An initial investigation into the contribution of a novel artificial surf reef to sustainable fisheries

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Project FES 250: *Can an Artificial Surf Reef make a significant contribution to sustainable inshore fisheries?*

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Contents

1. Summary

Boscombe Surf Reef is the first artificial surf reef (ASR) in Europe. Located 260m offshore to the east of Boscombe Pier near Bournemouth the reef was completed in the autumn of 2009 and is constructed of thirty-two giant sand-filled geo-textile bags with a basal area of 50 x 70 m. Although the original ecological assessment suggested the reef may actually lead to local enhancement of biodiversity through the increased hard substratum available for colonisation, the construction of the surf reef has raised concern among some stakeholders over its potential ecological impact. To complement simultaneous studies on both the benthic colonisation of the ASR and its impact on the commercial fishery of Poole Bay, we compared fish, pelagic invertebrates and zooplankton abundances within the close confines of the structure (1–10 m) and in control sites 1 km to the east and west. Sampling was undertaken using a beach seine net between July 2011 and November 2012 and light traps between July 2011 and July 2012. Between control and ASR sites, there were no significant differences recorded in fish community composition and catch per unit effort. No significant differences were recorded in zooplankton and invertebrate community structures between control and ASR sites. These data suggest there has yet to be any significant, measureable effect of the construction and presence of the Surf Reef on these aspects of the fish and pelagic invertebrate population. However, literature suggests that biomass and production may yet increase with continued successional development on the reef. It is recommended that this be monitored in the long-term to detect any future impacts.

2. Introduction

2.1 Artificial reefs

In broad terms, any submerged man-made structure constitutes an artificial reef. Sunken ships, oil platforms and breakwaters typically provide substratum for settlement of benthic flora and fauna, which are colonised and subsequently become feeding grounds for pelagic organisms (Reubens et al. 2013). However, artificial reefs are also purposely constructed and may be assembled to fulfil a number of different objectives. These include use as a fisheries management tool, to prevent coastal erosion, provide new sport-diving locations and improve wave quality for recreational activities such as surfing and body boarding (Gibson et al. 2012).

2.2 Artificial reefs as conservation tools

Artificial reefs can provide suitable habitat for a wide range of marine taxa including algae, sessile invertebrates, large mobile invertebrates such as crustaceans and cephalopods and fish. For example, studies have shown that artificial reefs significantly increase invertebrate biomass (e.g. Jensen et al. 2000). Likely causes for this increase in productivity include the trapping of zooplankton food items by the structure and increased surface area for benthic faunal use (Seaman 2000). Organisms may also be retained in sheltered areas within gaps and crevices of the structure (Perkol-Finkel et al. 2006). In particular, increased foraging opportunities have been credited with increasing settlement and proliferation of sessile invertebrates (Sampaolo and Relini, 1994) but mobile species are also attracted to the higher degree of turbulence and water movement around the structure that could potentially increase supply of food items (Baynes and Szmant, 1989). Localised primary and secondary productivity from benthic colonists on the artificial reef, including the release of planktonic larvae (meroplankton) and propagules, is attractive to fish and mobile invertebrates (Leitão et al. 2007). The presence of pelagic grazers may in turn increase the abundance of opportunistic carnivorous fish (piscivores) (Brickhall et al. 2005).

Despite the numerous studies that demonstrate an increase in biotic productivity associated with artificial reefs, concerns have been raised that the species composition of artificial reefs may not be the same as natural reefs, and their presence may also influence the biodiversity of surrounding areas (Rilov & Benayahu 2000). Artificial reefs may also promote the establishment and spread of non-native species (Page et al. 2006) and harmful algal blooms (Villareal et al. 2007). Furthermore, even though artificial reefs have been widely used throughout the world to help restore fisheries (Baine 2001, Inger et al. 2009), most documented examples are from North American, Australasian or Mediterranean regions, with studies in the cooler temperate waters of Northern Europe being comparatively rare (Jensen et al. 2000).

2.3 Artificial reef design and construction

Artificial reefs have been constructed using a wide range of materials. Historically, many structures were formed by dumping unwanted material such as tyres and construction debris but recently there is a growing trend towards purposely designed reefs (Baine 2001). Dedicated reef designs have varied from simple blocks to mixed shape designs. Complex designs include artificial reefs constructed of perforated steel panels (Foster et al. 1994) and cylindrical pipes (Moffitt et al. 1989). Despite the large number of artificial reefs built and the wide range of designs, little is known of the relative effectiveness of different construction materials and design types on marine productivity (Gibson et al. 2012). This is an important consideration because the extent to which artificial reefs attract marine life and the nature of the species attracted will largely be shaped by the design of the components of the installation, with structural complexity of exposed surfaces being a key driver of the extent of colonisation (Petersen & Malm 2006). In particular, there have been few studies concerning the effectiveness of geotextile reefs (Edwards et al. 2005) despite the construction of a relatively large number of this design type in recent years (Rendle and Davidson, 2012).

2.4 Artificial reefs for surfing

To date, only four artificial reefs have been constructed with the primary objective of improving surfing conditions. Cables Station, near Freemantle, Western Australia (completed 1999), was constructed using granite rock; Narrowneck reef along the Gold Coast, Queensland (1999), was constructed using geotextile containers; and both Pratte's Reef at El Segundo California (2000) and Boscombe surf reef in Bournemouth UK (2009) were constructed using sand filled geotextile bags.

2.5 Boscombe surf reef

Boscombe artificial surf reef is the first artificial surf reef in Europe. Completed in 2009 at a cost of £3.1 million, it is located 260 m offshore to the east of Boscombe Pier, near Bournemouth. The reef is constructed of thirty-two giant sand-filled geo-textile bags, set in opposing directions, with a basal area of 50 x 70m (size of a football pitch), held in place by 5 tonne anchor blocks. The ASR is located on the south coast of England near Bournemouth in Poole Bay (Figure 1).Designed and constructed by New Zealand firm ASR Ltd (http://www.asrltd.com), the reef construction is part of a large scale regeneration package supported by Bournemouth Borough Council (www.bournemouth.gov.uk). The reef acts as a ramp, pushing waves upwards and improving their quality for surfers Whilst designed to enhance the surfing experience, the presence of this new reef on the sea bed should enable the colonisation of different inshore flora and faunal assemblages that could enhance productivity at each trophic level of the food chain and so, subsequently, improve fish production and enhance native fish exploitation.

Although the original ecological assessment suggested the reef may actually lead to local enhancement of biodiversity through the increased hard substratum available for colonisation (Mead and Haggitt, 2007), the construction of the Boscombe Bay surf reef has raised concern among some stakeholders over its potential ecological impact. Fears were expressed by the Mudeford and District Fishermen's Association (MDFA) that there will be ecological interference with the fish, whelk and cuttlefish populations of the

Bay that will have a detrimental impact on their catches of cuttlefish, whelks, Bass and other fin fish.

2.6 Objectives of MMO funded project

The project objectives were to:

1. Obtain seasonal, quantitative catch per unit effort (CPUE) data of fish use within 0–50 m of the structure and to compare with control/reference areas away from the structure. These data will determine fish use and production within the close confines of the structure that will be compared with the data being collected from the wider fishery.
2. Determine estimates by season of other pelagic species (e.g. zooplankton, crustaceans and molluscs) around the structure for comparison with control/reference areas away from the structure. These data will provide production estimates in reef and control areas.
3. Identify the short-term fish productivity on the Boscombe surf reef in relation to the wider fishery.
4. Determine the community structure around Boscombe surf reef and compare this to the wider fishery.

3. Materials and methods

3.1 Sampling sites

The wave climate in Poole Bay has been described as 'moderate' especially in summer months and receives localised storm conditions during the winter (Rendle & Davidson, 2012). Hengistbury Head at the southeast extent of the bay and Old Harry Rocks in the west also dissipate energy, providing a natural shelter to the coastline (Rendle & Davidson, 2012). The tides are semi-diurnal with a maximum spring tidal range of almost 2 m. The flood tide runs west to east inshore across the ASR and Control sampling sites 1km east (CE) and 1 km west (CW). The seabed around the ASR and at Control sites consists of medium-coarse mobile sand and the depth is 4-5 m. Benthic fauna within the sandy seabed is of low species diversity and characterised by amphipods, polychaetes and the hermit crab *Diogenes pugilator.*

3.2 Beach seine net surveys

A beach seine net (sand eel net) of 30 m length was used to investigate inshore fish community structures on the leeward (beach side) of the ASR and in control sites 1 km to the east (CE) and west (CW). Surveys were carried out during the summer and autumn when juvenile fish were most likely to be present. The net was towed out from the beach using a small motor boat and then brought back to the beach, where it was hauled in and all fish were removed from the net In 2011, this was repeated three times in front of the ASR and CW on 19 July, and four times in front of the ASR, CW and CE on 28 November. In 2012, five samples were obtained from in front of the ASR, CW and CE on 8 August and 8 November. All fish were stored separately per seine net sample and preserved in 4% formal saline solution. Samples were processed in the laboratory where specimens were identified and fork lengths measured. Catch Per Unit Effort (CPUE) was calculated as the abundance of each fish species per haul.

3.3 Pelagic trap surveys

Trewhella light traps ("Trewtraps") were deployed for 24 hours on a shot line at 2.5 m depth below the water surface within 1–10 m distance of the sides of the ASR, and at a Control site 1 km to the east of the ASR (Figures 1 and 2). The traps are constructed from 15-Litre plastic drinking water bottles and have a waterproof diver's torch fitted to the inside of the trap (Figure 2b, Figure 3). The torch is powered by four AA 1.5v batteries, which were replaced after each deployment and last for 48 hours. The light from the torch attracts pelagic organisms, including plankton and small fish. As with the seine net surveys, sampling was carried out during the summer and autumn when juvenile fish were most likely to be present. However, logistical constraints due to bad weather and essential maintenance and repairs on the reef dictated the timing of the sampling programme over the course of the project. In 2011, three deployments, each containing 6 individual traps per site, were undertaken between July and August. In 2012, eleven deployments, each containing 5 traps per site, were undertaken between May and July. The traps were collected after 24 hours and the contents emptied in pots containing 4% formal saline solution. Samples were processed in the laboratory where specimens were identified. Catch Per Unit Effort (CPUE) is total number of organisms of each species caught in each trap.

3.4 Underwater video

To determine use of the ASR by larger fish, a pilot study using a baited underwater HD video camera (GoPro Hero 2) was deployed for 30 minutes adjacent to the reef and in a control area nearby on 1st November 2012. The camera was contained within an aluminium frame and a 250g piece of mackerel attached to a bait-arm at 1 m distance from the camera.

3.5 Data analysis

Differences in total fish and species abundances (CPUE) between the ASR and Control sites were tested using pair wise Kruskal-Wallis tests. Differences in the community compositions of ASR and control samples were analysed using SIMPER and tested using ANOSIM pair wise comparisons and 2D Multi-Dimensional Scaling (MDS) (PRIMER 6). Data were log transformed prior to ANOSIM testing and ranked using a Bray-Curtis similarity matrix for use in MDS scaling. To determine any differences between the age structure of fish at the ASR and in Control sites, we compared the mean fork lengths of fishes sampled from the ASR and control sites using one-way ANOVA and post-hoc pair wise Fisher's Least Significant Difference (LSD) tests (SPSS) after testing for normality. Size cohorts were estimated using modal progression analysis (MPA) of length frequencies using Bhattacharya's method (FISAT II).

4. Results

4.1 Fish community

Seine net surveying yielded a total of 14 different fish taxa. The most abundant species were sand smelt (*Atherina presbyter*), sand eel (*Ammodytes tobianus*) and European sprat (*Sprattus sprattus*) but juvenile fish of the Clupeidae family (whitebait) formed a substantial proportion (41%) of the mean yield (Figure 4). Lesser weever fish (*Echiichthys vipera*), transparent gobies, (*Aphia minuta*), and Atlantic herring (*Clupea harengus*) were occasional and 7 other species including two-spotted gobies (*Gobiusculus flavescens*), sand gobies (*Pomatoschistus minutus*) and grey mullet (*Chelon labrus*) were infrequently sampled. Despite variations in mean catch between sampling dates (Figure 5), mean species abundance per seine net catch (CW=2.6, CE=2.01, ASR=3) and per sample occasion (CW=4.8, CE=4.3, ASR=6, n= 4, 3 and 4 respectively) were similar and the total number of sampled species did not significantly differ between sites (Table 1a).

Mean fish abundance per seine net catch was low at CW (40) in comparison to CE (146) and ASR (139) but means varied considerably between sampling dates (CW: 24.6- 71.6, CE: 0.6-382.8, ASR: 27.8- 325.25, (Figure 6) and total fish abundances did not differ significantly between sites (Table 1b). Although not statistically significant (Table 1c,1d,1e), SIMPER analysis demonstrated that sand eel, sand smelt and whitebait compositions accounted for differences between control sites and ASR (Table 2). MDS plotting (Figure 7) revealed overlap between individual seine samples across all 3 sites with no site specific clustering and ANOSIM analysis confirmed that the fish community compositions of CE and ASR (Table 1f) and CW and ASR (Table 1g) samples did not significantly differ.

Analysis of mean fork length revealed significant site specific variance of sand eel (Figure 8; Table 1h) and sand smelt fork lengths (Figure 9; Table 1i). Subsequent post-hoc pair-wise testing revealed significant variance in sand eel lengths between all three sample sites (Table 1j, k, l) and variance in sand smelt lengths between control E and ASR (Table 1m) and control E and control W (Table 1n Figures 8, Figure 9). Modal progression analysis of length frequencies using Bhattacharya's method revealed one cohort per sample site with computed means for sand eel lengths of: control E=70.88 mm, control W=73.48 mm and ASR=67.34 mm, and sand smelt mean lengths of: control E=67.01 mm, control W =73.53 and ASR=66.57 mm.

Trewtrap samples (2012) contained 5 different fish taxa (Figure 11). Singular specimens of corkwing wrasse (*Crenilabrus melops*) and juvenile lumpsucker (*Cyclopterus lumpus*) were exclusively sampled from ASR. Unidentifiable juvenile fish (clupeidae) formed a substantial proportion of both CE and ASR samples (Figure 8). MDS plotting revealed overlap between CE and ASR Trewtrap samples with no site specific clustering (Figure 12). ANOSIM analysis (Table 1o) confirmed that the fish community compositions of CE and ASR samples did not significantly differ.

4.2 Pelagic productivity

Trewtrap samples (2011) were dominated by crustaceans. Copepods and amphipods comprised 85% and 13% of ASR and 54% and 42% of CE mean yields respectively. Specimens of Polychaeta and Decapoda (Brachyura) were infrequently sampled (Figure 13). Few meroplanktonic organisms were recorded that might have originated from spawning benthic adults that had colonised the structure (e.g. barnacle larvae).

The community compositions of samples from ASR and the Control site during 2011 did not significantly differ (Table 1p) as demonstrated by MDS plotting (Figure 14). ASR Trewtrap mean yield (2012) was dominated by mysids (53%) and amphipods (21%) (Figure 15). CE mean yield had a greater proportion of mysids (84%) and a comparable lower proportion of amphipods (8%). Copepods, decapods and gastropods were also frequently sampled in both CE and ASR sample sites (Figure 15). MDS plotting and ANOSIM analysis revealed no significant differences between sample sites (Table 1q, Figure 16). MDS plotting revealed that community compositions (CE and ASR) did not differ between 2011 and 2012 (Figure 17, Figure 18). Overall, (2011 and 2012 data combined) community compositions and species abundances did not significantly differ between CE and ASR (Table 1r) and both sample sites were dominated by copepods, amphipods and mysids (Figure 19).

4.3 Underwater video

Deployments of baited underwater video for 4 x 15 minutes in the east control area away from the reef structure revealed a sandy seabed with a high density and activity of the hermit crab *Diogenes pugilator* and a few sandmason worms (*Lanice conchilga*) were also seen. These observations are consistent with benthic samples taken from these regions (Bournemouth University unpublished data). The only fish species recorded on the video from this control site were gobies *Pomatoschistus* sp.

During a single 30 minutes deployment immediately beside the ASR structure, which was in view of the camera, two velvet swimming crabs (*Necora puber*) were recorded emerging from the structure and a single two-spot goby (*Gobiusculus flavescens*) was seen. Hermit crabs (*Diogenes pugilator*) were also evident on the sandy sea bed adjacent to the structure.

5. Discussion

5.1 Fisheries and invertebrate sampling

The objectives of this study were to generate seasonal, quantitative (CPUE) data of the fish and wider pelagic community within 0–50 m of the ASR structure and to compare these data with control/reference areas to determine the effects of the ASR on fish and invertebrate productivity. The project was successful in meeting these objectives despite major repairs undertaken on the ASR in August 2011 and May 2012 and bad weather conditions in both summers; due to the exposure of the site, deployments were not possible if the onshore winds exceeded 10 knots (Beaufort Force 3). This mostly limited survey effort to the summer when the wind was offshore (from the north) and did not allow for sampling on the ASR structure itself. Furthermore, the use of sampling nets and diver transects close to the structure that may have sampled and recorded larger fish, were prohibited during the time period of repairs and this limited sampling to Trewhella traps in the vicinity around the structure and seine netting from the beach in front of the ASR. The Trewtraps limited the size of fish caught, although the presence of juvenile fish around the structure was nonetheless a fundamental aspect of the study. Despite the logistical problems encountered during sampling, and the exceptionally wet and stormy summers of 2011 and 2012, the data collected in this report provides information on species abundances and community assemblages in the time period immediately following the construction of the ASR, which will provide an invaluable baseline of the reef community for years to come.

5.2 ASR productivity in relation to the wider Poole Bay fishery

Previous studies have stressed the importance of both reef design and construction material has in determining the ecological impacts of an ASR (Edwards et al. 2005; Petersen and Malm 2006; Gibson et al. 2012). Our results suggest that the geotextile surface of Boscombe ASR does not affect fish productivity in the localised area. Mean fish abundances did not differ from the other sampled sites in the bay suggesting that localised short term fish productivity has not been affected by the reef construction and repairs undertaken since 2009. A similar number of fish species and similar fish community structures were present at the ASR and control sites indicating that the construction and presence of the reef has so far not had an impact on fish biodiversity and that species compositions in the localised area around the reef does not markedly differ from the typical fauna which resides in the wider fishery of Poole Bay. Due to uncertainties in site fidelity of inshore fish sepcies, it is not possible to provide a categoric ecological explanation for the slight yet statistically significant variation in sand eel and sand smelt size frequency at the ASR in comparison to control areas.

Artificial reefs (AR) are used across the world for purposes including the mitigation of habitat loss, enhancement of fish and bivalve catches (Bohnsack and Sutherland 1985; Monteiro and Santos 2000), and habitat protection (Bayle-Sempere et al. 1994). They are very popular devices in southern European countries; for example, over 500 have been used in Portuguese waters where the aim is to increase the amount of hard-bottom habitat to provide refugia for juvenile fishes, promote biodiversity and increase fishing yields (Montiero and Santos 2000). Yet to-date, there appears little evidence that the ASR at Boscombe is acting as a fish aggregation device.

Given that this study was focused in the areas on the outside of the reef rather than within or on top of the structure, then it was not possible to demonstrate whether it increased fish biodiversity and biomass within its structure. However, seine net sampling surpassed 30–40 m from the beach into an area which has undergone significant changes in bathymetry since the introduction of the ASR (Rendle and Davidson 2012). There was no significant evidence of any spill-over of any juvenile and small fish from the reef into its immediate vicinity that might be attracted to the traps. The pelagic invertebrate and zooplankton community structure did not differ between ASR and control areas indicating that species compositions in the localised area around the reef do not differ from the typical fauna which resides in the wider fishery of Poole Bay. The localised area of seabed around the ASR remains a naturally species-poor invertebrate community dominated by worms and amphipod crustaceans that is typical of mobile sands in inshore waters (Bournemouth University unpublished information).

The neutral effect of the ASR on pelagic productivity in the localised area determined by this study may be explained by a number of contributing factors. Firstly, the lack of sheltered areas in the vicinity of the ASR may impede pelagic invertebrate biomass aggregation near the structure and the exposed coastline may wash productivity away from the immediate area. The relatively small surface area of the reef (13,000 m^3) in comparison to some other reefs (such as Narrow Neck AR which covers an area in excess of 70,000 m^3) may also impede the aggregation of sufficient invertebrate biomass required to attract significant numbers of pelagic grazers and consequently draw opportunistic piscivores to the area. Numerous studies have concluded that reef size influences biomass and most authors agree that productivity and biodiversity increase with increasing reef size (Pratt, 1994; Jordon et al. 2005).

The period of time since the construction of the ASR may have been insufficient to enable the development of a functional reef community. Research has indicated that diverse reef communities may take as long as 15 years to develop in temperate Pacific environments (Aseltine-Neilson et al. 1999) and even as long as 10 years in tropical ecosystems (Perkol-Finkel & Benayahu 2005). Certainly, the duration of time since construction of an ASR greatly affects its community structure. Some species, for example, can only colonise after primary benthic invertebrates increase the complexity of the surface. Although four years since completion of the ASR structure there has already been colonisation by over 75 species of benthic invertebrates and algae (Bournemouth University unpublished information) the coverage of colonisation is still patchy in places and it may take several years for significant biodiversity to accumulate on the surface of the ASR to support increased pelagic productivity. The localised distribution of natural reef habitat in Poole Bay may also affect the rate of colonisation of some species. The presence of fishes associated with natural reefs, particularly juvenile corkwing wrasse (*Crenilabrus melops*) and lumpsuckers (*Cyclopterus lumpus*) in the vicinity of the ASR is promising (although only singular specimens were sampled) and may suggest that these species have began nesting on the ASR (however, juvenile lumpsuckers generally disperse in the plankton).

A primary conservation benefit associated with ARs is an increase in the amount of hard-bottom habitat that can be used to provide refugia for juvenile fishes (Montiero and Santos 2000). This study did not find any significant evidence to suggest that the ASR is being used as a nursery ground, although the presence of juvenile wrasse in the traps suggest that there may be some refuge in the vicinity. Eggs of squid have been previously recorded on the structure. The number of juvenile fishes and the lengths of fishes sampled did not differ between reef and control areas. It is possible that the geotextile surface of the ASR does not contain crevices of sufficient depth to provide adequate shelter. The scarcity of large invertebrates such as common lobsters (*Homarus gammarus*) and edible crab (*Cancer pagurus*) from the ASR area may also suggest that the ASR does not provide adequate shelter for these commercially important benthic invertebrates. It is noteworthy that ARs which have successfully been colonised by crabs and lobsters and have been shown to provide long term habitat for these species do contain large crevices and areas of refugia. The Poole Bay AR constructed in the 1980s consisting of eight 1 m high conical units comprised of 40 x 20 x 20 gypsum, cement and gravel composite blocks, for example, has been shown to harbour large numbers of juvenile and mature lobsters (Jensen et al. 2000).

5.3 Future research and outputs

In the study period, no impact of Boscombe ASR has been detected on pelagic macro-invertebrates and fish catches in Poole Bay (Bournemouth University unpublished information). Given that the development of floral and faunal communities on ARs can take time to develop and mature (e.g. Perkol-Finkel & Benayahu 2005; Santos et al. 2011) and given that repairs to the structure were only recently completed, it is recommended that long term monitoring is undertaken to identify the impacts of the reef for the fisheries and benthic macro-invertebrate communities. In particular, seasonal sampling is needed to determine the abundance of species such as sea bass *Dicentrarchus labrax* which may increase in numbers around reefs in warmer temperatures (Leitao et al. 2008) but move into deeper offshore waters when water temperature is reduced. Tracking studies may be used to determine temporal habitat use.

A comprehensive sampling system involving netting, video surveillance and diver transects would be beneficial to long-term monitoring of the ASR and the surrounding waters. Due to particular bad weather conditions and extensive repairs undertaken on the ASR during the assigned sampling period it was not possible to use nets, undertake surveillance operations or deploy divers around the ASR structure. Monitoring the surface of the ASR would however demonstrate whether increased fish biodiversity and biomass occur within its structure and determine if the impacts on marine flora and fauna are localised to the surface of the ASR. Long-term monitoring using commercial fishing vessels would also provide valuable information on fish abundances and species diversity in specific reference areas.

Thus, this report provides a valuable record of short-term marine productivity in the immediate time period post construction of an artificial reef in temperate European waters.

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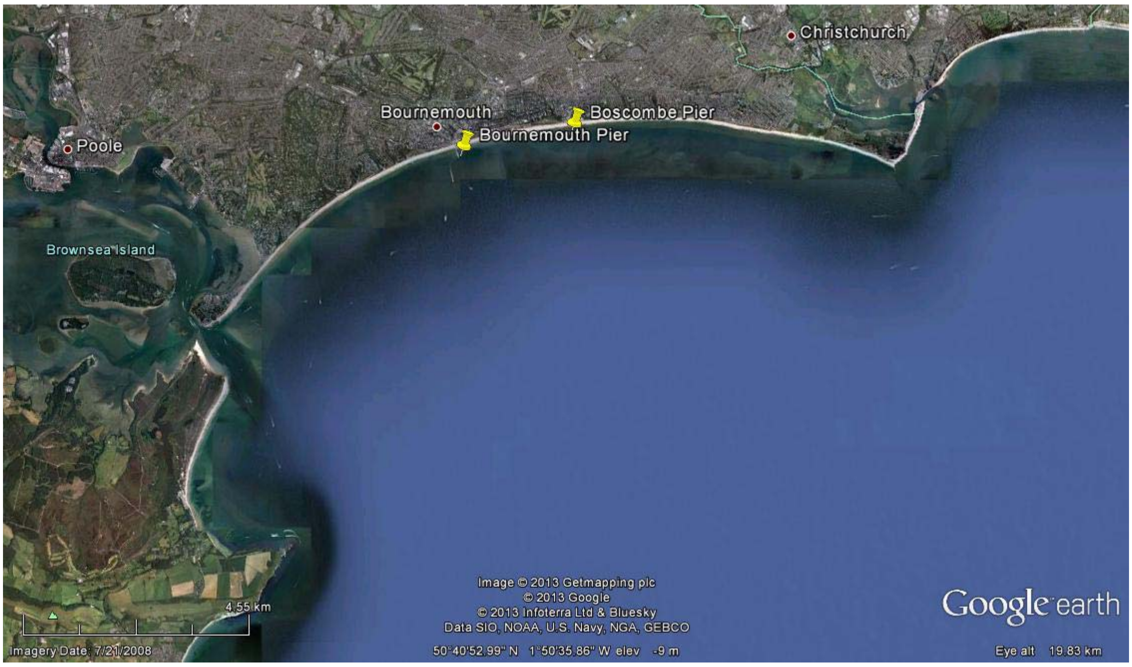
Figures and Tables

a)



b)

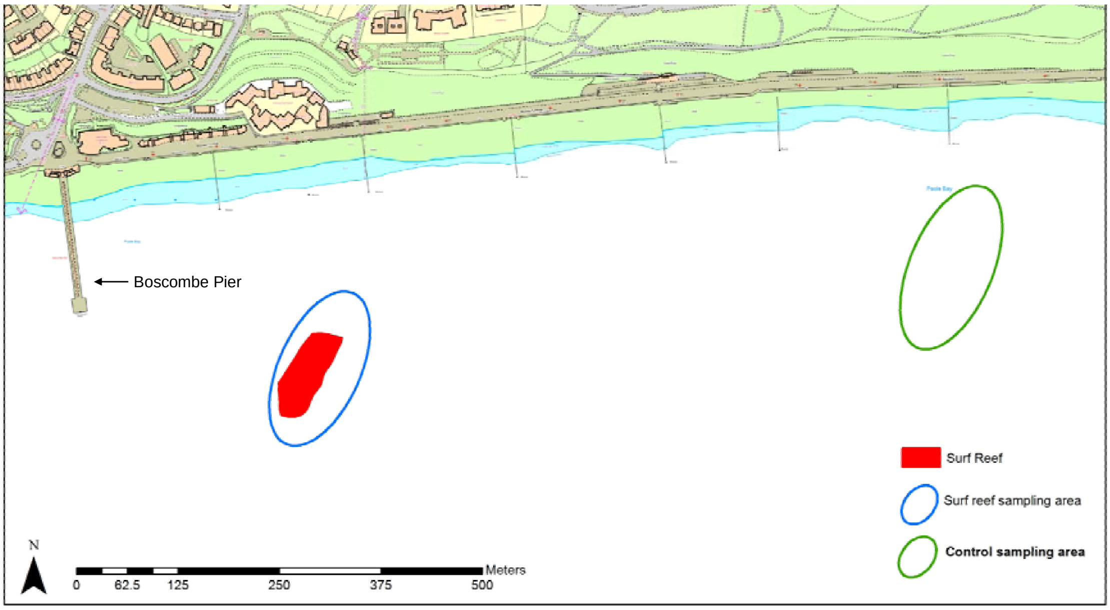


Figure 1.a) Poole Bay on the south coast of England showing location of Poole, Bournemouth and Boscombe b) position of Boscombe artificial surf reef (ASR) in relation to Boscombe Pier and the approximate Trewtrap sampling area (not to scale) around the ASR and the control area to the east.

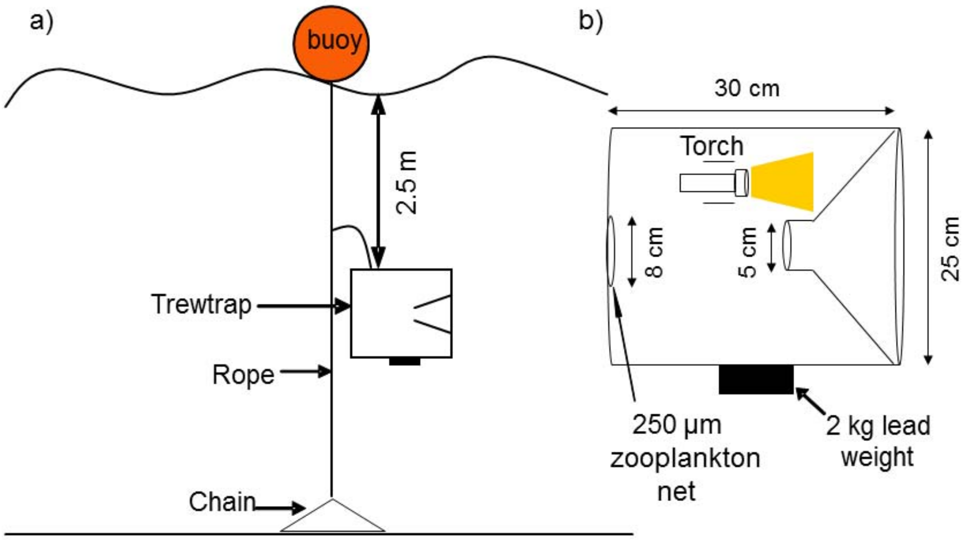


Figure 2. a) Trewhella traps were deployed on a shot line at 2.5 m depth below the water surface within 5–10 m of the side of the ASR and at 1 km to the east of the structure at a water depth 4–5 m CD. b) Trewhella trap design. The traps are constructed from 15-Litre water bottles and have a diver's torch fitted to the inside of the trap. The torch is switched on prior to deployment and the light is attractive to pelagic organisms. The contents of the traps were collected after 24 hours.

Figure 3. Trewhella traps being prepared on *Beowulf* for deployment off Boscombe artificial surf reef on 19 July 2011.

Table 1. Test statistics used and referred to in the report text and on graphs

Question	Test	n	statistic	*P* value
a	Kruskal-Wallis Test	ASR=17, CW=17, CE=14	X^2=2.3	0.31
b	Kruskal-Wallis Test	ASR=17, CW=17, CE=14	X^2=1.6	0.45
c	Kruskal-Wallis Test	ASR=17, CW=17, CE=14	X^2=3.6	0.161
d	Kruskal-Wallis Test	ASR=17, CW=17, CE=14	$X^{2=}$0.014	0.993
e	Kruskal-Wallis Test	ASR=17, CW=17, CE=14	$X^{2=}$0.86	0.650
f	ANOSIM	ASR=17, CE=14	R=0.008	33.5
g	ANOSIM	ASR=17, CW=17	R=0.017	30.1
h	One-way ANOVA	ASR=403, CE=789, CW=386	F=15.67	<0.001
i	One-way ANOVA	ASR=185, CE=56, CW=164	F=23.35	<0.001
j	Fisher LSD test	ASR=403, CE=789	-	<0.001
k	Fisher LSD test	ASR=403, CW=386	-	<0.001
l	Fisher LSD test	CE=789, CW=386	-	<0.001
m	Fisher LSD test	ASR=185, CE=56,	-	<0.001
n	Fisher LSD test	CE=56, CW=164,	-	<0.001
o	ANOSIM	ASR=12, CE=17	R=0.008	44.2
p	ANOSIM	ASR=18, CE-18	R=0.032	12.4
q	ANOSIM	ASR=55, CE=55	R=0.054	0.3
r	ANOSIM	ASR=73, CE=73	R=0.012	8.1

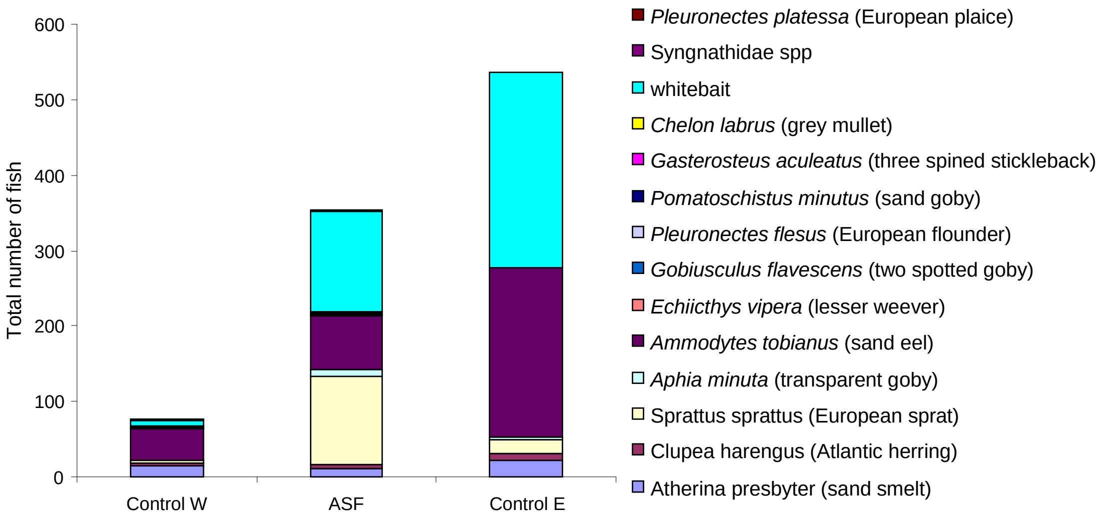


Figure 4. Fish community structure of beach seine net samples in front of the artificial surf reef (ASR) (n=17) and in control areas 1 km west (n=17) and 1 km east (n=14).

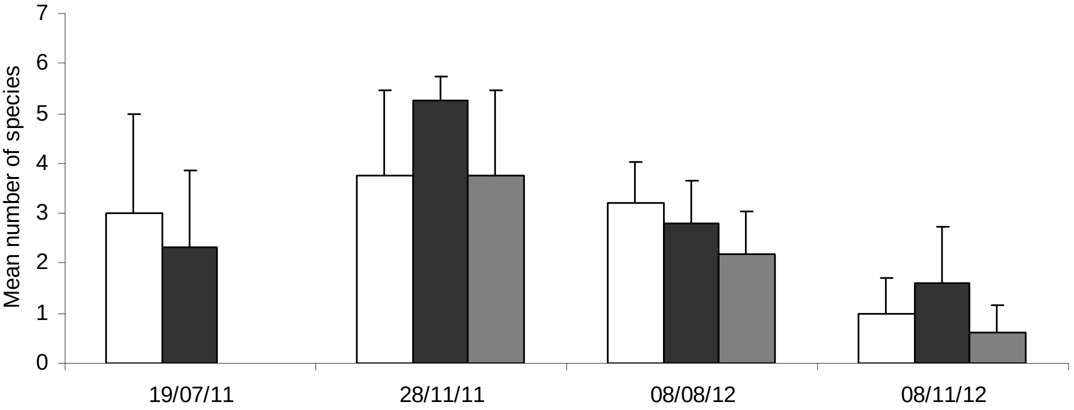


Figure 5. Mean (± standard deviation) number of species of fish caught using beach seine netting in front of the artificial surf reef (black bars) (n=17) and in control areas 1 km west (clear bars) (n=17) and 1 km east (grey bars) (n=14). NB no sample taken from CE in July 2011.

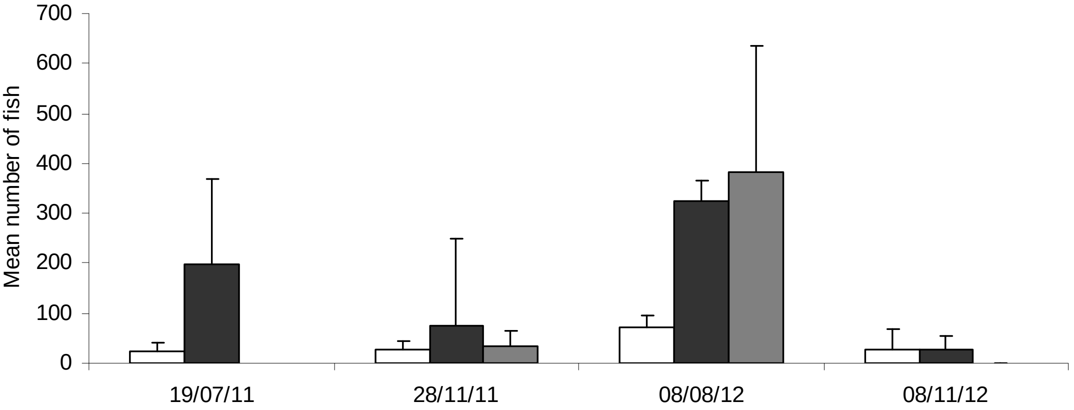


Figure 6. Mean (± standard deviation) number of fish caught using beach seine netting in front of the artificial surf reef (black bars) (n=17) and in control areas 1 km west (clear bars) (n=17) and 1 km east (grey bars) (n=14). NB no sample taken from CE in July 2011.

Table 2. SIMPER analysis of discriminating species between the seine net samples taken off the artificial surf reef (ASR) and control areas 1 km west (CW) and 1 km east (CE).

	CW vs ASR	CE vs ASR
Species	Contribution (%)	Contribution (%)
Ammodytes tobianus (sand eel)	29.60	29.73
Atherina presbyter (sand smelt)	18.47	14.27
Sprattus sprattus (European sprat)	18.18	16.70
Whitebait (juvenile and mixed Clupeidae)	17.61	23.58
Clupea harengus (Atlantic herring)	5.79	7.52
Echiichthys vipera (lesser weever fish)	2.54	-

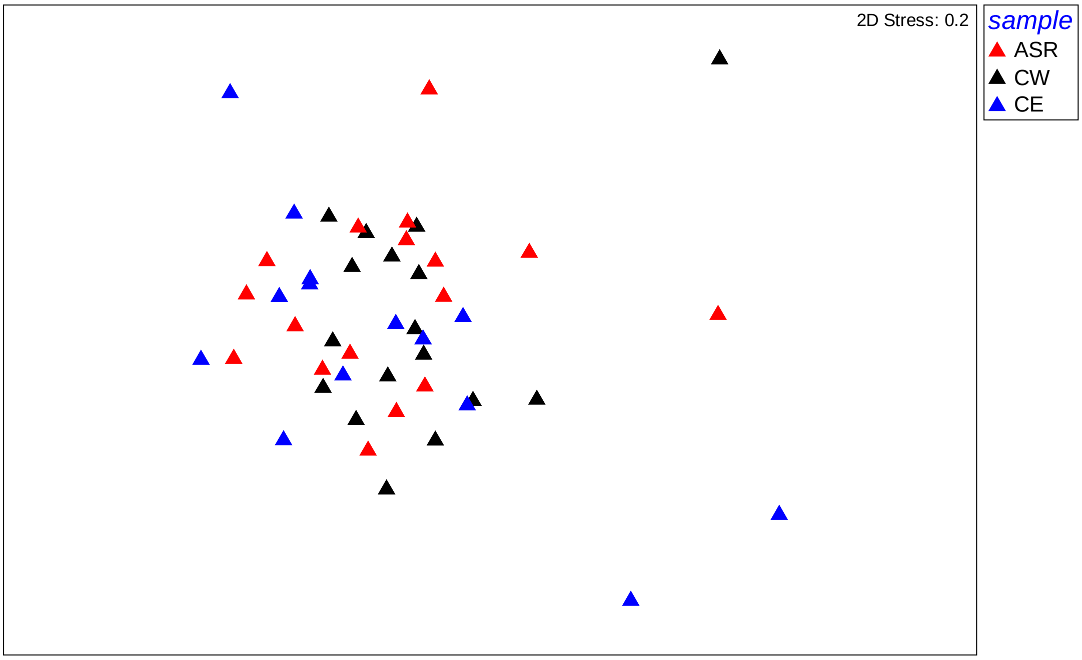
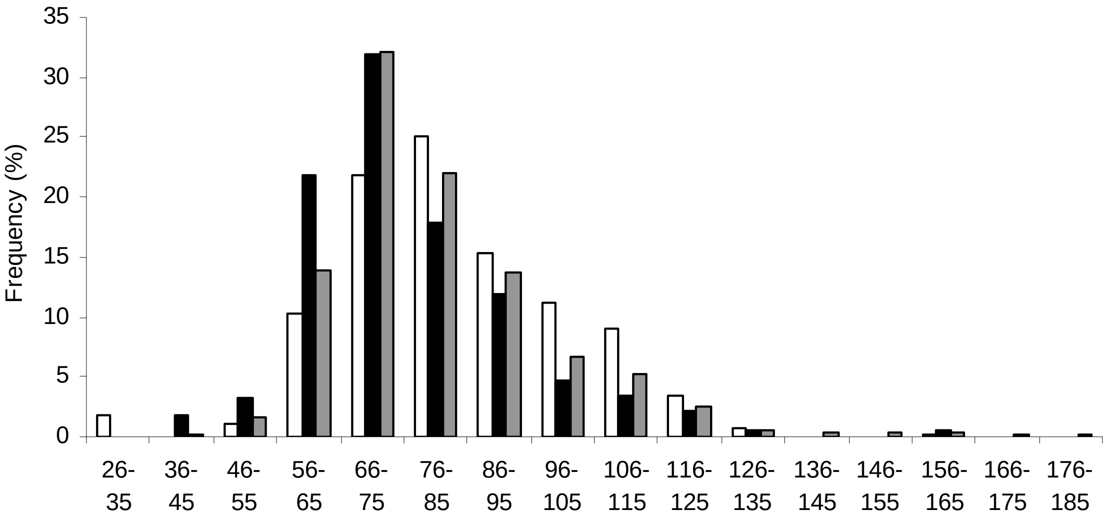


Figure 7. MDS plot of beach seine net samples in front of the artificial surf reef (ASR) (red triangle) (n=17) and in control areas 1 km west (CW, n=17) and 1 km east (CE, n=14). Multiple samples were taken on 19 July 2011, 28 November 2011, 8 August 2012 and 8 November 2012. Original data were analysed via square root transformation and ranked using a Bray Curtis similarity matrix.



August 2012 and 8 November 2012.

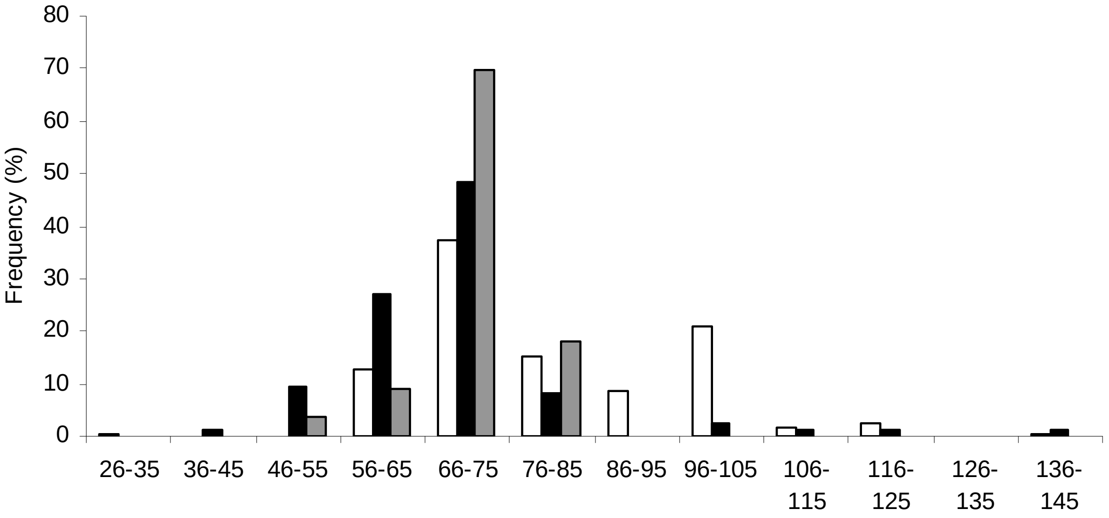


Figure 9. Length frequencies of sand smelt *Atherina presbyter* caught using a beach seine net in front of the artificial surf reef (black bars) (n=85) and in control areas 1 km west (clear bars) (n=164) and 1 km east (grey bars) (n=56). Multiple samples were taken on 19 July 2011, 28 November 2011, 8 August 2012 and 8 November 2012.

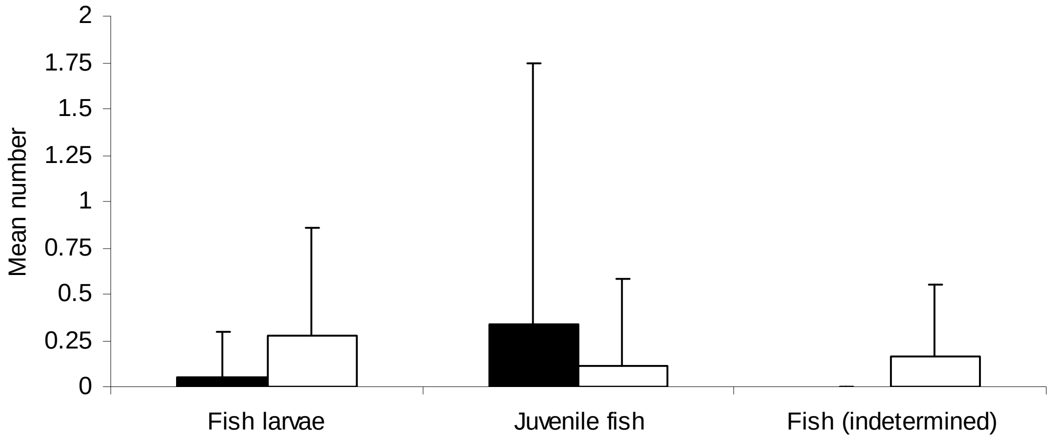


Figure 10. Mean (± standard deviation) number of fish and fish larvae collected in Trewtraps during 2011 off the artificial surf reef (black bar) (n=18) and in control site (clear bar) (n=18) 1 km to the east.

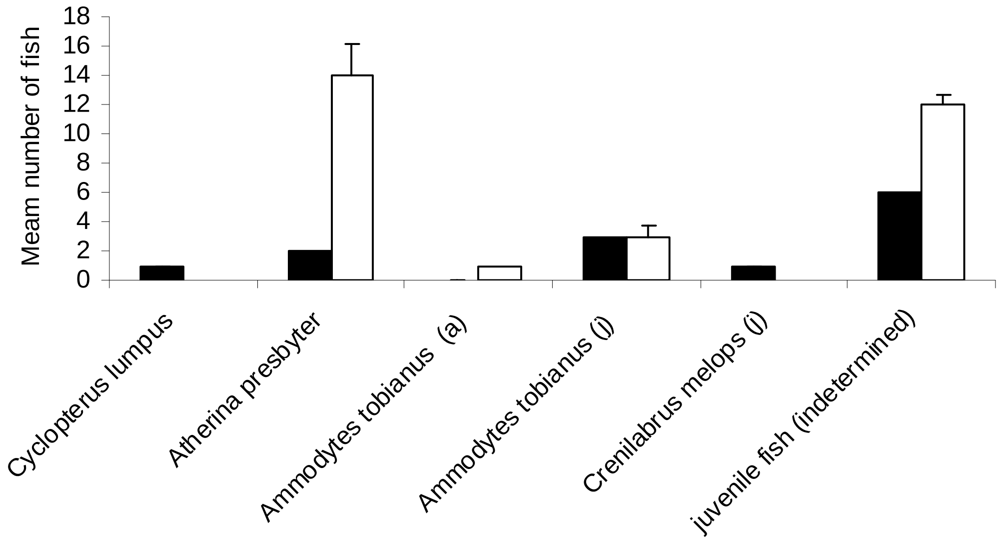


Figure 11. Mean (± standard deviation) number of fish (a)= adult, (J) = juvenile collected in Trewtraps during 2012 off the artificial surf reef (black bar) (n=55) and in control site (clear bar) (n=55) 1 km to the east.

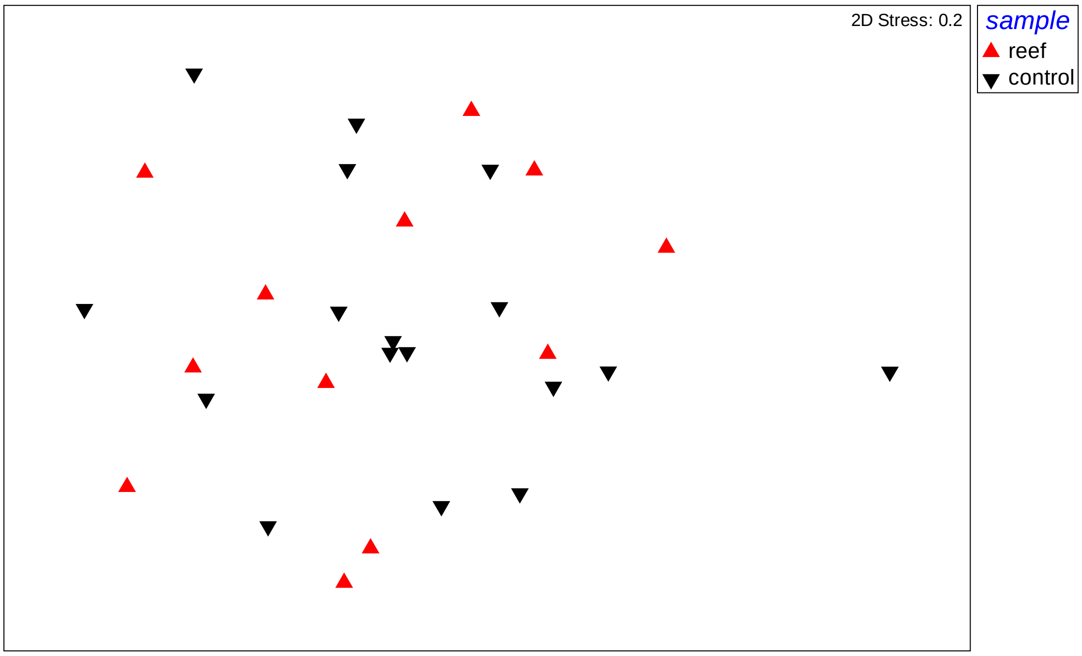


Figure 12. MDS plot showing fish samples collected in Trewtraps during 2012 off the artificial surf reef (ASR, n=12) and in Control site (n=17) 1 km to the east.

Table 3. Catalogue of fish and commercially important invertebrates previously recorded by SCUBA 2009–2011 on the surface of the reef (Bournemouth University & SeaSearch).

	Species	Abundance
Fishes	Ballen wrasse *Labrus bergylta*	Rare
	Black scorpionfish *Scropaena porcus*	Rare
	Black seabream *Spondyliosoma cantharus* (j)	Rare
	Corkwing wrasse *Crenilabrus melops*	Present
	Dragonet *Callionymus* sp.	Frequent
	Goby *Pomatoschistus* sp.	Common
	Goldsinny wrasse *Ctenolabrus rupestris*	Rare
	Long spined bullhead *Taurulus bubalis*	Rare
	Painted goby *Pomatoschistus pictus*	Occasional
	Gtr Pipe fish *Syngnathus acus*	Common
	Pollock *Pollachius pollachius* (j)	Rare
	Poor cod *Trisopterus minutus*	Present
	Sand eel Ammodytes tobianus	Abundant
	Two spotted goby *Gobiusculus flavescens*	Abundant
Invertebrates	European lobster *Homarus gammarus*	Rare
	Spider crab *Maja squinado*	Rare

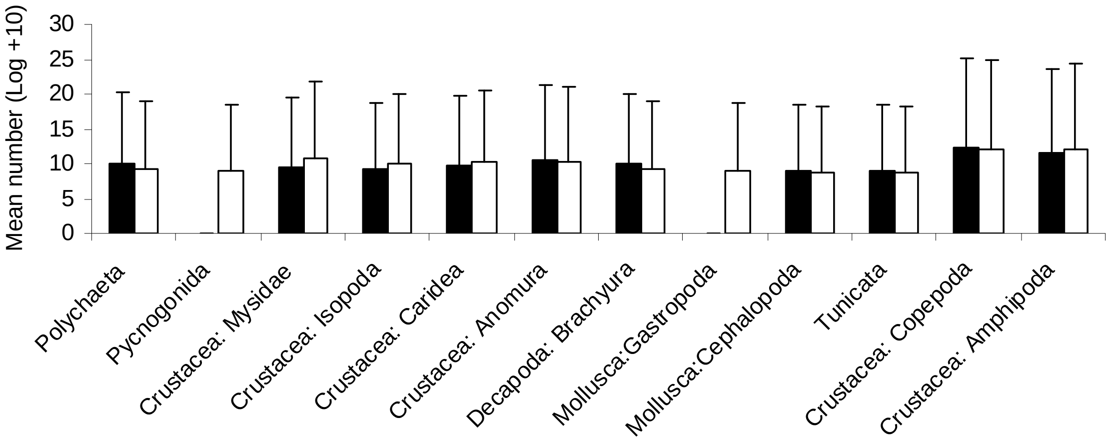


Figure 13. Mean number (± standard deviation) of pelagic organisms within each taxonomic group collected in Trewtraps deployed for 24 hrs around the artificial surf reef (black bars) (n=18) and in control area (clear bars) (n=18) 1 km east in 2011. Contents of 6 Trewtraps were collected during each of 3 individual sampling occasions on the 21–22 July 2011 and 2 August 2011.

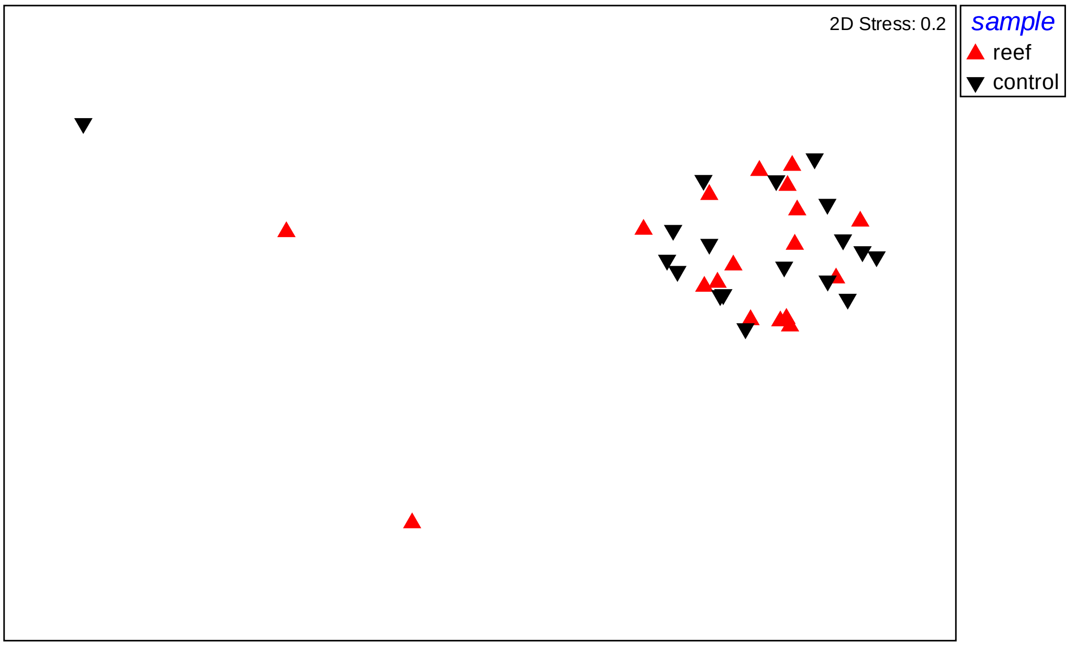


Figure 14. MDS plot showing samples of pelagic organisms collected in Trewtraps during 2011 off the artificial surf reef (ASR, n=18) and in control site (n=18) 1 km to the east in 2011. Contents of 6 Trewtraps were collected during each of 3 individual sampling occasions on the 21 July, 22 July and 2 August 2011.

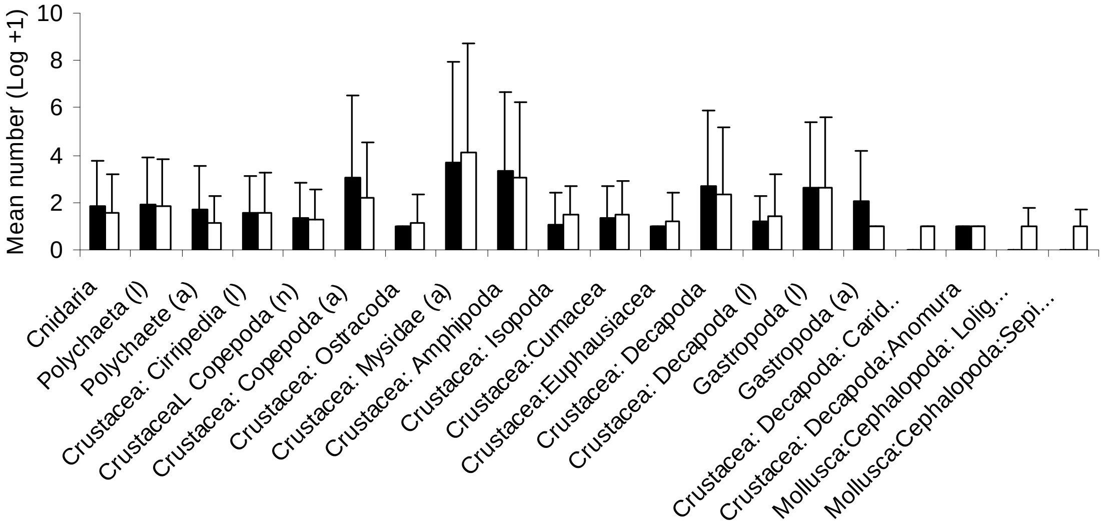


Figure 15. Mean number (± standard deviation) of pelagic organisms within each taxonomic group collected in Trewtraps deployed for 24 hrs around the artificial surf reef (black bars) (n=55) and in control area (clear bars) (n = 55) 1 km east in 2012. (l) = larvae, (a) = adult, n = nauplii. Contents of 5 Trewtraps were collected during each of 11 individual sampling occasions between 16 May and 25 July 2012.

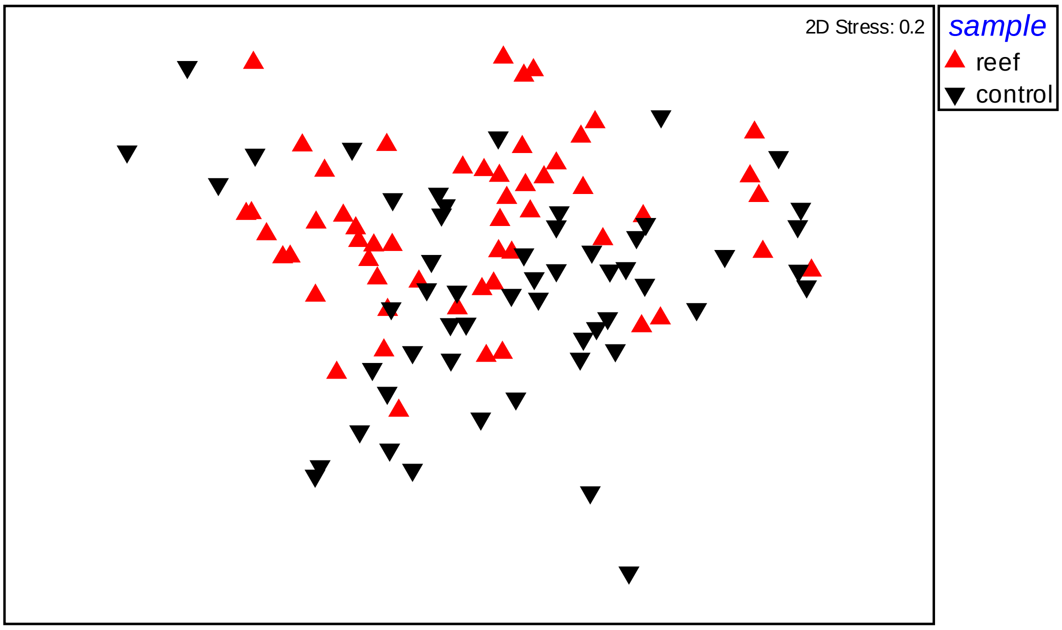


Figure 16. MDS plot showing samples of pelagic organisms collected in Trewtraps during 2012 off the artificial surf reef (n = 55) and in control site (n=55) 1 km to the east. Contents of 5 Trewtraps were collected for each of 11 sampling occasions between 16 May 2012 and 25 July 2012.

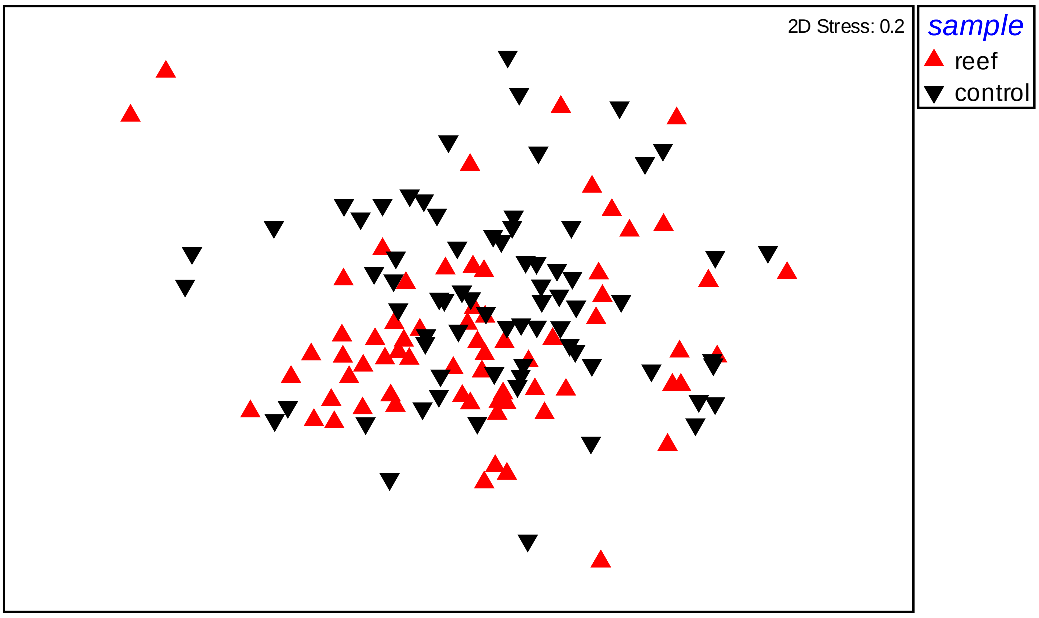


Figure 17. MDS plot showing combined pelagic samples collected in Trewtraps during 2011 and 2012 off the artificial surf reef (n=73) and in control site(n=72) 1 km to the east. Plot excludes a blank control sample from 2011.

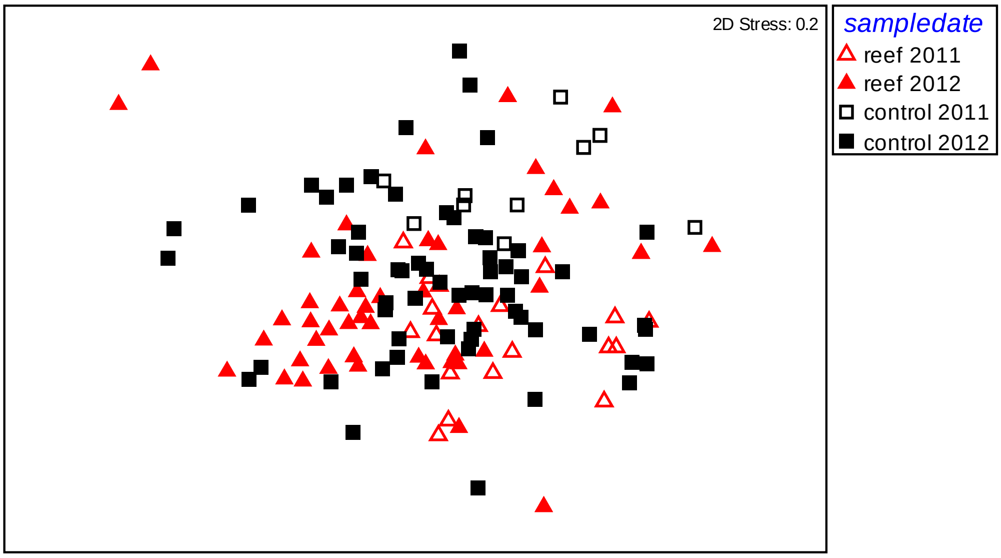


Figure 18. MDS plot showing combined pelagic samples collected in Trewtraps during 2011 (clear triangles) and 2012 (filled triangle) off the artificial surf reef (red triangle) (n=73) and in control site (black triangle) (n=72) 1 km to the east. Plot excludes a blank control sample from 2011.

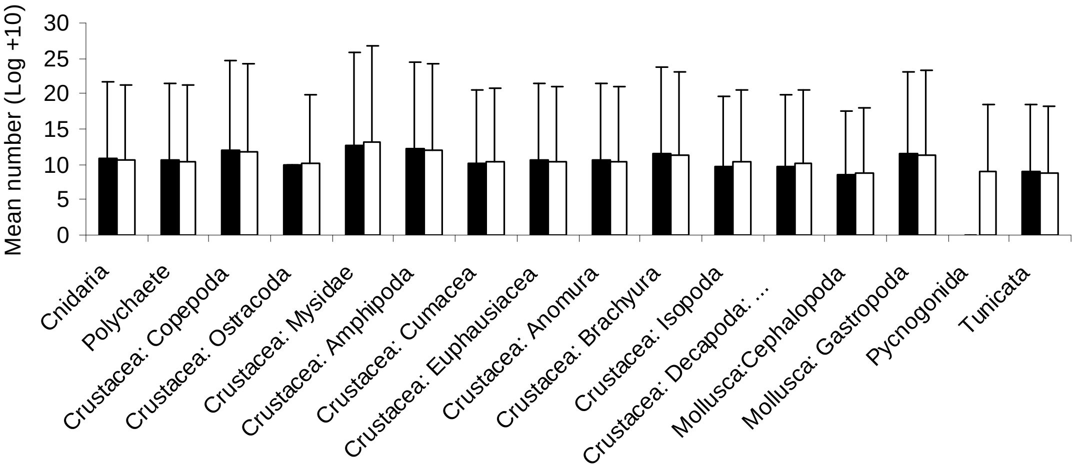


Figure 19. Mean number (± standard deviation) of pelagic organisms within each taxonomic group collected in Trewtraps deployed for 24 hrs around the artificial surf reef (black bars) (n=73) and in control area (clear bars) (n = 73) 1 km east in 2011 and 2012 combined.