Renewable Ocean Energy and the Marine Environment: Filling Gaps in Knowledge

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Abstract

Early deployments of wave and tidal energy projects are beginning to supply information on environmental effects of the devices, moorings, and power cables; these data will help inform later deployments and guide regulatory scrutiny as the industry makes the leap to commercial scale. In the United States, the U.S. Department of Energy sponsors research in support of U.S. renewable ocean energy development, through their national laboratories, universities, and industry partners. The U.S. also leads the Ocean Energy Systems-Implementing Agreement Annex IV, a collaborative study among member nations to bring together and assess information on environmental effects of renewable ocean energy. Information gathered to support U.S. development, as well as that of Annex IV, is hosted by Pacific Northwest National Laboratory (PNNL) on a public website known as *Tethys*, making results and analyses broadly available for the benefit of the industry, regulators and stakeholders worldwide. This paper introduces the *Tethys* website and Annex IV database, as well as reporting on the latest findings on the effects of EMF, turbine noise, and analysis of turbine blade strike on marine animals.

Keywords: Effects of marine energy, knowledge management system, Annex IV, EMF, acoustics, turbine blade strike.

1. Introduction

As early deployments of wave and tidal devices are taking place around the world, researchers are examining baseline assessments and post-installation monitoring data to understand the effects of marine energy devices, mooring lines and anchors, power cables, and associated systems on marine animals, habitats and ecosystem functions. Researchers are supplementing these data with laboratory studies of effects of marine energy devices on animals, and numerical modeling efforts to understand the effects of energy removal from estuarine and coastal systems.

2. Organizing Information about Environmental Effects

With small numbers of devices in the water, and even smaller numbers of arrays in operation, one of the challenges to creating a marine energy industry is ensuring that information and insight into the interactions of marine energy stressors and living receptors is captured and shared. The US Department of Energy is funding research and monitoring projects in the US to investigate environmental effects of marine energy through its national laboratories, university consortia, and marine energy companies. Part of that effort includes developing a web-based knowledge management system, dubbed *Tethys*, to capture, organize and make information broadly accessible. *Tethys* is focused largely on US marine energy projects, but also hosts the database of information for the Annex IV international collaboration under the Ocean Energy Systems-

Implementing Agreement (OES-IA). *Tethys* also supports data and information on environmental effects of offshore wind development in the US.

Tethys (http://mhk.pnnl.gov/wiki/index.php/Tethys_Home) has been developed from platforms and capabilities at Pacific Northwest National Laboratory (PNNL), written on the software platform Semantic MediaWiki (Figure 1). It is a fully searchable and integrated system of documents, data sources, mapping capabilities, and document archives. The knowledge base within *Tethys* is populated with papers and reports that are pertinent to the study of environmental effects, and hosts limited numbers of datasets and analyses (Figures 2 and 3). *Tethys* is a living system and is expected to continue to expand as more papers, documents, datasets, and analyses are added and updated. *Tethys* is accessible to the public; signing up for a free *Tethys* account provides additional access and capabilities to the user.

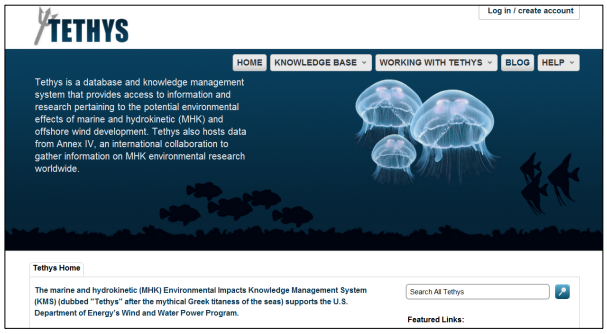

Figure 1. Screenshot of Tethys Homepage

Figure 2. Tethys Knowledge Base, with all documents displayed.

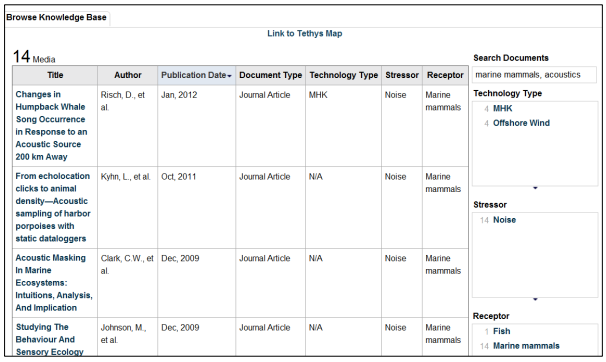

Figure 3. Tethys Knowledge Base, displaying documents that match the search criteria for "marine mammals" and "acoustics".

3. Annex IV

The Annex IV database housed on *Tethys* consists of metadata on environmental effects studies associated with marine energy projects worldwide, and documents that are pertinent to those data. The information is searchable from a global map or through a spreadsheet-designed knowledge base (Figure 4). Case studies that bring together common environmental challenges of marine energy development will also be housed on the database. The current case studies include: Interaction of marine animals with turbine blades; Effects of acoustic output from tidal and wave devices on marine animals; and Effects of energy removal from wave and tidal devices on physical systems. The Annex IV database is only available for viewing by Annex IV member nations and participants until the end of 2012, at which time it will be open to the public.

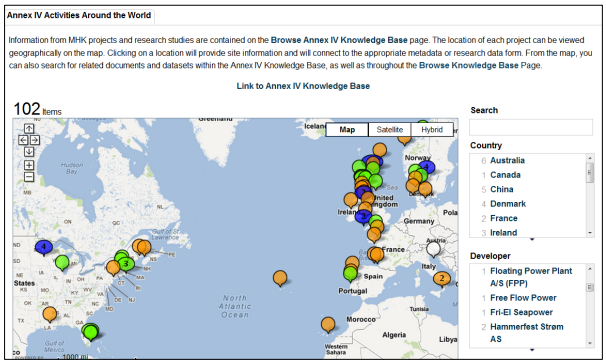

Figure 4. Annex IV map showing locations of project sites, research studies, and documents associated with the sites.

4. Research on EMF and Acoustic Outputs of Marine Energy Devices

Tethys acts as the repository of results from research at the US Department of Energy national laboratories and other research centers. Examples of the research highlighted in *Tethys* include laboratory research on the effects of EMF from power cables

and acoustic output from tidal turbines on marine animals, and an analysis of the effects of turbine blade strike on a marine mammal.

PNNL researchers have challenged marine fish and invertebrates in the laboratory with EMF levels produced by direct current, simulating the output of power cables and tidal turbines. While most marine animals tested to date show little effects, slight delays can be seen in the development of Atlantic halibut, Dungeness crab show a slight attraction, and American lobster seek to avoid the EMF field [1]. Further studies are needed to determine the effect of EMF from marine energy under real-world conditions.

PNNL has also challenged juvenile salmon with the acoustic output of a tidal turbine in the laboratory. The fish were placed and held in a position simulating close proximity to the turbine; even under these conditions simulating an extremely high exposure, effects were limited, equivalent to mild bruising with no loss or change in hearing [2]. Similar experiments are needed on other fish species. Models that will extrapolate the effects on fish to those of marine mammals are needed to understand the risk to top predators and other marine species.

5. Strike Analysis

In response to questions by regulators, PNNL and colleagues at Sandia National Laboratories analyzed the effect of an OpenHydro tidal turbine blade strike on an endangered orca, should the animal be curious enough to stick its head into the open center turbine. The engineering and biomechanical analysis showed that the animal might suffer bruising before being pushed aside, but that the blade would be unlikely to break the animal's skin. Additional analyses are needed to validate the modeling effort and to determine whether the animal might suffer from blunt force trauma to the head.

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