Lyme Bay - A case study: measuring recovery of benthic species, assessing potential spill-over effects and socio-economic changes; 3 years after the closure

Report 1: Response of the benthos to the zoned exclusion of bottom towed fishing gear in Lyme Bay

Final Report

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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.

The initial project was formed around seven key objectives, as defined by Defra (see Attrill et al. 2011), and following its completion, a one year extension was granted for the continuation of key aspects of the biodiversity and socio-economic monitoring. This included quantification of sessile and sedentary benthic taxa at sites within and outside the closure, quantification of reef-associated nekton and mobile benthic fauna at sites within and outside the closure, and an assessment of the changes resulting from the closure for commercial fishermen, recreational users, fish processors and merchants, and enforcement agencies. The extension was led by the Plymouth University Marine Institute and was partnered by Plymouth Marine Laboratory. This report is the biodiversity and the lead report. It focusses on the results of the biodiversity aspects of the project and includes an executive summary of the socioeconomic work. Results are presented from one additional year of monitoring (2008-2010 and 2011). Full details and methods for the work conducted can be found in the 2011 reports and in the interest of brevity have not been repeated.

To remotely sample the reef epibenthic 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 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: 1 New Closure (NC) and 3 controls - previously Closed Control (CC), Near Open Control (NOC) and Far Open Control (FOC), (Table 2.1). Within each treatment there were four areas, each comprising 4 sites (200 m video transect), which were sampled in the summers of 2008, 2009, 2010 and 2011 (Figure 2.3). The same design principles were used for the baited video as the towed sampling, there were however, less sites and no FOC due to logistical constraints. Sampling was carried out in summer 2009, 2010 and 2011.

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, 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. 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).

The first three years of the study (2008-2010) found that the level of protection afforded by the SI had altered the assemblage structure, abundance and diversity of taxa within Lyme Bay (Attrill et al. 2011). The principal evidence for this was that the assemblage structure in the NC had become more similar to that within the CC and less similar to that within the NOC and FOC over the course of the study. Strong spatial variation was, however, identified and it was concluded that whilst there were indications of a trend towards recovery it was not possible to determine whether the sites that were not exhibiting this trend would remain permanently in that condition or were simply recovering more slowly. This report has presented results from a further year of sampling (2011) which aimed to further investigate the identified trends.

It is clear from both the towed and baited survey results that 2011 has seen a marked improvement across the bay. All three survey methods identified new species, and abundance and species richness increased for towed and baited assemblages in both closed and open treatments. Increases have been more pronounced in closed treatments, and the results continue to suggest a trend towards recovery where sites within the new closure are becoming less similar to those within the open controls and more similar to those in the closed control.

When considering the towed video results, there is evidence of an increase in abundance of taxa and species richness across treatments with a significant difference identified for both metrics between 2011 and previous years. These increases were greatest in the CC, and significant differences were identified between these sites and those in the NOC and FOC, strengthening the conclusion that the level of protection afforded by the SI has altered the diversity, abundance and assemblage structure of taxa in Lyme Bay. The lack of a Year x Treatment interaction, however, suggests that, as in previous years, this is only an indication of recovery rather than evidence of recovery within the SI. The baited video data sets now comprise three years, increasing their power and the robustness of the results. The 2008-2010 survey was unable to identify any clear trends between Years, but a Year effect has been identified for abundance of reef associated nekton in 2011 when abundance was greatest across all treatments. As seen for the epibenthic assemblage, the increase in abundance of reef associated nekton between 2010 and 2011 was particularly marked suggesting that recruitment and survival of species has increased, independently of treatment.

Trends for indicator species have largely conformed to those identified for the main assemblages, with greatest abundance of all indicator species seen in the closed treatments in 2011. Despite this, considerable variation exists in the results, with abundance of *Eunicella verrucosa*, *Necora puber* and grouped gobies decreasing in the NC and CC between 2010 and 2011.

This study aimed to assess the recovery of Lyme Bay reefs following the cessation of fishing using bottom towed gear within the SI. Attrill et al. (2011) reported the results from the baseline survey and two 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 third 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 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, as 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 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 within the new closure where recovery can be detected for those species which are considered most functionally important and indicators of a healthy ecosystem.

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1 Introduction

1.1 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 bottom towed fishing gear. Following its implementation, the Marine Institute, Plymouth University (MI) and project partners, the Marine Biological Association of the United Kingdom (MBA), Plymouth Marine Laboratory Limited (PML) and Marine Bio-images were commissioned to undertake a comprehensive study of the SI (MB0101) with the aim of assessing its ecological and socio-economic impacts over a three year period.

1.2 The initial project was formed around seven key objectives, as defined by Defra (see Attrill 2011), involving: the identification of suitable reef indicator species that could signify changes within the reef ecosystem; a desk based assessment of the long-term effects of fisheries closures on long-lived and sessile benthic species (both led by the MBA, see Jackson et al. (2008) and Langmead et al. (2010)); the development of a cost effective ecological monitoring programme; quantification of the effects of the closure on epibenthic and nektonic reef species, including spillover; the collection of samples of pink sea fan *Eunicella verrucosa* for future DNA analysis; the quantification of any effects on adult scallop populations (all led by the MI with benthic monitoring also including Marine Bio-images and the University of Exeter, see Attrill et al. (2011)); and the assessment of any socio-economic changes resulting from the closure restrictions (led by PML, see Mangi et al. (2011)).

1.3 Following the completion of the initial project period, a one year extension was granted for the continuation of key aspects of the biodiversity and socio-economic monitoring. This included:

i. Quantification of sessile and sedentary benthic taxa using high definition video on a towed flying array at sites within and outside the closure
ii. Quantification of reef-associated nekton and mobile benthic fauna using baited, static frames at sites within and outside the closure
iii. An assessment of the changes resulting from the closure for commercial fishermen, recreational users, fish processors and merchants, and enforcement agencies using quantitative and qualitative methods.

1.4 The extension was led by the MI and was partnered by PML. The involvement of the MBA and Marine Bio-images ended at the close of the initial project period.

1.1 Approach and reporting methods

1.5 This reporting period marks the end of the project extension and aims to present the results from the objectives that have been continued (3, 3a & 7, see below), draw conclusions to inform the future monitoring of the Lyme Bay SI, and enable recommendations to be made.

1.6 The objectives were:

3. To quantify the recovery of the indicator species within the closure compared to areas which continue to be open to fishing using bottom towed gear;

3a. To quantify the effects of the closure on reef-associated nekton, compared to areas which continue to be open to fishing using bottom towed gear (added at the suggestion of MI);

7. To assess any socio-economic impacts (e.g. diversification, gear changes, changes to areas fished, effort changes) which result from the closure restrictions.

1.7 As in 2011, there were two separate components to the research so there are two separate reports:

i. Biodiversity component (objectives 3 & 3a) – Report 1 (this report)
ii. Socio-economic component (objective 7) – Report 2

1.8 The biodiversity report is the lead report and includes an executive summary of the socio-economic work (Box 2). Both reports are continuations of the 2011 reports (Attrill et al. 2011 and Mangi et al. 2011), and should therefore be read in conjunction. Full details and methods for the work conducted can be found in the 2011 reports and in the interest of brevity have not been repeated.

1.9 This biodiversity report aims to present the results from one additional year of monitoring for objectives 3 and 3a (2008-2010 and 2011; Attrill et al. 2011). To aid this, a summary of the 2008-2010 results is presented below.

1.2 Biodiversity results 2008-2010

1.2.1 Survey method

1.10 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 agreement (closed controls) and less similar to areas that continue to be open to fishing (open controls)'.

1.11 In this study, "reef" was considered to be hard substratum, including rocky reef, boulders and cobbles (> 64 mm diameter). The towed biodiversity survey methodology was designed to be cost effective, efficient and non-destructive so as to be appropriate for use in areas that have been protected from bottom towed fishing gear. High Definition (HD) video was used, firstly on a towed flying array designed to fly the camera over the sea bed to sample sessile and sedentary taxa, and secondly on a baited, static frame to sample reef-associated nekton and mobile benthic fauna. Full methods can be found in Sheehan et al. (2010) and Attrill et al. (2011).

1.12 It is important to note that this was an observational rather than experimental survey. We were not able to manipulate the level of fishing in the different treatments and we were unable to choose the starting condition of the new closure sites. The study area is also large and so we expect some spatial and temporal variation within treatments. To quantify the magnitude and direction of changes that have occurred following the SI implementation, sites grouped in treatment specific areas were established 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 survey in 2009.

1.13 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. This said, the anticipated changes in benthic species and community structure are expected to occur over annual or even decadal time spans, and we are confident that, if present, they will be detectable by the design implemented (Glasby, 1997).

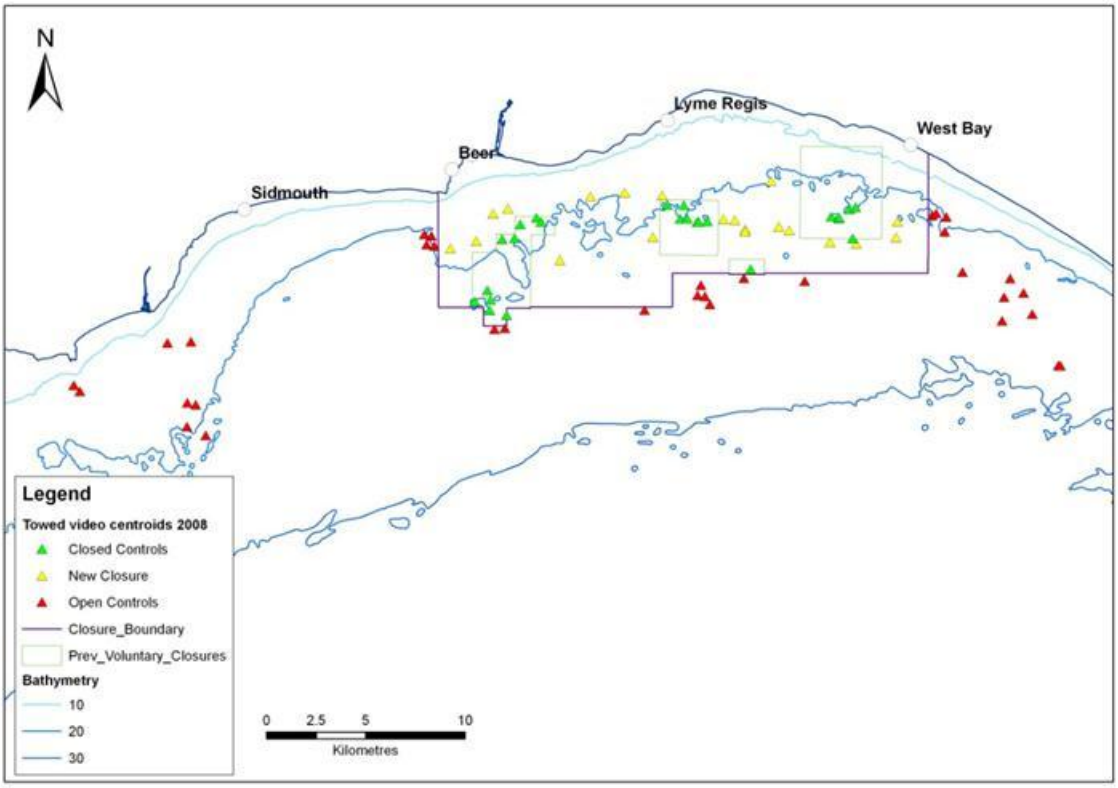
1.14 In addition to monitoring the indicator species as identified by Jackson et al. (2008), all species that could be identified using the video were counted. This meant that we could also assess the impact of the closure at the assemblage level.

1.15 For each sampling methodology the following response variables were considered:

i. Towed HD video: total observed abundance, species richness, assemblage composition, observed abundance of indicator species, size class distribution of key species
ii. Baited Remote Underwater Video (BRUV): total observed abundance, species richness, assemblage composition, observed abundance of scavenging species, observed abundance of indicator species

1.16 Marine Bio-images were subcontracted to undertake an additional benthic survey (2008-2010) using divers that would be able to quantify the earliest growth and/or smallest marine fauna which the video may not be able to detect. The diving survey was unable to have the same coverage as the towed video survey (Figure 1.1) and so focused on cobble/boulder habitat.

a)



b)

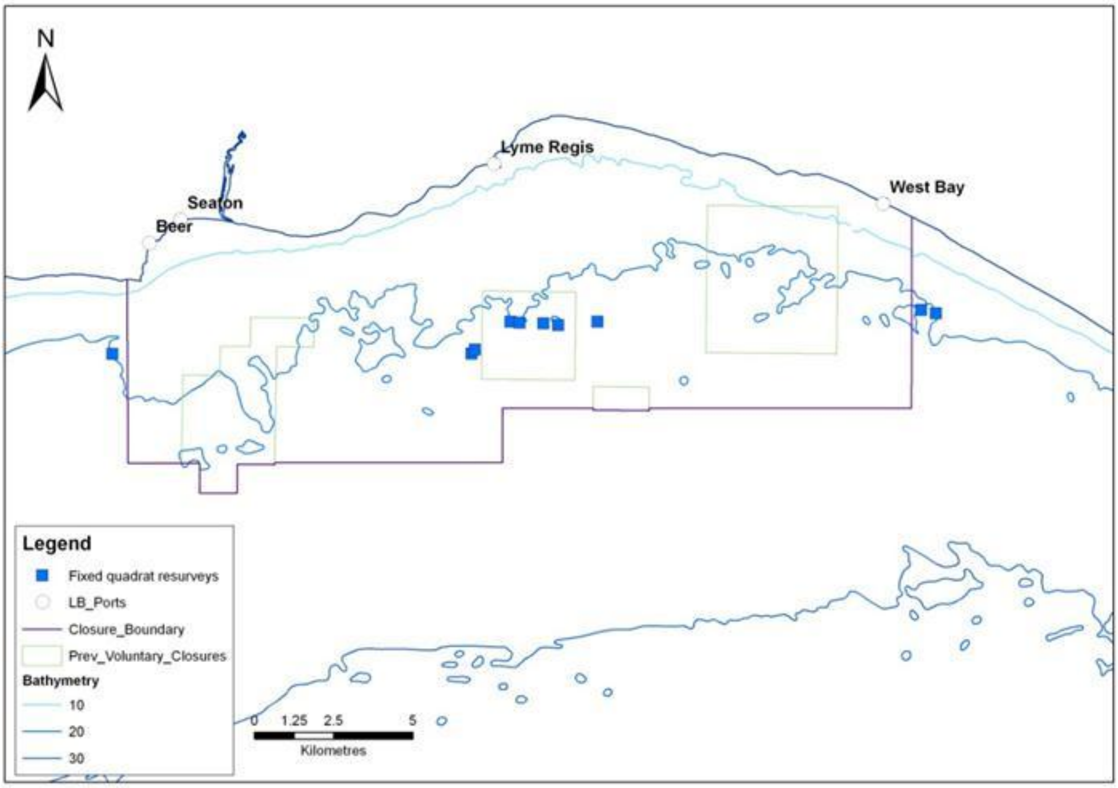


Figure 1.1: Location of a) towed video survey sites showing sites in the closed controls, new closure and open controls for the 2008 – 2010 survey period and b) fixed quadrat diver survey sites for the 2008 – 2010 surveys

1.2.2 Towed and baited video survey results

1.17 The results of the initial biodiversity survey showed that the protection afforded by the SI had altered the assemblage structure, abundance and diversity of taxa within Lyme Bay (Attrill et al. 2011). The measurement of a host of response variables (see paragraph 1.12) showed that assemblage structure in the closed area was becoming less similar to that in areas, which continue to be open to fishing.

1.18 The results supported the findings of the desk based study (Langmead et al. 2010), which assessed the recoverability of the indicator species identified by Jackson et al. (2008). The potential for a species to recover following disturbance (recoverability) was assessed based on its life history characteristics, and indicator species were grouped depending on whether they had high, medium or low recoverability (for full methods see Langmead et al. 2010).

1.19 The biodiversity results from the towed video survey showed some recovery two years after the closure for *Pecten maximus,* which was considered to have a high recoverability, *Phallusia mammillata*, *Necora puber*, *Ctenolabrus rupestris* and grouped hydroids, considered to have medium recoverability, and perhaps most encouragingly for *Pentapora fascialis* and *Alcyonium digitatum,* which were considered to have a low recoverability. With the exception of grouped gobies, species considered to have low or medium recoverability, which have shown no recovery to date, are those which continue to be fished within the closure (e.g. *Cancer pagurus*). As expected, the species group with the lowest recoverability contains the fewest species showing a trend towards recovery (Attrill et al. 2011).

1.20 Despite some evidence for a trend towards recovery, substantial variation was seen within the results. For example, the rate of change for some species varied with location, showing that it is not yet possible to completely separate natural spatial and temporal variability from the effects of the closure.

1.21 The diver survey conducted by Marine Bio-images was completed in 2010 and has been reported separately (Munro & Baldock, 2012). As analyses were completed following the publication of Attrill et al. (2011) they are incorporated and discussed here. Box 1 below presents an executive summary and the following text summarises the main findings and how they compare with the results of the towed video surveys presented above.

1.2.3 Diver survey results

Box 1: Marine Bio-images executive summary

Munro, C.D. & Baldock, B.M. (2012)
Marine Bio-images

As a consequence of growing concern about the impacts of mobile bottom fishing methods on the sessile (attached) epifauna living on subtidal reefs within Lyme Bay, southwest U.K., the Government closed a 60 nm^2 area to all bottom fishing towed gear (essentially bottom trawls and scallop dredges) in July 2008. This closure was designed to include all known vulnerable reefs and reefs known to support rich epifaunal assemblages within Lyme Bay, especially those supporting assemblages considered to be of high conservation importance and particularly vulnerable to bottom fishing towed gear, e.g. assemblages rich in erect sponge species and gorgonian (seafan) beds. It incorporated four pre-existing voluntary closures. These smaller areas had already been closed, with limited success, to towed bottom fishing gear on a voluntary agreement basis for between two and seven years.

The aim of the study was to monitor change in the sessile species assemblages occurring on boulder reefs in Lyme Bay following the exclusion of towed bottom fishing gear. In particular, to monitor change in species assemblages at sites within the new statutory closure (but outside the pre-existing voluntary closures) relative to change occurring at:

a) Sites within the pre-existing voluntary closure and
b) Nearby sites outside the closed area where fishing by towed bottom gear was still permitted.

The hypothesis being tested was that, over time, species assemblages within sites in the new statutory closure but outside the pre-existing voluntary closures would change to more closely resemble those in the pre-existing voluntary closures and become less similar to sites where fishing by towed bottom gear was still permitted.

Methods
Data were collected by SCUBA divers at 10 fixed sites across Lyme Bay in September 2008, August 2009 and July 2010. These sites represented the three treatments considered: three sites were located within the new closure but outside the established voluntary closures (termed New Closure); four within one of the pre-existing voluntary closures (termed Closed Controls) and three outside the closed area where fishing by towed bottom gear was still permitted (termed Open Controls). Closed Control sites were confined to only one of the four pre-existing voluntary closures (Lane's Ground reef) as the habitats and associated species assemblages were different in all four voluntary closures; Lane's Ground was the only one that comprised boulder and cobble reef. Two permanent markers (8 m apart) were haphazardly deployed at each site within an area of boulder and cobble reef. Between the two markers at each site, a line was laid and 8 x 1 m was surveyed either side of this line. Fixed transects were laid and surveyed annually; eight 0.25 m^2 quadrats were dropped haphazardly (up to 5 m either side of the transect centre line) and surveyed annually to record the conspicuous species present.

The habitat selected for study comprised a high proportion of cobbles and small boulders with mixed, fine sediment between them in a water depth of 20-22 m below chart datum. Areas of bedrock reef and extensive patches of sand and gravel seabed were avoided as far as possible, except for one station (New Closure Site 5) which was located on level bedrock with a thin silt veneer.

Change in benthic assemblages in Lyme Bay was investigated using multivariate statistical methods (PERMANOVA in PRIMER) which depended on the initial construction of a similarity matrix using the Bray-Curtis coefficient of similarity on variously transformed data. Univariate data were investigated employing matrices derived using the Euclidean distance measure.

PERMANOVA analysis was undertaken using 9999 permutations, all analyses returned more than 9910 unique permutations.

Results and interpretation
The total number of taxa recorded over the three years in the quadrat survey was 163, not all taxa being present in all years. The range of the mean number of taxa in the three treatments was 35-41 at the start of the study in 2008 increasing slightly to 27-43 in 2010. The most diverse assemblages were found at the Closed Control sites (41-45 taxa per site) contrasting with 27-35 taxa per site recorded at the Open Controls.

The univariate PERMANOVA tests on the total number of taxa and overall abundance in quadrats showed that there were statistically significant differences between treatments ($P<0.05$) but not years. There was no treatment by year effect.

PERMANOVA pair-wise test of assemblage composition for quadrat data for treatments showed that the three treatments were all statistically significantly different.

Distinct differences in species assemblage composition were noted between Open Control sites east and west of the statutory closure, reflecting the differences in the benthic conditions and strong environmental gradients across Lyme Bay from east to west. Markedly lower numbers of erect and encrusting sponges and *Phallusia mammillata* tunicates were recorded in all Open Control sites in all years compared to Closed and New Closure, again reflecting the differences in environmental conditions across Lyme Bay, east or west of the statutory closure.

The mean total number of taxa recorded from all replicates over the three year period for each treatment showed the Open Controls (three sites) supporting fewer taxa in total than either the Closed Controls (four sites) or the New Closure (three sites). The higher count at the Closed Control sites was likely to be partly due to a sample area effect with four sites in the treatment and three sites in the New Closure. The total number of taxa appeared to decline within the Open Control sites, possibly reflecting continued fishing impacts (and possibly increased effort through displaced fishing activity).

The multidimensional scaling (MDS) plots for both key taxa and total taxa in quadrats within the New Closure (in 2010) showed the samples for New Closure sites to be more widely dispersed (i.e. more dissimilar to each other) than Closed Controls and comparable to the dissimilarity of the Open Controls. This may reflect changes in stress within the New Closure following cessation of towed bottom fishing; it has been proposed that a change in the multivariate dispersion of assemblage data provides a measure of pressures (stresses) impacting on marine benthic communities (Warwick & Clarke, 1993).

Differences recorded between treatments, in terms of species richness, reflect the sensitivity to disturbance of the various taxa. The Closed Control sites showed a greater cover by encrusting sponges than either of the other two treatments and were statistically significantly different from Open Controls. Branching sponges were present in very low numbers at the Open Control sites while quadrat estimates showed highly variable numbers at Closed Control and New Closure sites. The fixed transect data, though again highly variable, indicate a possible slight recovery of this group over the study period within both the New Closure and Closed Controls. Sponge assemblages are considered the single most important feature of the boulder and cobble reefs within Lyme Bay, and regionally appear unique to the central nearshore benthos of Lyme Bay, the sponge diversity having been previously described as possibly unsurpassed in Southwest Britain (Devon Wildlife Trust, 1995). Sponge species, in particular, have been identified (through qualitative comparison of video data from the same site within Lane's Ground reef shot in 1996 and 2008) as appearing to have declined markedly in the twelve years prior to establishment of the statutory closure (Munro, pers. obs), whilst Kefalas et al. (2003) identified erect branching sponges as particularly sensitive to damage from scallop dredges. Thus a possible slight recovery in sponges is considered a welcome sign and, if confirmed by subsequent monitoring, would provide a strong endorsement of the statutory closure. It has been shown that recovery of sponge assemblages after cessation of disturbance is very slow, with one study showing little or no improvement after four years (Hiscock, 1994). It therefore seems likely that, if recovery of sponge assemblages is indeed occurring as initial data indicates, it will take require at least a further four years monitoring to confirm this.

1.22 The following text summarises the main findings of the diver survey work and how they compare with the results of the towed video surveys presented above.

i. *The divers were able to make more positive species identifications than the observers using the towed transect video data.* This was expected as some marine species are distinguished by small features that would be difficult to see using moving video.

ii. *The diver survey found that many of their response variables such as species richness, total abundance, abundance of branching sponges etc. in cobble/boulder habitats varied significantly between treatments, but not between years.* To take species richness as an example, there was lower species richness in sites open to fishing (OC) compared to sites previously closed (CC) and those within the new closure (NC) (Box 1). The CC sites were expected to be different from the OC sites as they had been protected from fishing, but from year one, the NC sites were more similar to the CC than the NOC. As they were located closer to the CC than the OC (Figure 1.1) it seems that the natural spatial difference between the sites was more profound than the fishing effect between the NC and CC. It is also possible that the NC sites were afforded some benefit due to their location close to the CC, or that both NC and CC sites were similarly affected by previous fishing effort.

iii. *The sites in the towed survey were able to be more spread out across the bay and so were more likely to be able to detect overall treatment effects.* A trend towards recovery was seen in the towed video survey as assemblage composition and abundance of three indicator species (king scallop *Pecten maximus*, ross coral *Pentapora fascialis* and dead man's fingers *Alcyonium digitatum*) in the NC became more similar to the CC and less similar to the NOC and FOC (Attrill et al. 2011). Differences between the two surveys were expected as the diver survey was more habitat and location specific, whereas the towed survey was able to take account of effects occurring across the bay.

1.3 Socio-economic results 2012

Box 2: Lyme Bay - A case study: measuring recovery of benthic species, assessing potential spill-over effects and socio-economic changes; 3 years after the closure

Mangi, S., Gall, S.C, Hattam, C., Rodwell L., Rees S.
Plymouth Marine Laboratory Limited

An impact assessment was conducted within Lyme Bay, UK following the implementation of a closed area inside which scallop dredging and bottom trawling were banned in July 2008.

This report presents the socio-economic changes resulting from the closure for commercial fishermen, recreational users, fish processors and merchants, and enforcement agencies. The report is part of a larger project funded by Defra and Natural England whose remit was to assess the ecological and socio-economic changes that have ensued as a result of protection of the 60 nm^2 area of Lyme Bay from mobile fishing gear.

An extensive stakeholder consultation was used to collate and collect primary and secondary quantitative and qualitative information. The secondary data that were collated include the wet weight and value of landings, sightings of vessels using the Lyme Bay area, and enforcement costs from the Marine Management Organisation (MMO) and Devon and Severn IFCA (Inshore Fisheries and Conservation Agency). Primary data were collected mainly through questionnaires, individual and small group interviews, and stakeholder workshops.

The report has the following key conclusions:

- Static gear fishermen who fish inside the closed area have been able to increase the number of crab and whelk pots they deploy. They have experienced improved fishing conditions, reporting gear safety and less conflict, and increased fishing income as a result.
- Static gear fishermen who fish outside the closed area have experienced increased conflicts with towed gear fishermen who now fish regularly in their traditional grounds. They feel they have been "sold out" by the closure and consider their fishing experiences to be worsening.

- Towed gear fishermen have been forced to look for other fishing grounds outside the closed area, and have seen their costs increase due to increased travel time and fishing duration and subsequently have reported declines in fishing income.
- Support for the closed area policy remains strong among static gear fishermen fishing inside the closed area and the recreational stakeholder groups.
- The closed area has had little or no impact on dive businesses which tend to use the same dive sites close to their business premises on an annual basis.
- Divers are being attracted to Lyme Bay to dive within the closed area and local divers are reporting an improvement to the diving experience within it.
- Anglers are actively choosing to spend time in Lyme Bay and within the closed area.
- Charter boat operators who are closer to the closed area are beginning to take more anglers to fishing sites within it and are reporting an improvement in the angling experience.
- The impacts of the closure have led to mixed effects for fish processors with smaller processors seeing no change in their businesses. Other impacts, such as a decrease in the quality of scallops, increase in haulage costs and employment difficulties have affected only a minority of fish processors and merchants.
- Local hotels have yet to experience any change as a consequence of the closure.
- As a result of more frequent patrols on the closed area and a consequent increase in fuel demand, enforcement costs have significantly increased after the closure.
- The impact of the closure has been minimal for the majority of stakeholders considered. However, after only four years of closure it still remains difficult to monetise the full costs and benefits arising, and hence the overall financial impact of the closure.
- This study provides an essential baseline for future long-term monitoring of the impacts of the Lyme Bay closed area in both social and economic terms.

The report has the following key recommendations:

- There is need to improve the management of activities within the closed area and many stakeholders are keen to be involved in the derivation of management plans and activities.
- Effective enforcement of the closure regulations is required to address concerns raised by stakeholders.
- Fully understanding the impacts of the closed area requires a longer term study to evaluate all costs and benefits. This Lyme Bay project therefore needs to continue over a longer period in order to monitor the ecological as well as the social and economic impacts. This would enable the impacts of natural cycles, (such as those of scallops, on local communities to be captured. Due to timescales involved these natural cycles were beyond the scope of this study.

2 Methods

2.1 Sampling methods

2.1 Methods for the 2011 survey period were consistent with previous years as outlined above, although some alterations were made to improve the BRUV survey. Methods are briefly outlined below but please refer to Sheehan et al. (2010) for details of the towed video and Attrill et al. (2011) for details of both towed and BRUV.

2.2 As in previous years, all fieldwork was carried out from the vessel 'Miss Pattie', a 10 m displacement trawler.

2.3 BRUV sampling took place between the 11th and 19th July 2011 and towed video between the 20th July and the 10th August 2011.

2.1.1 Towed video

2.4 To quantify changes in the abundance of sessile and sedentary benthic species, HD video was used, and the 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.

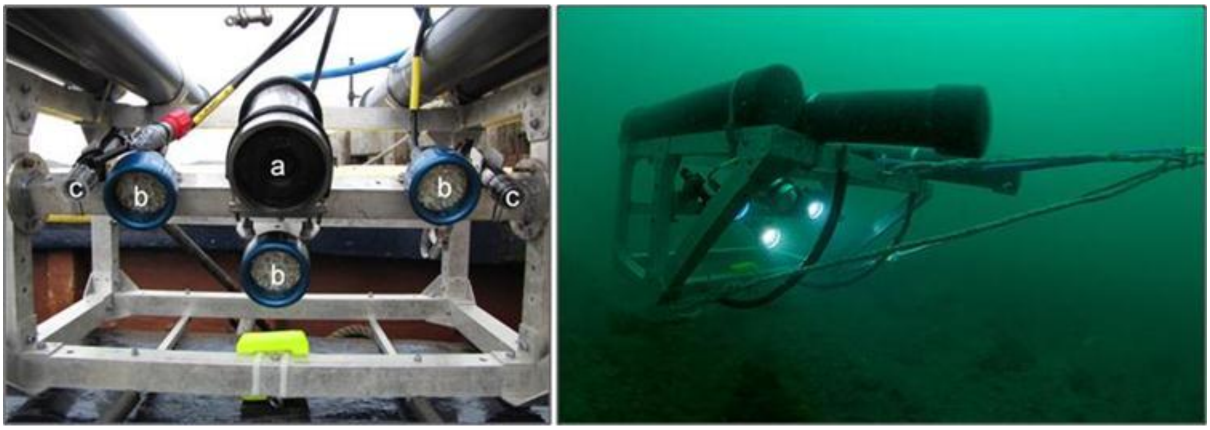


Figure 2.1: Flying array used for the towed video survey. a = high definition video camera, b = LED lights, c = lasers

2.1.2 Baited remote underwater video

2.5 To determine whether the closure affected reef-associated nekton species and mobile benthic fauna, BRUV was used. Developing a survey methodology that is cost effective and robust is a key component of this project, and following technological developments and the experience of the project team in previous years, the BRUV methods were improved for the 2011 sampling period (see Attrill et al. (2011) for 2008-2010 methods).

2.6 The static frame was previously attached to the boat through an umbilical, requiring the boat to anchor at each site and replicates to be deployed from the bow, starboard stern and port stern. The kit was therefore adapted for remote deployment, enabling replicates to be placed up to 100 m apart, eliminating anchor damage and improving sampling efficiency and statistical independence between replicates without compromising the comparability of the data with that collected using the original survey method.

2.7 Three custom made submersible rigs were built by Greenaway Marine Ltd. (Figure 2.2) with the design based on that of the original static frame to maintain the size of the field of view. Each housed a Panasonic HDC-SD60 Full HD Video Camera and had an LED light mounted on the housing. The bait pole, bait box, and quantity of mackerel bait used were identical to previous years. The cameras were deployed up to 100 m apart using a system of numbered buoys to indicate replicate numbers.

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

2.2 Sampling design

2.8 The design of the 2008-2010 survey was based on the need to document conditions in the newly closed sites at the time of the closure and then to resample annually to quantify the magnitude and direction of any changes. Towed video surveys used an asymmetric design with balanced sampling (Underwood, 1994; Glasby, 1997) and sites grouped into four areas per treatment, each comprising 4 sites (1 site = 1 x 200 m video transect), (see Attrill et al. 2011 for full details). The four treatments are defined in Table 2.1.

Table 2.1: Definition of treatments from which survey sites were selected giving the codes used for identification during analyses

Treatment	Code	Definition
Closed Control	CC	Previously un-fished under voluntary agreement, continuing to be un-fished
New Closure	NC	Previously fished, now closed to mobile ground gear
Near Open Control	NOC	Previously fished, continuing to be fished, < 5km from closure boundary
Far/Future Open Control*	FOC	Previously fished, continuing to be fished, > 5km from closure boundary

*Far = towed, Future = BRUV due to differences in sampling design

2.9 The towed video sampling design was altered in 2011 under contract from Natural England due to the designation of a candidate Special Area of Conservation (cSAC). The cSAC boundaries extended those of the SI and so sites that were open controls will in the future become protected. For this reason, new open sites were identified in 2011 that could be used in future as open controls for the SI and to monitor the newly protected areas in the cSAC (Figure 2.3). In addition, area groupings were increased to six per treatment, each comprised of three sites (Figure 2.3) to increase the overall power to detect treatment differences in the survey design. The cSAC restrictions which came into force in August 2010 are under assessment but are likely to be similar to those of the SI, although vessels taking part in a Vessel Monitoring System (VMS) trial are allowed access with mobile gear to fish areas between the reefs, and so for the purpose of this survey, the existing open controls are all still considered to be open to fishing.

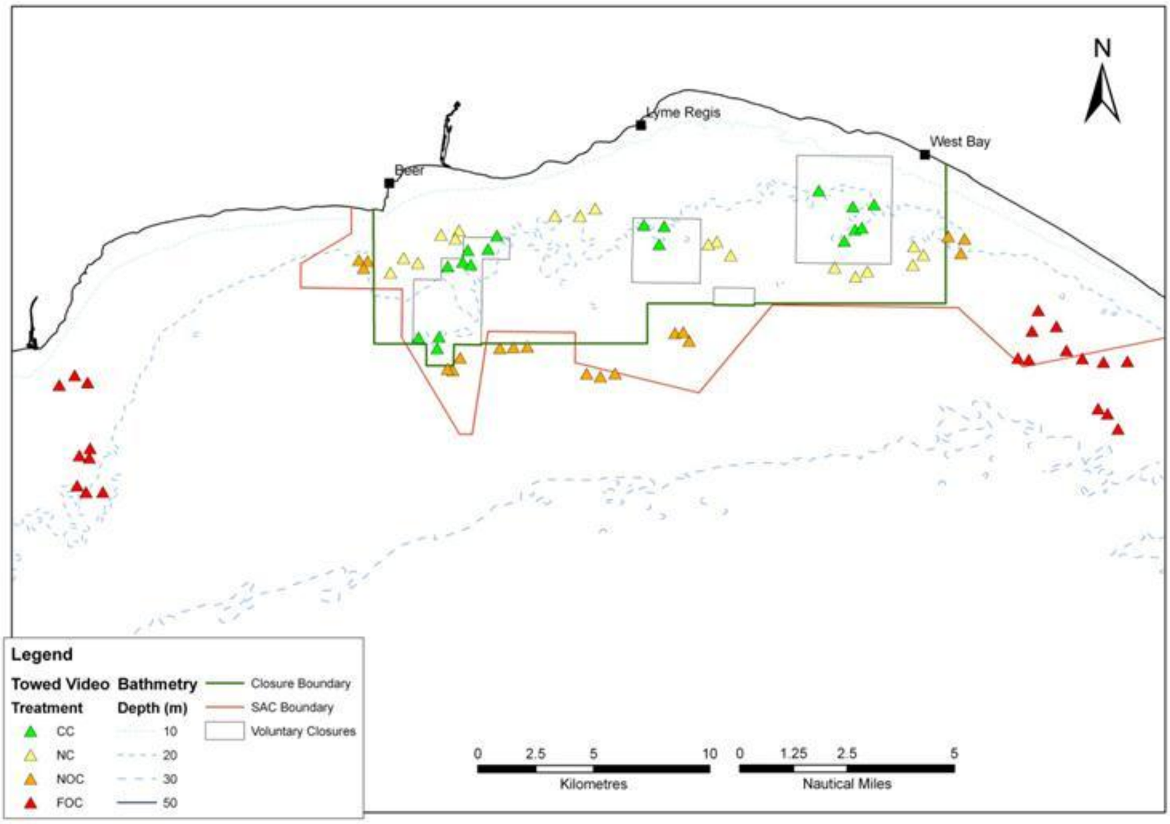


Figure 2.3: Locations of towed video transects in Lyme Bay coded by treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = far open control). The boundaries of the SI (closure boundary), voluntary closures and the new cSAC are also shown. Some symbols overlap at this scale.

2.10 The inclusion of the additional sites in 2011 to provide a baseline for monitoring of the cSAC, and for the purpose of this report have been combined into the existing NOC or FOC treatments as appropriate.

2.11 The design of the BRUV was also reconsidered, due both to the designation of the cSAC and as results from the 2009-2010 survey periods failed to identify a significant Season x Treatment interaction for the mobile species assemblage which suggested that differences between Treatments were consistent between seasonal sampling periods (Attrill et al. 2011). Consequently the seasonal component of the study was removed for 2011 and effort was transferred to allow inclusion of six additional sites which would provide controls for the cSAC (Figure 2.4). The sites outside the cSAC were named Future Open Controls (FOC) and the other treatment names were identical to those used for the towed video (Table 2.1).

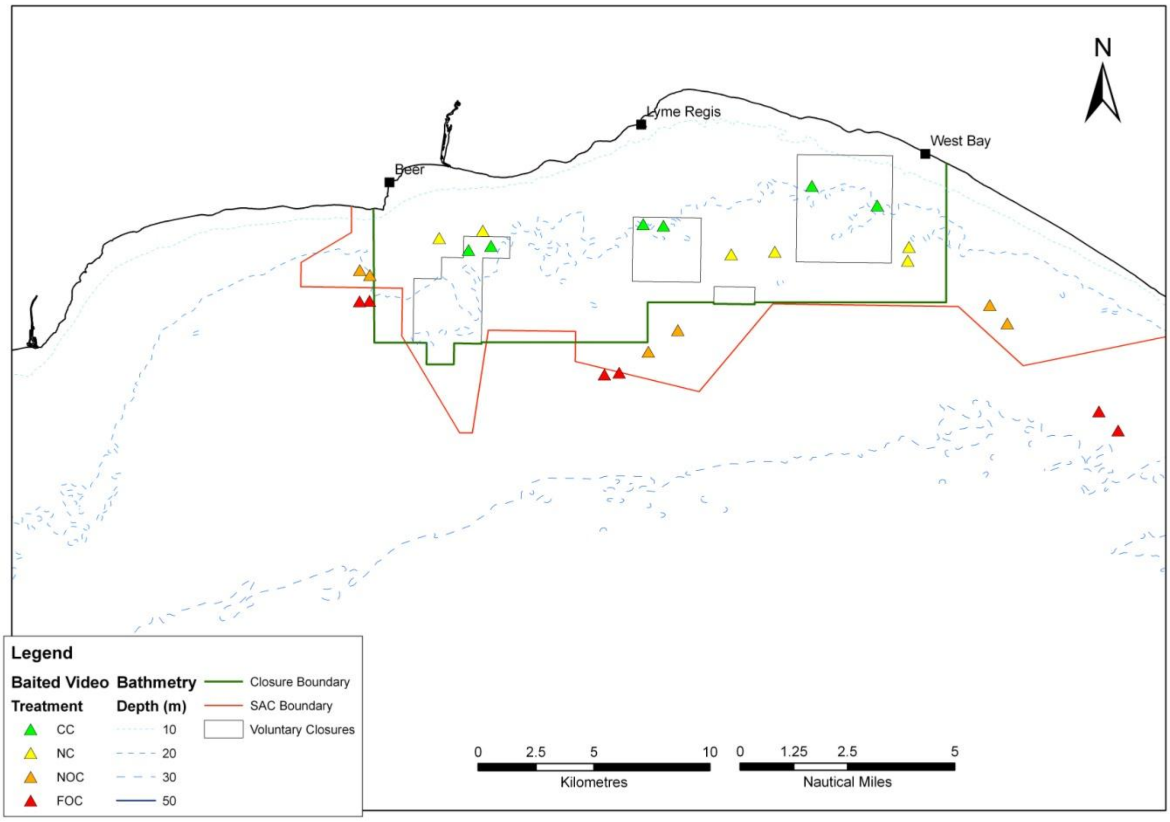


Figure 2.4: Locations of BRUV video sites in Lyme Bay coded by treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = future open control). The boundaries of the SI (closure boundary), voluntary closures and the new cSAC are also shown. Some symbols overlap at this scale.

2.3 Site Selection

2.12 The selection of additional sites for the 2011 monitoring followed the same criteria as that outlined in Attrill et al. (2011), ensuring their direct comparability to sites already established.

2.13 The factors considered were substratum type, depth, previous and current reserve locations, and historical (over the period for which effort data were available) fishing intensity of bottom towed fishing gear.

2.4 Indicator species

2.14 As in previous years, 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).

2.5 Video Analysis

2.15 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.

2.16 For the towed and baited video analyses *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.

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

i. All branching sponges, such as *Axinella damicornis, Haliclona oculata, Raspailia hispida* and *Raspailia ramosa*;
ii. The hydroid species *Halecium halecinum*, *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).

2.18 These groupings remain consistent with Attrill et al. (2011).

2.19 Previously, sponges that were not identified to species were grouped as ‘unidentified massive sponge’ or ‘unidentified encrusting sponge’. This classification has been improved for the 2011 survey, with individuals that were not identifiable to species level described and then identified as e.g. encrusting sponge 1, massive sponge 2 (Annex A, Table A1), ensuring taxonomic resolution was maximised.

2.20 Where a positive identification was not possible, categories were used (unidentified solitary ascidians for frame grab analyses and small juvenile fish for baited video).

2.21 The term “turf” incorporated hydroid and bryozoan turf which projected less than 1 cm above the seabed surface.

2.5.1 Extraction of quantitative data from the HD video transect

2.22 Analysis of the video transects was conducted in two stages:

i. Species counts were made from each entire video transect by counting individuals that passed through the ‘gate’ formed by the two laser dots for infrequent organisms (all mobile taxa), and conspicuous sessile fauna (Annex A, Table A2).

ii. 30 frame grabs were extracted from each video transect and overlaid with a calibrated grid to quantify the encrusting, sessile species, some abundant, free-living fauna and metrics of infaunal density and bioturbation such as burrow densities.

2.23 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).

2.24 To assess recovery based on the re-growth of taxa, size of individuals was measured for six taxa - *Alcyonium digitatum, Eunicella verrucosa, Pentapora fascialis, Nemertesia antennina,* the composite taxa branching sponges, and grouped hydroids, allowing analyses of changes in size class distribution over time. Taxa were sized using the calibrated grid overlaid on the frame grab and assigned to one of four size classes (Table 2.2). Size classes were calculated based on laser spacing.

Table 2.2: Size class categories used when sizing *Alcyonium digitatum, Eunicella verrucosa, Pentapora fascialis, Nemertesia antennina* the composite taxa branching sponges, and grouped hydroids. Sizes were calculated using the calibrated grid overlaid on each frame grab

Category	Description	Approx. actual size
A	Tiny	< 6 cm
B	Small	6 – 11 cm
C	Medium	11 – 18 cm
D	Large	> 18 cm

2.25 For full details of these methods used please see Sheehan et al. (2010) and Attrill et al. (2011)

2.5.2 Extraction of quantitative data from Baited Remote Underwater Video

2.26 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 max min^{-1}) per species per replicate. This method ensures that species swimming in and out of the frame multiple times are not over represented.

2.27 As in previous years, abundance of scavenging species was also recorded (Annex A, Table A3).

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

2.6 Data analysis

2.29 Univariate and multivariate analyses were conducted as reported in Attrill et al. (2011) using Permutational Multivariate Analysis of Variance (PERMANOVA, Anderson 2001) based on similarity matrices. 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.

2.30 The factors used for towed video were Year (fixed: 2008, 2009, 2010, 2011), Treatment (fixed: CC, NC, NOC, FOC), Area (random and nested in Treatment: 6 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 pseudoreplication.

2.31 For the baited video the factors were Year (fixed: 2009, 2010 and 2011), Treatment (fixed: CC, NC, OC), and Site (random x six) with three replicates per site. The three replicates were averaged as with the frame-grabs to avoid pseudoreplication and to increase the measured precision of the mobile fauna assemblage.

2.32 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.

2.33 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). Diffuse colonial or cover-forming 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).

2.34 Size class data were analysed using Multinomial Logit Log-linear models in SPSS v 18.0. Size class was the dependent and year and treatment were factors. See Attrill et al. (2011) for full details.

3 Results

3.1 A total of 144 taxa from ten phyla were recorded in the surveys; 121 were recorded in the frame grab analysis, 46 in the video analysis and 40 in the baited video (Annex A, Table A1).

3.2 Of the species recorded through counts from the quadrat data, grouped hydroids had the greatest mean abundance (59.12 m^{-2} ± 1.23 SE), followed by the colonial species *Cellepora pumicosa* (7.05 m^{-2} ± 0.23), and the tube worm *Serpula vermicularis* (5.48 m^{-2} ± 0.37). “Turf” had the greatest mean percentage cover (7.96 m^{-2} % ± 0.18), and out of the cover taxa identified to species, *Lithophyllum incrustans* abundance was greatest (0.10 m^{-2} % ± 0.01). For the species quantified in the video transects, *Alcyonium digitatum* was the most abundant sessile species (0.67 m^{-2} ± 0.10), followed by *Eunicella verrucosa* (0.20 m^{-2} ± 0.03), and *Pentapora fascialis* (0.17 m^{-2} ± 0.02). Of the free living species, abundance of *Aequipecten opercularis* (0.75 m^{-2} ± 0.09) was greatest, followed by *Asterias rubens* (0.44 m^{-2} ± 0.05) and *Pecten maximus* (0.27 m^{-2} ± 0.02).

3.3 *Trisopterus minutus* had the highest abundance of all nektonic taxa (1.87 min^{-1} ± 0.68), followed by grouped gobies (1.17 min^{-1} ± 0.16) and of the cryptic species *Pagarus bernhardus* had the greatest mean abundance (2.67 min^{-1} ± 0.66), with *Ophiura* spp. and *Inachus* spp. abundance also high (2.02 min^{-1} ± 0.44 and 0.62 min^{-1} ± 0.14 respectively).

3.4 For each PERMANOVA table (where these are not present please see Annex 1), significant low level spatial variation within interactions are not further interpreted as the hypotheses did not relate to different areas in the bay.

3.1 Frame grab data

3.1.1 Abundance

3.5 Observed abundance (number of individuals summed across taxa) was greatest in the CC in 2011 (18.89 m^{-2} ± 0.63) and lowest in the FOC in 2010 (5.98 m^{-2} ± 0.18), (Figure 3.1). Between 2010 and 2011, abundance in the CC increased by 55 %.

3.6 A significant difference in abundance was identified for Treatment and Year, with pairwise tests finding mean abundance to be significantly greater in the CC (12.35 m^{-2} ± 0.43) than the NOC (8.95 m^{-2} ± 0.34) or FOC (7.32 m^{-2} ± 0.28) sites and that it was greater in 2011 (13.36 m^{-2} ± 0.50) compared to any other year (2008 = 7.89 m^{-2} ± 0.31; 2009 = 8.60 m^{-2} ± 0.36; 2010 = 8.59 m^{-2} ± 0.27) (all $P < 0.01$), (Figure 3.1; Annex B, Table B1).

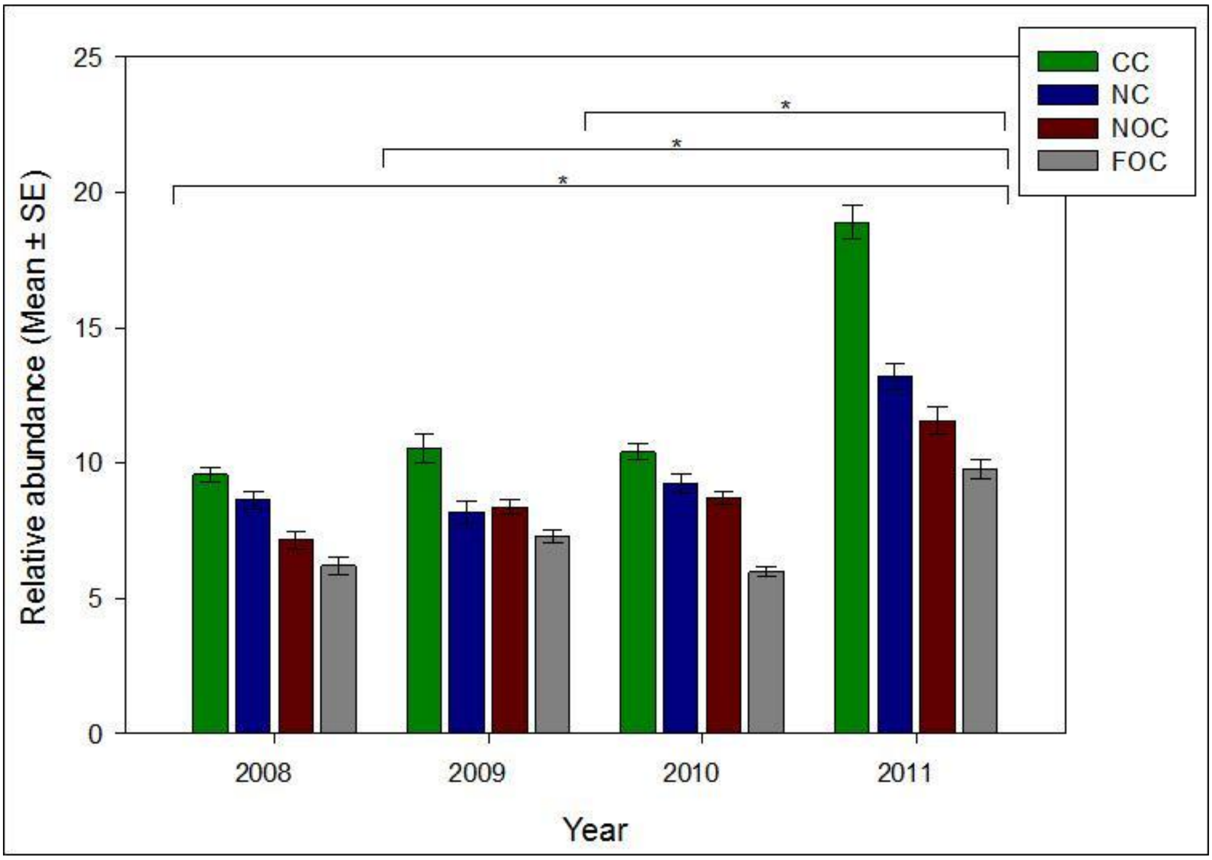


Figure 3.1: Relative abundance (Mean m^{-2} ± SE) of taxa from frame grab analyses for each year (2008, 2009, 2010, 2011) and treatment (CC – closed control, NC = new closure, NOC = near open control, FOC = far open control). Asterisks (*) indicate years that were significantly different

3.1.2 Taxon Richness

3.7 As with abundance, a significant difference was identified for Treatment and Year, with pairwise tests identifying that species richness was greater in the CC than the NOC or FOC and that it was greater in 2011 than any other year (Annex B, Table B2). Mean species richness (number of species) was greatest in the CC in 2011 (4.68 m^{-2} ± 0.05) and lowest in the FOC in 2010 (3.50 m^{-2} ± 0.05), (Figure 3.2).

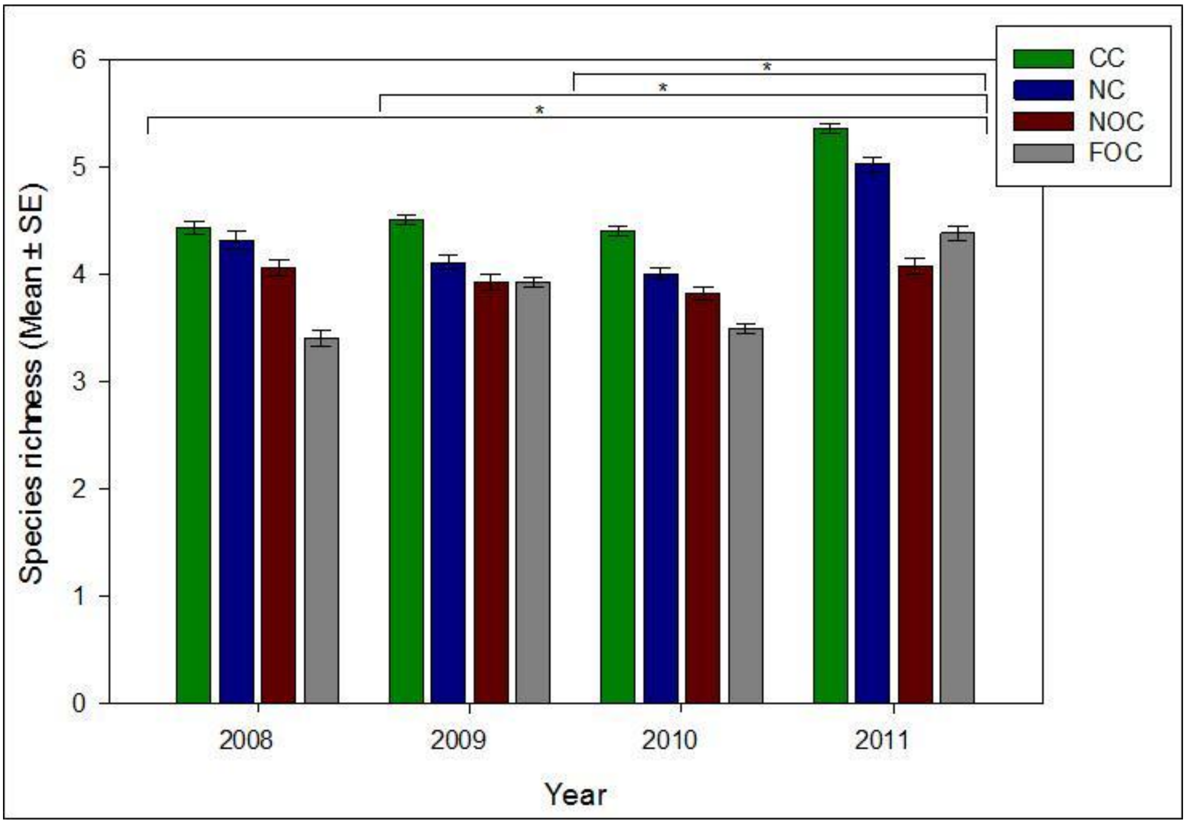


Figure 3.2: Species richness (Mean m^{-2} ± SE) from frame grab analyses for each year (2008, 2009, 2010, 2011) and treatment (CC – closed control, NC = new closure, NOC = near open control, FOC = far open control). Asterisks (*) indicate years that were significantly different

3.1.3 Assemblage composition

3.8 Assemblage composition was significantly different for every factor tested. Pairwise tests for Year x Treatment interaction (all $P < 0.01$, Table 3.1) showed significant differences in 2008 for assemblage composition between the FOC and NC and the FOC and CC. In addition in 2009 they existed between the NOC & CC and by 2010 were also apparent between the NOC and NC (Annex B, Table B3). These differences were consistent in 2011.

Table 3.1: PERMANOVA results for the relative distribution of the main assemblage, 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	3	21546	12.875	**0.0001**
Treatment Tr	3	22707	3.7456	**0.0002**
Area (Tr)	21	4701.4	4.0607	**0.0001**
Ye x Tr	9	2265.5	1.6539	**0.0006**
Site (Ar(Tr))	63	1081.7	1.4586	**0.0001**
Ye x Ar(Tr)	48	1171.9	1.5802	**0.0001**
Residual	110	741.61		
Total	257			

3.9 Figure 3.3 presents a nonmetric MultiDimensional Scaling nMDS illustrating the trajectory of change occurring averaged over sites within treatments for each year. It shows that treatments are most similar in 2008 and that over time similarity decreases between fished and non-fished treatments.

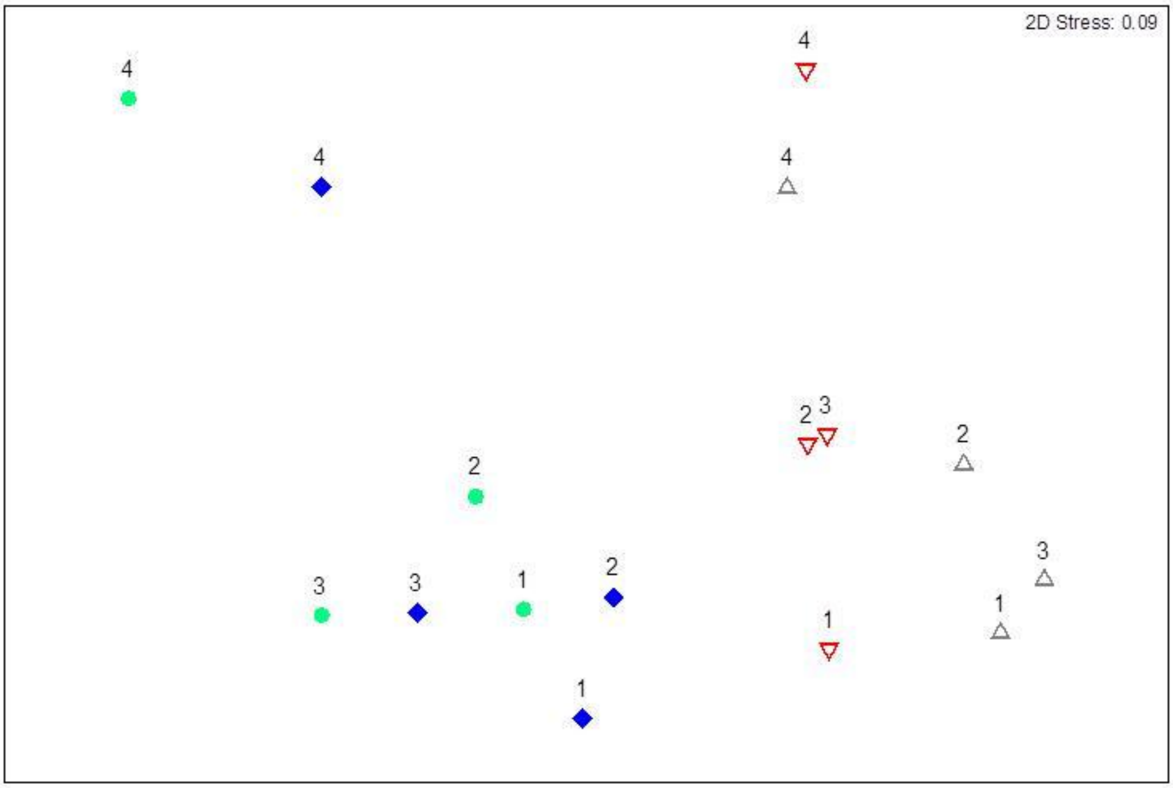


Figure 3.3: nMDS plot illustrating similarities in assemblage composition between Treatments (averaged for site within treatment), (closed control = green circles, new closure = blue diamonds, near open control = red triangles, far open control = grey triangles), over time (1 = 2008, 2 = 2009, 3 = 2010, 4 = 2011)

3.10 Before the 2011 survey, there was a trend where assemblages within the NC were becoming more similar to those of the CC and less similar to those of the NOC and FOC (Attrill et al. 2011). This is still apparent, with results from the 2011 survey suggesting that the NC treatment is moving with and towards the CC and away from the NOC and FOC sites (Figure 3.3).

3.11 SIMPER analysis was used to identify the taxa contributing most to these trends, and this showed that similarities between closed and open treatments were associated with the same taxa across all years. For closed treatments, average similarity was associated with abundance of grouped hydroids and turf, although in 2011 *Cellepora pumicosa* contributed to the similarities more than turf, and for open treatments similarities were associated more with grouped hydroids, turf, *Serpula vermicularis* and *Pagurus bernhardus*. Similarities were greater between sites within closed treatments than within open treatments, and for all treatments except the FOC where it was most pronounced in 2011, similarity between sites within treatment was greatest in 2010.

3.2 Baited Remote Underwater Video data

3.12 A total of 40 species from four Phyla were recorded during the BRUV surveys, consisting of 20 fishes, 11 crustaceans, six molluscs and three echinoderms (See Annex B, Table B4 for details). Of these, 24 were identified in the 2009 survey, 25 in the 2010 survey and 38 in the 2011 survey.

3.13 The species that were observed in the baited video for the first time in 2011, but had previously been quantified by the towed video or known to Lyme Bay, were the cuckoo wrasse *Labrus mixtus*; painted topshell *Calliostoma zizyphinum*; black seabream *Spondyliosoma cantharus;* broad-clawed porcelain crab *Porcellana platycheles;* Atlantic horse mackerel *Trachurus trachurus;* Houndsharks Triakidae sp.; and the pink sea fan nudibranch *Tritonia nilsodhneri*. The pink sea fan nudibranch was quantified for the first time as the video landed with a pink sea fan in the field of view.

3.14 The green sea urchin *Psammechinus miliaris*, and rock cook *Centrolabrus exoletus* were observed and quantified for the first time both on the towed and baited video in 2011.

3.2.1 Abundance

3.15 A significant difference was identified between Years ($P < 0.001$), (Annex 1, Table B4), with abundance found to be greater in 2011 (17.33 min^{-1} ± 1.64) than other years (2009 = 7.74 min^{-1} ± 2.26; 2010 = 7.46 min^{-1} ± 1.00), (Figure

3.4). Abundance was greatest in the FOC in 2011 (19.86 min^{-1} ± 1.72) and lowest in the CC in 2009 (3.72 min^{-1} ± 0.71), (Figure 3.4).

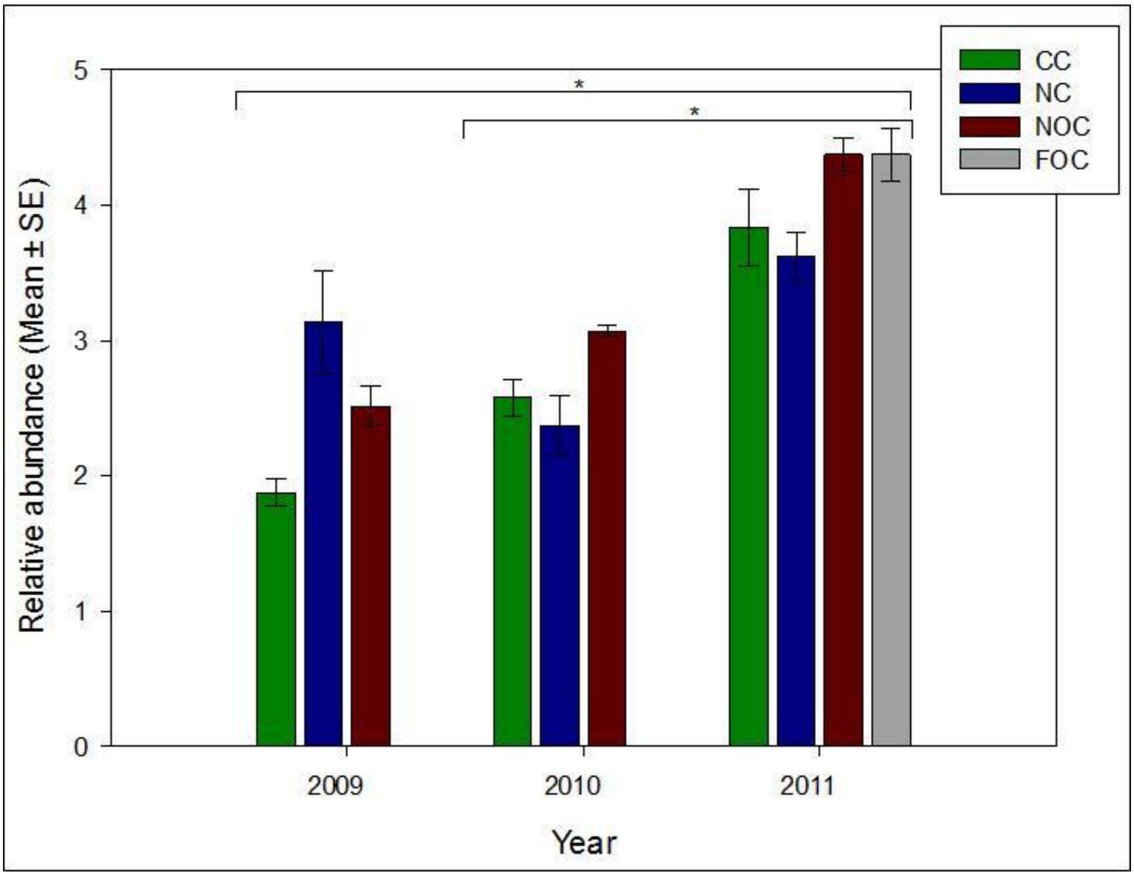


Figure 3.4: Relative abundance (mean m^{-2} ± SE) of mobile fauna (N) per site for each treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = future open control) in 2009, 2010 and 2011. Asterisks (*) indicate years that were significantly different

3.16 Pairwise tests showed that the abundance of mobile fauna in sites had become increasingly dissimilar over time. No significant differences were identified between 2009 and 2010, but differences between 2010 and 2011 and 2009 and 2011 were significant ($P < 0.001$), (Annex B, Table B4).

3.2.2 Species Richness

3.17 A significant Year x Treatment interaction was identified for species richness. In 2011, the NC was significantly different to the NOC for the first time. Increases were seen from previous years to 2011 in species richness for all treatments. Species richness was greatest in the NC in 2011 (13.50 min^{-1} ±1.67) and lowest within the CC in 2009 (6.17 min^{-1} ± 0.60), (Figure 3.5).

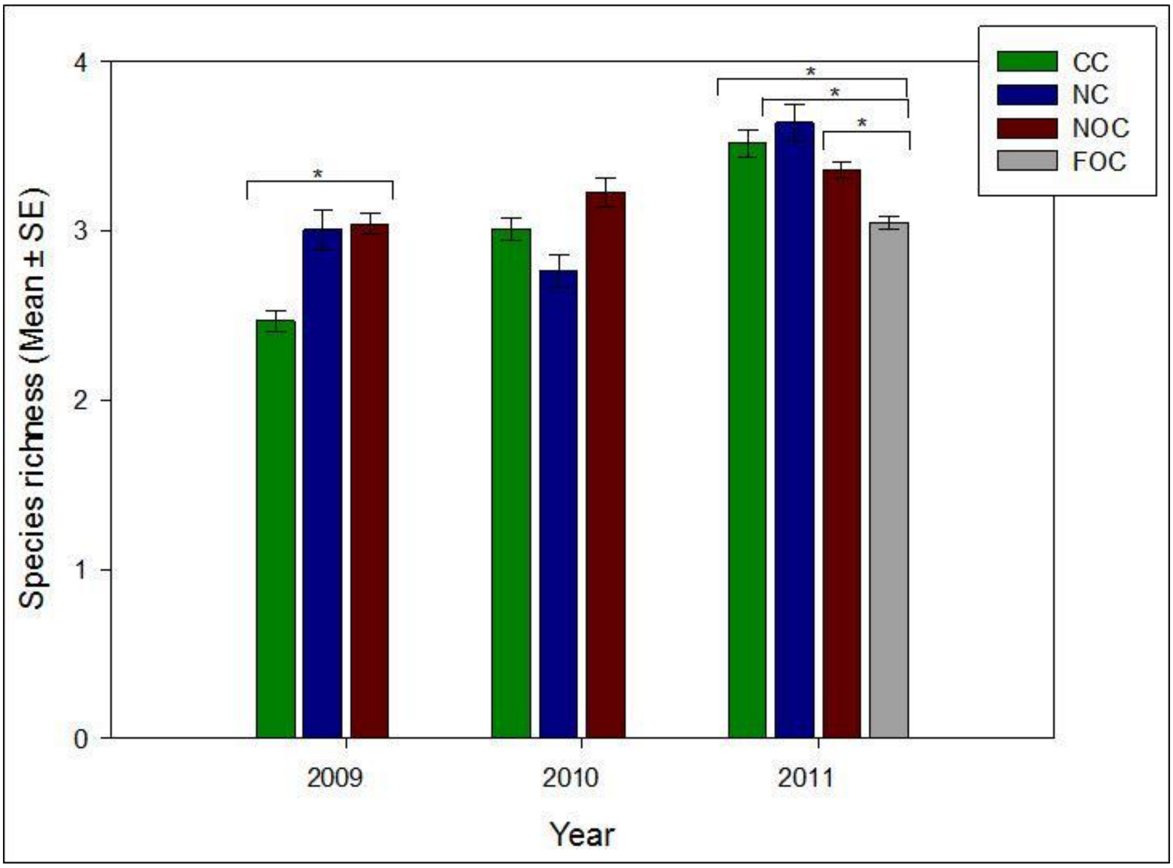


Figure 3.5: Mobile fauna species richness (Mean min^{-1} ± SE) (S) per site for each treatment (CC = closed control, NC = new closure, NOC = near open control) in 2009, 2010 and 2011. Asterisks (*) show pairs that were significantly different

3.18 Pairwise tests showed species richness to be significantly greater in the NOC (9.33 min^{-1} ± 1.43) than the CC in 2009, there to be no significant differences between treatments in 2010, and the FOC (9.33 min^{-1} ± 0.49) to have significantly lower species richness than all other treatments in 2011 (CC = 12.5 min^{-1} ± 1.12; NC = 13.5 min^{-1} ± 1.67; NOC = 11.33 min^{-1} ± 0.61) (Annex B, Table B5).

3.2.3 Abundance of scavengers

3.19 As in previous years, the finding of greater abundance in open sites (NOC & FOC) was somewhat counter intuitive, leading to analysis of the abundance of scavengers. A significant difference was identified in the abundance of scavenging species between Treatments ($P < 0.001$), (Figure 3.6), (Annex B, Table B7). Although no Year x Treatment interaction was identified as it had been previously, there were significantly more scavengers in the fished than non-fished treatments.

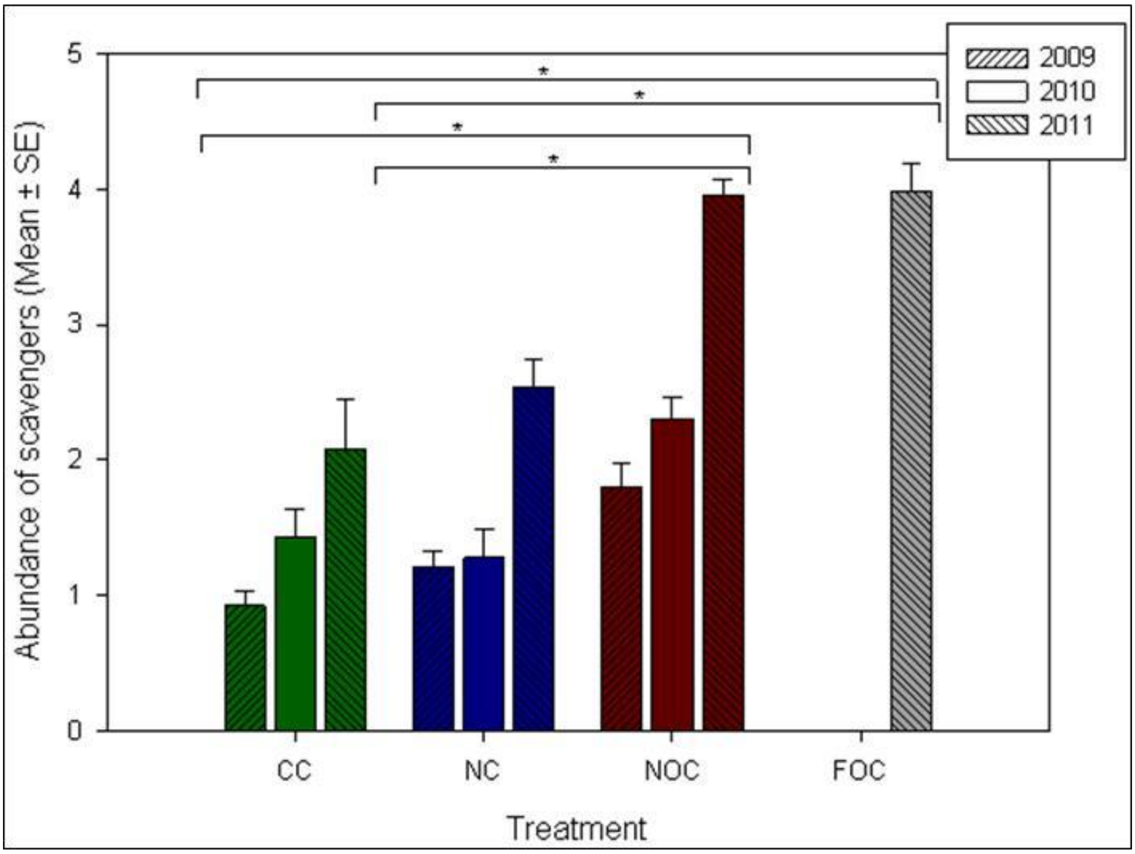


Figure 3.6: Abundance of scavengers (Mean min^{-1} ± SE) for each treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = Future Open Control) in 2009, 2010 and 2011. Asterisks (*) show significant pairings

3.2.4 Assemblage composition

3.20 A significant Year x Treatment interaction was identified for assemblage composition ($P < 0.001$) as illustrated in Figure 3.7 using non-metric multidimensional scaling. This shows increasing dissimilarity between years and a distinction between open (NOC & FOC) and closed (NC & CC) sites which is most apparent in 2011 (Year 3 on nMDS), (Figure 3.7).

3.21 Pairwise tests identified fluctuating trends in abundance between treatments (Annex B, Table B6). In 2009 significant differences were identified between all treatments, in 2010 no significant differences were identified between any treatment pairings, and in 2011 both the NOC and FOC had a significantly different species composition to the NC and CC, but no significant differences were identified between open treatment pairings (NOC & FOC) or closed treatment pairings (CC and NC).

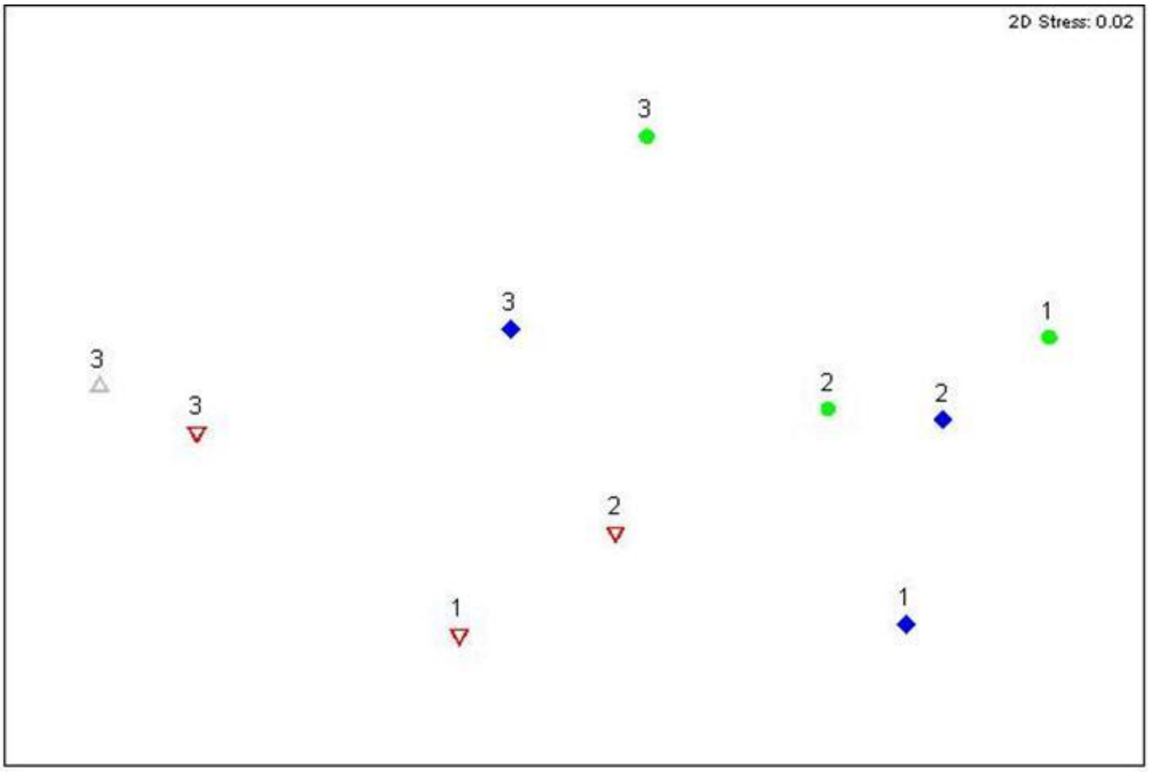


Figure 3.7: nMDS plot showing the degree of similarity between mobile species composition at sites within the 4 experimental treatments (closed control = green circles, new closure = blue diamonds, near open control = red triangle, future open control = grey triangle) between years (1 = 2009, 2 = 2010, 3 = 2011).

3.22 SIMPER analysis was used to identify the species associated with the similarities within treatments. It showed that the similarity between sites within the NC increased in 2011, but decreased in the CC and NOC. The species responsible varied between years, with no clear trend apparent as for the towed video. Similarities between sites within the NOC and FOC were, however, mainly due to scavenging species (e.g. *Pagurus bernhardus*, *Asterias rubens* and *Inachus* spp.) whereas those between CC and NC sites were not (e.g. *Trisopterus minutus*, Grouped gobies and *Ctenolabrus rupestris*). For closed sites, the top five species associated with the within treatment similarities included three scavenging species, whereas in 2010 and 2011 only one scavenging species was included in the top five. Conversely, the similarity within NOC and FOC treatments was consistently associated with scavenging species.

3.3 Analysis of indicator species

3.23 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 locked into the analysis, 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 B8 – B23.

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 B8 – B14 with results presented where a significant difference was detected. 'Trend towards recovery' refers to when 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 ≥ CC?**	**Trend towards recovery?**	**Year**	**Treatment**
P. maximus	V	High	Yes	Yes	2011	CC
P. mammillata	V	Medium	-	-	-	CC
C. pumicosa	F	Low	-	-	2011	CC
P. fascialis	F	Low	Yes	Yes	2011	CC
Grouped anemones	F	-	-	-	2011	-
A. digitatum	V	Low	-	-	2009	-
E. verrucosa	V	Low	-	-	-	-

Pecten maximus **– King scallop (V)**

3.24 Abundance of *Pecten maximus* increased in all treatments with the exception of the NOC in 2011 (Figure 3.8). A significant Year x Treatment interaction was identified ($P < 0.01$), with pairwise tests showing abundance to be significantly greater in the NC than the NOC and FOC in 2010 (mean abundance NC = 0.35 m^{-2} ± 0.03, NOC = 0.17 m^{-2} ± 0.02, FOC = 0.11 m^{-2} ± 0.01) and 2011 (mean abundance NC = 0.76 m^{-2} ± 0.06, NOC = 0.15 m^{-2} ± 0.03, FOC = 0.21 m^{-2} ± 0.02), (all $P < 0.05$, Annex B, Table B8). The increase in abundance of *P. maximus* in the NC is of particular note, with a 118 % increase in abundance seen between 2010 and 2011 (Figure 3.8).

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

3.25 A Year x Treatment interaction was identified ($P < 0.05$, Annex B, Table B9) with abundance of *Phallusia mammillata* continuing to increase in the CC and decrease in the NC as in 2010 (Figure 3.8). Pairwise tests showed abundance in the CC to be significantly greater than in the NOC in 2008 (mean abundance CC = 0.12 m^{-2} ± 0.01, NOC = 0.01 m^{-2} ± 0.002), 2010 (mean abundance CC =

0.28 m^{-2} ± 0.03, NOC = 0.004 m^{-2} ± 0.002) and 2011 (mean abundance CC = 0.39 m^{-2} ± 0.05, NOC = 0.01 m^{-2} ± 0.002) than in the FOC in all years (mean abundance 2008 – FOC = 0.04 m^{-2} ± 0.02; 2009 - CC = 0.28 m^{-2} ± 0.04, FOC = 0.01 m^{-2} ± 0.001; 2010 –, FOC = 0.01 m^{-2} ± 0.002; 2011 –, FOC = 0.01 m^{-2} ± 0.001), ($P < 0.05$, Annex B, Table B9).

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

3.26 Abundance of *Cellepora pumicosa* increased in all treatments in 2011 (Figure 3.8). Significant Year and Treatment effects were identified, and pairwise tests showed abundance to be significantly greater in the CC (mean abundance 12.05 m^{-2} ± 0.47) than the NOC (mean abundance 2.20 m^{-2} ± 0.16) or FOC (mean abundance 1.98 m^{-2} ± 0.16) and in 2011 (mean abundance 13.74 m^{-2} ± 0.55) than all other years (mean abundance 2008 = 6.70 m^{-2} ± 0.37; 2009 = 3.78 m^{-2} ± 0.22; 2010 = 2.76 m^{-2} ± 0.17), (Annex B, Table B10). The 2008-2010 trend of declining abundance within the closed treatments (NC & CC) has been reversed, with a 500 % increase in abundance seen between 2010 and 2011 (mean abundance CC – 2010 = 4.44 m^{-2} ± 0.22, 2011 = 26.62 m^{-2} ± 0.86; NC – 2010 = 3.98 m^{-2} ± 0.22, 2011 = 21.33 m^{-2} ± 0.90), (Figure 3.8).

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

3.27 Abundance of *Pentapora fascialis* was relatively stable between 2008 and 2010, with 2011 seeing its abundance increase across treatments (Figure 3.8). A significant interaction was identified for Year x Treatment ($P < 0.01$, Annex B, Table B11), with pairwise tests finding abundance to be significantly greater in the NC (2008 = 0.18 m^{-2} ± 0.03; 2009 = 0.43 m^{-2} ± 0.04; 2010 = 0.43 m^{-2} ± 0.06; 2011 = 1.81 m^{-2} ± 0.11) and CC (2008 = 0.82 m^{-2} ± 0.06; 2009 = 0.80 m^{-2} ± 0.05; 2010 = 0.84 m^{-2} ± 0.07; 2011 = 3.74 m^{-2} ± 0.16) than the NOC (2008 = 0.00 m^{-2}; 2009 = 0.06 m^{-2} ± 0.02; 2010 = 0.04 m^{-2} ± 0.01; 2011 = 0.18 m^{-2} ± 0.03) and FOC (2008 = 0.06 m^{-2} ±0.01; 2009 = 0.08 m^{-2} ± 0.02; 2010 = 0.02 m^{-2} ±0.01; 2011 = 0.04 m^{-2} ± 0.01) in all years except in the NC and FOC in 2008 ($P < 0.05$, Annex B, Table B11).

Grouped Anemones (F)

3.28 Abundance of the grouped anemones *Aiptasia mutabilis*, *Cerianthus* spp., *Peachia cylindrica* and *Sagartia* spp. increased in all treatments excepting the NC in 2011 (Figure 3.8). A significant difference was identified for Year, with pairwise tests finding greater abundance in 2010 (1.51 m^{-2} ± 0.16) than 2008 (1.25 m^{-2} ± 0.17) and in 2011 (4.52 m^{-2} ± 0.33) than all other years (2009 = 1.49 m^{-2} ±0.14), (Annex B, Table B12).

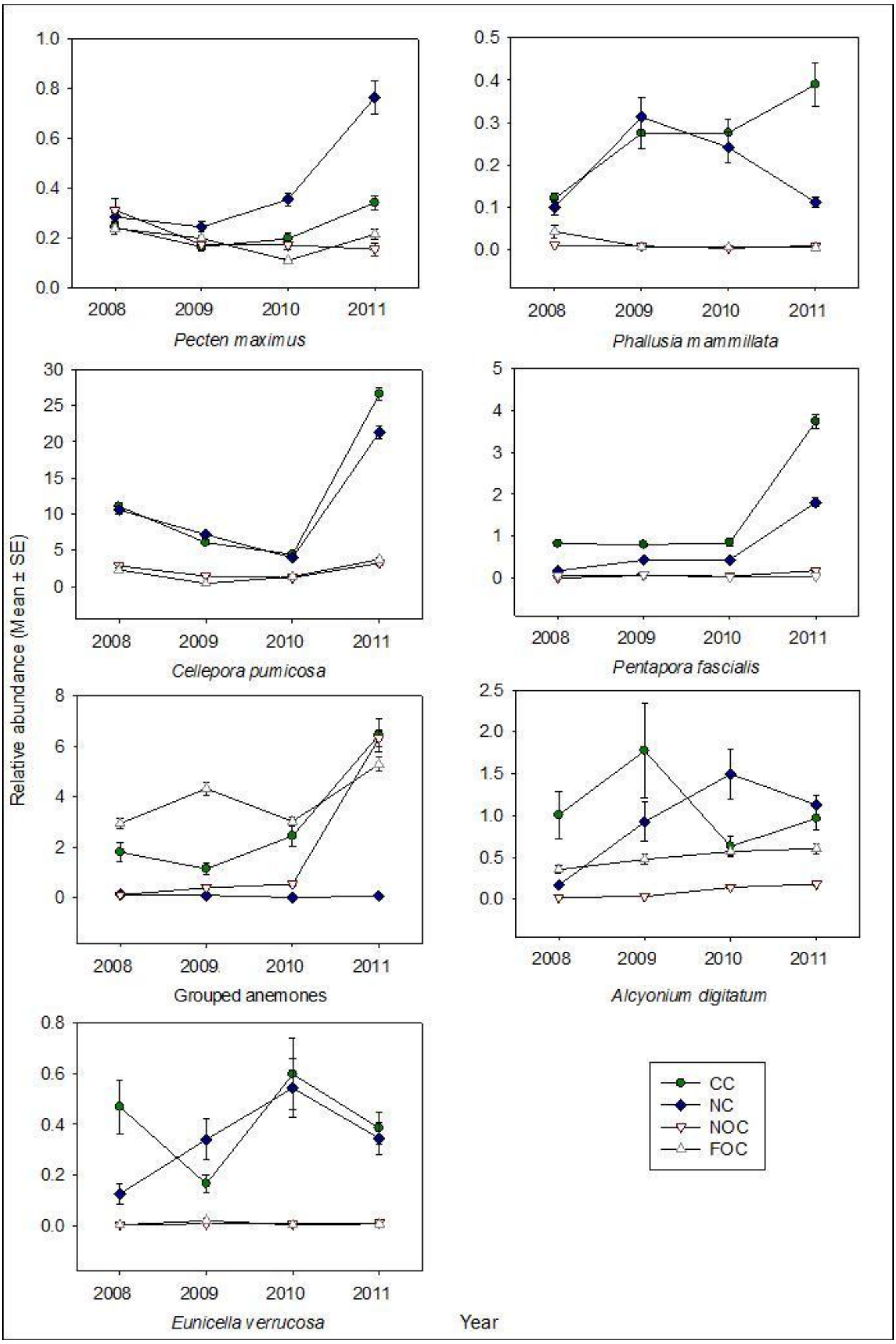


Figure 3.8: Relative abundance of key indicator species (Mean m^{-2} ± SE) per treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = far open control), per year (2008, 2009, 2010, 2011). Scales on the y-axes vary

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

3.29 Abundance of *Alcyconium digitatum* increased in all treatments with the exception of the NC in 2011 (Figure 3.8). A significant Year effect was identified (P < 0.05, Annex B, Table B13) and pairwise tests showed abundance to be greater in 2010 and 2011 than 2008 (mean abundance 2008 = 0.39 m^{-2} ± 0.09, 2010 = 0.71 m^{-2} ± 0.12, 2011 = 0.72 m^{-2} ± 0.09), (all P < 0.05, Annex B, Table B13). Mean abundance was greatest in 2009 (0.80 m^{-2} ± 0.21), (Table 3.2).

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

3.30 Abundance of *Eunicella verrucosa* decreased in both the CC and NC in 2011 and a Year x Treatment interaction was identified (P < 0.05, Annex B, Table B14). Despite abundance in the CC and NC being greater in 2010 than 2011, variation between sites within treatment decreased (Figure 3.8) and pairwise tests showed abundance to be significantly greater in the CC than the NOC or FOC in 2011 (mean abundance CC = 0.38 m^{-2} ± 0.06, NOC = 0.01 m^{-2} ± 0.003, FOC = 0.01 m^{-2} ± 0.003), (P < 0.01, Annex B, Table B14).

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 B15 – B17 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 ≥ CC?**	**Trend towards recovery?**	**Year**	**Treatment**
C. variopedatus	F	High	Yes	-	2011	-
T. auratium	-	-	-	-	-	-
Grouped hydroids	F	-	-	Yes	2011	CC
C. celata	-	-	-	-	-	-
Branching sponges	V	-	-	Yes	2011	CC

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

3.31 Abundance of *Chaetopterus variopedatus* increased in all treatments in 2011 (Figure 3.9). A significant interaction was identified for Year x Treatment (P < 0.05, Annex B, Table B15) and pairwise tests showed that in 2008 abundance in the CC (1.53 m^{-2} ± 0.17), NC (1.06 m^{-2} ± 0.18) and NOC (0.93 m-2 ± 0.08) was greater than in the FOC (0.00 m^{-2}); in 2010 abundance in the NC (0.89 m^{-2}

± 0.13) was greater than in the NOC (0.56 m^{-2} ± 0.14) and in 2011 it was greater in the NC (2.93 m^{-2} ± 0.36) than FOC (0.48 m^{-2} ± 0.05), (Annex B, Table B15). Between 2010 and 2011 abundance in the NC increased by 52 % (Figure 3.9).

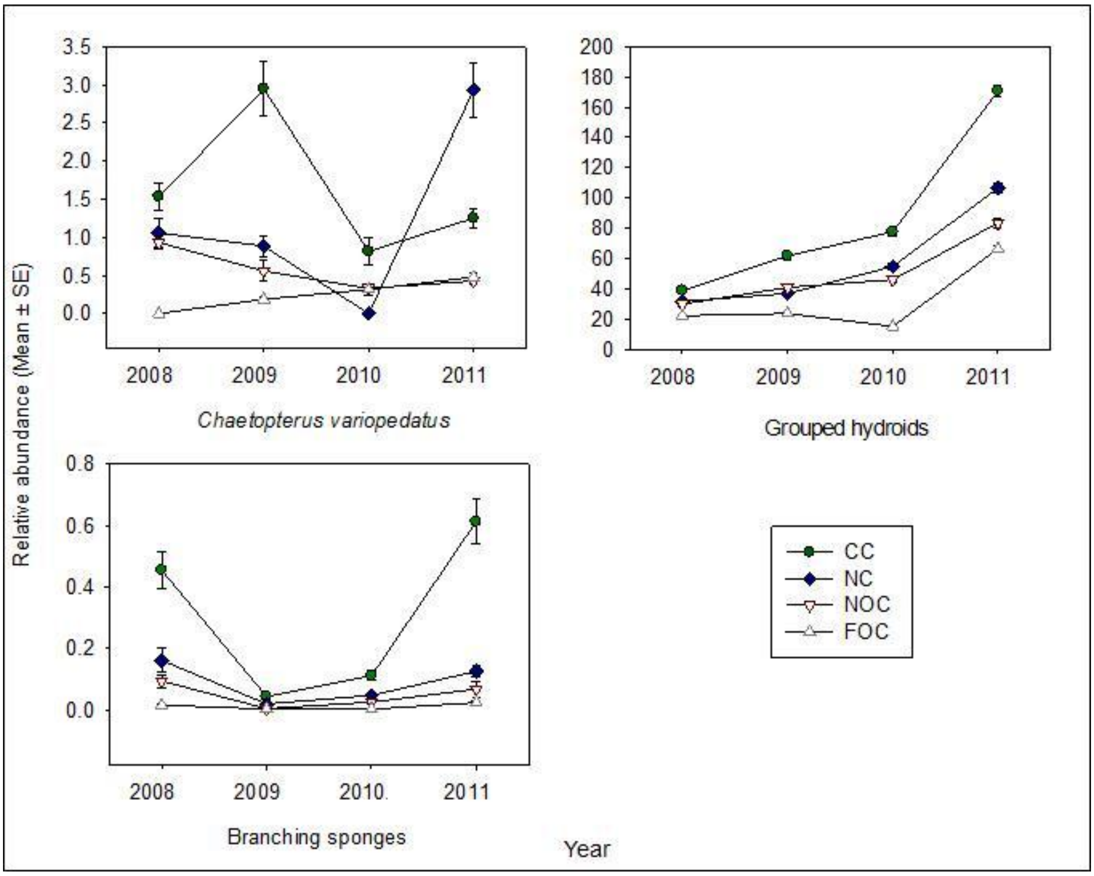


Figure 3.9: Relative abundance of sessile indicator species (Mean m^{-2} ± SE) per treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = far open control), per year (2008, 2009, 2010, 2011)

Tethya citrina – Golf ball sponge

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

Grouped hydroids (F)

3.33 Abundance of grouped hydroids increased in all treatments in 2011 (Figure 3.9). Significant Treatment and Year effects were identified (P < 0.05, Annex B, Table B16) with pairwise tests showing abundance to be greater in the NC (57.46 m^{-2} ± 2.11) than NOC (50.03 m^{-2} ± 2.08) and FOC (31.83 m^{-2} ± 1.33) and in 2011 (106.86 m^{-2} ± 2.90) than all other years (2008 = 30.60 m^{-2} ±1.64; 2009 = 40.75 m^{-2} ± 1.83; 2010 = 48.33 m^{-2} ± 1.94) (Annex B, Table B16).

Cliona celata – Boring sponge

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

Branching sponges (V)

3.35 Abundance of branching sponges increased in all treatments in 2011 (Figure 3.9), and a significant Year x Treatment effect was identified ($P < 0.05$, Annex B, Table B17). Pairwise tests showed abundance to be greater in the CC than FOC in 2008 (mean abundance CC = 0.45 m^{-2} ± 0.06, FOC = 0.02 m^{-2} ± 0.004),and in the CC than the NOC and FOC in 2009 (mean abundance CC = 0.04 m^{-2} ± 0.01, NOC = 0.004 m^{-2} ± 0.001, FOC = 0.003 m^{-2} ± 0.001), 2010 (mean abundance CC = 0.11 m^{-2} ± 0.01, NOC = 0.03 m^{-2} ± 0.01, FOC = 0.002 m^{-2} ± 0.001) and 2011 (mean abundance CC = 0.61 m^{-2} ± 0.07, NOC = 0.07 m^{-2} ± 0.03, FOC = 0.02 m^{-2} ± 0.007). Abundance was also greater in the NC than FOC in 2010 (mean abundance NC = 0.05 m^{-2} ± 0.01, FOC = 0.002 m^{-2} ± 0.001), (all $P < 0.05$, Annex B, Table B17). Abundance of branching sponges in the CC increased 454 % between 2010 and 2011 (Figure 3.9).

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 B18 – B23 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).

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

Asterias rubens – Common starfish (V)

3.36 Abundance of *Asterias rubens* increased in the CC and NC in 2011 and decreased in the NOC and FOC from previous years (Figure 3.10). No significant interactions were identified between years or treatments however (Annex B, Table B18), a trend towards recovery is apparent, with abundances in the CC and NC increasing since 2009 in the CC (mean abundance 2009 = 0.30 m^{-2} ± 0.03, 2010 = 0.42 m^{-2} ± 0.04, 2011 = 0.76 m^{-2} ± 0.09) and since 2010 in the NC (mean abundance 2010 = 0.20 m^{-2} ± 0.02, 2011 = 0.32 m^{-2} ± 0.04), (Figure 3.10).

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

3.37 No significant effects of Year or Treatment were identified for the abundance of *Trisopterus minutus* (Annex B, Table B19). Abundance remained low, but an increase was seen in the NC between 2010 and 2011 (mean abundance 2010 = 0.90 m^{-2} ± 0.28, 2011 = 1.48 m^{-2} ± 0.21), (Figure 3.10).

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

3.38 Abundance of *Necora puber* decreased in the CC, NC and NOC and increased slightly in the FOC in 2011 (Figure 3.10). Significant Year and Treatment effects were identified ($P < 0.05$), with pairwise tests showing abundance to be greater in the CC (mean abundance = 0.03 m^{-2} ± 0.005) than FOC (mean abundance = 0.004 m^{-2} ± 0.001) and lower in 2008 than all other years (mean abundance 2008 = 0.003 m^{-2} ± 0.001, 2009 = 0.01 m^{-2} ± 0.003, 2010 = 0.003 m^{-2} ± 0.005, 2011 = 0.02 m^{-2} ± 0.003), ($P < 0.05$, Annex B, Table B20).

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

3.39 Abundance of *Cancer pagurus* increased in the CC and FOC in 2011 and decreased in the NC and NOC (Figure 3.10). A significant Treatment effect was identified, and pairwise tests showed that abundance in the CC and the NOC was greater than the FOC (mean abundance CC = 0.009 m^{-2} ±0.003, NOC = 0.009 m^{-2} ± 0.002, FOC = 0.001 m^{-2} ± 0.001), ($P < 0.05$, Annex B, Table B21). Despite a 222 % increase in abundance of *C. pagurus* in the CC since 2009, abundance in the NC remained low (Figure 3.9).

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

3.40 No significant interactions were identified for the abundance of *Ctenolabrus rupestris* between Treatments or Years (Annex B, Table B22). Abundances have continued to increase in both the CC and NC in 2011 (CC - 2010 = 0.34 min^{-1} ± 0.08, 2011 = 0.81 min^{-1} ± 0.12; NC – 2010 = 0.15 min^{-1} ± 0.04, 2011 = 0.89 min^{-1} ± 0.15) and remain low in the NOC (2010 = 0, 2011 = 0.02 min^{-1} ± 0.01), (Figure 3.10).

Grouped gobies (B)

3.41 No significant interactions were identified for the abundance of gobies between treatments or years (Annex B, Table B23). Abundances have, however, been seen to decrease slightly since 2010 in the CC (2010 = 1.76 min^{-1} ±, 2011 = 1.14 min^{-1} ± 0.24) NC (2010 = 1.79 min^{-1} ± 0.28, 2011 = 1.65 min^{-1} ± 0.44) and NOC (1.10 min^{-1} ± 0.12) as shown by Figure 3.10.

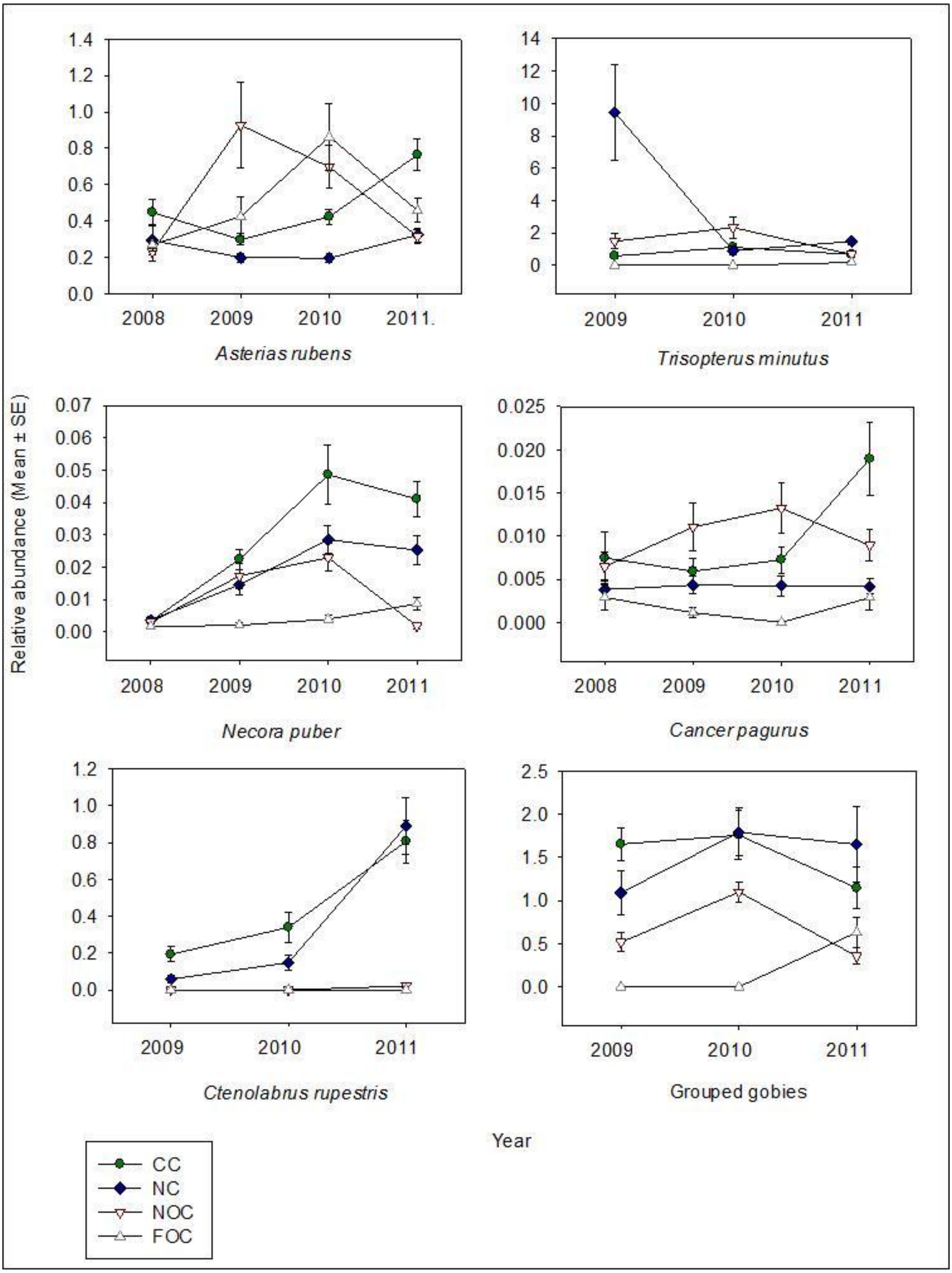


Figure 3.10: Relative abundance (Mean ± SE) of free living indicator species per treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = far open control), per year (2008, 2009, 2010, 2011). Abundance of *Asterias rubens, Necora puber and Cancer pagarus* presented as mean m^{-2}. Abundance of *Trisopterus minutus*, *Ctenolabrus rupestris and* Grouped gobies presented as mean min^{-1}

3.4 Size class analysis

3.42 Size class distribution was examined for key species producing Goodness of Fit (Pearson's Chi-square) values derived by removing the terms of interest from the saturated model (Table 3.5). *Post-hoc* significance tests are not possible with this type of analysis, but examination of the plots of size classes by treatment for each year (Figures 3.11, 3.12, 3.13) give an indication of where the most powerful interactions lie.

3.43 For a reserve effect to be apparent, a significant interaction between Year and Treatment would be expected, characterised by a shift in size class distribution within the NC treatment over time, towards a condition approximating the CC.

Table 3.5: Summary of goodness-of-fit tests on size-class distributions for 6 taxa, *Alcyonium digitatum, Eunicella verrucosa, Pentapora fascialis, Nemertesia antennina*, branching sponges and grouped hydroids for 2008-2011 data

Taxon	n	Factors	Df	Pearson's Chi-sq.	P
Alcyonium digitatum	2949	Ye	9	190.993	**<0.001**
		Tr	9	63.294	**<0.001**
		YexTr	27	77.634	**<0.001**
Branching Sponges	697	Ye	9	37.735	**<0.001**
		Tr	9	6.330	0.707
		YexTr	27	42.556	**0.029**
Eunicella verrucosa	721	Ye	9	22.782	**0.007**
		Tr	9	29.868	**<0.001**
		YexTr	27	23.499	0.658
Grouped Hydroids	56518	Ye	9	10050.413	**<0.001**
		Tr	9	1284.629	**<0.001**
		YexTr	27	1190.945	**<0.001**
Pentapora fascialis	631	Ye	9	47.755	**<0.001**
		Tr	9	14.514	0.105
		YexTr	27	34.149	0.162
Nemertesia antennina		Ye	9	659.553	**<0.001**
		Tr	9	26.424	**0.002**
		YexTr	27	123.292	**<0.001**

3.44 A Year x Treatment interaction was identified for *A. digitatum*, branching sponges, grouped hydroids and *N. antennina* ($P < 0.05$, Table 3.5), and examination of the size class distributions (Figure 3.11, 3.12, 3.13) suggests some reserve effect. Abundance of *A. digitatum* and branching sponges was greater in CC and NC sites than NOC and FOC sites across all years. Despite there being no Year x Treatment interaction, both a Treatment and a Year effect was identified for *E. verrucosa*, and a Year effect was identified for *P. fascialis* as evident in Figures 3.11 and 3.12.

3.45 Abundance of *E. verrucosa* of size class C has continued to increase in the NC in 2011, with other size classes remaining stable (Figure 3.12). As in previous years recruitment is almost entirely in the NC and CC treatments, and has continued to be successful, as evidenced by the presence of individuals in size class A.

3.46 Abundance of *P. fascialis* in the NC and CC increased substantially in 2011. Figure 3.11 shows that individuals recruited in 2010 have continued to grow, and that 2011 has been another successful recruitment year in the closed treatments.

3.47 As in previous years, the sample size for grouped hydroids was very large due to the presence of dense aggregations, and, as shown by Figure 3.12, the highly significant interaction ($P < 0.01$, Table 3.5) is not unequivocally a result of increasing size in the NC. It is apparent that abundance of hydroids in size class A has increased in the NOC and FOC as well as closed treatments. Similarly, *N. antennina* abundance has increased in all treatments in 2011 (Figure 3.11), suggesting that despite recruitment of smaller individuals in the CC and NC, the Year x Treatment interaction identified cannot be attributed solely to a reserve effect. Most notably, abundance in the open treatments has increased substantially between 2010 and 2011 in all size classes.

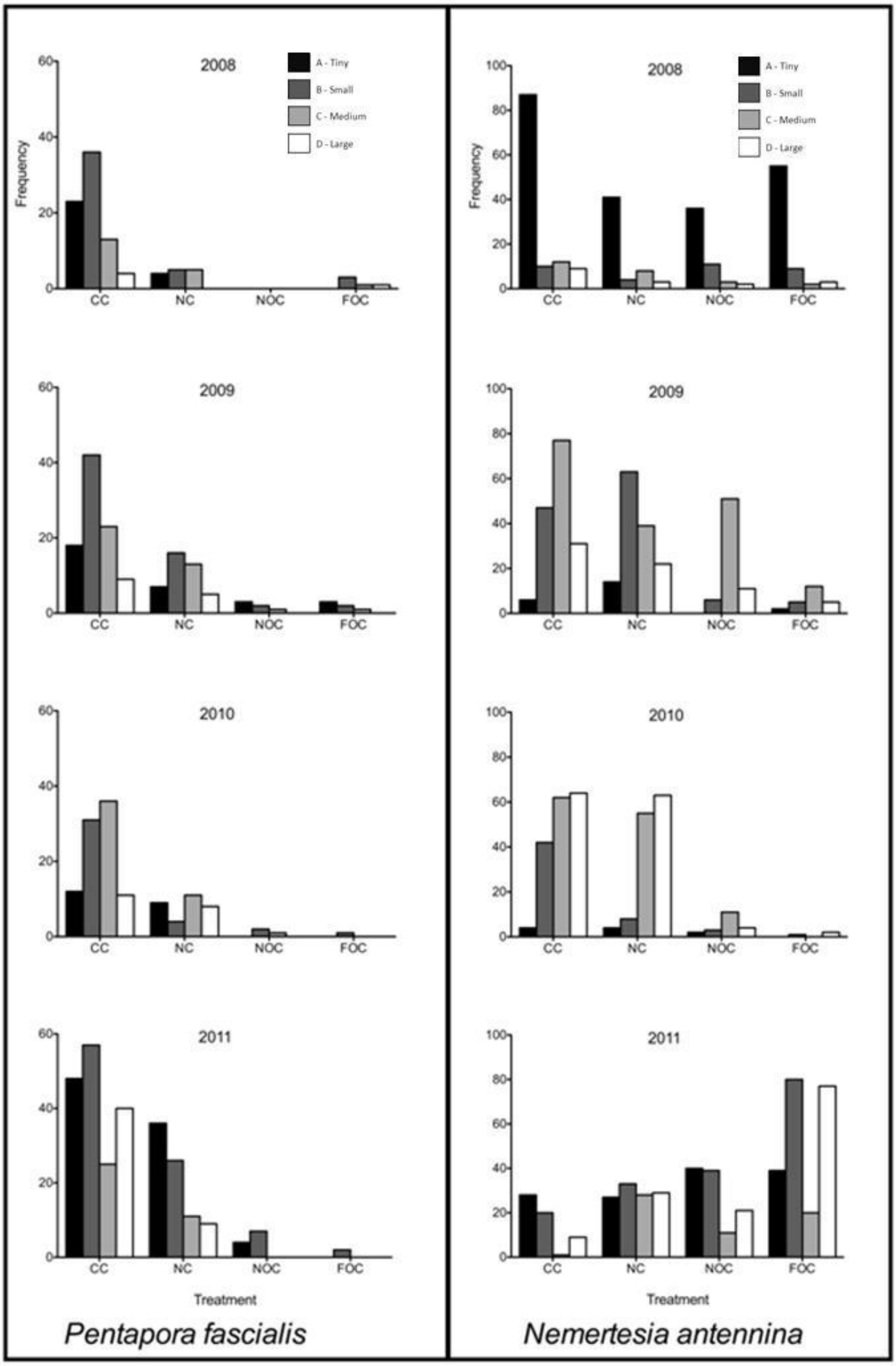


Figure 3.11: Size class distributions for *Pentapora fascialis* and *Nemertesia antennina* showing frequency of individuals by size class (A = Tiny (< 6 cm), B = Small (6 – 11 cm), C = Medium (11 – 18 cm), D = Large (> 18 cm), Treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = far open control) and year (2008, 2009, 2010, 2011)

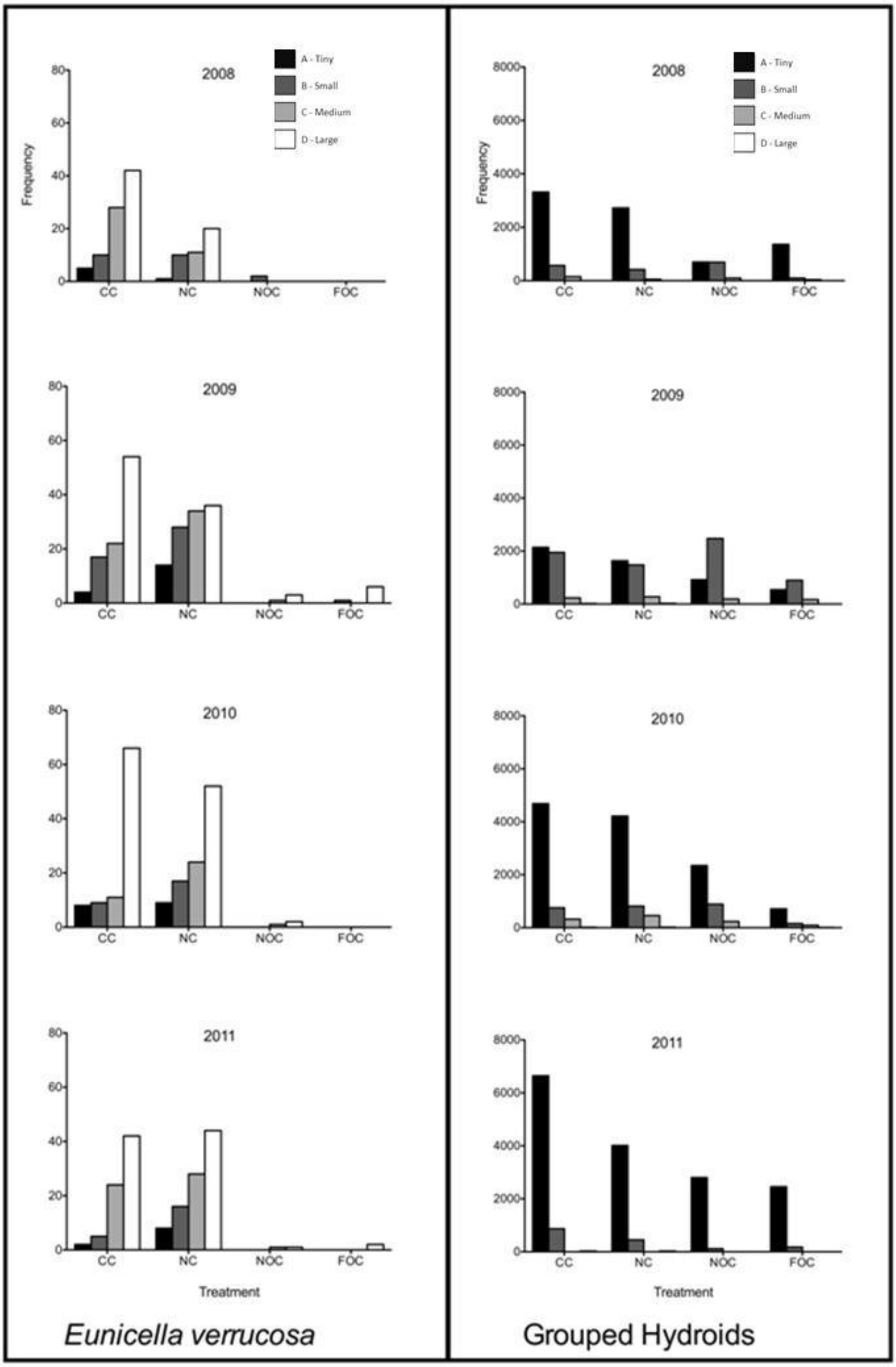


Figure 3.12: Size class distributions for *Eunicella verrucosa* and grouped hydroids showing frequency of individuals by size class (A = Tiny (< 6 cm), B = Small (6 – 11 cm), C = Medium (11 – 18 cm), D = Large (> 18 cm), Treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = far open control) and year (2008, 2009, 2010, 2011)

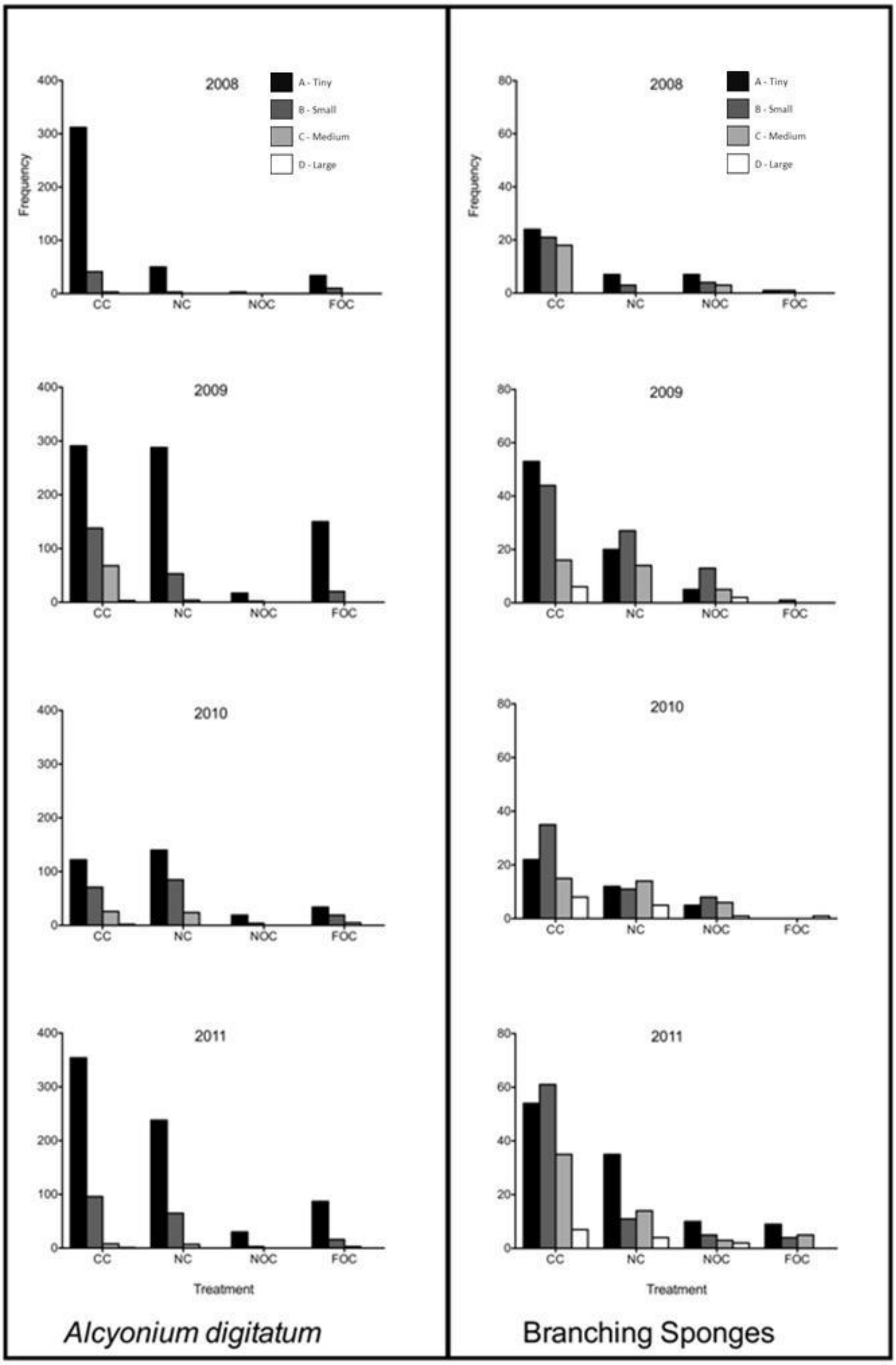


Figure 3.13: Size class distributions for *Alcyonium digitatum* and grouped branching sponges showing frequency of individuals by size class (A = Tiny (< 6 cm), B = Small (6 – 11 cm), C = Medium (11 – 18 cm), D = Large (> 18 cm), Treatment (CC = closed control, NC = new closure, NOC = near open control, FOC = far open control) and year (2008, 2009, 2010, 2011)

4 Discussion

4.1 The first three years of the study (2008-2010) found that the level of protection afforded by the SI had altered the assemblage structure, abundance and diversity of taxa within Lyme Bay (Attrill et al. 2011). The principal evidence for this was that the assemblage structure in the NC had become more similar to that within the CC and less similar to that within the NOC and FOC over the course of the study. Strong spatial variation was, however, identified and it was concluded that whilst there were indications of a trend towards recovery it was not possible to determine whether the sites that were not exhibiting this trend would remain permanently in that condition or were simply recovering more slowly. This report has presented results from a further year of sampling (2011) which aimed to further investigate the identified trends.

4.2 The 2011 sampling season marked the third year of sampling since the enforcement of the SI, and the fourth year of the survey. Monitoring of benthic assemblages and reef associated nekton continued to provide additional temporal data, the results of which have been reported here. The following discussion aims to report the findings of this in context with those from the 2008-2010 survey (Attrill et al. 2011).

4.3 As a result of the Lyme Bay cSAC being established and encompassing some of the near open controls, the 2011 monitoring has successfully identified new open control sites outside of the cSAC for the towed and baited video survey. The old sites will continue to be monitored as closed sites for the monitoring of the cSAC. For the purpose of this study the new open sites have been incorporated into the existing treatments, to assess their suitability as future controls.

4.4 It is clear from both the towed and baited survey results that 2011 has seen a marked improvement across the bay. All three survey methods identified new species, and abundance and species richness increased for towed and baited assemblages in both closed and open treatments. Increases have been more pronounced in closed treatments, and the results continue to suggest a trend towards recovery where sites within the new closure are becoming less similar to those within the open controls and more similar to those in the closed control.

4.1 Epibenthos

4.5 When considering the towed video results, there is evidence of an increase in abundance of taxa and species richness across treatments with a significant difference identified for both metrics between 2011 and previous years. These increases were greatest in the CC, and significant differences were identified between these sites and those in the NOC and FOC, strengthening the conclusion that the level of protection afforded by the SI has altered the diversity, abundance and assemblage structure of taxa in Lyme Bay. The lack of a Year x Treatment interaction, however, suggests that, as in previous years, this is only an indication of recovery rather than evidence of recovery within the SI.

4.6 The initial hypothesis stated that for recovery to be seen, sites within the NC would need to become more similar to those within the CC. Attrill et al. (2011) reported that whilst positive changes were occurring within the NC, CC sites were also changing, and therefore also 'recovering'. These trends have continued in 2011, with the increase in abundance in the CC of particular note, adding further weight to the theory that the CC sites are benefitting from the buffering effect of the NC (Attrill et al. 2011). This theory is widely supported in the literature, which reports enhanced benthic biodiversity in previously established closed areas encompassed by new closures (e.g. Claudet et al. 2008, Gaston et al. 2008). Despite this positive change within the CC, similarity between the NC and CC sites is in fact increasing, and the NC is becoming increasingly dissimilar to NOC and FOC sites. It is expected that with time, the assemblage structure in the CC will stabilise, and the NC will continue to increase in similarity to the CC and in dissimilarity to the NOC and FOC.

4.7 The finding of a trend towards recovery is further supported by changes in the species driving the similarities between sites in the NC and CC. Prior to 2011, grouped hydroids and turf were most responsible, but the addition of *Cellepora pumicosa* in 2011, a species with a low recoverability, suggests that the assemblage is becoming more evenly diverse with more species other than hydroids and turf driving the treatment differences for the species composition analysis.

4.8 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. These results show similarities to those from this study, where grouped hydroids were seen to increase in abundance in the open as well as closed sites, and were driving the similarities between sites within treatment. Density of hydroids was, however, much greater for this study, with a mean abundance of 138.72 m^{-2} ± 3.23 SE reported in 2011 for closed sites and of 75.00 m^{-2} ± 2.57 SE for open sites.

4.9 These findings are further supported by Kaiser et al. (2000) whose study of a closure that was established voluntarily in 1978 through agreements between local fishermen's associations and Devon Sea Fisheries Committee off the South Devon coast, UK (and has subsequently been enforced through a local byelaw) found abundance of sessile fauna including hydroids to be significantly greater in areas closed to fishing.

4.10 One trend which is of particular interest is that 2011 has seen some evidence of recovery at sites within the NC which were thought to be unable to recover due to the 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. It is important that this is 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 Size Classes

4.11 Results of size class analysis also supports the theory of a trend towards recovery, although the 2011 results did not consistently follow the trends from 2008-2010. Recruitment of *E. verrucosa* and *P. fascialis*, both low recoverability species, has continued to be successful in NC and CC sites, and abundance of individuals in other size categories has also increased.

4.12 Grouped hydroids and *N. antennina* size class distributions have, however, differed from previous years, with abundance of *N. antennina* of all sizes greatest in FOC sites in 2011. This suggests that despite initial signs of recovery as apparent due to the increase in size class A individuals in the CC and NC, temporal variation in hydroid abundance is occurring. These are high-moderate recoverability species suggesting that fishing effort at FOC sites in particular may have decreased in 2011, allowing some recovery of fast growing species.

4.3 Mobile species (reef associated nekton)

4.13 The baited video data sets now comprise three years, increasing their power and the robustness of the results. The 2008-2010 survey was unable to identify any clear trends between Years, but a Year effect has been identified for abundance of reef associated nekton in 2011 when abundance was greatest across all treatments. As seen for the epibenthic assemblage, the increase in abundance of reef associated nekton between 2010 and 2011 was particularly marked suggesting that recruitment and survival of species has increased, independently of treatment.

4.14 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 have not previously conformed to this theory, but the finding that abundance was significantly greater in the NOC than CC or NC due to the abundance of scavenging species, and that species richness was significantly greater in the CC and NC than NOC for the first time, provide evidence that the Lyme Bay system is beginning to conform to this theory. These results also contribute to evidence of a trend towards recovery for the assemblages within the SI.

4.15 At the assemblage level, increasing dissimilarity was identified between years and between closed and open treatments. 2011 data showed significant differences between closed and open treatments, but not between open pairings or closed pairings, supporting the trend towards recovery identified for the abundance and species richness results. The species responsible for driving the similarities within treatments were not consistent, as they were for the towed video. Instead of being explained by individual species, similarities could be explained by the abundance of scavenger species for the open treatments and by non-scavenging species for closed treatments. The contribution of scavenging species to the similarities between closed sites decreased with time, which is to be expected in a recovery scenario as the habitat becomes more stable and dominated by slow growing long-lived species rather than those associated with disturbed systems.

4.4 Indicator Species

4.16 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).

4.17 Trends have largely conformed to those identified for the main assemblages, with greatest abundance of all indicator species seen in the closed treatments in 2011. Despite this, considerable variation exists in the results, with abundance of *Eunicella verrucosa*, *Necora puber* and grouped gobies decreasing in the NC and CC between 2010 and 2011.

4.18 Evidence of recovery was identified for *Pecten maximus*, *Pentapora fascialis* and *Chaetopterus variopedatus*, all of which exhibited a significant Year x Treatment interaction with abundance in the NC equal to or greater than abundance in the CC. This is particularly of note for *P. fascialis,* a species with low recoverability as it is a functionally important bioconstructor which plays a key role in the formation of biogenic reef (Cocito & Ferdeghini 2001, McKinney & 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 increased abundance is particularly encouraging for the recovery of closed sites. Attrill et al. (2011) also identified a Year x Treatment trend for *Alcyonium digitatum*; however, between 2010 and 2011 abundance decreased in the NC. 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.

4.19 Recovery of king scallop *P. maximus* populations in the NC has been apparent since 2009, with the increase in abundance between 2010 and 2011 particularly marked. *P. maximus* is a high recoverability species and its early recovery was therefore expected. Similar studies such as that of Stokesbury et al. (2004) who assessed the north-east American *Placopecten magellanicus* population identified a greater abundance of scallops within areas closed to mobile fishing gear. 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 spillover of individuals from the SI into the fished areas, benefitting the scallop fishery in the bay.

4.20 In addition to these, *Ctenolabrus rupestris* (a species with medium recoverability), grouped hydroids, and branching sponges all showed a trend towards recovery although this was not statistically significant. The increase in abundance of branching sponges between 2010 and 2011 in the CC is particularly interesting, providing the first evidence of recovery for these taxa. The fluctuations seen in branching sponge abundance throughout the course of the study, however, and in particular the very low abundance recorded in 2009 suggests that factors other than the protection of the SI are having an effect.

4.21 The abundance of grouped anemones (*Aiptasia mutabilis*, *Cerianthus* spp., *Peachia cylindrica* and *Sagartia* spp.) has remained very low in the NC in 2011 despite increasing in all other treatments. The reasons for this are not clear, but it is thought that *Cerianthus* spp. are likely driving the increased abundance in the NOC and FOC as these are associated with soft sediment habitats and were therefore recorded in areas of cobble and boulder habitat with exposed sediment patches.

4.22 In 2010 it was thought that the trends in abundance of *C. pagurus* could be early evidence of spillover as abundance in the NOC was increasing and was greater than that in the CC or NC. The 2011 results, however, do not support this, as abundance has decreased in the NOC and increased in the CC, again showing that there is still variation in the results.

5 Conclusions and Considerations

5.1 This study aimed to assess the recovery of Lyme Bay reefs following the cessation of fishing using bottom towed gear within the SI. Attrill et al. (2011) reported the results from the baseline survey and two 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 third 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.

5.2 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 & Langlois 2008; Hoskin et al., 2011). It is therefore, accepted that recovery in the Lyme Bay system will take time. As of June 2011 the CC sites had been protected for five to ten years and NC sites for three years, so it is reasonable to assume that both treatments are still in the early stages of a recovery scenario. The positive change in the CC is also likely due to the buffering effect of the NC and the benefit of linkages between CC areas. Differing degrees of positive 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 as expected.

5.3 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.

5.4 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, as 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 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.

5.5 Continuation of the annual sampling of the benthos in Lyme Bay is planned with the aim of reaching a point within the new closure where recovery can be detected 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		V	B
		Count	Cover		
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	
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			
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			
Ciona intestinalis	A sea squirt	Y		Y	
Ciocalypta penicillus	A sponge	Y			
Cliona celata	A boring sponge		Y		
Unid. clingfish	Unid. clingfish			Y	
Unid. colonial ascidian	Unid. colonial ascidian	Y			

Scientific name	Common name	F		V	B
		Count	Cover		
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			
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			
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		
Lithophyllum incrustans	Encrusting coralline algae		Y		
Macropodia spp.	Spider crabs	Y		Y	Y
Maja squinado	Spiny spider crab	Y		Y	Y
Metridium senile	Plumose anemone	Y			
Microstomus kitt	Lemon sole			Y	

Scientific name	Common name	F		V	B
		Count	Cover		
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
Parablennius gattorugine	Tompot Blenny	Y		Y	Y
Pecten maximus	Great scallop	Y		Y	Y
Pentapora foliacea	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			
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			
Serpula vermicularis	A tubeworm	Y			
Solitary ascidian sp.	Unidentified solitary ascidian spp.	Y			
Solea solea	Sole	Y		Y	
Spondyliosoma cantharus	Black seabream				Y
Encrusting sponge 1	Red encrusting sponge		Y		
Encrusting sponge 2	Yellow encrusting sponge		Y		
Encrusting sponge 4	Orange encrusting sponge		Y		
Massive sponge 2	Beige, smooth, rounded sponge	Y			
Massive sponge 3	White sponge	Y			
Massive sponge 4	Yellow, lumpy sponge	Y			

Scientific name	Common name	F		V	B
		Count	Cover		
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			
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			
Unid. juvenile fish spp.	Unid. juvenile fish spp.				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	
Leptopsammia pruvoti	No	None suitable

Table A3: List of scavenging species used for baited video analyses

Species	Common name
Pagurus bernhardus	Common hermit crab
Pagarus prideaux	A hermit crab
Buccinum undatum	Common whelk
Asterias rubens	Common starfish
Maja squinado	Spiny spider crab
Inachus spp.	Spider crabs
Macropodia spp.	Spider crabs
Cancer pagurus	Edible crab
Necora puber	Velvet swimming crab
Limanda limanda	Dab
Aspitriglia cuculus	Red gurnard
Ophiura spp	A brittlestar

B. PERMANOVA results

Frame-grab Analysis

Abundance:

Table B1: Results of a) Permanova for the relative abundance of the main assemblage species identified using frame grabs in response to the fixed factors Treatment (Tr), Year (Ye), the random factors area (Ar) and site (Si) and their interactions and b) Pairwise testing for Treatment and Year. Data were dispersion weighted and square root transformed. Analyses were conducted using Euclidean distance.

a)

Source	***Df***	**MS**	**Pseudo-F**	**P(perm)**
Ye	3	430.81	25.157	**0.0001**
Tr	3	305.48	6.5005	**0.0013**
Ar(Tr)	21	36.251	3.9524	**0.0001**
YexTr	9	20.475	1.4155	0.2057
Si(Ar(Tr))	63	8.5648	1.5644	0.0633
YexAr(Tr)**	48	12.259	2.2390	**0.0009**
Res	110	5.4749		
Total	257			

b)

Pairing	**P(perm)**
Treatment	
NOC, NC	0.5041
NOC, CC	**0.0055**
NOC, FOC	0.1004
NC, CC	0.0733
NC, FOC	0.0585
CC, FOC	**0.0009**
Year	
2008, 2009	0.3233
2008, 2010	0.1459
2008, 2011	**0.0001**
2009, 2010	0.8115
2009, 2011	**0.0001**
2010, 2011	**0.0001**

Species Richness:

Table B2: Results of a) Permanova for the relative species richness of the benthic taxa identified using frame grabs in response to the fixed factors Treatment (Tr), Year (Ye), random factors area (Ar) and site (Si) and their interactions, and b) pairwise testing for the interaction Treatment x Year. Data were dispersion weighted and square root transformed. Analyses were conducted using Euclidean distance.

Source	***Df***	**MS**	**Pseudo-F**	**P(perm)**
Ye	3	8.3357	24.146	**0.0001**
Tr	3	9.6384	9.7057	**0.0003**
Ar(Tr)	21	0.7667	2.3936	**0.0045**
YexTr	9	0.5707	1.9792	0.0617
Si(Ar(Tr))	63	0.3017	1.5567	0.0278
YexAr(Tr)**	48	0.2455	1.2668	0.1563
Res	110	0.1938		
Total	257			

Pairing	**P(perm)**
Treatment	
NOC, NC	0.0402
NOC, CC	**0.0009**
NOC, FOC	0.3916
NC, CC	0.1038
NC, FOC	0.0082
CC, FOC	**0.0005**
Year	
2008, 2009	0.5685
2008, 2010	0.2047
2008, 2011	**0.0001**
2009, 2010	0.0576
2009, 2011	**0.0002**
2010, 2011	**0.0001**

Assemblage composition:

Table B3: Pairwise testing for the term Tr x Ye for the main frame grab assemblage showing P values for differences between treatment pairings. Analyses were conducted using Bray Curtis similarities and data were dispersion weighted and square root transformed. P values in bold type are significant

Pairing	**P(perm)**			
	2008	**2009**	**2010**	**2011**
NOC, NC	0.2048	0.0578	**0.0053**	**0.0067**
NOC, CC	0.0709	**0.0263**	**0.0094**	**0.0023**
NOC, FOC	0.0394	0.0816	0.0500	0.1005
NC, CC	0.8307	0.5042	0.3048	0.0535
NC, FOC	**0.0030**	**0.0348**	**0.0038**	**0.0034**
CC, FOC	**0.0071**	**0.0099**	**0.0022**	**0.0009**

Baited Video Analysis

Abundance

Table B4: 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 Treatment (Tr) and Year (Ye) and their interactions and b) pairwise testing for Year. Analyses were conducted using Bray Curtis similarity and data were square root transformed

a)

Source	***Df***	**MS**	**Pseudo-F**	**P(perm)**
Ye	2	15.587	15.329	**0.0001**
Tr	3	1.0967	1.0785	0.3598
YexTr**	4	1.3323	1.3103	0.2752
Res	48	1.0168		
Total	57			

b)

Pairing	**P(perm)**
Year	
2009, 2010	0.7630
2009, 2011	**0.0001**
2010, 2011	**0.0001**

Species Richness

Table B5: 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 Treatment (Tr), Year (Ye) and their interactions and b) pairwise testing for the interaction Year x Treatment. Analyses were conducted using Bray Curtis similarity and data were square root transformed.

a)

Source	***Df***	**MS**	**Pseudo-F**	**P(perm)**
Ye	2	1.7613	11.664	**0.0002**
Tr	3	0.4258	2.8196	**0.0491**
YexTr**	4	0.41718	2.7626	**0.0412**
Res	48	0.15101		
Total	57			

b)

Pairing	**P(perm)**		
	2009	**2010**	**2011**
CC, NC	0.0848	0.3399	0.6914
CC, NOC	0.0221	0.3300	0.4396
NC, NOC	0.9501	0.1458	**0.0350**
CC, FOC	-	-	0.3065
NC, FOC	-	-	**0.0349**
NOC, FOC	-	-	**0.0443**

Assemblage composition

Table B6: 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 treatment (Tr), year (Ye), Season (Se), and random factor site (Si) and their interactions and b) pairwise testing for the interaction Year x Treatment. Analyses were conducted using Bray Curtis similarity and data were square root transformed.

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	2	9987	8.8003	**0.0001**
Tr	3	7705.6	3.3399	**0.0003**
Si(Tr)	20	2382.1	2.2491	**0.0001**
YexTr**	4	1835.7	1.7332	**0.0065**
Res	28	1059.1		
Total	57			

b)

Pairing	P(perm) 2009	2010	2011
CC, NC	**0.0226**	0.8941	0.5089
CC, NOC	**0.0024**	0.1016	**0.0019**
NC, NOC	**0.0107**	0.0957	**0.0137**
CC, FOC	-	-	**0.0020**
NC, FOC	-	-	**0.0060**
NOC, FOC	-	-	0.8946

Abundance of scavengers

Table B7: Results of a) Permanova for the relative abundance of the scavenging reef associated nekton and mobile benthic fauna identified using baited video in response to the fixed factors Treatment (Tr) and Year (Ye), and their interactions and b) pairwise testing for the interaction Year x Treatment. Analyses were conducted using Bray Curtis similarity and data were square root transformed.

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	2	20.512	21.83	**0.0001**
Tr	3	6.6192	7.0444	**0.0005**
YexTr**	4	0.5997	0.63823	0.6365
Res	48	0.93963		
Total	57			

b)

Pairing	P(perm)
Treatment	
CC, NC	0.5911
CC, NOC	**0.0022**
CC, FOC	**0.0103**
NC, NOC	**0.0006**
NC, FOC	**0.0100**
NOC, FOC	0.9394

Indicator Species Analysis

Pecten maximus – Great scallop (V)

Table B8: Results of a) Permanova for the relative abundance of *Pecten maximus* identified using video in response to the fixed factors treatment (Tr), year (Ye), Location (East West) (EW), and random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the interaction Treatment x Year. Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	3	0.14786	5.7418	**0.0011**
Tr	3	0.41994	3.2062	**0.0342**
Ar(Tr)	21	0.10255	3.6514	**0.0001**
YexTr	9	0.072914	3.4117	**0.0024**
Si(Ar(Tr))	71	0.02572	1.6181	**0.0373**
YexAr(Tr)**	51	0.016777	1.0555	0.3945
Res	119	0.015895		
Total	277			

b)

Groups	P(perm)			
	2008	2009	2010	2011
NOC, NC	0.6147	0.2497	**0.0354**	**0.0111**
NOC, CC	0.5479	0.8484	0.8660	0.0897
NOC, FOC	0.4370	0.2940	0.1639	0.4351
NC, CC	0.4582	0.2382	0.0641	0.0845
NC, FOC	0.3577	0.5388	**0.0026**	**0.0023**
CC, FOC	0.8531	0.3318	0.1963	0.1406

Phallusia mammillata – A sea squirt (V)

Table B9: Results of a) Permanova for the relative abundance of *Phallusia mammillata* identified using video in response to the fixed factors treatment (Tr), year (Ye), Location (East West) (EW), and random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the interaction Treatment x Year. Data were Log (X+1) transformed and analyses conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	3	0.0425	1.7475	0.1565
Tr	3	0.7223	7.4429	**0.0009**
Ar(Tr)	21	0.0753	2.7078	**0.0046**
YexTr	9	0.0562	2.5506	**0.0162**
Si(Ar(Tr))	71	0.0253	3.4229	**0.0001**
YexAr(Tr)**	51	0.0168	2.2776	**0.0044**
Res	119	0.0074		
Total	277			

b)

Groups	P(perm)			
	2008	2009	2010	2011
NOC, NC	0.1880	**0.0192**	**0.0354**	**0.0014**
NOC, CC	**0.0003**	0.0542	**0.0483**	**0.0027**
NOC, FOC	0.3834	0.8955	0.5800	0.5546
NC, CC	0.7713	0.9863	0.9910	0.0751
NC, FOC	0.3903	**0.0106**	**0.0251**	**0.0007**
CC, FOC	**0.0200**	**0.0341**	**0.0318**	**0.0004**

Cellepora pumicosa – A sea mat (F)

Table B10: Results of a) Permanova for the relative abundance of *Cellepora pumicosa* identified using frame grabs in response to the fixed factors Treatment (Tr), Year (Ye), random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the terms Treatment (Tr) and Year (Ye). Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	3	2.7181	6.477	**0.0006**
Tr	3	10.218	10.453	**0.0001**
20(Tr)	21	0.75163	5.0808	**0.0001**
YexTr	9	0.19697	0.59152	0.7979
Si(20(Tr))	63	0.13821	1.1693	0.2362
Yex20(Tr)**	48	0.3085	2.6098	**0.0001**
Res	110	0.11821		
Total	257			

b)

Pairing	P(perm)
Treatment	
NOC, NC	0.0127
NOC, CC	**0.0002**
NOC, FOC	0.8101
NC, CC	0.4397
NC, FOC	0.0059
CC, FOC	**0.0004**
Year	
2008, 2009	0.1497
2008, 2010	0.1873
2008, 2011	**0.0195**
2009, 2010	0.7029
2009, 2011	**0.0012**
2010, 2011	**0.0027**

Pentapora fascialis – Ross coral (F)

Table B11: Results of a) Permanova for the relative abundance of *Pentapora fascialis* identified using frame grabs in response to the fixed factors treatment (Tr), year (Ye), Location (East West) (EW), and random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the terms Treatment and Location). Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	Df	MS	Pseudo-F	P(perm)
Ye	3	0.70023	9.8716	**0.0001**
Tr	3	4.90770	13.7170	**0.0001**
20(Tr)	21	0.27514	3.1201	**0.0006**
YexTr	9	0.17597	3.0340	**0.0045**
Si(20(Tr))	63	0.082401	1.8835	**0.0033**
Yex20(Tr)**	48	0.047621	1.0885	0.3511
Res	110	0.043749		
Total	257			

b)

Pairing	P(perm)			
	2008	2009	2010	2011
NOC, NC	0.0109	0.0388	0.0221	0.0025
NOC, CC	0.0116	0.0295	0.0168	0.0020
NOC, FOC	0.1634	0.7035	0.5638	0.7452
NC, CC	0.1193	0.4007	0.3364	0.0997
NC, FOC	0.1450	0.0348	0.0118	0.0011
CC, FOC	0.0270	0.0192	0.0069	0.0004

Grouped Anemones (F)

Table B12: Results of a) Permanova for the relative abundance of grouped anemones identified using frame grabs in response to the fixed factors Treatment (Tr), Year (Ye), random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the term Year. Data were Log (X+1) transformed and analyses conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	Df	MS	Pseudo-F	P(perm)
Ye	3	1.3084	6.1891	**0.0007**
Tr	3	3.5772	1.8987	0.1500
20(Tr)	21	1.4604	7.0487	**0.0001**
YexTr	9	0.20076	1.3802	0.2188
Si(20(Tr))	63	0.1919	2.44	**0.0001**
Yex20(Tr)**	48	0.12447	1.5826	**0.0322**
Res	110	0.078647		
Total	257			

b)

Pairing	P(perm)
Year	
2008, 2009	0.2753
2008, 2010	**0.0555**
2008, 2011	**0.0067**
2009, 2010	0.2446
2009, 2011	**0.0289**
2010, 2011	**0.0263**

Alcyonium digitatum – Dead man's fingers (V)

Table B13: Results of Permanova for a) the relative abundance of *Alcyonium digitatum* identified using video in response to the fixed factors treatment (Tr), Year (Ye), random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the term Year. Data were Log (X+1) transformed and analyses conducted using Euclidean distance. Bold type denotes a statistically significant difference

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	3	0.7011	2.9344	**0.0327**
Tr	3	2.3037	1.1394	0.3637
Ar(Tr)	21	1.5725	16.389	**0.0001**
YexTr	9	0.20939	1.2057	0.3007
Si(Ar(Tr))	71	0.08662	2.257	**0.0005**
YexAr(Tr)**	51	0.13919	3.6267	**0.0001**
Res	119	0.038378		
Total	277			

b)

Pairing	P(perm)
Year	
2008, 2009	0.2340
2008, 2010	**0.0333**
2008, 2011	**0.0058**
2009, 2010	0.2632
2009, 2011	0.1671
2010, 2011	0.5278

Eunicella verrucosa – Pink sea fan (V)

Table B14: Results of Permanova for relative abundance of *Eunicella verrucosa* identified using video in response to the fixed factors treatment (Tr), year (Ye), Location (East West) (EW), and random factors area (Ar) and site (Si) and their interactions. Data were Log (X+1) transformed and analyses conducted using Euclidean distance. Bold type denotes a statistically significant difference

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	3	0.0793	1.5989	0.1865
Tr	3	1.1924	1.4303	0.2541
Ar(Tr)	21	0.6479	14.9600	**0.0001**
YexTr	9	0.0632	2.1502	**0.0381**
Si(Ar(Tr))	71	0.0391	1.6439	**0.0413**
YexAr(Tr)**	51	0.0241	1.0155	0.4410
Res	119	0.0238		
Total	277			

b)

Groups	P(perm) 2008	2009	2010	2011
NOC, NC	0.3691	0.2340	0.1756	0.2251
NOC, CC	0.2602	0.2788	0.3094	**0.0062**
NOC, FOC	0.7741	0.6167	0.3517	0.7309
NC, CC	0.4759	0.8158	1.0000	0.8576
NC, FOC	0.3074	0.2353	0.1362	0.0898
CC, FOC	0.2173	0.3037	0.2593	**0.0016**

Chaetopterus variopedatus –Parchment worm (F)

Table B15: Results of a) Permanova for the relative abundance of *Chaetopterus variopedatus* identified using frame grabs in response to the fixed factors Treatment (Tr), Year (Ye), random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the interaction Treatment x Year. Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	3	0.67016	3.1152	**0.0292**
Tr	3	0.79435	1.3967	0.267
20(Tr)	21	0.45531	3.1978	**0.0006**
YexTr	9	0.62168	3.1644	**0.005**
Si(20(Tr))	63	0.13368	1.3582	0.082
Yex20(Tr)**	48	0.16125	1.6383	**0.019**
Res	110	0.098422		
Total	257			

b)

Pairing	P(perm) 2008	2009	2010	2011
NOC, NC	0.936	0.7231	**0.0132**	0.0652
NOC, CC	0.8391	0.2609	0.9617	0.5476
NOC, FOC	**0.0207**	0.7824	0.4203	0.6065
NC, CC	0.9263	0.4778	0.0933	0.1937
NC, FOC	**0.0055**	0.5134	0.2008	**0.0446**
CC, FOC	**0.0095**	0.1794	0.5009	0.7172

Grouped hydroids (F)

Table B16: Results of a) Permanova for the relative abundance of grouped hydroids identified using frame grabs in response to the fixed factors Treatment (Tr), Year (Ye), random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the terms Treatment and Year. Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	3	3.7738	8.7477	**0.0001**
Tr	3	3.1919	3.9386	**0.0173**
20(Tr)	21	0.63008	3.0819	**0.0009**
YexTr	9	0.40047	1.0728	0.3963
Si(20(Tr))	63	0.19145	1.6431	0.0223
Yex20(Tr)**	48	0.31911	2.7387	**0.0001**
Res	110	0.11652		
Total	257			

b)

Pairing	P(perm)
Treatment	
NOC, NC	**0.4863**
NOC, CC	0.0053
NOC, FOC	0.231
NC, CC	0.1169
NC, FOC	**0.0971**
CC, FOC	0.0108
Year	
2008, 2009	0.1711
2008, 2010	0.0574
2008, 2011	**0.0002**
2009, 2010	0.3527
2009, 2011	**0.0044**
2010, 2011	**0.0183**

Branching sponges (V)

Table B17: Results of a) Permanova for the relative abundance of branching sponges identified using video in response to the fixed factors treatment (Tr), year (Ye), Location (East West) (EW), and random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the terms Treatment and Year. Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	MS	Pseudo-F	P(perm)
Ye	3	0.3105	7.3485	0.0004
Tr	3	0.6565	7.3744	**0.0004**
Ar(Tr)	21	0.0691	3.2605	0.0054
YexTr	9	0.0818	2.196	0.0349
Si(Ar(Tr))	71	0.0195	1.4747	0.0906
YexAr(Tr)**	51	0.0296	2.2391	0.0012
Res	119	0.0132		
Total	277			

b)

Groups	P(perm)			
	2008	2009	2010	2011
NOC, NC	0.6709	0.5088	0.3005	0.448
NOC, CC	0.1443	**0.025**	**0.0469**	**0.0042**
NOC, FOC	0.077	0.796	0.1164	0.7706
NC, CC	0.2174	0.3175	0.1022	**0.0082**
NC, FOC	0.1574	0.411	**0.0143**	0.0837
CC, FOC	**0.0484**	**0.0136**	**0.0062**	**0.0009**

Asterias rubens – Common starfish (V)

Table B18: Results of Permanova for the relative abundance of *Asterias rubens* identified using video in response to the fixed factors treatment (Tr), year (Ye), random factors area (Ar) and site (Si) and their interactions. Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	3	0.2156	1.1472	0.3294
Tr	3	0.2866	0.3391	0.8716
Ar(Tr)	21	0.6911	9.9657	**0.0001**
YexTr	9	0.1389	0.8868	0.5453
Si(Ar(Tr))	71	0.0629	1.2499	0.1962
YexAr(Tr)**	51	0.1335	2.6528	**0.0003**
Res	119	0.0503		
Total	277			

Trisopterus minutus – Poor cod (B)

Table B19: Results of Permanova for the relative abundance of *Trisopterus minutus* identified using baited video in response to the fixed factors Treatment (Tr) and Year (Ye) and their interactions. Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	2	0.95741	2.1617	0.1277
Tr	3	1.071	2.418	0.0746
YexTr**	4	0.97297	2.1968	0.0816
Res	48	0.44291		
Total	57			

Necora puber – Velvet swimming crab (V)

Table B20: Results of Permanova for the relative abundance of *Necora puber* identified using video in response to the fixed factors treatment (Tr), year (Ye), random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the terms Treatment and Year. Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*df*	MS	Pseudo-F	P(perm)
Ye	3	0.0063	4.5679	**0.0033**
Tr	3	0.0069	3.0168	**0.0399**
Ar(Tr)	21	0.0018	1.7454	0.0612
YexTr	9	0.0015	1.3510	0.2335
Si(Ar(Tr))	71	0.0009	1.4688	0.1014
YexAr(Tr)**	51	0.0010	1.5010	0.0710
Res	119	0.0006		
Total	277			

b)

Pairing	P(perm)
Treatment	
NOC, NC	0.4277
NOC, CC	0.0910
NOC, FOC	0.1306
NC, CC	0.3984
NC, FOC	0.0566
CC, FOC	**0.0087**
Year	
2008, 2009	**0.0041**
2008, 2010	**0.0017**
2008, 2011	**0.0164**
2009, 2010	0.0627
2009, 2011	0.3607
2010, 2011	0.3745

Cancer pagurus – Edible crab (V)

Table B21: Results of Permanova for a) the relative abundance of *Cancer pagarus* identified using video in response to the fixed factors treatment (Tr), year (Ye), random factors area (Ar) and site (Si) and their interactions and b) pairwise testing for the term Treatment. Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

a)

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	3	0.0001	0.7368	0.5154
Tr	3	0.0010	2.9455	**0.0450**
Ar(Tr)	21	0.0003	1.0459	0.4211
YexTr	9	0.0002	1.0274	0.4307
Si(Ar(Tr))	71	0.0002	1.0195	0.4551
YexAr(Tr)**	51	0.0002	0.7972	0.7770
Res	119	0.0002		
Total	277			

b)

Pairing	P(perm)
Treatment	
NOC, NC	0.1175
NOC, CC	0.8163
NOC, FOC	**0.0377**
NC, CC	0.0916
NC, FOC	0.0792
CC, FOC	**0.0223**

Ctenolabrus rupestris – Goldsinny wrasse (B)

Table B22: Results of a) Permanova for the relative abundance of *Ctenolabrus rupestris* identified using baited video in response to the fixed factors Treatment (Tr) and Year (Ye), the random factor site (Si) and their interactions b) pairwise testing for the term Treatment. Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

Source	*Df*	MS	Pseudo-F	P(perm)
Ye	2	0.95741	2.1617	0.1223
Tr	3	1.071	2.418	0.0757
YexTr**	4	0.97297	2.1968	0.0823
Res	48	0.44291		
Total	57			

Grouped gobies (B)

Table B23: Results of Permanova for the relative abundance of grouped gobies identified using baited video in response to the fixed factors Treatment (Tr) and Year (Ye) and their interactions Data were Log (X+1) transformed and analyses were conducted using Euclidean distance. Bold type denotes a statistically significant difference.

Source	***Df***			
		MS	**Pseudo-F**	**P(perm)**
Ye	2	0.62896	2.4744	0.0924
Tr	3	0.47204	1.8571	0.1473
YexTr**	4	0.07782	0.30614	0.8710
Res	48	0.25418		
Total	57			