BOEM Pacific Region: Ongoing Study

Title	Development of Computer Simulations to Assess Entanglement Risk to Whales and Leatherback Sea Turtles in Offshore Floating Wind Turbine Moorings, Cables, and Associated Derelict Fishing Gear Offshore California (PC-19-x07)
Administered by	Pacific OCS Region
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Conducting Organizations(s)	National Oceanic and Atmospheric Administration
Total BOEM Cost	$500,000
Performance Period	FY 2019–2022
Final Report Due	August 22, 2022
Date Revised	March 24, 2022
PICOC Summary	
Problem	Offshore floating wind turbine moorings, power cables and associated derelict fishing gear may pose entanglement threats to protected marine species and there is currently no literature available that is applicable to deep water (>500 m) mooring designs.
Intervention	Develop a simulator designed to examine the risk and potential severity of entanglement of fin and humpback whales and leatherback sea turtles with at least two deep water (>500m) offshore floating wind turbine mooring systems and associated derelict fishing gear.
Comparison	This would be the first effort of its kind and will provide an important assessment tool that can be tested for validation once offshore floating platforms are installed in deeper water offshore California.
Outcome	In the absence of empirical data, the simulator will provide resource managers, regulators and industry with a tool to proactively assess and mitigate the risk of entanglement for protected whale species and leatherback sea turtles in deep water offshore floating turbine mooring systems and associated derelict fishing gear.
Context	Focused on the Pacific, but potentially applicable to all OCS regions.

BOEM Information Need(s): BOEM has already received one application to install floating wind turbines offshore northern California in waters approximately 500 m deep. There is currently no applicable information to accurately assess the potential impacts to protected whale and sea turtle species from this nascent industry. This information will assist in the identification of potential mitigation strategies. BOEM needs to acquire this information to inform the environmentally responsible development of any permitted offshore renewable floating energy activities offshore California. Impact assessment information is required under NEPA, ESA and MMPA.

Background: The Hywind Scotland floating wind farm is the world's first and only wind farm, consisting of 5 floating turbines in water 95-129 m in depth, operational since 2017 (https://www.equinor.com/en/what-we-do/hywind-where-the-wind-takes-us.html). The Fukushima

FORWARD Project currently only has a floating sub-station and 2 operational floating turbines offshore the Fukushima Prefecture in Japan in 50 m of water since 2013 (the 7 MW turbine was recently decommissioned; http://www.fukushima-forward.jp/english/). BOEM received an unsolicited application to install an offshore floating wind farm in northern California in 2018. Stakeholder comments received in response to BOEM's Call for Information and Nominations (January 28, 2019) highlighted entanglement as a significant impact of concern related to offshore floating wind farm installation.

BOEM has funded studies to try to visualize the potential interactions of whales with offshore floating wind turbines (e.g., Copping and Grear, 2018). However, there is no applicable scientific information available to inform the potential entanglement risk and impacts from offshore floating wind turbine mooring systems to marine protected species that occur in the deep waters offshore California. The most recent qualitative risk assessment done was for floating turbines in 50 m of water offshore Scotland (Benjamins et al., 2014; Harnois et al., 2015) and they state that recommendations need to be developed, assessing the risk of entanglement of offshore renewable energy mooring configurations at the beginning of their design process. In addition, the entanglement review stated that although risks of entanglement between derelict fishing gear and offshore marine renewable energy (ORE) moorings and structures clearly exist, further studies are required to quantify the level of risk (Benjamins et al., 2014).

Recent advances in the use of computer simulators allow the discovery of risk and severity of entanglement of highly endangered North Atlantic right whales with certain fixed fishing gear such as single-trap lobster pots commonly used in the northeastern fisheries of the United States (Howle et al., 2018). Additionally, one other entanglement simulator has been designed to demonstrate entanglement between the leatherback turtle and a vertical line (MacNicoll et al., 2016).

Following on these efforts, we will develop a morphologically accurate digital model of a fin and humpback whale and a leatherback sea turtle with realistic swimming motions and body appendage articulations. This will be coupled to a simulation environment including a subset of mooring and power cable configurations and designs representative of the current state of knowledge for offshore floating turbines. The moorings and power cables will have various combinations of chain/cable/rope diameters, lengths, strengths, bending strength and flotation systems. In addition, the most likely type(s) of derelict fishing gear anticipated to interact with these structures will be identified and included in the simulations.

Objectives:

- Develop morphologically accurate whale (fin, humpback) and leatherback sea turtle digital models. Additional species may be added dependent on available funds.
- Develop at least two digital models of floating turbine moorings, power cable systems, and associated derelict fishing gear.
    - Identify at least two appropriate and foreseeable mooring and power cable system designs for deployment in 500-1,100 meter water depths.
    - Analyze applicable and available fisheries data to identify the gear most likely to interact with the identified offshore renewable energy mooring and power cable structures.
- Investigate the dynamics of the interaction between the whale models and floating turbine moorings, power cable systems and associated derelict fishing gear.

    - Incorporate applicable and available data on whale and sea turtle entanglement from all sources, including stranding and necropsy reports.
    - Incorporate certain animal behaviors, such as maintain a pace, veer away, roll, startle reflex and feeding positions to study the effect of these behaviors on the probability of entanglement.
- Assess whale and sea turtle entanglement risk with floating turbine moorings and power cable systems and associated derelict fishing gear.
- Create a high-quality, professional educational product in support of a non-technical audience. This should include at least one non-technical, concise, BOEM branded animated video explaining the importance, application, and results of this study.
- Identify mitigation measures or recommendations, if any, to reduce the potential risk of entanglement from deep water (>500 m) ORE structures and derelict fishing gear to cetacean species and leatherback sea turtles in the California Call Areas.

Methods:

- Simulator program will make use of the Unity3D software system.
- Different gear configurations and protected species digital models will be programmed in C#, and added to the Unity project.
- Make use of applicable literature and expert elicitation for species behavioral information, fishing activities (to the availability of derelict fishing gear) and oceanographic conditions for the Humboldt and Central California Call Areas.

Specific Research Question(s):

1. What is the risk of entanglement in deep water (>500 m) ORE moorings and cables to protected leatherback sea turtles and fin and humpback whales that occur in the California Call Areas?
2. What is the risk of entanglement in derelict fishing gear associated with deep water (>500 m) ORE moorings and cables for protected leatherback sea turtles and fin and humpback whales that occur in the California Call Areas?
3. Are there mitigations that would minimize any identified risk of entanglement in deep water (>500 m) ORE moorings, cables and associated derelict fishing gear?

Current Status:

- **Virtual whale & turtle model drafts** – Accurate morphological, swimming, energetics, and biophysical whale models for humpback and North Atlantic right whales (Phase 1) as well as blue/fin whale and leatherback sea turtles (Phase 2) are now complete. Animations are complete, combinations of atomic motions for prioritized behaviors are being programmed, and the Team will continue to develop and prioritize the sequence of motions for complex behaviors. A draft species guide (literature review) has been created for North Atlantic, humpback, and blue/fin whales and leatherback sea turtles. Species guides will inform updates on morphology, kinematics, and performance (i.e., programmable movements).
- **Engineering considerations** – Whale model physics is being validated against gear and environmental variables. A draft report to explain validation methodology, considerations, and

interpretation of scaled model experiments (tank testing) has been created and is under review by Design Team engineers. The report will determine if the mass:gear ratio for protected species in this project will need to be altered for an "average" adult animal. Upcoming discussions will include prioritization of the next round of gear configurations (including secondary entanglement) to include for this project.

- **Virtual mooring system models** – The initial modeling and simulator infrastructure for development of two floating windfarm configurations: semi-taut and catenary floating turbine hull mooring systems models has been completed but will continue to be developed throughout the project. Chains and chain mooring systems have been modeled and ongoing work will include meetings with offshore wind engineers (global) to validate gear components, materials, connections, and specifications for gear models. The Design Team will determine an appropriate platform or software to validate mooring system components (e.g., OrcaFlex).
- **Derelict fishing gear models** – NOAA and BOEM have engaged NOAA's Protected Resources Division in conversations regarding secondary entanglement resulting from derelict gear. Meetings with gear and entanglement experts will continue in order to discuss derelict gear, secondary and tertiary entanglement, and mitigation options. NOAA, BOEM, and BelleQuant will determine which configuration(s) of fixed fishing gear/derelict gear will be prioritized as feedback is generated from protected resources and industry experts.
- **Simulator graphical capabilities** – The Gear Finite Element (FEM) model is complete and allows for calculation of an internal moment with three (3) vectors. Collision sets have been created to complement the skin mesh and skeletal "control rigs", and together they will generate accurate whale-gear interaction data. Scenarios have been developed for North Atlantic right whales on a single buoy line in an attempt to recreate a "Y wrap", as well as blue/fin whales swimming through and along mussel longlines. Future scenario planning will include programming sequential behaviors, complex initial interaction response behaviors, and additional interactions between different species-gear combinations. The Executive Team is working with offshore wind experts to identify appropriate fluid dynamic and drag coefficients moving forward.
- **Simulator analytical capabilities** – Visioning sessions for simulator analytical capabilities were held during work meetings and input was received. Additional visioning and input will be completed in the future.
- **Roundtable meeting** – A January 19-20, 2022 Roundtable meeting was attended by 60+ representatives from NOAA, BOEM, and invited experts in whale and sea turtle biology, behavior, entanglement, engineering, and offshore wind. Feedback from this meeting is being reviewed and will be incorporated wherever possible.

Publications Completed: None

Affiliated WWW Sites: None

References:

Copping A, Grear M. 2018. Humpback whale encounter with offshore wind mooring lines and inter-array cables. U.S. Department of Energy, Pacific Northwest National Laboratory, Final Report PNNL-27988. U.S. Department of the Interior, Bureau of Ocean Energy Management, OCS Study BOEM 2018-065. 34 p. https://www.boem.gov/BOEM-2018-065/

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Harnois V, Smith HCM, Benjamins S, Johanning L. 2015. Assessment of entanglement risk to marine megafauna due to offshore renewable energy mooring systems. International Journal of Marine Energy. 11:27–49.

Howle LE, Nowacek DP, Kraus SD, Werner TB. 2018. Simulation of the entanglement of a North Atlantic right whale (Eubalaena glacialis) with fixed fishing gear. Marine Mammal Science. DOI: 10.1111/mms.12562.

MacNicoll M, Akers R, Gougey C. 2016. Simulation of Marine Entanglement – A software tool used to predict entanglement of leatherback turtles. NOAA grant NA14NMF4720327 final report.