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Advances in Research to Understand the Impacts of Wave and Tidal Energy Devices in the United States

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ABSTRACT

The United States Department of Energy's Wind and Water Power Technologies Office (WWPTO) funds a research portfolio aimed at strategically filling knowledge gaps in the understanding of environmental impacts of wave and tidal energy devices. This portfolio includes research, monitoring, and modelling efforts to assess the impacts of marine energy devices; work to advance environmental monitoring instrumentation; and initiatives to aggregate, analyse, and disseminate the results of marine energy environmental research occurring around the world. This paper explores the approach that the WWPTO has taken to addressing two potential issues of concern regarding possible effects of wave and tidal devices on marine life, with an emphasis on recent results from this portfolio of work and research funded since the publication of the Annex IV report. Specifically, it focuses on the potential effects of device-generated noise on local marine organism behaviour, movement, and habitat use patterns and the potential for blade strike from tidal devices to cause harm to marine animals. For both these interactions, a combination of WWPTO-funded laboratory research, field monitoring, and modelling efforts have helped bound the understanding of the level of potential environmental effects of these technologies. As a whole, the U.S. Department of Energy research program seeks to provide data which can be used to inform the consenting process for future projects, reduce environmental uncertainty, inform the design of effective monitoring regimes, and identify potential mitigation strategies where necessary.

INTRODUCTION

Over the last five years, the United States Department of Energy's Wind and Water Power Technologies Office (WWPTO) has funded a suite of projects aimed at assessing and predicting the potential environmental impacts of renewable ocean energy technologies. This portfolio is designed to strategically evaluate the potential magnitude of effects through complementary suites of desktop analyses, laboratory research, field monitoring, and the development of tools for predicting project effects. The portfolio aims to ensure the sustainability of the emerging marine energy industry by enhancing the scientific understanding of effects and then aims to use these data to develop models and tools that help reduce the length and cost of future monitoring efforts by individual projects.

The WWPTO has invested in research regarding a number of potential environmental impacts, ranging from energy extraction to direct effects on aquatic organisms. The paper will explore the approach the WWPTO has taken to assess the effects of two of these potential environmental effects of ocean renewable energy devices and will highlight recent developments in our portfolio of research for these issues: the potential for noise generated by device operation to affect marine organism behaviour, movement, and habitat use patterns and the potential effects of strike from moving tidal turbine blades.

METHODOLOGY

Approach to Addressing Questions Regarding Effects of Operational Noise

While it is unlikely that the noise generated by operational wave and tidal devices will have large-scale effects at the pilot scale (Copping et al. 2013), there is increasing awareness of the effects of anthropogenic noise in the marine environment more generally, and questions remain regarding what effects, if any, noise from large commercial scale deployments will have. In order to address these concerns, the WWPTO has invested in a portfolio of work aimed at collecting field data on noise signatures from devices, collecting data on ambient sound budgets in high energy marine environments, laboratory studies to assess physiological and behavioural impacts of device noise, and use of surrogate noise sources as a proxy for predicting response to noise generated by ocean energy

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devices. This combination of research is strategically designed to help quantify the potential stressor, evaluate potential effects first in a controlled environment, followed by the field, and then to use these data to inform predictive tools for future effects assessments.

Currently, the WWPTO is funding a second wave of studies that explore the behavioural response of fish to turbine noise in mesocosm settings. In the first set of experimentation, researchers exposed largemouth bass, paddlefish, and pallid sturgeon to pre-recorded device noise at volumes representing a range of distances from the device. Fish movement was tracked by surgically implanted transmitters and data on fish location were used to evaluate attraction, avoidance, and change in activity.

Recently, the WWPTO provided funding to researchers at the University of Washington for a project that will characterize the behavioural responses of killer whales, harbour porpoises, and pinnipeds to the sounds produced by tidal turbines. This project will produce a description of the temporal and spatial variation in sound produced by a pair of open-centre, ducted tidal turbines deployed in Puget Sound, and demonstrate the effectiveness of wildlife observation techniques around marine renewable energy projects.

Finally, the WWPTO is investing in the development of noise generation and propagation models that aim to allow developers and consenters to predict the noise produced by devices and how it propagates in the environment without novel measurements at each project. Such tools will also allow for predictions of noise generated by larger arrays of devices than have been installed to date.

Approach to Addressing Questions Regarding Effects of Turbine Blade Strike

Concerns regarding the potential for injury or mortality to organisms from the moving turbine blades have been informed by concerns regarding strike issues surrounding conventional hydropower projects and ship propellers. There is mounting evidence that neither serves are a good proxy for informing questions of risk from current energy converters for a large number of reasons, however, questions remain regarding the extent to which blade strike might present a risk to marine organisms. In order to address these issues, the WWPTO has invested in a portfolio of work that systematically assesses the potential for blade strike through a combination of desk top analyses, flume experimentation, impact modelling for both fish and marine mammals, and finally field monitoring to both quantify behaviour around devices and inform the development of predictive behavioural models.

The WWPTO funded a second round of blade strike flume studies in 2013, building on the work conducted by Jacobson et al. (2012). This research explored the effects of light and dark on fish avoidance rates and measured injury and mortality rates for several species of fish in a flume setting.

Additionally, the WWPTO recently supported work to analyze fish behavior around tidal turbines. In the course of this project, researchers at Oak Ridge National Laboratory will quantify the distribution, behavioral response, and general patterns of fish movement around an operating tidal energy turbine. This study will provide a complete analysis of fish interaction data at a full- size turbine that developers and regulators can use to estimate the likelihood of encounter and injury at tidal and riverine sites.

In a related study, researchers at the University of Maine will collect data on the interactions of fish with ORPC's OcGen® turbine to predict the probability of fish encountering marine and hydrokinetic devices. Building on data gathered since 2010, which established baseline patterns of fish distribution at a nearby turbine's location, this project will provide post- deployment data for comparison, improve techniques for distinguishing between fish species using undersea acoustic sensors, and implement a probability- of-encounter model.

Finally, researchers at Argonne National Laboratory, the University of Maine, and the Army Corps of Engineers are applying an existing ecohydraulic model to analyse and simulate fish movements around ORPC's OcGen® turbine in Cobscook Bay, Maine. This project will use mobile hydroacoustic fish data to inform a Eulerian-Lagrangian-agent Method (ELAM) which uses simulation analyses of fish experience in a flow field (e.g., around MHK devices) to describe the nature and magnitude of measured behavioural changes (e.g., associated with turbine stressor effects).

OBSERVATIONS

Noise

Research funded by the WWPTO has helped advance the state of methodology for measuring sound in high energy marine environments (Basset et al. 2011, Polagye et al. 2011), determine noise levels from devices in the context of the ambient environment (Basset et al. 2011), and determine that physiological effects from device noise on fish are likely to be minimal at the pilot scale (Halvorsen et al. 2011). Recent mesocosm studies to investigate potential behavioural impacts of tidal noise on fish found no consistent patterns in avoidance or attraction responses at any of the sound levels tested (Bevelhimer, pers. comm.). Collectively, this body of work suggests that operational noise from pilot scale projects is unlikely to have large-scale effects on marine organisms. Future field research will help establish whether there are behavioural effects of operational noise.

Strike

Research funded by the WWPTO has helped advance the understanding of the potential risk of blade strike on marine organisms. Desktop analyses have indicated that many of the mechanisms of fish mortality differ significantly between conventional hydropower projects and current energy converters (Jacobson et al. 2012). Flume studies have indicated that avoidance rates of turbines are high and mortality levels generally commensurate with that of control groups (Jacobson et al. 2012).

Recent flume studies to investigate the potential for blade strike found that avoidance rates were similar for fish under light and dark conditions. Similar to previous trials, survival of fish passing through the turbine was high (Jacobson, pers. comm). Strike modelling efforts suggest that a strike event between an open-centre, ducted turbine and an orca is unlikely to result in mortality or large physical injury (Carlson et al. 2012).

Current and future field studies examining fish behaviour around turbines will help inform strike models that are able to incorporate fish avoidance and evasion variables.

CONCLUSIONS

Through a strategic suite of research projects, the WWPTO is working to reduce uncertainty regarding the potential effects of wave and tidal energy devices on the environment. Research funded to date have helped bound the understanding of the potential scale of effects of both operational noise generated by wave and tidal devices and of the potential for blade strike. Current and future research will help provide field data to further refine this understanding and flexible tools to predict project impacts. Collectively, this work will help accelerate the development of an environmentally sustainable ocean renewable energy industry.

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