



U.S. OFFSHORE WIND  
SYNTHESIS OF ENVIRONMENTAL  
EFFECTS RESEARCH

# Introduction of New Offshore Wind Farm Structures: Effects on Fish Ecology

## Benthic Disturbance from Offshore Wind Foundations, Anchors, and Cables

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*December 15, 2021*

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National Renewable Energy Laboratory

**Mark Severy, P.E.**  
Pacific Northwest National Laboratory

# Today's Agenda

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## Introduction

### Introduction of New Offshore Wind Farm Structures: Effects on Fish Ecology

Topic Overview

Panel Discussion

Q&A

### Benthic Disturbance from Offshore Wind Foundations, Anchors, and Cables

Topic Overview

Panel Discussion

Q&A

## Closing Remarks



# Introduction to SEER

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**At the direction of the U.S. Department of Energy's Office of Energy Efficiency & Renewable Energy Wind Energy Technologies Office, Pacific Northwest National Laboratory and National Renewable Energy Laboratory are jointly leading a multi-year collaborative effort to facilitate knowledge transfer for offshore wind (OSW) research.**

## Project Objectives

- Summarize the international understanding of environmental effects, monitoring tools, and mitigation strategies for OSW and how it applies to the U.S. Atlantic and Pacific Coasts.
- Examine which of the state-of-the-art methods and technologies are relevant to environmental issues specific to U.S. offshore wind development.
- Identify knowledge and research gaps based on the diversity of species, habitat uses, and stressors; U.S. environmental legal/regulatory structure; and technological innovations.
- Collaboratively develop outcomes together with existing science entities and regional working groups to fully leverage community expertise.

# Introduction to SEER

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## Research Briefs

Review state of the knowledge on stressor/receptor interactions, monitoring methods and technologies, mitigation measures, and cumulative impacts.



## Webinar Series

Disseminate findings presented in Research Briefs to the offshore wind industry and others who are interested.



## Research Recommendations

Summarize information gaps, barriers, and current challenges for U.S. Atlantic and Pacific Coasts to inform or guide future development efforts.

*For more information, visit: <https://tethys.pnnl.gov/seer>*

# Introduction to SEER



**Underwater Noise Effects  
on Marine Life**



**Bat and Bird Interactions with  
Offshore Wind Energy**



**Risk to Marine Life from Marine  
Debris & Floating Cable Systems**



**Benthic Disturbance from  
Foundations, Anchors, & Cables**



**Introduction of New Structures:  
Effects on Fish Ecology**



**Vessel Collision: Effects on  
Marine Life**



**Electromagnetic Field (EMF)  
Effects on Marine Life**



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## Introduction of New Offshore Wind Farm Structures: Effects on Fish Ecology

*Moderator:*

**Rebecca Green, Ph.D.**  
National Renewable Energy Laboratory

*Panelists:*

**Drew Carey, Ph.D.**  
INSPIRE Environmental

**Steven Degraer, Ph.D.**  
Royal Belgian Institute of Natural Sciences



# Introduction of New Structures

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**The introduction of new structures in the marine environment can:**

- Introduce different communities of organisms and alter the food web
- Alter habitat by providing novel hard surfaces that are rapidly colonized
- Attract fish and establish new predator and prey relationships
- Host a range of organisms: Epifaunal organisms; Demersal, benthopelagic, and pelagic fishes

**These shifts have been considered both an enhancement of the local environment by supporting biodiversity and a detriment by altering the local ecological system.**



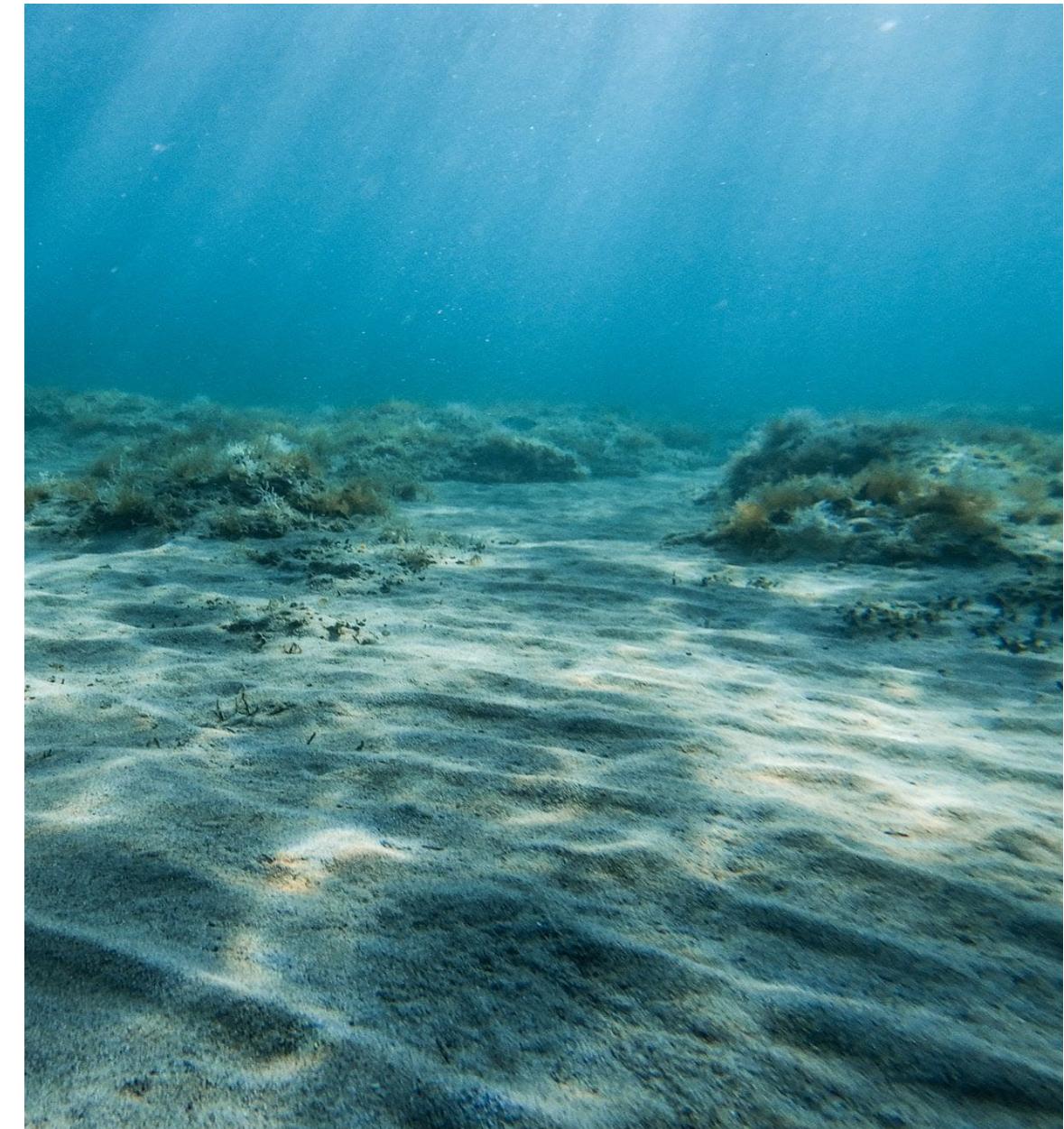
# New Structures: Risks & Effects

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**The placement of new structures during OSW farm construction can temporarily or permanently alter habitat directly beneath and in the vicinity of fixed-bottom foundations.**

**The footprint size and habitat effects of turbines depend on the foundation type, materials, and sediment type where constructed.**

**Sediment footprints range in size from smaller footprints associated with jacket foundations to larger footprints associated with monopiles and gravity-based foundations (due to scour protection).**



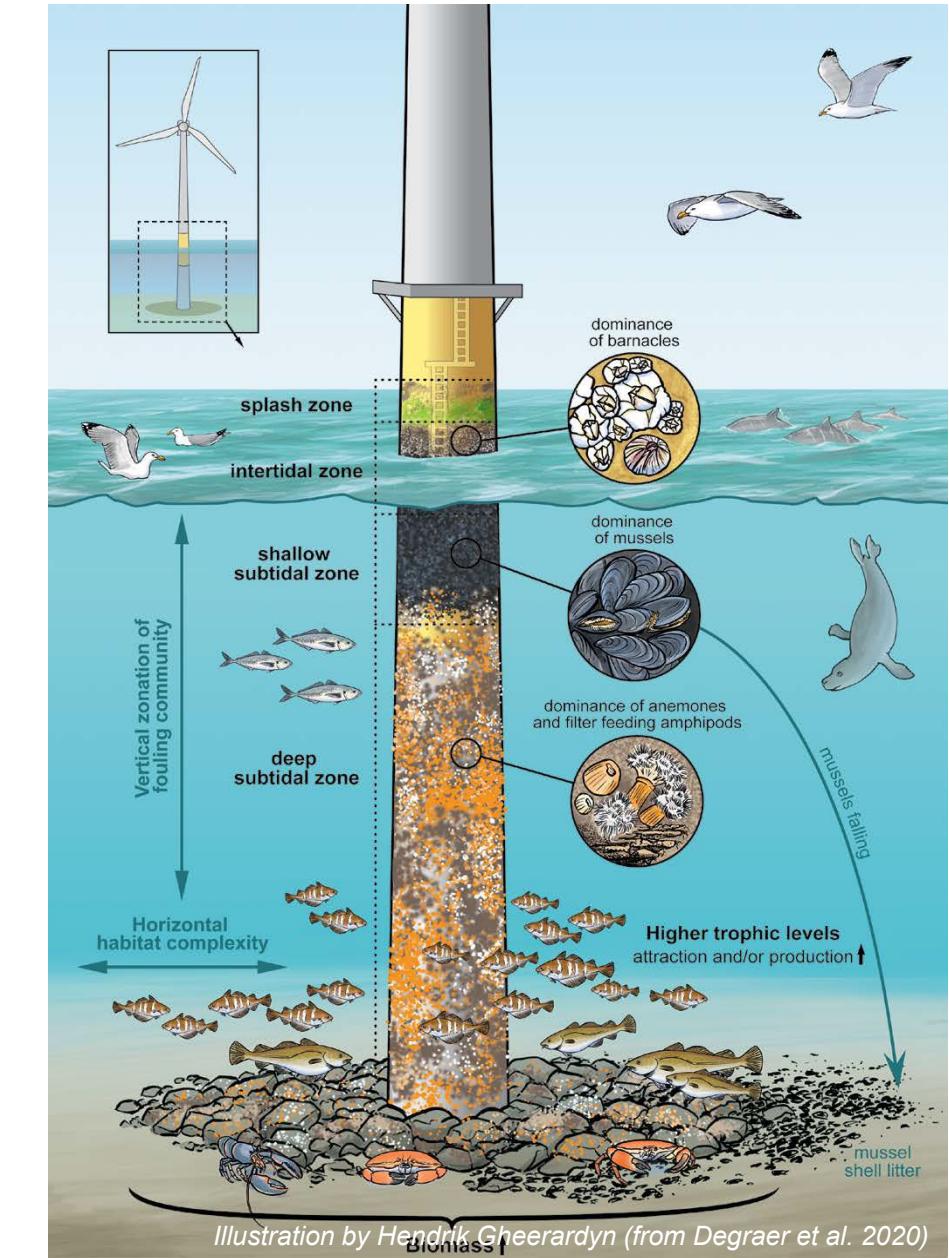
# New Structures: Risks & Effects

## Artificial Reef Effect

- Refers to structures' ability to mimic natural reefs and the associated attraction of fish and invertebrates
- Increased abundance of certain fish and shellfish species observed near OSW turbines and their scour protection
- However, not all fish species are attracted and some cases had no observed effects on fish abundance

## Other Potential Effects

- Spreading invasive species via “stepping stones”
- Altering species' migration patterns
- Altering hydrodynamic processes and larval transport
- Seabed disruption potential to release contaminants



# New Structures: Risks & Effects

**OSW farms may protect fished species and habitats by:**

- Limiting fishing
- Establishing new reef habitat
- Functioning as fish aggregators

**Floating OSW farms are relatively nascent and less is known about potential effects on fish ecology.**

**Floating farm considerations:**

- Direct effects on fish may be lower due to limited vertical profile of foundations
- Smaller sediment footprint is likely, associated with moorings and anchors



Illustration by Joshua Bauer, National Renewable Energy Laboratory.

# New Structures: Monitoring & Mitigation Methods

## OSW Fisheries monitoring guidelines

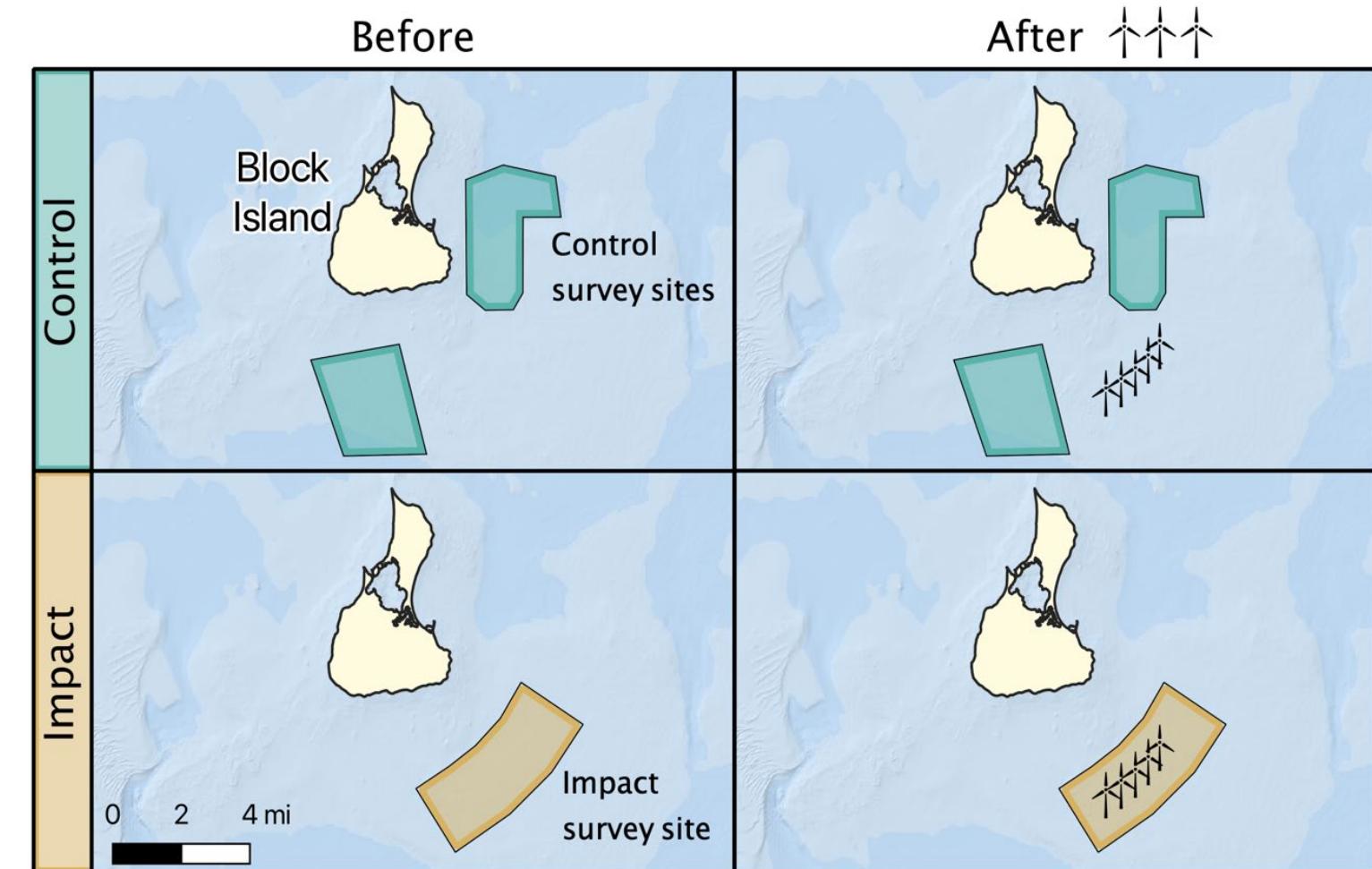
- Clear research objectives and hypotheses to guide methods
- Approaches for investigating changes between pre- and post-construction phases of OSW

### Before-After/Control-Impact (BACI)

- Compares an impact location with an unaffected control before and after the intervention

### Before-After-Gradient (BAG)

- Samples along a gradient with increasing distance from the turbines before and after the intervention

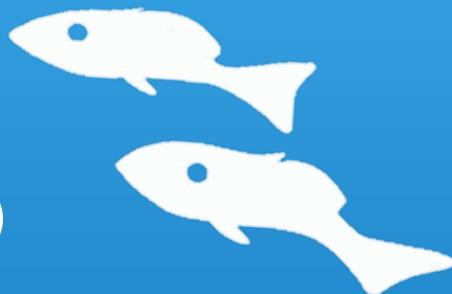


Example: Implementation of the BACI approach at the Block Island Wind Farm (Based on Carey et al., 2020)

# New Structures: Monitoring & Mitigation Methods

## Monitoring Methods

- Build on existing sampling programs
- Trawl surveys
- Scuba diving surveys
- Hydroacoustic surveys
- Fish tagging (telemetry)
- Gill nets, traps or pots
- Associated statistical analyses
  - E.g., BACI or BAG



## Best Management Practices

- Siting away from sensitive habitats and fish migration routes
- Minimizing seafloor disturbance during construction and installation
- Foundation designs for target fish populations and habitat needs
- Proper burial of mooring anchors and cables

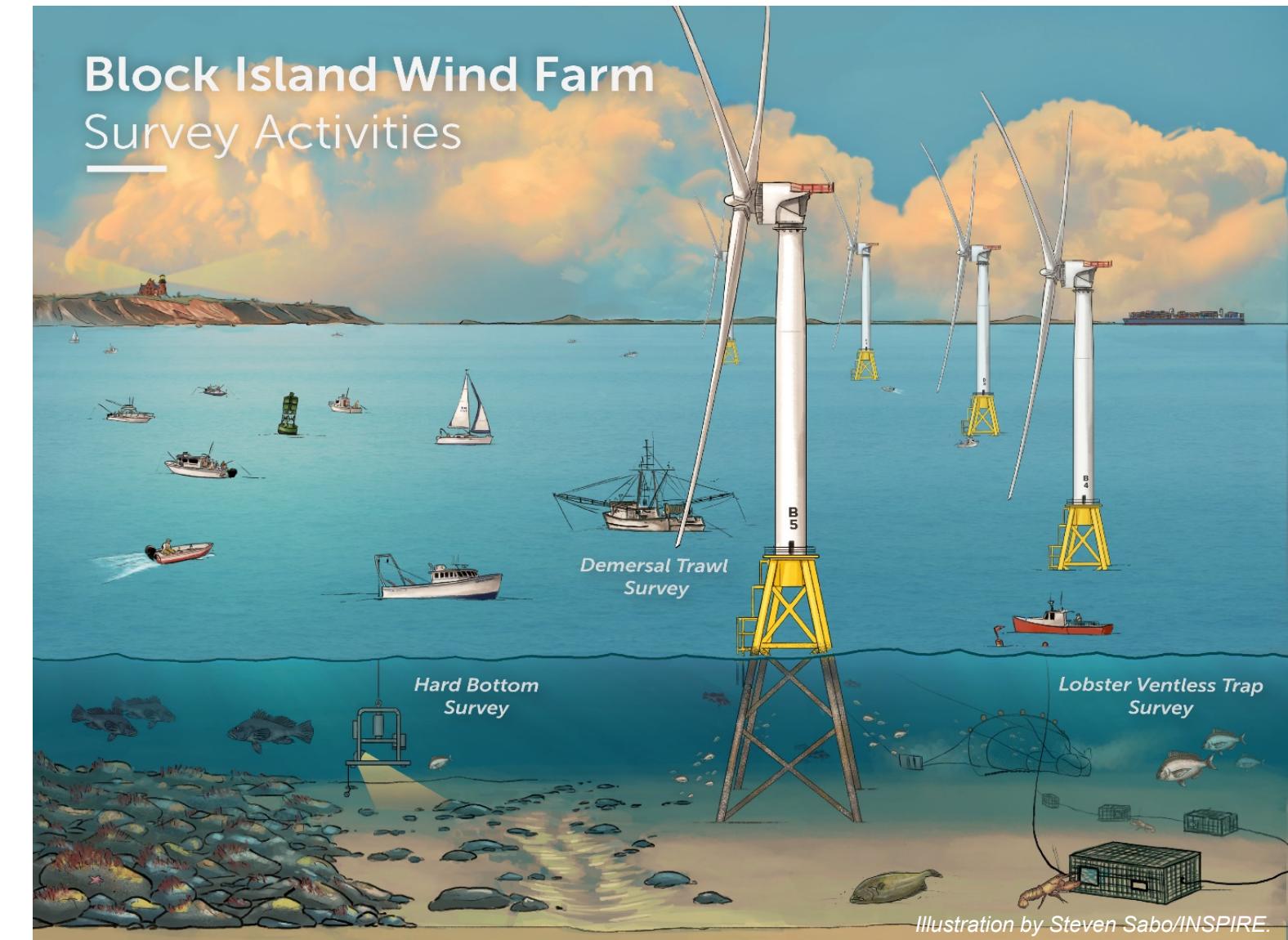


# New Structures: Monitoring & Mitigation Methods

**Multiyear studies conducted at the Block Island Wind Farm were used to separate the farm's effects from regional changes in environmental conditions.**

## **Study elements included:**

- Early stakeholder engagement
- Cooperative research with commercial fishermen
- Use of methods consistent with regional surveys
- Sampling within a BACI design
- Adaptive monitoring



# New Structures: Knowledge Gaps & Research Needs

## Example research questions relevant to the U.S. OSW development:

- Do fish density and species composition change significantly around OSW turbine structures in different regions, and what are the differences based on foundation type?
- What processes are responsible for any observed changes in fish communities at turbine structures (e.g., food availability, shelter, predation)?
- How do we disentangle changes in fish communities due to OSW farms from those due to other environmental factors, such as a warmer and more acidified marine environment?
- In terms of consequences for ecosystem functioning, are fish communities on the turbine structures isolated from or connected to each other at the larger scale across turbines and multiple wind farms?
- Does the artificial reef effect export measurable amounts of energy and biomass to the wider ecosystem or only serve locally as aggregating devices?



Credit: Dominion Energy

# New Structures: Knowledge Gaps & Research Needs

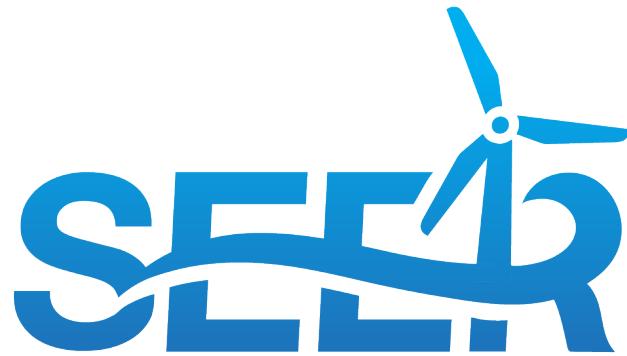
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**Collaborative approaches with regional scientists and the fishing industry will be important to ensure sampling methodology can be assessed in a regional context.**

**Long-term stock assessment surveys provide baseline datasets and will need to continue with reshaped designs to best inform assessment of OSW farm effects on fish distributions.**

**Linking monitoring at the local and regional scales will collate the knowledge needed to understand OSW farm effects and inform effective mitigation.**





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## Panel Discussion

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**For more information on the literature reviewed to develop the Research Brief, visit:**  
<https://tethys.pnnl.gov/summaries/introduction-new-offshore-wind-farm-structures-effects-fish-ecology>





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## Benthic Disturbance from Offshore Wind Foundations, Anchors, and Cables

*Moderator:*

**Mark Severy, P.E.**  
Pacific Northwest National Laboratory

*Panelists:*

**Monique LaFrance Bartley, Ph.D.**  
National Park Service

**Jan Vanaverbeke, Ph.D.**  
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# Benthic Habitats

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**Benthic habitat is the combination of physical, chemical, and biological conditions that create a home for organisms living on or in the seafloor.**

**Flora and fauna found within a benthic habitat include a diverse set of organisms that differ in size, mobility, and other characteristics.**

**Changes to benthic habitats and communities can be caused directly and/or indirectly by OSW farms during construction, operation, and/or decommissioning.**



*Image from Degraer et al. 2020)*

# Benthic Disturbance: Risks & Effects

## Habitat Loss

- Installation of OSW infrastructure removes some habitat by covering space on the seafloor
- Habitat loss is caused by the presence of turbine foundations, scour protection, and other equipment installed on the seafloor.
- The extent of habitat loss is typically small, covering a small percentage of the total wind farm area.
- Mobile organisms may move to new locations, but sessile organisms may be crushed or smothered depending on activities.

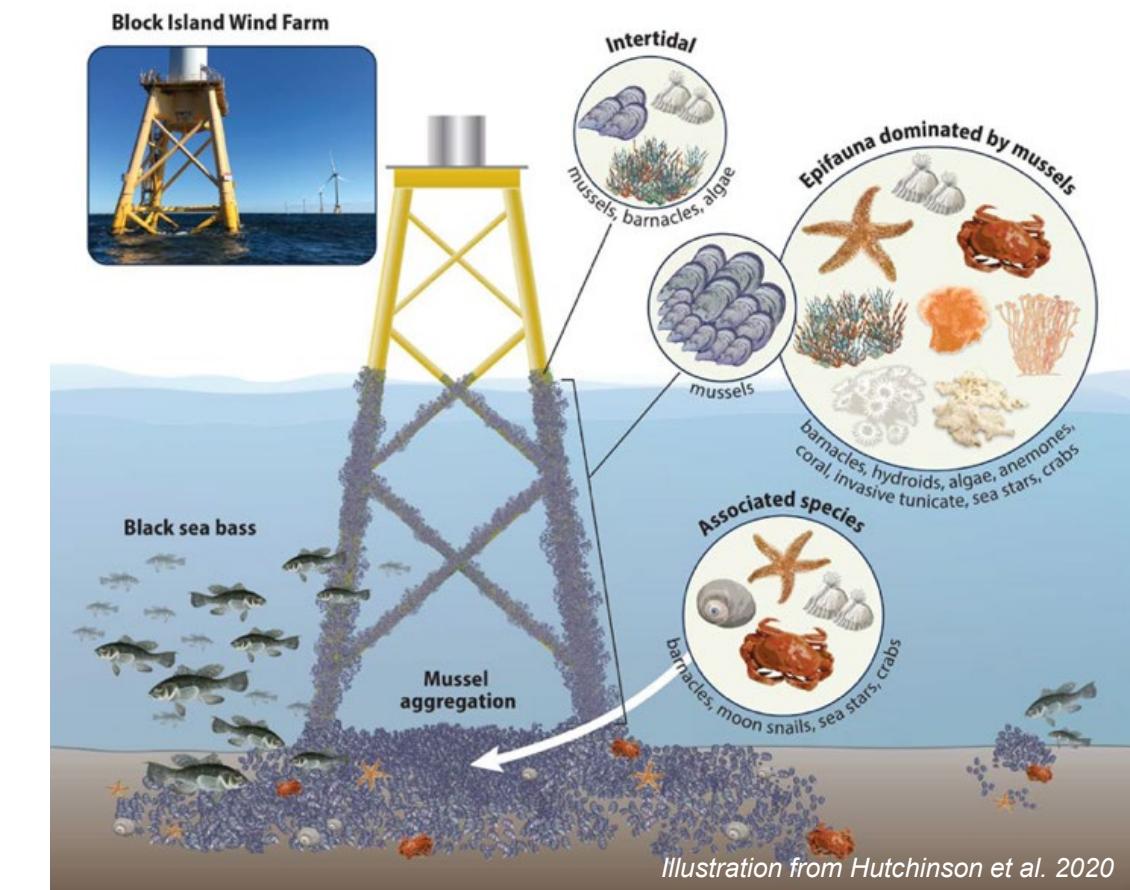


Illustration by Joshua Bauer, National Renewable Energy Laboratory.

# Benthic Disturbance: Risks & Effects

## Introduction of New Hard Substrate

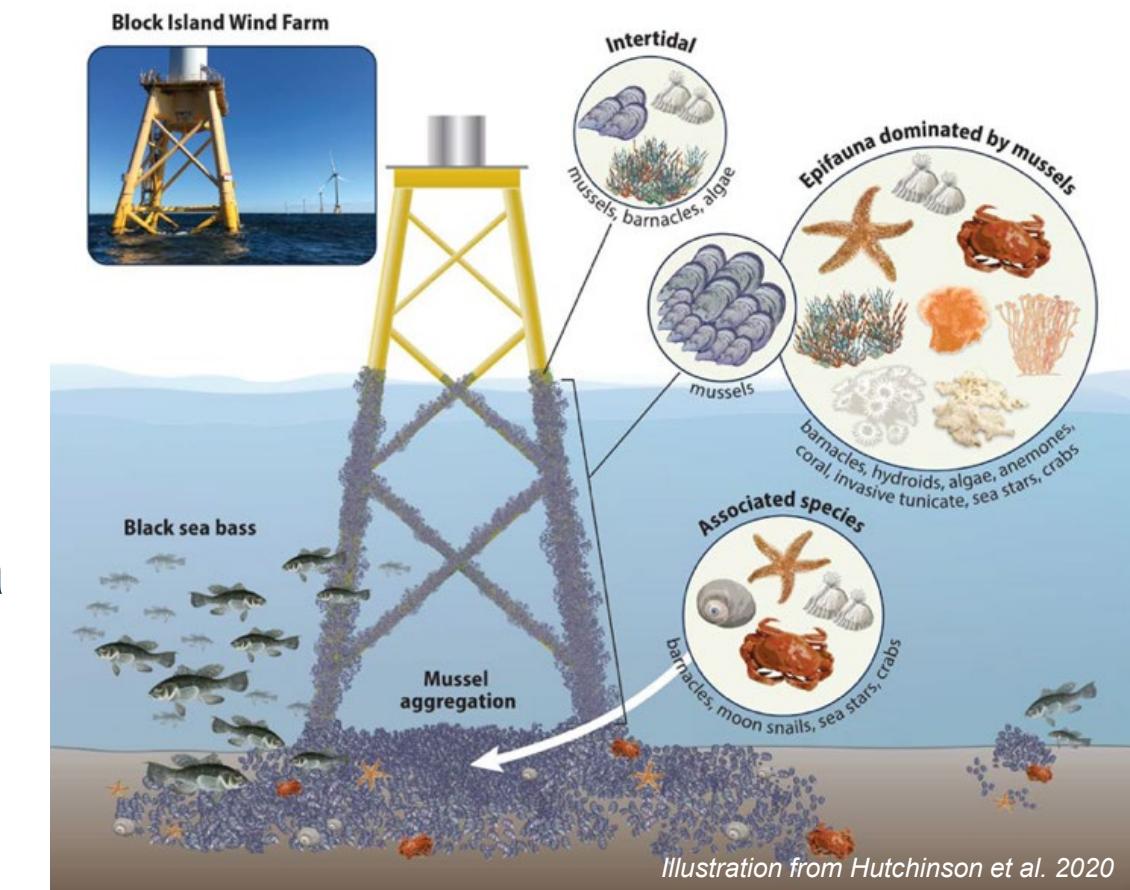
- Changes to benthic habitat are site-specific and depend on the foundation type and local sediment
- Foundations, anchors, and scour protection create new hard substrate habitat that is rapidly colonized
- Vertical foundation structures support colonizing communities whose presence can impart changes to the surrounding seabed and benthic community
- Over time, these changes can result in conversion of habitat and how organisms use the area of the seafloor.



# Benthic Disturbance: Risks & Effects

## Introduction of Non-native Species

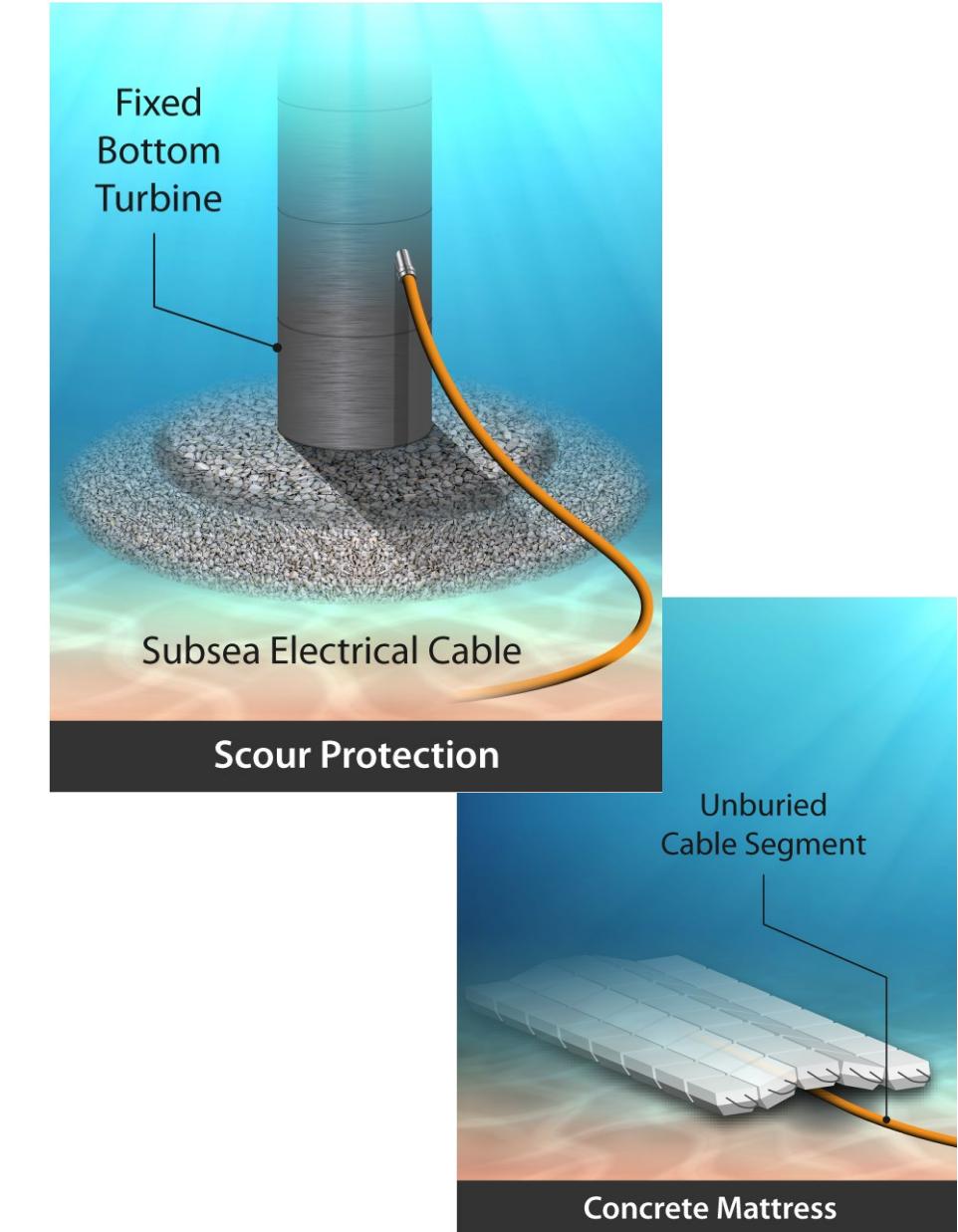
- Artificial structures provide opportunities for non-native species to colonize or spread
- Monitoring has identified some instances of non-native species at offshore wind farms. In these cases the species were already present in the area prior to the wind project
- Existing evidence has not shown that non-native species are not able to outcompete native species at offshore wind farms
- Continued monitoring can help identify if these species further expand their range



# Benthic Disturbance: Risks & Effects

## Seabed Disturbance

- Foundation Installation
  - Extent of sediment disturbance depends on type of foundation (piled, gravity, or floating)
- Scour Protection
  - May be installed around turbines to limit erosion
  - Causes localized disturbance and habitat conversion
- Cable Installation
  - Effects depend on method (trenching or physical protection), sediment type, and site-specific factors
  - Footprint of disturbance depends on method, length, and number of cables, but is small relative to a farm



# Benthic Disturbance: Risks & Effects

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## Seabed Recovery

- Physical disturbances during installation are typically followed by recovery of the benthic habitat as sediment moves back into disturbed areas
- After initial recovery, conditions may continue to change as the benthic community adapts to newly installed OSW infrastructure



## Water Quality, Sediment, and Turbidity

- Installation of OSW components can suspend sediment into the surrounding water, which could affect marine life, including by:
  - smothering or burying benthic sessile organisms
  - clogging filtration systems for filtering animals
  - decreasing visibility for animals that hunt prey by sight (e.g., flatfish)
- However, several monitoring campaigns at OSW farms have found that drilling, piling, jetting, and plowing did not create significant sediment plumes in the surrounding area due to best practice techniques that minimize sediment plumes

# Benthic Disturbance: Risks & Effects

## Decommissioning

- Full decommissioning involves removing the entire OSW structure while partial decommissioning leaves parts of the OSW structure in place
- Decommissioning causes similar effects to construction and is expected to follow a similar recovery pattern as the post-construction phase

## Additional Considerations

- Noise from OSW can cause a response in some benthic organisms but is not expected to cause mortality
- Heat emissions from cables are expected to have an insignificant effect
- Contaminated sediments could introduce undesired particles into the food chain

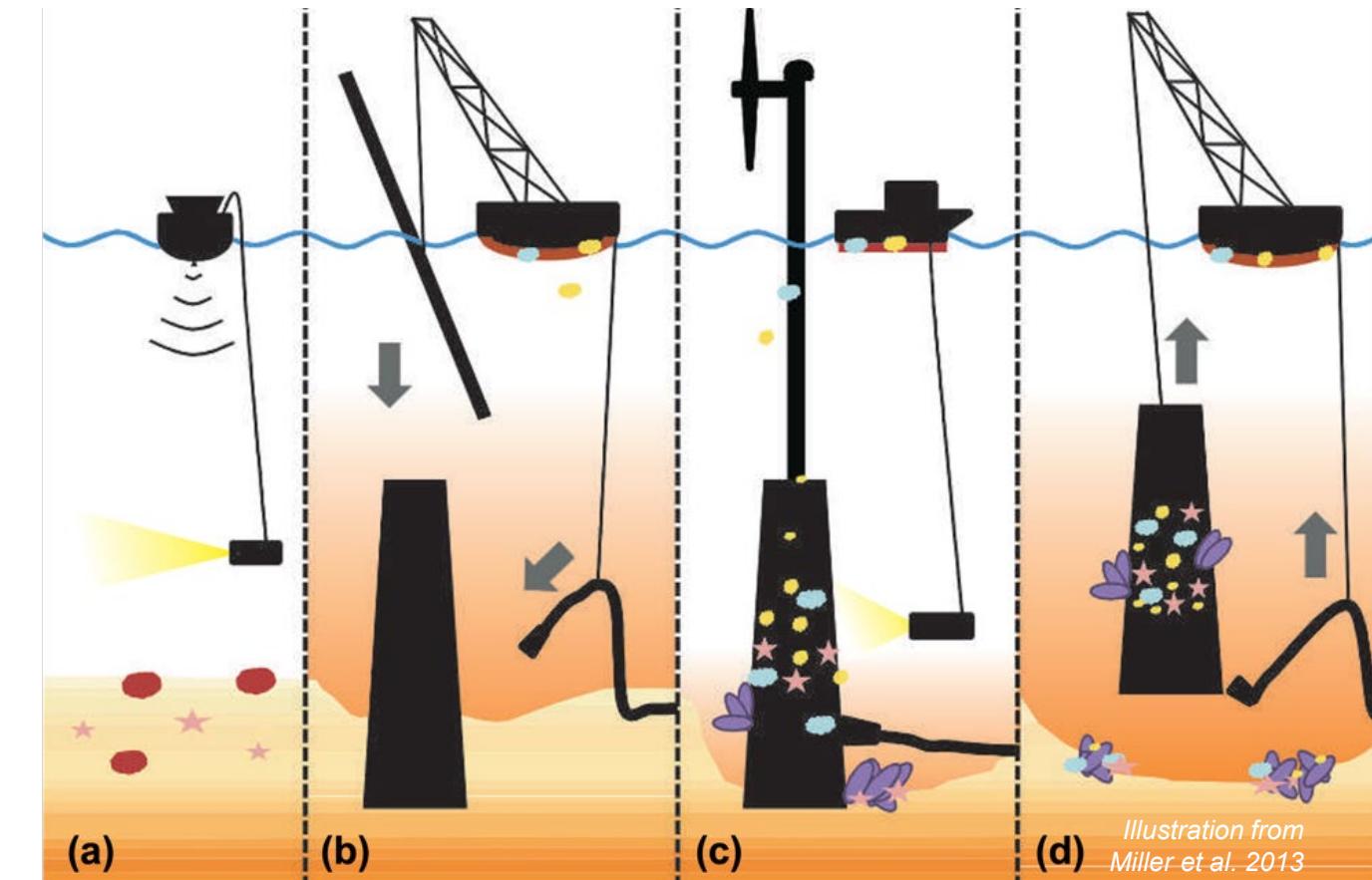
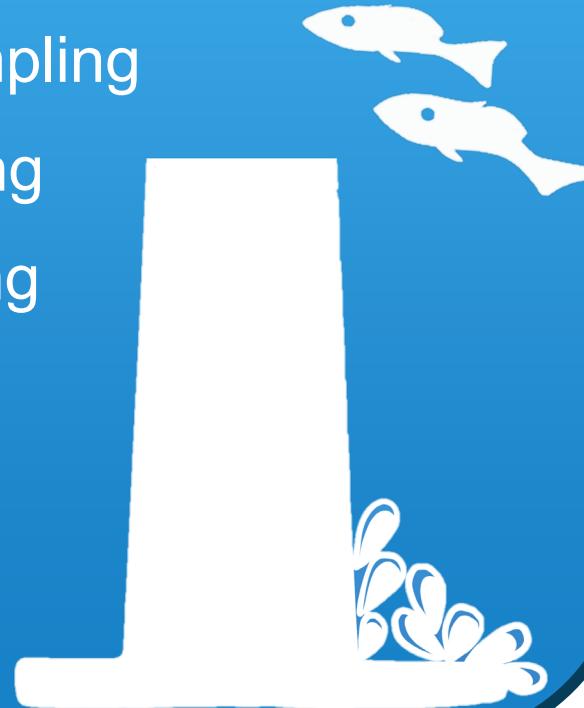


Illustration from  
Miller et al. 2013

# Monitoring & Best Management Practices

## Monitoring Methods

- High-resolution acoustic (sonar) surveys
- Water quality sampling
- Biological sampling
- Sediment sampling
- Video and photographic surveys



## Best Management Practices

- Siting turbines, anchors, and cables to avoid sensitive habitats and species
- Timing construction activities to avoid seasons with sensitive biological processes (e.g., spawning, migration)
- Using construction methods that limit benthic effects to the extent possible
- Using nature-inclusive design solutions when scour protection is needed

# Knowledge Gaps & Research Needs

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## Key Research Questions:

- How does the presence and abundance of benthic organisms change throughout the lifecycle of an OSW farm?
- Are ecosystem functions, energy pathways, and trophic interactions altered by the presence of OSW farm development?
- What is the net effect of new hard substrate provided by OSW structures for benthic communities in both soft and rocky habitats?
- How is this new habitat used by juvenile stages of local species and by potentially invasive, non-native species?

**Development of effective monitoring programs with hypothesis-driven research can improve the understanding of benthic interactions with OSW farms.**



## Panel Discussion

*Moderator:*

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**Members of the SEER Science and Technical Advisory Committee**

# Upcoming Webinars

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**Vessel Collision: Effects on Marine Life &  
Electromagnetic Field Effects on Marine Life**

**TBD**

**Bat and Bird Interactions with Offshore Wind Energy Development**

**TBD**