Environmental Studies Program: Ongoing Study

Field	Study Information
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 Regional Office
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Procurement Type(s)	Interagency Agreement
Conducting Organization(s)	National Oceanic and Atmospheric Administration
Total BOEM Cost	$1,000,000 (includes Environmental Studies Program and Pacific Region funds)
Performance Period	FY 2019–2025
Final Report Due	August 31, 2025
Date Revised	November 2, 2023
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.

Objective(s):

- 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:

- Animal models (juvenile models from Phase I, additional smaller cetaceans) – The Lead Developer has purchased sixteen (16) animal models (skin mesh and texture files) to increase available species and speed up the development process. Lead Developer has merged these files with the skeleton rig to create morphologically accurate animal models for three (3) priority species for Phase II: gray whale, common dolphin, humpback whale juvenile (chosen based on extensive outreach with NMFS West Coast Region). The Lead Developer has worked with Duncan Irschick (University of Massachusetts) and Frank Fish (West Chester U.) to finalize the three animal models and accompanying species guides. Lead Developer has updated the biophysics code for all Phase I animal models as of August 2023 (see change log).

- 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.
- Wind Mooring Configurations (continued improvements from Phase I) - The Lead Developer (LD) has added fully dynamic mooring system updates four (4) mooring configurations (tension, taut, semi-taut, catenary. LD has also updated callback methods and mooring conditions, added inter-array cables to the 4 mooring configurations, added transmission cable finite element model, and added static vectors to normalize the cables. LD has updated the Finite Elements Models (FEM) to reflect angular drag, and further developed the Graphical User Interface (GUI) to improve user functionality.
- Derelict fishing gear models – Phase II deliverables include new and improved digital models for five (5) pot fishery gear types (Dungeness – hagfish – sablefish - rockfish or rock crab – lobster) that represent single line and bucket trap configurations that will be modeled for secondary, and potentially tertiary entanglement, on mooring systems.
- Ocean Environment – Installed the optimal KWS HDRP water system. This system will allow the user to adjust water transparency, color, and turbidity. Reduced turbidity and glossiness on the seabed mean more clarity for the animal and mooring gear models in the ocean environment.
- Enhanced Simulator graphical capabilities – Made a series of improvements to the initial Gear Finite Element Model (FEM) and Graphical User Interface (GUI) created during Phase I. This includes updates to physics equations used to calculate drag and forces, and the outcome has resulted in a more fluid motion on the mooring chain and cable system. Future improvements to turbine dynamics, baleen entanglements, behavior state of whales (e.g., feeding vs transiting), extreme weather events, and a more advanced ocean simulation environment will be ongoing.
- Validation studies using observed entanglement scenarios – Initial validation studies are complete. Additional work to improve validation capabilities will be ongoing in future phases of the project.
- Outreach completed
    1. Morris J, Balling M. – NOAA Office of Aquaculture Leadership Outreach Meeting (Phase I updates & demo webinar), July 10, 2023.
    2. Morris J, Reeb D, Balling M. – NOAA Protected Resources Division Leadership Outreach Meeting (Phase I updates & demo webinar), July 11, 2023.
    3. Outreach video materials recorded for production of an informational video.

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/

Benjamins S, Harnois V, Smith HCM, Johanning L, Greenhill L, Carter C, Wilson B. 2014. Understanding the potential for marine megafauna entanglement risk from marine renewable energy developments. Page Scottish Natural Heritage Commissioned Report No. 791.

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.