SEER

U.S. OFFSHORE WIND SYNTHESIS OF ENVIRONMENTAL EFFECTS RESEARCH

RISK TO MARINE LIFE FROM MARINE DEBRIS & FLOATING OFFSHORE WIND CABLE SYSTEMS

MAIN TAKEAWAYS

- Primary entanglement risk: Current literature suggests that the risk of marine life becoming directly entangled with a floating offshore wind cable system (primary entanglement) is low; the mooring lines and cables have a large diameter and are sufficiently heavy which prevents them from looping and entangling marine life.
- Secondary entanglement risk: Marine debris, such as derelict fishing gear, may become snagged in floating offshore wind cable systems, which could potentially lead to the entanglement of marine life (secondary entanglement). There is insufficient information to evaluate secondary entanglement at this time.
- A broad range of marine life may be at risk of physically interacting with marine debris caught on floating OSW cable systems, including large migratory whale species (such as humpback and fin whales), fish species (such as whale sharks, basking sharks, and manta rays), sea turtles, seals, and diving seabirds, in part because of their feeding behaviors.
- Research is needed to develop more effective technologies for monitoring, detecting, and removing marine debris and derelict fishing gear snagged on floating offshore wind cable systems.
- Knowledge gaps related to marine life ecology are being addressed through ongoing research related to habitat preferences, migration patterns, and diving behaviors of marine life. This research will help inform future evaluations of entanglement risk.

Please visit **Tethys** to view the literature reviewed to inform the development of this Research Brief.

TOPIC DESCRIPTION

In the United States, floating offshore wind (OSW) development is being planned on the Atlantic and Pacific Coasts in water depths ranging from 60 to 1,300 meters. Floating cable systems associated with these developments, including mooring lines and inter-array cables (as shown in Figures 1 and 2), may present physical hazards to marine life.

Current literature suggests that the risk of primary entanglement is low because floating OSW cable systems have a large diameter and are sufficiently heavy, which prevents them from looping and entangling marine life. The relative spatial scales of floating OSW infrastructure and marine life further reduce the likelihood of marine life encountering such systems. Incidents of primary entanglement with the floating cable systems associated with oil and gas platforms (which are engineered in a similar manner to floating OSW cable systems) have not been publicly reported, suggesting the likelihood of marine life becoming directly entangled with floating OSW cable systems is low. However, these systems are not monitored extensively, a fact that limits the aptness of the comparison. Entanglement reports indicate that fishing gear is the primary cause of entanglement in large whale species, and a large number of other species of marine mammals, sea turtles, seabirds, fish, and invertebrates are also affected. Therefore, the potential for secondary

Primary Entanglement

The occurrence of marine life directly becoming entangled with a mooring line or inter-array cable.

Secondary Entanglement

The occurrence of marine life becoming entangled with marine debris, including derelict fishing gear, that is snagged on a mooring line or inter-array cable.

Floating Offshore Wind Mooring & Inter-Array Cable Configurations

The three most common and representative floating OSW platforms include the **single point anchor reservoir (SPAR), semi-submersible, and tension leg platform (TLP)**, which are moored using **catenary** or **tensioned lines** to maintain position and/or stability (Figure 1). Floating OSW platform designs and mooring configurations have been inspired by those constructed for the oil and gas industry.

- **Catenary mooring lines:** Catenary (curved) mooring lines are connected to the platform, hang freely in the water column, and are anchored to the seafloor; these lines may also include accessory buoys to reduce the weight of the mooring line on the platform. SPAR and semi-submersible platforms use catenary mooring lines for station keeping and rely on heavy ballasting at the bottom of the platform and buoyancy for stabilization.
- **Tensioned mooring lines:** Unlike catenary mooring lines, tensioned mooring lines do not hang freely in the water column. Instead, they are stretched until the lines are taut. TLPs rely on taut, pretensioned mooring lines for stabilization.

Inter-array electric cables (Figure 2) connect floating OSW platforms to one another and collect the power being generated. Inter-array cables are connected to the platform, hang freely in the water column, and may run along the seafloor between platforms; these cables may also include accessory buoys to reduce the weight of the cable on the platform and maintain location and configuration. In OSW developments in very deep water, developers expect that inter-array cables will be suspended below the sea surface rather than being buried.

entanglement of marine life with marine debris snagged on floating OSW cable systems is the leading cause of concern.

Knowledge of the potential consequences of secondary entanglement of marine life in floating OSW cable systems remains limited because of the infancy of the industry and lack of entanglement and marine debris monitoring for existing floating OSW developments. A broad range of marine life may be at risk of physically interacting with marine debris caught on floating OSW cable systems, including large migratory whale species (such as humpback and fin whales), fish species (such as whale sharks, basking sharks, and manta rays), sea turtles, seals, and diving seabirds, in part because of their feeding behaviors.

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Figure 1. *Designs of floating offshore wind platforms (left to right: single point anchor reservoir, semi-submersible, tension leg platform). Illustration by Joshua Bauer, National Renewable Energy Laboratory.*

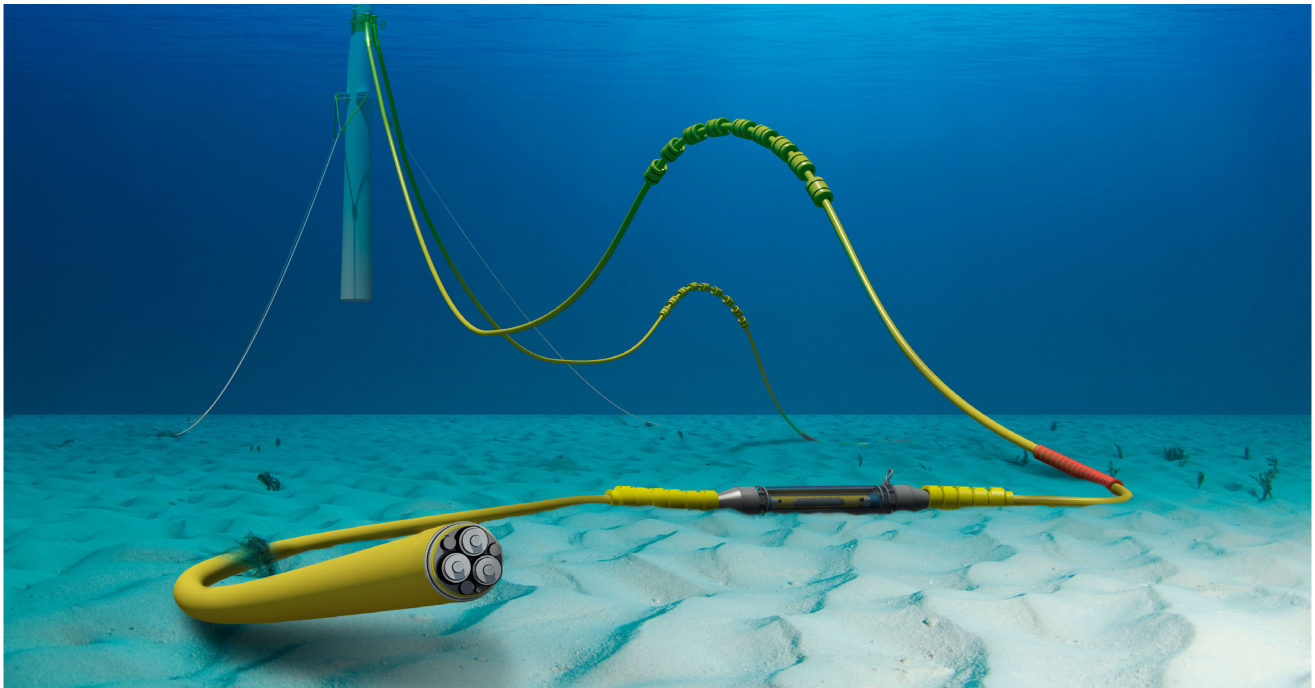

Figure 2. *Configuration of floating offshore wind inter-array cables. Illustration by Joshua Bauer, National Renewable Energy Laboratory.*

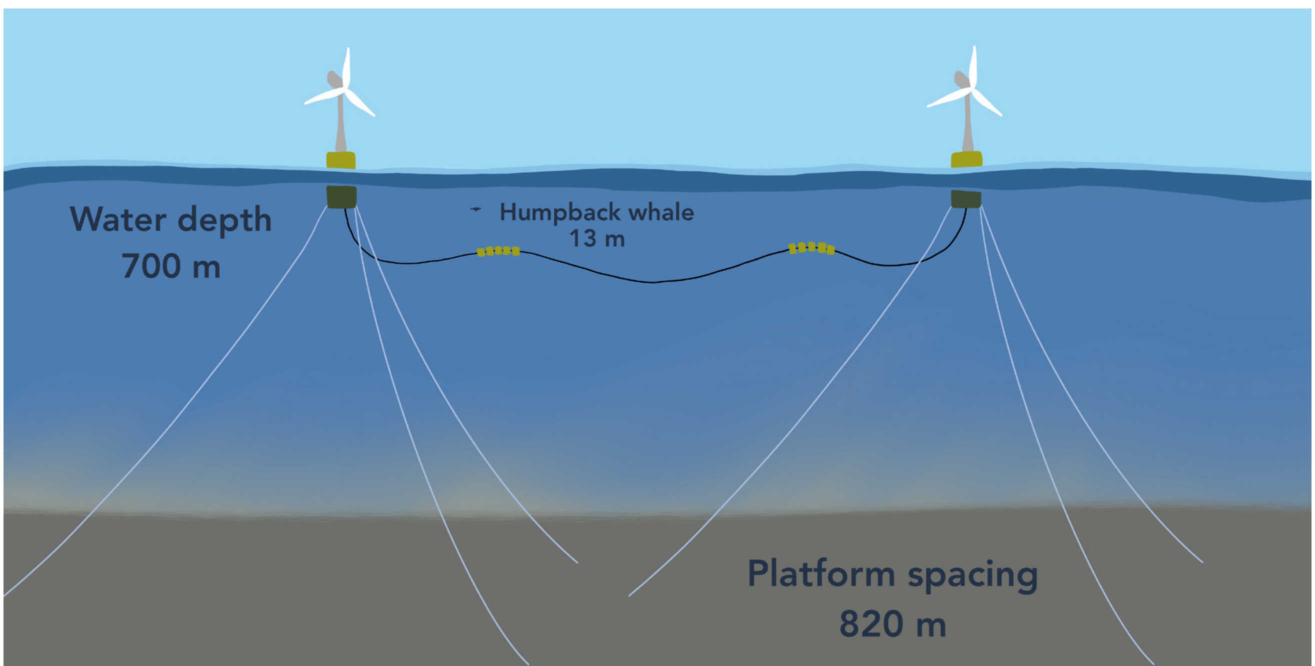

Figure 3. *Relative scale of an encounter of a humpback whale with floating offshore wind turbines. Illustration from Molly Grear, Pacific Northwest National Laboratory.*

Note: *The platform spacing shown in Figure 3 is an example of potential spacing. The number of turbines in a commercial-scale project will be on the order of 100, so the number of cables will be much higher than what is depicted here. Actual platform spacing will differ for each offshore wind farm and will be determined during siting processes.*

MAIN RISKS & EFFECTS

Although the likelihood of secondary entanglement remains unknown, the impacts of marine life entanglement with actively fished and derelict fishing gear may provide the greatest insight into the potential consequences associated with floating OSW cable systems. For example, the potential consequences of marine life becoming entangled in fishing gear include the following:

- **Asphyxiation or respiratory distress because of a lack of oxygen, known as underwater entrapment**
- **Tissue damage potentially resulting in scarring, muscle and/or nerve injury, infection, and in severe cases death**
- **Reduced foraging ability, potentially leading to emaciation**
- **Impacts on mobility, including the ability to dive, migrate, and reproduce**
- **Impacts on population growth as a result of mortality or reduced reproductive success for species that have low reproductive rates**

As multiple floating OSW arrays are constructed (each on the order of 100 turbines) and the number of floating cable systems in the water column increases, the potential cumulative effects of OSW development, combined with other ocean activities, will need to be examined. However, it is difficult to determine cumulative effects of OSW development due to the lack of projects currently deployed. The combined effects of multiple environmental stressors (the presence of floating OSW cable systems, vessel traffic, underwater noise, etc.) may result in biologically significant population-level responses in marine life and will need to be considered.

> Impacts of marine life entanglement with actively fished and derelict fishing gear may provide the greatest insight into the potential consequences of secondary entanglement.

General Entanglement Statistics

According to the National Oceanic and Atmospheric Administration (NOAA), at least 115 marine species in the United States, including marine mammals, sea turtles, seabirds, fish, and invertebrates, have been affected by entanglement in active and derelict fishing gear and other marine debris associated with non-OSW infrastructure. In 2018, NOAA reported 105 confirmed cases in the United States of large whale entanglement with fishing gear or marine debris, which was 25% higher than the 11-year average.

Entanglement with marine debris and derelict fishing gear is a primary cause of mortality in a number threatened and endangered large whale species; minimizing and preventing entanglements are critical to reducing the potential for population impacts.

MONITORING & MITIGATION METHODOLOGIES & TECHNOLOGIES

Monitoring approaches for floating OSW cable systems are similar to those employed for analogous structures. Floating OSW cable systems will require routine inspections during the operation and maintenance phase of their development, which will be typically conducted by remotely operated vehicles. However, these inspections are generally used to confirm the structural integrity of the cable systems rather than conduct environmental monitoring for entanglement and marine debris. Offshore wind stakeholders have identified the need for routine monitoring and mitigation measures to both understand and reduce the risk of entanglement. Recommended entanglement monitoring and mitigation techniques include the use of underwater cameras, monitoring mooring and line loads or motion, and the use of underwater vehicles to detect and remove marine debris.

For example, the Kincardine Floating Offshore Wind Farm in Scotland has integrated load cells with the mooring lines to periodically monitor line performance and potentially detect the entanglement of floating marine debris, including derelict fishing gear. The farm will use remotely operated vehicles and vessel-mounted sensors (such as multibeam sonar) to periodically survey floating cable systems, which could also monitor for the presence of derelict fishing gear.

Established methods for environmental monitoring can also be used to gather information about marine animal behavior, movement, and use of space in the vicinity of floating platforms, which in turn can be used to evaluate entanglement risk and develop mitigation methods. Potential monitoring approaches include using aerial and drone surveys, remote sensing technologies (e.g., infrared sensors and radar), passive acoustics, underwater cameras, and animal tagging.

KNOWLEDGE GAPS & RESEARCH NEEDS

Research is needed to develop more effective technologies for monitoring, detecting, and removing marine debris snagged on floating OSW cable systems. A quantification of commercial and recreational fishing activity in OSW and adjacent areas is also needed to inform estimates of the amount of fishing gear that could become entangled in floating OSW cable systems and the likelihood of secondary entanglement. NOAA, supported by the Bureau of Ocean Energy Management (BOEM), is developing a modeling tool to evaluate the risk of whale species and leatherback sea turtles in deep water becoming entangled in derelict fishing gear snagged on floating OSW cable systems. The tool will assess whale and sea turtle entanglement risk and the potential severity of entanglement, which will assist NOAA and BOEM in identifying mitigation measures that can be implemented to reduce the potential risks of such entanglement.

Additional research is also needed on the habitat preferences, migration patterns, and diving behaviors of marine life to support a comprehensive evaluation of entanglement risk, with a specific focus on large whales, large pelagic sharks and rays, and sea turtles. Local-scale information about species behavior, movement, and use of space around floating OSW platforms is critical to this effort and will help increase the accuracy of risk models, such as the modeling tool described above. Stakeholders acknowledge the high level of biodiversity present in U.S. waters and key migration routes for marine mammals, turtles, and birds. In California specifically, stakeholders have identified the need for additional data about California marine ecosystems and species migration routes to inform approaches to mitigate the risk of secondary entanglement. Federal agencies are conducting research to assess the abundance, occurrence, and distribution of threatened and endangered species and their ecosystems in areas of the Pacific.

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As the U.S. OSW industry grows and planning for floating OSW continues, the potential entanglement hazards to marine life from floating OSW cable systems will continue to be a high-priority issue for the protection of marine life. Several national and international research and assessment efforts are underway to establish a more comprehensive understanding of entanglement risk and develop effective approaches to monitoring and mitigating this risk for offshore renewable energy applications. Open dialogue among researchers, industry, regulators, and the international OSW community is needed to share lessons learned, identify knowledge gaps, and develop research agendas to address outstanding research needs.

For more information on the literature reviewed to develop this Research Brief, visit: Tethys

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