International Journal of Marine Energy 16 (2016) 235–249

Contents lists available at ScienceDirect

International Journal of Marine Energy

journal homepage: www.elsevier.com/locate/ijome

Comparing nekton distributions at two tidal energy sites suggests potential for generic environmental monitoring

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ARTICLE INFO

Article history:
Received 23 February 2016
Revised 6 July 2016
Accepted 15 July 2016
Available online 16 July 2016

Keywords:
Biological monitoring
Pelagic nekton
Marine renewable energy
Hydroacoustics

ABSTRACT

Tidal energy is a renewable resource that can contribute towards meeting growing energy demands, but uncertainties remain about environmental impacts of device installation and operation. Environmental monitoring programs are used to detect and evaluate impacts caused by anthropogenic disturbances and are a mandatory requirement of project operating licenses in the United States. In the United Kingdom, consent conditions require monitoring of any adverse impacts on species of concern. While tidal turbine sites share similar physical characteristics (e.g. strong tidal flows), similarities in their biological characteristics have not been examined. To characterize the generality of biological attributes at tidal energy sites, metrics derived from acoustic backscatter describing temporal and spatial distributions of fish and macrozooplankton at Admiralty Inlet, Washington State and the Fall of Warness, Scotland were compared using *t*-tests, *F*-tests, linear regressions, spectral analysis, and extreme value analysis (EVA). EVA was used to characterize metric values that are rare but potentially associated with biological impacts, defined as relevant change as a consequence of human activity. Pelagic nekton densities were similar at both sites, as evidenced by no statistically significant difference in densities, and similar daily density patterns of pelagic nekton between sites. Biological characteristics were similar, suggesting that generic biological monitoring programs could be implemented at these two sites, which would streamline permitting, facilitate site comparison, and enable environmental impact detection associated with tidal energy deployment.

1. Introduction

Environmental monitoring is used to identify impacts caused by anthropogenic disturbances. Biological components of monitoring programs focus on the detection of change in variables such as diversity, size, or abundance of monitored species [1]. Prior to establishing long term monitoring, regulatory agencies typically require the collection of baseline data before projects can be implemented that may cause alteration to an ecosystem [2]. At a single site, biological characteristics before and after an alteration can be compared to detect change, as in classic Before – After – Control – Impact (BACI) sample designs [3]. Standard sampling protocols permit monitoring datasets to be compared between or among sites to evaluate if observed changes are site-specific or generic.

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http://dx.doi.org/10.1016/j.ijome.2016.07.004
2214-1669/© 2016 Published by Elsevier Ltd.

Biological monitoring programs are mandatory for marine renewable energy (MRE) tidal energy projects in the US, yet no standards for monitoring procedures, technologies, or metrics currently exist [4]. This lack of standardization has resulted in site-specific monitoring programs for each tidal energy pilot project in the US. In Scotland, an Environmental Impact Assessment and a post-installation monitoring program are required for each MRE project, and these are also site-specific [5]. Standardization of a portion or all monitoring components would enable monitoring plans to be proposed in a time-efficient manner, and make monitoring datasets comparable across sites.

Determining what the maximum level of "acceptable" impact, or biologically significant change, is a high priority when forming a monitoring plan [6]. Because impact above a threshold can determine if a tidal project requires operational modifications, additional monitoring, mitigation, or removal [7], impact thresholds and characterizations should be determined before post-installation monitoring begins [8]. Extreme value analysis (EVA) is an approach used to model values that are infrequent but potentially associated with impacts [9]. This approach also provides a threshold to identify infrequent values, and could provide statistically significant thresholds for use in biological monitoring [10].

Few studies of fish and macrozooplankton in the water column (i.e. pelagic nekton) have been conducted at tidally dynamic sites because these sites are challenging to sample. One option for studying biota in the water column is active acoustic technology. Acoustic instruments use sound to evaluate distributions, abundances, and behavior of fish and macrozooplankton [11,12]. Acoustic instruments offer non-invasive methods to continuously sample large volumes of water, regardless of current speed or light levels. These instruments can be deployed on autonomous or cabled platforms that are suitable for monitoring at high spatial and temporal resolution [13], and low cost [14].

It is important to evaluate and compare MRE site biological characteristics so that the potential for standardized monitoring programs can be assessed, and if applicable, developed and implemented. MRE tidal sites share similar physical characteristics (e.g. high tidal flows), but it is unknown whether these sites share similar biological characteristics. In this study we describe and compare biological characteristics of pelagic nekton distributions at two tidal energy sites, to examine whether density distributions are similar or site-specific. We also evaluate whether EVA is an appropriate general approach to determine impact thresholds of biological monitoring variables at tidal energy sites and comment on the feasibility of developing generic monitoring programs.

2. Methods

2.1. Site descriptions

Active acoustic data used for this study were collected at two tidal energy sites. Admiralty Inlet, on the west side of Whidbey Island in Puget Sound, Washington State, was the proposed site of the Snohomish Public Utility District 1 (SnoPUD) pilot tidal energy project that received its project license from the Federal Energy Regulatory Commission (FERC) on March 20, 2014. The project, now dormant, would have deployed two OpenHydro turbines (http://www.openhydro.com/) approximately one kilometer off Whidbey Island (Fig. 1a). Two buried cables were to connect the turbines to the electric grid [15]. The second dataset was collected at the European Marine Energy Council (EMEC) test facility in the Fall of Warness, located centrally in the North Isles of Orkney, Scotland (Fig. 1b). The Fall of Warness provides eight grid-connected turbine berths in depths of 12–50 m with current speeds up to 4 ms^{-1}. Although the site has actively generating turbines, the dataset used for this study was collected in the tidal channel, away from any turbine structure to provide a control dataset for the FLOWBEC project (http://noc.ac.uk/project/flowbec).

2.2. Data acquisition

Acoustic backscatter (i.e. reflected energy) data were recorded at Admiralty Inlet using a seabed mounted BioSonics DTX echosounder (http://www.biosonicsinc.com/) operating at 120 kHz from May 9 to June 9, 2011 [16]. The echosounder was placed on the seabed at 55 m depth about 750 m off Admiralty Head at the SnoPUD tidal turbine site. The echosounder sampled at 5 Hz for 12 min every 2 h (Table 1). Tidal velocity data were collected once every 10 min by a Nortek acoustic Doppler current profiler (http://www.nortek-as.com) operating at 1 Hz.

At the Fall of Warness, a seabed-mounted acoustic platform containing a multibeam sonar and an EK60 echosounder [17] was deployed at 35 m depth over an 18 day period from June 18 to July 5, 2013. The echosounder collected data at 38 kHz, 120 kHz, and 200 kHz, sampling at 1 Hz (Table 1). Water column mean tidal speeds were modeled from tidal velocity data that were collected every minute using an SonTek/YSI ADVOcean acoustic Doppler velocimeter (http://www.sontek.com/) [17].

2.3. Data processing

2.3.1. Admiralty Inlet

Acoustic data from Admiralty Inlet data were processed prior to this study, with processing described in [16] and [18]. Due to a 3rd surface echo in the water column, data values were constrained to 25 m from the seabed, a height corresponding to approximately twice that of the proposed turbines. A volume backscattering strength (S_v) threshold of −75 dB re