Improving Habitat Heterogeneity on Coastal Defence Structures

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Abstract
Sea level rise and higher storm frequency is increasing the need for hard coastal defences worldwide. The majority of these structures lack optimal habitats for intertidal species, resulting in low diversity. Here, we evaluate low-cost enhancement techniques which increase habitat heterogeneity and surface texture on different rock types. Arrays of holes and grooves inspired by 'blast features' produced during the quarrying process were created on both granite rock armour and limestone rock groynes in two locations in England. After 12 months the treatments were successful at attracting new species to the defence structures and increasing the overall diversity and abundance of organisms. Mobile fauna including crabs and fish were recorded utilising the holes and grooves. Non-native species were recorded in grooves at one site but in no greater abundance than control areas. At the southern site, species known to be spreading in response to climate changes were found in both treatments but not in controls. The cost of these treatments was low in relation to that of the defence scheme and could be easily replicated either during or after construction. Through evaluation of the use of these ecological enhancement techniques on coastal structures, we suggest that they have considerable potential to enhance local patterns of biodiversity when used within large-scale defence projects.

Introduction & Background

Coastal defence structures
The proliferation of hard coastal defence structures reflect worldwide concerns relating to sea level rise and projected increased storm intensity resulting from climate change (Pethick, 2001) . These structures are predominately constructed from materials that are novel to the local geology and marine environment and are designed to be durable, effective and efficient. Coastal defence structures are designed to provide a long-term cost effective way of protecting land from flooding or erosion. A variety of materials including concrete, wood and rock are used, although rock armour consisting of boulders have more recently been favoured due to their longevity and efficiency at dispersing wave energy(Bradbury & Allsop, 1987; Crossman et al., 2003). However the cost of transportation and aesthetic influences can also determine the type of rock used in a particular area. The design of coastal defence structures is then determined by the specific erosion risks and local environmental conditions.

Ecological Enhancements

Adaptations can be made to coastal defence structures to encourage the colonisation and survival of intertidal species, a process termed as ‘ecological enhancement’ or ‘ecological engineering’ (Firth et al., 2014; Ido & Shimrit, 2015). The purpose of ecological enhancement is to increase and/ or improve the habitat for biodiversity whilst also protecting human health and the environment (ITRC, 2004). These adaptations can take many forms, including features that can be retrofitted on to existing structures or which can be incorporated into the construction of new defence projects. When compared to natural shores, the main habitats that coastal defence structures usually lack are holes, crevices and areas for water retention such as pools (Firth et al., 2013). Trials that have aimed to address this have included core-drilling rock pools into the Tywyn Breakwater in Wales (Evans et al., 2015), drilling pits into concrete blocks at Plymouth Breakwater (Firth et al., 2013) and in a seawall in the Azores to encourage limpet settlement (Martins et al., 2010). In Sydney Harbour, water retaining features have been created by omitting blocks in the concrete and attaching flowerpots to seawalls (Browne & Chapman, 2011) and at Sheldon (UK) by creating pits in wet mortar (Naylor et al., 2011).

Site Description and Methodology

Site Description

Field trials were conducted to examine the ecological response to two treatments at Runswick Bay, North Yorkshire and Poole Bay, Dorset. Runswick Bay is a popular tourist area with a moderately exposed sandy shore and shale bedrock platforms approximately 100m to the north of the test site. The rock armour was constructed in 2000 to dissipate wave energy and reduce over topping of defences and consists of 5-10 ton granite boulders sourced from the High Force Quarry in Middleton, England. Poole Bay is a large, moderately exposed, sandy bay. The test site was 3-6 tonne Portland Limestone rock armour that was constructed in 2010 at Mean Low Water to strengthen the toe of older concrete groynes designed to intercept prevailing eastward longshore drift and maintain beach levels. Compared to nearby natural shores the rock armour at both sites had a very low density and diversity of colonising species, including barnacles and limpets that are important constituents of rocky shore ecosystems.

Methods

Two habitat enhancement treatments were evaluated that created a more heterogeneous surface texture and habitat for intertidal organisms on the rock armour boulders

(a) ‘Holes’, consisting of an array of four 20mm deep x 16mm diameter holes, orientated to retain water at low tide, were drilled into vertical and horizontal surfaces of boulders using a cordless hand drill. At Runswick Bay, two arrays were created on each of six separate boulders located between Mean Tide Level (MTL) and Mean Low Water at (MLW) (N=12) (Figure 2). At Poole Bay, two arrays were created on each of six boulders located on both the East and West side of two rock groynes (N=48).

(b) ‘Grooves’ that aimed to replicate the groove-microhabitat occasionally observed in rock armour as a consequence of use of explosives in the quarrying process. Each array consisted of two, thin horizontal grooves (approx. 60cm long x 1cm deep) and one thicker, coarser groove (approx. 60cm long x 2cm wide) that were cut in to the rock using a petrol saw/angle grinder. The coarser middle grooves were chiselled out, which created a rough surface texture on the base and sides of the groove (Figure 2). At Runswick Bay, three arrays were created on each of six boulders located between MTL and MLW (N=18). At Poole Bay, three arrays were created on each of six boulders located on both the east and west side of two groynes (N=72). The differences in number of boulders used in the trials were determined by the time taken, and therefore cost, to install treatments on limestone versus granite rock armour. At each location, control areas were created in proximity **to** each treatment on the same boulders by removing encrusting fauna and flora with a wire brush and paint-scraper.

The financial cost of the treatments in Poole Bay was £500 which covered the cost of two workers’ wages for 4 hours and the cost of a replacement blade/ drill bit. For Runswick Bay the cost was £660. As the Runswick Bay structures were built of granite, the time taken to complete the enhancements was longer than in Poole Bay due to the hardness of the rock, so less replication of treatments were made. In addition diamond tipped drill bits and blades were needed that added to the cost.

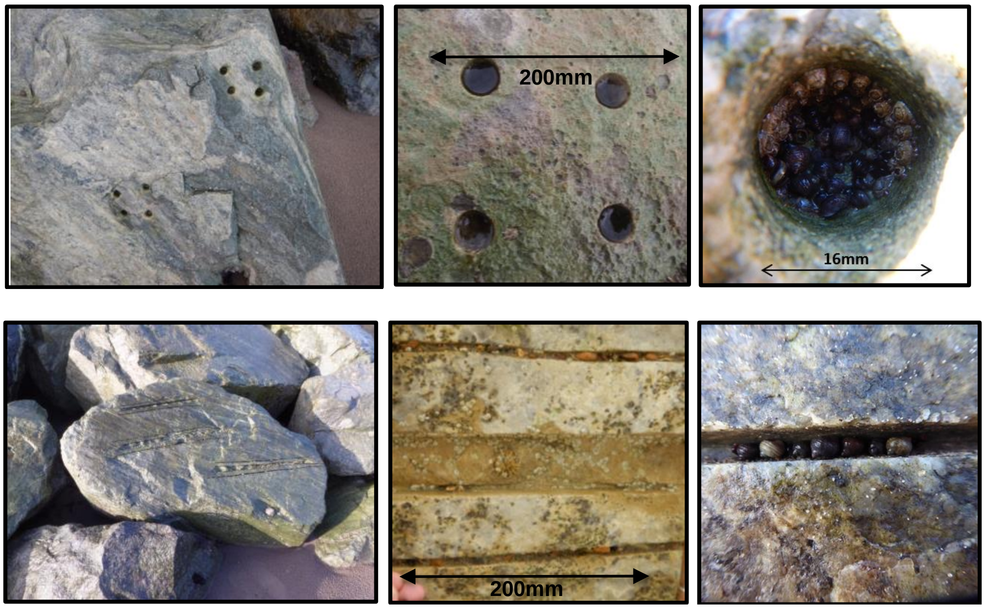
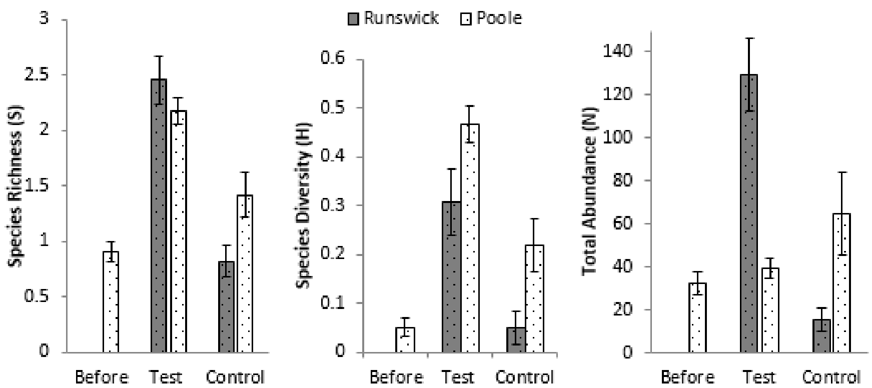


Figure 1: Examples of an array of Holes and an array of Grooves.

Results

The holes and grooves habitat enhancement techniques on both the granite rock armour at Runswick Bay and the limestone rock groynes in Poole Bay significantly increased species richness and diversity compared to the control areas. The creation of grooves on the boulders also significantly increased total abundance of organisms on both shores, however the ‘holes’ treatment was only significant for granite boulders at Runswick Bay and not the limestone at Poole. Whilst a significant increase in number of barnacles occupying the grooves was observed on both shores, this was not the case for the holes treatment. This was possibly due to the limited amount of space in the holes. At Poole, the number of limpets was significantly greater in areas with the holes treatment, but the same effect was not observed at Runswick Bay. Furthermore, the grooves at Poole Bay regularly trapped stones, shells and sand which could both encourage and deter species from colonising. Overall, the use of these simple treatments had a positive effect on richness and diversity and enhanced the colonisation of common rocky shore species.

a)



b)

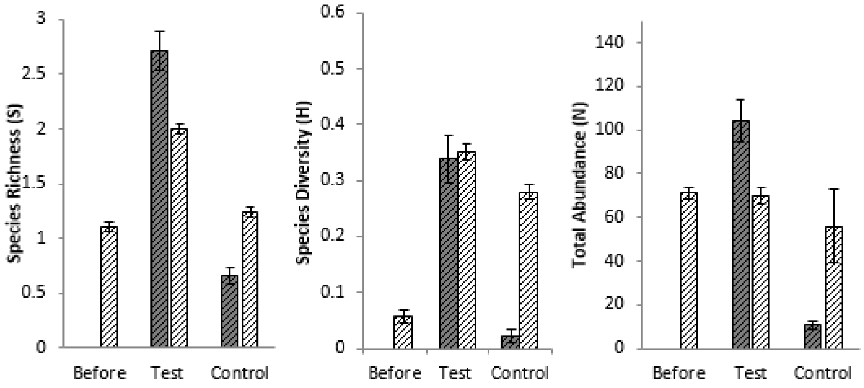


Figure 2: Mean species richness(S), species diversity (H) and total abundance (N) for a) holes and b) grooves before installation compared to the test and control after 12 months at Runswick Bay and Poole Bay (+/- SE)

Future Considerations

Future projects should include a variety of size and depth of holes and grooves to further increase species richness and diversity. The correct positioning of quarried boulders can also create habitat where 'blast lines' or holes are present to maximise water retention. Due to the success of the current trial, a large scale ecological enhancement project will be implemented at Runswick Bay in a new rock armour defence due to be constructed in 2017. This will involve a variety of techniques and will test further ideas to improve biodiversity on artificial structures. For ecological enhancement techniques to become standard practice for coastal engineers, collaboration between ecologists and engineers is needed to develop multifunctional structures which can protect the land from coastal erosion and also create suitable habitat for marine organisms. Providing engineers with a potential list of available options to mitigate for habitat loss by incorporating ecological enhancement would be beneficial.

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