and Plymouth University jointly supported the continuation of the ecological monitoring component from 2012-2014, enabling a 4^{th}, 5^{th} and 6^{th} year of annual monitoring following the closure of the area and baseline study in 2008. Here we present the benthic data from 2008-2014. The 2014 data have also been used to compare the protected assemblages called Sensitive Areas in the cSAC and sites which continue to be fished, three years after the cSAC was implemented.

To remotely sample the epibenthic reef fauna, two methods were employed using High Definition (HD) video. Firstly, a towed flying array was developed to fly the camera over the seabed to sample the sessile and sedentary taxa (Sheehan et al., 2010). Secondly, cameras were deployed on baited, static frames to sample the reef nekton and mobile benthic fauna.

To test for recovery inside the Statutory Instrument (SI) relative to controls for the towed video analysis, three treatment levels (or experimental units) were used: the Statutory Instrument (SI), Pre-existing Voluntary Closure (PVC) and Open Control (OC) (Table 2.1). Within each treatment there were five or six areas, each comprising three sites (200 m video transect), which were sampled in the summers of 2008, 2009, 2010, 2011, 2012, 2013 and 2014 (Figure 2.3). The same design principles were used to test for recovery in the SI for the baited video as the towed sampling, however there were fewer sites due to logistical constraints. Sampling was carried out in summer 2009, 2010, 2011, 2012, 2013 and 2014. To test for recovery in the Sensitive Areas (SA) three treatment levels were used: PVC, OC and SA in the summers of 2011, 2012, 2013 and 2014: for towed and baited video, again only a subset of sites were surveyed using the baited video.

Species counts were made from each entire video transect for infrequent organisms (all mobile taxa) and conspicuous sessile fauna. Frame grabs were extracted from the video and overlaid with a digital grid to define the area to be analysed. The stills were then used in conjunction with the HD video to quantify the encrusting, sessile species and some abundant, free-living fauna. Taxa were recorded as density for the species counts and either density or percentage cover as appropriate for the frame grabs. Quantitative data were extracted from the baited video samples by counting the number of mobile taxa in the field of view within one minute slices of video for 15 minutes. Counting started after waiting for the settlement of sediment after the initial impact. Species counts were averaged to give a relative abundance (mean min^{-1}) per taxa, per replicate. Data were then analysed for differences between treatments for Number of taxa, Abundance, and Assemblage composition. Analyses of the Abundance of pre-determined indicator species were undertaken. Indicator species were identified as a result of Objective 1 in the 2009 report (Jackson et al., 2008) and representatives selected from the range of species of differing biological traits present in Lyme Bay (Jackson et al., 2008).

The visibility in the 2014 towed and baited video survey was generally very poor (Figure 3.1 and 3.2) due to the winter storms resulting in more suspended sediment in Lyme Bay. Compared to the 2013 survey, 57 fewer species were recorded in 2014. In 20 % of the baited videos analysed, the visibility was less than a metre (bait box could not be seen). The winter storms clearly had a large impact on the benthos but it was still decided to present the data as although the bait box was unclear, where organisms approached it, it was still possible to see them. Ideally, we would have repeated sampling when conditions improved, but the water visibility did not clear over a month of attempting to collect the samples.

The Statutory Instrument analysis showed that average Number of sessile taxa was relatively stable in the SI from 2008, increased from 2010-2013, however decreased in 2014. For mobile fauna, Number of taxa was varied from 2009-2013 with a peak in 2011 but decreased in 2014. Abundance of sessile taxa showed an overall increase from 2008-2013 but also decreased in 2014. Mobile species Abundance was more varied from 2009-2013 but showed a decrease in 2014. These decreases in Number of Taxa and Abundance are likely to be a result of the severe winter storms. While Abundance and Number of taxa do not show trends of recovery since the cessation of fishing, the Assemblage composition of SI and PVC sites is still significantly different to OC sites in 2014 as it has been since 2009 suggesting that the protected sites had some resilience to the storms. Recovery of ecosystems from natural disturbances has been found to be faster than recovery from anthropogenic disturbances (Jones & Schmitz, 2009) so it is hoped that Lyme Bay will recover more quickly after the storms compared to the rate of recovery after the cessation of bottom towed fishing gear.

A range of trajectories of recovery were observed in indicator species from 2008-2013 (Sheehan et al., 2014). However many species were possibly affected by the storms, as all Key and Sessile indicators showed a decrease in abundance in the SI in 2013-2014 whilst four out of six Free-living indicators decreased and two increased in the SI (Gobies and *Cancer pagurus*).

Two species which provide habitat complexity increased in Abundance overall since 2008, including the low recoverability species *Eunicella verrucosa*, which is listed as vulnerable on the IUCN red list (IUCN 2013) and is a UK BAP species. In addition, Hydroids have increased overall in the PVC and SI from 2008-2014 compared to fished controls.
Whilst some indicator species are showing positive responses towards recovery, variation within the results demonstrate that it is still too early for firm conclusions to be drawn.

The 2013 results from the Sensitive Areas analysis showed that Assemblage composition within protected sites in the cSAC (SA sites) was significantly different to PVC and OC sites for the first time; however in 2014 the Assemblage composition in the sites within the SA was not significantly different to the OC. For the assemblage of mobile taxa recorded using baited video, there was no indication of recovery for SA sites. In all four years from 2011-2014, SA sites were more similar to OC sites and less similar to PVC sites. The impact of the protection afforded by the cSAC on mobile taxa therefore remains to be seen. It is expected that over time the SA sites will become more similar to the PVC and less similar to the OC sites that continue to be fished.

The reduction in all response variables in 2014 is most likely a result of the series of severe storms experienced by the south west UK in the winter of 2013-2014. Studies suggest that an increase in the intensity of these Atlantic storms that take a more southerly track is expected (Met Office and Centre for Ecology & Hydrology – CEH, 2014). A detailed study about the impacts of the storms on the benthos in Lyme Bay will be published in due course. It is imperative that Marine Protected Areas (MPAs) in the south west in particular are monitored at regular intervals to assess changes attributable to fishing and weather regimes.

It is hoped that annual sampling of the benthos in Lyme Bay will continue with a view to establishing conclusive signs of recovery in the SI.

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1 Introduction

Lyme Bay, located off the south west coast of England, is host to some of the UK's most important reef habitat and is considered to be both nationally and internationally important in ecological and conservation terms. The reef habitat in Lyme bay is unique due to its complex strata comprising a variety of bedrock with locally occurring stony reef (Natural England, 2013). The priority Biodiversity Action Plan (BAP) species pink sea fan *Eunicella verrucosa* and the nationally rare sunset cup coral *Leptopsammia pruvoti* are both known to occur in Lyme Bay (Cork et al., 2008). It is also an important area for commercial fishing and has a substantial number of recreational users.

In July 2008, the UK Department for Environmental, Food and Rural Affairs (Defra, 2008) implemented a Statutory Instrument (SI) - The Lyme Bay Designated Area (Fishing Restrictions) Order 2008, which closed a 60 nm^2 area of Lyme Bay to towed demersal fishing gear. In 2010, a candidate Special Area of conservation (cSAC) was proposed to the EU which enveloped the SI extending to the east, south and west due to the presence of extended Annex 1 reef habitat, protected under the Habitats Directive (92/43/EEC) (Natural England, 2010; The Council of the European Communities, 1992). The cSAC was accepted by the EU in 2011 so that it is now designated as a Site of Community Interest (SCI).

The primary aim of the SI closure was the protection of benthic biodiversity, namely to ensure that the reef structure was maintained and to allow the recovery of the benthos. The reefs of Lyme Bay are defined under Annex 1 of the Habitats Directive and include outcropping bedrock, cobbles and boulders, which are characterised by species such as the sea squirt *Phallusia mammillata*, corals *Alcyonium digitatum* and *E. verrucosa*, and bryozoan *Pentapora foliacea* (Figure 1.1).

Monitoring the ecological and socio-economic changes that occurred following the closure was undertaken by a Plymouth University led consortium and was funded by Defra from 2008-2011 (see Attrill et al., 2011; Mangi et al., 2011). Natural England and Plymouth University have been jointly supporting the continuation of the ecological monitoring component since 2011, enabling a sixth year of annual monitoring following the closure of the area in 2008. Here we present the benthic data from 2008-2014.

The objective of this study was to measure the 'recovery' of epibenthic reef fauna. Recovery cannot be truly measured due to the absence of pristine sites for comparison. Recovery was therefore defined as: Protected areas in the SI and cSAC becoming more similar to previously protected areas and less similar to areas which remained open to towed demersal fishing. Sessile and sedentary benthic taxa were monitored using High Definition (HD) video on a towed flying array, while nekton and mobile benthic fauna were monitored using baited, static frames.

The response variables used to assess recovery in the SI were: Number of taxa, Abundance (number of organisms), Assemblage composition, and Abundance of Key, Sessile and

Mobile indicator taxa (Figure 1.1) (Jackson et al., 2008). The response variables used to assess recovery in the cSAC were: Number of taxa, Abundance (number of organisms) and Assemblage composition. Recovery of the cSAC is still in the early stages, therefore, in the interest of brevity, the abundance of indicator species was not fully explored.

The indicator taxa were 16 pre-determined taxa as identified by Jackson et al. (2008) (Annex B, Table B2). These were grouped into three categories; ‘Key’ species selected by Defra, ‘Sessile’ and ‘Free-living’ by Jackson et al. (2008) and are presented in the same format here.

This is the sixth annual report that describes the recovery of the Lyme Bay Reefs since protection in 2008 from bottom towed fishing gear. Over this time, the recovery of the benthic community has been variable; however, this year’s survey followed extreme winter storms which are likely to have impacted the seabed.

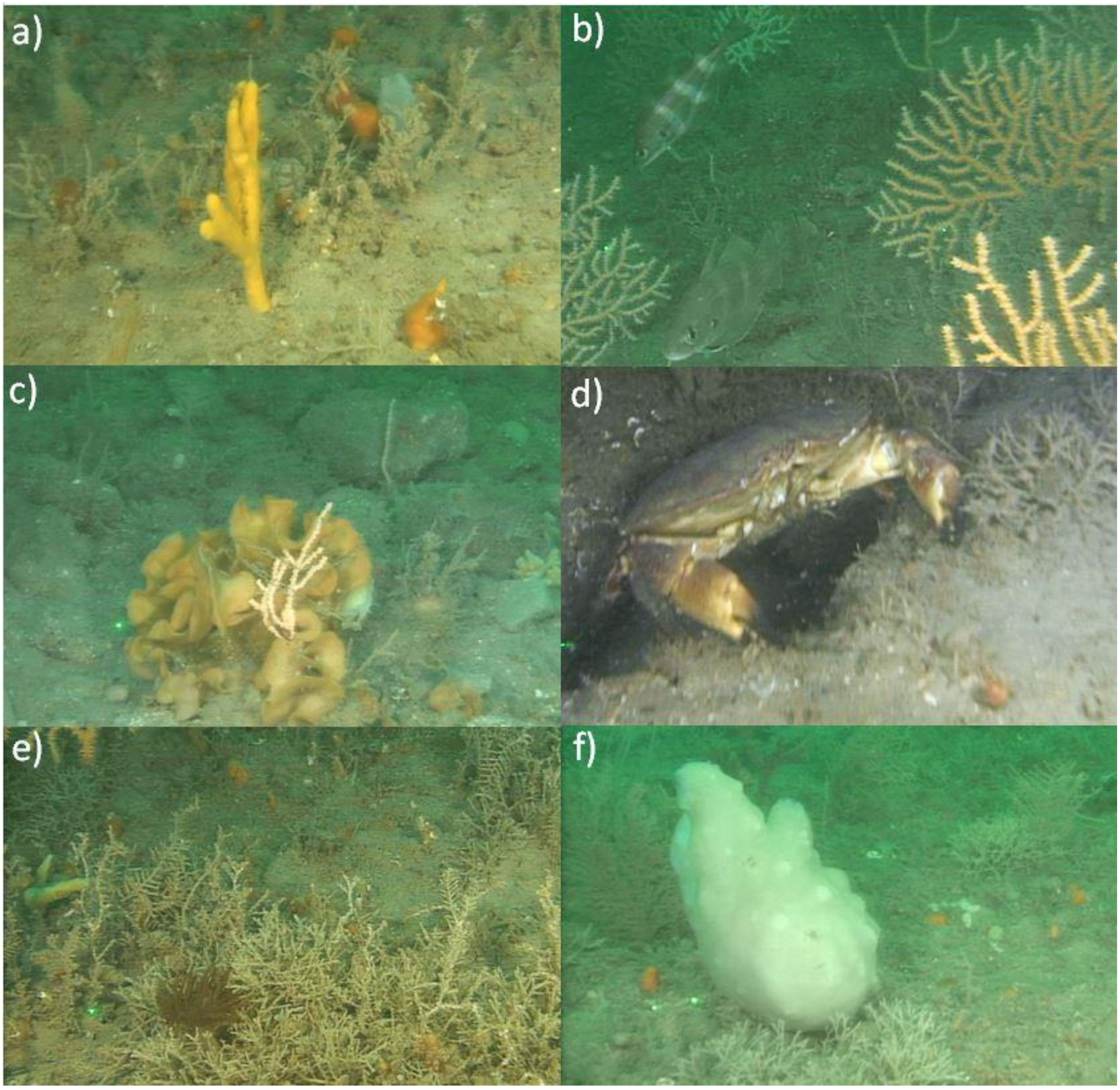

Figure 0.1 Examples of indicator Lyme Bay reef species from the 2013 survey; a) Branching sponge, b) *Eunicella verrucosa*, c) *Pentapora foliacea*, d) *Cancer pagurus*, e) *Aiptasia mutabilis*, f) *Phallusia mammillata.*

2 Methods

2.1 Sampling methods

Lyme Bay (Figure 2.3) has a diverse range of benthic habitats, from rocky and cobble reefs to mixed pebbly sand and gravel sediments and muddy soft substrata. This study focused on those reefs defined by Annex I of the Habitats Directive as ‘habitats where animal and plant communities develop on rock or stable boulders and cobbles’ (Jackson & Mcleod, 2000). Annual surveys took place over the summer months from 2008-2014. The 2008 baseline took place six weeks after the implementation of the Statutory Instrument (SI); however the anticipated changes in the benthic assemblage were expected to occur over annual or decadal time spans (Glasby, 1997) so this was considered an adequate baseline. Fieldwork was carried out from the vessel ‘Miss Pattie’, a 10 m displacement trawler. This year’s sampling took place from the 15th of July 2014 to 1st of August 2014 where the average water temperature was 18.9 ºC and salinity was 34.4 (at ~2 m depth). The average depth of the survey sites was 24.4 m. A summary of the methods used is presented below, while more detailed methods are described in Attrill et al. (2011).

2.1.1 Towed video

To quantify changes in the abundance of sessile and sedentary benthic species, a HD video camera was mounted on a flying array (Sheehan et al., 2010) (Figure 2.1). This method is particularly suitable for rapidly surveying large areas and is relatively low impact. This is necessary in a recovery study to avoid confounding assessments of change over time, with impacts associated with the sampling method. It is also very applicable when sampling in areas of high conservation importance. A Site sample comprises a ~200 m video transect (Table 2.1). Each year the gear is deployed at the same starting position using the wind and tide to select a unique transect that is independent from previous years.

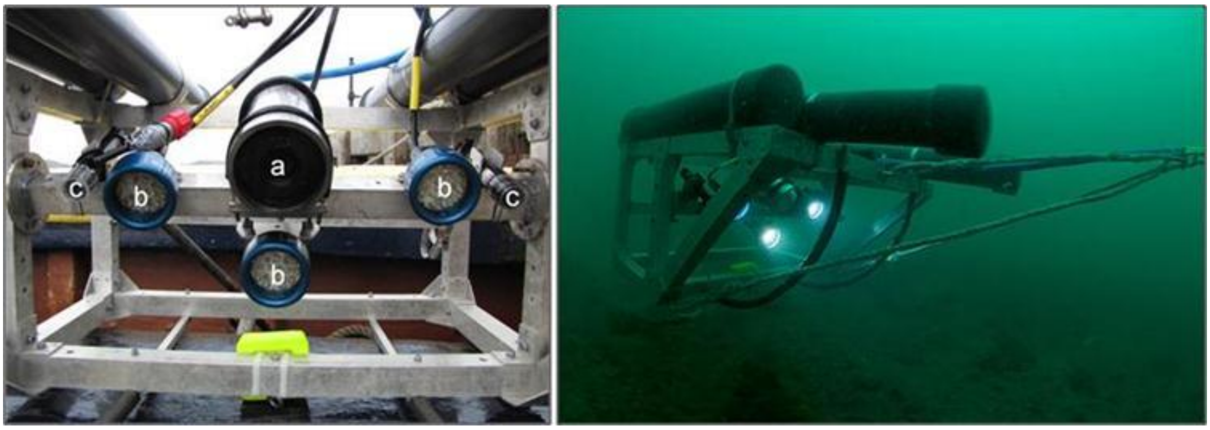

Figure 0.1 Flying array used for the towed video survey. a = high definition video camera, b = LED lights, c = lasers.

2.1.2 Baited remote underwater video (BRUV)

To determine whether the closure affected reef-associated nekton species and mobile benthic fauna, BRUV was used. The remote deployment of cameras on static frames increased sampling efficiency and statistical independence (Figure 2.2).

Six static frames (Greenaway Marine Ltd.) each housed a Panasonic HDC-SD60 full HD video camera and a battery operated LED light mounted on the frame (Figure 2.2). Two 15 kg weights attached to the housing and a 1 m pole extended out from the camera's field of view held a wire cage bait box (Figure 2.2) with 100 g fresh mackerel bait, which was replenished at the start of each deployment. At each site, three cameras were deployed off the side of the boat approximately 100 m away from each other, with a surface marker buoy attached.

Figure 0.2 BRUV static frames with bait box.

2.1.3 Sampling design (Towed and BRUV)

Species assemblages within the Statutory Instrument (SI) were surveyed at sites in treatment specific areas across Lyme Bay (Table 2.1; Figures 2.3 & 2.4). The three treatments for towed and BRUV were Statutory Instrument, Pre-existing Voluntary Closure and Open to fishing Controls. An additional treatment 'Sensitive Area' was added in 2011 to monitor the recovery of assemblages inside the cSAC (see Annex A, Figure A1 & A2 for Sensitive Areas inside the cSAC). For the towed video, each treatment comprised five or six areas. Three replicate sites (~200 m transect) were surveyed in each area in each year where possible (Annex A, Table A1 & Figure A2). For BRUV there were six sites per treatment, selected as a smaller supplementary version of the towed survey. Each site comprised three replicate cameras, baited with 100 g mackerel and deployed for 35 min. Survey locations were selected in 2008 before the baseline survey to control for habitat and fishing effort variability (Attrill et al. 2011).

As a result of changing management regimes in Lyme Bay (see introduction) some additional OC sites were located outside of protected areas in 2011 to compensate for those lost when the cSAC was established (Figures 2.3 & 2.4; Annex A, Table A1).

Table 0.1 Definitions of survey units.

Term	Definition
Site	A ~200 m transect (towed) or 3 cameras deployed for 35 min (baited)
Area	A group of 3 sites that are averaged for statistics (towed only)
Treatment	An experimental condition: PVC = Pre-existing Voluntary Closure (closed to demersal fishing since early 2000s), SI = Statutory Instrument (closed in 2008), OC = Open to fishing Controls or SA = Sensitive Areas inside the cSAC (areas closed to fishing in cSAC, not in SI)

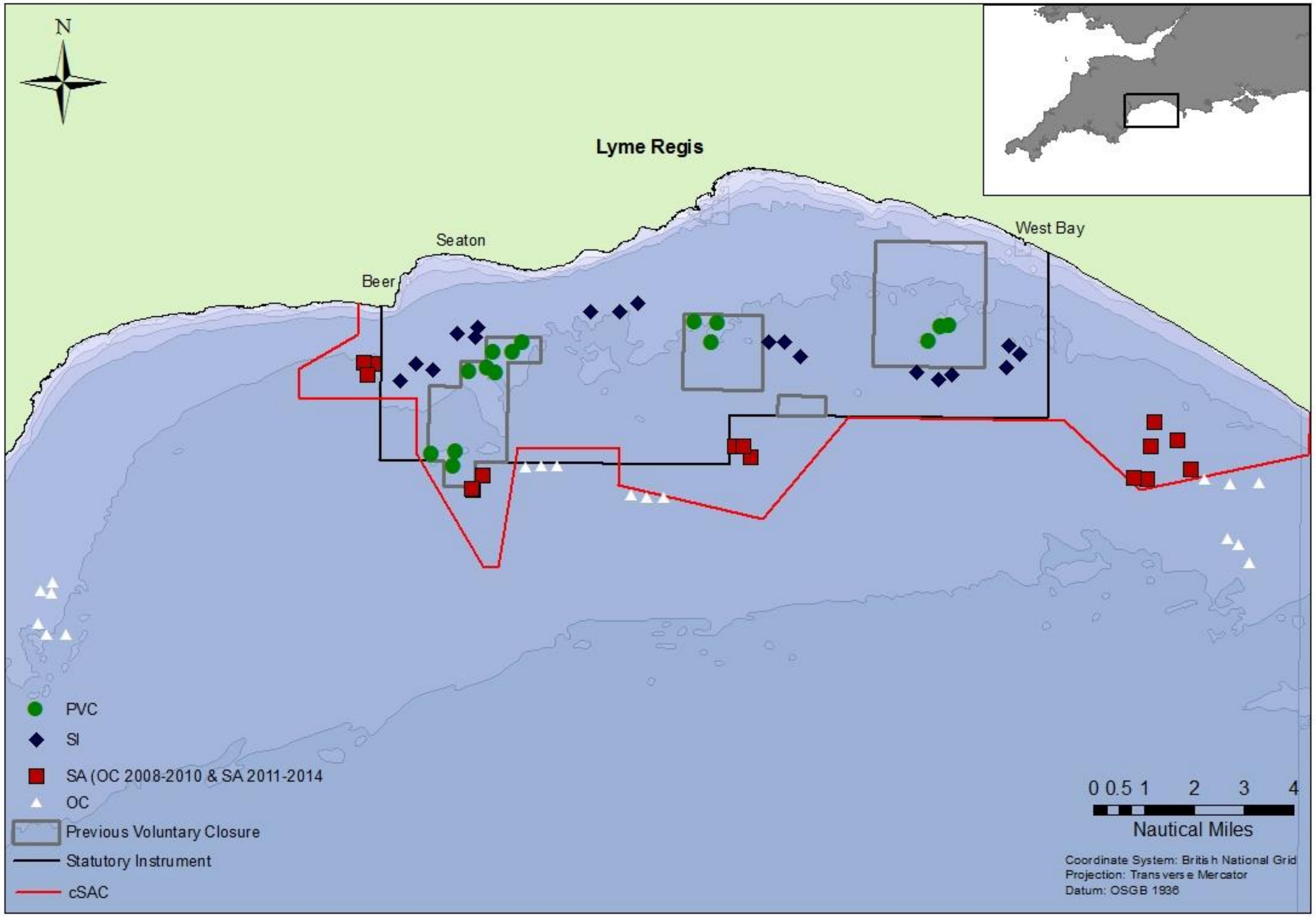

Figure 0.3 Locations of towed video transects in Lyme Bay coded by treatment (SI = Statutory Instrument, PVC = Pre-existing Voluntary Closure, OC = Open Control, SA = Sensitive Area). Some symbols overlap at this scale.

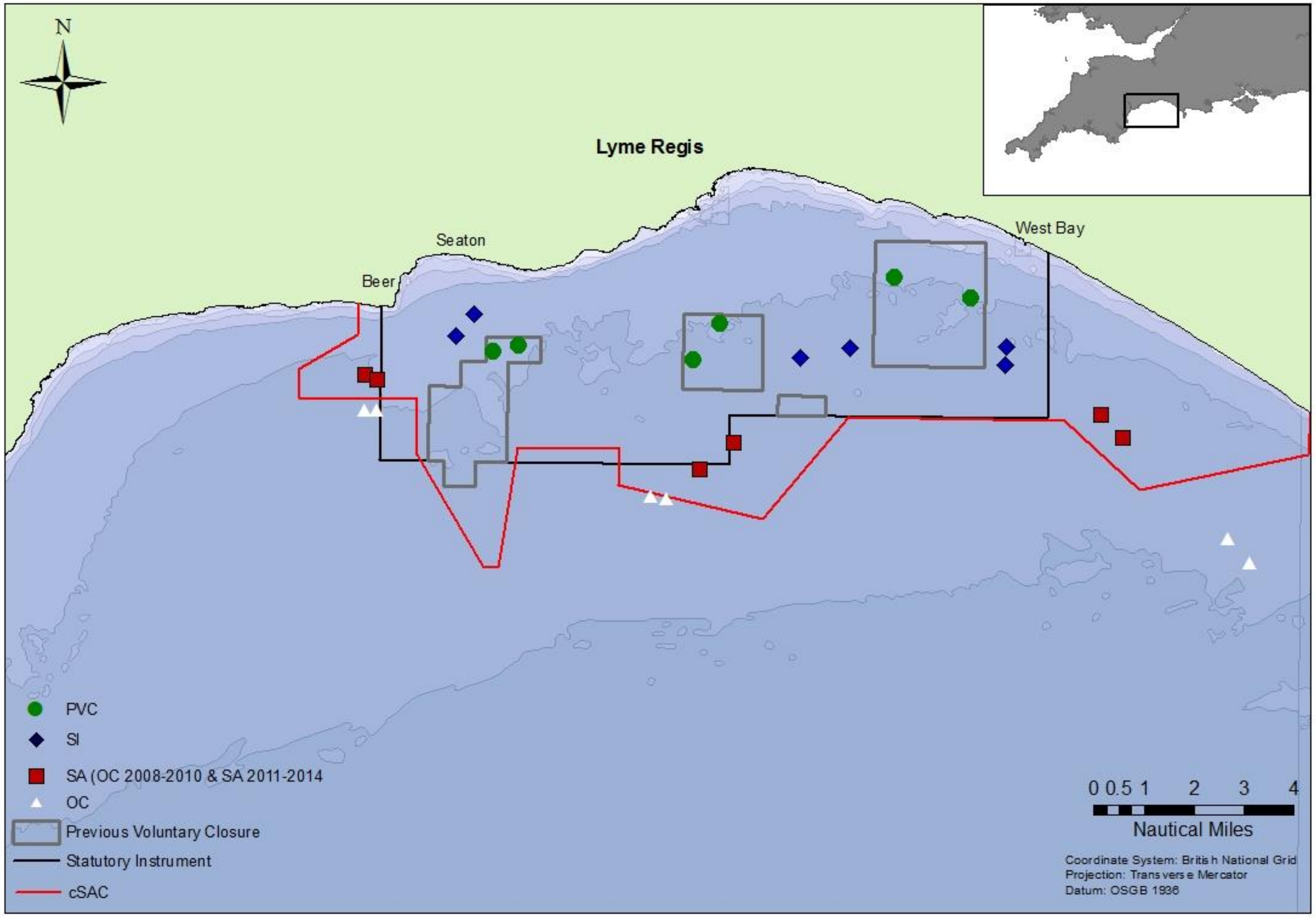

Figure 0.4 Locations of BRUV video sites in Lyme Bay coded by treatment (SI = Statutory Instrument, PVC = Pre-existing Voluntary Closure, OC = Open Control, SA = Sensitive Area). Some symbols overlap at this scale.

2.2 Video Analysis

For towed and baited video, all taxa present were identified and their abundance recorded. A full species list is presented in Annex B, Table B1. Identification was made to the highest taxonomic level deemed possible. On occasion organisms are seen in extremely high abundance. Where these species were not identifiable to species level from the video, physical samples were analysed by experts. For example the occurrence of sea cucumber *Ocnus planci* was confirmed by Dr. Keith Hiscock, Dr. Eve Southward and Bryan Wasson. Some groupings still occur due to between-species similarities, as outlined below:

i. All branching sponges, such as *Axinella dissimilis, Haliclona oculata, Raspailia hispida* and *Stelligera stuposa* were grouped as Branching sponges;
ii. The hydroid species *Halecium halicinium*, *Hydrallmania falcata* and unidentified hydroids excepting *Nemertesia antennina, Nemertesia ramosa* and *Gymnangium montagui*;
iii. The goby species *Gobius niger*, *Thorogobius ephippiatus* and unidentified gobies;
iv. The anemones *Aiptasia mutabilis*, *Cerianthus* spp. and *Peachia cylindrica* were grouped as Anemones because they were not differentiated in the 2008 survey;
v. The anemones *Actinia* spp. were identified to genus level;
vi. *Flustridae* spp. were identified to genus level;
vii. All red algae species;
viii. The sponges *Amphilectus fucorum* and *Iophon* spp. as *A. fucorum* is currently under taxonomic review (Ackers et al., 2007) and both genera are similar in appearance and have been classed as taxonomically difficult (Ackers et al. 2007);
ix. *Inachus* spp. and *Macropodia* spp. were identified to genus level. Additionally, for the baited video, and *Ophiura* spp. were identified to genus level, and *Triakidae* spp., was identified to family level;
x. Sponges that were not identifiable to species level were described and then identified as e.g. Red encrusting sponge, massive sponge 2 (Annex B, Table B1), ensuring taxonomic resolution was maximised;
xi. The term “turf” incorporated hydroid and bryozoan turf which projected less than 1 cm above the seabed surface;
xii. An organism which may be an alternative colour morph of the species *Cellepora pumicosa* was observed from 2012-2014. However, these individuals could not be identified as such with confidence and so are excluded from the indicator species Abundance for *Cellepora pumicosa* and recorded as ‘Brown Cellepora.’

2.2.1 Extraction of quantitative data from the HD video transect

Analysis of the video transects was conducted in two stages:

i. Species counts were made from each entire video transect by counting individuals that passed through the 'gate' formed by the two laser dots for infrequent organisms (all mobile taxa), and conspicuous sessile fauna (Annex B, Table B1).
ii. 30 frame grabs were extracted from each video transect and overlaid with a calibrated grid to quantify the encrusting, sessile species, some abundant, free-living fauna and metrics of infaunal density and bioturbation such as burrow densities. The grid identifies the area of species to be enumerated. Analysts then locate the position of the grid in the HD video and use this in conjunction with the frame grab. This is to ensure that species identification can be made to the highest resolution possible.

Taxa were recorded as density for the species counts and either density or percentage cover as appropriate for the frame grabs (Annex B, Table B1).

2.2.2 Extraction of quantitative data from Baited Remote Underwater Video

Quantitative data were extracted from the BRUV samples by counting the number of mobile taxa in the field of view within one minute slices of video for 15 min at normal speed. Counting started after waiting for the sediment to settle after the initial impact and the time was noted to refer back if needed. Organisms were identified to the lowest taxonomic rank possible and the counts were averaged to give a relative abundance (mean min^{-1}) per taxa, per replicate. This method ensures that individuals seen multiple times within one frame were not over represented. The three replicates were averaged to increase precision and avoid pseudo-replication.

2.3 Data analysis

Univariate and multivariate analyses were conducted using Permutational Multivariate Analysis of Variance (PERMANOVA, Anderson, 2001; Clarke & Warwick, 2001) based on similarity matrices (univariate = Euclidean distance, multivariate = Bray Curtis similarity). Univariate data were Log (x+1) transformed and multivariate were fourth root transformed for towed video analysis and square root transformed for baited video (Anderson & Millar, 2004). The null hypothesis of no difference among species assemblages (see response variables in introduction) between protected and fished treatments that is consistent over temporal and spatial scales was examined. Analyses were done using PRIMER 6 (Clarke & Warwick, 2001), with PERMANOVA + For PRIMER.

The factors used to test for recovery inside the SI and SA relative to controls for towed video were Year (fixed: 2008, 2009, 2010, 2011, 2012, 2013, 2014 or 2011, 2012, 2013, 2014 respectively), Treatment (fixed: PVC, SI, OC or PVC SA and OC), Area (random and nested in Treatment: five or six within each Treatment), and Site (random and nested in Treatment and Area: three per Area). The 30 frame grabs per site were averaged to avoid pseudo replication.

To test for recovery in the SI and SA using the baited video, the factors were Year (fixed: 2009, 2010, 2011, 2012, 2013, 2014 or 2011, 2012, 2013 2014), Treatment (fixed: PVC, SI, OC or PVC, SA, OC), and Site (random: six per treatment) with three replicates per site. The three replicates were averaged as with the frame grabs to avoid pseudo-replication and to increase the measured precision of the mobile fauna assemblage.

Significant Year x Treatment (Ye x Tr) interactions were interpreted using Pairwise tests. Significant differences for Year or Treatment or Area were not further interpreted as the hypotheses did not relate to overall spatial or temporal differences in the bay.

For each indicator species specific univariate analysis the sampling method in which Abundance was best captured was used; Frames, Video or Baited (Annex C, Table C3).

Measures of Abundance presented in the results appear with different units depending on the survey method from which they were derived. Individual or discrete colonial organisms counted within entire video transects (video transect data) are expressed as individual per linear metre of each transect (m^{-2}), with standard error of the mean (± SE). Individual or discrete colonial organisms counted within the 30 frames sub-sampled from each video transect are expressed as densities (m^{-2} ± SE). Cover-forming colonial taxa quantified from the frame grabs are expressed as percentage cover (m^{-2} % ± SE). Counts of benthic-associated nekton derived from the BRUV surveys are expressed as the mean number of fish appearing within a one minute segment of video (min^{-1} ± SE).

Ophiothrix fragilis was excluded from the analysis as their abundance could not be recorded reliably from video, and their density did not allow identification of habitat type.

All dates in the results section refer to survey periods, not the year in which reports were published.

3 Results

The water visibility during the 2014 survey was generally very poor due to the winter storms resulting in more mobile sediment in Lyme Bay (Figures 3.1 & 3.2). In 20 % of the baited videos analysed, the visibility was less than a metre (bait box could not be seen). It was decided that the data was still analysable as organisms could still be seen when they approached the bait. Ideally, we would have repeated sampling when conditions had improved, but the water visibility did not clear over a month of attempting to collect the samples.

A total of 75 taxa from 9 phyla were recorded in the 2014 survey; 69 count taxa and 6 cover taxa were recorded in the frame grab analysis, 37 in the video analysis and 31 in the baited video (Annex B, Table B1). This is compared with a total of 132 taxa from 9 phyla which were recorded in the 2013 survey; where 90 count taxa and 16 cover taxa were recorded in the frame grab analysis, 45 in the video analysis and 37 in the baited video. The reduction in mobile taxa abundance recorded may be due to storm damage or the resulting poor visibility. Despite this reduced visibility, Policeman anemone *Mesacmaea mitchellii* was observed for the first time in the towed video analysis and three species were observed for the first time in the baited video; the Grey gurnard *Eutrigla gurnardus*, Common smoothound *Mustelus mustelus* and Striped red mullet *Mullus surmuletus.* In 2014, of the species recorded through counts from the frame grab data, hydroids had the greatest mean Abundance (49.65 m^{-2} ± 7.60), followed by hermit crab *Pagurus* spp*.* (5.80 m^{-2} ± 2.64) and sea squirt *Stolonica socialis* (2.89 m^{-2} ± 1.48). "Turf" had the greatest mean percentage cover (7.18 m^{-2} % ± 1.97), and out of the cover taxa identified to species *Lithophyllum incrustans* had the greatest mean percentage cover (0.02 m^{-2} % ± 0.01). For conspicuous sessile and mobile species quantified in the video transects, *Alcyonium digitatum* was the most abundant sessile species (0.24 m^{-2} ± 0.07) followed by *Eunicella verrucosa* (0.18 m^{-2} ± 0.08), branching sponges (0.11 m^{-2} ± 0.03) and *Phallusia mammillata* (0.02 m^{-2} ± 0.01). Of the free living species, Abundance of *Pagurus* spp*.* (0.93 m^{-2} ± 0.54) was greatest, followed by *Asterias rubens* (0.33 m^{-2} ± 0.11), *Aequipecten opercularis* (0.22 m^{-2} ± 0.07) and *Pecten maximus* (0.16 m^{-2} ± 0.03). From the baited data, Gobies were the most abundant of all nektonic taxa (0.57 min^{-1} ± 0.19), followed by *Scyliorhinus canicula* (0.42 min^{-1} ± 0.09) and of the cryptic species *Pagurus* spp. had the greatest mean Abundance (2.17 min^{-1} ± 0.65), followed by *Ophiura* spp. (0.73 min^{-1} ± 0.58).

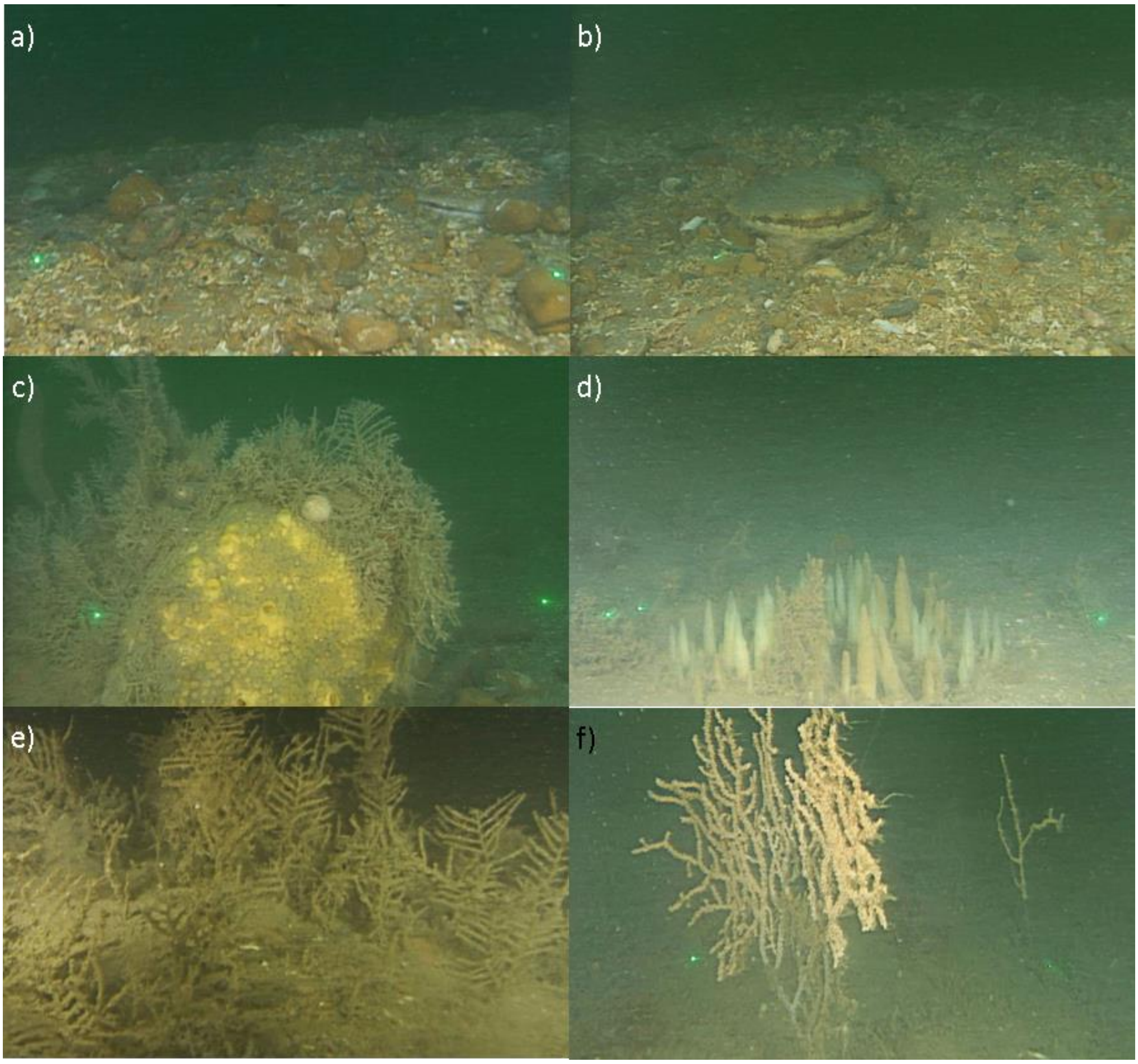

Figure 0.1 Images from the towed video survey 2014; a & b) *Pecten maximus*, c) Yellow Boring sponge *Cliona celata*, d) *Ciocalypta penicillus*, e) *Halecium halecinum* and f) *Eunicella verrucosa.*

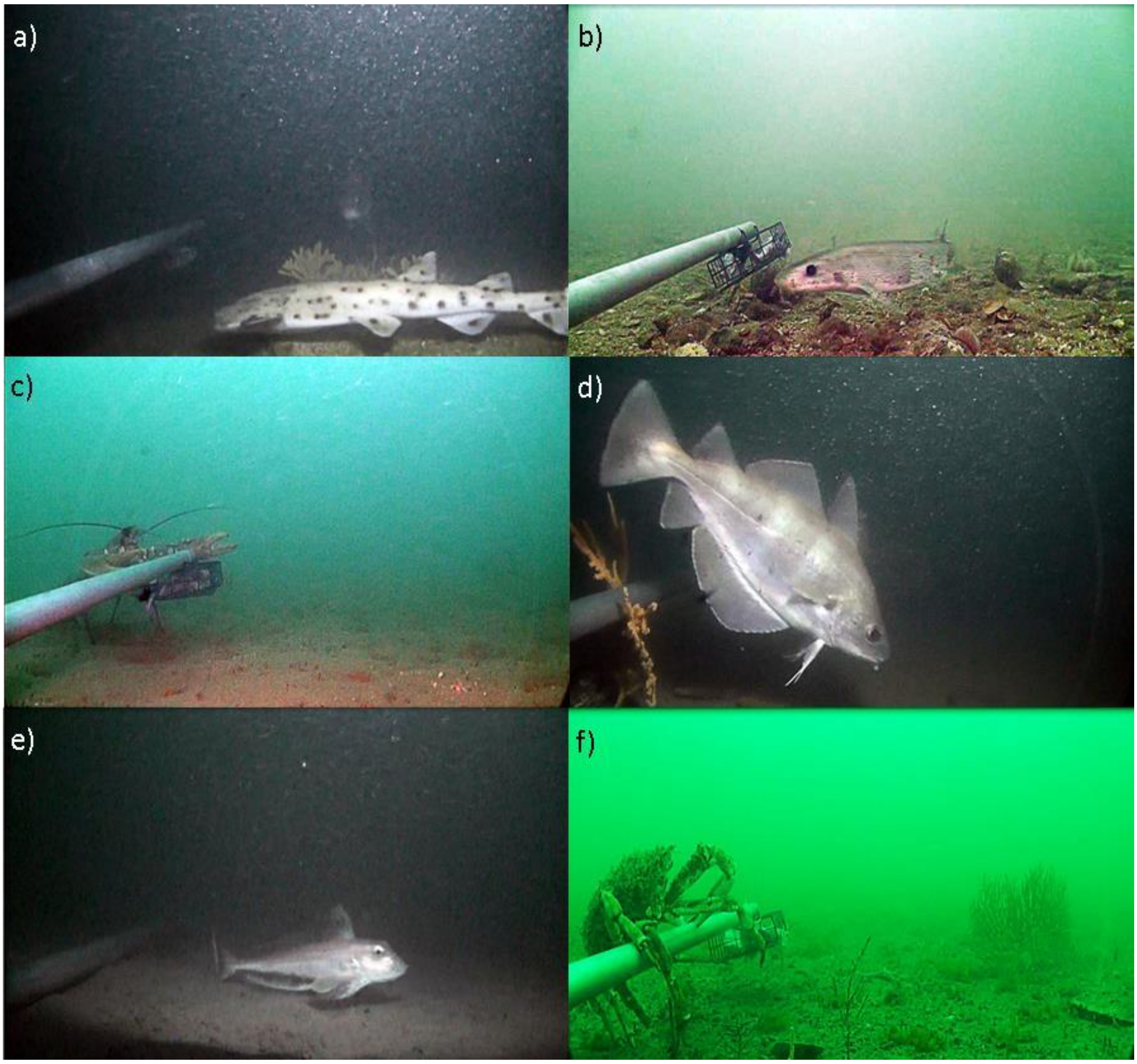

Figure 0.2 Images from the baited video survey 2014; a) *Scyliorhinus stellaris*, b) *Scyliorhinus canicula*, c) *Homarus gammarus*, d) *Trisopterus luscus,* e) *Eutrigla gurnardus* and f) *Maja squinado.*

Statutory Instrument analysis

The data presented below consider the results for the Statutory Instrument (SI), Pre-existing Voluntary Closure (PVC) and Open Control (OC).

3.1 Frame grab data (SI analysis)

3.1.1 Number of taxa

Average Number of taxa was stable in the SI from 2008-2010 (mean Number of taxa 2008 = 19.44 m^{-2} ± 0.96, 2010 = 16.06 m^{-2} ± 1.33), increased from 2010-2013 (2013 = 32.28 m^{-2} ± 2.02) and decreased in 2014 (17.33 m^{-2} ± 1.38). Number of taxa in the SI has been significantly greater than in the OC since 2011 (Figure 3.3) (Ye x Tr $P < 0.05$; see Annex C, Table C1 for pairwise tests).

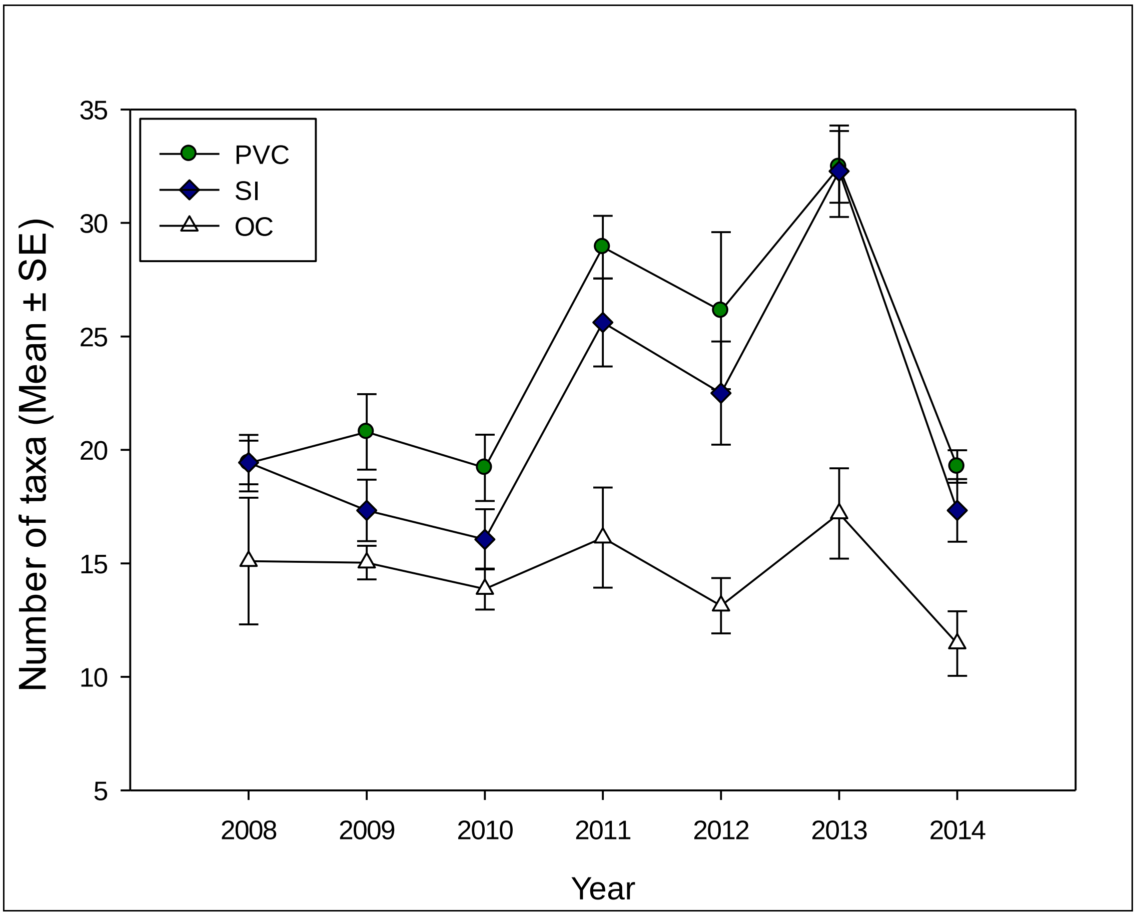

Figure 0.3 Number of taxa (mean m^{-2} ± SE) for each treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control) in 2008, 2009, 2010, 2011, 2012, 2013 and 2014.

3.1.2 Abundance

Abundance (number of individuals) increased in the SI from 2008-2011 (mean Abundance 2008 = 83.99 m^{-2} ± 14.08, 2011 = 242.99 m^{-2} ± 44.23), decreased in 2012 (141.09 m^{-2} ± 17.16), increased in 2013 (332.13 m^{-2} ± 74.97) and decreased once again in 2014 (71.71 m^{-2} ± 11.05) (Figure 3.4). In 2013 abundance was significantly greater than in the OC for the first time ($P < 0.05$) but this was not the case in 2014 (Annex C, Table C1).

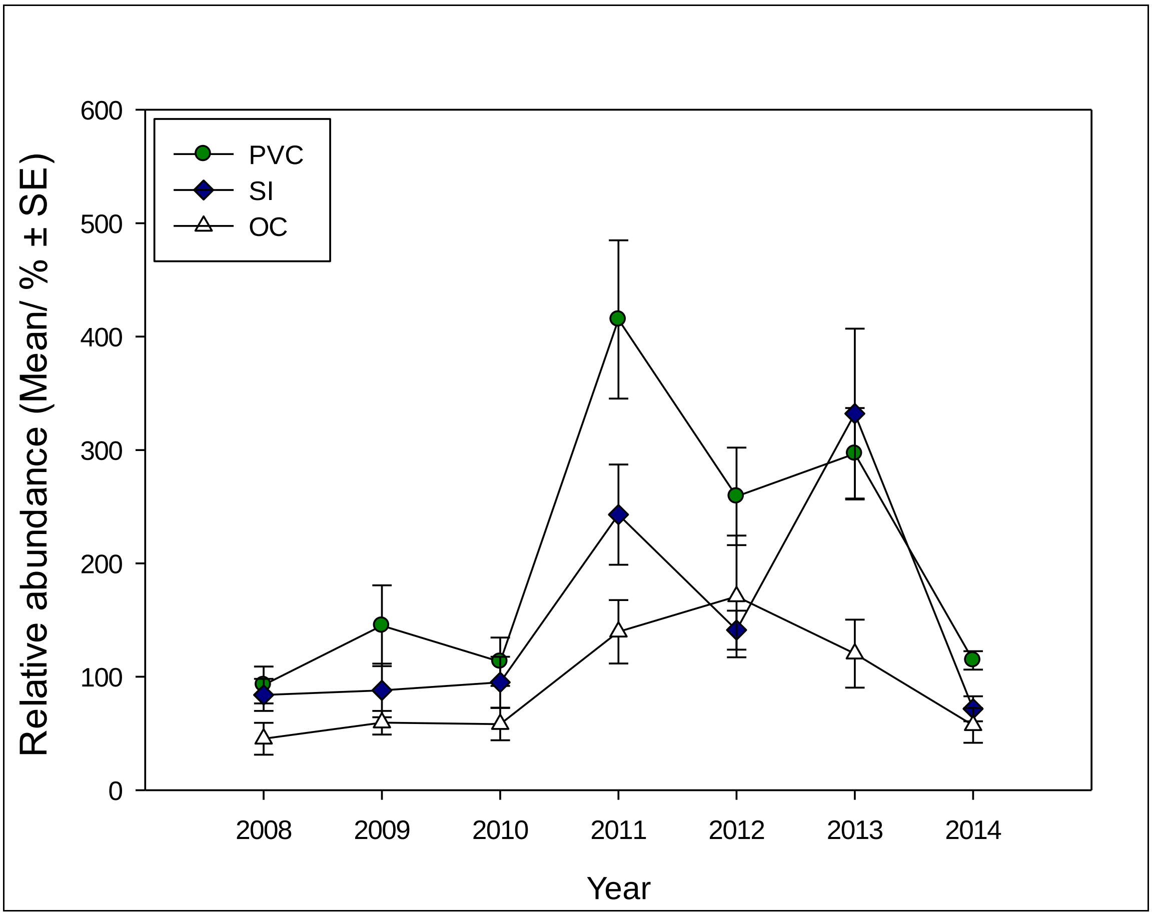

Figure 0.4 Abundance (mean m^{-2} and % ± SE) of fauna for each treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control) in 2008, 2009, 2010, 2011, 2012, 2013 and 2014.

3.1.3 Assemblage composition

Assemblage composition from 2008-2010 was similar for PVC and SI sites, whilst OC sites were not too dissimilar from the protected sites (Figure 3.5). Clear partitioning of the assemblage compositions between treatments began in 2011. The SI diverged away from the OC and maintained similarity with PVC. In 2014, differences between protected sites (SI and PVC) and OC were maintained. Assemblage composition has been significantly different in the SI to the OC every year since 2010 ($P < 0.05$) (Ye x Tr $P < 0.001$; Table 3.1; see Annex C, Table C1 for pairwise tests; Figure 3.6).

The results from SIMPER analysis show that in 2008 *Cellepora pumicosa, Ophiura* spp. and Anemones contributed 20 % of the differences in assemblage between the OC and SI. Average abundance of *C. pumicosa* in the SI in 2008 was 1.65 m^{-2} compared to only 0.76 m^{-2} in the OC. The abundance of *Ophiura* spp. and Anemones was greater in the OC than the SI (3.16 and 5.08 times greater respectively). In 2013, *Alcyonidium diaphanum,* Turf, Anemones and *Nemertesia antennina* contributed most towards the differences in assemblages, while in 2014 Turf, *Pagurus* spp. and *Ophiura* spp*.* were the key discriminatory taxa. In the SI in 2014, there was four times the abundance of Turf compared to the OC but the ratio of *Pagurus* spp. remained relatively unchanged (2.94 times greater in the OC compared to the SI).

Table 0.1 PERMANOVA results for the relative Abundance of the main assemblage species identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factor Area (Ar) and their interactions. Data were forth root transformed. Analyses were conducted using Bray Curtis similarity. Bold type denotes a statistically significant difference.

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	6	76330	12722.0	12.24	**0.0001**
Treatment Tr	2	74747	37373.0	6.75	**0.0001**
Area Ar(Tr)	13	70437	5418.20	9.56	**0.0001**
YexTr	12	24902	2075.20	2.05	**0.0001**
YexAr(Tr)	75	74895	998.60	1.76	**0.0001**
Residual	195	110470	566.52		
Total	303	431780			

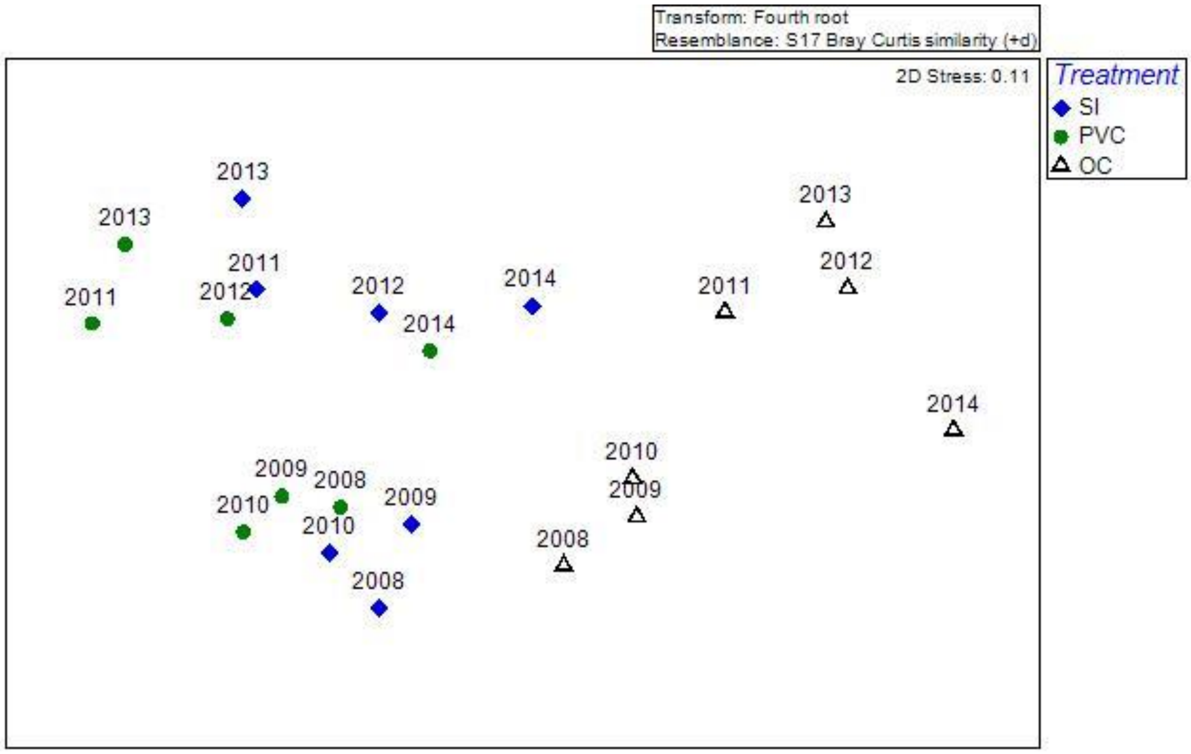

Figure 0.5 nMDS plot illustrating similarities in Assemblage composition between Treatments (averaged for site within treatment), (Pre-existing Voluntary Closure = green circles, Statutory Instrument = blue diamonds, Open Control = white triangles), over time (2008, 2009, 2010, 2011, 2012, 2013, 2014).

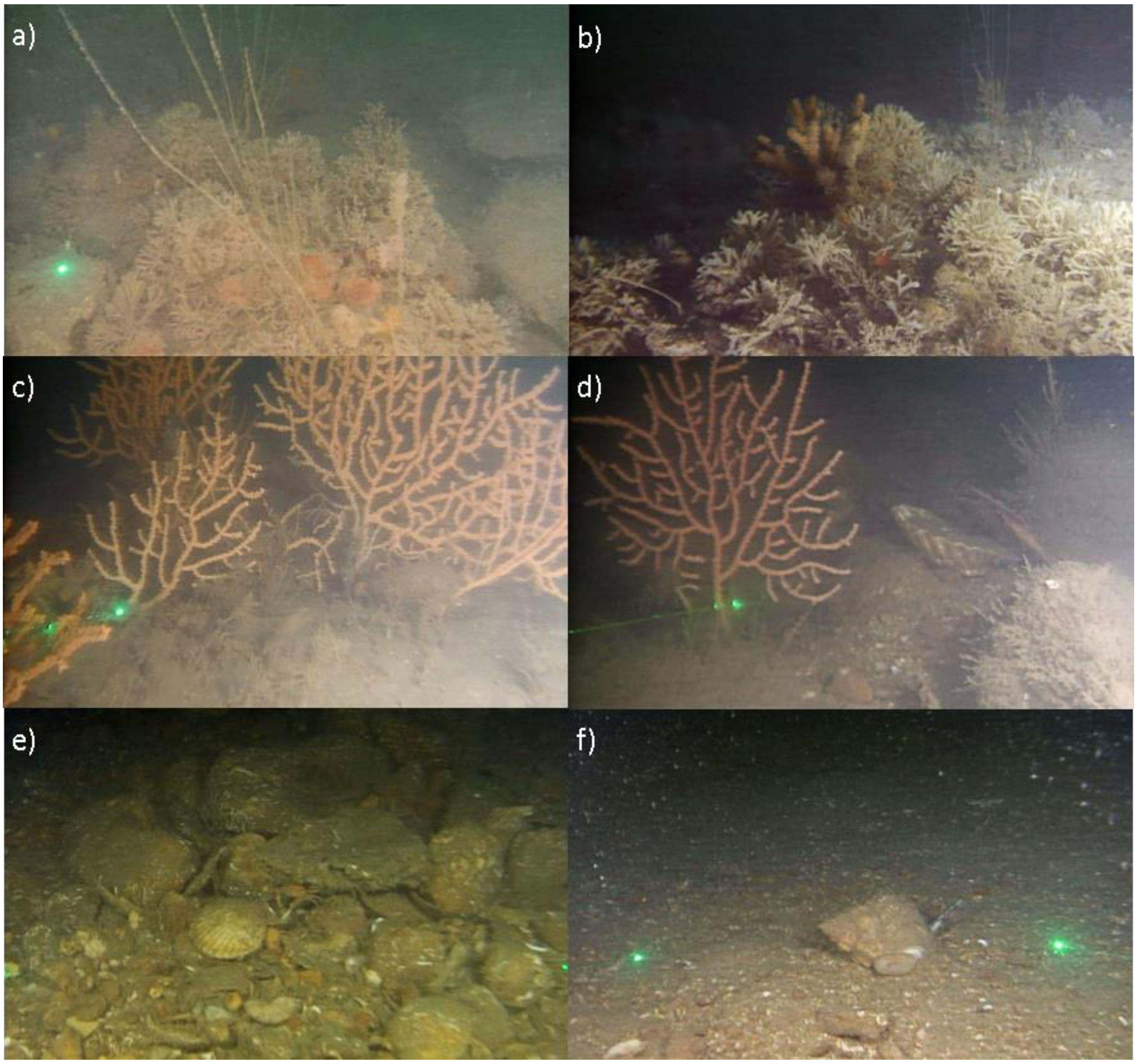

Figure 0.6 Images from the towed video survey 2014 showing assemblages in each treatment; a & b) PVC, c & d) SI, e & f) OC.

3.2 Baited Remote Underwater Video data (SI analysis)

3.2.1 Number of taxa

Mean Number of Taxa in the SI varied from 2008-2013. In 2011 the mean Number of taxa in the SI was significantly greater than in the OC ($P < 0.05$) but in 2014 the mean number of mobile fauna decreased in all treatments (Figure 3.7; Annex C, Table C2).

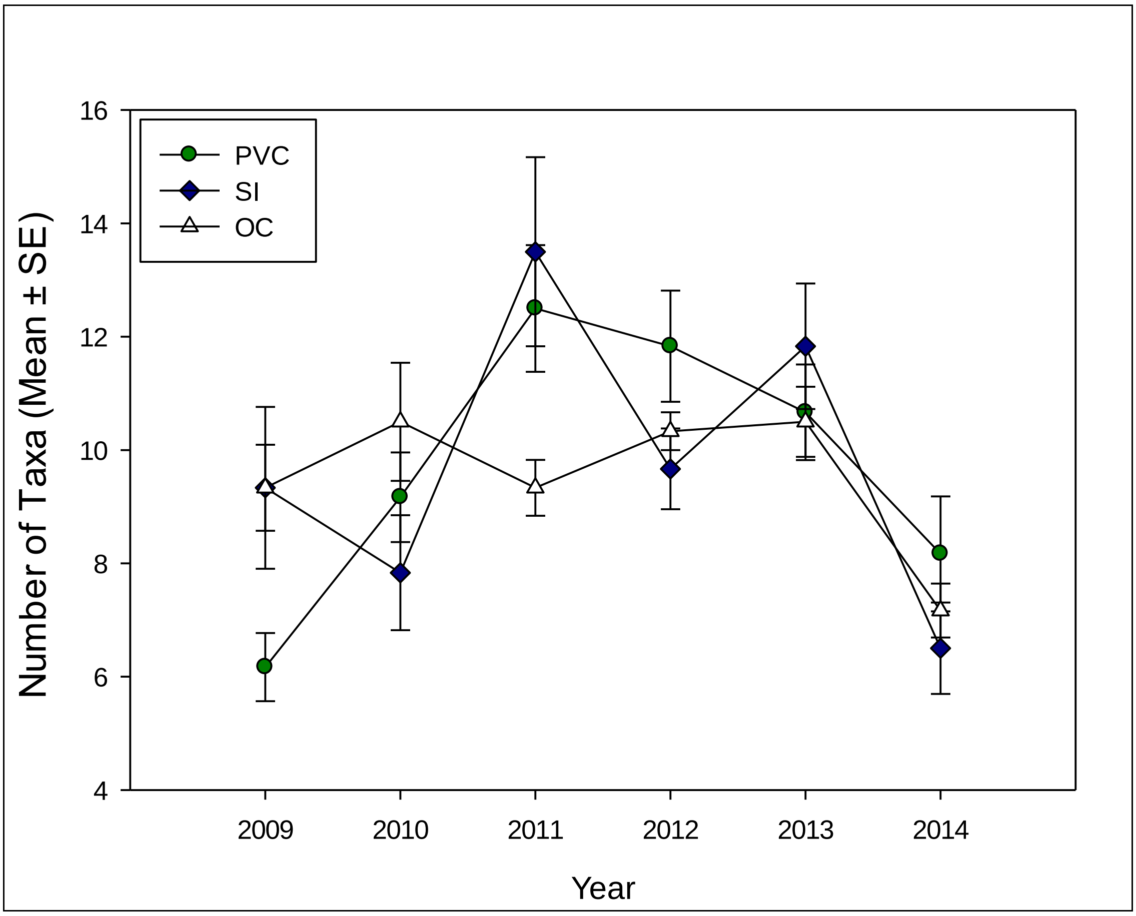

Figure 0.7 Number of mobile taxa (mean min^{-1} ± SE) for each treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control) in 2009, 2010, 2011, 2012, 2013 and 2014.

3.2.2 Abundance

Mobile species Abundance varied in all treatments from 2008-2013 and decreased by 50 % from 2013-2014 in the SI (mean Abundance SI 2013 = 10.35 min^{-1} ± 1.46, 2014 = 5.13 min^{-1} ± 2.13; Figure 3.8). In 2014, Abundance in the SI was not significantly different to the OC (Annex C, Table C2).

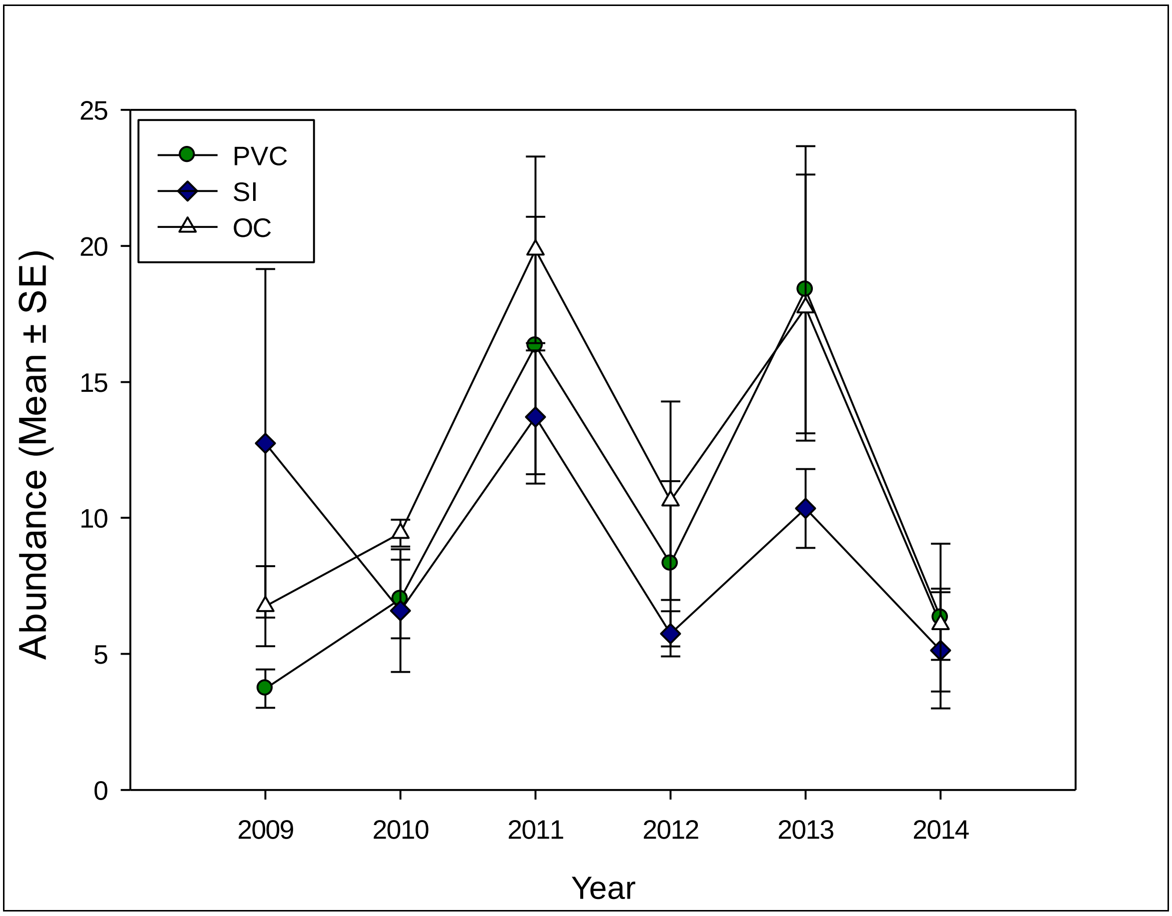

Figure 0.8 Abundance (mean min^{-1} ± SE) of mobile fauna (N) for each treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control) in 2009, 2010, 2011, 2012, 2013 and 2014.

3.2.3 Assemblage composition

The Assemblage composition of mobile fauna in the SI was generally following a similar trajectory to the PVC from 2009-2013; away from the OC. However in 2014 the assemblages appear to have altered trajectory and the SI assemblage was more similar to the OC than the PVC (Figure 3.9; Ye x Tr $P < 0.01$; Annex C, Table C2).

In 2009, all Treatments were significantly different from each other (all $P < 0.05$) and in 2011 and 2013, the Assemblage composition was significantly different in the PVC and the SI to the OC (both $P < 0.01$; Annex C, Table C2). However, in 2014 there are no significant differences between treatments for Assemblage composition.

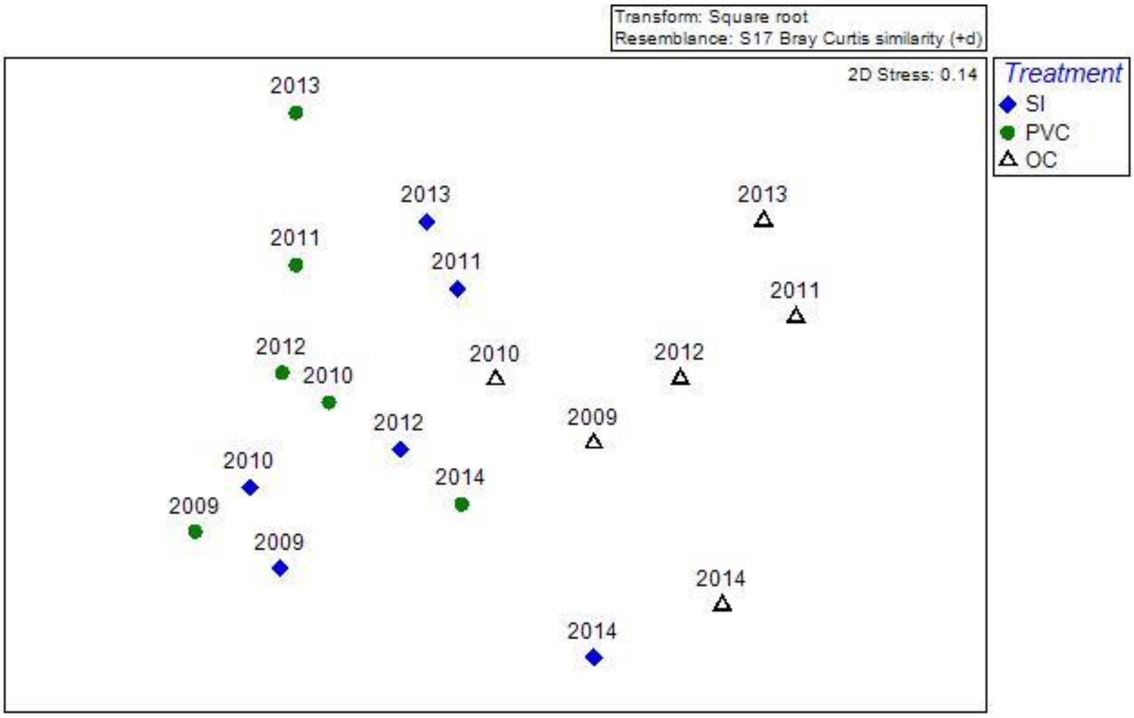

Figure 0.9 nMDS plot illustrating similarities in mobile fauna Assemblage composition between Treatments (averaged for site within treatment), (Pre-existing Voluntary Closure = green circles, Statutory Instrument = blue diamonds, Open Control = white triangles), over time (2009, 2010, 2011, 2012, 2013, 2014).

The results from SIMPER analysis show that in 2009 *Trisopterus minutus*, *Pagurus* spp., *Ophiura* spp. and Gobies contributed 50 % of the differences in assemblage between the OC and SI. There were more than twice the number of *T. minutus* in the SI than the OC, more than seven times the number of *Pagurus* spp. in the OC than the SI and one and a half times the number of Gobies in the SI compared to the OC.

In 2014; *Pagurus* spp., Gobies, *Trisopterus luscus,* Schooling fish and *Ophiura* spp. contributed to 50 % of the overall treatment dissimilarity. There were twice the number of *Pagurus* spp. in the OC compared to the SI in 2014, three times the abundance of *T. luscus* and one and a half times the number of Gobies in the SI compared to the OC.

3.3 Analysis of indicator species (SI analysis)

The indicator species' univariate analyses were based on data from one of the three video datasets, either video transect, frame grab or baited (as indicated by V= video, F = Frames or B = Baited). They are presented here in three categories (Jackson et al., 2008): Key species that were preselected by Defra, Sessile species, and Free-living species. For clarity and readability, full results of pairwise tests are given in Annex C, Table C3.

A range of trajectories of recovery were observed in indicator species from 2008-2013. As a result of the potential severity of the storms the following section will highlight the most recent changes from 2013-2014. All Key and Sessile indicators showed a decrease in abundance in the SI in 2013-2014 whilst four out of six Free-living indicators decreased and two increased.

3.3.1 Key Species

***Pecten maximus* – King scallop (V)**
Abundance of *Pecten maximus* increased by 289 % in the SI from 2008 to 2011 (mean Abundance 2008 = 0.26 m^{-2} ± 0.05, 2011 = 0.76 m^{-2} ± 0.21) (Figure 3.10). By 2011, *P. maximus* was significantly more abundant in the SI than the OC (P < 0.01). Abundance decreased in all treatments in 2014 (SI = 0.23 m^{-2} ± 0.02, PVC = 0.19 ± 0.06 and OC = 0.04 m^{-2} ± 0.01). Abundance in the SI remained significantly greater than the OC (P < 0.01; Ye x Tr P = 0.0001; Annex C, Table C3).

***Phallusia mammillata* – A sea squirt (V)**
Abundance of *Phallusia mammillata* decreased by 95 % from 2013-2014 in the SI (mean Abundance 2013 = 0.20 m^{-2} ± 0.10, 2014 = 0.01 m^{-2} ± 0.004) (Figure 3.10). Abundance in the SI was significantly greater than the OC from 2009-2013 (P < 0.05) but in 2014 only the Abundance in the PVC was significantly greater than the OC (P < 0.01). Abundance in the PVC also decreased from 2013-2014 but remained stable in the OC. (Ye x Tr P < 0.01; Annex C, Table C3).

***Cellepora pumicosa* – A sea mat (F)**
Abundance of *Cellepora pumicosa* decreased by 98 % in the SI from 2013-2014 (mean Abundance SI 2013 = 12.93 m^{-2} ± 4.00, 2014 = 0.30 m^{-2} ± 0.18) (Figure 3.10). Abundance in the PVC also decreased but remained steady in the OC. In 2014, Abundance in the SI was not significantly greater than in the OC (Ye x Tr P < 0.01; Annex C, Table C3).

***Pentapora foliacea* – Ross coral (V)**
Abundance of *Pentapora foliacea* in the SI steadily increased by 267 % from 2008-2011 (mean Abundance 2008 = 0.09 m^{-2} ± 0.02, 2011 = 0.33 m^{-2} ± 0.06), and decreased by 99 % from 2011-2014 (2014 = 0.002 m^{-2} ± 0.002) (Figure 3.10). Abundance was significantly greater in the PVC and SI compared to the OC from 2008-2013 (all P < 0.05; Ye x Tr P < 0.001). In 2014 the Abundance in the SI was not significantly greater than the OC but was significantly less than the PVC (P = 0.04; Annex C, Table C3).

Anemones (F)

Abundance of Anemones in the SI remained steady from 2008-2011 then increased in 2012, decreased in 2013 and decreased slightly again in 2014 (mean Abundance SI 2012 = 2.39 m^{-2} ± 1.70, 2013 = 0.21 m^{-2} ± 0.12, 2014 = 0.00 m^{-2}) (Figure 3.10). Abundance was significantly greater in the OC compared to the SI from 2010-2013 (all $P < 0.05$; Ye x Tr $P < 0.01$). There were no significant differences between treatments in 2014 (Annex C, Table C3).

Alcyonium digitatum **– Dead man's fingers (V)**

Abundance of *Alcyonium digitatum* increased tenfold in the SI from 2008-2010 (mean Abundance 2008 = 0.21 m^{-2} ± 0.07, 2010 = 2.27 m^{-2} ± 1.36), decreased in 2011 (1.13 m^{-2} ± 0.34), increased again in 2012 (2.63 m^{-2} ± 0.98) and decreased from 2012-2014 (2014 = 0.37 m^{-2} ± 0.15) (Figure 3.10). Abundance has not been significantly greater in the SI or PVC compared to the OC (Annex C, Table C3). This trend is confusing and during video analysis the anecdotal observation was made that *A. digitatum* in the OC tended to comprise small tufts, whereas large growths were observed in the SI and PVC. Unfortunately, the data does not differentiate between these categories. In future we would like to reanalyse this species to tease these two categories apart.

Eunicella verrucosa **– Pink sea fan (V)**

Abundance of *Eunicella verrucosa* increased by 311 % in the SI from 2008-2010 (mean Abundance 2008 = 0.18 m^{-2} ± 0.12, 2010 = 0.74 m^{-2} ± 0.44), decreased in 2011 (0.34 m^{-2} ± 0.22), increased again in 2012 (0.54 m^{-2} ± 0.32) and finally decreased 46 % from 2013-2014 (2013 = 0.50 m^{-2} ± 0.30, 2014 = 0.27 m^{-2} ± 0.19) (Figure 3.10). Abundance also decreased in the PVC from 2013-2014, by 52 % (2013 = 0.5 m^{-2} ± 0.37, 2014 = 0.24 m^{-2} ± 0.13). Abundance in the SI was only significantly greater than the OC in 2013 ($P < 0.05$; Annex C, Table C3).

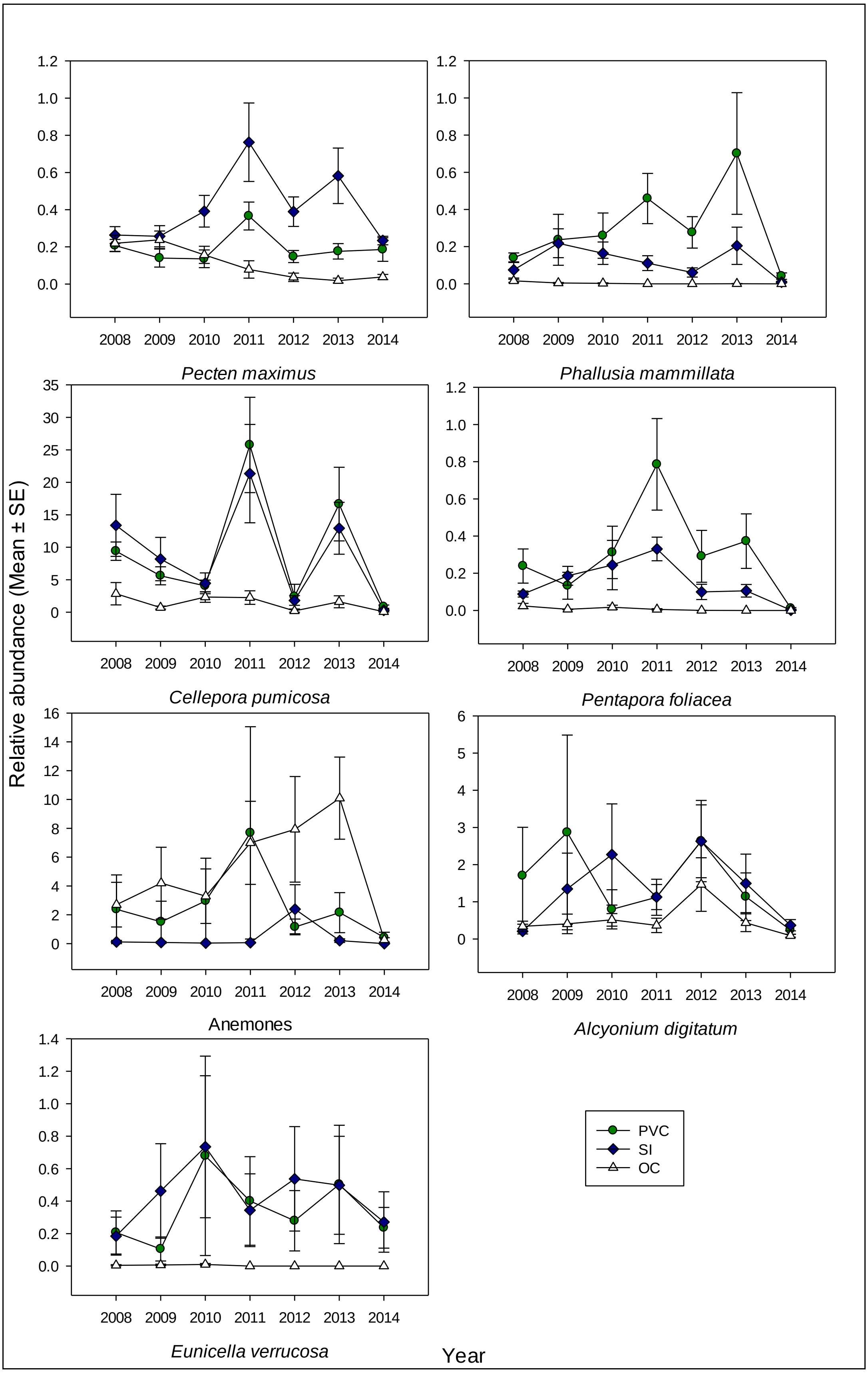

Figure 0.10 Abundance of key indicator species (mean m^{-2} ± SE) per treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control), per year (2008, 2009, 2010, 2011, 2012, 2013, 2014). Scales on the y-axes vary.

3.3.2 Sessile species

***Chaetopterus variopedatus* – Parchment worm (F)**

Abundance of *Chaetopterus variopedatus* in the SI was varied from 2008-2013 with a peak in abundance in 2011 (mean Abundance 2011 = 2.93 m^{-2} ± 1.35) and decreased from 2013-2014 (2013 = 1.01 m^{-2} ± 0.40, 2014 = 0.31 m^{-2} ± 0.26) (Figure 3.11). Abundance in the SI has not been significantly greater than the OC for *C. variopedatus* (Ye x Tr $P < 0.05$; Annex C, Table C3).

***Tethya citrina* – Golf ball sponge**

Abundance of *Tethya citrina* was too low to be interpreted or analysed.

Hydroids (F)

Abundance of Hydroids increased by almost 250 % in the SI from 2008-2011 (mean Abundance 2008 = 30.58 m^{-2} ± 8.25, 2011 = 106.65 m^{-2} ± 19.27), decreased in 2012 (2012 = 68.92 m^{-2} ± 12.49), increased by 183 % in 2013 and then decreased in 2014 (2013 = 195.18 m^{-2} ± 56.42, 2014 = 42.96 m^{-2} ± 7.56) (Figure 3.11). Abundance in the SI has not been significantly greater than the OC (Annex C, Table C3).

***Cliona celata* – Boring sponge**

Abundance of *Cliona celata* was too low to be interpreted or analysed.

Branching sponges (V)

Abundance of Branching sponges decreased in the SI from 2008 to 2009 (mean Abundance 2008 = 0.22 m^{-2} ± 0.10, 2009 = 0.03 m^{-2} ± 0.02), increased from 2009 to 2013 (2013 = 0.45 m^{-2} ± 0.13) and decreased from 2013 to 2014 (2014 = 0.09 m^{-2} ± 0.03) (Figure 3.11). Abundance in the SI has been significantly greater than the OC since 2012 (all $P < 0.05$; Ye x Tr $P < 0.001$; Annex C, Table C3).

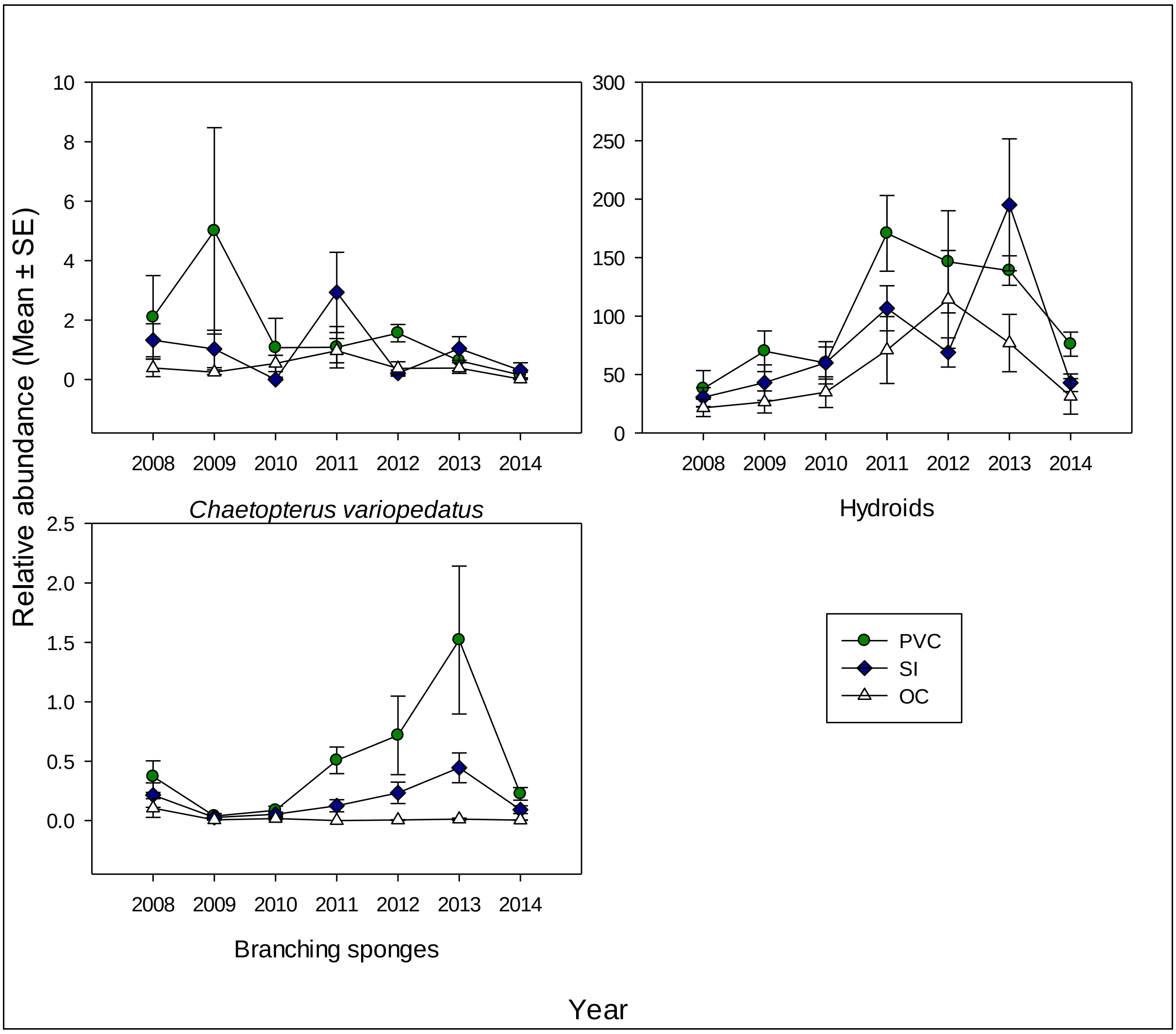

Figure 0.11 Abundance of Sessile indicator species (mean m^{-2} ± SE) per treatment (PVC = pre-existing voluntary closure, SI = Statutory Instrument, OC = Open Control), per year (2008, 2009, 2010, 2011, 2012, 2013, 2014) Scales on the y-axes vary.

3.3.3 Free-living species

***Asterias rubens* – Common starfish (V)**

Abundance of *Asterias rubens* increased by 135 % in the SI from 2008-2012 (mean Abundance 2008 = 0.14 m^{-2} ± 0.09, 2012 = 0.33 m^{-2} ± 0.13) but decreased by ~27 % from 2012-2014 (2014 = 0.24 m^{-2} ± 0.08) (Figure 3.12). Abundance increased by 110 % in the OC from 2013-2014 (2013 = 0.28 m^{-2} ± 0.09, 2014 = 0.59 m^{-2} ± 0.32). Abundance in the SI was significantly less than the OC in 2010 (Ye x Tr $P < 0.05$; Annex C, Table C3).

***Trisopterus minutus* – Poor cod (B)**

Abundance of *Trisopterus minutus* in the SI decreased by 90 % from 2009-2010 (mean Abundance 2009 = 9.45 min^{-1} ± 5.87, 2010 = 0.90 min^{-1} ± 0.56). Abundance remained steady from 2010-2012 (2012 = 0.54 min^{-1} ± 0.27), increased by 440 % from 2012-2013 (2013 = 2.94 min^{-1} ± 1.73) and decreased by 95 % from 2013-2014 (2014 = 0.13 min^{-1} ± 0.07) (Figure 3.12). Abundance was only significantly greater in the SI than the OC in 2011 ($P < 0.05$; Ye x Tr $P < 0.01$; Annex C, Table C3).

***Necora puber* – Velvet swimming crab (V)**

Abundance of *Necora puber* in the SI increased by 650 % from 2008-2010 (mean Abundance 2008 = 0.004 m^{-2} ± 0.003, 2010 = 0.03 m^{-2} ± 0.01), decreased by 83 % from 2010-2012 (2012 = 0.005 m^{-2} ± 0.003) and remained steady from 2012- 2014 (2012 = 0.005 m^{-2} ± 0.003, 2014 = 0.007 m^{-2} ± 0.002) (Figure 3.12). According to the pairwise analysis, abundance in the SI was not significantly greater than the OC in any year (Annex C, Table C3).

***Cancer pagurus* – Edible crab (V)**

Abundance of *Cancer pagurus* in the SI increased by 50 % from 2008-2010 (mean Abundance 2008 = 0.004 m^{-2} ± 0.003, 2010 = 0.006 m^{-2} ± 0.004), decreased from 2010-2013 (2013 = 0.00 m^{-2} ± 0.00) and has increased from 2013-2014 (2014 = 0.001 m^{-2} ± 0.001) relative to the OC (2013 and 2014 = 0.00 m^{-2}) (Figure 3.12). Abundance in the SI has not been significantly greater than in the OC (Annex C, Table C3).

***Ctenolabrus rupestris* – Goldsinny wrasse (B)**

Abundance of *Ctenolabrus rupestris* in the SI increased by 1383 % from 2009-2011 (mean Abundance 2009 = 0.06 min^{-1} ± 0.04, 2011 = 0.89 min^{-1} ± 0.31) and decreased 89 % in 2012 (mean Abundance 2012 = 0.09 min^{-1} ± 0.05). It increased once again in 2013 and decreased in 2014 (mean Abundance 2013 = 0.29 min^{-1} ± 0.23, 2014 = 0.02 min^{-1} ± 0.02) (Figure 3.12). Abundance in the SI was significantly greater than the OC in 2009 and 2014. In 2014 pairwise tests showed no significant differences between treatments (Annex C, Table C3).

Gobies (B)

Abundance of Gobies in the SI showed an overall decrease of 94 % from 2009 to 2013 (mean Abundance 2009 = 1.09 min^{-1} ± 0.51, 2013 = 0.07 min^{-1} ± 0.05) (Figure 3.12). Abundance increased by 743 % from 2013-2014 in the SI and PVC (SI 2014 = 0.59 min^{-1} ± 0.37, PVC 2013 = 0.09 min^{-1} ± 0.37, 2014 = 0.89 min^{-1} ± 0.41) relative to the OC (2013 = 0.28 min^{-1} ± 0.16, 2014= 0.24 min^{-1} ± 0.13). Pairwise tests showed no significant differences between treatments across all years (Annex C, Table C3).

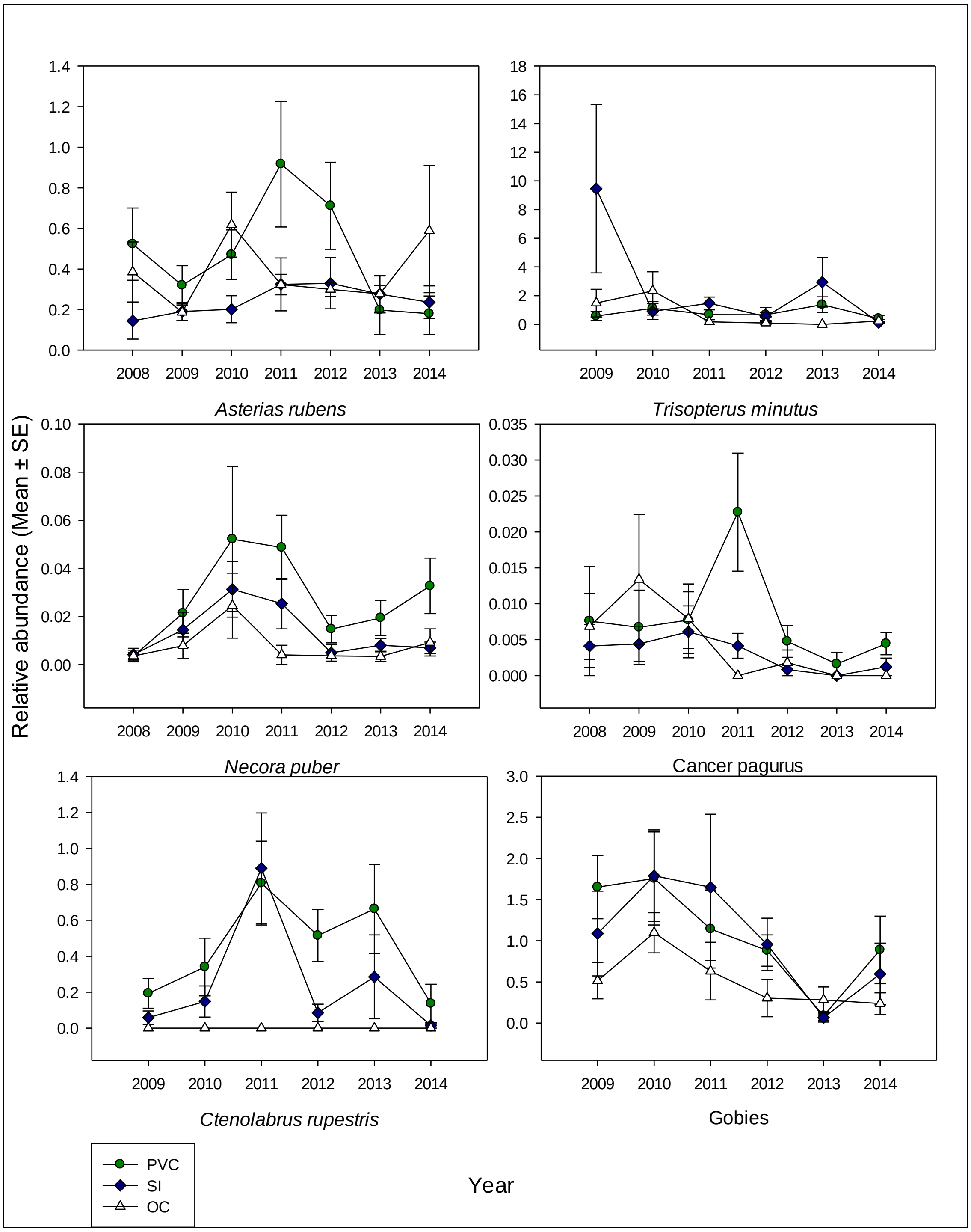

Figure 0.12 Abundance (mean m^{-2} / min^{-1} ± SE) of free living indicator species per treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control), per year (2008, 2009, 2010, 2011, 2012, 2013, 2014). Abundance of *A. rubens*, *N. puber* and *C. pagurus* presented as mean m^{-2}. Abundance of *T. minutus*, *C. rupestris* and Gobies presented as mean min^{-1}. Scales on the y-axes vary.

Sensitive Areas analysis

The data presented above consider the results for the SI, PVC and OC. The following analyses assess the results for the Sensitive Areas (SA) when compared with the PVC and OC.

3.4 Frame grab data (SA analysis)

3.4.1 Number of taxa

Average Number of taxa decreased in all treatments from 2011-2012 (mean Number of taxa SA 2011 = 18.40 m^{-2} ± 1.17, 2012 = 17.47 m^{-2} ± 1.26), increased from 2012-2013 (SA 2013 = 23.47) and decreased from 2013-2014 (SA 2014 = 13.80 m^{-2} ± 0.86). Number of taxa has been higher in the PVC than the SA and OC since 2011 (Figure 3.13). Number of taxa did not show a significant change over time in the SA compared to the control treatments (Annex C, Table C4).

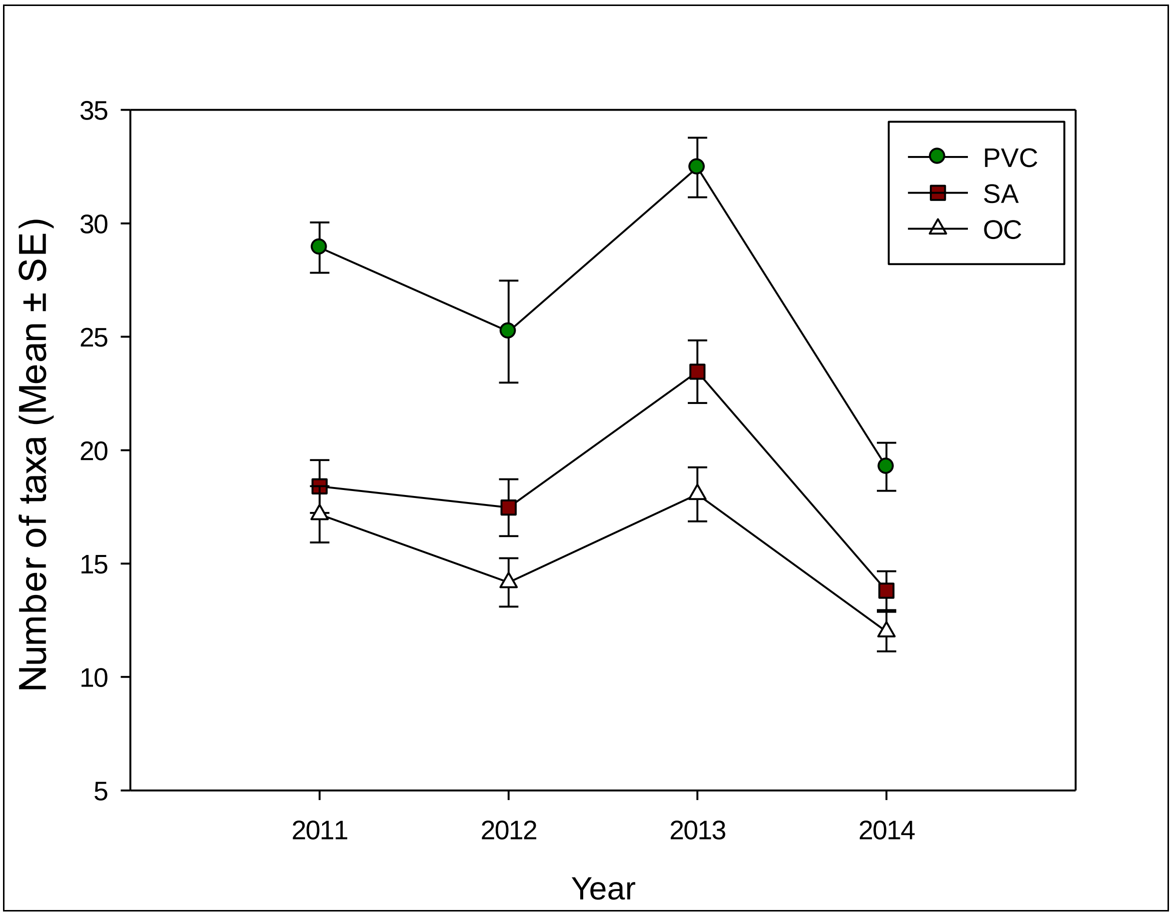

Figure 0.13 Number of taxa (mean m^{-2} ± SE) for each treatment (PVC = Pre-existing Voluntary Closure, SA = Sensitive Area, OC = Open Control) in 2011, 2012, 2013 and 2014.

3.4.2 Abundance

Abundance in the SA increased steadily from 2011-2013 (mean Abundance SA 2011 = 152.81 m^{-2} ± 16.22, 2013 = 209.63 m^{-2} ± 17.28) and decreased in all treatments from 2013-2014 (2014 = 70.45 m^{-2} ± 7.65) (Figure 3.14). Abundance has been greater in the PVC than the SA and OC from 2011-2014. Abundance did not show a significant change over time in the SA compared to the control treatments (Annex C, Table C4).

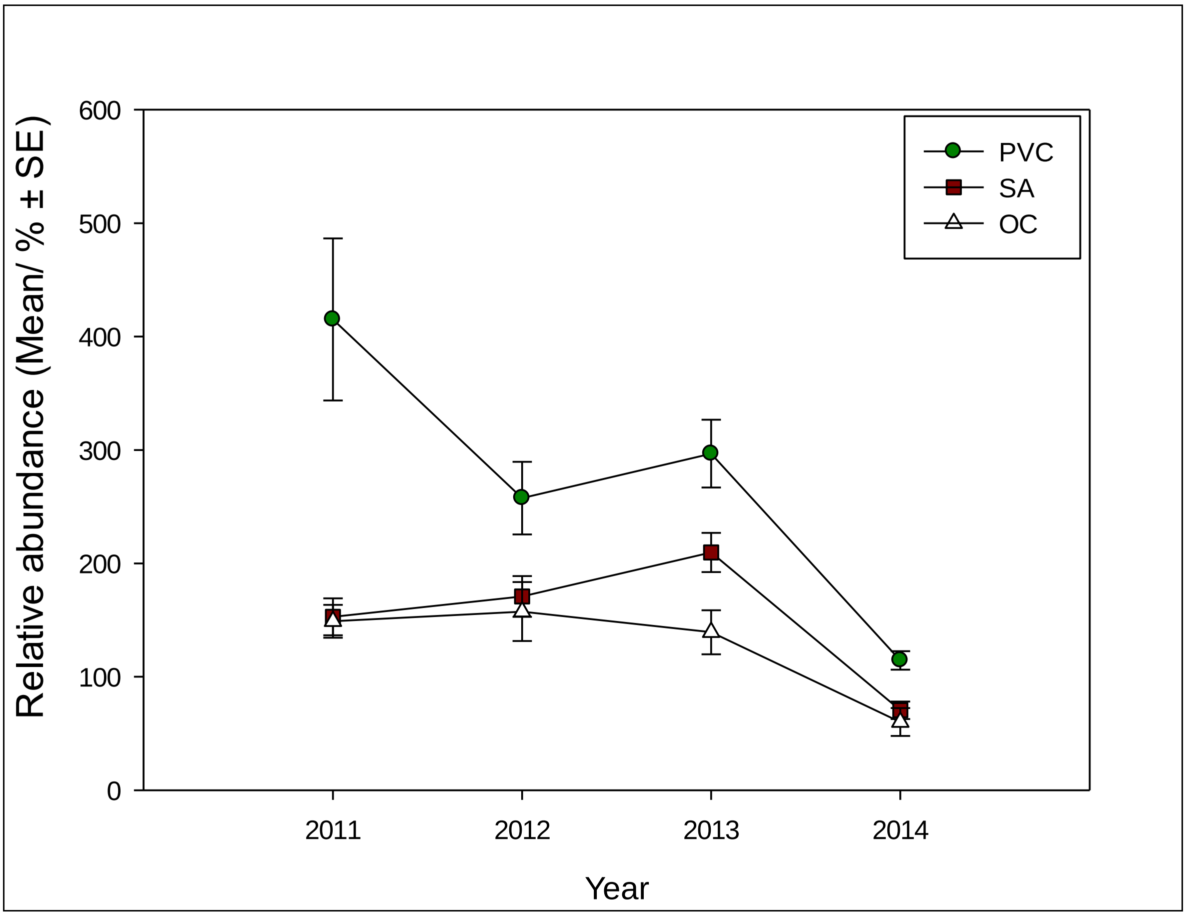

Figure 3.14 Abundance (mean m^{-2} and % ± SE) of fauna for each treatment (PVC = Pre-existing Voluntary Closure, SA = Sensitive Area, OC = Open Control) in 2011, 2012, 2013 and 2014.

3.4.3 Assemblage composition

In 2011 the SA assemblage was similar to the OC and both were different to the PVC ($P < 0.01$). In 2013 the SA assemblage diverged away from the OC ($P < 0.05$), and was showing a trajectory towards the PVC (Figure 3.15). In 2014 the trajectory of change for assemblage composition has altered for all three treatments but the assemblage in the SI in 2014 is more similar to the OC once again (Ye x Tr $P < 0.001$; Annex C, Table C4).

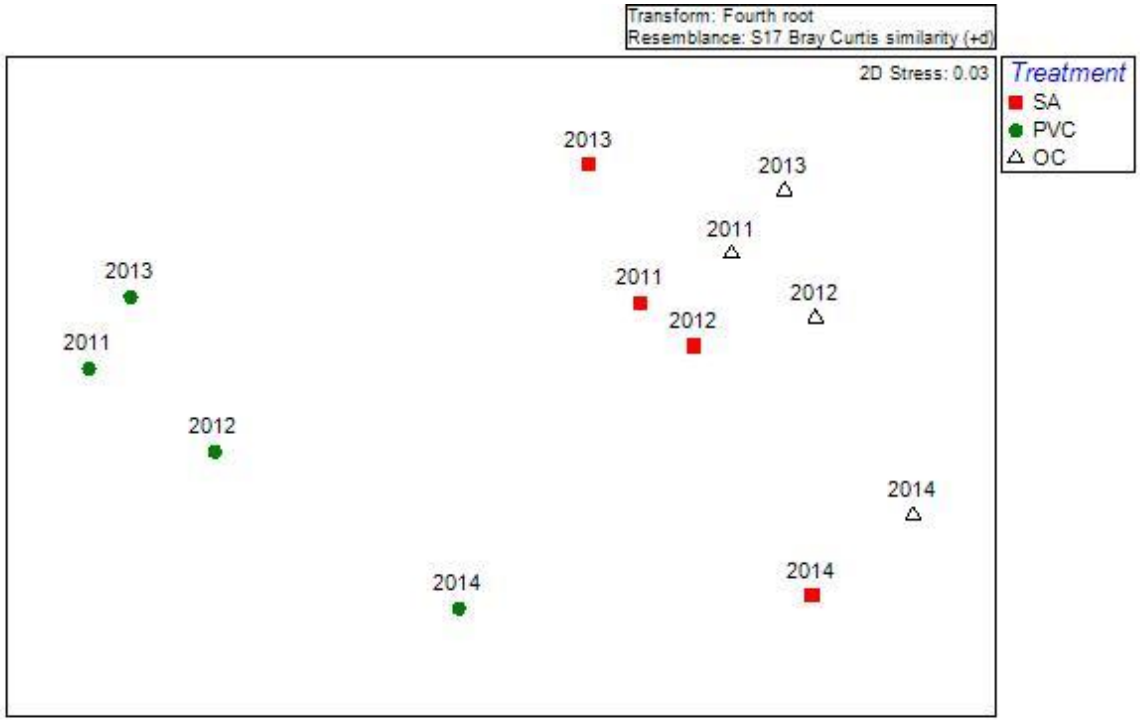

Figure 0.15 nMDS plot illustrating similarities in Assemblage composition between Treatments (averaged for site within treatment), (Pre-existing Voluntary Closure = green circles, Sensitive Area = red squares, Open Control = white triangles), over time (2011, 2012, 2013, 2014).

The results from SIMPER analysis show that in 2011 Hydroids, Turf, Anemones and *Psammechinus miliaris* contributed 20 % of the differences in assemblage between OC and SA. Hydroids and Turf had a greater abundance in the SA compared to the OC (1.5 % and 29 % greater abundance in SA respectively) whereas the abundance of Anemones and *P. miliaris* was greater in the OC (2 % and 48 % respectively). In 2014, Turf, *Ophiura* spp., Hydroids and *Asterias rubens* contributed 20 % of the dissimilarity between SA and OC sites. Turf and hydroids were still more abundant in the SA compared to the OC in 2014 (114 % and 12 % greater in the SA respectively). The difference in abundance between the SA and OC has therefore increased from 2011-2014 for Hydroids and Turf. *Ophiura* spp. and *A. rubens* were both more abundant in the OC compared to the SA (68 % and 15 % greater in the OC respectively).

3.5 Baited Remote Underwater Video data (SA analysis)

3.5.1 Number of taxa

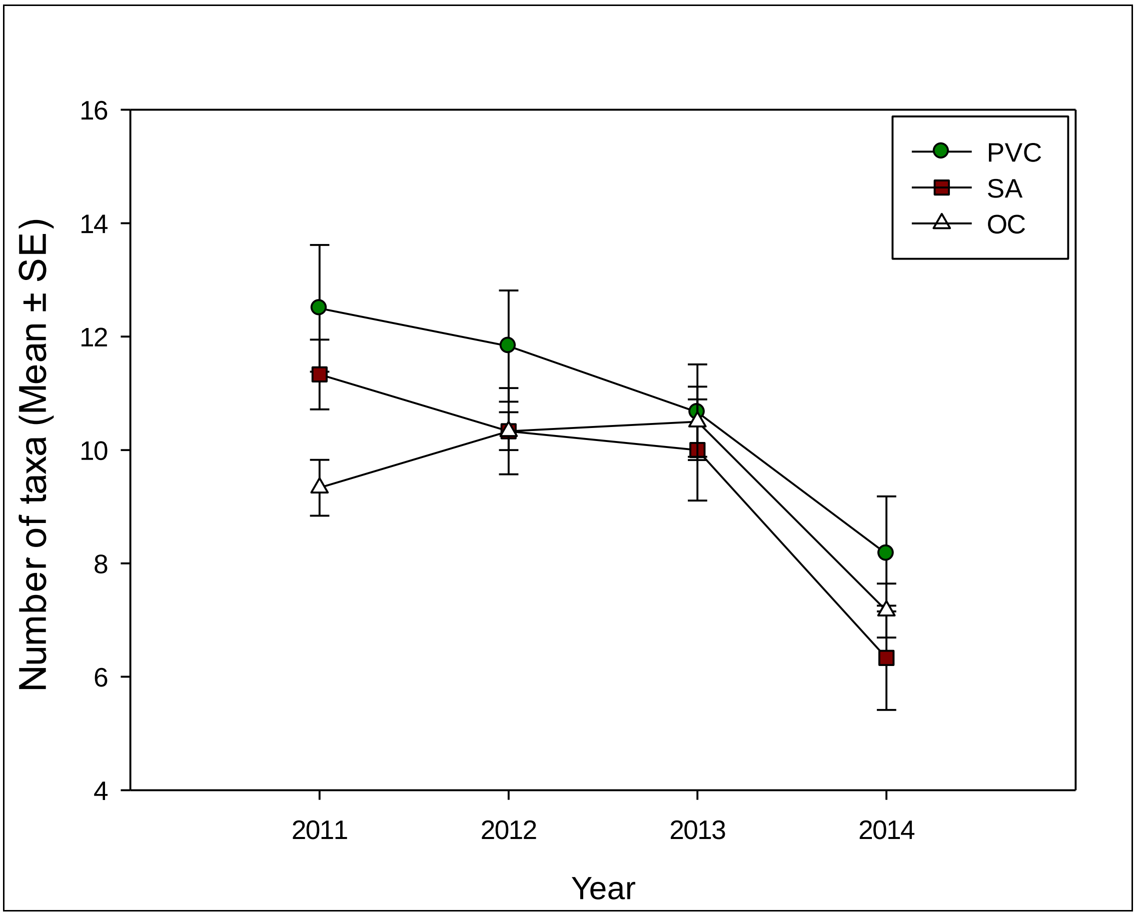

Figure 0.16 Number of taxa for mobile fauna (mean min^{-1} ± SE) for each treatment (PVC = Pre-existing Voluntary Closure, SA = Sensitive Area, OC = Open Control) in 2011, 2012, 2013 and 2014.

Average Number of taxa for mobile fauna has decreased overall from 2011-2014 in the SA (Average Number of taxa 2011 = 11.33 min^{-1} ± 0.62, 2014 = 6.33 min^{-1} ± 0.92) (Figure 3.16). Number of taxa in the OC increased steadily from 2011-2013 (2011 = 9.33 min^{-1} ± 0.49, 2013 = 10.50 min^{-1} ± 0.62) then decreased from 2013-2014 (2014 = 7.17 min^{-1} ± 0.48). Number of taxa did not show a significant change over time in the SA compared to the control treatments (Annex C, Table C5).

3.5.2 Abundance

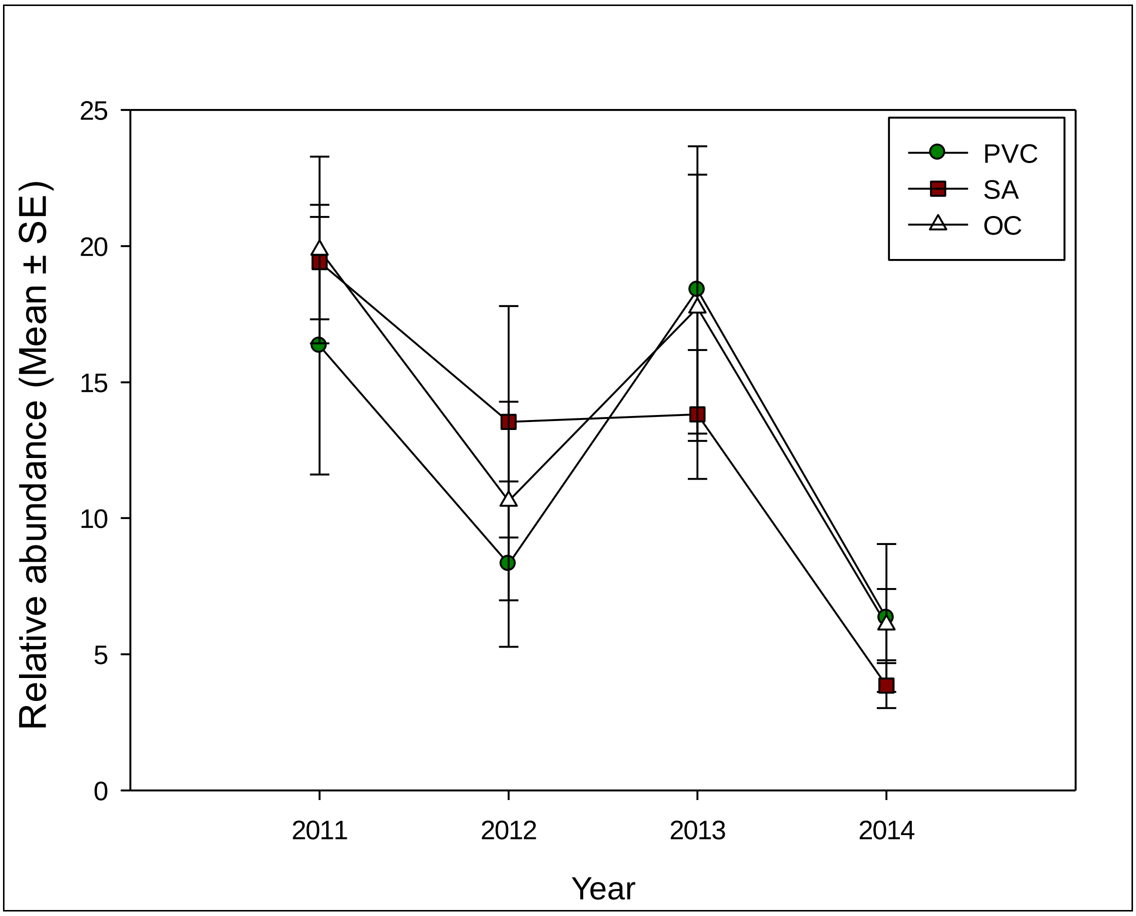

Figure 0.17 Abundance (mean min^{-1} ± SE) of mobile fauna (N) for each treatment (PVC = Pre-existing Voluntary Closure, SA = Sensitive Area, OC = Open Control) in 2011, 2012, 2013 and 2014.

Abundance of mobile fauna decreased by 80 % in the SA from 2011-2014 (Abundance 2011 = 19.42 min^{-1} ± 2.10, 2014 = 3.85 min^{-1} ± 0.83) (Figure 3.17). Abundance in the PVC and OC varied but decreased 61 % and 69 % respectively (PVC 2011 = 16.34 min^{-1} ± 4.73, 2014 = 6.33 min^{-1} ± 2.72, OC 2011 = 19.86 min^{-1} ± 3.43, 2014 = 6.09 min^{-1} ± 1.31). Abundance did not show a significant change over time in the SA compared to the control treatments (Annex C, Table C5).

3.5.3 Assemblage composition

From 2011-2012 the mobile fauna Assemblage composition in the SA was similar to the OC and different to the PVC (all $P < 0.01$). In 2014, the SA has followed the trajectory of the OC and the PVCs trajectory has changed following the storms to become more similar to the SA and OC, as illustrated in the nMDS plot (Figure 3.18; Annex C, Table C5).

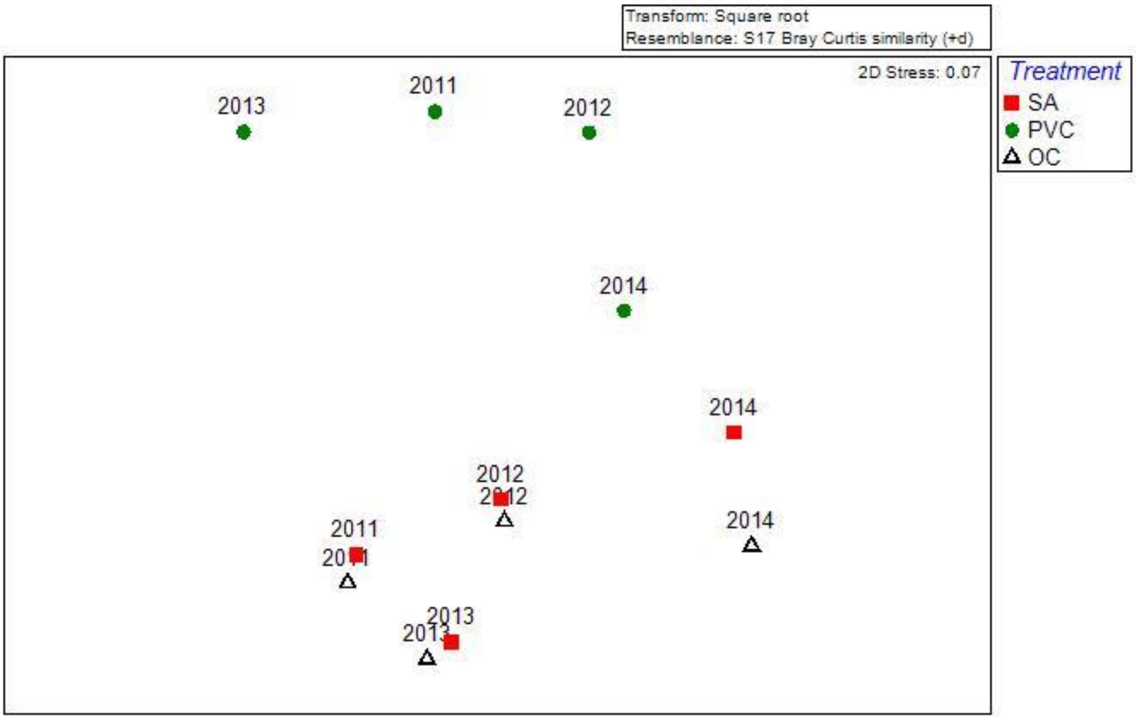

Figure 0.18 nMDS plot illustrating similarities in mobile fauna Assemblage composition between Treatments (averaged for site within treatment), (Pre-existing Voluntary Closure = green circles, Open Control = white triangles, Sensitive Area = red squares), over time (2009, 2010, 2011, 2012, 2013, 2014).

The results from SIMPER analysis show that in 2011 *Pagurus* spp. and *Inachus* spp. contributed 20% of the differences in assemblage between the OC and SA. Abundance of *Pagurus* spp. was 9 % greater in the OC compared to the SA and there were 9 % more *Inachus* spp. individuals in the SA compared to the OC. In 2014, *Pagurus* spp. and *Ophiura* spp. contributed 20% of the differences in assemblage between the OC and SA. The abundance of *Pagurus* spp. was 36 % greater in the OC compared to the SA in 2014 and there were 22 % more *Ophiura* spp. individuals in the SA compared to the OC.

3.6 Analysis of Indicator species (SA analysis)

The abundance of indicator species in the SA showed a similar variable pattern to the indicator species in the SI. As a result of the length of time since the protection of the SA, combined with the potential effects of the winter storms of 2013-2014, recovery was not observed in the abundance of indicator species in the SA. In the interest of brevity, the results from two key indicator species are shown to demonstrate the variable effects seen (Figure 3.19).

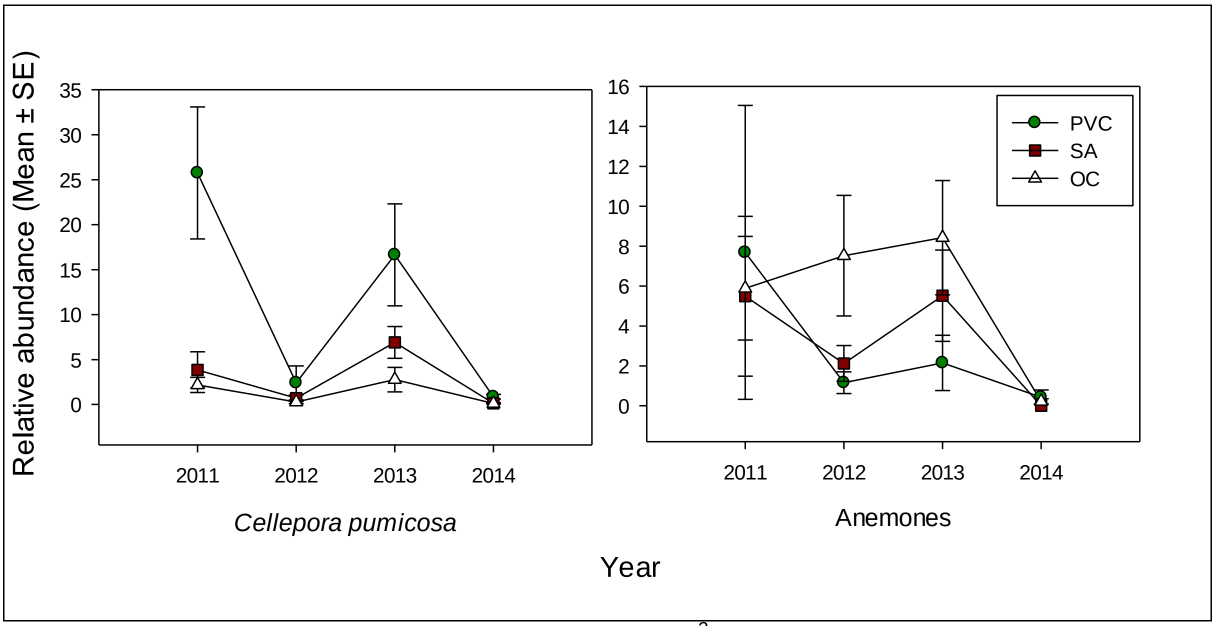

Figure 3.19 Abundance of indicator species (mean m^{-2} ± SE) per treatment (PVC = Pre-existing Voluntary Closure, SA = Sensitive Area, OC = Open Control), per year (2011, 2012, 2013, 2014). Scales on the y-axes vary.

4 Discussion

4.1 Summary of recovery 2008-2013

Early signs suggested that habitat forming, functionally important and commercially valuable species were beginning to recover in Lyme Bay (Sheehan et al., 2014).

4.4.1 Towed video survey

From 2008 to 2011 positive trends were observed for Number of taxa and Abundance in the SI and PVC relative to the Open Controls (OC). 2011 stood out as a particularly good year for the benthos however the abundance decreased in 2012. The abundance of count and cover organisms increased from 2012-2013 in both the Statutory Instrument (SI) and Pre-existing Voluntary Closure (PVC) relative to the OC. The Assemblage composition of SI and PVC sites also became less similar to OC sites, suggesting that the assemblages are still diverging.

The target species *Pecten maximus* showed a positive response to the closure, as did Hydroids. Other species which provide habitat complexity increased in abundance including the low recoverability species *Eunicella verrucosa*, which is listed as vulnerable on the IUCN red list (IUCN 2013) and is a UK BAP species. In addition, Branching sponges dramatically increased in the PVC (~400 %) and SI (~250 %) from 2008-2013 compared to fished controls where they have decreased in abundance in the same period.

4.4.2 Baited video

There was a significant Year x Treatment interaction for Number of taxa and Assemblage composition of mobile fauna from the baited video. Abundance increased in all treatments after a dip in 2012 but Number of taxa decreased from 2012-2013.

4.4.3 Indicator Species

Overall, in 2013 9 out of 16 indicator species increased in abundance in the SI relative to the OC. All of the sessile indicator species, *Chaetopterus variopedatus*, hydroids and branching sponges increased in the SI. The abundance of four taxa had their greatest abundances in 2013 including *Phallusia mammillata* which is considered to have a medium potential for recovery. A decrease in abundance of *P. foliacea* was seen in 2012 and no increase has been seen in 2013. A Year x Treatment interaction was found for this species though and abundance was greater in closed sites compared to the OC. This was encouraging for the recovery of closed sites as *P. foliacea* is a species with low recoverability and is functionally important as a bioconstructor (Cocito and Ferdeghini, 2001; McKinney and Jackson, 1989 in: Lombardi, 2007). The abundance increases in *P. mammillata*, Hydroids and Branching sponges were also promising as such species are known to improve survivorship of taxa such as juvenile fish through the provision of a structurally complex habitat (Bradshaw et al., 2003).

A positive response towards recovery of king scallop *P. maximus* populations in the SI had been apparent since 2009, with an increase in abundance apparent until 2011. A decrease in abundance in 2012 caused concern for the recovery of the population but the abundance increased in the SI for 2013 whilst the PVC and OC continued to decline.

A significant Year x Treatment trend was found for *Trisopterus minutus* and abundance was found to be greater in the SI than the PVC and OC; however SI and OC were not significantly different so this species was not quite showing a positive response towards recovery. Abundance of *Ctenolabrus rupestris* increased in closed treatments in 2013 but a Year x Treatment interaction was not found. These increases could be attributed to increased survivorship of juvenile fishes as a result of the increased provision of structurally complex habitats as sessile species recover (Bradshaw et al., 2003).

The abundance of Anemones (*Aiptasia mutabilis*, *Cerianthus* spp. and *Peachia cylindrica*) decreased in the SI in 2013 but continued to increase in the OC. In 2013 it was noted that high abundances of *Cerianthus* spp. were present in the OC sites on the west of the bay on habitats that looked less disturbed than in previous years.

There was still considerable variation in the results for indicator species. For example, a Year x Treatment interaction was identified in 2012 for *Cellepora pumicosa*, but this trend was not apparent in 2013, although abundance in the SI and PVC sites increased relative to the control.

4.2 Sensitive Areas

The 2013 results show that assemblage composition within sites in the SA was significantly different to PVC and OC sites for the first time since 2011. This suggests that after two years the protection has allowed the assemblage to diverge away from the OC sites. It is expected that over time the SA sites will become more similar to the PVC and less similar to the OC which continues to be fished. The taxa which contributed the most towards the differences between the OC and SA in 2013 were Hydroids, *Ophiura* spp*., Serpula vermicularis, Alcyonidium diaphanum* and Anemones.

For the assemblage of mobile taxa recorded using baited video, there was no indication of recovery for SA sites. In all three years SA sites were more similar to OC sites and less similar to PVC sites.

4.3 Post 2013-2014 winter storm

The 2014 sampling season marked the seventh benthic survey since the SI came into force in 2008. This annual summer monitoring of benthic assemblages and reef associated nekton has provided the first large scale recovery data set for temperate reef assemblages in the UK that is a valuable resource for the future monitoring of national, European and international habitats.

Early signs suggested that habitat forming, functionally important and commercially valuable species were beginning to recover in Lyme Bay, however this year we have seen a considerable number of negative changes which could be attributed to the 2013-2014 winter storms. On a positive note, the impacts of the winter storms now provide an unprecedented opportunity to assess the resilience of UK MPAs to discrete extreme storm events, which are set to increase under most climate change scenarios. By continuing the annual monitoring, Lyme Bay could provide a case study to compare the recovery of benthic habitats from fishing disturbance compared to the recovery from extreme climatic events. We therefore strongly recommend the continuation of the current conservation measures to protect the assemblages within the SI and cSAC in Lyme Bay.

4.4 Towed video survey

From 2008 to 2011 there were fluctuations in Number of taxa and Abundance which showed an overall positive trend in the Statutory Instrument (SI) and Pre-existing Voluntary Closure (PVC) relative to the Open Controls (OC). 2011 stood out as a particularly good year for the benthos however the Abundance decreased in all treatments from 2013-2014.

The reduction in response variables in 2012 was attributed to the extremely poor weather experienced that year, including an increased average rainfall in June and July (Met Office, 2012) and strong westerly winds that were responsible for bad visibility (Langmead et al., 2010). This poor visibility possibly resulted in reduced quality images which might have affected our ability to observe benthic fauna from the video. However, temporal variability within marine reserves has been recorded previously (e.g. Francour, 1994, see review by García-Charton & Pérez-Ruzafa, 1998). It is thought that this variability may exist partly because prevailing conditions affect ecological processes (Sæther, 1997) and therefore population dynamics are influenced by climate (McCarty, 2001; Stenseth et al., 2002; Walther et al., 2002). The temporal variability in these Lyme Bay data may therefore be explained by the variable weather experienced from 2011, though recruitment and other ecosystem processes are also temporally variable (Sale et al., 1984; Shugart & Urban, 1988). The reduction in metrics for 2014 is most likely to be a result of the series of severe storms experienced by the south west UK in the winter of 2013-2014.

During January and February 2014, storm tracks fell at relatively low latitude, resulting in severe gales along the south and west coasts of the UK and pushing the majority of the resulting wave energy toward the south west of Ireland and England. Peak wave periods were exceptionally long; each wave carried a considerable amount of energy and was able to inflict significant damage (Met Office and Centre for Ecology & Hydrology – CEH, 2014). Chesil beach in Lyme Bay experienced three storms considered to have a return period of 1 in 50 years, the most of any location on the south coast between January and February 2014 (Bradbury & Mason, 2014).

In addition, recent studies suggest that an increase in the intensity of these Atlantic storms that take a more southerly track is expected (Met Office and Centre for Ecology & Hydrology – CEH, 2014) suggesting it is imperative that Marine Protected Areas (MPAs) in the south west in particular should be monitored at regular intervals to assess changes attributable to fishing and weather regimes.

While Abundance and Number of taxa do not show trends of recovery since the fishing cessation in 2014, the Assemblage composition of SI and PVC sites is still significantly different to OC sites as it has been since 2009, suggesting that the protected sites had some resilience to the storms. Recovery of ecosystems from natural disturbances has been found to be faster than recovery from anthropogenic disturbances (Jones & Schmitz, 2009). It is now imperative to continue monitoring the reefs in Lyme Bay to determine whether these assemblages can recover from the storms more quickly than they showed signs of recovery from the long term effects of fishing.

Two species which provide habitat complexity have increased in Abundance overall since 2008, including the low recoverability species *Eunicella verrucosa*, which is listed as vulnerable on the IUCN red list (IUCN, 2013) and is a UK BAP species. In addition, Hydroids have increased overall in the PVC and SI from 2008-2014 compared to fished controls. There is hope that recovery of the benthos from the storms can be achieved and that it might be at a faster rate than the rate of recovery observed from long term fishing impacts.

The taxa which contributed most towards the differences in assemblage between the SI and OC in 2014 were Turf, *Pagurus* spp. and *Ophiura* spp*.* In the SI in 2014 there was four times the abundance of Turf compared to the OC, perhaps suggesting the stabilisation of cobbles and boulders but the ratio of *Pagurus* spp. remained relatively unchanged supporting the theory that on some habitats scavenging species are more abundant in areas of fishing disturbance (Ramsay et al., 1998).

4.5 Baited video

The baited video data comprise six years of surveys, 2009-2014. Number of taxa and Abundance were varied from 2009-2013 but show decreases from 2013-2014, probably due to the storms. The 2014 baited results, therefore, still do not conform to the theory that disturbed systems are often typified by high abundance and low species diversity compared to un-disturbed sites (Kaiser et al., 2000; Halpern, 2003; Hixon, 2007). The trajectory of change towards recovery seen in mobile fauna Assemblage composition from 2009-2013 has probably been altered in 2014 by the severe storms. It is hoped that the assemblages will revert back to their trend toward recovery in 2015, post storms.

4.6 Indicator Species

Indicator species were selected to be representative of the range of species with differing biological traits present in Lyme Bay, and their recoverability (low, medium or high) was determined (Jackson et al., 2008). These indicator species have been used throughout the study to aid the explanation of the results provided by the towed and baited video and for comparison between these results and studies published in the literature (Langmead et al., 2010).

In 2014, two of 16 indicator species increased in abundance in the SI relative to the OC; Gobies and *Cancer pagurus.* The overall trends for 2008-2014 show that two taxa have increased in abundance in the SI relative to the OC since 2008; *Eunicella verrucosa* and Hydroids, but this is not yet supported by a significant Year x Treatment interaction.

Abundance of *P. foliacea* in the SI decreased by 98 % from 2013-2014 and notably fewer colonies were seen during the survey overall probably due to the storms. A larger decrease in abundance was seen from 2011-2012 after another storm event. Populations of *P. foliacea* therefore potentially only had one year to recover before the larger storm events of winter 2013-2014. It remains to be seen if 2011 was just a particularly good year for the benthos or if the 2012 storms were to blame for the initial decrease. Mortality in *Pentapora* spp. due to severe winter storms was previously documented by Cocito et al. (1998) in the Mediterranean. A 1 in 100 year storm in 1993 with a maximum wave height of 5 m caused all but one colony to be swept away at one site. The storm mortality was not size selective and partial mortality or necrosis due to epibiosis or siltation was also recorded (Cocito et al., 1998). The maximum wave height recorded during the 2013-2014 storms in Lyme Bay was 7.2 m (Southwest Regional Coastal Monitoring Programme for wave height data). These trends are worrying for the recovery of closed sites as *P. foliacea* is a species with low recoverability and is functionally important as a bioconstructor which plays a key role in the formation of biogenic reef (Cocito & Ferdeghini, 2001; McKinney & Jackson, 1989 in: Lombardi, 2007). The Abundance decreases in 2014 in *Phallusia mammillata* and Branching sponges are also of concern as such species are known to improve survivorship of taxa such as juvenile fish through the provision of a structurally complex habitat (Bradshaw et al., 2003). A previous abundance decrease in *P. mammillata* was seen in 2012 potentially due to the smaller storm but Branching sponges increased suggesting that they were possibly more resilient to a smaller storm. Continuation of the annual survey may enable the disentanglement of the effect of storms compared to temporal variation.

The positive response of scavenger species *Asterias rubens, Necora puber, Cancer pagurus* and Gobies is in line with previous disturbance studies including Ramsey et al. (1998) who found that in some assemblages, scavengers increased in response to demersal fishing disturbance.

A positive response of king scallop *P. maximus* populations in the SI was apparent from 2009, with an increase in Abundance apparent until 2011. The Abundance from 2011-2013 was variable until 2014 when the Abundance of *P. maximus* in the SI decreased. The Abundance in the PVC and OC increased marginally, however despite the storms the Abundance of *P. maximus* remains greater in the SI and PVC compared to the OC. This is partially in line with the expectation from the literature as similar studies such as Stokesbury et al. (2004), who identified a greater abundance of scallops within areas closed to mobile fishing gear in the north-east American *Placopecten magellanicus* population.

The Abundance of Anemones (*Aiptasia mutabilis*, *Cerianthus* spp. and *Peachia cylindrica*) decreased in all treatments in 2014. A larger decrease was previously seen from 2011-2012 in the PVC whilst the protected treatments increased. It was thought that *Cerianthus* spp. were likely driving the higher Abundance in the OC compared to the PVC and SI in 2013 as these are associated with soft sediment habitats, and were therefore recorded in areas of cobble and boulder habitat with exposed sediment patches. In addition, in 2013 it was noted that high Abundances of *Cerianthus* spp. were present in the OC sites on the west of the bay on habitats that looked less disturbed than in previous years. It is likely that the 2013-2014 winter storm has disturbed these habitats again and therefore resulted in a decrease in the Abundance of Anemones. As these sediments stabilise again after the storms it will be interesting to note the difference in recovery rate compared to the recovery seen after the cessation of fishing before the storms. It is also interesting that in 2011 the abundance decrease was only seen in the PVC whereas in 2014 the largest decrease was seen in the OC. It remains unclear why A nemones in the SI have shown a downward trend since 2012.

Abundance of Biodiversity Action Plan species *E. verrucosa* decreased in closed treatments in 2014, perhaps due to the storms but there was also an unexplained decrease in Abundance in closed areas between 2010 and 2011. Abundance was significantly greater in the PVC than the OC in 2014 and greater in the SI than the OC, but not significantly so. However, Abundance in the closed sites is greater than it was in 2008 at the start of the survey despite the storms, suggesting a positive response overall. Gorgonians such as *E. verrucosa* have been shown to demonstrate complete detachment as a result of storms like *P. foliacea* (Woodley et al., 1981; Cocito et al., 1998) but are possibly more robust to the effects of storms as they can also withstand complete detachment but sustain abrasion and tearing of the tissue or skeleton (Woodley et al., 1981). Eno et al., (2001) observed *E. verrucosa* bending under the weight of crustacean pots and springing back whereas sponges, and ascidians demonstrated detachment whilst *P. foliacea* showed partial damage. Hydroids have increased overall in the PVC and SI from 2008-2014 compared to fished controls. *E. verrucosa* and Hydroids are now the only taxa showing a positive response towards to the closure (defined as; abundance increasing in the SI relative to controls). However Hydroids have an important ecosystem function as an increase in the abundance of hydroids in the Isle of Man scallop fishery closure was linked with an increase in habitat complexity and enhanced scallop stocks (Bradshaw et al., 2003).

There is still considerable variation in the recovery of indicator species from human disturbance, highlighting the need for continued annual monitoring particularly in the light of the storms as their recovery from a natural disturbance can be compared to their recovery since the cessation of fishing.

4.7 Sensitive Areas

The Abundance and Number of taxa within sites in the SA do not show signs of recovery after three years protection. The 2013 results showed that Assemblage composition within sites in the SA was significantly different to PVC and OC sites for the first time since 2011. This suggested that after two years, the protection afforded by the cSAC had allowed the assemblage to diverge away from the OC sites. However, following the storms in 2014 the Assemblage composition in the sites within the SA was not significantly different to the OC.

It is expected that over time the SA sites will become more similar to the PVC and less similar to the OC which continues to be fished. The taxa which contributed the most towards the differences between the OC and SA in 2014 were Turf, *Ophiura* spp., Hydroids and *Asterias rubens*. Habitat complexity forming taxa Hydroids and Turf were both more abundant in the SA compared to the OC and in 2014 compared to 2011 (Bradshaw et al., 2003).

For the Number of taxa and Abundance of mobile fauna recorded using baited video, there was no indication of recovery for SA sites. In addition, there was no indication of recovery for Assemblage composition in SA sites. In all four years, SA sites were more similar to OC sites and less similar to PVC sites. The impact of the protection afforded by the cSAC on mobile taxa therefore remains to be seen. The taxa which contributed the most towards the differences in mobile taxa assemblage between the OC and SA in 2014 were *Pagurus* spp.

and *Ophiura* spp. *Pagurus* spp. were more abundant in the OC whereas *Ophiura* spp. were more abundant in the SA. Both are scavenging species which suggests that both assemblages are still affected by the disturbance caused by fishing and storms.

5 Further notes of interest

In 2011 a large population of the sea cucumber *Ocnus planci* was apparent. Individuals were seen in large numbers again in 2013, in the east of the SI and PVC and the west of the SI. In 2014 individuals were not seen in the PVC but on the east and west of the SI. It was previously thought that these individuals were *Cucumaria frondosa,* but physical samples of this species have since been examined and it is now thought that it is likely these are large populations of *O. planci,* a species less common in the UK. *O. planci* is known to occur in large populations and has previously been misidentified as *Aslia lefeverei* (McKenzie, 1991). This discovery highlights the benefits of the towed array method, cost-effectively surveying large areas of benthic habitat.

In 2012 a large increase in the numbers of brittlestars *Ophiothrix fragilis* was observed. In 2013 and 2014 high numbers of brittlestars *O. fragilis* were observed once again in a PVC area to the west and to the east of the SI. *O. fragilis* was not included in the analysis for towed video data due our inability to identify rocky reef habitat as a result of their presence. This phenomenon of extreme population density fluctuations has previously been observed in many species of echinoderm, which could be attributed to their broadcast spawning and planktotrophic larval life history. The combination of these traits can result in positive feedback loops that can lead to rapid population increase once an 'outbreak' cycle has been initiated (Uthicke et al., 2009). It is possible that these two particular areas to the east and west of the bay are a larval sink, resulting in population increases.

A towed video survey to assess the damage caused by the storms on the benthos in Lyme Bay was completed in April 2014, immediately after the winter of 2013-2014 storms.

The six years of annual surveys from 2008-2013 provide the 'Before storm' data and the survey methods used for this study were replicated in April to provide the 'After storm' data. These results are due to be submitted as a paper imminently and these data are not included in this report. The effect of the storms will be discussed in more detail and reveal whether the Marine Protected Area (MPA) assemblages are more resilient to the storms due to their protection from the most damaging human pressures since 2008. Further monitoring of Lyme Bay is imperative to assess the rate of recovery of the benthos from storm damage and put this into context of recovery from fishing damage. These data will also inform discussions regarding the resilience of MPAs in an increasingly stormy south west.

6 Conclusions and Considerations

This study aimed to assess the recovery of Lyme Bay reefs following the cessation of towed demersal fishing gear within the SI. This report has provided the results from the baseline survey and six years post closure. It was understood from the outset that a short term study would not be sufficient to see the re-establishment of most species in the SI due to their life history traits, and the addition of a sixth year of sampling has shown that whilst some indicator species are showing positive responses towards recovery, variation within the results demonstrate that it is still too early for firm conclusions to be drawn. In addition, the effects of a natural disturbance regime have been seen in the context of a seven year study.

Previous studies have shown that the speed of recovery of assemblages in Marine Protected Areas (MPA) varies. For some species, such as those previously targeted by fisheries, those undergoing rapid recovery or those subject to other trophic and structural changes can take in excess of 25 years (Ballantine & Langlois, 2008; Hoskin et al., 2011). It is therefore, anticipated that recovery in the Lyme Bay system will take time.

As of June 2014, the PVC sites had been protected for between eight to 13 years and SI sites for six years. This report considers it reasonable to assume that both treatments are still in the early stages of a recovery scenario. Differing degrees of change have been identified across the SI. Some species are exhibiting recovery trends since the cessation of bottom towed fishing gear however there is still too much variance among other species to conclude that an overall trend towards recovery is evident. On the other hand, the Assemblage composition of SI and PVC sites is still significantly different to OC sites as it has been since 2009 suggesting that the protected sites had some resilience to the storms

There is a paucity of quantitative comparable studies with which to compare the results of this study or make predictions regarding the likely recovery of epibenthic assemblages in the bay (Langmead et al., 2010). To date, the majority of the literature has focussed on tropical latitudes as MPAs were first established in these regions. The continuation of the Lyme Bay monitoring is therefore of importance, not only to quantify patterns and rates of recovery in a priority UK habitat, but also to add to the global body of knowledge relating to temperate reef systems and their recovery from physical disturbance.

The Lyme Bay annual data and subsequent publications (Sheehan et al., 2013 b) could prove a valuable resource that managers can draw on to make informed decisions for the management of new Special Areas of Conservation and Marine Conservation Zones.

The observation that areas appearing to be soft sediment can support a range of reef species, between the reefs is also of importance for the understanding of temperate systems and for future management (Sheehan et al., 2013 a).

In 2013 after two years, the protection afforded by the cSAC to the sites in Sensitive Areas (SA), allowed the assemblage to diverge away from the OC sites. However the 2014 data appears to have been affected by the severe storms. It is expected that over time the SA sites will become more similar to the PVC and less similar to the OC, which continue to be fished by bottom towed gear. Ideally these sites will continue to be monitored in order to assess the level of recovery within the sites selected for protection within Lyme Bay.

It is hoped that annual sampling of the benthos in Lyme Bay will continue with a view to establishing conclusive signs of recovery in the SI for key indicator species within the ecosystem, to determine whether the early recovery identified to date is more than a short term phenomenon and to determine whether the rate of recovery from natural disturbance is faster than fishing impact recovery.

7 Acknowledgments

We are grateful to all those who assisted in the preparation, research and collation of this piece of work or in supporting the research. In particular we would like to thank the following:

- Natural England for funding the project and support.
- DEFRA for funding previous annual surveys
- John Walker for building the sled used in the baited video, for housing our kit in times of need, for helping to develop suitable methods to deploy and retrieve the field work kit, often in challenging conditions, and most of all for sharing his immense knowledge of Lyme Bay history and natural history, which helped us identify suitable sites in a large bay with considerable habitat variation.
- Kieran Perree, skipper of Miss Pattie, for allowing us the use of his boat, sharing his local knowledge and his patience during challenging field work.
- SWRDA for funding for the HD flying array.
- 3dive John Hawker for designing the software to extract frame grabs from HD video and Cybertronix for their continued support with the frame extractor.
- All the students and volunteers who helped with the data collection.
- Harry in Lyme Regis for providing storage of mackerel bait, and the fish shop in Axminster.
- Moby Nicks for providing mackerel bait.
- Dr. Keith Hiscock, Dr. Eve Southward and Bryan Wasson for their help with species identification.

8 Disclaimer

Photoshop was used to finalise the composition of images for presentation purposes in the report only. Image processing was basic and included auto colour curve correction and sharpening.

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10 Annexes

A. Survey design

Table A1 Sites surveyed within Areas per year for SI and SA analysis

	2008	2009	2010	2011	2012	2013	2014
SI analysis							
OC1	22, 23	22, 23	22, 23	22, 23, 116	22, 23, 116	22, 23, 116	22, 23, 116
OC2	24, 25	24, 25	24, 25	24, 25, 115	24, 25, 115	24, 25, 115	24, 25, 115
OC3	60, 61, 62	60, 61, 62	60, 61, 62	130, 131, 132	130, 131, 132	130, 131, 132	130, 131, 132
OC4	8, 9, 10	8, 9, 10	8, 9, 10	120, 121, 122	120, 121, 122	120, 121, 122	120, 121, 122
OC5	71, 72	71, 72	71, 72	70, 106, 107	70, 106, 107	70, 106, 107	70, 106, 107
PVC1	63, 64, 65	63, 64, 65	63, 64, 65	63, 64, 65	63, 64, 65	63, 64, 65	63, 64, 65
PVC2				59, 67, 119	59, 67	59, 67, 119	59, 67, 119
PVC3	14, 15	14, 15	14, 15	14, 15, 118	14, 15	14, 15, 118	14, 15, 118
PVC4	33, 49, 50	33, 49, 50	33, 49, 50	33, 49, 50	33, 49, 50	33, 49, 50	33, 49, 50
PVC5	43, 48, 77	43, 48, 77	43, 48, 77	43, 48, 77	43, 48, 77	43, 48, 77	43, 48, 77
SI1	7, 16	7, 16	7, 16	7, 16, 102	7, 16, 102	7, 16, 102	7, 16, 102
SI2	39, 40, 58	39, 40, 58	39, 40, 58	39, 103, 104	39, 103, 104	39, 103, 104	39, 103, 104
SI3	5, 41, 44	5, 41, 44	5, 41, 44	5, 41, 44	5, 41, 44	5, 41, 44	5, 41, 44
SI4	54, 55, 56	54, 55, 56	54, 55, 56	54, 55, 56	54, 55, 56	54, 55, 56	54, 55, 56
SI5	47, 57	47, 57	47, 57	47, 57, 105	47, 57, 105	47, 57, 105	47, 57, 105
SI6	19, 20	19, 20	19, 20	19, 20, 101	19, 20, 101	19, 20, 101	19, 20, 101
SA analysis							
OC1				22, 23, 116	22, 23, 116	22, 23, 116	22, 23, 116
OC2				24, 25, 115	24, 25, 115	24, 25, 115	24, 25, 115
OC3				130, 131, 132	130, 131, 132	130, 131, 132	130, 131, 132
OC4				120, 121, 122	120, 121, 122	120, 121, 122	120, 121, 122
OC5				70, 106, 107	70, 106, 107	70, 106, 107	70, 106, 107
OC6				123, 124, 125	123, 124, 125	123, 124, 125	123, 124, 125
PVC1				63, 64, 65	63, 64, 65	63, 64, 65	63, 64, 65
PVC2				59, 67, 119	59, 67	59, 67, 119	59, 67, 119
PVC3				14, 15, 118	14, 15	14, 15, 118	14, 15, 118
PVC4				33, 49, 50	33, 49, 50	33, 49, 50	33, 49, 50
PVC5				43, 48, 77	43, 48, 77	43, 48, 77	43, 48, 77
SA1				28, 45, 46	28, 45, 46	28, 45, 46	28, 45, 46
SA2				60, 61, 62	60, 61, 62	60, 61, 62	60, 61, 62
SA3				8, 9, 10	8, 9, 10	8, 9, 10	8, 9, 10
SA4				73, 74, 75	73, 74, 75	73, 74, 75	73, 74, 75
SA5				71, 72, 126	71, 72, 126	71, 72, 126	71, 72, 126

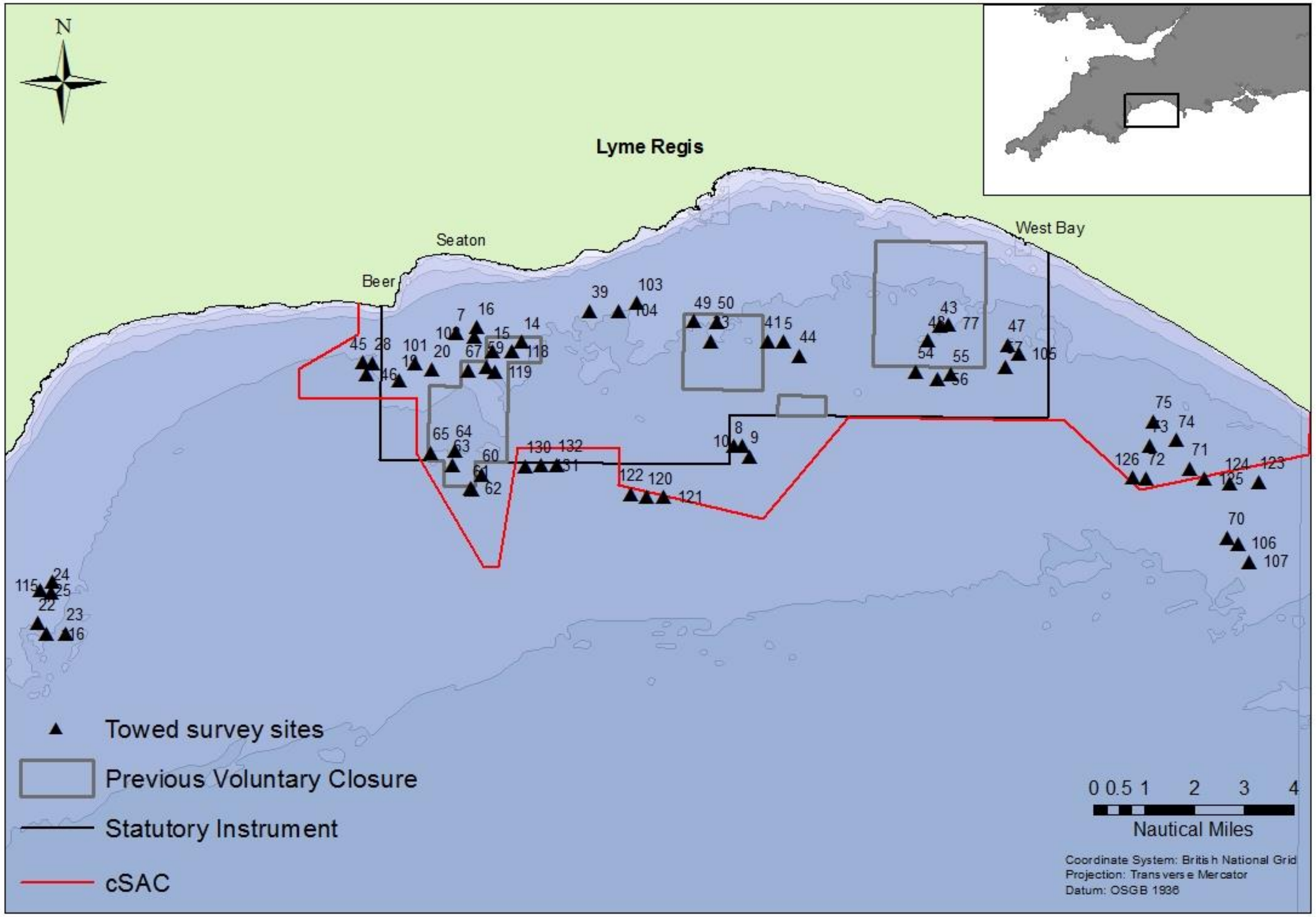

Figure A1 Lyme Bay showing the Statutory Instrument and cSAC boundaries. Survey sites are indicated by a black triangle and are labelled with their site number. Some symbols overlap at this scale

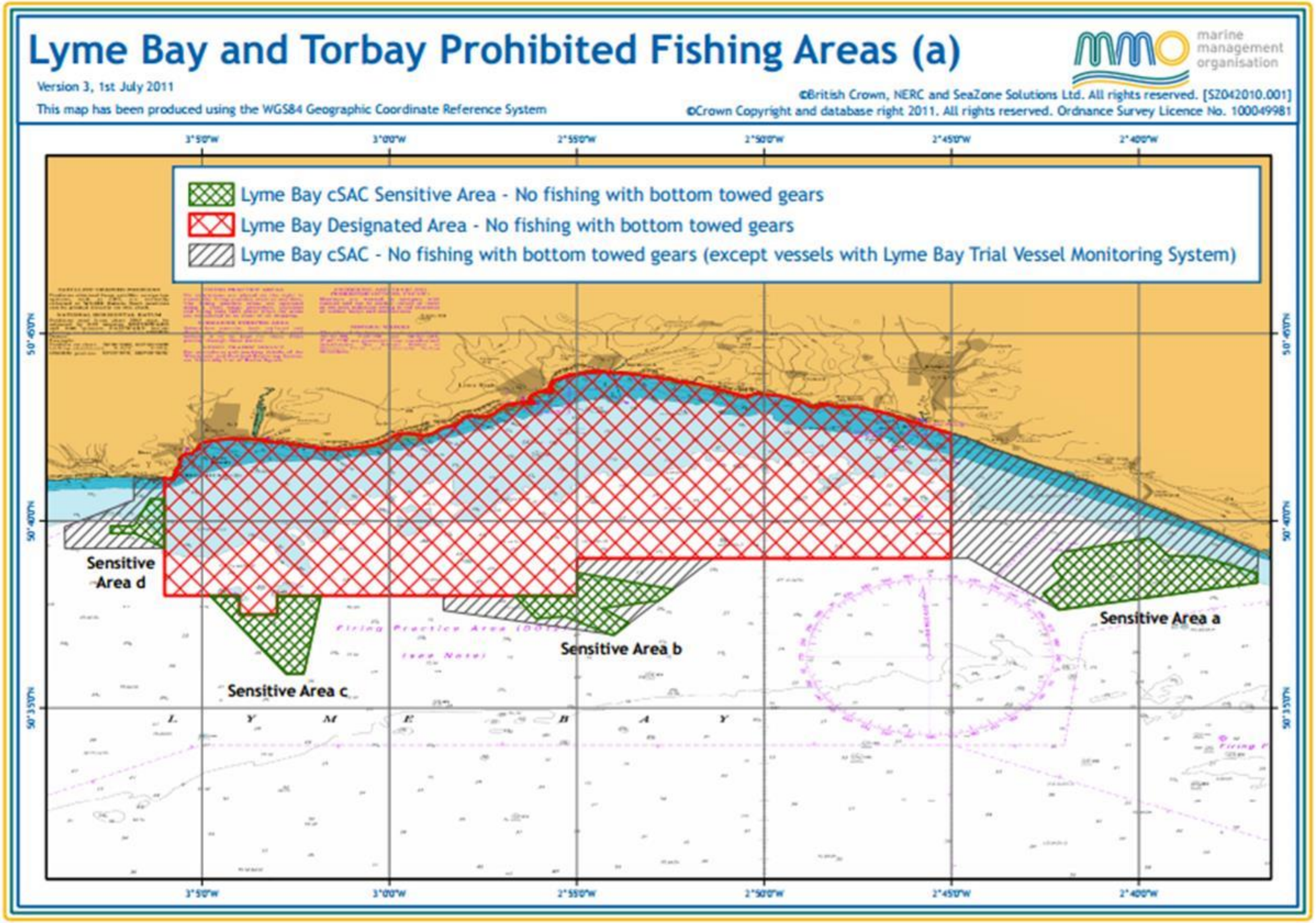

Figure A2 Chart showing management regimes in Lyme Bay

B. Species lists

Table B1 Species list detailing the taxa present and the survey method(s) that they were recorded by (F = Frames, V = Video, B = Baited)

Species name	Common name	F Count	F Cover	V	B
Actinia spp.	Actinia spp.	Y			
Actinothoe sphyrodeta	Sandalled anemone	Y			
Aequipecten opercularis	Queen scallop	Y		Y	Y
Alcyonidium diaphanum	Sea chervil	Y			
Alcyonium digitatum	Dead man's fingers	Y		Y	
Ammodytes marinus	Raitt's sand eel				Y
Amphilectus fucorum	Shredded carrot sponge		Y		
Anemones (grouped)	Anemones (grouped)	Y			
Anseropoda placenta	Goose foot starfish	Y		Y	
Aphrodita aculeata	Sea mouse	Y		Y	
Aplidium elegans	Sea-strawberry	Y			
Archidoris pseudoargus	Sea lemon	Y			
Ascidia mentula	Red sea squirt	Y			
Ascidiella aspersa	Fluted Sea Squirt	Y			
Aslia lefevrii	Brown Sea Cucumber	Y			
Asterias rubens	Common starfish	Y		Y	Y
Astropecten irregularis	Sand star	Y		Y	
Atelecyclus rotundatus	Circular crab	Y		Y	
Bispira volutacornis	Twin fan worm	Y			
Blennius ocellaris	Butterfly blenny				Y
Botryllus schlosseri	Star ascidian		Y		
Branching sponges (grouped)	Branching sponges (grouped)	Y		Y	
Brown Cellepora	Brown Cellepora	Y			
Buccinum undatum	Common whelk	Y			Y
Bugula sp.	Erect bryozoan	Y			
Callionymus lyra	Common dragonet	Y		Y	Y
Calliostoma zizyphinum	Painted topshell	Y			Y
Cancer pagurus	Edible crab	Y		Y	Y
Caryophyllia smithii	Devonshire cup coral	Y			
Cellaria fistulosa	A bryozoan	Y			
Cellepora pumicosa	A bryozoan	Y			
Centrolabrus exoletus	Rock cook			Y	Y
Cereus pedunculatus	Daisy anemone	Y			
Chaetopterus variopedatus	Parchment worm	Y			
Chelidonichthys cuculus	Red Gurnard	Y		Y	Y
Chrysaora hysoscella	Compass jellyfish				Y
Ciocalypta penicillus	A sponge	Y			
Ciona intestinalis	A sea squirt	Y		Y	
Clingfish spp.	Clingfish spp			Y	
Cliona celata	Boring sponge		Y		
Conger conger	European conger				Y
Corynactis viridis	Jewel anemone	Y			

Corystes cassivelaunus	Masked crab			Y	
Crenilabrus melops	Corkwing wrasse	Y		Y	Y
Crepidula fornicata	Slipper limpet	Y			
Ctenolabrus rupestris	Goldsinny wrasse	Y		Y	Y
Dendrodoa grossularia	Baked bean ascidian	Y			
Dercitus bucklandi	An encrusting sponge		Y		
Diazona violacea	Football sea squirt	Y			
Dicentrarchus labrax	European seabass				Y
Didemnum coriaceum	A colonial ascidian		Y		
Diplosoma spongiforme	An encrusting sponge		Y		
Dysidea fragilis	A sponge	Y			
Ebalia granulosa	Crab	Y		Y	
Echinus esculentus	Edible urchin	Y			
Epitonium clathrus	Common wentletrap	Y			
Eunicella verrucosa	Pink sea fan	Y		Y	
Eutrigla gurnardus	Grey gurnard				Y
Fish spp.	Fish spp.	Y		Y	
Flustridae spp.	Flustridae spp.	Y			
Gadus morhua	Cod			Y	
Gaidropsarus spp.	Rockling spp.				Y
Gobies (grouped)	Gobies (grouped)	Y		Y	Y
Goneplax rhomboides	Mud Runner/Square Crab	Y		Y	Y
Grantia compressa	Purse Sponge	Y			
Grey encrusting sponge	Grey encrusting sponge		Y		
Gymnangium montagui	Yellow feathers	Y			
Halichondria spp.	A sponge		Y		
Hemimycale columella	Crater sponge		Y		
Holothuria forskali	Cotton spinner	Y		Y	
Homarus gammarus	Common lobster	Y		Y	Y
Hyas coarctatus	Toad crab	Y		Y	
Hydroids (grouped)	Hydroids (grouped)	Y			
Inachus spp.	Scorpion spider crab	Y		Y	Y
Janolus cristatus	A nudibranch	Y			
Juvenile fish	Juvenile fish	Y		Y	Y
Labrus bergylta	Ballan wrasse	Y		Y	Y
Labrus mixtus	Cuckoo wrasse	Y		Y	Y
Lanice conchilega	Sand mason	Y			
Limanda limanda	Dab				Y
Liocarcinus depurator	Harbour crab	Y		Y	Y
Lipophrys pholis	Shanny	Y		Y	
Lissoclinum perforatum	A colonial ascidian		Y		
Lithophyllum incrustans	An encrusting coralline alga		Y		
Luidia cilaris	Seven armed starfish	Y		Y	Y
Macropodia sp.	Long legged spider crab	Y		Y	Y
Maerl (sp not distinguished)	Maerl	Y			
Maja squinado	Spiny spider crab	Y		Y	Y
Massive Sponge 2	Massive Sponge 2	Y			

Massive sponge 3	Massive sponge 3	Y			
Massive sponge 4	Massive sponge 4	Y			
Massive sponge 5	Massive sponge 5	Y			
Massive sponge 6	Massive sponge 6	Y			
Massive sponge 7	Massive sponge 7	Y			
Massive sponge 8	Massive sponge 8	Y			
Megalomma spp.	Fan worm	Y			
Mesacmaea mitchelli	Policeman anemone			Y	
Metridium senile	Plumose anemone	Y			
Microstomus kitt	Lemon sole			Y	
Molgula manhattensis	Sea grapes	Y			
Mullus surmuletus	Striped red mullet				Y
Mustelus mustelus	Common smooth-hound				Y
Myxicola infundibulum	A fanworm	Y			
Nassarius reticulatus	Netted dog whelk	Y			Y
Necora puber	Velvet swimming crab	Y		Y	Y
Nemertesia antennina	Sea beard	Y			
Nemertesia ramosa	A hydroid	Y			
Neopentadactyla mixta	Gravel sea cucumber	Y			
Nudibranch spp.	Nudibranch spp.	Y		Y	
Ocnus planci	Small sea cucumber	Y			
Ophiura spp.	A brittlestar	Y			Y
Orange encrusting sponge	Orange encrusting sponge		Y		
Pachymatisma johnstonia	Elephant's ear sponge		Y		
Pagurus spp.	Hermit crab	Y		Y	Y
Palaemon spp.	Palaemon spp.	Y		Y	
Parablennius gattorugine	Tompot blenny	Y		Y	Y
Pecten maximus	King scallop	Y		Y	Y
Pentapora foliacea	Ross coral	Y		Y	
Phallusia mammillata	White sea squirt	Y		Y	
Pholis gunnellus	Rock gunnel			Y	
Piddock?	Piddock?	Y			
Pink encrusting sponge	Pink encrusting sponge		Y		
Pink/orange encrusting sponge	Pink/orange encrusting sponge		Y		
Pisidia longicornis	Long-clawed porcelain crab	Y			
Pleuronectes platessa	European Plaice	Y		Y	
Pollachius pollachius	Pollack	Y		Y	Y
Polyclinidae sp.	Colonial ascidian	Y			
Polymastia boletiformis	A massive sponge	Y			
Polymastia penicillus	Chimney sponge	Y			
Porcellana platycheles	Broad-clawed porcelain crab				Y
Psammechinus miliaris	Green Sea Urchin	Y			Y
Raja clavata	Thornback ray	Y		Y	Y
Red algae	Red algae	Y			
Red encrusting sponge	Red encrusting sponge		Y		
Sabella pavonina	Peacock worm	Y			
Sagartia elegans	A sea anemone	Y			

Salmacina dysteri	Coral worm	Y			
Sarcodictyon roseum	Star like polyps	Y			
Schooling fish spp.	Schooling fish spp.				Y
Scyliorhinus stellaris	Nursehound			Y	Y
Scyliorhinus canicula	Small spotted cat shark	Y		Y	Y
Sediment tube worm spp.	A tube worm	Y			
Sepia atlantica	Little cuttlefish			Y	
Sepia officinalis	Common cuttlefish	Y		Y	Y
Serpulidae spp.	A tube worm	Y			
Shotgun bivalve?	Shotgun bivalve?	Y			
Solea solea	Sole	Y		Y	
Solitary ascidian spp.	Solitary ascidian spp.	Y			
Spondyliosoma cantharus	Black seabream				Y
Stolonica socialis	Orange sea grapes	Y			
Styela clava	Leathery sea squirt	Y			
Suberites spp.	A massive sponge	Y			
Sycon ciliatum	A sponge	Y			
Syngnathus acus	Greater Pipefish			Y	
Tethya aurantium	Golf ball sponge	Y			
Thalassema thalassemum	Spoon worm				Y
Trachurus trachurus	Jack mackerel				Y
Triakidae spp.	Houndshark spp.				Y
Trigla lucerna	Tub gurnard				Y
Trisopterus luscus	Pouting	Y		Y	Y
Trisopterus minutus	Poor cod	Y		Y	Y
Tritonia nilsodhneri	Whip fan nudibranch	Y		Y	Y
Turf	Turf		Y		
Turritella communis	Common tower shell	Y			
Urticina felina	Dahlia anemone	Y			
White encrusting sponge	White encrusting sponge		Y		
White/pink encrusting sponge	White/pink encrusting sponge		Y		
Xantho incisus	Montagu's crab			Y	Y
Yellow encrusting sponge	Yellow encrusting sponge		Y		
Zeugopterus punctatus	Topknot	Y		Y	
Zeus faber	John dory			Y	Y

Table B2 Indicator species as identified in Jackson et al. (2008) showing whether species were sighted in the biodiversity monitoring. Alterations in species used for analysis are noted and are fully explained in Attrill et al. (2011)

Original indicator species	Sighted?	Revised indicator species
Pecten maximus	Yes	
Phallusia mammillata	Yes	
Cellepora pumicosa	Yes	
Pentapora foliacea	Yes	
Aiptasia mutabilis	Yes	Anemones
Eunicella verrucosa	Yes	
Alcyonium digitatum	Yes	
Chaetopterus variopedatus	Yes	
Tethya citrina	Yes	Insufficient data. No suitable replacement
Halecium halecinum	Yes	Hydroids
Actinothoe sphyrodeta	No	None suitable
Hydrallmania falcata	Yes	Hydroids
Cliona celata	Yes	Insufficient data. No suitable replacement
Erect branching sponges	Yes	
Asterias rubens	Yes	
Hommarus gammarus	No	None suitable
Pollachius pollachius	No	*Trisopterus minutus*
Necora puber	Yes	
Cancer pagurus	Yes	
Labrus bergylta	Yes	Insufficient data. *Ctenolabrus rupestris*
Thorogobius ephippiatus	Yes	Gobies
Leptopsammia pruvoti	No	None suitable

C. PERMANOVA results

Frame grab Analysis

Table C1 Results of Permanova for the Number of taxa, relative Abundance and Assemblage composition of the main assemblage species identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), random factor Area (Ar) and their interactions. Results of pairwise testing for the interaction Year x Treatment. Data were 4th root (assemblage) or Log (X+1) transformed (Abundance and taxa). Analyses were conducted using Euclidean distance (Abundance and taxa) or Bray Curtis similarity (assemblage). Bold type denotes a statistically significant difference

							2008		**2009**		**2010**		**2011**		**2012**		**2013**		**2014**	
Source	***df***	**SS**	**MS**	***F***	**P**	**Groups**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
Number of taxa																				
Ye	6	9.455	1.576	18.25	**0.0001**	PVC, SI	0.4	0.70	1.6	0.15	1.7	0.11	1.4	0.212	0.6	0.56	0.1	0.92	1.2	0.26
Tr	2	11.701	5.850	18.01	**0.001**	PVC, OC	1.0	0.40	3.4	**0.01**	3.2	**0.02**	4.7	**0.009**	3.8	**0.00**	5.4	**0.00**	4.0	**0.00**
Ar(Tr)	13	4.130	0.318	7.710	**0.0001**	SI, OC	1.2	0.31	1.0	0.32	1.3	0.21	3.4	**0.017**	3.6	**0.01**	5.3	**0.00**	2.8	**0.02**
YexTr	12	1.984	0.165	1.954	**0.04**															
YexAr(Tr)	75	6.258	0.083	2.025	**0.0002**															
Residual	195	8.035	0.041																	
Total	303	41.562																		
Abundance																				
Ye	6	82.88	13.81	38.06	**0.0001**	PVC, SI	0.6	0.57	1.3	0.22	0.9	0.37	2.1	0.070	2.7	**0.03**	0.1	0.92	2.9	**0.02**
Tr	2	31.93	15.97	5.60	**0.02**	PVC, OC	2.0	0.09	2.3	0.07	2.3	0.07	3.9	**0.009**	1.3	0.25	3.8	**0.02**	3.6	**0.01**
Ar(Tr)	13	36.28	2.79	16.93	**0.0001**	SI, OC	1.8	0.10	0.2	0.82	1.3	0.23	2.0	0.087	0.1	0.93	3.2	**0.02**	1.3	0.24
YexTr	12	5.74	0.48	1.37	0.2															
YexAr(Tr)	75	25.87	0.34	2.09	**0.0001**															
Residual	195	32.16	0.16																	
Total	303	214.85																		
Assemblage composition																				
Ye	6	76330	12722.0	12.24	**0.0001**	PVC, SI	0.8	0.87	0.9	0.60	1.0	0.45	1.5	**0.04**	1.2	0.22	1.4	0.07	1.2	0.17
Tr	2	74747	37373.0	6.75	**0.0001**	PVC, OC	1.4	0.09	1.8	**0.01**	1.9	**0.00**	3.2	**0.009**	2.6	**0.00**	3.7	**0.00**	2.9	**0.00**
Ar(Tr)	13	70437	5418.20	9.56	**0.0001**	SI, OC	1.5	0.05	1.5	**0.03**	2.0	**0.00**	2.5	**0.002**	2.5	**0.00**	3.1	**0.00**	2.2	**0.00**
YexTr	12	24902	2075.20	2.05	**0.0001**															
YexAr(Tr)	75	74895	998.60	1.76	**0.0001**															
Residual	195	110470	566.52																	
Total	303	431780																		

Baited Video Analysis

Table C2 Results of Permanova for the Number of taxa, relative Abundance, and Assemblage composition of the mobile fauna identified using baited video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factor Site (Si) and their interactions. Data were square root (assemblage) or Log (X+1) transformed (Abundance and taxa). Analyses were conducted using Euclidean distance (Number of taxa and Abundance) or Bray Curtis similarity (Assemblage). Bold type denotes a statistically significant difference

							2009		**2010**		**2011**		**2012**		**2013**		**2014**	
Source	***df***	**SS**	**MS**	***F***	**P**	**Groups**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
Number of taxa																		
Ye	5	2.71	0.54	16.46	**0.0001**	PVC, SI	1.9	0.09	1.09	0.33	0.40	0.71	1.73	0.13	0.75	0.46	1.16	0.28
Tr	2	0.00	0.00	0.04	0.95	PVC, OC	3.1	**0.02**	1.03	0.33	2.71	**0.03**	1.32	0.23	0.10	0.94	0.62	0.59
Si(Tr)	21	2.65	0.13	4.34	**0.0001**	SI, OC	0.2	0.87	1.66	0.15	2.55	**0.04**	0.93	0.38	0.90	0.40	0.89	0.40
YexTr	9	0.87	0.10	3.32	**0.002**													
Residual	68	1.98	0.03															
Total	10	8.21																
Abundance																		
Ye	5	16.04	3.21	10.86	**0.0001**	PVC, SI	1.7	0.12	0.59	0.57	0.18	0.85	0.51	0.66	1.14	0.28	0.42	
Tr	2	1.60	0.80	1.10	0.36	PVC, OC	1.7	0.11	1.50	0.19	0.95	0.35	0.57	0.58	0.06	0.96	0.44	
Si(Tr)	21	13.62	0.65	2.31	**0.006**	SI, OC	0.6	0.60	1.42	0.20	1.44	0.17	1.23	0.26	1.11	0.30	0.92	
YexTr	9	2.87	0.32	1.14	0.35													
Residual	68	19.09	0.28															
Total	10	53.22																
Assemblage composition																		
Ye	5	34069	6813.8	6.71	**0.0001**	PVC, SI	1.5	**0.031**	0.72	0.86	0.94	0.519	0.91	0.605	0.97	0.524	0.64	0.89
Tr	2	25630	12815.0	4.00	**0.0006**	PVC, OC	2.1	**0.001**	1.44	0.11	2.44	**0.003**	2.09	**0.004**	2.49	**0.003**	1.10	0.29
Si(Tr)	21	57466	2736.5	2.90	**0.0001**	SI, OC	1.6	**0.009**	1.38	0.08	2.04	**0.002**	1.45	0.055	1.76	**0.009**	1.19	0.20
YexTr	9	12357	1373.0	1.45	**0.007**													
Residual	68	64236	944.7															
Total	10	193760																

Indicator Species Analysis

Table C3 Results of Permanova for the relative Abundance, of the indicator species identified using frame grabs (F), video (V) and baited video (B) in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) (F &V only) and their interactions. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference

							2008		**2009**		**2010**		**2011**		**2012**		**2013**		**2014**	
Source	***df***	**SS**	**MS**	***F***	**P**	**Groups**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
***Pecten maximus* (V)**																				
Ye	6	0.84	0.14	6.30	**0.0001**	PVC, SI	0.84	0.41	1.17	0.26	2.29	0.06	1.66	0.15	2.63	**0.02**	2.79	**0.007**	0.89	0.41
Tr	2	2.88	1.44	9.48	**0.003**	PVC,	0.34	0.70	1.06	0.34	0.31	0.75	3.35	**0.02**	3.11	**0.009**	3.71	**0.008**	2.33	**0.03**
Ar(Tr)	13	1.95	0.15	12.25	**0.0001**	SI, OC	0.54	0.58	0.21	0.83	2.06	0.08	3.42	**0.008**	4.48	**0.002**	4.42	**0.002**	7.31	**0.003**
YexTr	12	1.44	0.12	5.51	**0.0001**															
YexAr(Tr)	78	1.66	0.02	1.74	**0.001**															
Residual	19	2.39	0.01																	
Total	30	11.16																		
***Phallusia mammillata* (V)**																				
Ye	6	0.95	0.16	5.76	**0.0001**	PVC, SI	1.15	0.28	0.33	0.76	0.58	0.60	2.79	**0.03**	2.54	**0.04**	1.63	0.14	1.99	0.05
Tr	2	2.45	1.23	7.22	**0.008**	PVC,	4.58	**0.004**	1.90	**0.02**	2.11	**0.03**	3.98	**0.008**	3.31	**0.04**	2.82	**0.007**	2.44	**0.008**
Ar(Tr)	13	2.18	0.17	9.42	**0.0001**	SI, OC	1.25	0.23	2.95	**0.01**	2.83	**0.007**	2.69	**0.01**	2.35	**0.03**	2.01	**0.02**	1.88	0.18
YexTr	12	0.86	0.07	2.65	**0.004**															
YexAr(Tr)	78	2.08	0.03	1.49	**0.03**															
Residual	19	3.48	0.02																	
Total	30	12.00																		
***Cellepora pumicosa* (F)**																				
Ye	6	144.0	24.02	28.76	**0.0001**	PVC, SI	0.14	0.89	0.25	0.80	0.27	0.79	0.81	0.43	0.1	0.93	0.86	0.41	2.07	0.07
Tr	2	82.31	41.15	10.08	**0.004**	PVC,	2.63	0.06	5.15	**0.005**	1.75	0.13	5.15	**0.008**	1.32	0.19	4.78	**0.008**	3.69	**0.009**
Ar(Tr)	13	51.91	3.99	13.59	**0.0001**	SI, OC	2.08	0.07	2.12	0.07	0.99	0.34	3.59	**0.010**	2.19	0.08	4.48	**0.002**	1.14	0.38
YexTr	12	24.64	2.05	2.52	**0.009**															
YexAr(Tr)	75	60.24	0.80	2.73	**0.0001**															
Residual	19	57.31	0.29																	
Total	30	420.5																		
***Pentapora foliacea* (V)**																				
Ye	6	1.58	0.26	10.69	**0.0001**	PVC, SI	2.01	0.08	0.28	0.78	0.80	0.44	1.95	0.099	1.55	0.19	2.01	0.06	2.31	**0.04**
Tr	2	2.64	1.32	7.49	**0.003**	PVC,	2.74	**0.02**	2.14	**0.002**	2.42	**0.006**	3.57	**0.008**	2.27	**0.001**	2.86	**0.006**	2.82	**0.007**
Ar(Tr)	13	2.27	0.17	8.23	**0.0001**	SI, OC	3.08	**0.02**	3.16	**0.006**	1.84	**0.02**	5.17	**0.005**	2.52	**0.02**	3.18	**0.007**	0.90	1
YexTr	12	1.17	0.10	4.04	**0.0002**															
YexAr(Tr)	78	1.85	0.02	1.12	0.26															
Residual	19	4.14	0.02																	
Total	30	13.66																		

Anemones (F)																				
Ye	6	21.96	3.66	7.47	**0.0001**	PVC, SI	0.98	0.49	1.27	0.17	1.21	0.28	1.37	**0.03**	0.07	0.94	1.77	0.09	1.49	0.06
Tr	2	48.71	24.35	4.69	**0.03**	PVC,	0.55	0.61	0.57	0.60	0.44	0.67	0.74	0.50	2.56	**0.02**	3.65	**0.02**	0.06	1.0
Ar(Tr)	13	66.01	5.08	11.72	**0.0001**	SI, OC	2.04	0.04	1.59	0.20	2.57	**0.02**	4.29	**0.002**	2.60	**0.03**	6.61	**0.002**	2.00	0.06
YexTr	12	16.99	1.42	3.03	**0.001**															
YexAr(Tr)	75	34.63	0.46	1.07	0.35															
Residual	19	84.47	0.43																	
Total	30	272.7																		
Alcyonium digitatum **(V)**																				
Ye	6	12.74	2.12	8.31	**0.0001**	PVC, SI	1.26	0.21	0.21	0.82	0.97	0.38	0.18	0.83	0.10	0.92	0.34	0.71	0.60	0.56
Tr	2	4.89	2.45	0.70	0.53	PVC,	0.95	0.47	0.72	0.64	0.20	0.89	1.41	0.22	0.72	0.47	1.03	0.38	1.23	0.24
Ar(Tr)	13	45.19	3.48	34.53	**0.0001**	SI, OC	0.51	0.61	0.76	0.54	1.20	0.27	1.95	0.08	0.84	0.42	1.45	0.19	1.62	0.15
YexTr	12	2.75	0.23	0.93	0.52															
YexAr(Tr)	78	18.91	0.24	2.41	**0.0001**															
Residual	19	19.63	0.10																	
Total	30	104.1																		
Eunicella verrucosa **(V)**																				
Ye	6	0.62	0.10	2.35	**0.03**	PVC, SI	0.49	0.66	0.66	0.55	0.09	0.96	0.17	0.86	0.47	0.72	0.02	0.98	0.04	0.98
Tr	2	3.77	1.88	1.13	0.41	PVC,	1.65	**0.02**	1.48	**0.03**	1.17	0.19	1.66	**0.01**	1.64	**0.02**	1.55	**0.007**	2.08	**0.007**
Ar(Tr)	13	21.39	1.65	74.47	**0.0001**	SI, OC	1.28	0.36	1.26	0.39	1.42	0.26	1.43	0.23	1.57	0.23	1.55	**0.20**	1.37	0.23
YexTr	12	0.51	0.04	1.05	0.42															
YexAr(Tr)	78	3.11	0.04	1.80	**0.002**															
Residual	19	4.31	0.02																	
Total	30	33.69																		
Chaetopterus variopedatus **(F)**																				
Ye	6	9.61	1.60	3.80	**0.001**	PVC, SI	0.20	0.82	0.95	0.38	1.60	**0.0001**	1.37	0.20	5.59	**0.004**	0.72	0.46	0.21	0.86
Tr	2	2.78	1.39	1.71	0.21	PVC,	1.12	0.30	1.52	0.20	0.45	0.71	0.45	0.60	3.67	**0.02**	0.74	0.54	1.39	0.45
Ar(Tr)	13	10.38	0.80	3.41	**0.0003**	SI, OC	1.31	0.22	1.00	0.40	2.50	**0.01**	1.06	0.34	0.44	0.69	1.45	0.18	1.14	0.27
YexTr	12	9.52	0.79	1.90	**0.04**															
YexAr(Tr)	75	30.85	0.41	1.76	**0.002**															
Residual	19	45.70	0.23																	
Total	30	108.8																		

Hydroids (F)																				
Ye	6	92.47	15.41	15.62	**0.0001**	PVC, SI	0.59	0.56	1.10	0.31	0.47	0.65	1.95	0.09	2.48	**0.02**	0.25	0.80	2.67	**0.03**
Tr	2	46.55	23.28	2.71	0.09	PVC,	0.54	0.59	1.68	0.14	1.59	0.16	1.94	0.05	0.97	0.39	2.51	0.05	3.01	**0.01**
Ar(Tr)	13	109.2	8.40	20.28	**0.0001**	SI, OC	0.16	0.87	0.45	0.66	1.26	0.24	1.41	0.25	0.24	0.81	2.07	0.07	1.66	0.14
YexTr	12	15.54	1.29	1.37	0.21															
YexAr(Tr)	75	70.12	0.93	2.26	**0.0001**															
Residual	19	80.79	0.41																	
Total	30	414.7																		
Branching sponges (V)																				
Ye	6	3.38	0.56	11.91	**0.0001**	PVC, SI	1.32	0.22	0.96	0.36	1.16	0.28	3.27	**0.02**	1.69	0.09	2.05	0.07	2.23	0.05
Tr	2	4.71	2.36	10.50	**0.0009**	PVC,	1.66	0.12	2.02	**0.03**	2.12	0.05	5.26	**0.009**	2.84	**0.004**	3.77	**0.01**	4.34	**0.008**
Ar(Tr)	13	2.88	0.22	7.73	**0.0001**	SI, OC	0.47	0.68	0.93	0.49	1.66	0.13	2.23	0.07	2.47	**0.02**	3.34	**0.01**	2.51	**0.03**
YexTr	12	2.65	0.22	4.74	**0.0001**															
YexAr(Tr)	78	3.56	0.05	1.59	**0.01**															
Residual	19	5.60	0.03																	
Total	30	22.79																		
***Asterias rubens* (V)**																				
Ye	6	1.13	0.19	2.21	0.05	PVC, SI	1.60	0.14	1.15	0.28	1.51	0.17	1.73	0.12	1.32	0.23	0.61	0.54	0.51	0.61
Tr	2	0.84	0.42	1.03	0.38	PVC,	0.37	0.71	1.06	0.31	0.82	0.42	1.70	0.15	1.52	0.17	0.62	0.63	1.12	0.31
Ar(Tr)	13	5.29	0.41	14.53	**0.0001**	SI, OC	1.29	0.23	0.25	0.81	2.59	0.04	0.17	0.88	0.03	0.98	0.04	0.97	0.97	0.38
YexTr	12	2.07	0.17	2.05	**0.03**															
YexAr(Tr)	78	6.43	0.08	2.94	**0.0001**															
Residual	19	5.46	0.03																	
Total	30	21.22																		
***Trisopterus minutus* (B)**																				
Ye	5	5.61	1.12	3.91	**0.003**	PVC, SI			2.33	0.021	0.43	0.69	1.41	0.19	0.01	1.00	0.29	0.78	1.01	0.43
Tr	2	3.04	1.52	2.21	0.13	PVC,			0.81	0.468	0.54	0.59	1.49	0.16	1.22	0.24	2.89	**0.01**	0.46	0.64
Si(Tr)	21	12.57	0.60	2.18	**0.01**	SI, OC			1.66	0.134	0.82	0.43	2.88	**0.03**	1.58	0.22	1.96	0.07	0.82	0.44
YexTr	9	7.15	0.79	2.90	**0.006**															
Residual	68	18.64	0.27																	
Total	10	47.02																		
***Necora puber* (V)**																				
Ye	6	0.03	0.01	6.13	**0.0002**	PVC, SI	0.29	0.77	0.80	0.43	0.67	0.63	1.40	0.18	1.72	0.11	1.54	0.16	2.42	**0.01**
Tr	2	0.02	0.01	3.53	0.05	PVC,	0.34	0.75	1.31	0.23	0.74	0.58	3.20	**0.006**	2.17	0.08	2.09	0.09	1.84	0.09
Ar(Tr)	13	0.04	0.003	4.05	**0.0002**	SI, OC	0.26	0.84	0.59	0.56	0.32	0.74	1.77	0.08	0.32	0.86	1.30	0.22	0.39	0.76
YexTr	12	0.01	0.001	0.86	0.59															
YexAr(Tr)	78	0.07	0.001	1.31	0.08															
Residual	19	0.13	0.001																	
Total	30	0.29																		

***Cancer pagurus* (V)**																				
Ye	6	0.004	0.0006	3.14	**0.01**	PVC, SI	0.62	0.58	0.55	0.64	0.61	0.53	2.42	**0.04**	1.63	0.14	1.11	0.45	1.67	0.13
Tr	2	0.002	0.0008	2.41	0.12	PVC,	0.24	0.76	0.68	0.55	0.33	0.75	2.79	**0.04**	0.92	0.41	1	1	2.89	0.05
Ar(Tr)	13	0.004	0.0003	1.52	0.11	SI, OC	0.86	0.40	1.15	0.30	0.79	0.43	2.17	0.06	0.50	0.73			0.90	1.00
YexTr	12	0.004	0.0003	1.66	0.09															
YexAr(Tr)	78	0.014	0.0002	0.90	0.69															
Residual	19	0.040	0.0002																	
Total	30	0.067																		
***Ctenolabrus rupestris* (B)**																				
Ye	5	1.27	0.25	6.08	**0.0001**	PVC, SI			1.49	0.20	1.01	0.40	0.09	0.93	2.93	**0.02**	1.28	0.20	1.15	0.31
Tr	2	1.84	0.92	15.76	**0.0009**	PVC,			2.45	**0.003**	1.82	0.06	4.60	**0.003**	3.98	**0.003**	3.05	**0.002**	1.34	0.18
Si(Tr)	21	1.04	0.05	1.19	0.30	SI, OC			1.64	**0.02**	1.47	0.16	3.51	**0.01**	1.79	0.18	1.34	0.06	1.00	1.00
YexTr	9	0.75	0.08	2.00	0.05															
Residual	68	2.82	0.04																	
Total	10	7.72																		
Gobies (B)																				
Ye	5	5.50	1.10	8.22	**0.0001**	PVC, SI			1.02	0.33	0.05	0.96	0.19	0.83	0.04	0.98	0.31	0.92	0.60	0.55
Tr	2	1.28	0.64	1.35	0.28	PVC,			2.29	0.05	0.76	0.47	0.80	0.45	2.35	0.05	1.11	0.31	1.48	0.16
Si(Tr)	21	8.67	0.41	3.37	**0.0001**	SI, OC			0.95	0.38	0.59	0.57	0.84	0.41	1.79	0.08	1.28	0.21	0.70	0.55
YexTr	9	0.93	0.10	0.85	0.57															
Residual	68	8.33	0.12																	
Total	10	24.71																		

Frame Grab Analysis (SA analysis)

Table C4 Results of Permanova for the relative Abundance of the main assemblage count species identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr) including SA, and random factors Area (Ar) and Site (Si) and their interactions. Data were 4th root (frames) or square root (baited) transformed. Analyses were conducted using Bray Curtis similarity. Bold type denotes a statistically significant difference

							2011		2012		2013		2014	
Source	***df***	**SS**	**MS**	***F***	**P**	**Groups**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
Number of taxa														
Ye	3	5.79	1.93	32.89	**0.0001**									
Tr	2	9.31	4.66	14.62	**0.001**									
Ar(Tr)	13	4.14	0.32	7.72	**0.0001**									
YexTr	6	0.20	0.03	0.58	0.75									
YexAr(Tr)	39	2.27	0.06	1.41	0.08									
Residual	126	5.20	0.04											
Total	189	26.91												
Abundance														
Ye	3	32.60	10.87	29.65	**0.0001**									
Tr	2	22.03	11.02	8.20	**0.002**									
Ar(Tr)	13	17.48	1.34	12.57	**0.0001**									
YexTr	6	1.88	0.31	0.86	0.52									
YexAr(Tr)	39	14.19	0.36	3.40	**0.0001**									
Residual	126	13.49	0.11											
Total	189	101.67												
Assemblage composition														
Ye	3	36765	12255	15.15	**0.0001**	PVC, SA	3.14	**0.008**	1.9	**0.02**	2.5	**0.00**	2.1	**0.00**
Tr	2	55725	27863	7.48	**0.0002**	PVC, OC	3.22	**0.003**	2.5	**0.00**	3.4	**0.00**	2.7	**0.00**
Ar(Tr)	13	48443	3726	7.38	**0.0001**	SA, OC	1.18	0.22	1.0	0.38	1.6	**0.03**	1.2	0.20
YexTr	6	13031	2172	2.70	**0.0001**									
YexAr(Tr)	39	31307	803	1.59	**0.0001**									
Residual	126	63614	505											
Total	189	248890												

Baited Video Analysis (SA Analysis)

Table C5 Results of Permanova for the Number of taxa, relative Abundance, and Assemblage composition of the mobile fauna identified using baited video in response to the fixed factors Year (Ye) and Treatment (Tr) including SA, and random factor Site (Si) and their interactions. Data were square root (assemblage) or Log (X+1) transformed (Abundance and taxa). Analyses were conducted using Euclidean distance (Number of taxa and Abundance) or Bray Curtis similarity (Assemblage). Bold type denotes a statistically significant difference

							2011		**2012**		**2013**		**2014**	
Source	***df***	**SS**	**MS**	***F***	**P**	**Groups**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
Number of taxa														
Ye	3	1.97	0.66	17.80	**0.0001**									
Tr	2	0.23	0.12	2.46	0.12									
Si(Tr)	15	0.71	0.05	1.27	0.26									
YexTr	6	0.21	0.04	0.95	0.47									
Residual	45	1.66	0.04											
Total	71	4.78												
Abundance														
Ye	3	15.27	5.09	15.70	**0.0001**									
Tr	2	0.34	0.17	0.31	0.73									
Si(Tr)	15	8.20	0.55	1.69	0.09									
YexTr	6	1.08	0.18	0.55	0.75									
Residual	45	14.59	0.32											
Total	71	39.47												
Assemblage Composition														
Ye	3	17303	5768	6.72	**0.0001**	PVC, SA	2.30	**0.002**	1.98	**0.002**	2.36	**0.002**	1.09	0.28
Tr	2	22089	11045	4.80	**0.0004**	PVC, OC	2.44	**0.002**	2.09	**0.005**	2.49	**0.003**	1.10	0.28
Si(Tr)	15	34540	2303	2.68	**0.0001**	SA, OC	0.60	0.89	0.40	1.00	0.71	0.80	0.79	0.71
YexTr	6	7559	1260	1.47	**0.02**									
Residual	45	38614	858											
Total	71	120100												