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Tidal Energy: The benthic effects of an operational tidal stream turbine

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ABSTRACT

The effect of modified flow on epifaunal boulder reef communities adjacent to the SeaGen, the world's first grid-compliant tidal stream turbine, were assessed. The wake of the SeaGen was modelled and the outputs were used in conjunction with positional and substrate descriptor variables, to relate variation in epifaunal community structure to the modified physical environment. An Artificial Neural Network (ANN) and Generalised Linear Model (GLM) were used to make predictions on the distribution of Ecological Status (ES) of epifaunal communities in relation to the turbulent wake of the SeaGen. ES was assigned using the High Energy Hard Substrate (HEHS) index. ES was largely High throughout the survey area and it was not possible to make predictions on the spatial distribution of ES using an ANN or GLM. Spatial pattern in epifaunal community structure was detected when the study area was partitioned into three treatment areas: area D1; within one rotor diameter (16 m) of the centre of SeaGen, area D2; between one and three rotor diameters, and area D3; outside of three rotor diameters. Area D1 was found to be significantly more variable than D2 and D3 in terms of epifaunal community structure, bare rock distributions and ES.

1. Introduction

Significant changes in energy production methods are required if recent global targets for reducing CO_2 emissions are to be met (IPCC, 2016). Marine renewable energy production provides a viable alternative to traditional carbon and nuclear based energy production methods and poses significantly less environmental threats (Inger et al., 2009). Tidal energy extraction is a relatively novel form of anthropogenic interaction with the coastal environment and its effects on the benthos are still not fully understood (Miller et al., 2013; Sheehan et al., 2013; Broadhurst and Orme, 2014; Kregting et al., 2016; O'Carroll et al., 2017).

Optimal sites for tidal energy extraction are characterized by high tidal velocities. These velocities cause the seafloor to be dominated by rocky outcrops, boulders and coarse sediments (Marine Current Turbines, 2006, 2010; Tidal Energy Ltd, 2009; Meygen, 2011; Sheehan et al., 2013; Broadhurst and Orme, 2014). The SeaGen is the world's first grid-compliant tidal stream turbine with rated output of 1.2 MW (Macenri et al., 2013). It is situated in the Strangford Lough Narrows (Hereinafter referred to as 'the Narrows'; See Fig. 1), a 1 km wide tidal rapid that is dominated by a glacial boulder drop field characterized by a unique biotope under the European Nature Information System (EUNIS) classification scheme (Savidge et al., 2014). Strangford Lough is designated under Natura 2000, it is both a Special Area of Conservation (SAC; UK0016618) under the Habitats Directive (HD, 1992: 92/43/EEC) and a Specially Protected Area (UK9020111) under the Birds Directive (BD, 1979: 79/409/EEC). The subtidal boulder fields of the Narrows are included as part of the Reefs (1140) qualifying interest for the SAC.

Tidal stream turbines actively remove energy from the environment and the hydrodynamic perturbations created result in the formation of a turbulent wake on the leeward side of the device (Batten and Bahaj, 2006). This turbulent wake may have the potential to negatively affect epifaunal reef communities through

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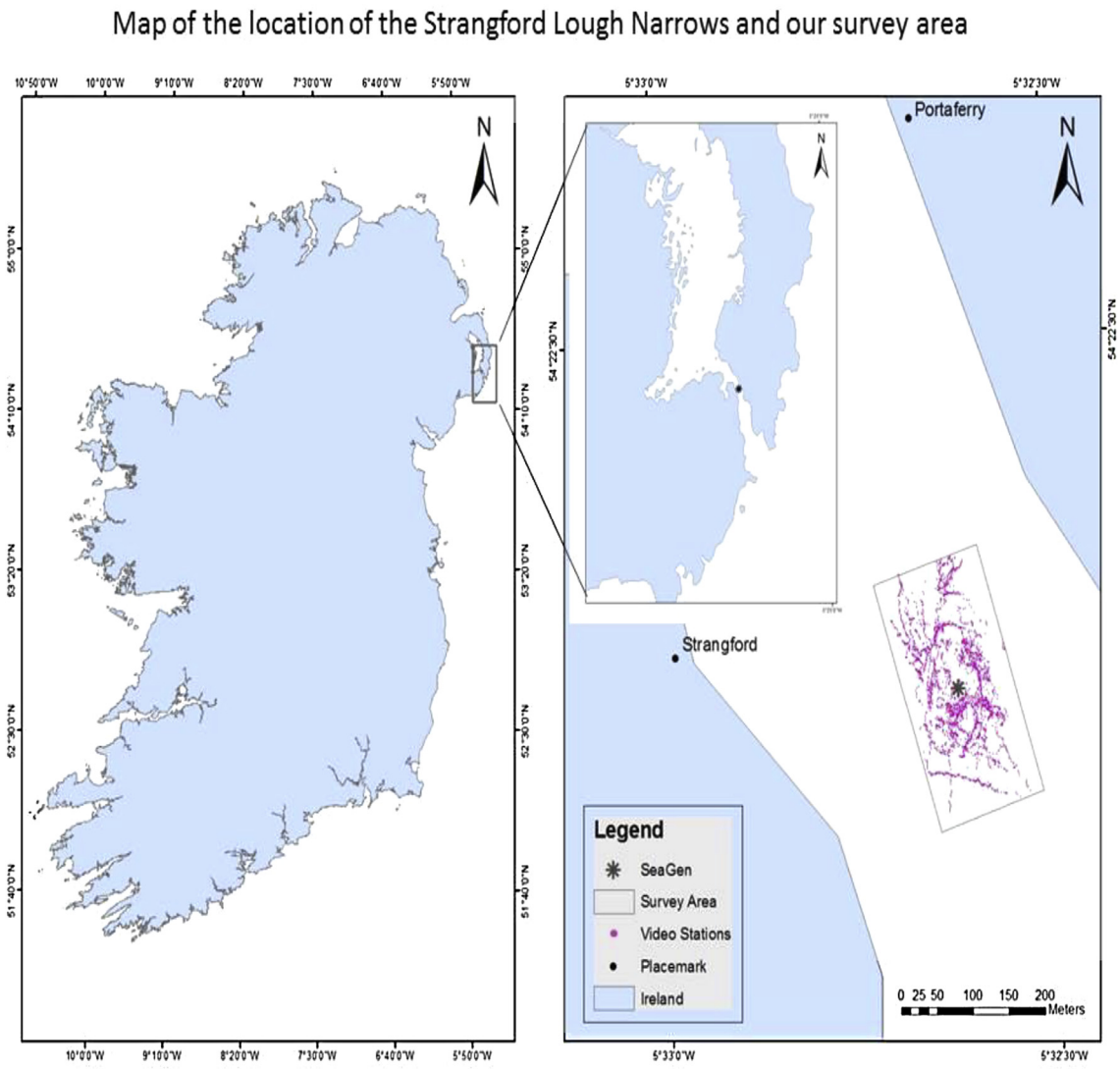

Fig. 1. Map of Ireland, the Narrows, the survey area, position of the SeaGen and the georeferenced drop-down video stations.

scouring and increased physical disturbance. This hypothesis, until now, had not been definitively assessed.

Variation in epifaunal community structure on boulders is attributed to physical disturbance in the form of the mobilisation and overturning of substrates, and scouring by suspended sediment (Palmer and Palmer, 1977; Daly and Mathieson, 1977; Osman, 1977; Sousa, 1979a, 1984; Mcguinness, 1987b, Mcguinness, 1987a, Chapman, 2002a, 2002b, 2003, 2005, 2007). Most studies that have assessed community structure on boulders have focussed on intertidal and shallow subtidal habitats. Comparatively little literature exists for epifaunal communities on boulders in the lower infralittoral to the circalittoral (Kregting et al., 2016; O'Carroll et al., 2017).

In high energy environments such as tidal rapids, variability in benthic community structure is more likely to be influenced by physical processes rather than biological interspecific interactions (Sousa, 1984; Dean and Connell, 1987). Communities that are predominantly structured by abiotic physical processes tend to exhibit highly variable community structure (Berlow, 1997). The physical processes that govern variability on subtidal rock and boulders have the potential to be amplified in intensity within the turbulent wake created by a tidal stream turbine, potentially damaging or removing resident epifauna (Miller et al., 2013; O'Carroll et al., 2017).

Naturally occurring animal-flow interactions have been shown to be variable and scale dependent (Vogel, 1977; Okamura, 1984, Okamura, 1985, 1988; Wildish et al., 1987; Okamura, 1988; Leonard et al., 1988; Patterson, 1991; Hentschel and Herrick, 2005; Hentschel and Larson, 2006), with the highest level of variability existing at the faunal level (Underwood and Petraitis, 1993; Underwood and Chapman, 1996; Wootton, 2001; Terlizzi et al., 2007). Current speed has been shown to directly influence the structure of benthic assemblages over a variety of spatial scales, from the feeding-polyp level (Patterson, 1991) to community (Wildish et al., 1987) and habitat levels (Fonseca et al., 1983; Fonseca and Kenworthy, 1987). Spatial patterns in community structure resulting from animal-flow interactions can be more apparent when observed at coarse ecological resolutions such as ecological functional groups (Warwick and Uncles, 1980; Sebens and Johnson, 1991; Leichter and Witman, 1997; Gili and Coma, 1998).

The epifauna of the Narrows inhabit a stressful environment relative to most other coastal marine habitats. The dynamic physical environment of the Narrows is likely to introduce high amounts