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Artificial reef effect and fouling impacts on offshore wave power foundations and buoys – a pilot study

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ABSTRACT

Little is known about the effects of offshore energy installations on the marine environment, and further research could assist in minimizing environmental risks as well as in enhancing potential positive effects on the marine environment. While biofouling on marine energy conversion devices on one hand has the potential to be an engineering concern, these structures can also affect biodiversity by functioning as artificial reefs. The Lysekil Project is a test park for wave power located at the Swedish west coast. Here, buoys acting as point absorbers on the surface are connected to generators anchored on concrete foundations on the seabed. In this study we investigated the colonisation of foundations by invertebrates and fish, as well as fouling assemblages on buoys. We examined the influence of surface orientation of the wave power foundations on epibenthic colonisation, and made observations of habitat use by fish and crustaceans during three years of submergence. We also examined fouling assemblages on buoys and calculated the effects of biofouling on the energy absorption of the wave power buoys. On foundations we demonstrated a succession in colonisation over time with a higher degree of coverage on vertical surfaces. Buoys were dominated by the blue mussel *Mytilus edulis*. Calculations indicated that biofouling have no significant effect in the energy absorption on a buoy working as a point absorber. This study is the first structured investigation on marine organisms associated with wave power devices.

1. Introduction

A significant expansion on new large-scale renewable energy generation sources is expected worldwide (Shaw et al., 2002). There is a high potential for offshore renewable energy development, such as wave power installations that takes advantage of the high energy density of ocean waves. Wave power is still in a stage of development and more than one technique is employed today, with most devices being floating on the surface as buoyancy devices (Oxley, 2006). Potential environmental impacts of offshore energy installations in coastal waters are of concern for a range of stakeholders. Disturbance effects may include noise, electromagnetic fields, habitat alterations, and changed hydrological conditions, as well as local enhancements of biomass of for example fish and bivalves (Gill, 2005; Petersen and Malm, 2006; Wilhelmsson et al., 2006a,b; Wilhelmsson and Malm, 2008). In addition to effective energy generation, there is, thus, a need to include environmental costs and benefits during the planning, construction and operational phases of offshore energy development.

Solid structures placed on the seabed to support, or as a part of, the offshore energy units create new habitats in areas dominated by soft bottoms, and can be defined as artificial reefs. Construction and deployment of artificial reefs, often specially designed, is a concept used worldwide for fisheries management/enhancement and coastal protection. In addition, artificial reefs are often used for preservation and rehabilitation of marine habitats (Pickering et al., 1998; Jensen, 2002). Many artificial submerged structures do not have the primary function of reefs but will inevitably be colonised by organisms.

How well artificial reefs mimic natural habitats, particularly in their role in maintaining natural ecological assemblages, is a cause for concern and discussions in a world of increasing urbanization. Artificial reefs may host communities different to those on natural reefs, and could also alter or modify the diversity of species in nearby areas (Connell and Glasby, 1999; Connell, 2001). When a hard substrate is added to former soft bottom significant changes can occur due to new trophic opportunities and changes in local food webs (Bohnsack and Sutherland, 1985).

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Artificial structures are colonised by marine organisms either through adult or juvenile migration from neighbouring natural reefs, or by planktonic larvae settling on the added hard substrate.

Whether the biomass enhancement is a result of mere aggregation from the surroundings or an actual increase in biomass varies with species and a number of environmental factors and, in most cases, site specific input data only allows for general assumptions (Bohnsack et al., 1997; Baine, 2001).

Most artificial constructions in the marine environment consist of non-natural materials, such as treated wood, metal, glass, rubber, rigid plastic, concrete, or fibreglass. Other studies have shown an increase in species abundance with increasing structural volume and complexity of artificial reefs (Potts and Hulbert, 1994; Spieler et al., 2001). More complex substrata provide more ecological niches, which may allow more animals to recruit and thus may lead to a higher local biodiversity (Menge, 1976).

Colonisation of motile and sessile organisms is a complex series of events, influenced by several chemical, physical and biological processes (Roughgaarden et al., 1988; Pineda, 1991; Miron et al., 1995; Menge, 2000). Surface orientation appears to play an important role in colonisation patterns, and has been suggested to be more important than for example age and quality of the substrata (Connell, 2000; Maughan, 2001; Knott et al., 2004; Perkol-Finkel et al., 2006). In earlier studies it was shown that vertical surfaces hosted a higher biomass of sessile invertebrates compared to horizontal surfaces, while algae exhibited a greater coverage on the latter (Baynes, 1999; Knott et al., 2004).

Since 2005, a test park for wave power is being developed at the Swedish west coast north of Gothenburg. A wave power unit consists of a point absorber buoy on the surface which via a wire drives a piston in a linear generator (Gustafsson et al., 2005). The generator is attached to a concrete foundation placed on the seafloor. The habitat generally comprise sediment substrata and the wave power park has added hard substrata to the area. At the moment, we can only speculate about the implications of this impact in a larger scale. As an example, a 10 MW wave power park, consisting of 1000 units of 10 kW each (which may be a typical size in calmer waters) would claim an area of approximately 2 km^2. Within this area, impacts from fishing would be limited as trawling would be prohibited, and concomitant local enhancements of fish, crab and lobster abundances could be expected (Halpern, 2003; Sundberg and Langhamer, 2005). Considering the potential scale of the disturbances from wave power installations, that may cause positive or negative effects, it is essential to estimate the magnitude of various influences on the marine environment. Investigations of marine fouling communities on artificial structures in Kattegat and Skagerrak are rare (Berntsson and Johnsson, 2003); there are only a few studies on artificial reefs that include motile fauna in cold temperate waters (Baine, 2001; Jensen, 2002; Wilhelmsson et al., 2006a,b; Wilhelmsson and Malm, 2008) and none of them have been conducted below 15 m depth. This makes predictions about colonisation of wave power devices in cold temperate waters uncertain.

If biofouling, potentially increasing local diversity and productivity, is considered positive from certain ecological or economic perspectives, it may conflict with the efficiency of wave power generation. In addition to the influence of wave parks on the marine biota, another aspect is namely, in reverse, the impact of the environment on the wave power devices. For example, fouling on artificial structures can cause large economic costs by impairing equipment performance or life span. Wave power buoys floating on the surface may be heavily overgrown by epibiotic assemblages and this may, literally, become a technical burden. The dynamics and thus the buoys ability to extract energy from an ocean wave is determined by the size and shape of the buoy, the mass of the moving parts, together with the power take-off system (Eriksson et al., 2005). Biofouling will change the mass of the buoy and the flow of water around the buoy. It is therefore important to investigate how it will affect the energy absorption of a wave energy converter, and ideally, wave power buoys should be formed in a way that fouling has a negligible impact on performance.

In the present study, conducted in the test park for wave power anchored at 25 m depth on the west coast of Sweden, we addressed the following questions: (1.) What is the structure of fouling assemblages developing on wave power concrete foundations? (2.) Are there any structural differences between vertical and horizontal surfaces at this depth (25 m) in cold temperate waters? (3.) Do wave power foundations have an effect on local distribution patterns of mobile organisms? (4.) What is the structure of fouling assemblages developing on wave power buoys? (5.) Does biofouling affect the energy absorption of wave power buoys?

2. Materials and methods

2.1. Artificial reef effect

2.1.1. Study site

The test park Islandsberg is situated at the Swedish west coast in an archipelago about 100 km north of Gothenburg, and about 2 km offshore, between a northern marker (58°11’850”N, 11°22’460”E) and a southern marker (58°11’630”N, 11°22’460”E) and will it cover about 40,000 m^2 when finished. It will then contain approximately 40 buoys: ten with generators and an additional 30 for environmental studies (Sundberg and Langhamer, 2005). The first experimental setup consisted of 5 wave power foundations without generators for biological studies: 4 cylindrical 10 t concrete foundations with a diameter of 2.5 m and a height of 1 m each and one bigger quadratic foundation with a weight of 40 t and an area of 16 m^2. The dimensions of the foundation were adapted for extreme wave conditions and lifting capacities of buoys. A typical wave power buoy has a diameter of 3 m and a height of 0.8 m (Leijon et al., 2008). Three foundations were constructed with holes and two without. The devices were deployed during spring 2005 with a distance of between 100 m and 300 m from each other, all on a 25 m deep soft bottom. The sediment consisted mostly of sandy silt with patches of coarser material (Cato and Kjellin, 2008). Further, it is a transport bottom mixed by frequent strong wave-induced moves and varies over time. The salinity is around 24‰ at the surface and around 33‰ at 30 m depth.

2.1.2. Epibiota on foundations

Field sampling by scuba diving was carried out between the 9th and 11th August 2005, between the 18th and the 20th of July 2006 and between the 7th and the 9th of August 2007 on the five wave power foundations. One foundation was not investigated in 2005, and on another no epibiota was sampled during 2007. A total of 194 epibiota samples were taken on foundations by photographing 7.0 cm $\times$ 10.6 cm areas of the horizontal and vertical surfaces. 20 photographs (10 vertical and 10 horizontal) per foundation were taken from the same, evenly distributed, positions every year.

2.1.3. Effects on fish and mobile fauna

In 2006 and 2007, fish, edible crabs (*Cancer pagurus*) and European lobsters (*Homarus gammarus*) associated with the five foundations were recorded through visual censuses on the structures, including the holes where present, and on the surrounding bottom within 1 m distance. To identify any aggregation of motile organisms on or around the foundations, similarly sized controls were sampled on bare sand bottoms at 10 m distance from the foundations. In 2006, controls were sampled for only three of the