
Learning from the Experts Webinar Series

# Environmental Considerations for Fixed Offshore Wind Foundation Technologies

**Drew Carey, PhD**
CEO
INSPIRE Environmental

**September 01, 2021**

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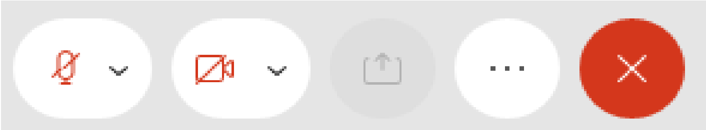
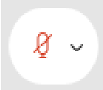


You'll see  when your microphone is muted

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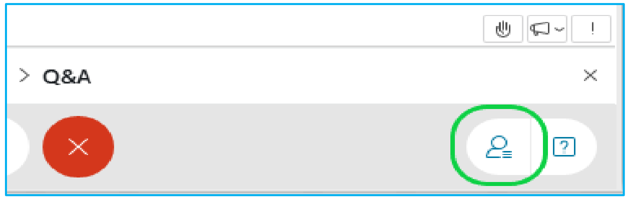


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# Learning from the Experts

**This webinar series is hosted by NYSERDA's offshore wind team and features experts in offshore wind technologies, development practices, and related research.**



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# Environmental Considerations for Foundations

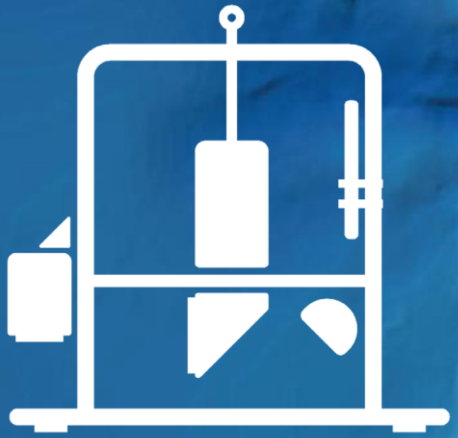

Drew A. Carey

INSPIRE Environmental


September 1, 2021


INSPIRE Environmental
513 Broadway, Suite 314, Newport, RI 02840

www.INSPIREenvironmental.com
Tel: 401.849.9236



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Drew A. Carey, PhD | +1 (401) 225-0038 | www.INSPIREenvironmental.com | 513 Broadway Ave. Newport, RI 02840

# Environmental Considerations for Foundations

- Foundation Types
  - Engineering constraints and selection criteria
- Acoustic and benthic habitat effects of installation
  - Monopile – Coastal Virginia Offshore Wind (CVOW)
  - Lattice Jacket – Block Island Wind Farm (BIWF)
  - Gravity Base – Thornton Bank 1 Belgium
  - Suction Bucket – Borkum Riffgrund
- Artificial Reef Effect
  - Epifaunal growth
  - Carbon Flow
  - Connectivity
- What do we know – what don't we know?

# Foundation Types

- Monopile
- Lattice Jacket
- Gravity Base
- Suction Bucket

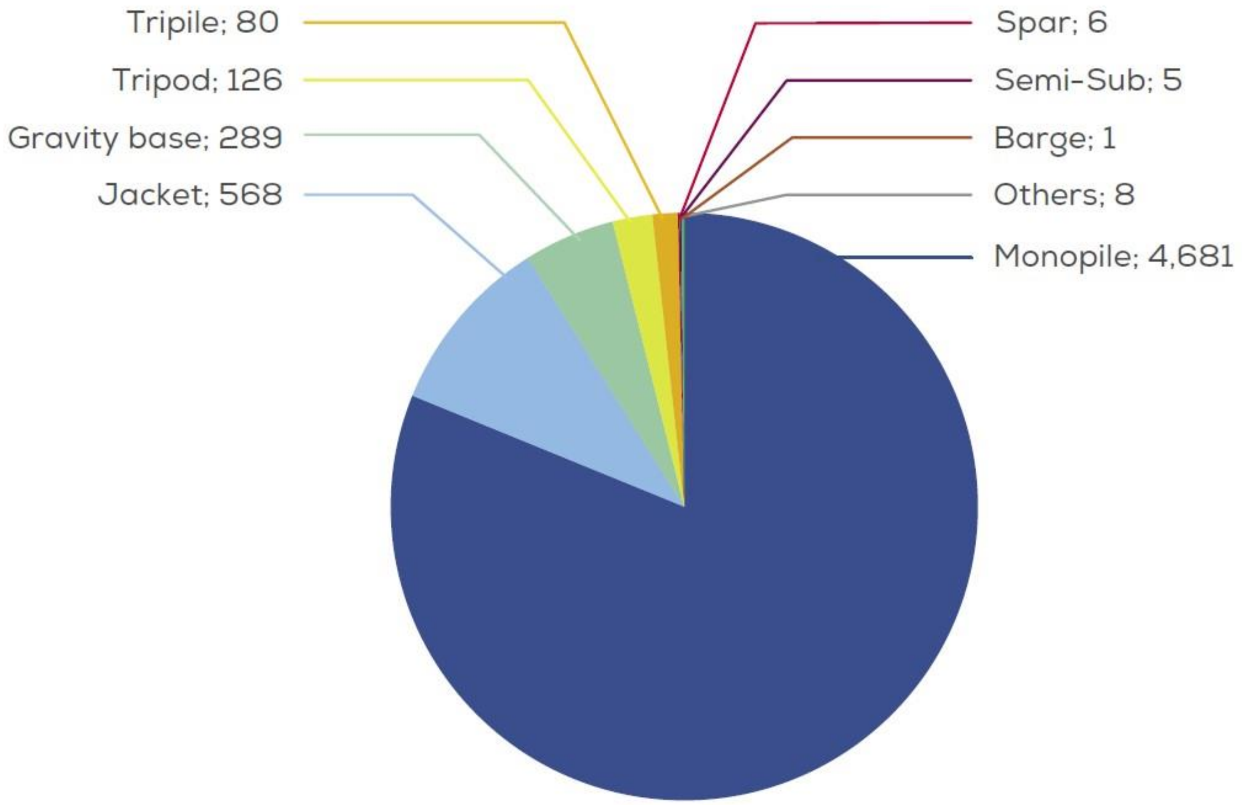
Monopiles remain the preferred choice of developers with over two-thirds of all installations in Europe in 2020 (80.5%).

Jackets were second (19%) with the installation of 100 foundations.

Floating is increasing but not considered here

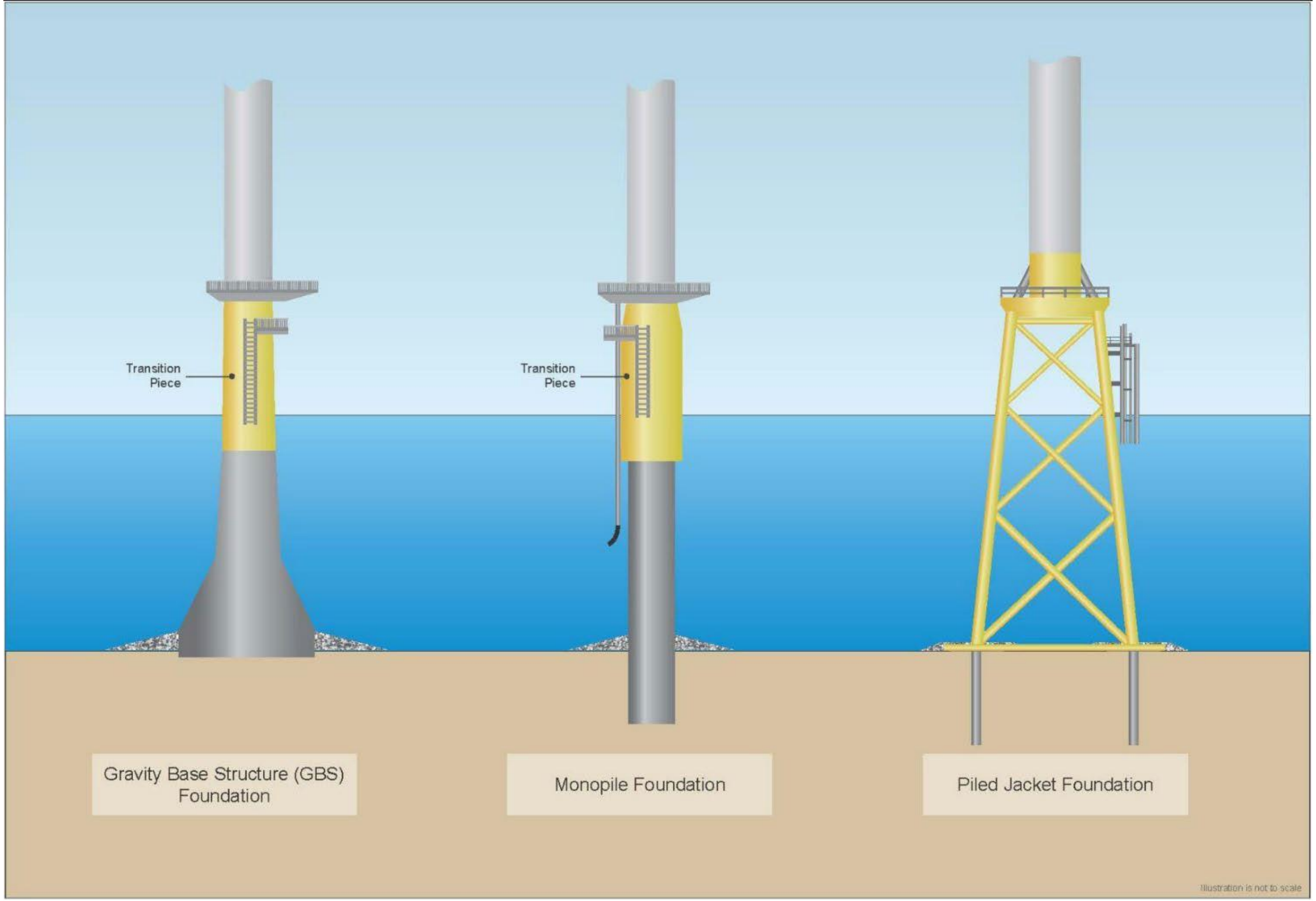
Expect competitive designs for > 40 m (130')

Cumulative number of foundations installed by substructure type[7]




Source: WindEurope

This includes all foundations installed with and without grid connection by the end of 2020.



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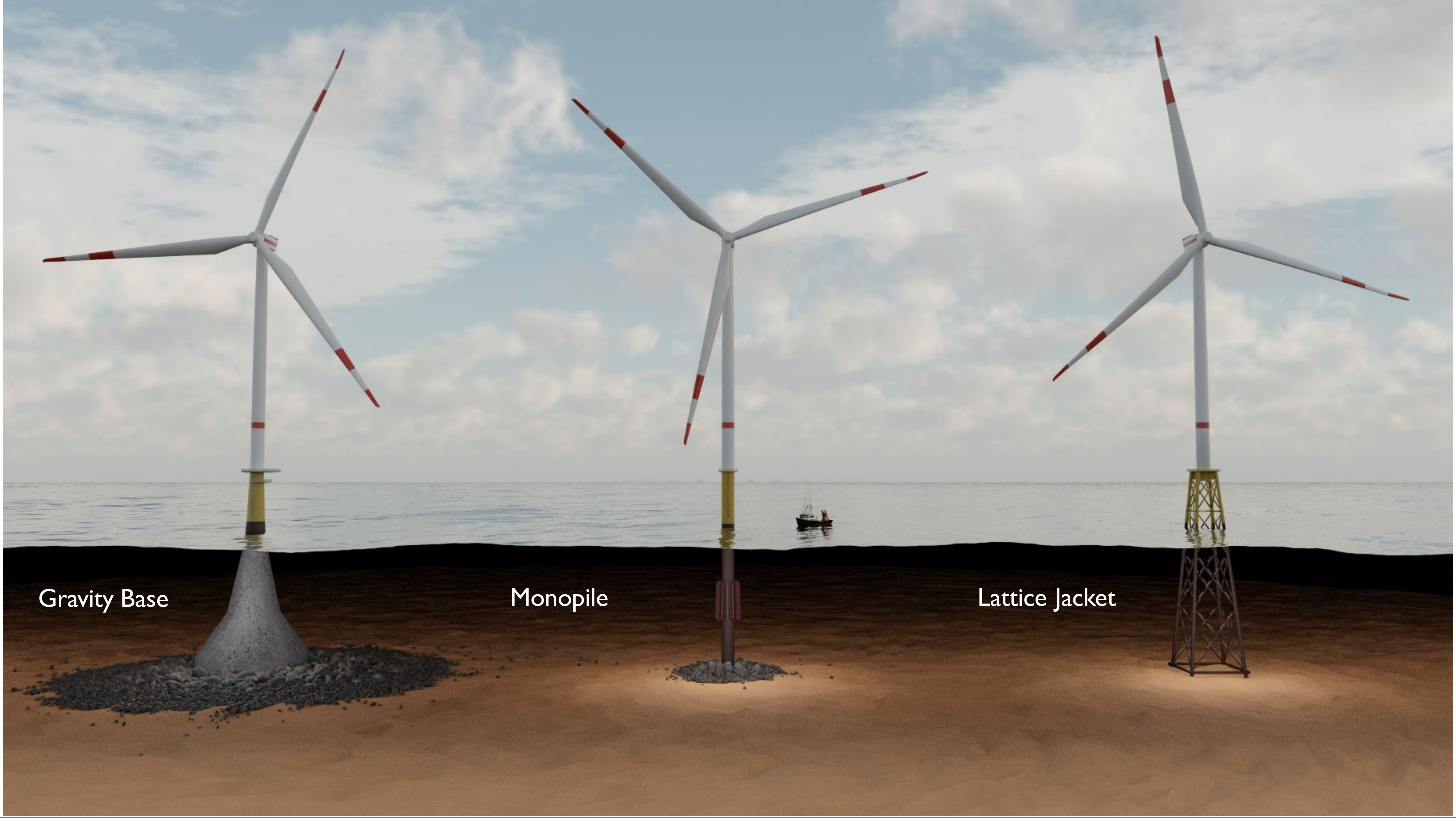
| Type | Depth (to date) | Geotechnical Conditions | Acoustic Impacts | Supply Chain | Logistics |
|---|---|---|---|---|---|
| Monopile | 0.5 - 50 m<br>1.6 - 164 ft | Low to high load bearing soil<br>Small footprint<br>Surface and subsurface clear of boulders<br>Scour protection | Pile driving<br>Vessel noise | Steel, fabrication<br>Feeder vessels/barge<br>Heavy lift vessel<br>Pile driving | Specialized fabrication and heavy transport<br>Laydown<br>Fast pile driving |
| Lattice Jacket | 20 - 80 m<br>65 - 260 ft | Low to high load bearing soil<br>Large footprint<br>Surface and subsurface clear of boulders<br>Only filter layer in most cases | Pin pile driving<br>2.5 x longer<br>Vessel noise | Steel, fabrication<br>Feeder barge<br>Tugs<br>Lift vessel<br>Pile driving | Specialized fabrication and heavy transport<br>Laydown<br>Slower pile driving (x4) |
| Gravity Base | 0.5 - 65 m<br>1.6 - 213 ft | High load bearing soils (sandy or rocky)<br>Large footprint<br>Flat surface<br>Consistent shallow subsurface<br>Large scour protection | Vessel noise | Concrete, fabrication<br>Lower cost<br>Float to Fixed<br>Bollard tugs<br>Large areas to fabricate and marshall | Less specialized fabrication, highly specialized loadout and marshalling<br>Laydown +<br>Transport +<br>Fast placement |
| Suction Bucket | 25 - 30 m<br>82 – 98 ft | High load bearing soils<br>Large footprint<br>Shallow subsurface clear of boulders<br>Large scour protection<br>New designs no scour protection | Vessel noise<br>Pump noise | Steel, fabrication<br>Feeder barge<br>Tugs<br>Lift vessel<br>Suction pump | Specialized fabrication and heavy transport<br>Laydown<br>Fast placement |

New York Lease Areas Depths 20-61m (65-200 ft)

[Comparison of Environmental Effects from Different Offshore Wind Turbine Foundations (boem.gov)]

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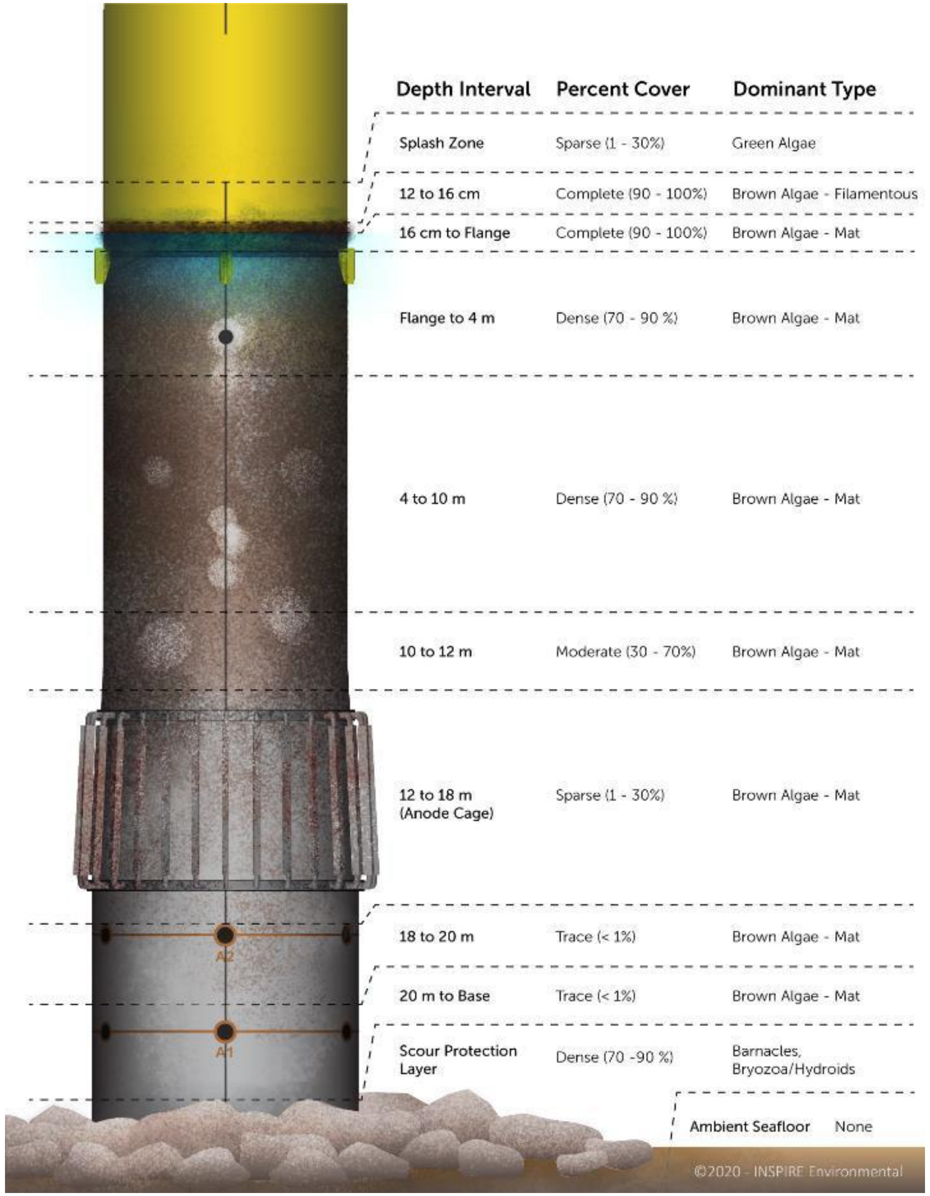
Suction Bucket

# Acoustic effects of operations

- Underwater sound from operating wind turbines originates in moving parts of the nacelle, including the gear box, transmitted down to the foundation where the sound is radiated into the water and sediment.
- Different foundation types do not appear to influence the noise produced.
- Direct drive turbines are expected to be 10 dB quieter than existing gear box technologies.
- The combined source level of a large wind farm (81 turbines spaced 500 m apart) is less than or comparable to that of a large cargo ship.

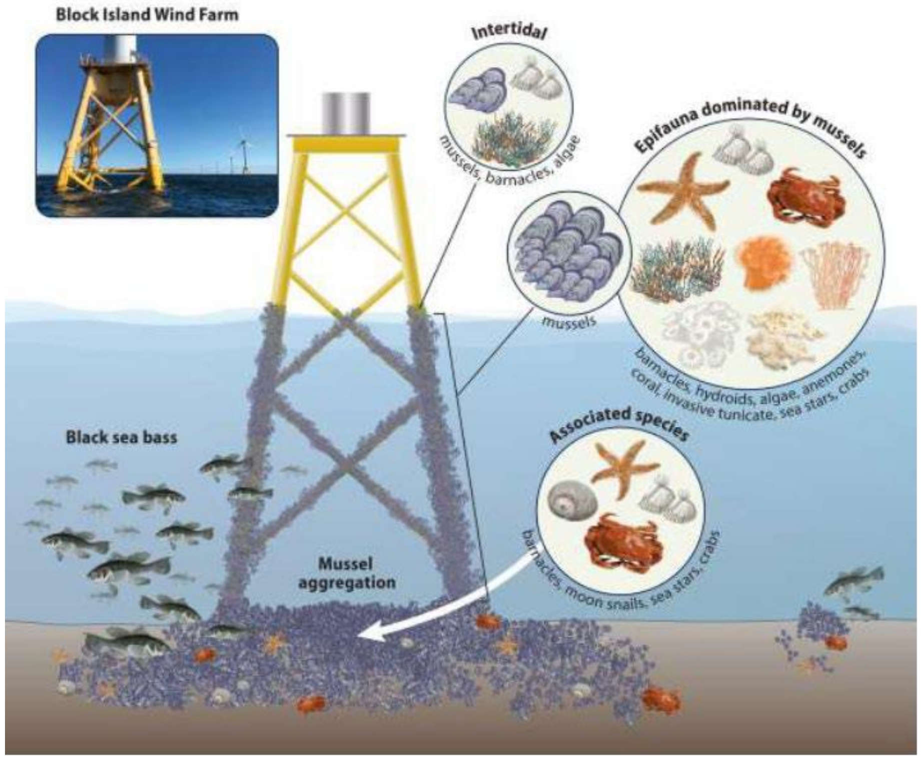
# Monopile (CVOW)

- Simple construction, many installations. Generally used in water shallower than 50 m (164 ft)
  - Scour protection dependent of water depth, exposure and sediment type
- Potential acoustic impacts on the surrounding marine environment:
  - Pile driving of single large diameter steel cylinder for each foundation up to 200' into sediment.
  - Pressure wave and particle motion imparted to water column and sediment during pile driving
  - Some vibration of operation and hydrodynamic flow may affect sediment
- Potential changes in benthic habitat from epifaunal growth on surface of cylinder and spread of debris onto scour protection and surrounding seafloor; attraction of structure loving finfish, limited shelter in anode cage



# Lattice Jacket (BIWF)

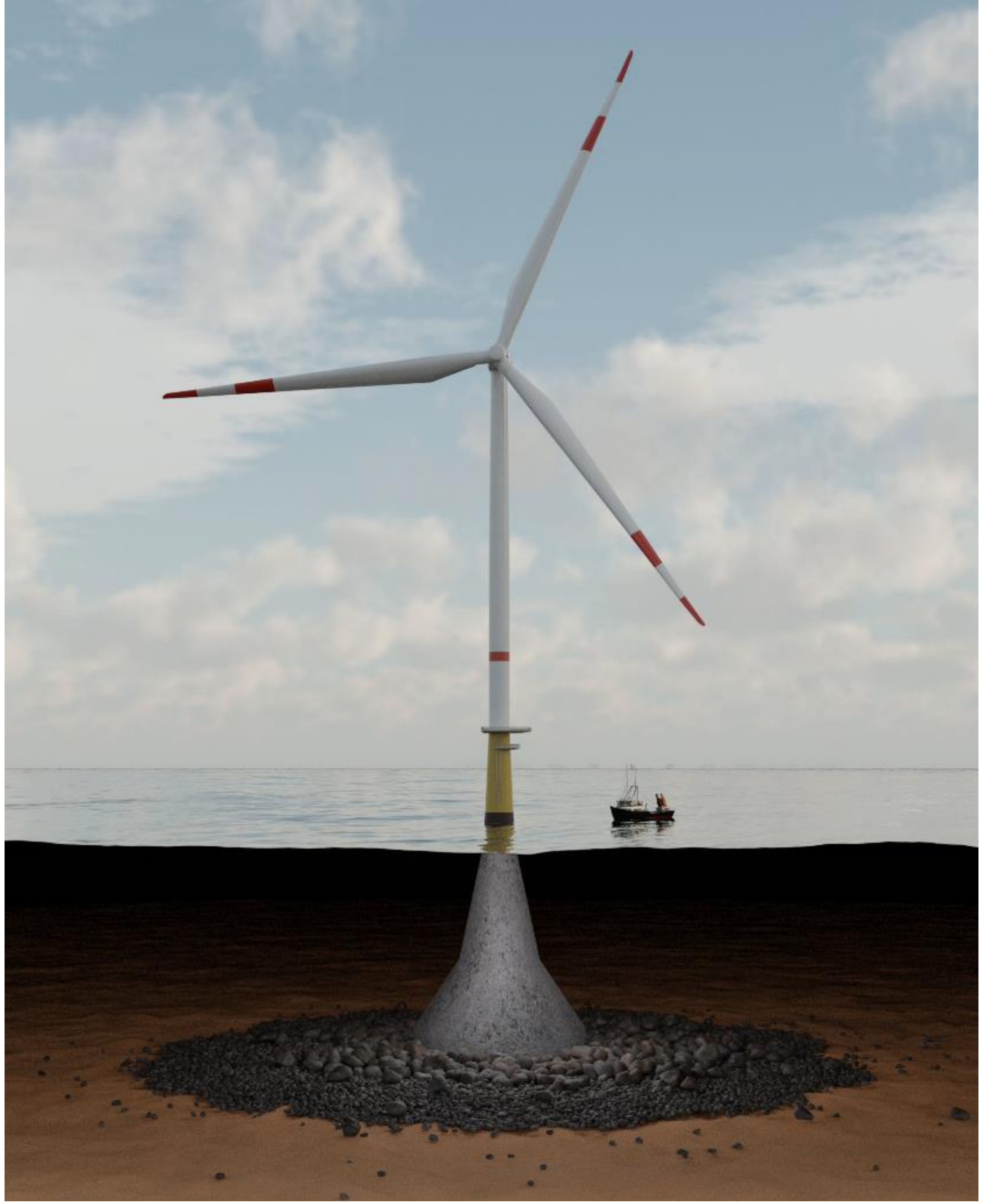
- Complex construction, some installations. Generally used in water deeper than 20 m (65 ft)
  - Scour protection dependent of water depth, exposure and sediment type
- Potential acoustic impacts on the surrounding marine environment:
  - Pile driving of four small diameter steel piles for each foundation up to 200’ into sediment.
  - Pressure wave and particle motion imparted to water column and sediment during pile driving
  - Some vibration of operation and hydrodynamic flow may affect sediment
- Potential changes in benthic habitat from epifaunal growth on surface of jacket and spread of debris onto scour protection and seafloor; attraction of structure loving finfish and debris inside footprint




HDR. 2020. Benthic and Epifaunal Monitoring During Wind Turbine Installation and Operation–OCS Study BOEM 2020-044.

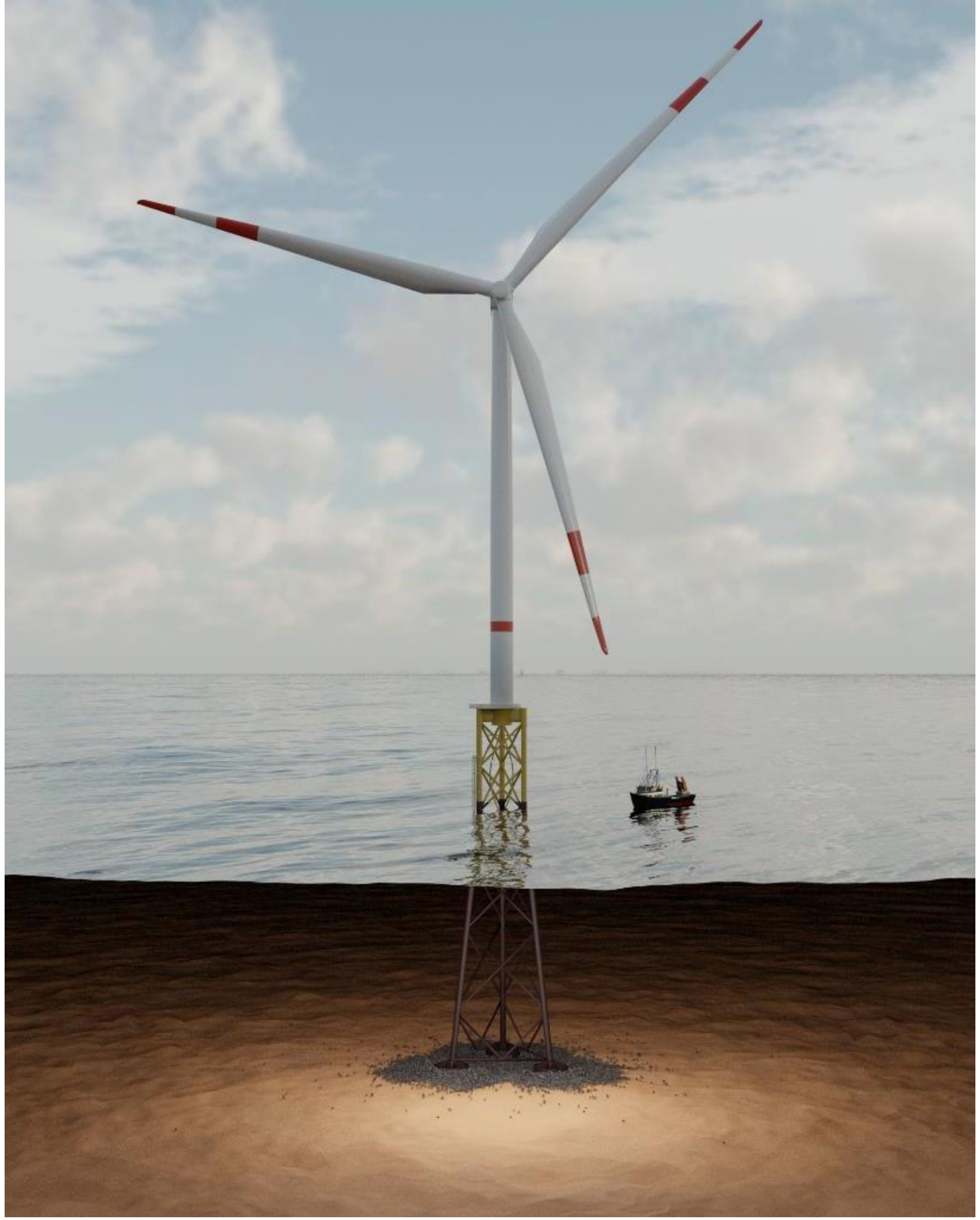
# Gravity Base (Thorton Bank 1)

- Simple construction, few installations. Generally used in high load bearing soils
    - May require dredging of seabed
    - Scour protection dependent on water depth, exposure and sediment type
- Potential acoustic impacts on the surrounding the marine environment:
    - Minimal effect of placement.
    - Pressure wave and particle motion imparted to water column and sediment during placement
    - Some vibration of operation and hydrodynamic flow may affect sediment
- Potential changes in benthic habitat from epifaunal growth on surface of base and spread of debris onto scour protection and surrounding seafloor; attraction of structure loving finfish. Much larger habitat footprint



# Suction Bucket (Borkum Riffgrund)

- Complex construction, very few installations. Generally used in high load bearing soil
  - Sediment type must allow suction placement
  - Scour protection greater because shallow footing greater risk, but may be eliminated with smaller buckets
- Potential acoustic impacts on the surrounding the marine environment:
  - Suction pump driving of one or three moderate to large diameter steel cylinders for each foundation.
  - Pressure wave and particle motion imparted to water column and sediment during pile driving
  - Some vibration of operation and hydrodynamic flow may affect sediment
- Potential changes in benthic habitat from epifaunal growth on surface of jacket and spread of debris onto scour protection and surrounding seafloor; attraction of structure loving finfish, shelter inside jacket



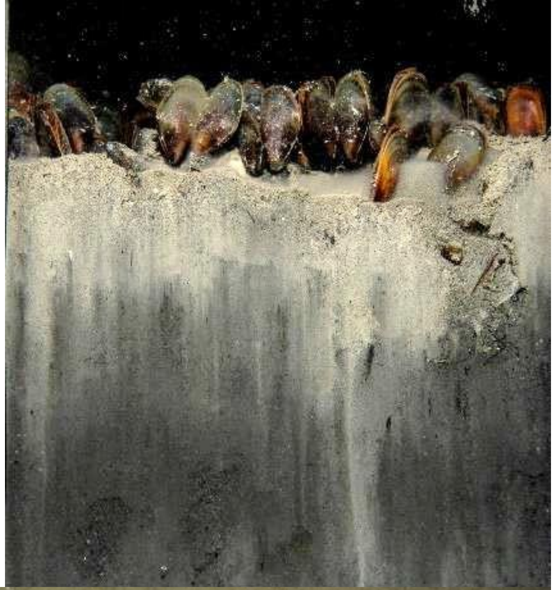
# Artificial Reefs

- All foundation types introduce hard substrata (surfaces) into the ocean
- Intertidal surfaces are not typically found offshore, so vertical 'island' from sea surface to seafloor
- Materials used and complexity of structure affects 'epifaunal growth' – plants and animals that attach
- Attached epiflora use nutrients and create 'biomass' (primary productivity)
- Attached epifauna feed on phyto- and zooplankton in water column, create biomass and discharge waste
- Presence of epifloral and epifauna attract fish and mobile epifauna (crabs, lobsters, small crustacea)
- Presence of structure attracts finfish that use structure as refuge
- Complexity of structure might provide more refuge and variety of use
- Growth and feeding activities increase local biomass (secondary productivity) that spreads to seafloor


Video available at Dominion CoastalVirginia OffshoreWind

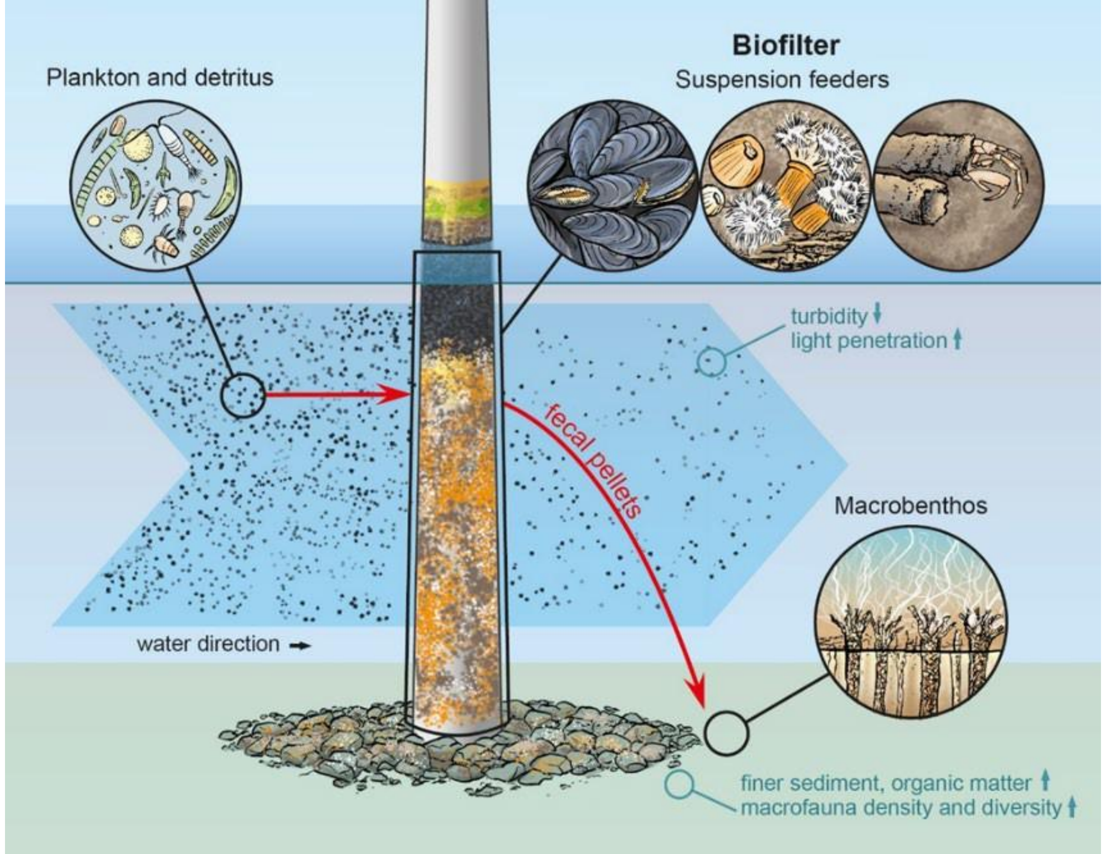
# Benthic Habitats

- Benthic Habitat Modification
  - Soft sediments
  - Hard sediments
- Enrichment: Benthic-Pelagic Coupling
  - Energy flow
  - Fate of energy
  - Food webs
- Connectivity / Habitat Expansion
  - Islands of complexity
- Habitat Suitability
  - Changing trophic structure



# Bottom Sediment Modification

- Organic enrichment
- Energy flow
- What we know
  - Changes in particle size
  - Changes in organic content
  - Changes to flora and fauna
- What we need to know
  - What is the fate of the energy?
  - What is the appropriate spatial scale?




Degraer et al., 2020, Oceanography Special Issue Vol. 33, 4



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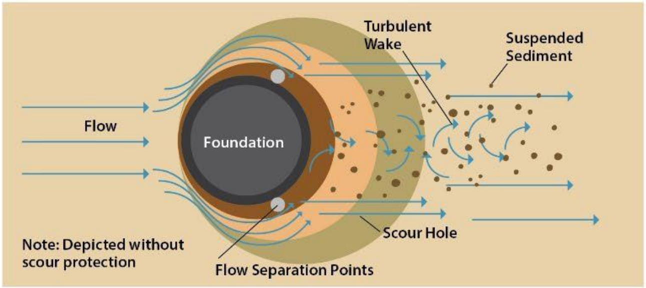
# Wake and scour effects

BOEM 2021-053

- Turbulence created by structure = wake effect
  - May affect suspended sediment, larval dispersal, refuge
  - Likely a few 100 m in tidal currents
- Wake effects on seafloor can cause differential scour
  - Greater with shallower water
  - Greater with larger diameter
  - Can alter benthic habitats

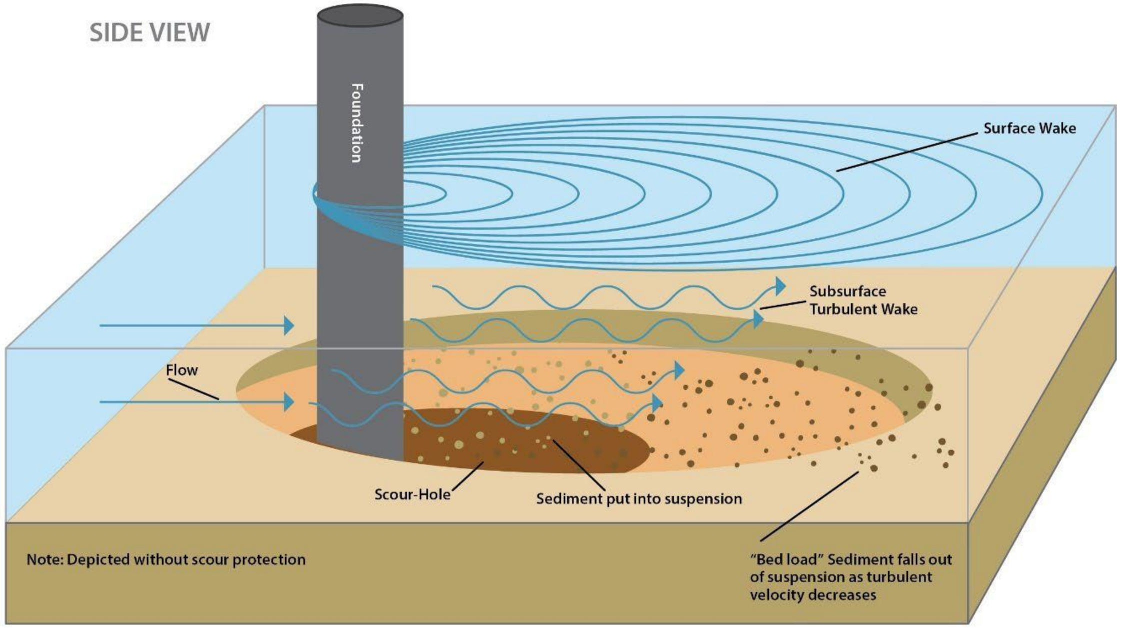
- Similar across foundation types
- Less wake effects from lattice jacket
- More scour from gravity and suction bucket monopiles

TOP VIEW

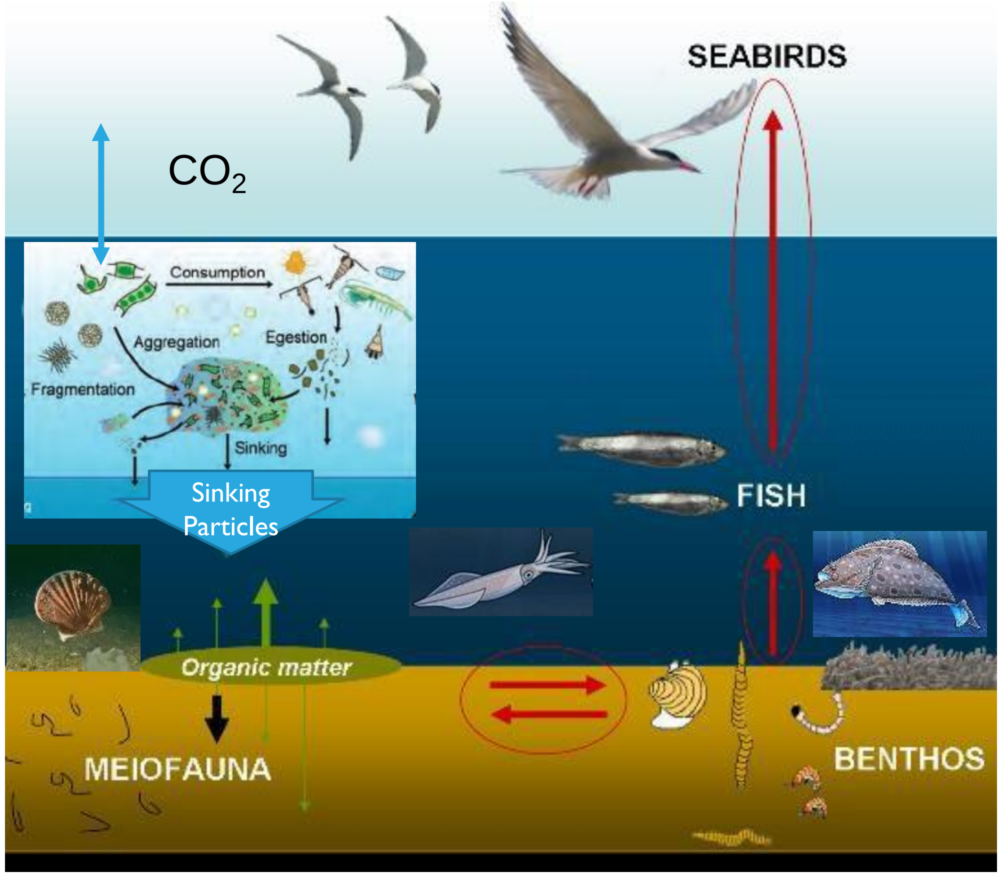


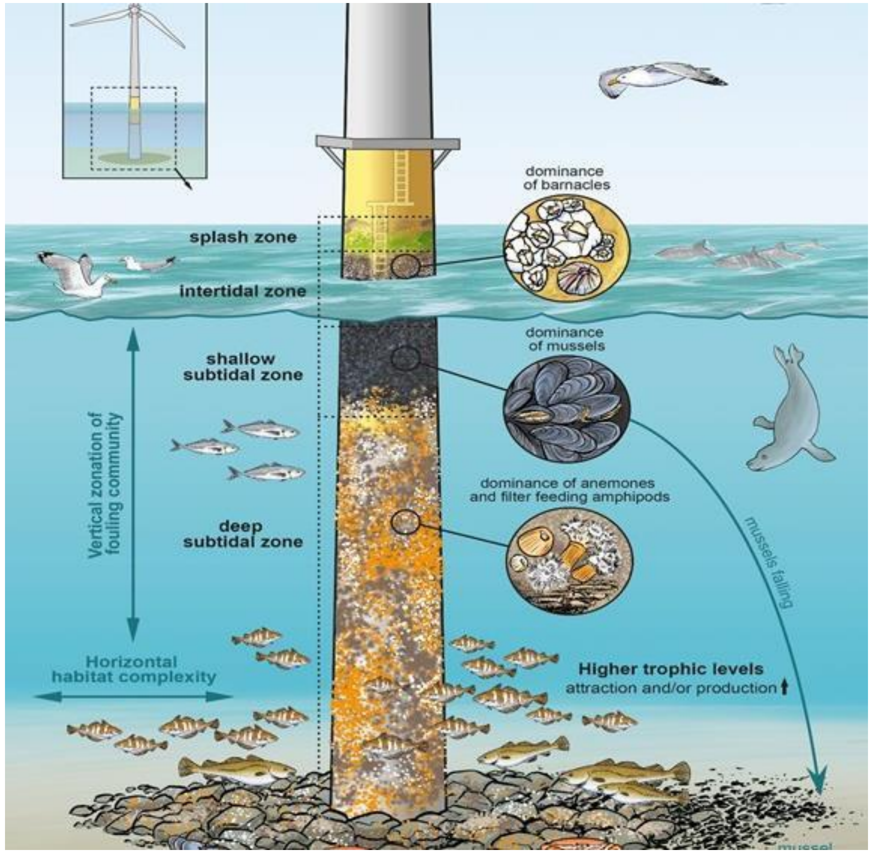

TURBULENT WAKE EFFECT ON SEDIMENTARY PROCESSES (SCOUR, EROSION, AND SUSPENSION AND TRANSPORT OF SEDIMENT)

SIDE VIEW



# Benthic-Pelagic Processes in shallow shelf (0-100m) before and after WTGs




Degraer et al., 2020, Oceanography Special Issue Vol. 33, 4

From WestBanks vliz.be, Buessler et al., 2007, Pew Trust

After Gill et al., 2019, Wildlife and Wind farms

# Enrichment: Benthic-Pelagic Coupling

Biomass growth on foundation

Predation increased

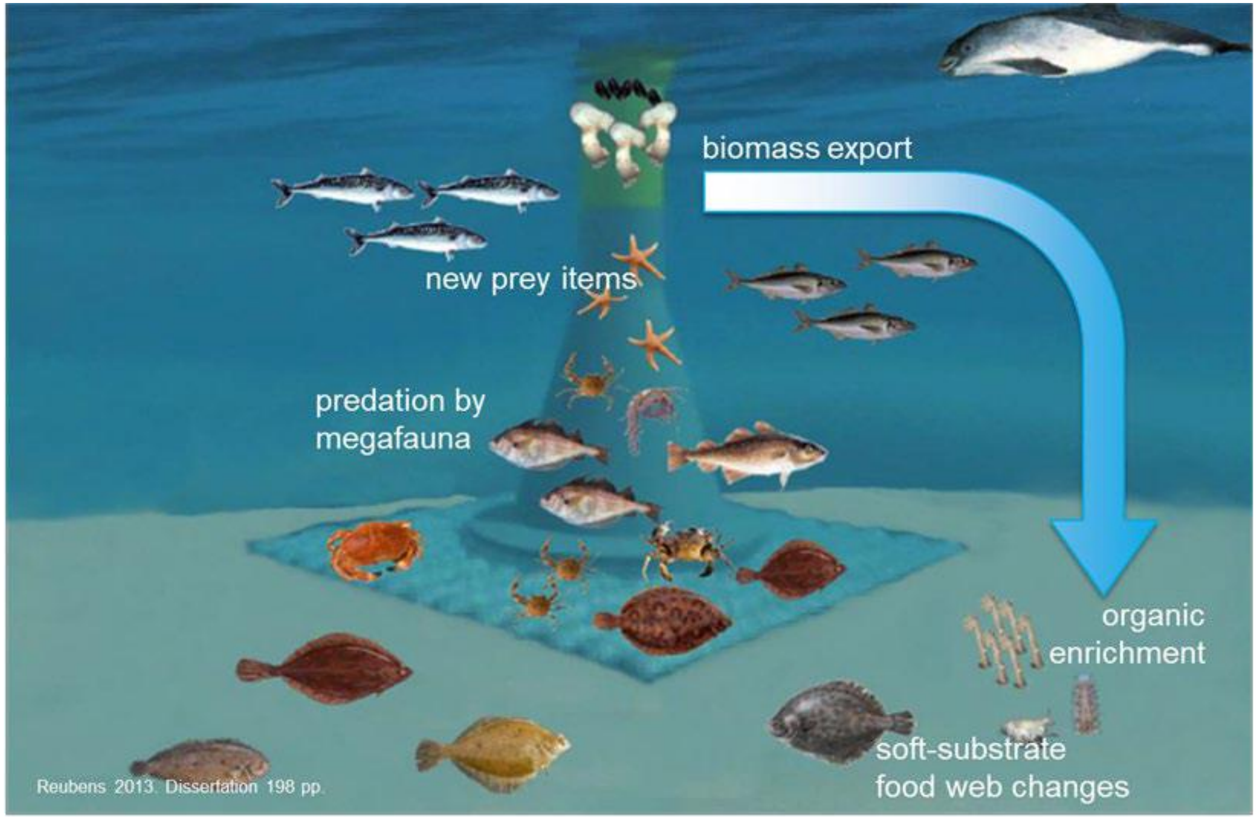
Biomass exported

How much reaches Benthos?

Does benthic production increase?

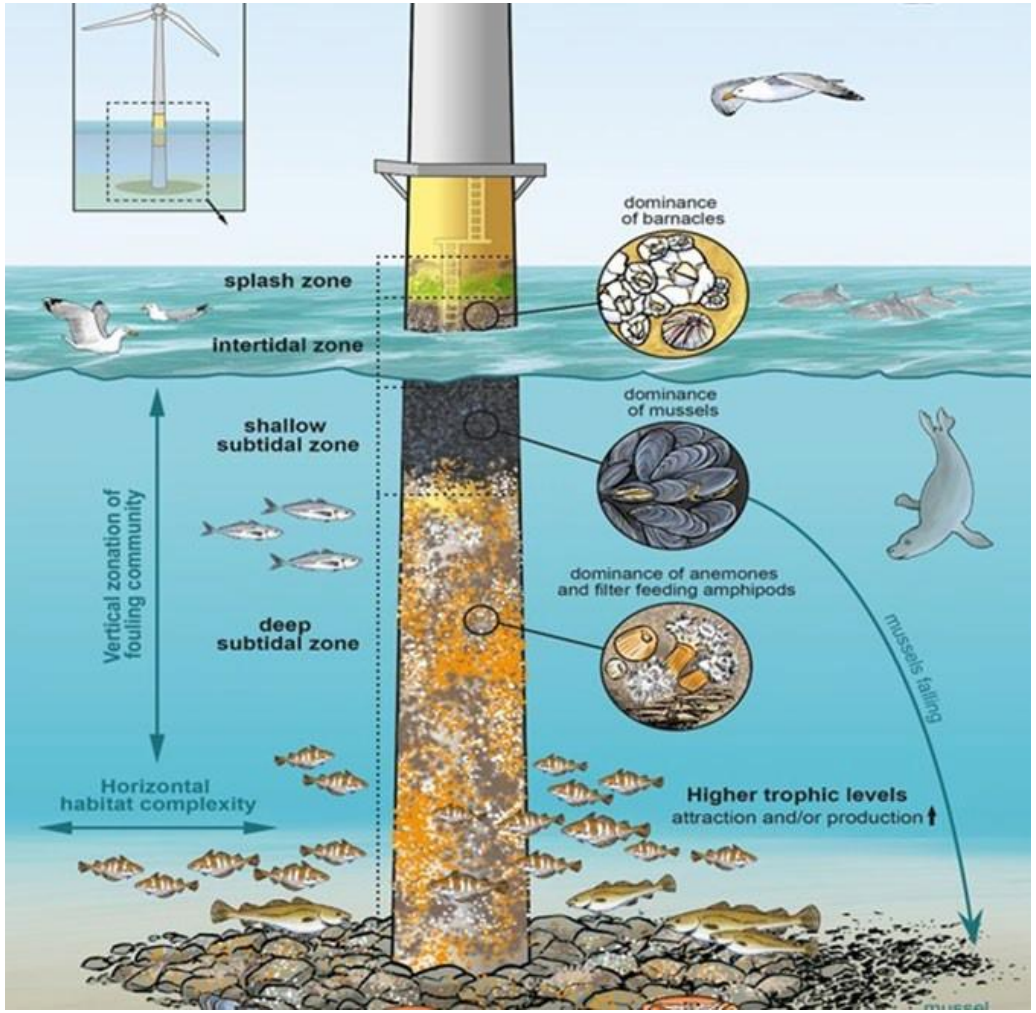
Does food web change?

How far does this go?



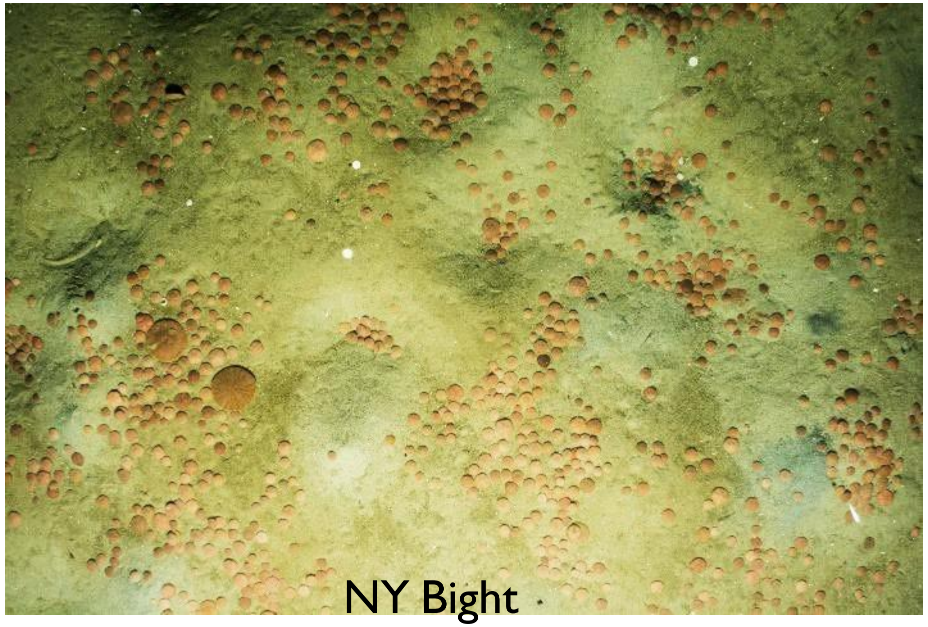
# Enrichment

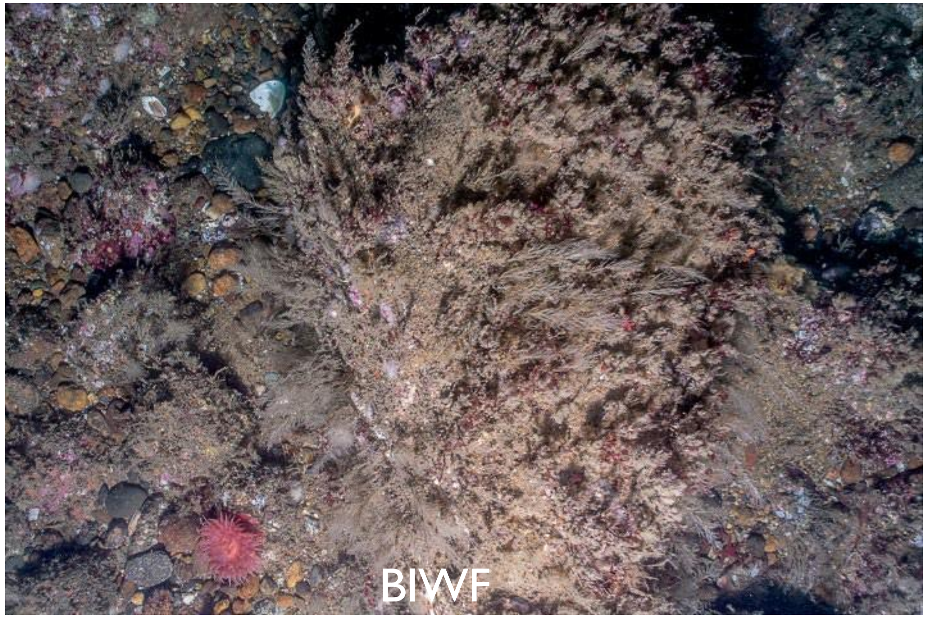
- Predation and increase in prey species
- Brings demersal species into water column
  - Starfish
  - Demersal-pelagic finfish (structure loving)
  - Crabs
- Top trophic species attracted to predators
  - Marine mammals
  - Highly migratory species
- Benthic food web responds to energy and complexity



# Energy flow to Benthos

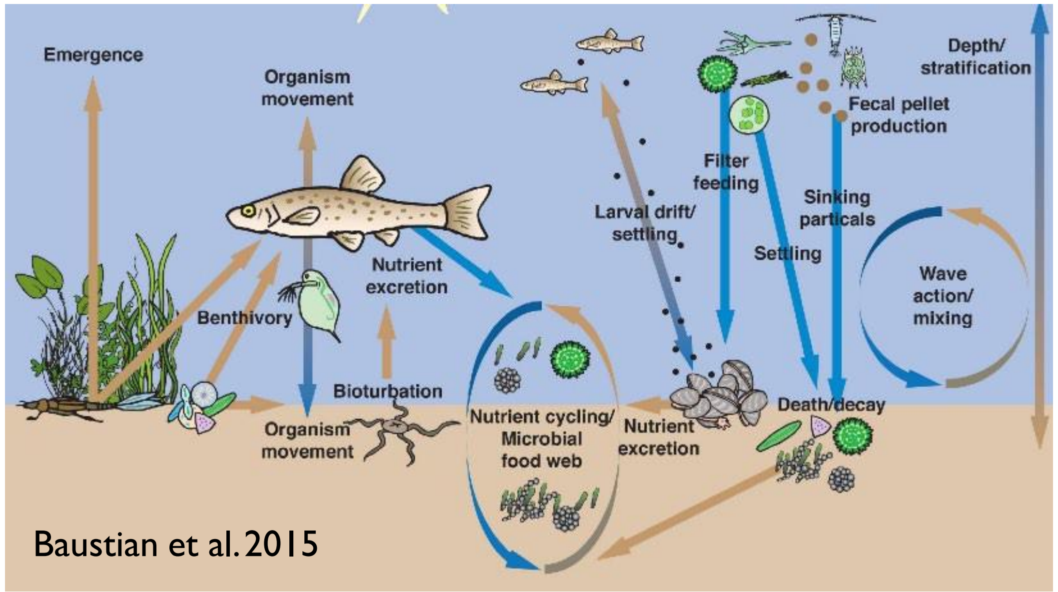
- Primary production captured locally (energy in phytoplankton or epiflora)
- Energy turned into biomass of epifauna (gC or kJ)
- Energy exported to benthos (soft and hard)
- Energy exported to demersal-pelagic fish and invertebrates
- Increased secondary production in benthos and water column
- Alter food web to support scavengers, surface deposit feeders



# Biomass exported

- Mobile predators move away from site – energy export
- Mobile predators stay at site – energy to benthos
- Suspension feeders feed on waste – energy to benthos
- Detritus and shell litter – energy to benthos (some refractory)
- Remineralization of detritus in benthos
- Release of energy back to water column



Baustian et al. 2015



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# Spatial and temporal scale of energy flows

- Most studies = 1,3,5 years
  - Result in localized effects 5-50 m and initial food web

- Belgian studies = 10 + years
  - Result in wider effects (>200 m) and changes in food web

- Unknown effects on benthos beyond 10 years and 200 m
  - Does the system stabilize or continue to change?
  - Does a measurable amount of energy export have a wider ecosystem effect?

- Connectivity
  - May be affected by the nature of benthic habitats near projects (Wilhelmsson and Malm, 2008) – hard substratum vs. soft substratum



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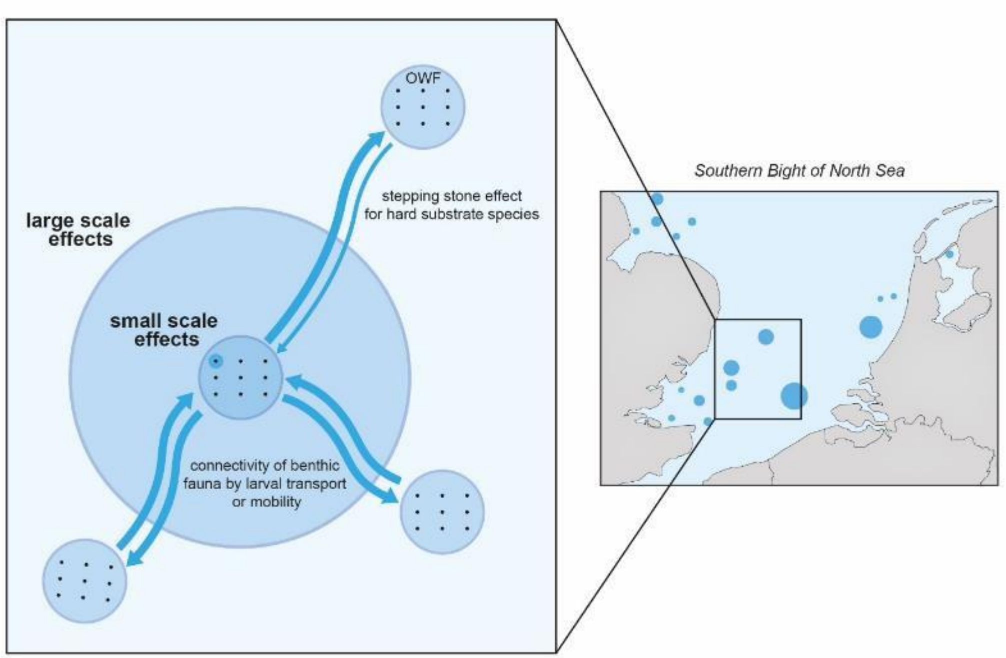
# Connectivity

- Introduction of inter-tidal habitat in deeper water
- Potential habitat expansion for both desirable and undesirable species.
- May be affected by the nature of benthic habitats near projects (Wilhelmsson and Malm, 2008)
- What we know
  - Inter-tidal species colonize offshore structures
- What we need to know
  - At what scale does this connectivity move from small-scale effect to large scale effect?




Degraer et al., 2020, Oceanography Special Issue Vol. 33, 4



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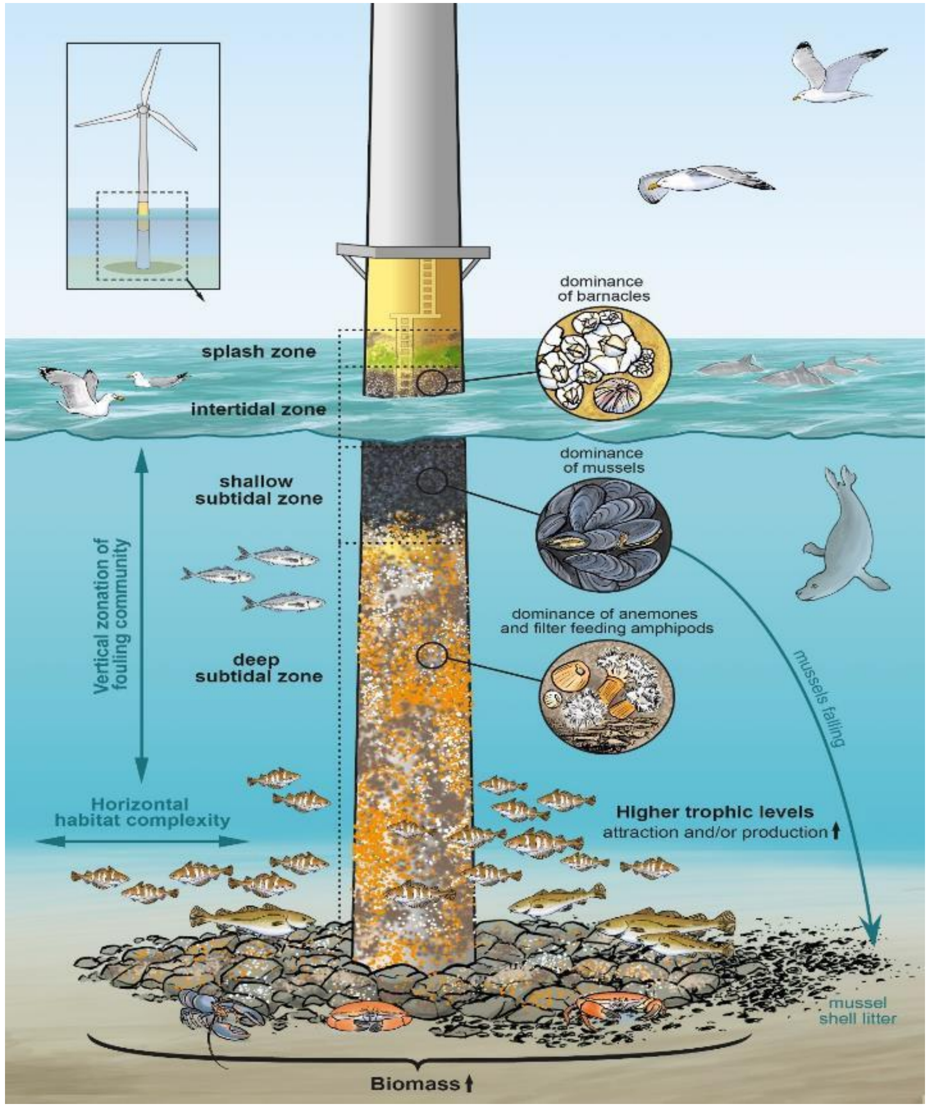
# Habitat Suitability

- Food web dynamics
  - Primary productivity
  - Predator-prey relationships
- What we know
  - Documentation of species presence/absence
  - Spatial/temporal resolution
- What we need to know
  - How does this affect habitat function?
  - How is it functioning at an ecosystem scale?
  - Is effect positive or negative? Functionally equivalent?




Degraer et al., 2020, Oceanography Special Issue Vol. 33, 4

# What we know

- Installation requires complex logistics, large vessels, detailed site engineering surveys
- Installation can have temporary impacts from underwater noise, sediment disturbance
- Each foundation type has distinct advantages and challenges
- Ongoing R&D to reduce risk, noise, cost, logistics

- Operation has low levels of vibration
- Operation has distinct time horizon of biological growth on foundations
- Biological growth and physical presence creates 'Artificial Reef Effect'
- Presence of foundation attracts specific finfish and mobile epifauna

# What we don't know

- Installation logistics for every future project
- Cumulative effects of installation
- Optimum foundation type for New York Bight
- Ongoing R&D to reduce risk, noise, cost, logistics
- Does low level operation noise vary with foundation type? Does it create impacts?
- How long does it take for Artificial Reef Effect to stabilize?
- Does Artificial Reef Effect increase production or simply aggregate species?
- How far does Artificial Reef Effect extend in space?
- What are ecosystem effects of many foundations on primary productivity, secondary productivity, larval dispersal, pycnocline, circulation, Cold Pool, fish and shellfish stocks?

# Foundation considerations

- Site characterization surveys are first step in foundation selection followed by logistics and supply chain
- Decommissioning: will vary with foundation design
  - Potential subject of future webinar
  - Value of habitat associated with foundation vs. restoring original habitat
  - "Repowering" existing foundations
- Nature Based Design
  - Enhance habitat value of foundation and scour protection
  - Considerations of decommissioning on enhanced habitat

# QUESTIONS?

drew@inspireenvironmenal.com

# Coming Next:

September 15, 1:00 p.m. ET

**Regional Collaboration on Wildlife & Fisheries Research**

Emily Shumchenia, Regional Wildlife Science Entity (RWSE)
and
Lyndie Hice-Dunton, Responsible Offshore Science Alliance (ROSA)

Visit wind.ny.gov to register

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