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Lyme Bay - A case study

Response of the benthos to the zoned exclusion of towed demersal fishing gear in Lyme Bay; 4 years after the closure

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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.

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Marine Institute
PLYMOUTH UNIVERSITY

Natural England Project Manager - Joana Smith, 9 Renslade House, Bonhay Rd, Exeter, Devon, EX4 3AW
joana.smith@naturalengland.org.uk

Contractor - E.V. Sheehan, Plymouth University Marine Institute, Marine Building, Drake Circus, Plymouth, Devon, PL4 8AA

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Further information
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Lyme Bay - A case study: Response of the benthos to the zoned exclusion of towed demersal fishing gear in Lyme Bay; 4 years after the closure

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Natural England Contract Manager: Joana Smith

Funded by:

Natural England,
3rd Floor,
Touthill Close,
City Road,
Peterborough,
PE1 1XN

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Executive Summary

In July 2008 the UK Government (Defra) closed a 60 nm^2 area through a Statutory Instrument (SI) (The Lyme Bay Designated Area (Fishing Restrictions) Order 2008) to bottom towed fishing gear. 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. The bay was then put forward as a candidate Special Area of Conservation (cSAC) by Natural England in August 2010 under the EC Habitats Directive.

Monitoring the ecological and socio-economic changes that occurred following the closure was undertaken by a Plymouth University led consortium and was funded by the Department for Environment, Food and Rural Affairs (Defra) from 2008-2011 (see Attrill et al. 2011; Mangi et al. 2011; Attrill et al. 2012 *in press*; Mangi et al. 2012). Natural England and Plymouth University jointly supported the continuation of the ecological monitoring component in 2012 enabling a 4th year of annual monitoring following the closure of the area in 2008. Here we present the benthic data from 2008-2012. The 2012 data were also used to provide a baseline condition assessment for the Lyme Bay reef section of the Lyme Bay and Torbay cSAC (Sheehan et al. *in prep*).

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), ensuring sampling was relatively non-destructive and allowing sampling of a variety of seabed habitats without snagging on rocky ledges or boulders (Sheehan et al., 2010). Secondly, cameras were deployed on baited, static frames to sample the reef nekton and mobile benthic fauna. These taxa typically take refuge under rocks and therefore would be missed using the towed array; however, using a static frame and bait attracts these organisms into the field of view.

The focus of the survey was to measure the ‘recovery’ of epibenthic reef fauna. We cannot truly measure ‘recovery’ as there were no pristine sites for comparison, so here the term recovery means ‘positive change’ and is defined as ‘with time, species assemblages in the new closure will become more similar to the areas previously closed under voluntary agreements (closed controls) and less similar to areas that continue to be open to fishing (open controls)’.

For the towed video analysis, four treatment levels were used: the Statutory Instrument (SI) and 3 controls – Pre-existing Voluntary Closure (PVC), Open Control (OC) and Sensitive Area (SA), (Table 2.1). Within each treatment there were five or six areas, each comprising 3 sites (200 m video transect), which were sampled in the summers of 2008, 2009, 2010, 2011 and 2012 (Figure 2.3). The same design principles were used for the baited video as the towed sampling, however, there were less sites due to logistical constraints. Sampling was carried out in summer 2009, 2010, 2011 and 2012.

Analysis of the video transects was conducted in two stages (Sheehan et al., 2010). Firstly, species counts were made from each entire video transect for infrequent organisms (all mobile taxa) and conspicuous sessile fauna. Secondly, frame grabs were extracted from the video to quantify the encrusting, sessile species, some abundant and 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 maximum number of each taxon seen in the field of view within 1 minute slices of video (to prevent counting mobile species swimming in and out of the frame several times). The resulting data were then analysed for differences between treatments for species richness, relative abundance, abundance of scavenging species and assemblage composition. To facilitate the quantification of recovery and changes in assemblage structure resulting from the closure, analyses of the abundance and distribution of pre-determined indicator species were undertaken. The indicator species were identified in Objective 1 (Jackson et al., 2008) with representatives selected from the range of species of differing biological traits present in Lyme Bay (Jackson et al., 2008).

From 2008 to 2011 we observed positive trends for species richness and overall abundance in the SI and the PVC relative to the OCs, however, these trends decreased in 2012. While it can be expected that natural cycles will vary over time, the reduced metrics experienced in 2012 could be explained by extremely poor weather in 2012. However the 2012 metrics remain greater than in 2010 across all treatments. Abundant species in the SI and PVC which were found to be driving the differences between these treatments and the OC included some with predicted low recoverability, such as *Cellepora pumicosa* and *Alcyonium digitatum* rather than scavenging species that were more abundant in the OC sites, such as *Ophiura ophiura* and *Pagurus bernhardus*.

The baited video results show a significant Year x Treatment interaction for species richness and assemblage composition from 2009-2012. Overall, abundances of the indicator species that were increasing in the SI relative to the OCs from 2008 to 2011 have decreased in 2012, such as *Pecten maximus*, *Pentapora fascialis* and *Ctenolabrus rupestris*. The assemblage composition within sites in the SA was found not to be different to OC sites but is significantly different to PVC sites, suggesting that the period of time that the SA sites have been protected for is not sufficient to see a difference compared to fished sites.

This study aimed to assess the recovery of Lyme Bay reefs following the cessation of fishing using bottom towed gear within the SI. It was understood from the outset that three years would not be sufficient for the re-establishment of most species in the SI due to their life history traits, and the addition of a fourth year of sampling has shown that whilst some indicator species are showing signs of recovery, variation within the results is still too great for firm conclusions to be drawn. It is essential that the monitoring is continued over a long timescale to determine whether the early recovery identified to date is more than a short term phenomenon. Monitoring is essential to assess the state and pace of recovery. The suggestion that recovery is possible in areas of softer sediment between the reefs is also of great importance for the understanding of temperate systems and for future management, with the possibility that the introduction of Vessel Monitoring Systems (VMS) will result in boats which are fitted with this technology being permitted to fish between the reefs.

Continuation of the annual sampling of the benthos in Lyme Bay is planned with the aim of reaching a point where recovery can be detected within the new closure for those species which are considered most functionally important and indicators of a healthy ecosystem.

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1 Introduction

Lyme Bay, located off the south west coast of England is home 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. It is also an important area for commercial fishing and has a substantial number of recreational users.

In July 2008, the UK Government (Defra) 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 2011, a candidate Special Area of conservation cSAC enveloped the SI extending to the east, south and west due to the presence of extended Annex 1 reef habitat (Natural England, 2010) (Figure 1.1). The cSAC complicated the study in that some of the 'open to fishing' controls became protected and some became part of a fishing monitoring trial. Fishers involved in the trial were permitted to continue fishing inside the cSAC over ground that was away from 'Sensitive Areas' (Figure 1.2). Figure 1.2 shows the MMO chart of management strategies in Lyme Bay.

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, pebbles, cobbles and boulders, which are characterised by species such as the sea squirt *Phallusia mammillata*, corals *Alcyonium digitatum* and *Eunicella verrucosa*, and bryozoan *Pentapora fascialis* (Figure 1.3).

Monitoring the ecological and socio-economic changes that occurred following the closure was undertaken by a Plymouth University led consortium and was funded by the Department for Environment, Food and Rural Affairs (Defra) from 2008-2011 (see Attrill et al. 2011; Mangi et al. 2011; Attrill et al. 2012 *in press*; Mangi et al. 2012). Natural England and Plymouth University jointly supported the continuation of the ecological monitoring component in 2012 enabling a 4th year of annual monitoring following the closure of the area in 2008. Here we present the benthic data from 2008-2012. The 2012 data were also used to provide a baseline condition assessment for the Lyme Bay reef section of the Lyme Bay and Torbay cSAC (Sheehan et al. *in prep*).

The objectives of this study were:

i. Quantification of sessile and sedentary benthic taxa using high definition video on a towed flying array at sites within and outside protected areas
ii. Quantification of reef-associated nekton and mobile benthic fauna using baited, static frames at sites within and outside protected areas.

The Lyme Bay annual data are proving a valuable resource that government and environmental managers can draw on to make informed decisions for the designation and management of new Special Areas of Conservation and Marine Conservation Zones.

The report should be read in conjunction with those from the 2011 and 2012 reporting periods (Attrill et al. 2011, 2012 *in press*). Full details and methods for the work conducted can be found in the 2011 report and in the interest of brevity have not been repeated.

The focus of the survey 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 newly protected areas becoming more similar to previously protected areas and less similar to areas which remained open to towed demersal fishing.

As a result of some changes in the management of the bay and four years passing since the SI was instigated a rebranding for treatments and some sites was called for. Inside the cSAC there will be three treatment levels. The old Closed Controls will now be referred to as Pre-existing Voluntary Closures PVC. The new closure sites are no longer new and will be referred to by their legal designation which is Statutory Instrument SI. Areas in the SAC, which are outside the SI and are protected from towed demersal fishing as they comprise reef are a new treatment called Sensitive Areas SA. Areas outside the SI but inside the cSAC that were being used as the VMS trial allowing a subset of fishers to tow over the ground are not included in this report. It was also necessary to add new Open Controls (OCs) in 2011 to compensate for those lost when the cSAC was established.

The open to fishing controls comprise just one treatment level Open Controls OC. The focus of the study was still to measure the recovery of those sites inside the SI. Using the new treatments the updated hypothesis was 'over time the SI will become less similar to the OC and more similar to the PVC'. The response variables used were species richness, abundance of count organisms, abundance of cover organisms, assemblage composition, and abundance of the indicator species.

The same hypothesis was also used to evaluate the recovery of the Sensitive Areas (SAs): 'over time the SA will become less similar to the OC and more similar to the PVC'. For these recently protected areas, we will specifically look at assemblage change.

Sites were selected to monitor reef defined as hard substratum, including stony reef, as described in Irving (2009). The towed biodiversity survey methodology was designed to be cost effective, efficient and non-destructive so as to be appropriate for use in protected areas. High Definition (HD) video was used, firstly on a towed flying array designed to fly the camera over the seabed to sample sessile and sedentary taxa, and secondly on baited, static frames to sample reef-associated nekton and mobile benthic fauna. Full methods can be found in Sheehan et al. (2010) and Attrill et al. (2011).

It is important to note that this was an observational rather than experimental survey. It was not possible to manipulate the level of fishing in the different treatments or choose the starting condition of the Statutory Instrument sites. Due to the large size of the study area some spatial and temporal variation was expected within treatments. To quantify the magnitude and direction of changes that have occurred following the SI implementation, sites were located in treatment specific areas in 2008 and have been resampled every year since. Baited video surveys were an addition made by Plymouth University and sites were established at the beginning of the 2009 survey.

The first (2008) sampling event constituted the 'before' element of the design. It is important to consider, however, that the closure had already been in place for six weeks when the towed video sampling program commenced, and therefore, unfortunately, the opportunity for a true 'before' sampling effort had passed. Changes in benthic species and community structure are however, expected to occur over annual or even decadal time spans, and consequently, if present, these changes would be detectable by the design implemented (Glasby, 1997).

In addition to monitoring the indicator species as identified by Jackson et al. (2008), all species that could be identified using the video were counted. This meant that assessment of the impact of the closure at the assemblage level could also be made.

For each sampling methodology the following response variables were considered:

i. Towed HD video: Species richness, Overall abundance (count organisms), Overall abundance (cover organism), Assemblage composition, Abundance of indicator species
ii. Baited Remote Underwater Video (BRUV): Species richness, Overall abundance, Assemblage composition, Abundance of indicator species

Both the towed and baited survey results showed that a marked improvement occurred across the bay in 2011. Both survey methods identified new species, and abundance and species richness increased in the protected treatments relative to the open to fishing controls.

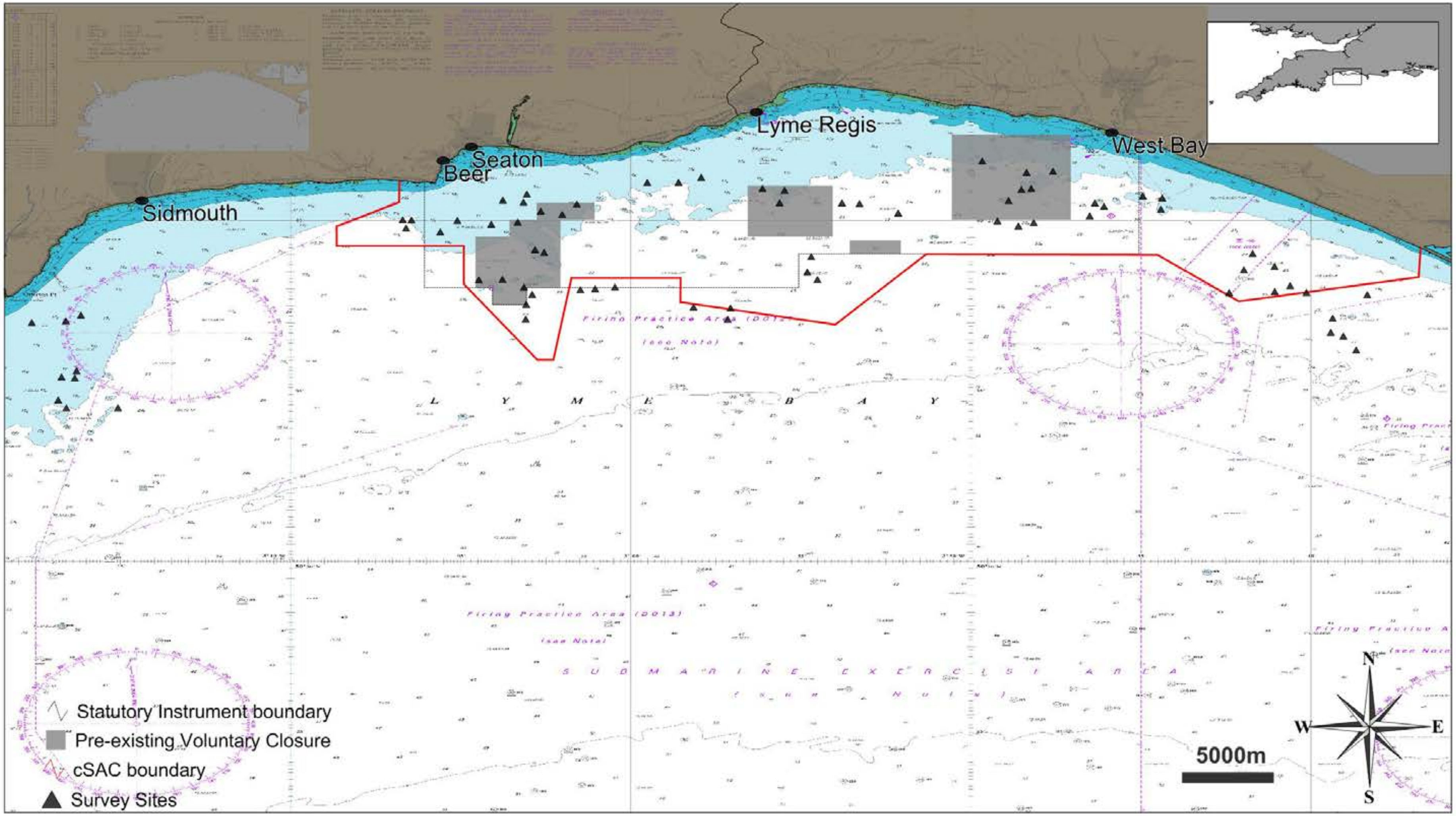

Figure 1.1 Lyme Bay showing the Statutory Instrument and SAC boundaries. Survey sites are indicated by a black triangle.

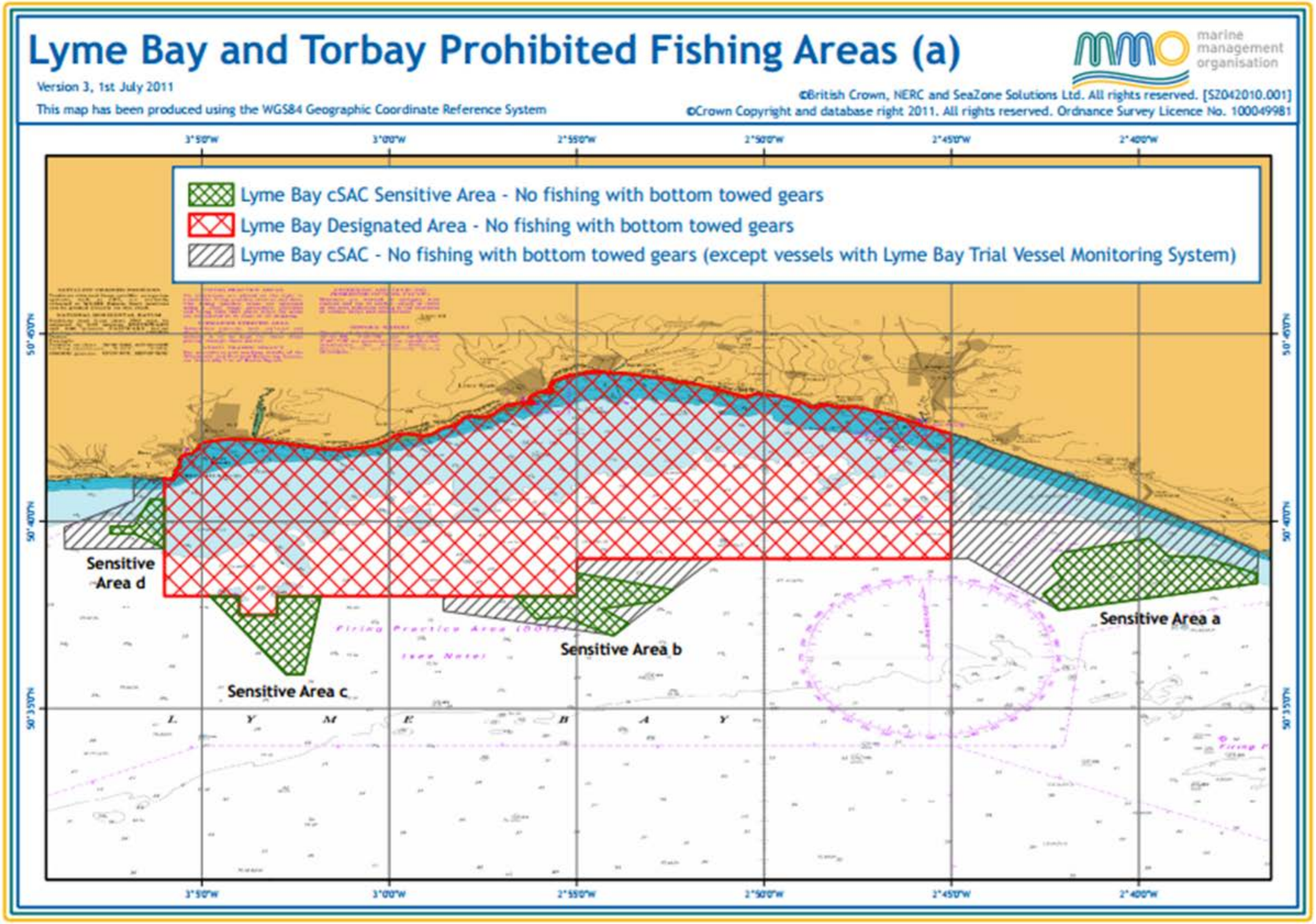

Figure 1.2 Chart showing management regimes in Lyme Bay

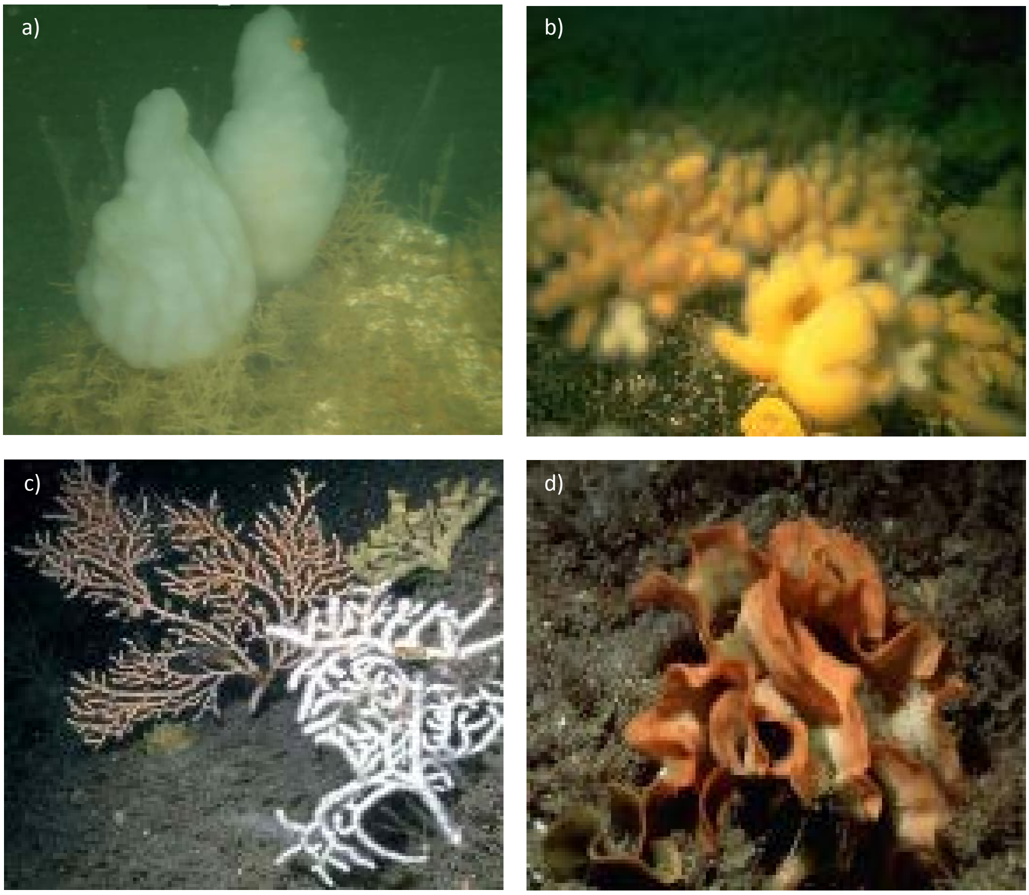

Figure 1.3 Examples of Lyme Bay reef species; a) *Phallusia mammillata*, b) *Alcyonium digitatum*, c) *Eunicella verrucosa*, d) *Pentapora fascialis*

2 Methods

2.1 Sampling methods

Methods for the 2012 survey period were consistent with previous years, methods are briefly outlined below but please refer to Sheehan et al. (2010) for details of the towed video and Attrill et al. (2011) and Attrill et al. (2012 *in press*) for details of both towed and BRUV. As in previous years, all fieldwork was carried out from the vessel ‘Miss Pattie’, a 10 m displacement trawler. Sampling took place over the summer from June - August 2012.

2.1.1 Towed video

To quantify changes in the abundance of sessile and sedentary benthic species, an HD video camera was mounted on a flying array (Figure 2.1). This method is particularly suitable for rapidly surveying large areas and is relatively low impact, which 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.

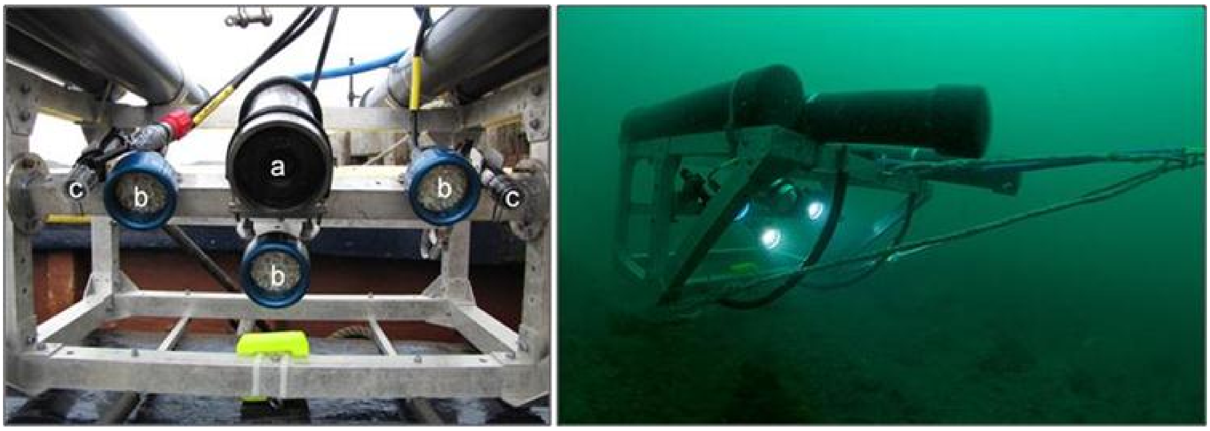

Figure 2.1 Flying array used for the towed video survey. a = high definition video camera, b = LED lights, c = lasers

2.1.2 Baited remote underwater video

To determine whether the closure affected reef-associated nekton species and mobile benthic fauna, BRUV was used. Methods were identical to those developed in 2011 as outlined in Attrill et al. (2012 *in press*), with the remote deployment of cameras on static frames increasing sampling efficiency and statistical independence (Figure 2.2).

Figure 2.2 BRUV static frame with bait box developed for the 2011 survey

2.2 Sampling design

To determine whether species assemblages were recovering in the SI, sampling Sites were located in treatment specific Areas across Lyme Bay. The three treatments were Statutory Instrument, Pre-existing Voluntary Closure, Open to fishing Controls each comprising six or seven areas comprising three sites (the three treatments are defined in Table 2.1 along with the other treatments in Lyme bay). The other treatments have arisen as a result of changing management regimes in Lyme Bay in areas where sites were originally located (see introduction section 1.9). This allowed the conditions in the newly closed sites to be documented and the magnitude and direction of any changes to be determined (Figures 2.3, 2.4).

Table 2.1 Definitions and codes of survey treatments

Treatment	Code	Definition
Pre-existing Voluntary Closure	PVC	Previously closed to towed demersal fishing under voluntary agreements.
Statutory Instrument	SI	Towed demersal fishing gear excluded since July 2008
Open Control	OC	Open to towed demersal fishing gear
Sensitive Area	SA	Towed demersal fishing gear excluded since 2011
Vessel Monitoring System	VMS	Towed demersal fishing gear excluded since 2011 except vessels with Lyme Bay Trial Vessel Monitoring System

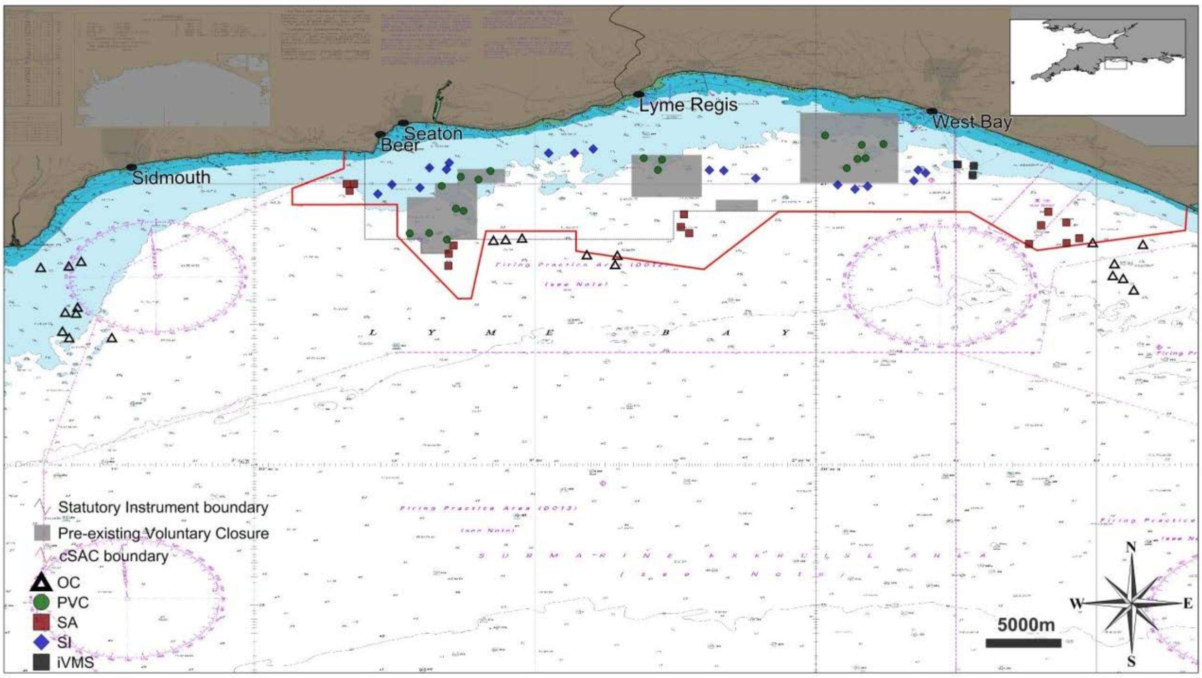

Figure 2.3 Locations of towed video transects in Lyme Bay coded by treatment (SI = Statutory Instrument, PVC = Pre-existing Voluntary Closure, OC = Open Control, SA = Sensitive Area, iVMS = inshore Vessel Monitoring System). Some symbols overlap at this scale

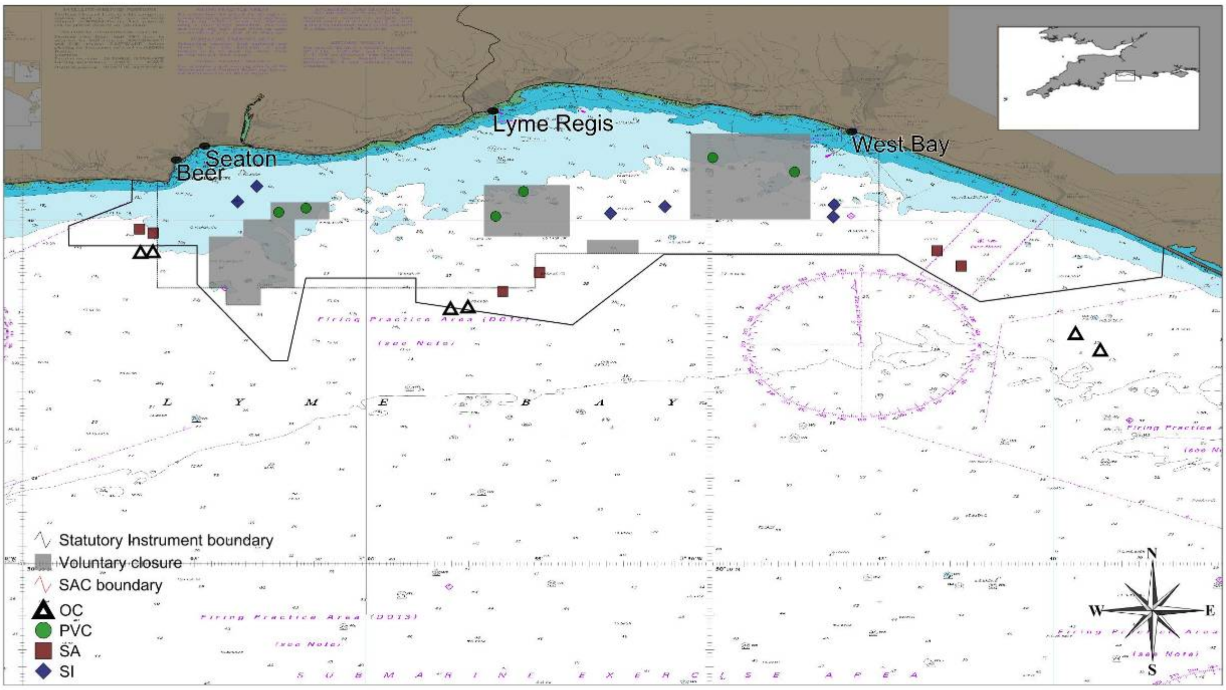

Figure 2.4 Locations of BRUV video sites in Lyme Bay coded by treatment (SI = Statutory Instrument, PVC = Pre-existing Voluntary Closure, OC = Open Control, SA = Sensitive Area). The boundaries of the SI (closure boundary), voluntary closures and the new cSAC are also shown. Some symbols overlap at this scale

2.3 Indicator species

Analyses of the abundance and distribution of 17 pre-determined indicator species as identified by Jackson et al. (2008) was undertaken (Annex A, Table A2).

2.4 Video Analysis

For each analysis, all taxa present were identified and their abundance recorded. Identification was to the highest taxonomic level possible although some groupings occurred due to between-species similarities, as outlined below. A full species list is presented in Annex A, Table A1.

Taxonomically similar species which could not be easily distinguished from each other were grouped:

i. All branching sponges, such as *Axinella dissimilis, Haliclona oculata, Raspailia hispida* and *Stelligera stuposa*;
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., *Peachia cylindrica* and *Sagartia* spp. excepting all other anemone species;
v. All red algae species; and
vi. 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).
vii. *Inachus* spp. and *Macropodia* spp. were identified to genus level. Additionally, for the baited video, *Ophiura* spp., and *Pomatoschistus* spp. were identified to genus level, and *Triakidae* spp., was identified to family level.
viii. Sponges that were not identifiable to species level were described and then identified as e.g. encrusting sponge 1, massive sponge 2 (Annex A, Table A1), ensuring taxonomic resolution was maximised.
ix. The term “turf” incorporated hydroid and bryozoan turf which projected less than 1 cm above the seabed surface.
x. An organism which may be an alternative morph of the species *Cellepora pumicosa* was observed in 2012. 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 ‘Unidentified bryozoan’.

2.4.1 Extraction of quantitative data from the HD video transect

Analysis of the video transects was conducted in two stages:

xi. 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 A, Table A2).

xii. 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.

Taxa were recorded as density for the species counts and either density or percentage cover as appropriate for the frame grabs (Annex A, Table A1).

2.4.2 Extraction of quantitative data from Baited Remote Underwater Video

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. These data were pooled to give relative abundance (mean min^{-1}) per species per replicate. This method ensures that species swimming in and out of the frame multiple times are not over represented.

For full details of these methods used please see Attrill et al. (2011).

2.5 Data analysis

Univariate and multivariate analyses were conducted using Permutational Multivariate Analysis of Variance (PERMANOVA, Anderson, 2001; Clarke, 2001) based on similarity matrices (univariate = Euclidean distance, multivariate = Bray Curtis similarity). Univariate data were Log (x+1) transformed and multivariate were dispersion weighted and square root transformed (Anderson and Millar, 2004). The null hypothesis of no difference among species assemblages (see response variables, paragraph 1.12) 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 relative to controls for towed video were Year (fixed: 2008, 2009, 2010, 2011, 2012), Treatment (fixed: PVC, SI, OC), Area (random and nested in Treatment: 6 or 7 within each Treatment), and Site (random and nested in Treatment and Area; 3 per Area). The 30 frame grabs per site were averaged to avoid pseudo replication. To test for recovery in the SA the factors used were Year (fixed: 2008, 2009, 2010, 2011, 2012), Treatment (fixed; PVC, OC, SA), Area (random and nested in Treatment) and Site (random and nested in Treatment and Area).

For the baited video the factors were Year (fixed: 2009, 2010, 2011, 2012), Treatment (fixed: PVC, SI, OC), and Site (random x six) 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.

The life history of each indicator species dictated which sampling method dataset was used (see Tables 3.2, 3.3, 3.4) for each species specific univariate analysis.

Measures of abundance presented in the results appear with different units depending on the survey method from which they were derived. The units were not mixed within any single analysis. Individual or discrete colonial organisms counted within entire video transects (video transect data) are expressed as incidence 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 (% ± 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 abundance data as the huge spatial and temporal variation skewed the data.

3 Results

A total of 144 taxa from ten phyla were recorded in the surveys; 109 count taxa and 19 cover taxa were recorded in the frame grab analysis, 51 in the video analysis and 51 in the baited video (Annex A, Table A1).

Of the species recorded through counts from the quadrat data, grouped hydroids had the greatest mean abundance (100.18 m^{-2} ± 2.9), followed by *Pagurus bernhardus* (10.7 m^{-2} ± 0.65), and dead man's fingers *Alcyonium digitatum* (6.71 m^{-2} ± 0.40). "Turf" had the greatest mean percentage cover (17.45 m^{-2} % ± 0.53), and out of the cover taxa identified to species. For the species quantified in the video transects, *A. digitatum* was the most abundant sessile species (1.87 m^{-2} ± 0.28), branching sponges second (0.28 m^{-2} ± 0.06), followed by *Eunicella verrucosa* (0.20 m^{-2} ± 0.06) and *Pentapora fascialis* (0.09 m^{-2} ± 0.02). Of the free living species, abundance of *P. bernhardus* (3.38 m^{-2} ± 0.98) was greatest, followed by *Aequipecten opercularis* (1.09 m^{-2} ± 0.27), *Asterias rubens* (0.37 m^{-2} ± 0.05) and *Pecten maximus* (0.19 m^{-2} ± 0.02).

From the baited data, *Trisopterus minutus* had the highest abundance of all nektonic taxa (0.41 min^{-1} ± 0.14), followed by *Scyliorhinus caniculus* (0.33 min^{-1} ± 0.05) and of the cryptic species *Pagurus bernhardus* had the greatest mean abundance (3.77 min^{-1} ± 0.77), followed by *Ophiura* spp. and *Asterias rubens* (1.81 min^{-1} ± 0.59 and 0.35 min^{-1} ± 0.09, respectively).

For each PERMANOVA table (Annex B), significant low level spatial or temporal differences were not further interpreted as the hypotheses did not relate to spatial differences between areas in the bay or overall differences between years. While significant Treatment differences were further interpreted main focus for further interpretation was if there was significant Year x Treatment interaction that could indicate recovery.

3.1 Frame grab data

3.1.1 Overall Abundance

Abundance of count taxa (number of individuals) was greatest in the PVC in 2011 (3.49 m^{-2} ± 0.14) and lowest in the OC in 2008 (0.38 m^{-2} ± 0.03) (Figure 3.1). Significant Year ($P < 0.01$) and Treatment ($P < 0.05$) effects were identified, with pairwise tests finding mean abundance of count taxa to be significantly greater in the PVC than in the OC ($P < 0.01$). No significant Year x Treatment interaction was found (Annex B, Table B1).

Abundance of cover taxa (percentage cover) was greatest in the SI in 2011 (2.81 m^{-2} ± 0.07) and lowest in the OC in 2009 (0.27 m^{-2} ± 0.02) (Figure 3.2). Significant Year and Treatment effects were identified (both $P < 0.01$), with pairwise tests finding mean abundance of cover taxa to be significantly greater in the PVC and SI than in the OC ($P < 0.05$). No significant Year x Treatment interaction was found (Annex B, Table B2).

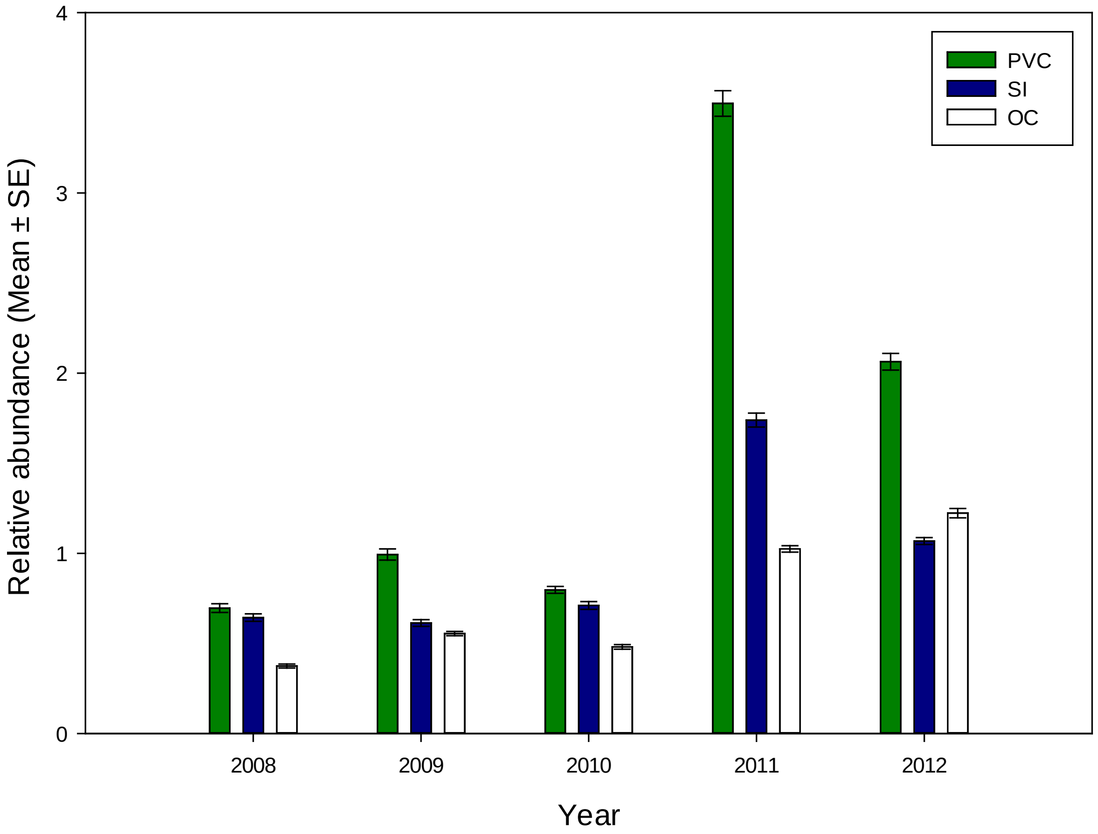

Figure 3.1 Relative abundance (Mean m^{-2} ± SE) of count taxa from frame grab analyses for each year (2008, 2009, 2010, 2011, 2012) and treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control)

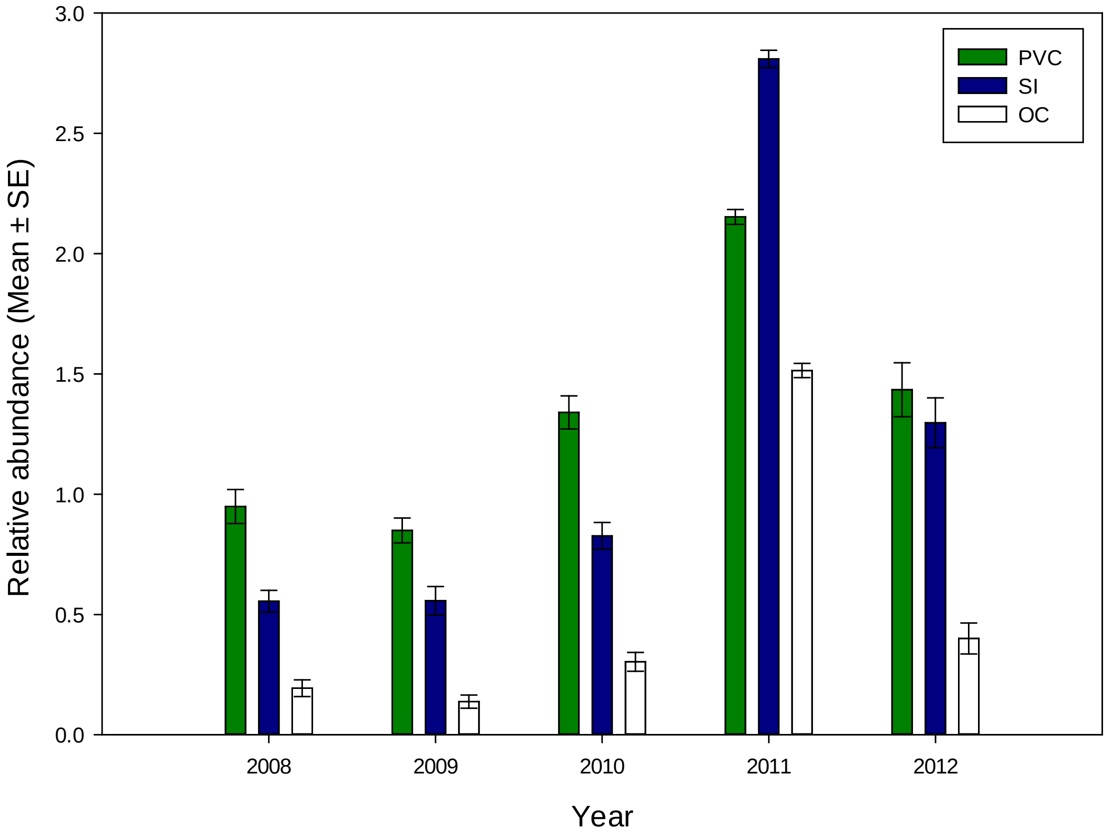

Figure 3.2 Relative abundance (mean m^{-2} ± SE) of cover taxa from frame grab analyses for each year (2008, 2009, 2010, 2011, 2012) and treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control)

3.1.2 Species Richness

Both Year and Treatment had a significant effect on mean species richness (number of taxon) (both $P < 0.01$), with pairwise tests identifying that species richness was greater in the PVC and the SI than in the OC (both $P < 0.01$), although no Year x Treatment interaction existed (Annex B, Table B3). Mean species richness was greatest in the PVC in 2011 (6.25 m^{-2} ± 0.10) and lowest in the OC in 2008 (2.28 m^{-2} ± 0.05), (Figure 3.3).

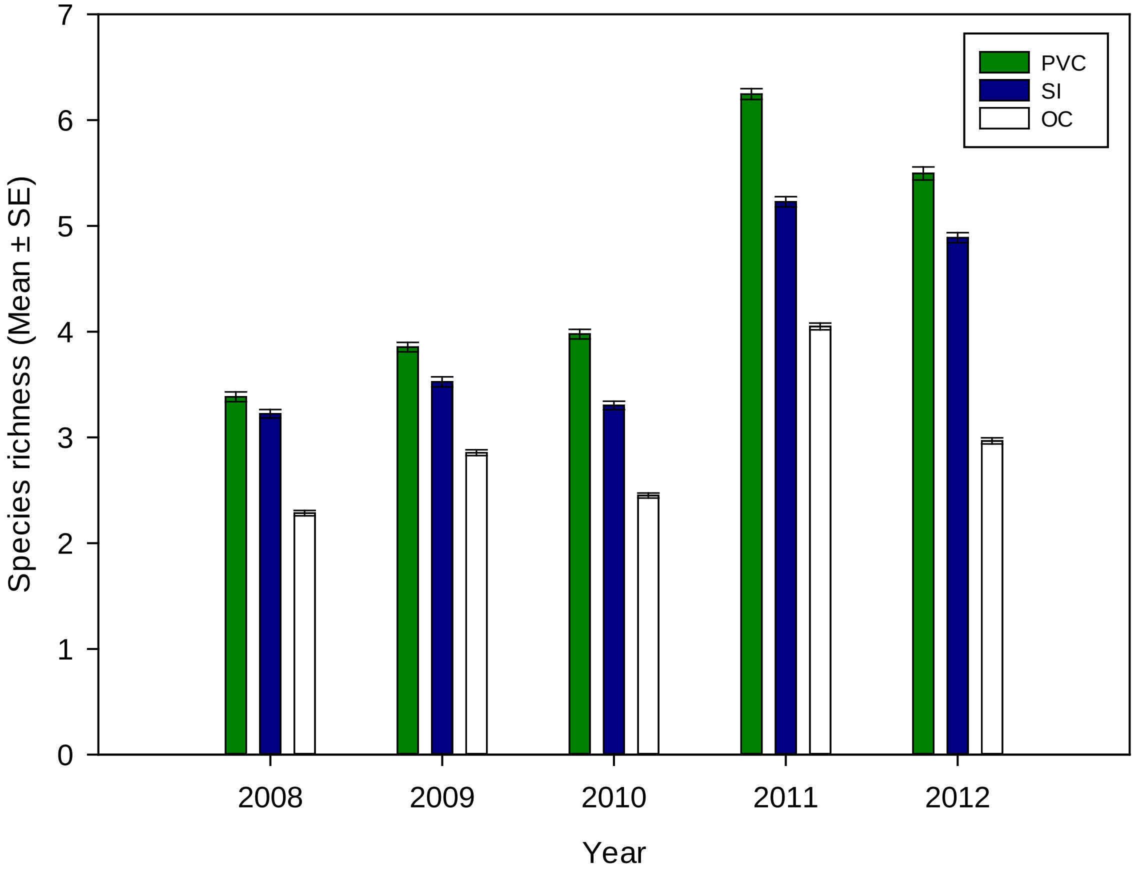

Figure 3.3 Species richness (Mean m^{-2} ± SE) from frame grab analyses for each year (2008, 2009, 2010, 2011, 2012) and treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control)

3.1.3 Assemblage composition

Assemblage composition was significantly different for every factor tested. Pairwise tests for Year x Treatment interaction (all $P < 0.01$, Table 3.1) showed that across all years the PVC and the SI were significantly different from the OC for assemblage composition. In addition in 2011, the assemblage composition of all treatments was significantly different (all $P < 0.05$) and a Year x Treatment interaction was identified (Annex B, Table B4).

Table 3.1 PERMANOVA results for the relative distribution of the species assemblage composition, identified through frame grab analyses in response to the fixed factors Treatment (Tr) and Year (Yr), random factors Area (Ar) and Site (Si) and their interactions. Data were dispersion weighted and square root transformed and analyses conducted using Bray Curtis similarities. Bold type denotes a significant result (P < 0.05)

Source	*Df*	MS	Pseudo-F	P(perm)
Year Ye	4	14529	9.4816	**0.0001**
Treatment Tr	2	32000	5.8976	**0.0001**
Area (Tr)	22	4342.4	4.2455	**0.0001**
Ye x Tr	8	1844.2	1.5724	**0.0004**
Site (Ar(Tr))	61	978.73	1.5399	**0.0001**
Ye x Ar(Tr)	58	1067.3	1.6793	**0.0001**
Residual	133	635.57		
Total	288			

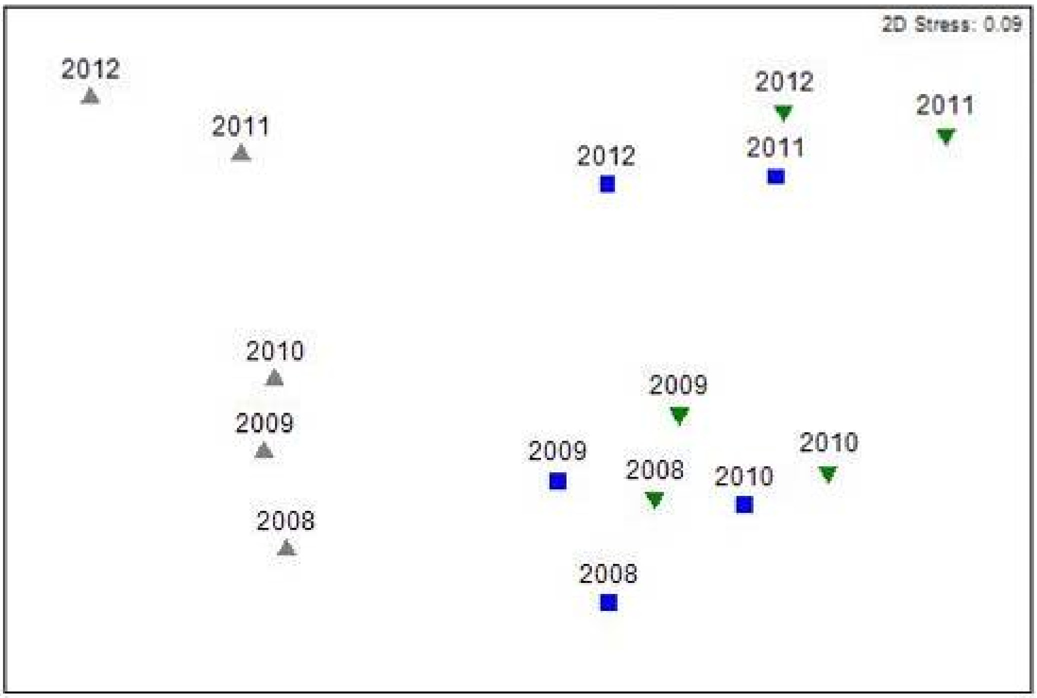

Figure 3.4 nMDS plot illustrating similarities in assemblage composition between Treatments (averaged for site within treatment), (Pre-existing Voluntary Closure = green triangles, Statutory Instrument = blue squares, Open Control = grey triangles), over time (2008, 2009, 2010, 2011, 2012)

The SI is moving in a similar projection as the PVC. Until 2011, both PVC and SI paths were on a trajectory away from the OCs, but in 2012 they appear to moving back to towards OCs (Figure 3.4).

3.2 Baited Remote Underwater Video data

A total of 51 taxa from six phyla were recorded during the BRUV surveys, consisting of 27 fishes, 12 crustaceans, seven molluscs, three echinoderms, one echiura and one hydrozoa (See Annex A, Table A1 for details).

The species that were observed in the baited video for the first time in 2012 were the lesser sand eel *Ammodytes marinus*; European sea bass *Dicentrarchus labrax*; spoon worm *Thalassema thalassemum;* butterfly blenny *Blennius ocellaris;* compass jellyfish *Chrysaora hysoscella* and ray *Raja* sp.. The common cuttlefish *Sepia officinalis* was also seen for the first time in the baited video, but had been seen in the towed video in previous years.

3.2.1 Abundance

Mobile species abundance was greatest in the SI in 2009 (0.31 min^{-1} ± 0.09) and lowest in the OC in 2012 (0.05 min^{-1} ± 0.005) (Figure 3.5). A significant difference was identified between Years ($P < 0.001$) but no Year x Treatment interaction was identified (Annex B; Table B5).

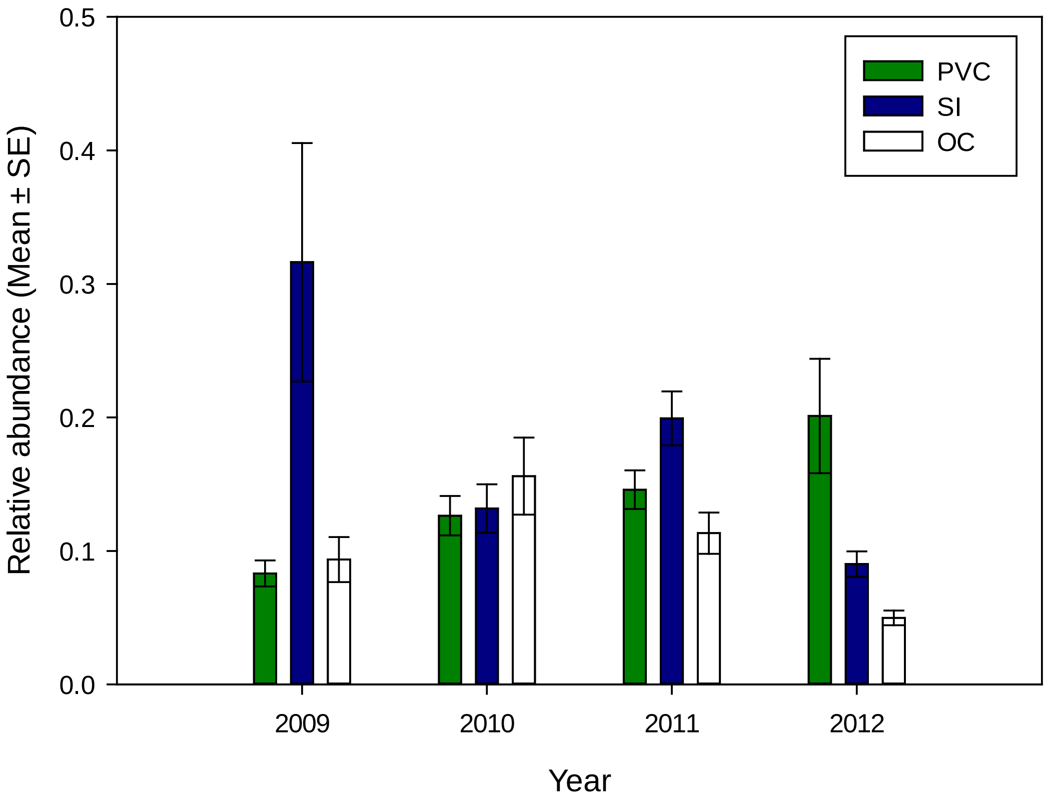

Figure 3.5 Relative abundance (mean m^{-2} ± SE) of mobile fauna (N) for each treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control) in 2009, 2010, 2011 and 2012

3.2.2 Species Richness

Species richness was greatest in the SI in 2011 (13.8 min^{-1} ± 0.87) and lowest within the PVC in 2009 (7.00 min^{-1} ± 0.34), (Figure 3.6). A significant difference was identified between Years, and a significant Year x Treatment interaction was identified (both $P < 0.01$; Annex B, Table B6).

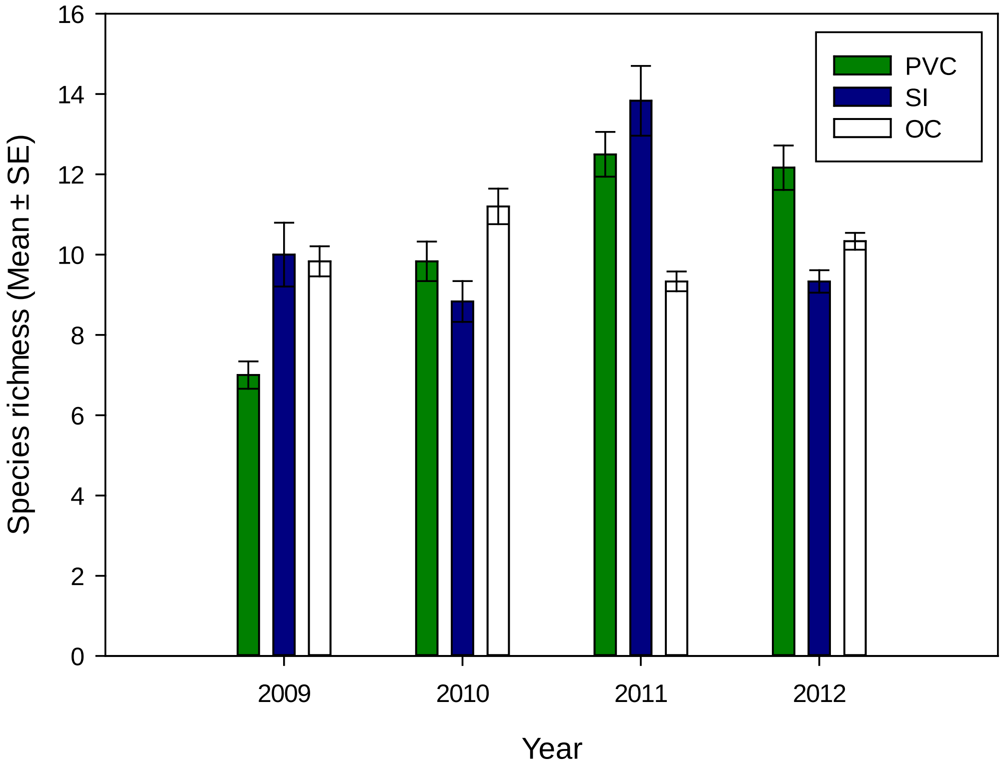

Figure 3.6 Mobile fauna species richness (Mean min^{-1} ± SE) for each treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control) in 2009, 2010, 2011 and 2012

3.2.3 Assemblage composition

A significant Year x Treatment interaction was identified for assemblage composition ($P < 0.05$) as illustrated in Figure 3.7 using non-metric multidimensional scaling (nMDS). The MDS plot shows in 2011 the SIs became more similar to the OCs and this trajectory has continued into 2012. Until 2011, the PVC path was on a trajectory away from the OC, but in 2012 it appears to be moving back towards the OCs (Figure 3.7).

Pairwise tests for the Year x Treatment interaction showed that in 2009, all Treatments were significantly different from each other (all $P < 0.05$). Also, in 2011, the assemblage composition was significantly different in the PVC and the SI to the OC (both $P < 0.05$). In 2012, assemblage composition was significantly different in the PVC to the OC ($P < 0.01$; Annex B, Table B6).

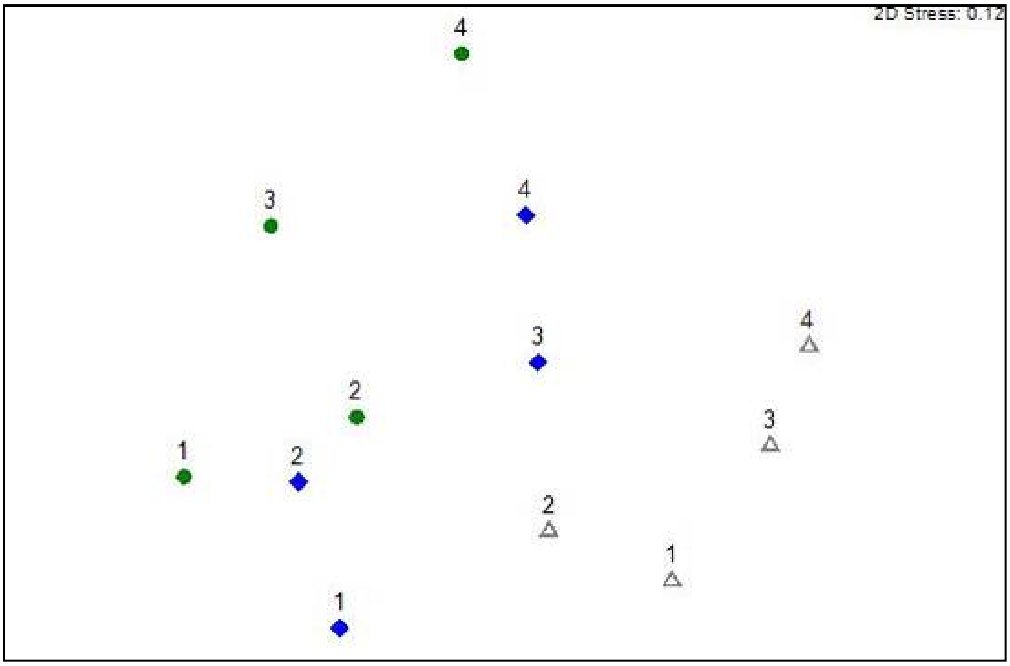

Figure 3.7 nMDS plot showing the degree of similarity between mobile species composition at sites within the 4 experimental treatments (Pre-existing Voluntary Closure = green circles, Statutory Instrument = blue diamonds, Open Control = grey triangles) between years (1 = 2009, 2 = 2010, 3 = 2011, 4 = 2012)

3.3 Analysis of indicator species

The indicator species' univariate analyses were based on data from one of the three video datasets, either video transect (V), frame grab (F) or BRUV (B) (as indicated in Tables 3.2, 3.3 & 3.4). They are presented here in three categories (Jackson et al. 2008): Key species that were preselected by Defra, sessile species, and free living species. Summary tables are included for each grouping detailing the results per species which relate to evidence for recovery (Tables 3.2, 3.3, 3.4), along with graphs summarising abundance by Treatment and Year (Figures 3.8, 3.9, 3.10). For clarity and readability, full results of pairwise tests are given in Annex B, Tables B9 – B24.

3.3.1 Key Species

Table 3.2 Summary table of key results showing evidence for recovery of key indicator species quantified using towed video (V) or frame grabs (F). With the exception of 'Trend towards recovery?' all results are taken from PERMANOVA and pairwise tables presented in Annex B Tables B9 – B15 with results presented where a significant difference was detected. 'Yes' in the Yr * Tr SI ≥ PVC column indicates that Yr * Tr was significant and the abundance in SI is now greater than in the PVC treatment. 'No' indicates a significant Yr * Tr difference but SI treatment is not more than or equal to that in the PVC. A dash indicates no significant difference. 'Trend towards recovery' refers to when a recovery trend is apparent but not statistically significant. In the highest abundance column if year and treatment were significant, the year and treatment with the highest abundance are noted. The recoverability (low, medium, high) of each species is also given (Jackson et al*.* 2008).

			Evidence of recovery?		**Highest abundance**	
Species	**1° data source**	**Recover -ability**	**Yr * Tr SI ≥ PVC?**	**Trend towards recovery?**	**Year**	**Treatment**
P. maximus	V	High	Yes	-	2011	-
P. mammillata	V	Medium	No	-	-	PVC
C. pumicosa	F	Low	No	-	2011	PVC
P. fascialis	F	Low	No	-	2011	PVC
Grouped anemones	F	-	-	-	2011	-
A. digitatum	V	Low	-	Yes	2012	-
E. verrucosa	V	Low	-	Yes	-	-

***Pecten maximus* – King scallop (V)**

Abundance of *Pecten maximus* increased in the SI from 2008 to 2011 (mean abundance 2008 = 0.29 m^{-2} ± 0.04, 2012 0.76 m^{-2} ± 0.13) (Figure 3.8) relative to the controls indicated by a Treatment x Year interaction (P < 0.01). By 2010, Pecten was significantly more abundant in the SI than the OC (P < 0.01), but Pecten abundance then decreased in the SI in 2012 (Annex B, Table B9).

***Phallusia mammillata* – A sea squirt (V)**

Abundance of *Phallusia mammillata* increased in the SI relative to the Open Controls from 2008-2009 (mean abundance 2008 0.08 m^{-2} ± 0.04, 2009 0.25 m^{-2} ± 0.09) (Figure 3.8). A Year x Treatment interaction was identified (P < 0.05) and from 2009-2012 *P. mammillata* was significantly more abundant in the SI than the OC (P < 0.05; Annex B, Table B10).

***Cellepora pumicosa* – A sea mat (F)**

A Year x Treatment interaction was identified for the abundance of *Cellepora pumicosa* (P < 0.05) (Figure 3.8). Abundance in the SI and PVC was significantly greater than the OC from 2008-2012 (all P < 0.05; Annex B, Table B11).

Pentapora fascialis – Ross coral (F)

Abundance of *Pentapora fascialis* was steady from 2008-2010 (mean abundance 2008 0.32 m^{-2} ± 0.07, 2010 0.45 m^{-2} ±0.12), increased in 2011 (mean abundance 2011 1.81 m^{-2} ± 0.23) and decreased in 2012 (mean abundance 2012 0.54 m^{-2} ± 0.09) (Figure 3.8). Abundance was significantly greater in the PVC and SI compared to the OC from 2008-2012 (all $P < 0.05$), identified by a Year x Treatment interaction ($P < 0.001$; Annex B, Table B12).

Grouped Anemones (F)

Abundance of the grouped anemones *Aiptasia mutabilis, Cerianthus* spp*., Peachia cylindrica and Sagartia* spp. increased in the SI (mean abundance 2011 = 0.06 m^{-2} ± 0.04, 2012 = 2.38 m^{-2} ± 1.08) and OC (mean abundance 2011 = 6.76 m^{-2} ± 0.62, 2012 = 6.89 m^{-2} ± 0.29) and decreased in the PVC (mean abundance 2011 = 6.44 m^{-2} ± 1.34, 2012 = 1.08 m^{-2} ± 0.25) (Figure 3.8). There was a significant Year effect on abundance ($P < 0.01$) but there was Treatment effect (Annex B, Table B13).

Abundance of grouped anemones in the SI remained steady from 2008-2011 then increased in 2012 (mean abundance 2011 0.07 m^{-2} ± 0.04, 2012 2.39 m^{-2} ± 1.08) (Figure 3.8). Abundance showed a significant Year effect ($P < 0.01$) but no Year x Treatment effect from 2008-2012 (Annex B, Table B13).

Alcyonium digitatum – Dead man's fingers (V)

Abundance of *Alcyonium digitatum* increased in all treatments in 2012. The greatest increase was seen in the SI (mean abundance 2011 = 1.13 m^{-2} ± 0.23, 2012 = 2.63 m^{-2} ± 0.71) (Figure 3.8). A significant Year effect was identified ($P < 0.01$), but there was no Year x Treatment effect (Annex B, Table B14).

Eunicella verrucosa – Pink sea fan (V)

Abundance of *Eunicella verrucosa* increased in the SI compared to controls from 2008-2010, decreased in 2011 then increased in 2012 (mean abundance 2008 0.14 m^{-2} ± 0.09, 2010 0.67 m^{-2} ± 0.27, 2011 0.34 m^{-2} ± 0.13, 2012 0.53 m^{-2} ± 0.19) (Figure 3.8) although this is not yet indicated by a significant Year x Treatment interaction(Annex B, Table B15).

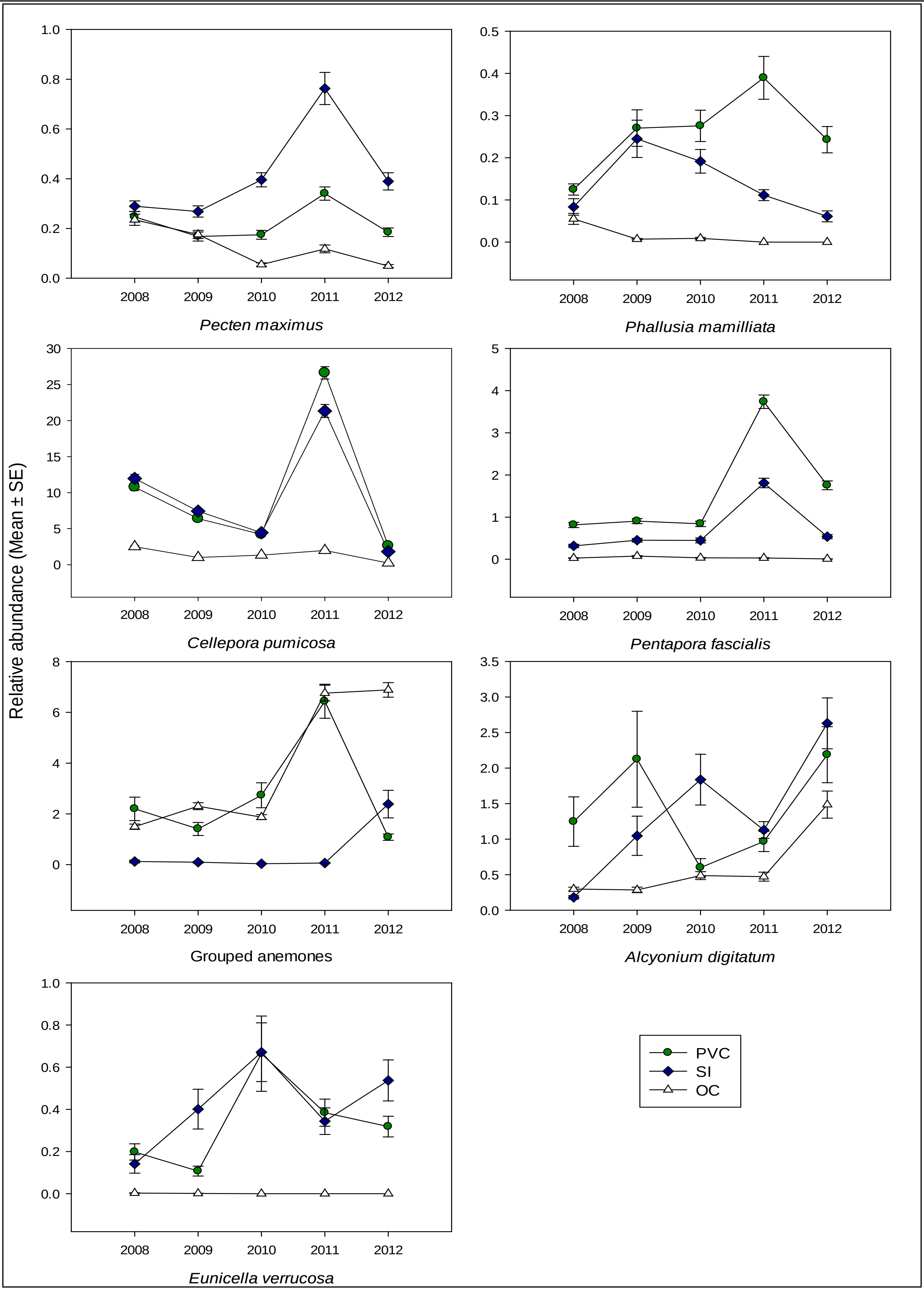

Figure 3.8 Relative abundance of key indicator species (Mean m^{-2} ± SE) per treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control), per year (2008, 2009, 2010, 2011, 2012). Scales on the y-axes vary

3.3.2 Other sessile species

Table 3.3 Summary table of the key results showing evidence for recovery for the sessile indicator species quantified using towed video (V) or frame grabs (F). With the exception of 'Trend towards recovery?' all results are taken from the PERMANOVA and pairwise tables presented in Annex B Tables B16-B18 with results presented where a significant difference was detected. 'Trend towards recovery' refers to when a recovery trend is apparent but not statistically significant in NC sites. The recoverability (low, medium, high) of each species is also given (Jackson et al*.* 2008).

			Evidence of recovery?		**Highest abundance:**	
Species	**1° data source**	**Recover-ability**	**Yr * Tr NC ≥ PVC?**	**Trend towards recovery?**	**Year**	**Treatment**
C. variopedatus	F	High	-	-	2011	-
T. auratium	-	-	-	-	-	-
Grouped hydroids	F	-	-	-	2011	PVC
C. celata	-	-	-	-	-	-
Branching sponges	V	-	No	-	2012	PVC

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	5.9361	1.484	2.75	**0.0239**
Treatment Tr	2	4.0198	2.0099	2.09	0.1405
Area Ar(Tr)	22	17.342	0.78825	3.26	**0.0003**
YexTr	8	7.321	0.91512	1.92	0.0705
Site (Ar(Tr))	61	14.223	0.23316	0.92	0.6238
YexAr(Tr)	58	25.276	0.4358	1.73	**0.0064**
Residual	133	33.545	0.25222		
Total	288	107.66			

Chaetopterus variopedatus – Parchment worm (F)

Abundance of *Chaetopterus variopedatus* decreased from 2008-2010 (mean abundance 2008 1.22 m^{-2} ± 0.36, 2010 0 m^{-2} ± 0). A rise in abundance was seen in 2011 (mean abundance 2011 2.93 m^{-2} ± 0.77) but a decrease was seen in 2012 (2012 0.21 m^{-2} ± 0.06) (Figure 3.9). No Year x Treatment interaction has been identified for the abundance of *Chaetopterus variopedatus* (Annex B, Table B16).

Tethya citrina – Golf ball sponge

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

Grouped hydroids (F)

Abundance of grouped hydroids increased in the SI from 2008-2011 (mean abundance 2008 30.37 m^{-2} ± 3.7, 2011 106.65 m^{-2} ± 5.53) and decreased in 2012 (mean abundance 68.92 m^{-2} ± 3.69) (Figure 3.9). No Year x Treatment interaction has been identified (Annex B, Table B17).

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 0.17 m^{-2} ± 0.09, 2009 0.02 m^{-2} ± 0.01) but has increased from 2009 to 2012 (mean abundance 2012 0.23 m^{-2} ± 0.07), indicated by a significant Year x Treatment interaction ($P < 0.01$) (Figure 3.9). Abundance in the SI has been significantly greater than Open Controls since 2010 (all $P < 0.05$; Annex B, Table B18).

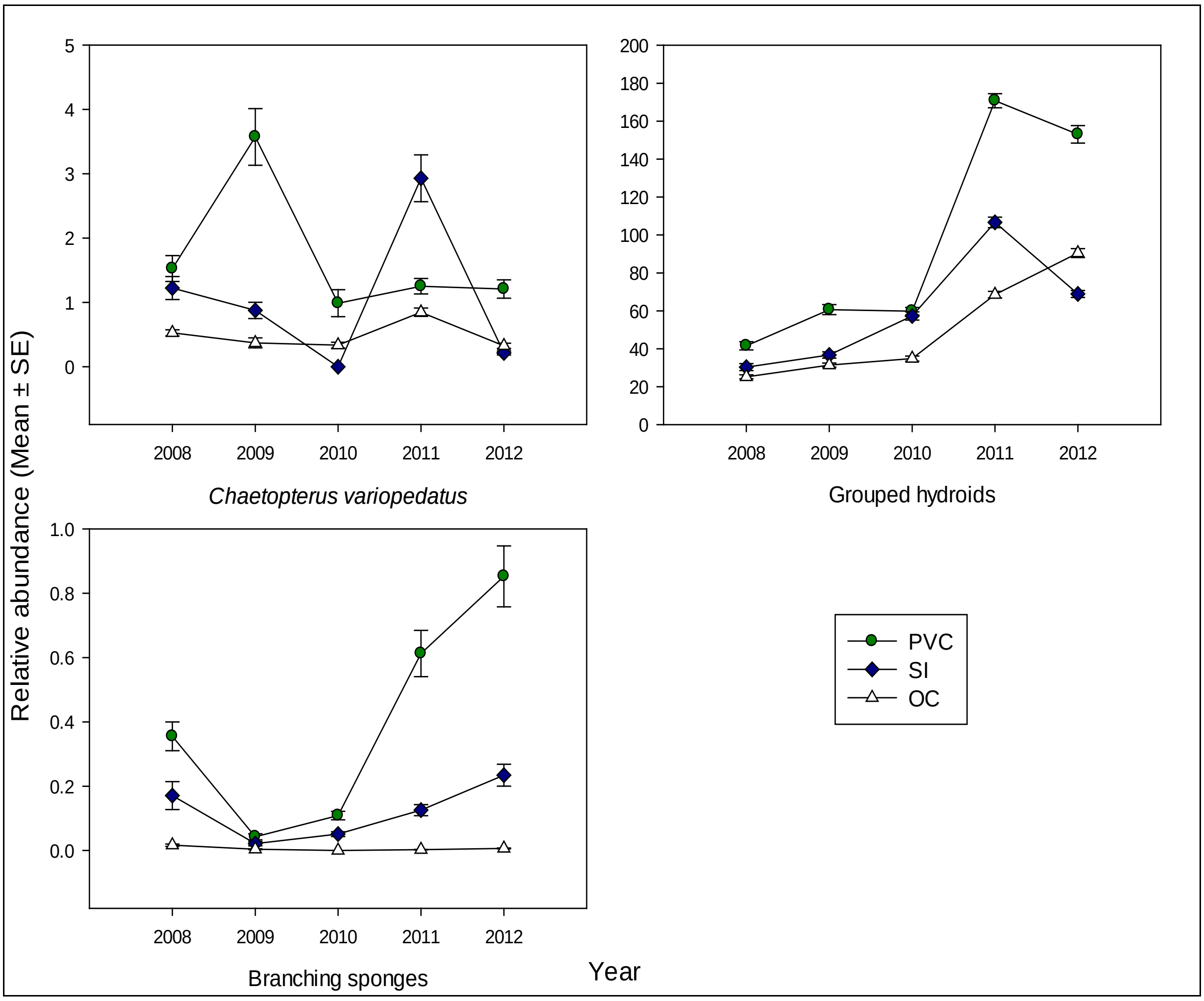

Figure 3.9 Relative abundance of sessile indicator species (Mean m^{-2} ± SE) per treatment (PVC = pre-existing voluntary closure, SI = Statutory Instrument, OC = Open Control), per year (2008, 2009, 2010, 2011, 2012) Scales on the y-axes vary

3.3.3 Free living species

Table 3.4 Summary table of the key results showing evidence for recovery for the free living indicator species quantified using towed video (V) or baited video (B). With the exception of 'Trend towards recovery?' all results are taken from the PERMANOVA and pairwise tables presented in Annex B Tables B19 – B24 with results presented where a significant difference was detected. 'Trend towards recovery' refers to when a recovery trend is apparent but not statistically significant in NC sites. The recoverability (low, medium, high) of each species is also given (Jackson et al*.* 2008)

			Evidence of recovery?		Highest abundance:	
Species	**1° data source**	**Recover-ability**	**Yr * Tr NC ≥ PVC?**	**Trend towards recovery?**	**Year**	**Treatment**
A. rubens	V	High	-	-	-	-
T. minutus	B	High	No	-	2009	-
N. puber	V	Medium	-	-	2010	PVC
C. pagurus	V	Medium	-	-	-	PVC
C. rupestris	B	Medium	No	-	2011	PVC
Grouped gobies	B	-	-	-	2010	-

Asterias rubens – Common starfish (V)

Abundance of *Asterias rubens* has increased in the SI from 2008-2012 (mean abundance 2008 0.16 m^{-2} ± 0.07, 2012 0.33 m^{-2} ± 0.08) (Figure 3.10) although no Year x Treatment interaction has been identified (Annex B, Table B19).

Trisopterus minutus – Poor cod (B)

Abundance of *Trisopterus minutus* in the SI decreased from 2009-2010 (mean abundance 2009 9.4 m^{-2} ± 5.86, 2010 1.00 m-2 ± 0.58) and has remained steady from 2010-2012 (mean abundance 2012 0.68 m^{-2} ± 0.26) (Figure 3.10), indicated by a significant Year x Treatment interaction ($P < 0.05$; Annex B, Table B20).

Necora puber – Velvet swimming crab (V)

Abundance of *Necora puber* in the SI increased from 2008-2010 (mean abundance 2008 0.004 m^{-2} ± 0.002, 2010 0.03 m-2 ± 0.01) and decreased from 2010-2012 (mean abundance 2012 0.004 m^{-2} ± 0.003) (Figure 3.10), although no Year x Treatment interaction was identified (Annex B, Table B21).

Cancer pagurus – Edible crab (V)

Abundance of *Cancer pagurus* in the SI remained steady from 2008-2011 (mean abundance 2008 0.004 m^{-2} ± 0.003, 2011 0.004 m^{-2} ± 0.001) and decreased in 2012 (mean abundance 2012 0.0009 m^{-2} ± 0.0009) (Figure 3.10). No Year x Treatment interaction was identified (Annex B, Table B22).

Ctenolabrus rupestris – Goldsinny wrasse (B)

Abundance of *Ctenolabrus rupestris* in the SI was steady in 2009 and 2010 (mean abundance 2009 0.25 m^{-2} ± 0.07, 2010 0.21 m^{-2} ± 0.1), then increased in 2011 (mean abundance 2011 0.9 m^{-2} ± 0.31) and decreased in 2012 (mean abundance 2012 0.15 m^{-2} ± 0.08) (Figure 3.10), indicated by a significant Year x Treatment interaction ($P < 0.05$). Abundance was significantly greater in the SI compared to Open Controls in 2011 ($P < 0.05$) but not in 2012 (Annex B, Table B23).

Grouped gobies (B)

Abundance of grouped gobies in the SI has shown an overall decrease but has been variable from 2009 to 2012 (mean abundance 2009 1.13 m^{-2} ± 1.13, 2010 2.34 m^{-2} ± 2.34, 2012 0.96 m^{-2} ± 0.96) (Figure 3.10). No Year x Treatment interaction has been identified (Annex B, Table B24).

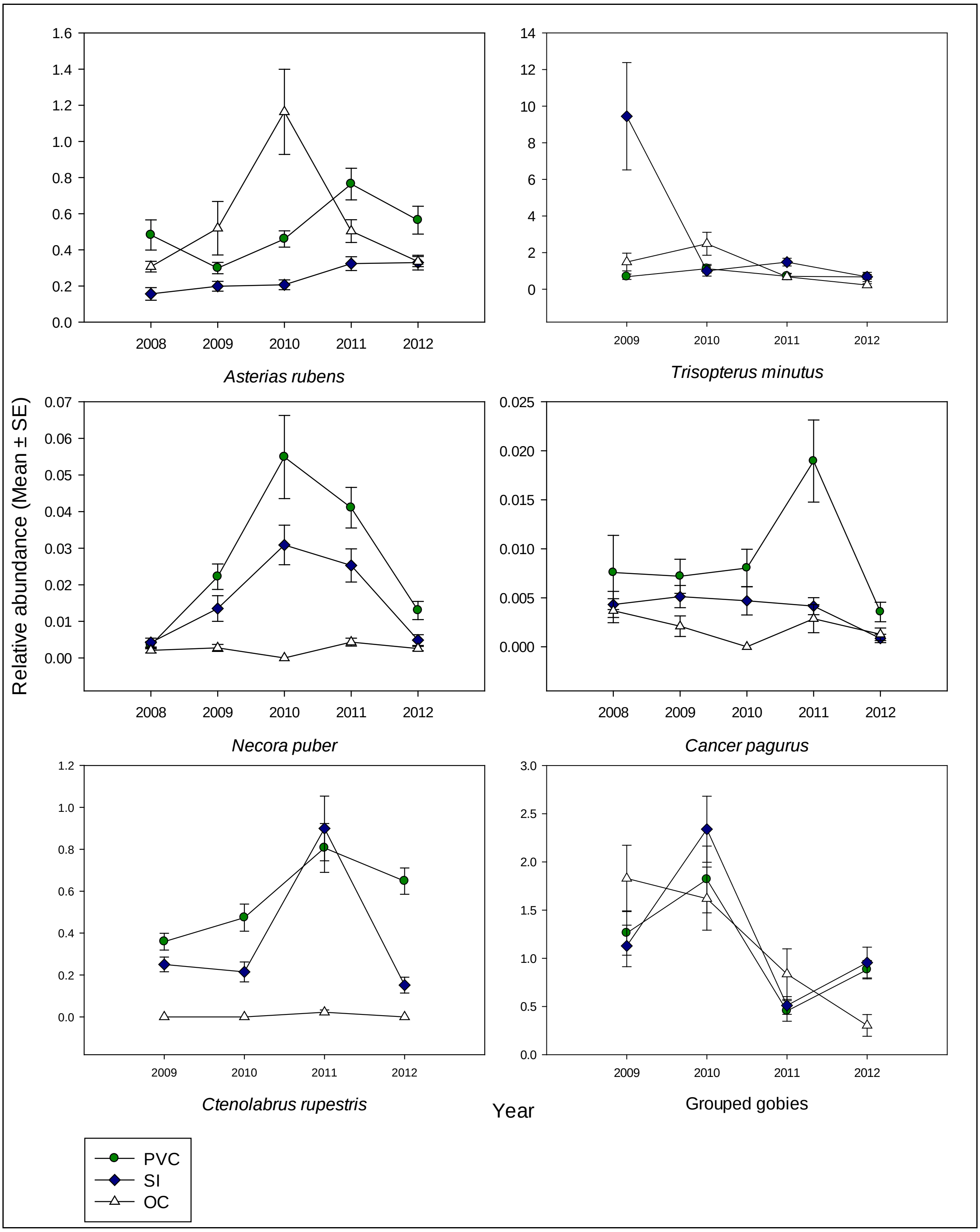

Figure 3.10 Relative abundance (Mean m^{-2} / min^{-1} ± SE) of free living indicator species per treatment (PVC = Pre-existing Voluntary Closure, SI = Statutory Instrument, OC = Open Control), per year (2008, 2009, 2010, 2011, 2012). Abundance of *Asterias rubens, Necora puber and Cancer pagurus* presented as mean m^{-2}. Abundance of *Trisopterus minutus*, *Ctenolabrus rupestris* and Grouped gobies presented as mean min^{-1}. Scales on the y-axes vary

3.4 Sensitive Areas analysis

Assemblage composition was significantly different for every factor tested. A significant Year x Treatment interaction was found ($P < 0.01$) with pairwise tests showing that in 2011 and 2012, the assemblage composition in the SA was significantly different from the PVC (both $P < 0.01$), but not from the OC (Annex B, Table B25).

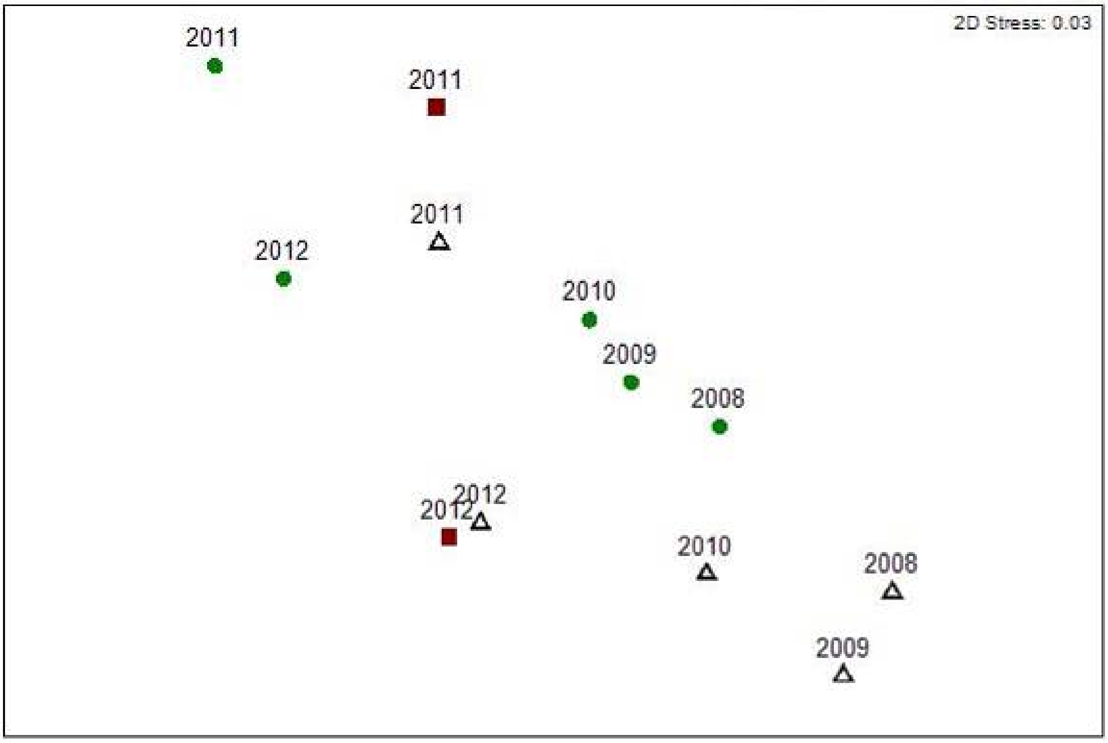

Figure 3.11 nMDS plot illustrating similarities in assemblage composition between Treatments (averaged for site within treatment), (Pre-existing Voluntary Closure = green circles, Sensitive Area = red squares, Open Control = black triangles), over time (2008, 2009, 2010, 2011, 2012)

In 2011 assemblage composition had become less similar compared to the same metric in 2008. The assemblage composition of sites in the SA and OC treatments became more similar to each other in 2012, whereas assemblage composition in the PVC was less similar to these treatments (Figure 3.11).

4 Discussion

The 2012 sampling season marked the fourth year of sampling since the enforcement of the SI, and the fifth benthic survey. Annual monitoring of benthic assemblages and reef associated nekton has provided the first large scale recovery data set for temperate reef assemblages that is a valuable resource for future marine management over national, European and international scales. Before this project, it was unknown whether alleviating fishing pressure would allow benthic communities to functionally recover, and thereby restore lost marine goods and services provided by diverse benthic assemblages. While it is still early days, and we would not like to overstate the degree of recovery, the early signs are clear that habitat forming and commercially valuable species are beginning to recover in Lyme Bay, and this should be used as a case study to promote MPAs as both a fisheries and conservation tool. We strongly recommend that the current SI remains in place and that the monitoring is continued to provide a benchmark for other MPAs so that managers can predict over what timescales delivery of goods and services can be expected from newly protected benthic assemblages.

In 2012, new species were observed for the first time using the baited video method: sand eel *Ammodytes marinus*; European sea bass *Dicentrarchus labrax*; spoon worm *Thalassema thalassemum;* butterfly blenny *Blennius ocellaris;* compass jellyfish *Chrysaora hysoscella;* and ray *Raja* sp. The common cuttlefish *Sepia officinalis* was also seen for the first time in the baited video, but had been seen in the towed video in previous years.

4.1 Towed video survey

From 2008 to 2011 we observed positive trends for species richness and overall abundance in the SI and the PVC relative to the OCs, however, these trends decreased in 2012. While it can be expected that natural cycles will vary over time, the reduced metrics experienced in 2012 could be explained by extremely poor weather in 2012. There was an increased average rainfall in June and July of 2012 in the UK, (Met Office, 2012) and strong westerly winds that were responsible for bad visibility (Langmead et al. 2010), which may have affected our ability to observe species from the video. However the 2012 metrics remain greater than in 2010 across all treatments.

If adverse conditions continue high levels of suspended material could impact the benthic assemblages. High turbidity reduces the feeding ability of *Eunicella verrucosa* due to soft tissue damage (Langmead et al. 2010). Also, increased turbidity levels can directly affect the growth and survival of fish by interfering with gill function (Bash et al. 2001) and filtration rates in scallops (Wildish et al. 1987). Furthermore, suspended sediment at higher current speeds can cause direct mortality in other organisms from abrasion or burial (Maurer et al. 1986).

Despite the overall trends for 2012 not continuing the marked improvement seen in 2011, abundant species in the SI and PVC sites driving the differences between these treatments and the OC included some with predicted low recoverability such as *Cellepora pumicosa* and *Alcyonium digitatum* rather than scavenging species that were more abundant in the OC sites, such as *Ophiura ophiura* and *Pagurus bernhardus*.

Results from the Isle of Man scallop fishery closure are particularly relevant here, showing evidence of enhanced scallop stocks, enhanced habitat complexity and increased biodiversity 11 years after closure (Bradshaw et al. 2003). The increase in habitat complexity and biodiversity was attributed to an increase in the density of hydroids with mean values of 0.30 m^{-2} in areas open to fishing and 0.50 m^{-2} in closed areas (Bradshaw et al. 2003). The authors were surprised that the density of hydroids outside the closure was not lower, but they attributed this to a lack of fishing effort in the period preceding the study as seasonal closures were in place and hydroids can be quick to recover. We found that by 2011, both the protected treatments had greater abundances of hydroids than the open treatment, however, in 2012 the SI had on average fewer hydroids than the other two treatments.

One trend which was of particular interest in 2011 was evidence of recovery at sites within the SI which were thought to be unable to recover due to the apparent scarcity of hard substrata. Species such as *Alcyonium digitatum,* which require hard substrate to attach to were, however, observed growing on areas of soft sediment between cobble reefs, leading to the assumption that the sediment is overlaying harder substrata. The finding that *A. digitatum* populations, which were thought to have a low potential of recovery, have increased in abundance in 2012 across all treatments highlights the importance of this trend being further examined to inform management, as it is possible that these areas will provide stepping stones between the areas of rocky reef within the SI.

4.2 Baited video

The baited video data comprise four years of survey, 2009-2012. Over this time there was a significant Year x Treatment interaction for species richness and assemblage composition. Diversity is increasing inside the SI relative to the OCs. Similarly to the towed video dataset though, fewer species were observed in the SI in 2012 than in 2011.

The literature supports 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 baited survey results do not yet conform to this theory.

For closed sites, the top five species associated with the within treatment similarities in 2012 included one and two scavenging species (PVC and SI respectively; *Pagurus bernhardus and Pagurus bernhardus and Ophiura* spp.) whereas four of the top five species associated with within treatment similarities in the OC were scavengers (*Pagurus bernhardus, Ophiura* spp., *Inachus* spp. and *Asterias rubens*). These assemblages have altered since 2009 as there were two scavenging species within the top five in PVC, three in the SI and three in the OC.

4.3 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). They 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).

Overall, trends of the indicator species that were increasing in the SI relative to the OCs from 2008 to 2011 then decreased in 2012, such as *P. maximus*, *P. fascialis* and *Ctenolabrus* *rupestris*. Only the abundance of two taxa had their greatest abundances in 2012, which were *A. digitatum* and branching sponges. Increasing trends of *P. fascialis* were encouraging as it 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 and Ferdeghini, 2001, McKinney and Jackson, 1989 in: Lombardi, 2007). 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), so its decreased abundance since 2011 is a worrying sign for the recovery of closed sites. The 2013 survey will identify whether downward trends are indicative of actual abundance changes or down to poor visibility.

Recovery of king scallop *P. maximus* populations in the SI had been apparent since 2009, with the increase in abundance between 2010 and 2011 particularly marked. However, between 2011 and 2012, there was a decrease in abundance with numbers similar to those seen in 2010. *P. maximus* is a high recoverability species and its early recovery was therefore expected. However, the recent decline is not expected as similar studies such as that of Stokesbury et al. (2004), who assessed the north-east American *Placopecten magellanicus* population, and identified a greater abundance of scallops within areas closed to mobile fishing gear. Abundance of *P. maximus* was still greater in the PVC and the SI than in the fished area. It is hoped that with time, the protection of the SI will increase the survival of *P. maximus*, leading to a more stable and fecund population as large individuals are no longer being removed. This could result in spill over of individuals from the SI into the fished areas, benefitting the scallop fishery in the bay.

A significant Year x Treatment trend was found for *Alcyonium digitatum* and abundance in the SI was greater than the abundance in the PVC; therefore this species is showing a trend towards recovery. The abundance of this species increased between 2011 and 2012 in the PVC and the SI. A trend towards recovery has also been seen in *Eunicella verrucosa* due to abundance declining in the PVC, and increasing in the SI between 2011 and 2012.

The abundance of grouped gobies and branching sponges have also increased between 2011 and 2012, however neither show a trend towards recovery. This highlights that there is still very high variability in abundance of some species, and that more time is required to determine whether trends identified remain consistent between years and recovery can definitely be identified.

The abundance of grouped anemones (*Aiptasia mutabilis*, *Cerianthus* spp., *Peachia cylindrica* and *Sagartia* spp.) is highest in the OC in 2012. Also, abundance has markedly decreased in the PVC. The reasons for this are not clear, but it is thought that *Cerianthus* spp. are likely driving the higher abundance in the OC as these are associated with soft sediment habitats and were therefore recorded in areas of cobble and boulder habitat with exposed sediment patches.

The abundance of grouped hydroid species have declined in the PVC and the SI for the first time. However, abundance in the OC still continues to increase. Despite an increase in the abundance of *Cancer pagurus* in the PVC in 2011, there has been a decrease between 2011 and 2012. These findings support the indication in Attrill et al. (2012 *in press*) that there is still variation in the results.

4.4 Sensitive Areas

Assemblage composition within sites in the sensitive areas is not significantly different to the open control sites but is significantly different to PVC sites, potentially suggesting that the period of time that the SA sites have been protected for is not sufficient to see a difference compared to fished sites.

4.5 Further notes of interest

In 2011 the population of the sea cucumber *Cucumaria frondosa* was seen to have expanded dramatically from 2010. Individuals were seen in large numbers within communities growing on sediment with species including *Alcyonium digitatum*. In 2012 a large increase in the numbers of brittlestars *Ophiothrix fragilis* was observed. Video from two sites in the 2012 survey could not be obtained because so many brittlestars were present that the seabed was obscured. The species was not included in the overall abundance graphs for towed video data due our inability to identify rocky reef habitat. 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).

5 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. Attrill et al. (2012 *in press*) reported the results from the baseline survey and three years post closure, and this report has provided results from an additional year. It was understood from the outset that two years would not be sufficient for the re-establishment of most species in the SI due to their life history traits, and the addition of a fourth year of sampling has shown that whilst some indicator species are showing signs of recovery, variation within the results demonstrate that it is still too early for firm conclusions to be drawn.

Previous studies have shown that the speed of recovery of assemblages in MPAs varies, with some species, such as those previously targeted by fisheries, undergoing rapid recovery and other trophic and structural changes taking in excess of 25 years (Ballantine and Langlois, 2008; Hoskin et al. 2011). It is therefore, accepted that recovery in the Lyme Bay system will take time. As of June 2012 the PVC sites had been protected for between six to 11 years and SI sites for four years, so it is 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, with some species already exhibiting recovery trends whilst others are still varying too much for a trend towards recovery to be evident, suggesting that the Lyme Bay system is recovering.

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 reef systems and their recovery from physical disturbance.

It is also essential that the monitoring is continued over a long timescale to determine whether the early recovery identified to date is more than a short term phenomenon. This has major implications; if it is determined that no recovery is occurring there is likely to be pressure from the fishing industry for the area to be reopened. Monitoring is essential to assess the state and pace of recovery in order to robustly deal with such requests. The suggestion that recovery is possible in areas that appear to be soft sediment, probably overlying bedrock, between the reefs is also of great importance for the understanding of temperate systems and for future management. This is particularly relevant due to the possibility that the introduction of Vessel Monitoring Systems (VMS) will result in boats which are fitted with this technology being permitted to fish between the reefs.

Continuation of the annual sampling of the benthos in Lyme Bay is planned with the aim of reaching a point where recovery can be detected within the new closure for those species which are considered most functionally important and indicators of a healthy ecosystem.

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Annexes

A. Species lists

Table A1 Species list detailing the taxa present and the survey method(s) that they were recorded by (F = Frames, V = Video, B = Baited)

Scientific name	Common name	F Count	F Cover	V	B
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	Lesser sand-eel				Y
Amphilectus fucorum/ Iophon spp.	Shredded carrot sponge/*Iophon* spp.		Y		
Grouped anemones	Grouped anemones	Y			
Anseropoda placenta	Goose foot starfish	Y		Y	
Aplidium elegans	Sea-strawberry	Y			
Archidoris pseudoargus	Sea lemon	Y			
Ascidiella aspersa	Fluted Sea Squirt	Y			
Ascidia mentula	A sea squirt	Y			
Aslia lefevrei	Brown sea cucumber	Y			
Aspitrigla cuculus	Red Gurnard	Y		Y	Y
Asterina gibbosa	Cushion Star	Y			
Asterias rubens	Common starfish	Y		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	Branching sponges (grouped)	Y		Y	
Buccinum undatum	Common whelk	Y			Y
Callionymus lyra	Common Dragonet	Y		Y	Y
Calliostoma zizyphinum	Painted topshell	Y			Y
Cancer pagurus	Edible crab	Y		Y	Y
Caryophyllia smithii	Devon 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			
Chrysaora hysoscella	Compass jellyfish				Y
Ciona intestinalis	A sea squirt	Y		Y	
Ciocalypta penicillus	A sponge	Y			
Cliona celata	A boring sponge		Y		
Unid. clingfish	Unid. clingfish			Y	

Scientific name	Common name	F Count	F Cover	V	B
Unid. colonial ascidian	Unid. colonial ascidian	Y			
Conger conger	Conger eel				Y
Corystes cassivelanus	Masked crab			Y	
Corynactis viridis	Jewel anemone	Y			
Unidentified crab	Unidentified crab			Y	
Crepidula fornicata	Slipper limpet	Y			
Crenilabrus melops	Corkwing wrasse	Y			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 sea squirt		Y		
Diplosoma spongiforme	A sea squirt		Y		
Dysidea fragilis	A sponge	Y			
Ebalia granulosa	A crab	Y			
Echinus esculentus	Edible sea urchin	Y			
Encrusting coralline algae	Encrusting coralline algae		Y		
Epitonium clathrus	Common wentletrap	Y			
Eunicella verrucosa	Pink sea fan	Y		Y	
Flustra foliacea	Hornwrack	Y			
Gadus morhua	Atlantic cod			Y	
Grouped gobies	Grouped gobies	Y		Y	Y
Goneplax rhomboides	Mud runner/Square crab	Y		Y	Y
Grantia compressa	Purse sponge	Y			
Gymnangium montagui	Yellow feathers	Y			
Halichondria spp.	A sponge		Y		
Hemimycale columella	An encrusting sponge		Y		
Henricia oculata	Bloody henry	Y			
Hinia reticulata	Netted dog whelk				Y
Holothuria forskali	Cotton spinner	Y		Y	
Hyas coarctatus	Toad crab	Y		Y	
Grouped hydroids	Grouped hydroids	Y			
Hommarus gammarus	Common lobster				Y
Inachus spp.	Spider crabs	Y		Y	Y
Labrus bergylta	Ballan wrasse			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			
Lissoclinum perforatum	A sea squirt		Y		
Luidia ciliaris	Seven-armed starfish	Y			

Scientific name	Common name	F Count	F Cover	V	B
Macropodia spp.	Spider crabs	Y		Y	Y
Maja squinado	Spiny spider crab	Y		Y	Y
Megalomma vesiculosum	A fanworm	Y			
Metridium senile	Plumose anemone	Y			
Microstomus kitt	Lemon sole			Y	
Molgula manhattensis	Sea grapes	Y			
Myxilla incrustans	A sponge		Y		
Myxicola infundibulum	A fanworm	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			
Neptunea antiqua	Red whelk	Y			
Ocnus planci	Small sea cucumber	Y			
Ophiothrix fragilis	Common brittlestar	Y			
Ophiura ophiura	A brittlestar	Y			Y
Pachymatisma johnstonia	A sponge		Y		
Pagurus bernhardus	Common hermit crab	Y		Y	Y
Pagurus prideaux	A hermit crab	Y		Y	Y
Palaemon spp.	Unidentified shrimp	Y			
Parablennius gattorugine	Tompot blenny	Y		Y	Y
Pecten maximus	Great scallop	Y		Y	Y
Pentapora fascialis	Ross coral	Y		Y	
Phallusia mammillata	A sea squirt	Y		Y	
Pisidia longicornis	Long-clawed porcelain crab	Y		Y	
Pleuronectes platessa	Plaice			Y	
Polymastia boletiformis	A sponge	Y			
Polymastia penicillus	Chimney sponge	Y			
Porcellana platycheles	Broad-clawed porcelain crab				Y
Pollachius pollachius	Pollack	Y		Y	
Psammechinus miliaris	Green sea urchin	Y			Y
Raja clavata	Thornback ray	Y		Y	Y
Red algae	Red algae (grouped)	Y			
Sabella pavonina	Peacock worm	Y			
Sagartia elegans	A sea anemone	Y			
Salmacina dysteri	Coral worm	Y			
Scyliorhinus canicula	Lesser spotted dogfish	Y		Y	Y
Scyliorhinus stellaris	Nursehound				Y
Sepia atlantica	Little cuttlefish			Y	
Sepia officinalis	Common cuttlefish	Y		Y	Y
Serpula vermicularis	A tubeworm	Y			
Solitary ascidian sp.	Unidentified solitary ascidian spp.	Y			
Solea solea	Sole	Y		Y	
Spondyliosoma cantharus	Black seabream				Y

Scientific name	**Common name**	**F Count**	**F Cover**	**V**	**B**
Encrusting sponge 1	Red encrusting sponge		Y		
Encrusting sponge 2	Yellow encrusting sponge		Y		
Encrusting sponge 3	Pinkish orange encrusting sponge		Y		
Encrusting sponge 4	Orange encrusting sponge		Y		
Encrusting sponge 6	Grey encrusting sponge		Y		
Encrusting sponge 7	Pink encrusting sponge		Y		
Massive sponge 2	Beige, smooth, rounded sponge	Y			
Massive sponge 3	White sponge	Y			
Massive sponge 4	Yellow, lumpy sponge	Y			
Massive sponge 5	Orangey-pink sponge	Y			
Massive sponge 6	Orange, lumpy, uneven sponge	Y			
Massive sponge 7	Beige, smooth, elongated sponge	Y			
Massive sponge 8	Orangey-pink rounded sponge	Y			
Stolonica socialis	Orange sea grapes	Y			
Styela clava	Leathery sea squirt	Y			
Suberites carnosus	A sponge	Y			
Suberites domuncula	Sea orange, sulphur sponge	Y			
Sycon ciliatum	A sponge	Y			
Symphodus melops	Corkwing wrasse	Y			
Syngnathus acus	Greater pipefish			Y	
Tethya aurantium	Golf ball sponge	Y			
Thalassema thalassemum	A spoon worm				Y
Thorogobius ephippiatus	Leopard goby	Y			
Trachurus trachurus	Atlantic horse mackerel				Y
Trisopterus luscus	Pouting	Y		Y	Y
Trisopterus minutus	Poor-cod	Y		Y	Y
Tritonia nilsodhneri	A sea slug				Y
Triakidae sp.	Houndshark				Y
Turritella communis	Auger/tower shell	Y			
Turf	Turf algae		Y		
Urticina felina	Dahlia anemone	Y			
Xantho incises	Montagu's crab			Y	Y
Zeus faber	John dory	Y		Y	
Zeugopterus punctatus	Topknot	Y		Y	
Unid. juvenile fish spp.	Unid. juvenile fish spp.				Y
Unid. bryozoan	Unid bryozoan	Y			

Table A2 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 fascialis	Yes	
Aiptasia mutabilis	Yes	Grouped anemones
Eunicella verrucosa	Yes	
Alcyonium digitatum	Yes	
Chaetopterus variopedatus	Yes	
Tethya citrina	Yes	Insufficient data. No suitable replacement
Halecium halecinum	Yes	Grouped hydroids
Actinothoe sphyrodeta	No	None suitable
Hydrallmania falcata	Yes	Grouped 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 pagarus	Yes	
Labrus bergylta	Yes	Insufficient data. *Ctenolabrus rupestris*
Thorogobius ephippiatus	Yes	Grouped gobies
Leptopsammia pruvoti	No	None suitable

B. PERMANOVA results

Frame grab Analysis

Abundance:

Table B1 Results of a) Permanova for the relative abundance of the main assemblage cover species identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the term Treatment. Data were dispersion weighted and square root transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	4	72.517	18.129	25.08	**0.0001**
Treatment Tr	2	28.198	14.099	5.27	**0.0116**
Area Ar(Tr)	22	47.069	2.1395	6.16	**0.0001**
YexTr	8	6.4932	0.81165	1.49	0.1775
Site (Ar(Tr))	61	20.212	0.33135	1.54	**0.0252**
YexAr(Tr)	58	28.707	0.49495	2.30	**0.0002**
Residual	133	28.657	0.21547		
Total	288	231.85			

b)

Groups	t	P
PVC, SI	2.13	0.0531
PVC, OC	3.25	**0.0037**
SI, OC	1.30	0.2107

Table B2 Results of a) 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), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the term Treatment. Data were dispersion weighted and square root transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	4	75.229	18.807	16.31	**0.0001**
Treatment Tr	2	77.944	38.972	6.85	**0.0052**
Area Ar(Tr)	22	99.918	4.5417	4.28	**0.0001**
YexTr	8	6.056	0.757	0.96	0.477
Site (Ar(Tr))	61	61.7	1.0115	2.82	**0.0001**
YexAr(Tr)	58	41.633	0.71781	2.00	**0.0004**
Residual	133	47.695	0.35861		
Total	288	410.18			

b)

Groups	t	P
PVC, SI	1.21	0.2542
PVC, OC	3.41	**0.003**
SI, OC	2.37	**0.0246**

Species Richness:

Table B3 Results of a) Permanova for the relative species richness of the benthic taxa identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the term Treatment. Data were dispersion weighted and square root transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	4	4.8511	1.2128	14.05	**0.0001**
Treatment Tr	2	8.1814	4.0907	11.26	**0.0002**
Area Ar(Tr)	22	6.3801	0.29	4.31	**0.0001**
YexTr	8	0.60971	7.6214E-2	1.24	0.2801
Site (Ar(Tr))	61	3.922	6.4296E-2	1.64	**0.01**
YexAr(Tr)	58	3.3102	5.7073E-2	1.45	**0.0432**
Residual	133	5.2216	3.926E-2		
Total	288	32.476			

b)

Groups	t	P
PVC, SI	1.54	0.1553
PVC, OC	4.84	**0.0001**
SI, OC	2.97	**0.0077**

Assemblage composition:

Table B4 Results of a) Permanova for the assemblage composition of the benthic taxa identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the interaction Year x Treatment. Data were dispersion weighted and square root transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	4	58117	14529	9.48	**0.0001**
Treatment Tr	2	64000	32000	5.90	**0.0001**
Area Ar(Tr)	22	95533	4342.4	4.25	**0.0001**
YexTr	8	14754	1844.2	1.57	**0.0004**
Site (Ar(Tr))	61	59703	978.73	1.54	**0.0001**
YexAr(Tr)	58	61905	1067.3	1.68	**0.0001**
Residual	133	84530	635.57		
Total	288	4.3854E5			

b)

	2008		2009		2010		2011		2012	
Groups	t	P	t	P	t	P	t	P	t	P
PVC, SI	0.77	0.894	0.97	0.482	1.13	0.2304	1.54	**0.0294**	1.20	0.1661
PVC, OC	1.60	**0.007**	2.03	**0.0054**	2.36	**0.0003**	3.28	**0.0005**	2.82	**0.0019**
SI, OC	1.53	**0.008**	1.72	**0.0131**	2.24	**0.0003**	2.35	**0.0007**	2.35	**0.0031**

Baited Video Analysis

Abundance:

Table B5 Results of a) Permanova for the relative abundance of the reef associated nekton and mobile benthic fauna identified using baited video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factor Site (Si) and their interactions and b) Pairwise testing for the term Year. Data were square root transformed. Analyses were conducted using Bray Curtis similarity. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	3	8.329	2.7763	1.50	**0.0001**
Treatment Tr	2	1.3191	0.65957	1.19	0.3223
Site (Tr)	21	10.271	0.4891	2.18	**0.0204**
YexTr	5	2.1225	0.4245	1.89	0.1083
Residual	38	8.5266	0.22438		
Total	69	30.568			

b)

Groups	t	P
2009, 2010	0.64	0.5303
2009, 2011	7.83	**0.0001**
2009, 2012	0.79	0.4484
2010, 2011	5.01	**0.0004**
2010, 2012	0.21	0.8326
2011, 2012	4.08	**0.0002**

Species Richness:

Table B6 Results of a) Permanova for the relative species richness of the reef associated nekton and mobile benthic fauna identified using baited video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factor Site (Si) and their interactions and b) Pairwise testing for the interaction Year x Treatment. Data were square root transformed. Analyses were conducted using Bray Curtis similarity. Bold type denotes a statistically significant difference.

a)

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	3	1.6006	0.53354	3.91	**0.0001**
Treatment Tr	2	4.3457E-2	2.1728E-2	0.33	0.7326
Site (Tr)	21	1.5732	7.4916E-2	2.09	**0.0245**
YexTr	5	0.74421	0.14884	4.15	**0.0042**
Residual	38	1.3625	3.5855E-2		
Total	69	5.324			

b)

	2009		**2010**		**2011**		**2012**	
Groups	**t**	**P**	**T**	**P**	**t**	**P**	**t**	**P**
PVC, SI	1.97	0.0948	1.09	0.3374	0.40	0.7115	1.73	0.1338
PVC, OC	3.14	**0.0197**	1.03	0.3336	0.84	0.4413	1.60	0.1466
SI, OC	0.22	0.8663	1.66	0.1475	1.10	0.6247	0.47	0.6432

Assemblage composition:

Table B7 Results of a) Permanova for the relative distribution of the reef associated nekton and mobile benthic fauna identified using baited video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factor Site (Si) and their interactions and b) Pairwise testing for the interaction Year x Treatment. Data were square root transformed. Analyses were conducted using Bray Curtis similarity. Bold type denotes a statistically significant difference.

a)

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	3	34743	11581	9.89	**0.0001**
Treatment Tr	2	24225	12113	3.64	**0.0012**
Site (Tr)	21	58772	2798.7	2.64	**0.0001**
YexTr	5	8077.1	1615.4	1.53	**0.018**
Residual	38	40239	1058.9		
Total	69	1.6606E5			

b)

	2009		2010		2011		2012	
Groups	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
PVC, SI	1.52	**0.0227**	0.69	0.9025	0.95	0.5055	0.91	0.6113
PVC, OC	2.14	**0.0032**	1.45	0.1083	2.30	**0.0026**	2.07	**0.0056**
SI, OC	1.59	**0.0111**	1.33	0.0948	1.77	**0.0126**	1.43	0.0644

Indicator Species Analysis

Pecten maximus – Great scallop (V)

Table B9 Results of a) Permanova for the relative abundance of *Pecten maximus* identified using video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the interaction Year x Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	4	0.53876	0.13469	5.02	**0.0013**
Treatment Tr	2	2.2067	1.1033	8.40	**0.0018**
Area Ar(Tr)	17	1.8965	0.11156	4.99	**0.0001**
YexTr	8	0.6543	8.1788E-2	3.73	**0.0017**
Site (Ar(Tr))	48	0.9909	2.0644E-2	1.81	**0.0061**
YexAr(Tr)	51	0.95445	1.8715E-2	1.64	**0.019**
Residual	106	1.2097	1.1413E-2		
Total	236	8.4514			

b)

	2008		2009		2010		2011		2012	
Groups	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
PVC, SI	0.82	0.4984	1.30	0.2122	2.06	0.058	1.97	0.084	2.35	**0.0409**
PVC, OC	0.50	0.7377	0.29	0.9846	1.79	0.1147	2.94	**0.0117**	3.32	**0.0063**
SI, OC	1.08	0.3209	1.04	0.349	3.41	**0.0071**	3.7	**0.0005**	4.99	**0.0009**

***Phallusia mammillata* – A sea squirt (V)**

Table B10 Results of a) Permanova for the relative abundance of *Phallusia mammillata* identified using video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the interaction Year x Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	0.2096	5.2399E-2	2.06	0.0824
Treatment Tr	2	1.5365	0.76823	8.63	**0.002**
Area Ar(Tr)	17	1.2882	7.5776E-2	2.09	**0.0316**
YexTr	8	0.42007	5.2509E-2	2.31	**0.0293**
Site (Ar(Tr))	48	1.6138	3.3621E-2	3.58	**0.0001**
YexAr(Tr)	51	0.97025	1.9024E-2	2.03	**0.0031**
Residual	106	0.99427	9.38E-3		
Total	236	7.0327			

b)

	2008		**2009**		**2010**		**2011**		**2012**	
Groups	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
PVC, SI	0.96	0.3932	0.44	0.8985	0.65	0.6269	2.06	0.0778	2.46	**0.0314**
PVC, OC	2.09	0.0645	1.99	0.0761	2.10	0.069	3.69	**0.0011**	3.97	**0.0025**
SI, OC	0.57	0.7443	2.98	**0.0111**	2.62	**0.0253**	3.23	**0.0008**	2.82	**0.0006**

***Cellepora pumicosa* – A sea mat (F)**

Table B11 Results of a) Permanova for the relative abundance of *Cellepora pumicosa* identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the interaction Year x Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	77.758	19.439	16.73	**0.0001**
Treatment Tr	2	101.22	50.61	13.81	**0.0001**
Area Ar(Tr)	22	64.258	2.9208	6.91	**0.0001**
YexTr	8	15.604	1.9505	2.11	**0.0432**
Site (Ar(Tr))	61	24.648	0.40407	1.20	0.1989
YexAr(Tr)	58	48.106	0.82942	2.46	**0.0001**
Residual	133	44.767	0.33659		
Total	288	376.36			

b)

	2008		2009		2010		2011		2012	
Groups	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
PVC, SI	0.49	0.8111	0.46	0.8369	0.41	0.8883	1.04	0.3194	5.95E-2	1
PVC, OC	3.12	**0.0071**	6.92	**0.0001**	3.40	**0.00234**	6.93	**0.0004**	1.83	**0.0942**
SI, OC	2.20	**0.0392**	2.91	**0.0091**	2.14	**0.0458**	4.41	**0.0012**	2.46	**0.0325**

***Pentapora fascialis* – Ross coral (F)**

Table B12 Results of a) Permanova for the relative abundance of *Pentapora fascialis* identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the interaction Year x Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	9.2155	2.3039	13.90	**0.0001**
Treatment Tr	2	24.95	12.475	14.16	**0.0002**
Area Ar(Tr)	22	15.447	0.70215	4.35	**0.0001**
YexTr	8	4.0625	0.50782	4.36	**0.0009**
Site (Ar(Tr))	61	9.3947	0.15401	2.01	**0.0012**
YexAr(Tr)	58	5.8323	0.10056	1.31	0.1108
Residual	133	10.209	7.6761E-2		
Total	288	79.111			

b)

	2008		2009		2010		2011		2012	
Groups	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
PVC, SI	1.79	0.0995	1.13	0.2887	1.09	0.3079	1.83	0.0947	2.43	0.0366
PVC, OC	4.23	**0.0012**	3.84	**0.0027**	3.86	**0.0026**	5.05	**0.0006**	4.32	**0.0011**
SI, OC	2.79	**0.0091**	2.57	**0.0191**	2.66	**0.0154**	6.63	**0.0004**	3.51	**0.0032**

Grouped Anemones (F)

Table B13 Results of Permanova for the relative abundance of grouped anemones identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	13.642	3.4106	3.82	**0.0051**
Treatment Tr	2	30.873	15.436	2.97	0.0653
Area Ar(Tr)	22	91.539	4.1608	6.03	**0.0001**
YexTr	8	3.7392	0.46741	0.828	0.5728
Site (Ar(Tr))	61	40.113	0.65759	2.25	**0.0004**
YexAr(Tr)	58	30.765	0.53043	1.81	**0.0036**
Residual	133	38.878	0.29231		
Total	288	249.55			

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

Table B14 Results of Permanova for the relative abundance of *Alcyonium digitatum* identified using video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	8.0825	2.0206	5.99	**0.0007**
Treatment Tr	2	2.1629	1.0815	0.37	0.7428
Area Ar(Tr)	17	42.908	2.524	8.49	**0.0001**
YexTr	8	2.3595	0.29493	1.32	0.2411
Site (Ar(Tr))	48	13.111	0.27314	3.79	**0.0001**
YexAr(Tr)	51	9.7723	0.19161	2.66	**0.0001**
Residual	106	7.6395	7.207E-2		
Total	236	86.036			

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

Table B15 Results of Permanova for relative abundance of *Eunicella verrucosa* identified using video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	0.57578	0.14395	1.61	0.1644
Treatment Tr	2	2.9821	1.491	1.39	0.2696
Area Ar(Tr)	17	15.49	0.91115	17.91	**0.0001**
YexTr	8	0.39454	4.9317E-2	0.98	0.4609
Site (Ar(Tr))	48	2.2415	4.6698E-2	3.38	**0.0002**
YexAr(Tr)	51	2.2499	4.4116E-2	3.19	**0.0001**
Residual	106	1.4643	1.3814E-2		
Total	236	25.398			

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

Table B16 Results of Permanova for the relative abundance of *Chaetopterus variopedatus* identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	5.9361	1.484	2.75	**0.0239**
Treatment Tr	2	4.0198	2.0099	2.09	0.1405
Area Ar(Tr)	22	17.342	0.78825	3.26	**0.0003**
YexTr	8	7.321	0.91512	1.92	0.0705
Site (Ar(Tr))	61	14.223	0.23316	0.92	0.6238
YexAr(Tr)	58	25.276	0.4358	1.73	**0.0064**
Residual	133	33.545	0.25222		
Total	288	107.66			

Grouped hydroids (F)

Table B17 Results of a) Permanova for the relative abundance of grouped hydroids identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the term Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	87.71	21.927	12.62	**0.0001**
Treatment Tr	2	43.266	21.633	3.62	**0.0403**
Area Ar(Tr)	22	105.49	4.7952	5.59	**0.0001**
YexTr	8	19.702	2.4628	1.82	0.0885
Site (Ar(Tr))	61	49.95	0.81885	1.52	**0.0294**
YexAr(Tr)	58	70.44	1.2145	2.26	**0.0001**
Residual	133	71.553	0.53799		
Total	288	448.12			

b)

Groups	**t**	**P**
PVC, SI	2.10	0.0575
PVC, OC	2.51	**0.0192**
SI, OC	1.15	0.2794

Branching sponges (V)

Table B18 Results of a) Permanova for the relative abundance of branching sponges identified using video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the interaction Year x Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	1.361	0.34025	7.58	**0.0001**
Treatment Tr	2	3.595	1.7975	8.91	**0.001**
Area Ar(Tr)	17	2.9102	0.17119	5.29	**0.0001**
YexTr	8	0.91008	0.11376	3.08	**0.0059**
Site (Ar(Tr))	48	1.4344	2.9883E-2	2.05	**0.003**
YexAr(Tr)	51	1.6107	3.1582E-2	2.17	**0.0015**
Residual	4	1.361	0.34025	7.58	**0.0001**
Total	2	3.595	1.7975	8.91	**0.001**

b)

	2008		2009		2010		2011		2012	
Groups	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
PVC, SI	1.21	0.2581	0.88	0.465	1.47	0.1658	3.58	**0.0076**	2.14	0.0563
PVC, OC	2.36	**0.0451**	1.70	0.1213	2.62	**0.0275**	6.08	**0.0007**	3.88	**0.0039**
SI, OC	1.22	0.2582	0.86	0.4943	2.51	**0.0278**	2.62	**0.0092**	2.95	**0.0012**

Asterias rubens – Common starfish (V)

Table B19 Results of Permanova for the relative abundance of *Asterias rubens* identified using video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

Source	*df*	SS	MS	*F*	P
Year Ye	4	0.74017	0.18504	1.84	0.1205
Treatment Tr	2	1.2864	0.64321	1.05	0.378
Area Ar(Tr)	17	8.9171	0.52454	12.38	**0.0001**
YexTr	8	0.79143	9.8929E-2	1.30	0.2587
Site (Ar(Tr))	48	1.8781	3.9127E-2	0.89	0.6547
YexAr(Tr)	51	3.5904	7.04E-2	1.6	**0.0279**
Residual	106	4.652	4.3887E-2		
Total	236	21.856			

Trisopterus minutus – Poor cod (B)

Table B20 Results of Permanova for the relative abundance of *Trisopterus minutus* identified using baited video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factor Site (Si) and their interactions, and b) Pairwise testing for the interaction Year x Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	3	3.4501	1.15	3.42	**0.0228**
Treatment Tr	2	2.0822	1.0411	1.83	0.1879
Site (Tr)	21	10.512	0.50058	1.54	0.1329
YexTr	5	5.0227	1.0045	3.09	**0.0167**
Residual	38	12.361	0.32528		
Total	69	33.428			

b)

	2009		2010		2011		2012	
Groups	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
PVC, SI	2.34	**0.0206**	0.43	0.6958	1.41	0.1934	8.50E-3	1
PVC, OC	0.81	0.81194	0.53	0.588	5.69E-2	0.9653	1.22	0.227
SI, OC	1.67	1.669	0.82	0.4924	1.39	0.1713	1.58	0.2134

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

Table B21 Results of Permanova for the relative abundance of *Necora puber* identified using video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions and b) Pairwise testing for the term Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	4	2.107E-2	5.2675E-3	4.07	**0.0029**
Treatment Tr	2	2.0386E-2	1.0193E-2	4.60	**0.0176**
Area Ar(Tr)	17	3.2375E-2	1.9044E-3	1.69	0.0821
YexTr	8	1.1822E-2	1.4777E-3	1.28	0.2619
Site (Ar(Tr))	48	5.1009E-2	1.0627E-3	1.86	**0.0144**
YexAr(Tr)	51	5.2621E-2	1.0318E-3	1.80	**0.0168**
Residual	106	6.0706E-2	5.727E-4		
Total	236	0.24999			

b)

Groups	t	P
PVC, SI	1.14	0.2951
PVC, OC	3.29	**0.0043**
SI, OC	2.08	**0.0462**

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

Table B22 Results of Permanova for a) the relative abundance of *Cancer pagarus* identified using video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions and b) Pairwise testing for the term Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	4	1.1171E-3	2.7928E-4	1.22	0.2929
Treatment Tr	2	2.099E-3	1.0495E-3	4.23	**0.0218**
Area Ar(Tr)	17	3.7002E-3	2.1766E-4	1.16	0.3254
YexTr	8	1.5254E-3	1.9067E-4	0.89	0.5316
Site (Ar(Tr))	48	9.0042E-3	1.8759E-4	0.83	0.7239
YexAr(Tr)	51	1.1305E-2	2.2167E-4	0.98	0.5004
Residual	106	2.3909E-2	2.2555E-4		
Total	236	5.266E-2			

b)

Groups	t	P
PVC, SI	1.79	0.0969
PVC, OC	2.31	**0.0283**
SI, OC	1.15	0.1765

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

Table B23 Results of a) Permanova for the relative abundance of *Ctenolabrus rupestris* identified using baited video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Site (Si) and their interactions, and b) Pairwise testing for the term Treatment. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	SS	MS	*F*	P
Year Ye	3	0.96187	0.32062	8.45	**0.0002**
Treatment Tr	2	1.3525	0.67625	13.84	**0.0007**
Site (Tr)	21	0.85757	4.0837E-2	1.08	0.4078
YexTr	5	0.58347	0.11669	3.09	**0.017**
Residual	38	1.4346	3.7754E-2		
Total	69	5.1901			

b)

	2009		2010		2011		2012	
Groups	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
PVC, SI	1.49	0.1831	1.01	0.3992	8.61E-2	0.9332	2.93	**0.0222**
PVC, OC	2.45	**0.0025**	1.82	0.0585	4.37	**0.0025**	3.98	**0.0026**
SI, OC	1.64	**0.0144**	1.47	0.1638	3.36	**0.0145**	1.79	0.181

Grouped gobies (B)

Table B24 Results of Permanova for the relative abundance of grouped gobies identified using baited video in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Site (Si) and their interactions, and b) Pairwise testing for the term Year. Data were Log (X+1) transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	3	6.8863	2.2954	3.90	**0.0001**
Treatment Tr	2	0.97552	0.48776	1.62	0.2312
Site (Tr)	21	5.5826	0.26584	1.68	0.087
YexTr	5	0.24167	4.8334E-2	0.31	0.9064
Residual	38	6.0139	0.15826		
Total	69	19.7			

b)

Groups	**t**	**P**
2009, 2010	1.57	0.1442
2009, 2011	0.72	0.4806
2009, 2012	5.47	**0.0001**
2010, 2011	2.31	**0.0415**
2010, 2012	6.95	**0.0001**
2011, 2012	3.45	**0.0028**

Sensitive Areas

Assemblage composition:

Table B25 Results of a) Permanova for the assemblage composition of the benthic taxa identified using frame grabs in response to the fixed factors Year (Ye) and Treatment (Tr), and random factors Area (Ar) and Site (Si) and their interactions, and b) Pairwise testing for the interaction Year x Treatment. Data were dispersion weighted and square root transformed. Analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	***df***	**SS**	**MS**	***F***	**P**
Year Ye	4	47720	11930	7.09	**0.0001**
Treatment Tr	2	56631	28316	7.15	**0.0002**
Area Ar(Tr)	21	79643	3792.5	4.32	**0.0001**
YexTr	5	10254	2050.7	1.83	**0.0002**
Site (Ar(Tr))	55	47872	870.4	1.42	**0.0001**
YexAr(Tr)	42	43868	1044.5	1.70	**0.0001**
Residual	102	62551	613.24		
Total	231	3.4854E5			

b)

	2008		**2009**		**2010**		**2011**		**2012**	
Groups	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
PVC, OC	1.60	**0.0078**	2.03	**0.0044**	2.36	**0.0004**	3.78	**0.0008**	2.83	**0.0014**
PVC, SA							3.14	**0.002**	2.18	**0.0086**
OC, SA							1.11	0.2851	1.00	0.3938