VISUAL SIMULATION OF WHALES AND OFFSHORE RENEWABLE ENERGY MOORING LINES AND ELECTRICAL CABLES

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INTRODUCTION

Surface-placed wave energy converters, floating tidal turbines, and floating offshore wind platforms all require anchoring to the seabed with multiple mooring lines and electrical cables passing through the water column, from near surface to the sea floor. Concerns have been raised that large whales may collide with or become entangled in the lines and cables from ocean renewable energy installations, causing injury or death. Currently there are few floating arrays where this encounter can be tested, and no appropriate industrial analogues that can be applied.

Visualization of potential impact between underwater lines and humpback whales

Assessing the encounter between whales and offshore mooring lines or electrical cables poses a problem of scale. Floating wave or offshore wind installations are typically proposed for deep water (30m-1000m), such as offshore California, requiring that mooring lines and inter-array electrical cables be deployed in the water column. At the same time, whales travel large distances over relatively short periods of time. Envisioning the spatial scale of the floating offshore installations and the spatial and temporal scale of whale movements concurrently, is challenging. Animating whales traveling through an offshore platform can aid in visualizing the potential risk of encounter with moorings and cables. An animation can also serve as a public-facing demonstration of the geometry of mooring lines and cables, demonstrating the small volume taken up by the lines and cables in the water column.

Humpback whales were chosen as the iconic whale for this animation. Humpbacks are worldwide in distribution and may be found in areas proposed for offshore energy development. Their long pectoral fins might increase their potential interaction with lines in the water column. We have used an array of floating offshore wind turbines to exemplify the potential for interactions between whales and floating energy installations, including wave and tidal arrays.

METHODS

Creation of a typical mooring configuration

Information was gathered to model a hypothetical floating offshore wind installation in the Pacific. Geometry and layout of the installation, material specifications for mooring lines and electrical cables, and water depth were provided by the Bureau of Ocean Energy Management (BOEM), based on existing and proposed for offshore wind installations. These data serve as the 'scene' used for the animation (Figure 1).

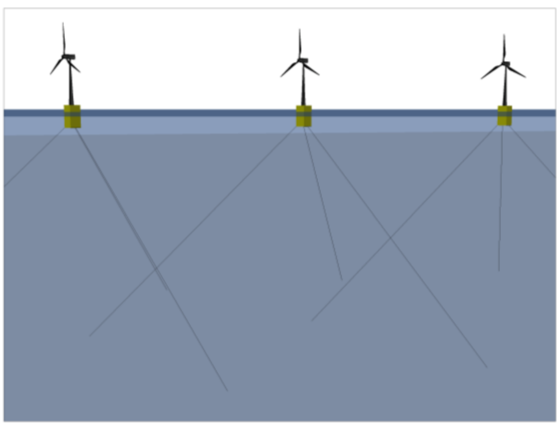

FIGURE 1. CONFIGURATION OF THREE TURBINES WITHIN A WIND INSTALLATION CONSTITUTING THE ANIMATION SCENE. THE TURBINES ARE SPACED 820 M APART, IN 700 M DEPTH OF WATER.

Using the specifications for materials, water depth and platform geometry, and applying appropriate gravity and buoyancy approximations, the mooring lines can be realistically weighted and the resulting movement of lines in the water column can be accurate. Figures 1 and 2 are static AutoCAD drawings; the video animation software allows this same geometry to be weighted appropriately and move in response to wind and wave conditions (Figure 3).

For the animation, inter-array cables that carry power between the floating platforms are buoyed with floats along the length of the cable at a depth of 100m (**Error! Reference source not found.**). Export cables laid on the seabed to transport power to the shore are not included in the animation.

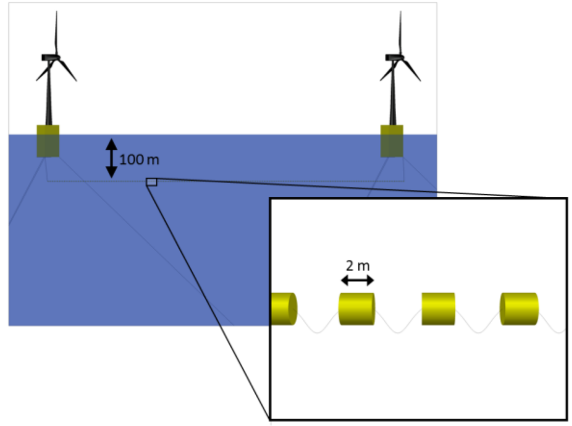

FIGURE 2. SCALE DRAWING OF AN INTER-ARRAY CABLE BETWEEN TWO TURBINES.

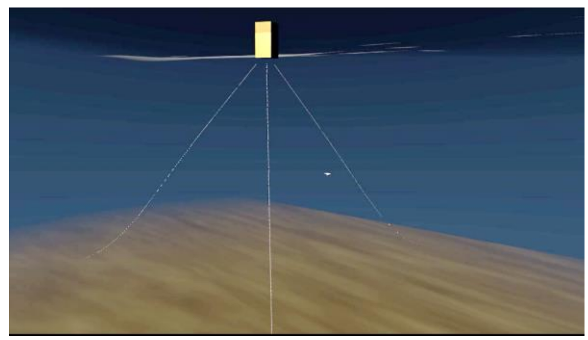

FIGURE 3. EXAMPLE OF A VIDEO FRAME OF MOORING LINES AND WINDFARM FOUNDATION RENDERED WITH GRAVITY IN OPEN SOURCE ANIMATION SOFTWARE BLENDER. THE SMALL DOT NEXT TO THE FURTHEST RIGHT LINE IS THE ADULT HUMPBACK WHALE, DISPLAYED AT SCALE.

Modeling the *typical* humpback whale

A humpback adult and calf were chosen for this animation, and were modeled using morphometrics from the literature. The humpback mother-calf pair represent a typical grouping of whales that may travel together. Typically humpback females are larger than males [1],[2],[3]. As the animation focuses on a mother calf pair, only the female morphometrics were used to create the adult whale model. Calf morphometrics were also collected from the literature based on the size of a weaning calf, approximately half the size of an adult (Table 1).

Figure 4 shows the model of the adult whale and calf geometry.

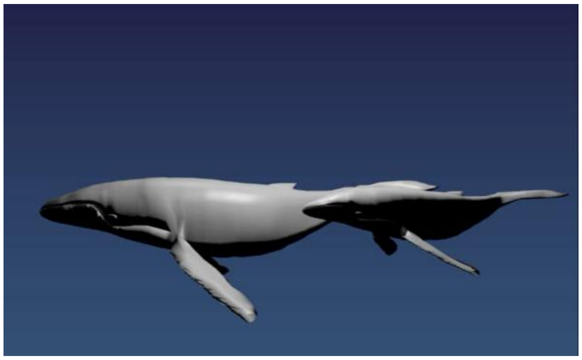

FIGURE 4. ADULT WHALE AND CALF GEOMETRY RENDERED IN THE OPEN SOURCE ANIMATION SOFTWARE BLENDER.

TABLE 1. AVERAGE MORPHOMETRIC DATA USED FOR ENCOUNTER SCENARIOS. CALF DATA IS BASED ON HALF SIZE ADULT OR A WEANING CALF. [1],[2],[3],[4],[5],[6].

Adult Female Length	13.18 m	Calf Length[(a)]	6.59 m
Adult Female Girth[(b)]	9.85 m	Calf Girth[(b)]	4.92 m
Adult Female Fluke Length[(c)]	4.44 m	Calf Fluke Length[(c)]	2.22 m
Adult Female Flipper Length[(d)]	4.06 m	Calf Flipper Length[(d)]	2.03 m

(a) *Calculated as half the adult length*
(b) *Calculated as girth = 0.747*length, at the axilla.*
(c) *Calculated as Fluke Span Length = 0.337*Length.*
(d) *Calculated as Flipper Length = 0.308*Length.*

Humpback whale behavior

In order to realistically simulate interactions between humpback whales and offshore platforms, it is necessary to apply behavioral data to the movement of the animals. The animation will include the movement of a mother–calf pair travelling through the array, as well as an adult humpback foraging. The behavioral data used includes swimming speeds, diving depths, and breathing times. Additional more subtle aspects of the whales' behavior were gleaned by reviewing video of humpback movement and general swimming kinematics. Finally, descriptions of feeding at depth, with the whale accelerating rapidly and changing direction, were documented for re-creation in the animation.

The video will be created in two modes: 1) The mother-calf humpback pair will be simulated travelling near the surface in a straight-line pattern. 2) The adult (mother) whale will also be simulated foraging, which causes her to dive and lunge at food such as krill. The diving and foraging behavior will entail more erratic movements perhaps creating more potential for encountering the mooring lines.

RESULTS AND DISCUSSION

The output of the animation project will be a 3 minute video that depicts the humpback pair moving through a hypothetical floating wind array. The animation will allow visualization and enhanced understanding of potential future interactions between whales and offshore renewable installations. However, animations have their limitations; the animator prescribes many of the parameters and actions that take place. This prescription may be biased by her or his concept of what may happen, limiting the true predictive capability of the medium.

In future, predictions of encounters between whales and offshore platforms could be enhanced through numerical modeling, delineating the probabilities of encountering the mooring lines or inter-array cables based both on the whale morphometrics and the behavioral data collected during this effort.

CONCLUSIONS

As commercial scale wave, tidal, and offshore wind installations develop, determining the risk to whales and other marine mammals from mooring lines and inter-array cables will be essential. By creating a scale animation of humpback whales (mother-calf pair) traveling through an offshore energy floating platform, the potential encounters can be visualized and explained to the public, improving understanding by illustrating the potential for risk. While the animation is neither predictive nor quantitative, and much of the behavioral responses of the whales to new technologies remain uncertain, this tool can be used to provide perspective for discussions among project developers, regulators, researchers, and other stakeholders.

ACKNOWLEDGEMENTS

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