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Colonisation of fish and crabs of wave energy foundations and the effects of manufactured holes – A field experiment

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ABSTRACT

Several Western European countries are planning for a significant development of offshore renewable energy along the European Atlantic Ocean coast, including many thousands of wave energy devices and wind turbines. There is an increasing interest in articulating the added values of the creation of artificial hard bottom habitats through the construction of offshore renewable energy devices, for the benefit of fisheries management and conservation. The *Lysekil Project* is a test park for wave power located about 100 km north of Gothenburg at the Swedish west coast. A wave energy device consists of a linear wave power generator attached to a foundation on the seabed, and connected by a wire to a buoy at the surface. Our field experiment examined the function of wave energy foundations as artificial reefs. In addition, potentials for enhancing the abundance of associated fish and crustaceans through manufactured holes of the foundations were also investigated. Assemblages of mobile organisms were examined by visual censuses in July and August 2007, 3 months after deployment of the foundations. Results generally show low densities of mobile organisms, but a significantly higher abundance of fish and crabs on the foundations compared to surrounding soft bottoms. Further, while fish numbers were not influenced by increased habitat complexity (holes), it had a significantly positive effect on quantities of edible crab (*Cancer pagurus*), on average leading to an almost five-fold increase in densities of this species. Densities of spiny starfish (*Marthasterias glacialis*) were negatively affected by the presence of holes, potentially due to increased predator abundance (e.g. *C. pagurus*). These results suggest a species-specific response to enhanced habitat complexity.

1. Introduction

A number of countries are planning for a significant development of offshore renewable energy along for example the European Atlantic Ocean coast, including many thousands of wave energy devices and wind turbines forming energy farms that will require areas of several square kilometres each (Oxley, 2006; Callaway, 2007; Cruz, 2008; IEA, 2008). Nature conservation concerns with respect to offshore energy development commonly centre around adverse effects of habitat and hydrodynamic alterations, noise, and electromagnetic fields on the marine environment (e.g. Gill, 2005; Wahlberg and Westerberg, 2005; Petersen and Malm, 2006; Broström, 2008; Tyack, 2008). At the same time, there is an increasing interest in articulating the potentially positive aspects of creating artificial hard bottom habitats through the construction of offshore renewable energy devices (Wilhelmsson et al., 2006a; Langhamer et al., 2009; Wilson and Elliot, 2009). The foundations of the energy devices will exclude trawling activities from the claimed area, and will also constitute "secondary artificial reefs" (Pickering et al., 1998) for fish and invertebrates and may also function as fish aggregating devices (FADs) (Wilhelmsson et al., 2006a; Fayram and de Risi, 2007; Wilhelmsson and Malm, 2008; Langhamer et al., 2009). These aspects of local impacts of offshore renewable energy development may, in theory, be beneficial for fisheries management and species conservation.

Availability of shelter from predation may be a demographic bottleneck for several species, such as European lobster *H. gammarus*, and to some extent edible crab *C. pagurus* (e.g. Jensen et al., 1994; Pickering and Whitmarsh, 1997; Ackefors, 2005). Deployment of wave and wind power foundations could thus be hypothesised not only to aggregate marine biota and decrease fishing mortality, but also to significantly enhance biomass production of these shellfishes at local scale. By considering certain habitat preferences of marine organisms in the design of the structures,

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given acceptable costs, abundance and diversity of associated species could be enhanced. Commercially important or threatened species could be specially catered for where desired (e.g. Nakamura, 1985; Bortone et al., 1994; Kawazaki et al., 2002). For instance, the structural complexity of the foundations could be increased at relevant scales, to enhance the abundance, diversity and biological productivity of motile macrofauna. This would primarily be coupled to enhanced shelter properties, the creation of physical barriers and compartments of the habitat, and various behavioural responses (Risk, 1972; Luckhurst and Luckhurst, 1978; Hixon and Beets, 1989; Chabanet et al., 1997; Friedlander and Parrish, 1998; Bortone et al., 1994; Potts and Hulbert, 1994; Speiler et al., 2001). For standardized examinations of the influence of structural complexity at various scales and on different species on both natural and artificial reefs, manufactured or already existing holes of different numbers, densities, sizes, and combinations have commonly been considered (e.g. Hixon and Beets, 1989; Friedlander and Parrish, 1998; Sherman et al., 2002).

There is, however, a great variability in taxon- and age specific responses of fishes to the deployment of differently designed artificial reefs, and regional ecological and environmental factors strongly influence the function of an artificial reef (Hueckel et al., 1989; Bohnsack et al., 1991; Baine, 2001). The information base for optimising artificial reef design to provide the specific habitat requirements of desired species and age groups, or enhancement of fish biomass production is generally weak (Seaman and Sprague, 1991; Baine, 2001; but see Nakamurás (1985) review on research in Japan). Invertebrates, fish, and algae may also be negatively affected by the presence of an artificial reef, through increased predation pressure in its vicinity (Davis et al., 1982; Kurz, 1995; Jordan et al., 2005).

Since 2005, the Lysekil wave energy research site, located near the city of Lysekil on the Swedish west coast, is being developed. Both technical and environmental studies are carried out within the project, in order to evaluate the wave energy converter concept for further commercialisation. One wave power unit consists of a steel buoy on the surface that drives a translator in a direct-driven linear generator moored to a concrete foundation on the seabed (Fig. 1). This type of device functions at water depths ranging from 20 to 100 m. The Lysekil research site covers about 40,000 m^2 and currently comprises 29 wave power devices; 3 with generators and 26 without generators for initial ecological studies (Leijon et al., 2008).

Predictions of the influence of the wave power foundations on the distribution of macrobenthos are uncertain. There are only a few examples of artificial reef studies in cold temperate waters (Baine, 2001), and even fewer have included experiments with different structural factors or, additionally, been conducted at the depths below 15 m, at higher latitudes (but see Wilhelmsson et al., 2006b; Langhamer et al., 2009). A pilot study by Langhamer et al. (2009), conducted in the Lysekil wave energy park, indicated a sparse colonisation by fish while edible crabs seemed more affected by the hard substrata deployed. However, the number of foundations quantitatively surveyed was low ($n = 3$), providing weak evidence for the conclusions.

The purpose of this study was to examine to what extent added, protruding but non-complex, hard substrate, through the deployment of wave power foundations on bare sandy bottoms, affect local distribution patterns of fish and motile invertebrates. Effects of low cost enhancements of shelter availability and compartment through holes in the foundations were also investigated. We hypothesised that wave energy foundation would aggregate fish and crustaceans, and that holes in the foundations would further enhance their abundance.

2. Methods

2.1. Study site and experimental design

The Lysekil research site is situated on the Swedish west coast, about 100 km north of Gothenburg, near Lysekil (Fig. 2). The site is located 2 km offshore between a northern (58°11′850″N, 11°22′460″E) and a southern (58°11′630″N, 11°22′460″E) marker. The shoreline of the area is characterised by rocky slopes covered by algae, with sandy and muddy bottoms below the rocky outcrops (Cato and Kjellin, 2008). The site is a flat sandy bottom at 25 m depth, with little relief. The area is exposed to predominantly westerly winds and waves and the tidal range is about 0.3 m (Johannesson, 1989). The temperature of the surface water is in the range of 15–20 °C in the summer and 0–2 °C in the winter. Average salinity is 25‰, and covering ice occurs on average every forth year (Åberg, 1992).

In May 2005, the first experimental set-up, including five wave power devices (without generators), was launched in the Lysekil research site on otherwise featureless soft bottom. The scope of the deployment of these devices was to conduct pilot-studies on environmental impacts and colonisation patterns of marine organisms on both wave power buoys and foundations (Langhamer et al., 2009). In spring 2006, the first wave energy converter (WEC) was deployed in the research site.

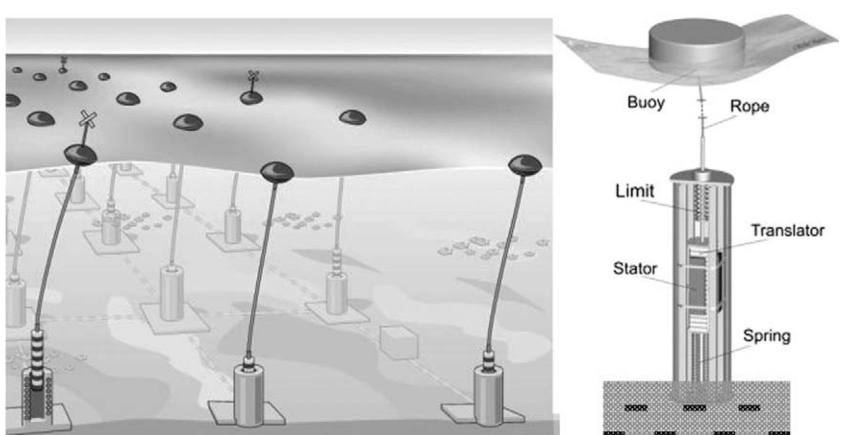

Fig. 1. Wave energy park and technical description of the wave power devices developed in the Lysekil Project. © Centre for Renewable Electric Energy Conversion and Seabased Ltd, respectively.