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# Cumulative impact assessment of tidal stream energy extraction in the Irish Sea

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## ABSTRACT

A cumulative impact assessment of tidal stream developments in the Irish Sea has been conducted on a high-resolution depth-averaged hydrodynamic model, using Telemac2D. Eight sites were investigated, representing the proposed developments at the time of study. These included: Ramsey Sound, Anglesey, Strangford Loch, Mull of Kintyre, Torr Head, Fair Head, Sound of Islay and West of Islay. Only three projects showed array-array interaction: Fair Head, Torr Head and Mull of Kintyre. A smaller model domain was created for further analysis. Results showed Mull of Kintyre had little impact. Fair Head reduced the energy production at Torr Head by 17%, whereas, Fair Head only reduced by 2%. This was caused by the tidal asymmetry whereby the flood was stronger. When operated concurrently, the maximum power-output at Torr Head is 64.5 MW, representing 31% reduction. If Torr Head can still operate commercially in the presence of Fair Head, then the additional environmental impact of Torr Head, such as the change in bed shear stress, is small. Within the Irish Sea, very few of the tidal projects investigated are geographically close to each other. As the industry develops, the risk of interaction to these sites will grow when more intermediary sites are developed.

## 1. Introduction

The development of tidal stream energy extraction technology and the establishment of a tidal stream industry has seen considerable growth in the past two decades (Neill et al., 2017). As the tidal stream industry is only just starting to take the first steps moving from testing full-scale prototypes toward commercially viability, strategic planning of the marine environment is needed to maximise its full potential (Renewable UK, 2015). Many of the high velocity sites suitable for energy extraction are in close proximity and therefore could potentially interact significantly with one another. It is not efficient or in the best interest of the industry to consider each project in isolation. Cumulative impact assessments should be conducted, but have only recently been considered (Fairley et al., 2015; Wilson et al., 2012). Wilson et al. (2012) investigated the interaction between energy extraction from tidal stream and tidal barrages across the UK and its effect on the European continental shelf. Results showed severe near-field effects if tidal stream extraction is not limited and would require close management between nearby projects to limit environmental and economic impacts (Wilson et al., 2012).

Whilst a lot of focus has been given to modelling the Pentland Firth (Martin-Short et al., 2015; Draper et al., 2014; Woolf, 2013), it is not the only site being developed within the UK; the Irish Sea also has a number of proposed developments. The Irish Sea has long been studied (Robinson, 1979; Pingree and Griffiths, 1987; Davies and Jones, 1992; Young et al., 2000). Depths in the Irish Sea range from intertidal mud flats to ~140 m in the central Irish Sea, to the extreme of 250 m in the North Channel. Two amphidromic systems are found in the Irish Sea, one on the east coast of Ireland and one to the north of Northern Ireland. Tidal ranges in the east Irish Sea are the largest in the UK, with ranges more than 9 m at Workington and 12 m at Hinkley (British Oceanographic Data Centre). Large tidal velocities ( > 2 m/s) can be found in several locations in the Irish Sea, notably around Pembrokeshire, Anglesey and Northern Ireland (Robins et al., 2015).

Several studies have been conducted assessing these locations for the available tidal energy resource and the suitability for tidal stream extraction (Robins et al., 2015; Lewis et al., 2015; Neill et al., 2014). However, these studies do not include the presence of tidal stream devices, nor the interaction of devices or arrays of devices with one another. Robins et al. (2015) investigate how the ratio of the M2 and S2 harmonics can affect the annual practical power and estimate the spatial distribution of a tidal stream capacity factor. Whilst an annual

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power production is calculated for two sites, the Pentland Firth and Alderney, *"power extraction from individual turbines has not been simulated"* and *"neglect any device feedbacks"*. Lewis et al. (2015) investigate the total annual mean tidal resource of the Irish Sea within the constraints of 1st generation devices (velocities > 2.5 m/s and depths between 25 and 50 m) and show that the total potential resource could be larger if devices could be deployed in water depths greater than 50 m. Neill et al. (2014) investigate the phasing of tidal sites around the European shelf for power generation, but conclude there is minimal phase diversity between sites for power generation.

As well as the discussed resource assessments, studies have been conducted in the Irish Sea including the presence of tidal turbines. Robins et al. (2014) assessed the impact of tidal-stream arrays in relation to the natural variability of sedimentary processes at Anglesey, but only included a single tidal array of increasing capacity. Hashemi et al. (2015) investigated the influence of waves on tidal resource at Anglesey, showing that extreme wave-current interactions can reduce the tidal resource by 20%. Walkington & Burrows (2009) conducted an assessment of tidal stream power at multiple sites. However, the hydrodynamic effect of the tidal array at each of the four locations was considered in isolation. Furthermore, the tidal turbines were represented as a constant drag term, neglecting the operation of the turbine and the drag due to the support structure, leading to an under-representation of the total force and influence exerted by the turbine.

At the time of this study, there were eight existing and proposed tidal projects within the Irish Sea, totalling 264 MW. These include: Ramsey Sound (10 MW), Anglesey (10 MW), Strangford Loch (1.2 MW), Mull of Kintyre (3 MW), Torr Head (100 MW), Fair Head (100 MW), Sound of Islay (10 MW) and West of Islay (30 MW) (see Fig. 1). The size of these arrays represent the actual proposed installed capacities of the site developers and not the maximum theoretical capacities of the sites. Wilson et al. (2012) have previously investigated the interaction of extreme future large scale deployments ( > 85 GW by 2050). The aim of this study is to investigate the interaction of actual projects detailed by site developers. Since this work has been undertaken, funding for the Anglesey project was removed and the project stalled. However, for the purpose of this analysis, it has been retained. This paper will investigate the cumulative impact of tidal energy in the Irish Sea to examine the extent to which the projects interact with each other. For this study, only tidal stream developments have been considered; tidal barrages were not included.

## 2. Irish Sea model

A high-resolution depth-averaged model of the Irish Sea was built using an unstructured triangular mesh, with the hydrodynamic software Telemac2D (v7p1) (Telemac). The model domain extends between 50.14°N–56.72°N and 2.38°W–7.73°W and is shown in Fig. 1. The unstructured mesh was discretised with 305,000 nodes, and has a resolution of 15 km around the open boundary, reducing to 1 km along the coastline. Bathymetry of the area, relative to Chart Datum, was sourced from the Department for Environment, Food & Rural Affair's UKSeaMap 2010 and was provided by the Centre for Environment, Fisheries and Aquaculture Sciences. The resolution of the bathymetry points from this dataset are 1 arc-second (~30 m). The bathymetry was corrected to Mean Sea Level by applying the maximum tidal range to the depths. As bathymetry strongly influences hydrodynamic characteristics, a high resolution 2 m and 4 m resolution bathymetry, from

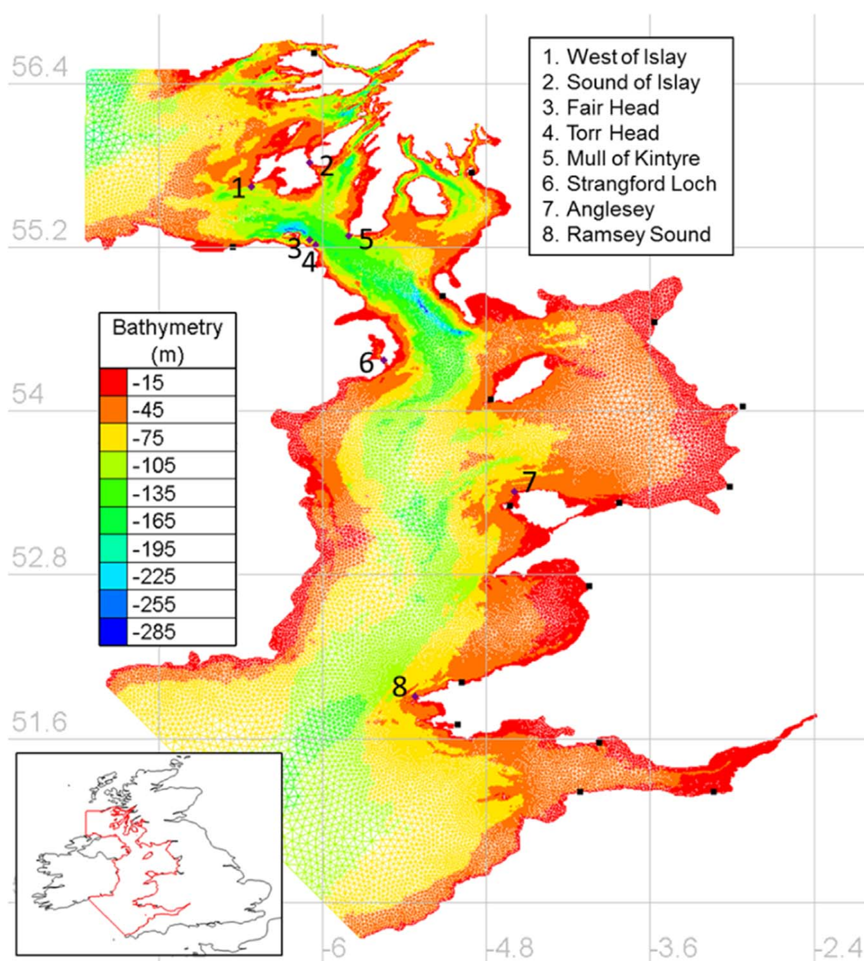


**Fig. 1.** Irish Sea model domain showing the locations of the tidal arrays (purple diamonds) and tide gauge locations (black squares) used for validation.