Workshop on Nature-Inclusive Design of Offshore Wind Structures
Held in Support of Project for BOEM on Corrosion Project Systems for Monopile Internals

Guide to the Video Recording with Links to Additional Information

The Video Recording of the workshop is available at
https://tufts.zoom.us/rec/share/QosNSxLy8RIWMG3lfCD0D_9U8Y6SldwglELKnl90a3Qkyv9f-oKfYuT6WQ_Xfo6Y.fdtRg0DO3TtdVKA1
The timeline and content of the recording is given below along with reference to additional information in papers and online materials

0:00 – 7:40: Agenda, BOEM Project Motivation and Objectives, Workshop Objectives, and Logistics

PART 1: PRESENTATIONS ON MOTIVATIONS AND EXAMPLES FOR NATURE-INCLUSIVE DESIGN

7:40 – 19:06: U.S. Synthesis of Offshore Wind Environmental Effects Research (SEER) Project (Rebecca Green from the National Renewable Energy Laboratory (NREL) and Mark Severy from the Pacific Northwest National Laboratory (PNNL))

This presentation summarized the objectives and main tasks of the DOE-funded SEER project. In the first task, a series of 7 educational research briefs were developed on environmental topics identified by a range of stakeholders. The topics included: (i) Underwater Noise Effects; (ii) Bat and Bird Interactions with Offshore Wind Energy; (iii) Risk to Marine Life from Marine Debris & Floating Cable Systems; (iv) Benthic Disturbance from Foundations, Anchors, & Cables; (v) Introduction of New Structures: Effects on Fish Ecology on Marine Life; (vi) Presence of Vessels: Effects of Vessel Collision on Marine Life; and (vii) Electromagnetic Field (EMF) Effects on Marine Life. Four webinars were also conducted. This SEER work is presented at https://tethys.pnnl.gov/us-offshore-wind-synthesis-environmental-effects-research-seer.

A webinar series was also presented to disseminate information on each topical area and included input from panels of experts. Most pertinent to this ongoing project for BOEM is the SEER work on topics (iv) and (v) that was presented in the second webinar. The following link provides access to a recording of the second webinar, and to the associated slides: https://tethys.pnnl.gov/events/seer-webinar-2-effects-offshore-wind-farm-structures-fish-ecology-benthic-disturbance.

The following link provides access to the research brief on topic (vi) Benthic Disturbance and to a table with the references that were used to inform the development of this brief:
https://tethys.pnnl.gov/summaries/benthic-disturbance-offshore-wind-foundations-anchors-cables.

The link below provides access to the research brief on topic (v) Effects on Fish Ecology and to a table with the references that were used to inform the development of this brief:
https://tethys.pnnl.gov/summaries/introduction-new-offshore-wind-farm-structures-effects-fish-ecology.

The list of references is being updated as the project team becomes aware of new sources of information. If you are familiar with work that you believe would be useful to the SEER project, then it would be greatly appreciated if you would provide this information to the SEER project leads Rebecca.Green@nrel.gov and mark.severy@pnnl.gov.

The current SEER task is identifying research needs and recommendations associated with understanding the environmental effects of offshore wind development on the U.S. Atlantic and Pacific coasts. These recommendations will be informative to the various entities that identify, and address research priorities associated with offshore wind development.

19:06 – 23:11: Environmental Observations on Offshore Wind Structures including RODEO Project
(Presented by Drew Carey INSPIRE Environmental)

In this presentation, Drew Carey from INSPIRE Environmental summarized a series of different projects focused on the environmental impact of offshore wind turbines. This presentation was designed to provide an overview of work done in the US and in Europe. A series of references and links to relevant papers are provided at the end of this abstract. The RODEO project, described in the presentation, monitored the environmental effects of the development and operation of the Block Island Wind Farm. The elements considered included Pile Driving Sound, Operational Sound, Particle Motion, Cable Laying, Scour Protection Monitoring, Seafloor Disturbance and Recovery, Benthic Habitat Changes, Epifaunal growth on the Turbines, and Fish around the Turbines. Environmental monitoring is also being conducted on the Virginia offshore wind farm. There are two foundations in Virginia, and one will be augmented with nature-based design components while the other is left without augmentation.

For Block Island it is important to remember that the farm is made up of 5 lattice jacket structures and is not representative of the focus of the workshop, monopiles. However, we know that when we place a structure in the ocean, the local flow of energy changes. This is a result of epifaunal growth directly on the structures, which leads to changes to the local seafloor and trophic dynamics. Key areas for future study include how the biomass and energy on and around a structure are transferred to the larger ecosystem and larger food web, how marine structures may serve as both new refuge and new supply of food to higher trophic levels, and how this might influence use of the structures as new, potentially valuable, habitat, and whether this habitat can be augmented or enhanced with the use of nature based design concepts.

Links & References:

Guarinello and Carey 2020. Multi-modal Approach for Benthic Impact Assessments in Moraine Habitats: a Case Study at the Block Island Wind Farm
https://link.springer.com/article/10.1007/s12237-020-00818-w
Carey et al. 2020 Effects of the Block Island Wind Farm on Coastal Resources: Lessons Learned
https://doi.org/10.5670/oceanog.2020.407
Wilber et al. 2022a Offshore wind farm effects on flounder and gadid dietary habits and condition on the northeastern US coast
https://doi.org/10.3354/meps13957
Wilber et al. 2022b Demersal fish and invertebrate catches relative to construction and operation of North America's first offshore wind farm
https://doi.org/10.1093/icesjms/fsac051
HDR. 2020. Benthic and Epifaunal Monitoring During Wind Turbine Installation and Operation–OCS Study BOEM 2020-044.
https://espis.boem.gov/final%20reports/BOEM_2020-044.pdf
Degraer et al., 2020, Oceanography Special Issue Vol. 33, 4
https://tos.org/oceanography/issue/volume-33-issue-4
Turbine Reef Report – Nature-Based Designs Offshore Wind Structures – The Nature Conservancy and INSPIRE Environmental 2022

https://www.inspireenvironmental.com/wp-content/uploads/2022/01/Turbine-Reef-Report-Nature-Based-Designs-Offshore-Wind-Structures-FINAL-2022.pdf

Popper, A. N., Hice-Dunton, L., Jenkins, E., Higgs, D. M., Krebs, J., Mooney, A., Rice, A., Roberts, L., Thomsen, F., Vigness-Raposa, K., Zeddies, D., and Williams, K. A., 2022, "Offshore Wind Energy Development: Research Priorities for Sound and Vibration Effects on Fishes and Aquatic Invertebrates," J. Acoust. Soc. Am., **151**(1), pp. 205–215.
https://asa.scitation.org/doi/10.1121/10.0009237

"Realtime Opportunity for Development Environmental Observations (RODEO) Project" https://www.boem.gov/rodeo

23:11 – 39:11: Developer/Academic Initiatives in Nature-Inclusive Design (Presented by Anthony Dvarskas Orsted and Marcel Rozemeijer Wageningen University)

This joint presentation contains two parts. First Anthony provided an overview of different activities related to Orsted's initiative to have a net positive biodiversity impact from all their renewable energy projects commissioned from 2030. Next Marcel provided a detailed look at an ongoing study focused on activities at the Borssele II wind farm in the Netherlands. These activities included acoustic monitoring, cod tagging, lobster tagging, and eDNA sampling.

In Anthony's overview several different activities were discussed. For example, the ReCoral proof of concept trial at an offshore wind farm in Taiwan takes surplus indigenous coral spawn from the Penghu islands, incubates the spawn in a laboratory setting, and transfers the larvae to the Greater Changhua turbine foundations. Another project for Anholt wind farm relocated 5,000 boulders to create artificial reefs after they needed to be moved for project activities. Biohuts have also been installed at Grenå harbour in Denmark. These biohuts are being monitored to see if they achieve their goal of restoring cod populations and enhancing the broader ecosystem. Finally, the last project described is a series of 4 cod pipe reefs installed alongside the Borssele II wind farm in 2020. These reefs are being monitored as a part of Marcel's presentation.

Marcel's presentation described the monitoring activities for the cod reefs at the Borssele II wind farm. To monitor the 4 reefs, the project has 16 antennas to read signals from acoustic tags placed on cod and lobsters. The monitoring has tagged around 45 different cod with the goal of determining the distribution of cod in time and space. For example, one key question is what are the differences in cod behavior between different reefs and the monopiles in the middle of the reef. A similar study is being done with tagged lobsters to learn more about their behavior and habitat use. The monitoring program also includes collecting e-DNA to monitor associated biodiversity to the reefs. The presentation also includes some early monitoring results.

Borssele II Monitoring

Research on cod and lobster behaviour around artificial reefs in wind farm Borssele 1 & 2 - WUR

ReCoral Links:

- Press release: https://orsted.com/en/media/newsroom/news/2022/05/13650474
- Landing page: https://orsted.com/en/sustainability/our-priorities/nature/recoral
- YouTube video: https://youtu.be/qvLWG4ZvxQE

39:11 – 48:02: Artificial Reefs, Offshore Wind Farms as Sanctuaries, and Defining Success (Jamie Lescinski from Boskalis)

This presentation shared examples of projects and technologies that can support the creation or restoration of marine habitats as part of offshore wind farms as well as separate to this. An emphasis was placed on the composition of the project team needed to ensure successful projects, and this included developers, permitting authorities, governmental bodies, marine contractors, research entities, marine specialists, suppliers, fisheries, NGOs, and other community organizations.

One of the presented activities was the Boskalis Artificial Reef Program that used modest-sized steel and concrete structures (2-8 feet in the largest dimension) that were designed to have geometries that were expected to be suitable to support the development of the desired habitats. Boskalis has explored and installed both stand alone structures as well as those that have a modular design. See the following link for more information about their artificial reef program https://boskalis.com/artificialreefs/
An example of a reef with large 3D printed concrete reef elements that was created off the coast in Monaco is presented at https://www.youtube.com/watch?app=desktop&v=K_O5EGvqEQA
https://riviera-press.fr/insider/content/3d-printed-reefs-monaco-reforms-its-underwater-landscape

48:02 – 49:23: Comments on Part 1 and Introduction to Part 2

PART 2: DISCUSSIONS ON FOUR TOPICS CENTRAL TO ONGOING PROJECT FOR BOEM

49:23 – 59:00: Impact of Perforations and Cathodic Protection on Marine Growth (Monica Maher from the Wind Energy Technologies Office at the U.S. Department of Energy)

This research was conducted by Monica Maher and Geoff Swain in 2018 at the Center for Corrosion and Biofouling Control (CCBC), Florida Institute of Technology https://research.fit.edu/ccbc/. The research investigated incorporating perforations in monopile walls that allow the free flow of ambient seawater into the interior, improve the predictability of cathodic protection, and enable the interior structure to provide a habitat for marine life. Partially submerged steel pipes with different treatments were deployed. The results demonstrated that a cathodically protected perforated monopile structure creates an environment with more favorable corrosion mitigation and water chemistry compared to a sealed structure. Furthermore, the perforated cathodically protected pipe recruited a diverse population of settled and mobile organisms. The results are reported in an award-winning paper in the Journal of Materials Performance. Similar to an artificial reef, perforated monopiles could enhance regional ecosystems and potentially add economic benefit for the seafood and sport fishing industries. Such economic benefits can help win citizen support for offshore windfarms.
https://www.researchgate.net/publication/334974010_Corrosion_Control_and_Ecosystems_Enhancement_for_Offshore_Monopiles

59:00 – 01:16:06: Biofouling Profiles (Andrew Want from Heriot-Watt University)

In this presentation, Dr. Andrew Want provided an overview of the factors affecting offshore biofouling profiles including communities recorded in the North Sea and on the east coast of U.S. He discussed the influence of temperature, water depth, distance from shore, substrate, hydrologic processes, hydrodynamic properties, and water chemistry on macrofouling. Since fouling periods are seasonal, this can be taken into consideration for planning the deployment and maintenance of offshore wind structures. While much is understood about macrofouling, and expected levels and type of marine growth, the significant dependence on many factors means that each region of interest often requires specific evaluation.

Dr. Andrew Want is a marine ecologist specialized in biofouling and hard substrate epifaunal and epifloral assemblages. He is a Research Associate at Heriot-Watt University, located in Stromness, Orkney. He also works in a close partnership with the European Marine Energy Centre (EMEC). Dr. Want has worked with the Oil & Gas and Offshore Wind communities, and with EMEC in many cases, on developing a better understanding between environmental factors and their effects on marine population responses of epibenthic organisms associated with offshore energy infrastructure.

Dr. Want has participated in several GloFouling Partnership webinar series and delivered presentations on interactions between biofouling and offshore renewable energy structures. He is currently leading the IMO-UNESCO GESAMP 44 Working Group on Offshore Renewable Energy and is a member of the Marine Alliance for Science and Technology for Scotland Forum on Marine Renewable Energy.

Monitoring biofouling in the offshore renewable energy industry - https://www.glofouling.imo.org/webinar-past/3

Biofouling on offshore renewable energy structures - https://www.glofouling.imo.org/webinar-past/22

He is also the lead author on a research paper published in 2021 that discusses the development of a novel settlement panel deployment system to monitor marine growth at different depths of offshore renewable energy sites. The paper is called Sea-trial verification of a novel system for monitoring biofouling and testing anti-fouling coatings in highly energetic environments targeted by the marine renewable energy industry and was published in Biofouling (https://www.tandfonline.com/doi/full/10.1080/08927014.2021.1928091). Other recent peer-reviewed scientific papers include: Biodiversity characterisation and hydrodynamic consequences of marine fouling communities on marine renewable energy infrastructure in the Orkney Islands Archipelago, Scotland, UK (https://www.tandfonline.com/doi/pdf/10.1080/08927014.2017.1336229); and, A new range-extending record of the invasive sea squirt *Styela clava* in the north of Scotland (https://mbr.biomedcentral.com/articles/10.1186/s41200-021-00211-x).

01:16:06 – 01:34:58: Internal Chemistry in Monopiles (Niek Bruinsma and Stefan Jansen from Deltares)

Niek Bruinsma, a medior advisor, researcher and project manager at Deltares, reported on their conduct of physical experiments to understand the fluid flow through perforations in monopiles, and their development of computational modeling tools to simulate the pressures and wave action inside the monopile, the effect of marine growth, flow velocities through replenishment holes and pH levels in the monopile. This information can be referenced to optimize the positioning and the dimension of replenishment holes (https://www.deltares.nl/en/software/module/d-water-quality/). Stefan Jansen, a biochemist, reported on their work to understand the internal chemistry of monopiles as impacted by the type of cathodic protection system that was used (Zinc, Aluminum, ICCP) and of perforations. He discussed how changes in internal chemistry may determine the microbiological community established inside offshore wind monopiles. They also reported on their finding on the seasonal variation in chemical profiles in the monopiles.

Deltares is an institute in the field of water and subsurface conditions that works extensively with the offshore wind industry; it is located in Delft, The Netherlands. https://www.deltares.nl/en/

01:34:58 – 01:46:21: Interactions between Marine Growth and Internal Water Chemistry (Geoff Swain and Caglar Erdogan, Center for Corrosion and Biofouling Control, Florida Institute of Technology) https://research.fit.edu/ccbc/.

The importance of understanding how marine growths and associated fauna on the internal surfaces of offshore monopiles are perceived was discussed. If they are classified as biofouling, then the marine life needs to be controlled. However, if they are classified as ecology or mariculture then the internal space needs to be managed to create an environment where life can flourish. The factors that influence the conditions that develop in the internal space were summarized and numbers were provided that show how the volume to surface area ratio increases with monopile diameter. The internal surface is where the reactions occur (corrosion, cathodic protection and biology) and the internal seawater volume supplies the reactants and receives the products. An example of how the total available dissolved oxygen increases exponentially with increasing monopile diameter was used to demonstrate how managing oxygen concentrations maybe applied to either control biofouling or support ecology and mariculture. An improved understanding of these processes is required to develop models that can be applied to the design and management of the internal space of monopiles. This will start to be addressed this summer by the upcoming field deployments of steel pipes that will be placed at the Woods Hole Oceanographic Institution and the Florida Institute of Technology to further investigate the processes of corrosion, cathodic protection, coatings, and biology.