Contract No. 140M0120C0010 Offshore Wind Impact: North Carolina to New York

Webinar for the National Academy of Science, Engineering & Medicine

18 December 2024

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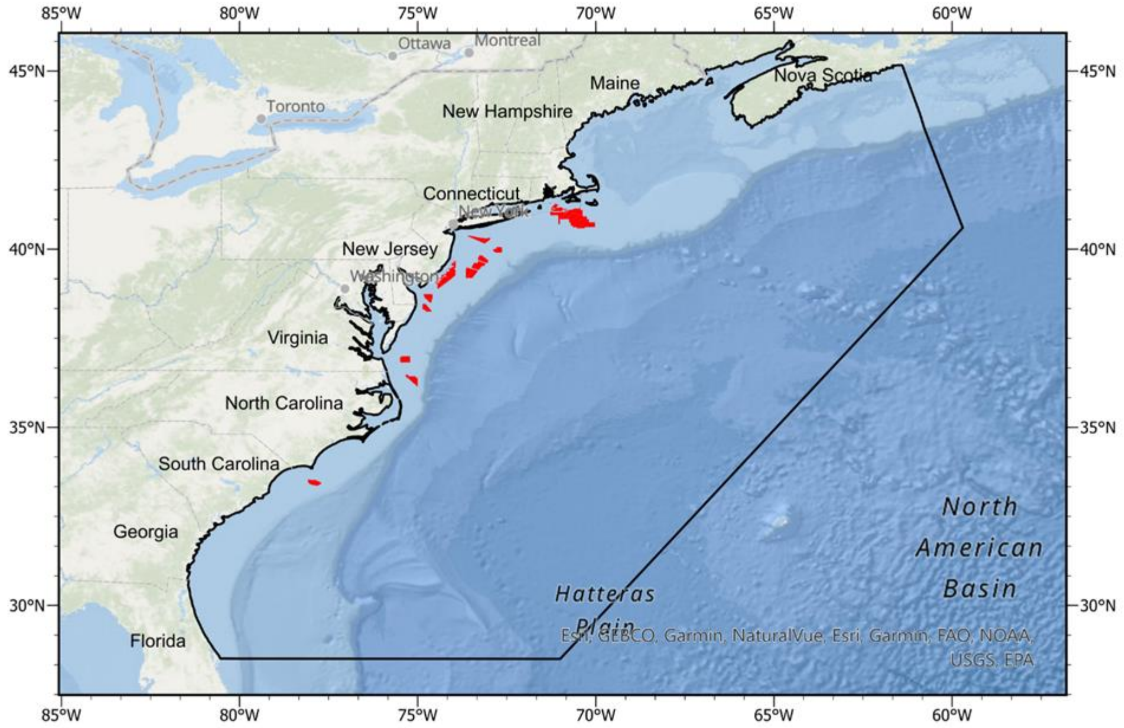
Agenda

1. Introduction
2. Agent Based Model set-up
3. Agent Based Model results
4. Conclusions and relevance of Offshore Wind (OSW) farm related changes
5. Recommendations for further study
6. Acknowledgments

Introduction

Background - Offshore Wind Impact: North Carolina to New York Study

- The goal: Assess the potential cumulative regional impacts on oceanographic transport patterns in the study area resulting from the development of offshore wind (OSW) energy leases in the region.
- The study assesses the potential changes in hydrodynamic conditions resulting from OSW development and the associated impacts on the transport of fisheries pertinent larvae from northern South Carolina to Massachusetts.
  - Atlantic Sea Scallop
  - Atlantic Surfclam
  - Summer Flounder
- This study builds upon previous work completed on the potential impacts on larvae transport, dispersal, and settlement patterns (Chen et al., 2016; Johnson et al., 2021), extending the model domain from Johnson et al., (2021) to include from Nova Scotia to Florida.

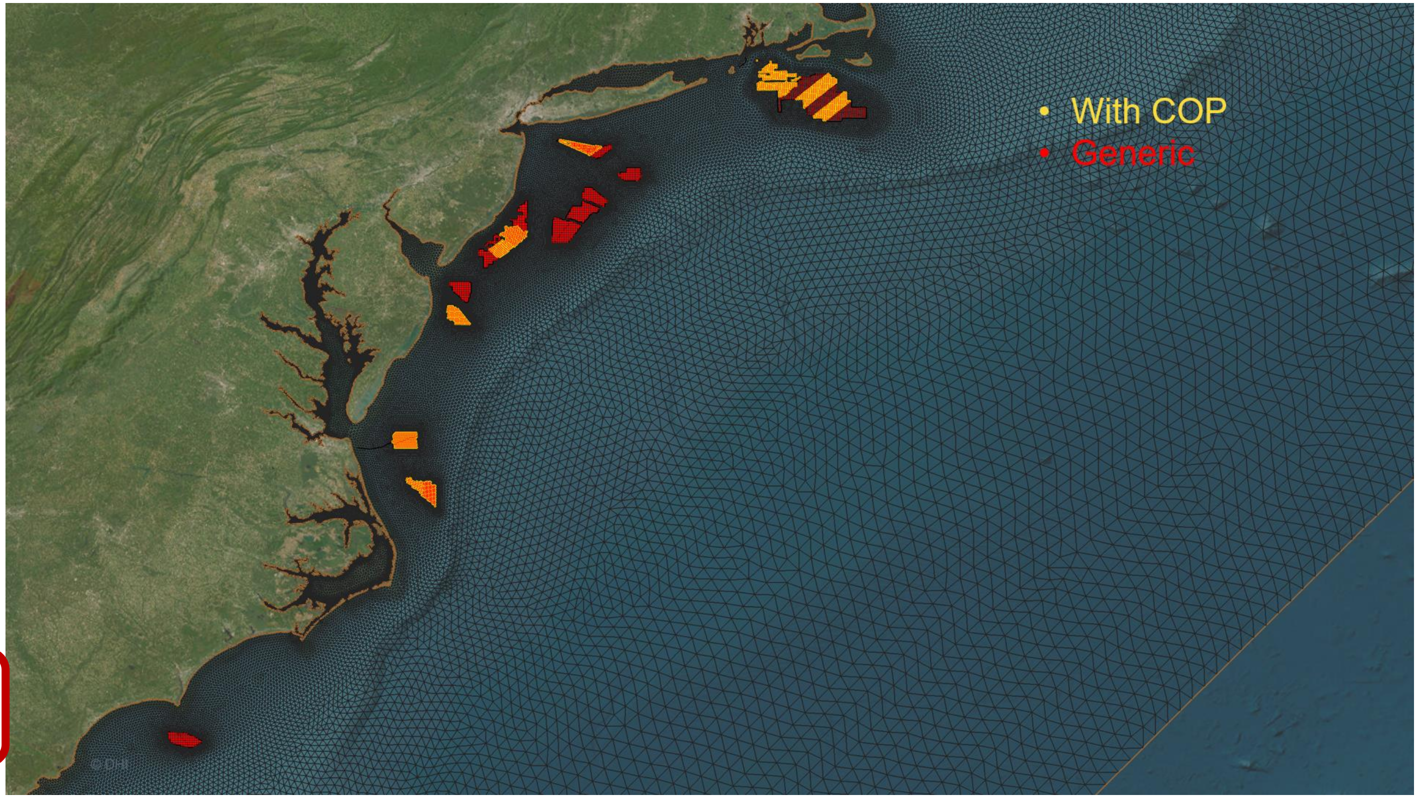


Model Domain Extent from Nova Scotia to Florida in Black

(Credit: Esri, GEBCO, Garmin, NaturalVue, FAO, NOAA, USGS, EPA)

Baseline and Build-Out Scenarios

- **Scenario 1**: Baseline for years 2017, 2018, and 2020,
- **Scenario 2:** Partial Build-out 12 MW (2,083 WTGs with COP) for year 2017,
- **Scenario 3:** Partial Build-out 15 MW (2,083 WTGs with COP) for year 2017,
- **Scenario 4:** Full build-out 12 MW (4,650 WTGs with COP + Generic) for year 2017,
- **Scenario 5**: Full build-out 15 MW (4,650 WTGs with COP + Generic) for year 2017.
- **Scenario 6:** Full build-out 15 MW (4,650 WTGs with COP + Generic) for years 2017, 2018, and 2020.



Hydrodynamic Model Summary

- MIKE 3 FM HD (MIKE Flexible Mesh Hydrodynamic Model that is a 3-D Reynolds Averaged Navier Stokes model)
  - Wind shear stress
  - Tidal currents
  - Salinity
  - Horizontal viscosity
  - Temperature / Heat Exchange
    - Latent Heat Flux
    - Sensible Heat Flux
    - Net short wave radiation
    - Net long wave radiation

- Wind Turbine Generators (WTGs):
  - Wind wake model: Wind Industry standard model – PyWake calculates the wind field change due to the WTGs

- Wind Turbine Generators (continued):
  - Subsurface: Each turbine is implemented as sub-grid feature using extra source terms for:
    - The drag force from the tower as a mean momentum sink
    - A source term for turbulent kinetic energy from the extra production in the wake,
    - Increase the eddy viscosity adding mixing of momentum, temperature and salinity

Input Data

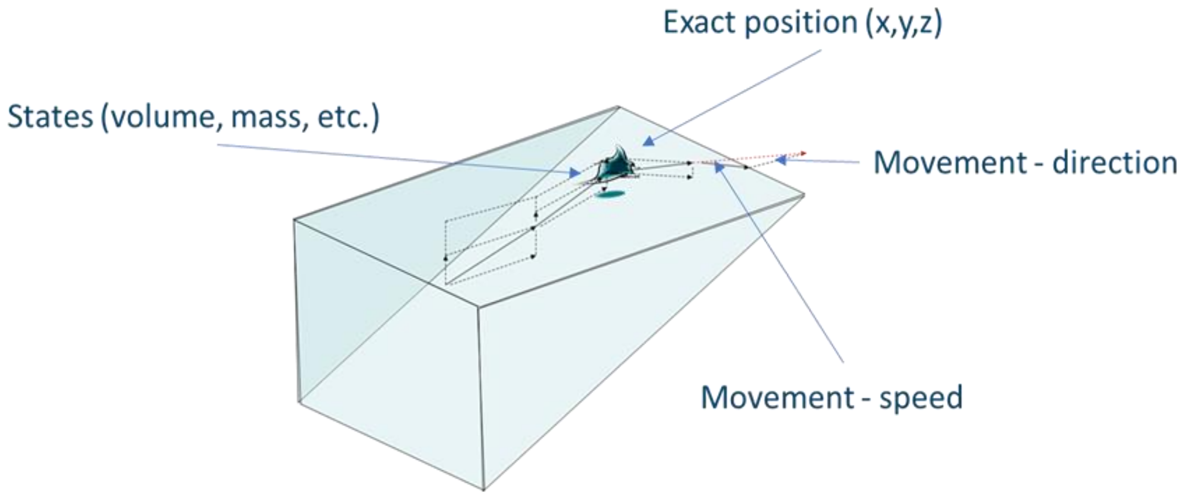
- **Bathymetric Data**: Combination of MIKE C-Map, NOAA NCEI and GEBCO data
- **Meteorological Data**: Climate Forecast System Reanalysis (CFSR) wind field, air temperature, relative humidity, cloud cover
- **Oceanographic Data**: Hybrid Coordinate Ocean Model (HYCOM) global circulation model
- **Astronomical Tide Data**: DHI’s global tidal model DTU10 (Andersen and Knudsen 2009)
- **River Discharge Data**: USGS streamflow of 36 major rivers included in the model
- **Boundary Conditions**: Combination of HYCOM and DHI’s global tide model (DTU10)

Agent Based Model Set-up

What is Agent Based Modeling (ABM)?

Computational model for simulating actions and interactions of autonomous agents.

- Agent behavior is governed by algorithms and equations based on known behavioral traits of the organisms of interest:
    - Spawning
    - Growth and development time
    - Vertical movement (e.g., in response to temperature)
    - Horizontal movement
    - Preferred settlement habitat



Species Modeled

Atlantic Sea Scallop
(*Placopecten magellanicus*)

2017, 2018, 2020

Atlantic Surfclam
(*Spisula solidissima*)

2017

Summer Flounder
(*Paralichthys dentatus*)

2017

Modeling steps

1. Customize ABM for each species

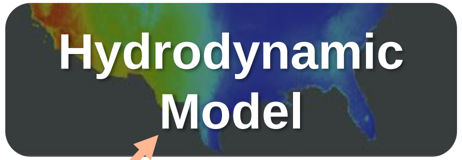
Sea Scallop

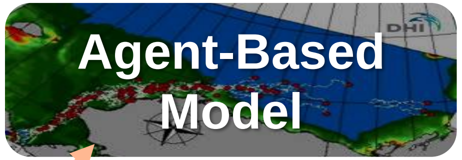
Surfclam

Summer Flounder

Image source: NOAA

2. Coupling of ABM to HDM

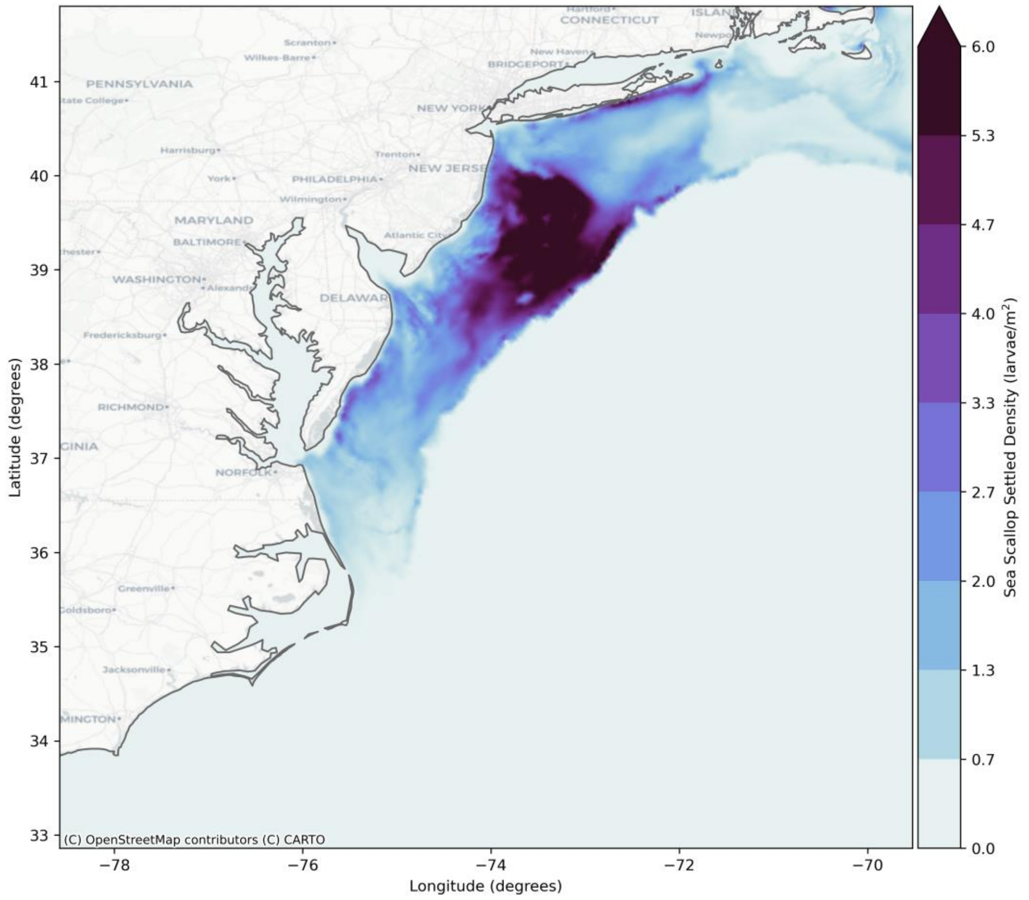




Baseline
12MW full and partial
15 MW full and partial

Run multiple times as an ensemble

3. Settlement pattern results



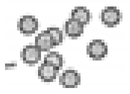
Sea Scallop Baseline Settled Density 2017 (Mean of all ensemble runs)

ABM – Set-up Steps: Life cycle

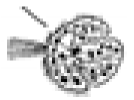
Life cycle → Spawning → Movement → Settlement

Egg → (fertilization) → Zygote → (1-2 days, hatching) → Trochophore Larvae → (2-5 days) → Veliger Larvae → (Avg 20 – 30 days, up to 35 days) → Pediveligers → (5-15 days) → Settled Juvenile

End of model simulation

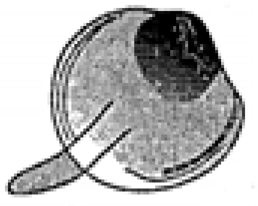


Diameter = –66 µm

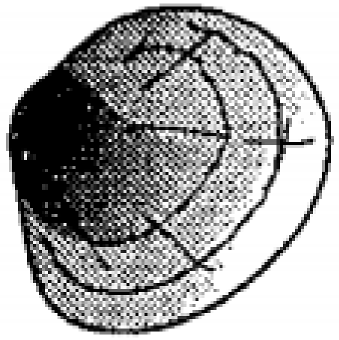


–70 µm

–110 µm



–230 µm

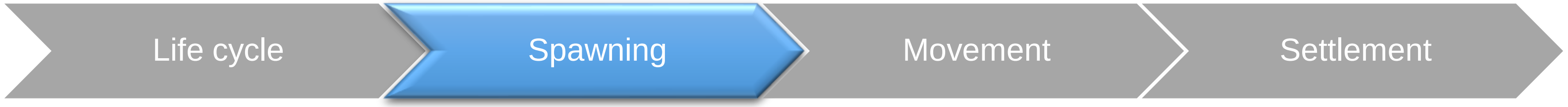


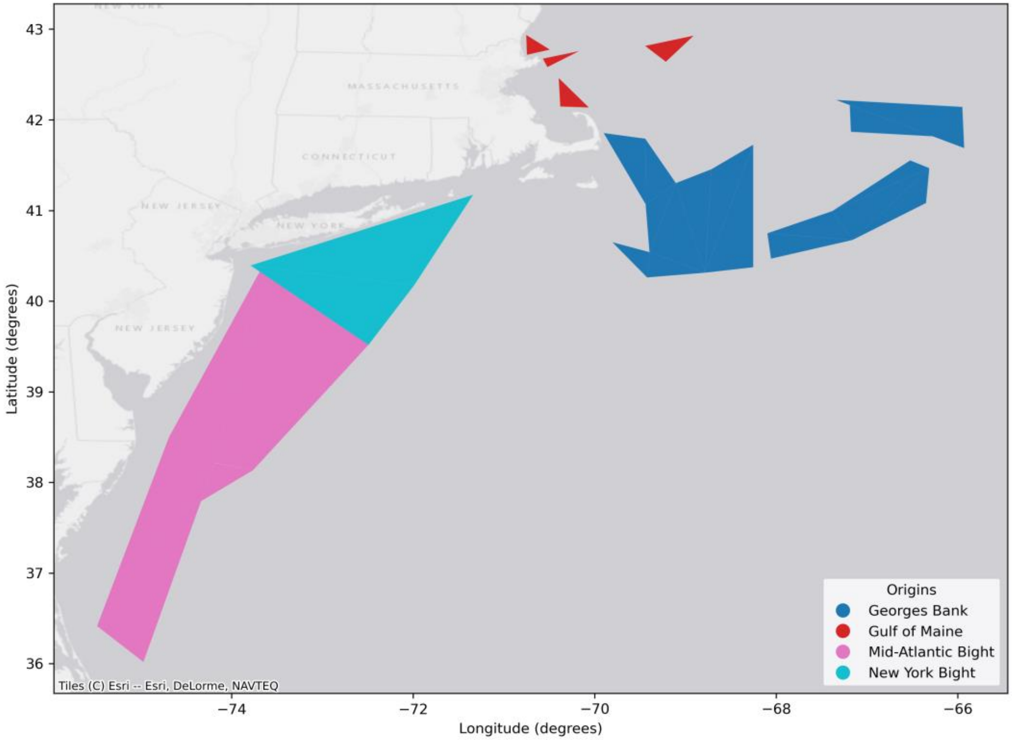
–1 mm

Negatively buoyant; released near bottom

Generally considered to be pelagic; drift with water currents

ABM – Set-up Steps: Spawning





Release areas are indicated by polygons

Gulf of Maine - Red polygons
September - October

Georges Bank – Blue polygons
September – October

New York Bight– Light Blue
September – November

Mid-Atlantic Bight – Pink
May – June, November

ABM – Set-up Steps: Movement

Life cycle → Spawning → **Movement** → Settlement

Zygotes

If AGE < 1 hour (i.e. agent was just released), *Agent rises at initial rising rate*

Else, *Agent's vertical speed is a function of hydrodynamic forcing and rising rate*

Pelagic eggs

Pre-Competent Larvae

If < 1°C, *Agent's vertical speed is a function of hydrodynamic forcing and upward swimming speed*

If > 16.5°C, *Agent's vertical speed is a function of hydrodynamic forcing and downward swimming speed*

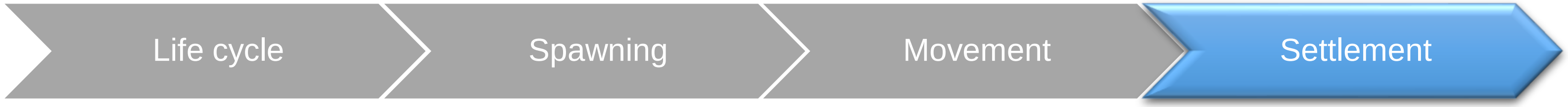
Competent Larvae

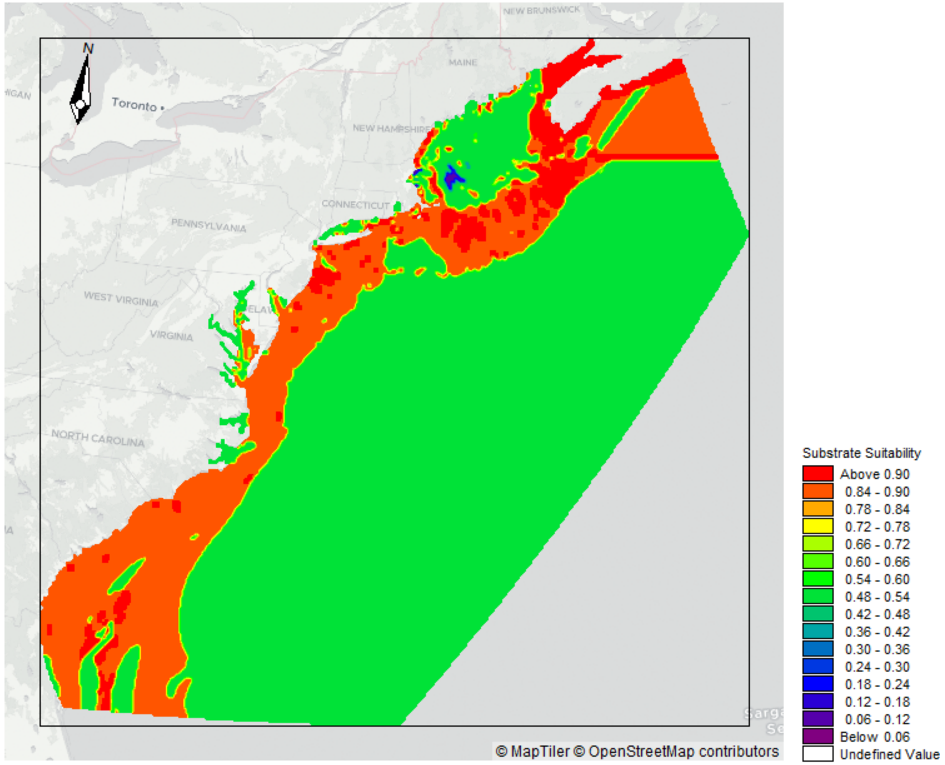
Agent's vertical speed is a function of hydrodynamic forcing and average settling speed

Settling to seabed

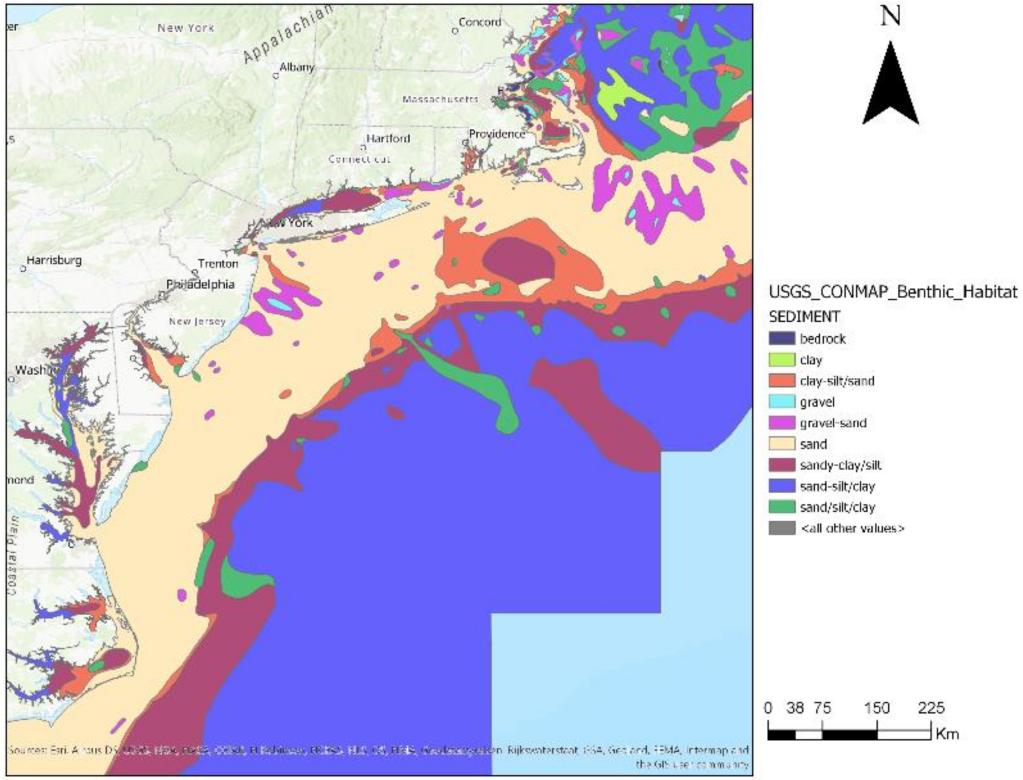
DHI

ABM – Set-up Steps: Settlement





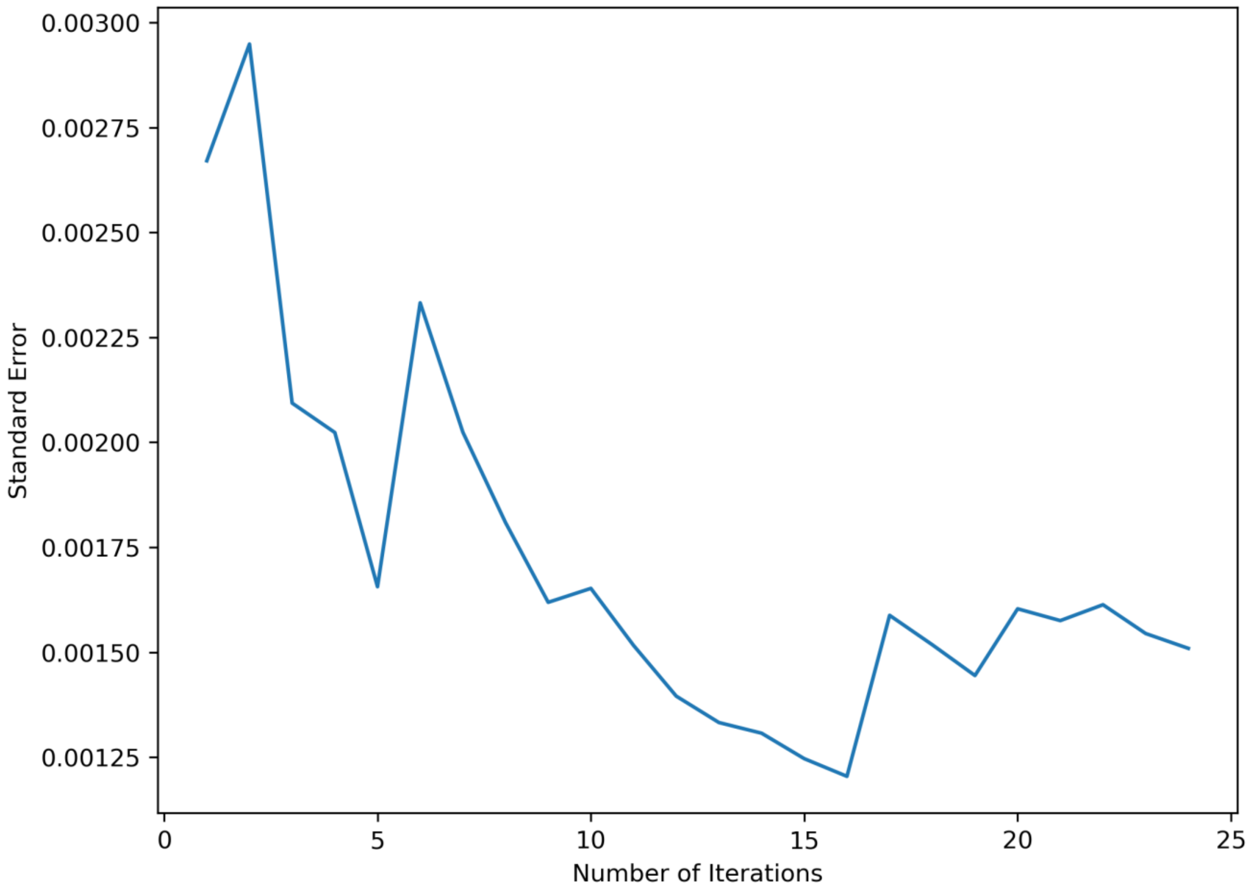
Sea scallop substrate suitability map



USGS CONMAP benthic substrate map

Ensemble Modeling

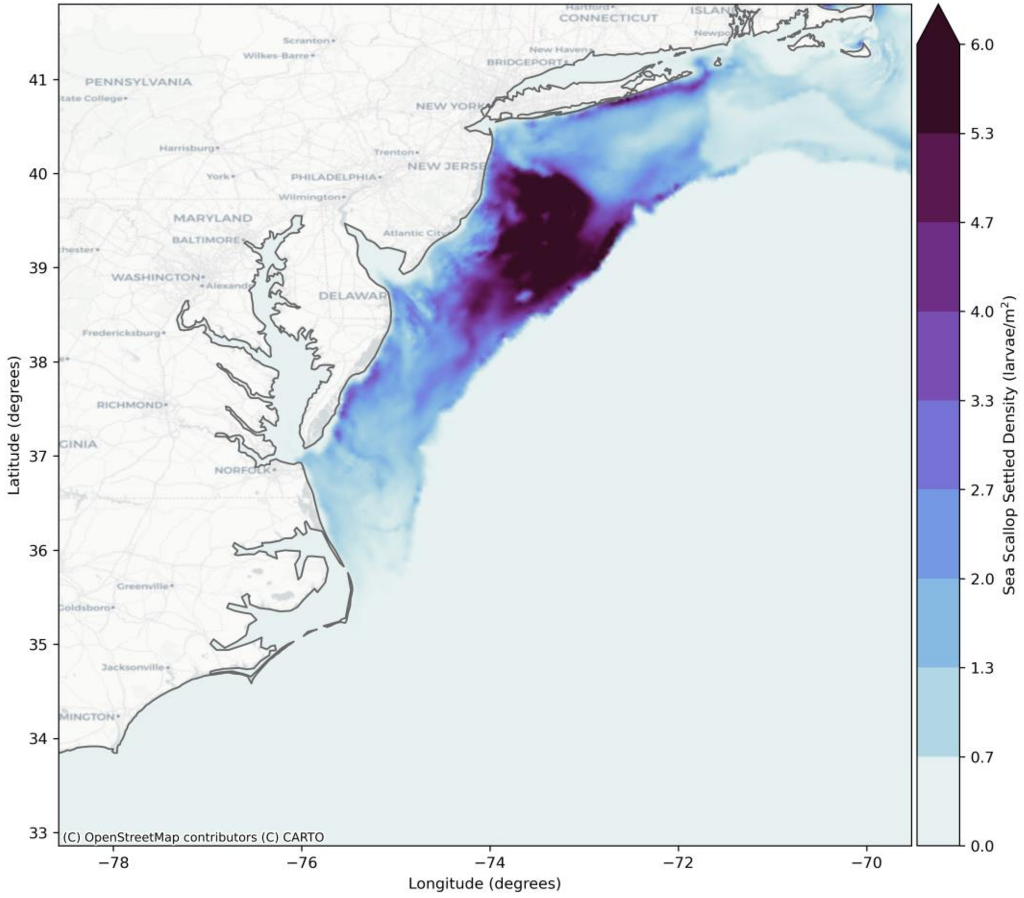
- Manages model stochasticity and increases the robustness of model results.
- Initial conditions and inputs were kept the same
- 25,000 to 30,000 super-agents were released from within the designated spawning areas randomly.
- Each super agent was representative of ~50,000,000 zygotes (depending on fecundity of the species)
- After 20-25 simulations the results start to converge – ensemble size of 25 clones was chosen



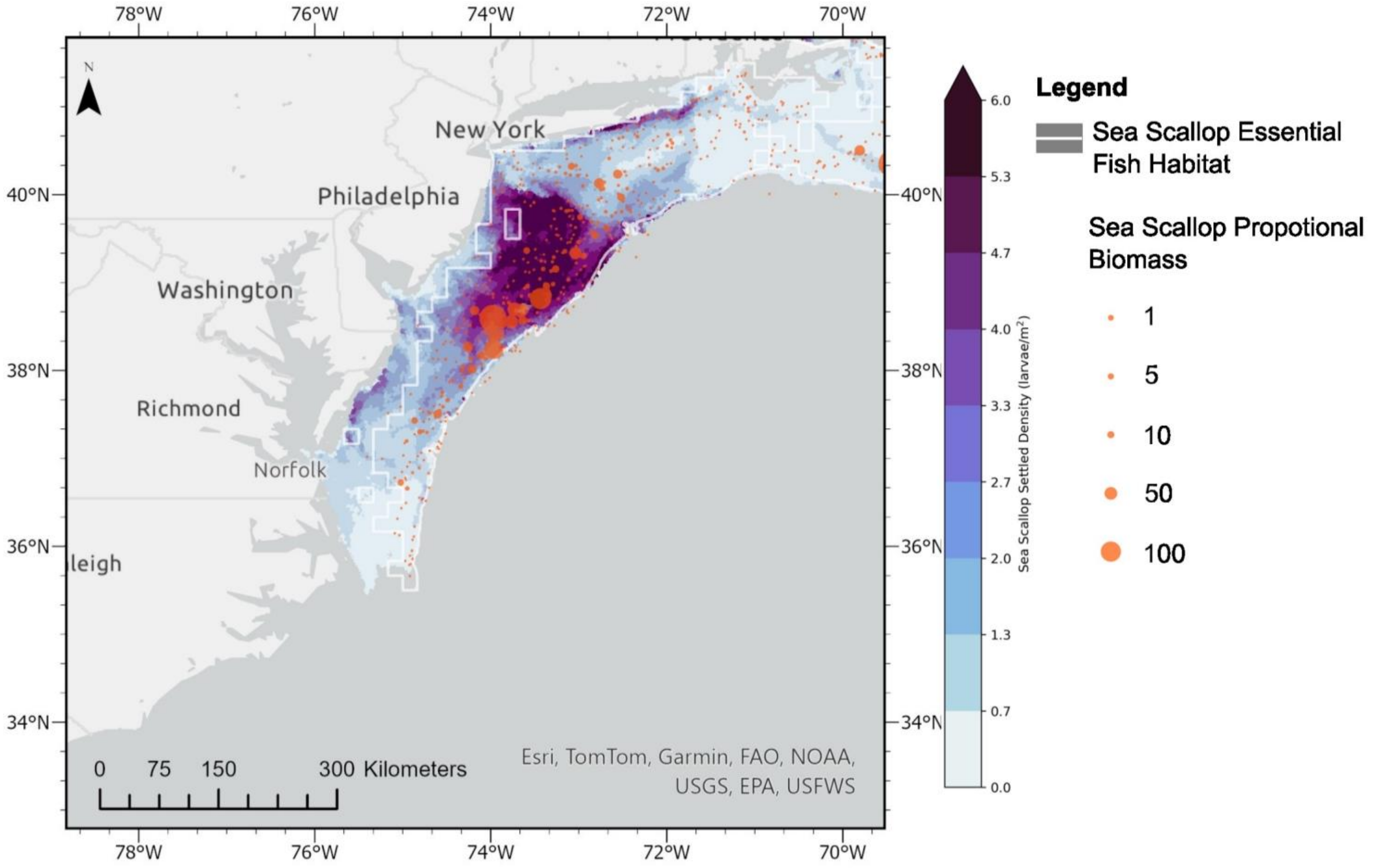
Sea scallop ensemble model convergence

Agent Based Model Results

Sea Scallop Baseline Settled Density 2017 (Mean of all ensemble runs)



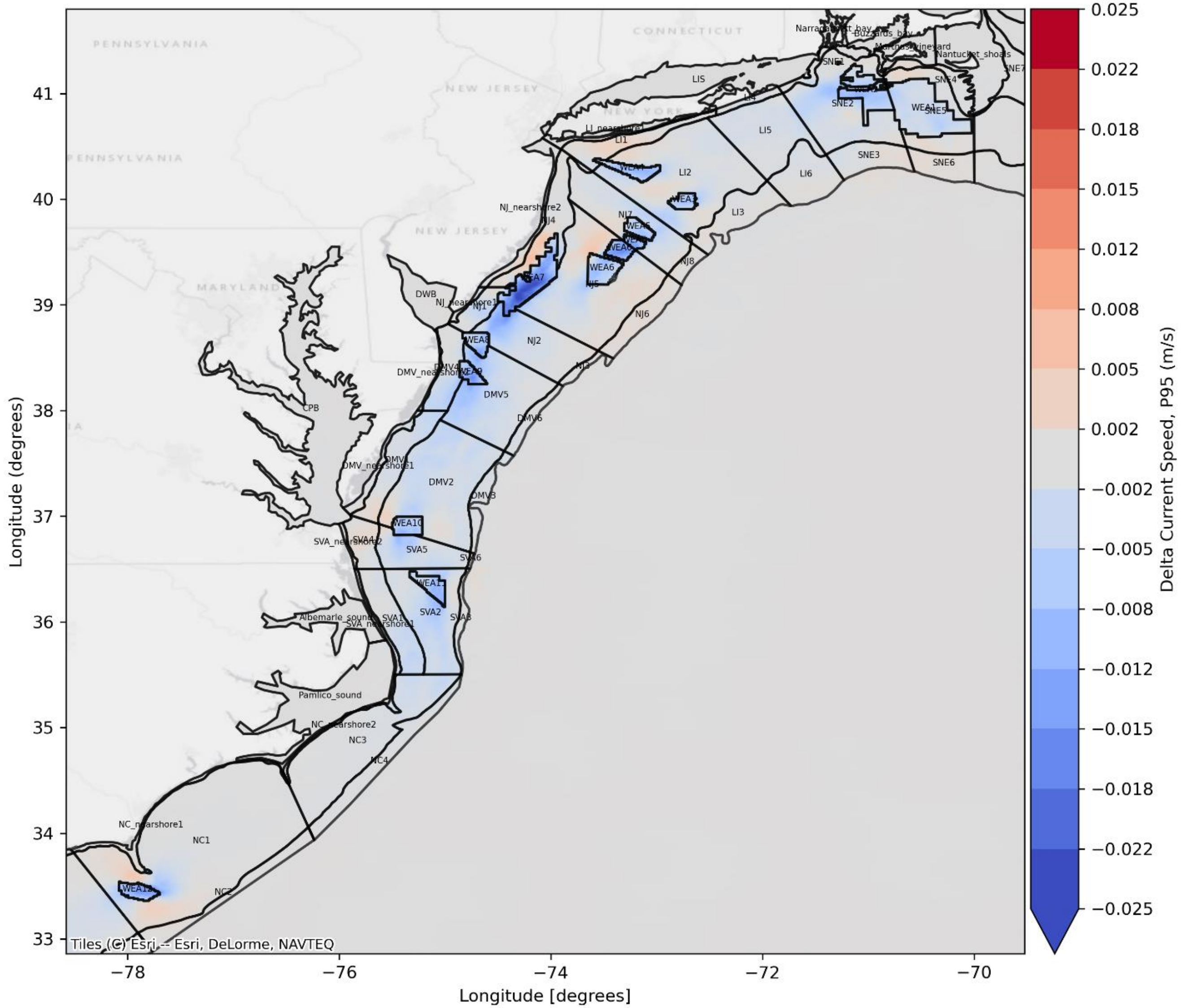
Sea scallop baseline settlement density (2017)



Sea scallop baseline settlement density with Essential Fish Habitat and available biomass data overlain

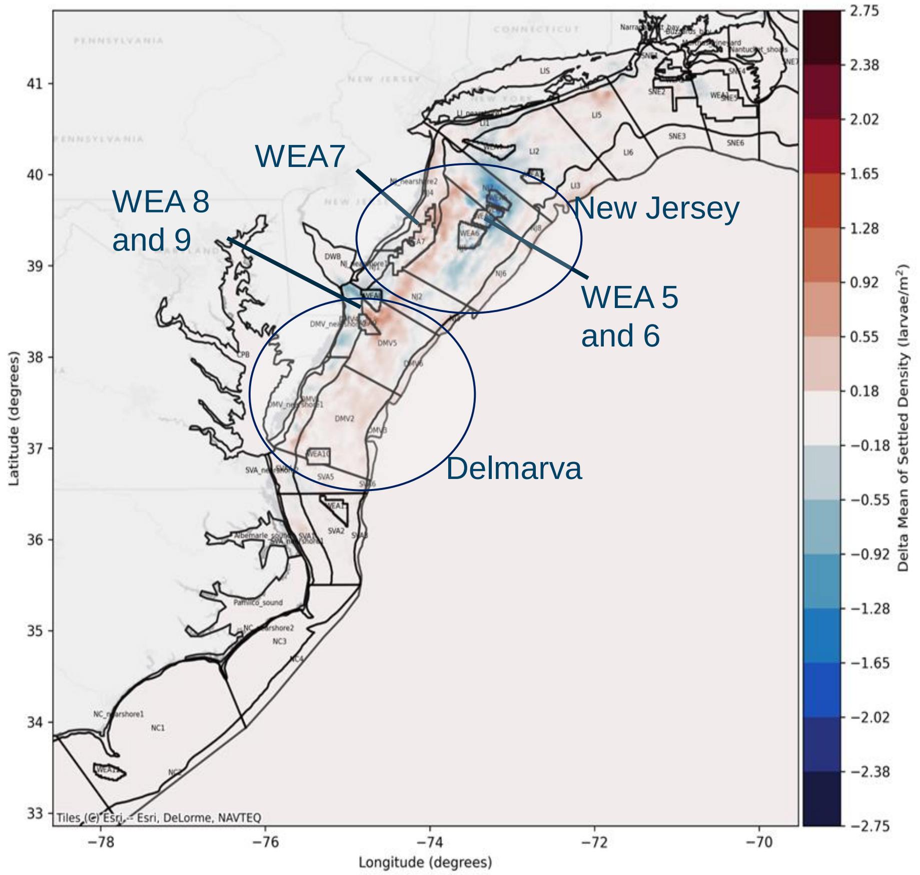
Changes in Current Speed Resulting from OSW

- There are clear changes in current speed resulting from the OSW ~ but these are no more than +/- 0.025m/s in the depth averaged currents.
- There **is no clear direct spatial correlation** between changes in larval settlement and areas of current speed increase/decrease, but changes in settlement do occur for all 3 species.

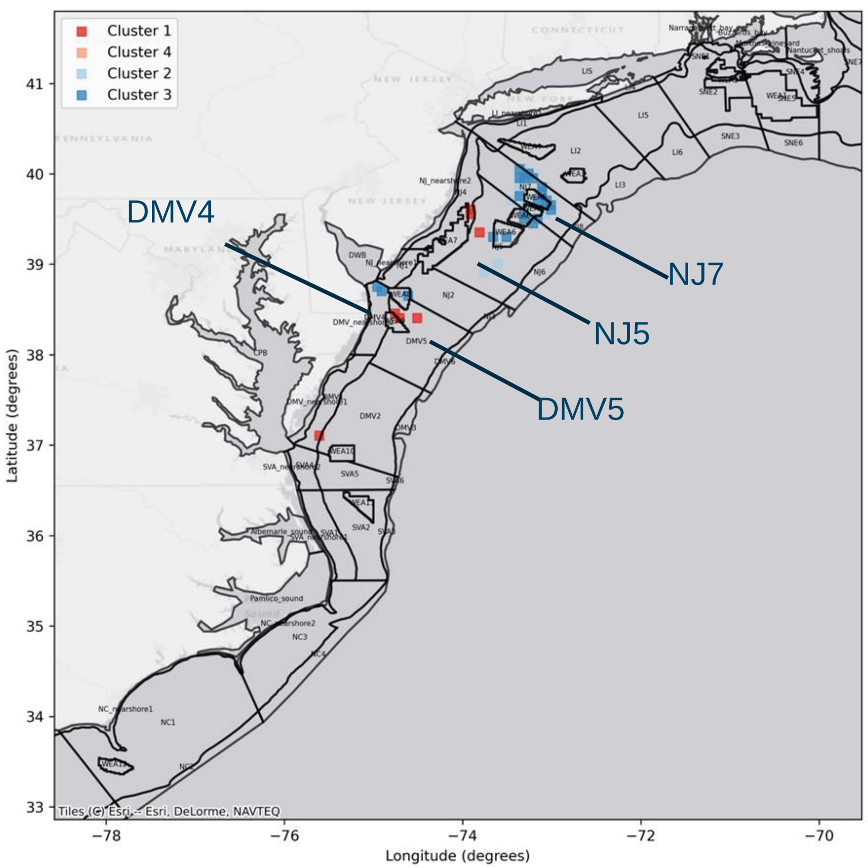


Change in Current Speed 15MW Full Build-Out vs Baseline 2017
Difference in the depth averaged current speed for model year 2017. Showing the difference in the 95th percentile baseline results and 95th percentile 15 MW full build-out results.

Sea Scallop Difference Plots: 15 MW Full Build-out Scenario for 2017



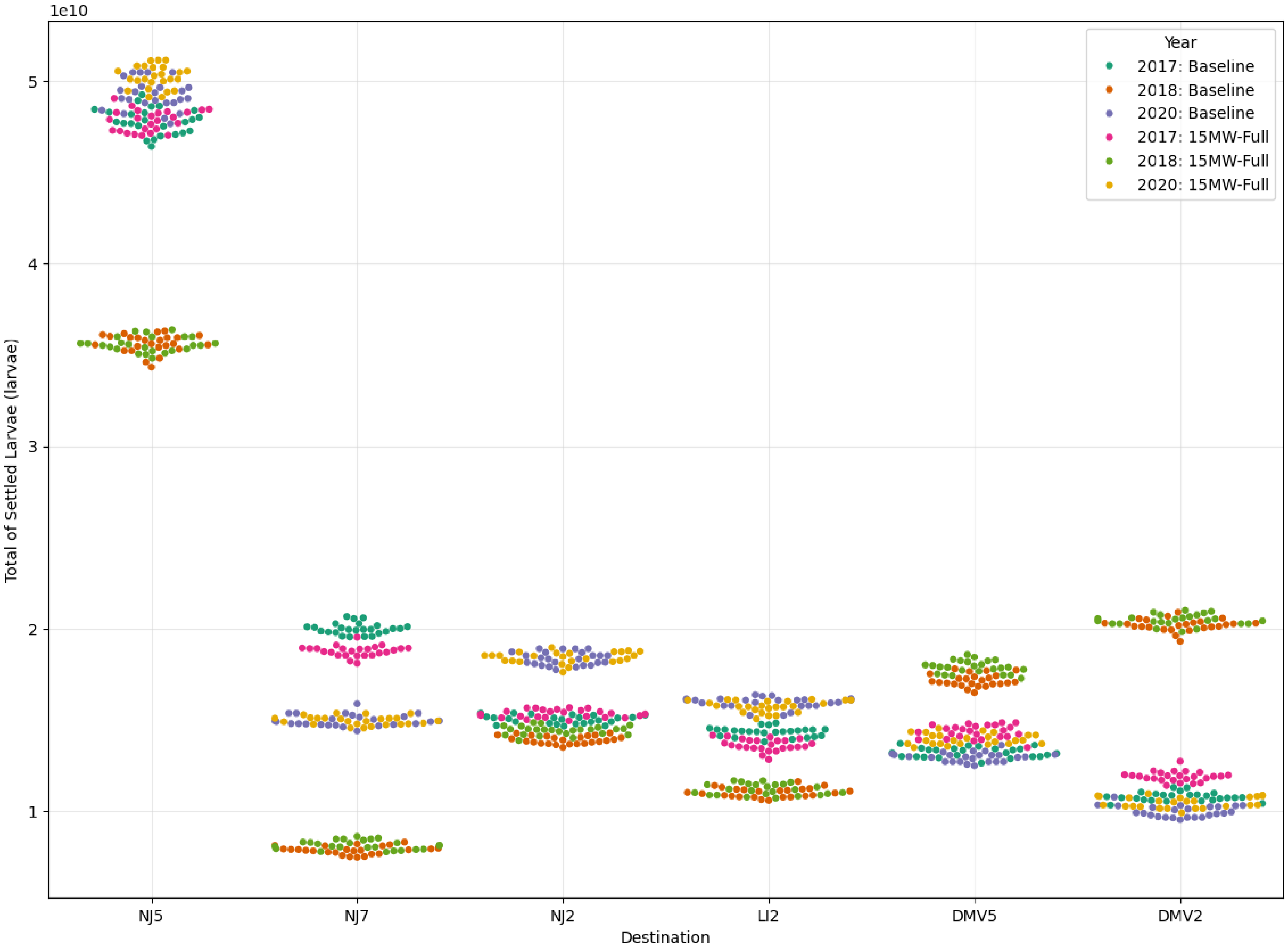
Difference in Settled Larvae Density 15MW Full Build-Out vs Baseline 2017
Difference in sea scallop settled larvae density for model year 2017. Showing the difference in the mean of all ensemble baseline results and mean of all ensemble 15 MW full build-out results. Settled larvae density averaged for each model grid element. Red shows an increase in settlement in the 15 MW scenario compared to the baseline, blue shows a decrease in settlement compared to the baseline.



DBSCAN (Density-Based Spatial Clustering of Applications with Noise) Difference in Settled Larvae Density15MW Full Build-Out vs Baseline 2017
Spatial clusters identified using DBSCAN to filter out noise from the difference plot and identify areas of greatest change. Clusters of settlement increase are identified in red and clusters with settlement decrease are shown in blue.

- Changes in settlement (both decrease and increase) are **concentrated in the New Jersey and Delaware-Maryland-Virginia (Delmarva)** regions and extend **beyond the Wind Energy Areas (WEAs)**.
- **Decrease** in settlement found in and around **WEAs 5 and 6 to the North of the New Jersey region**, and **along the coast of Delaware near WEA 8 and 9.**
- Average changes in sea scallop settlement (decrease and increase) per destination area are **four orders of magnitude lower** than total settlement.

Sea Scallop Swarm Plot - Baseline and 15 MW Full Build-out (2017, 2018 and 2020)



- There is inter-annual variability between 2017, 2018 and 2020 years with **slightly different hotspots** of increase or decrease within New Jersey,
- **The overall patterns are the same** (i.e., changes found mainly in New Jersey, same order of magnitude, around the same WEAs and areas).

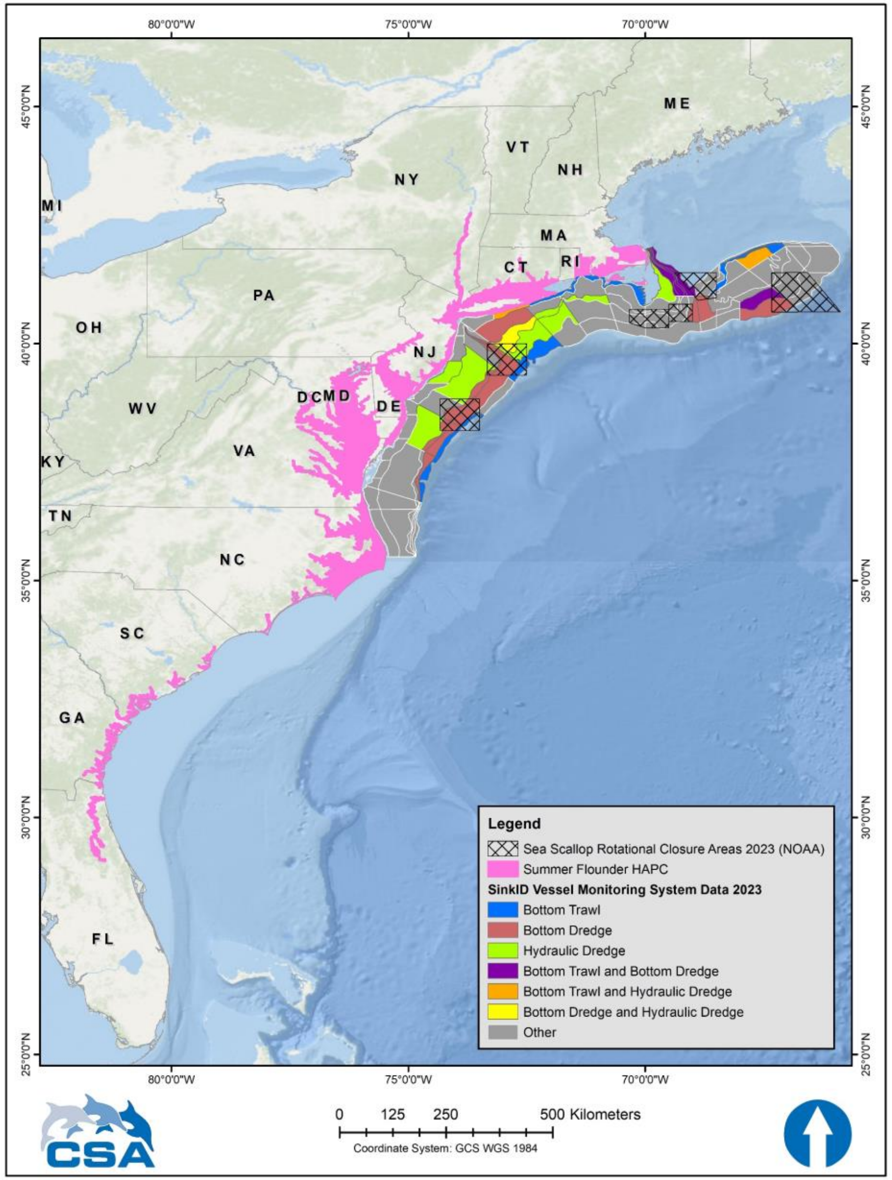
Summary

- Sea Scallop settlement changes occur primarily in the **New Jersey region** and extend **through Delmarva.**
- Average changes in settlement per destination area for Sea Scallop are **four orders of magnitude (10^4) lower** than total settlement
- There is inter-annual variability between 2017, 2018 and 2020 years with **slightly different hotspots** of increase or decrease but **The overall patterns are the same**

Conclusions and Relevance of OSW Farm Related Changes

Conclusions and Relevance

- Hotspots of change are identified in areas where there are harvest efforts
- Over the entire modeling domain these differences are small but persistent (over the life of the projects, about 30 years)
- It is noted that **settlement does not necessarily equal recruitment**
- It is **not likely** that the modeled changes in settlement **will lead to measurable declines in the landings of sea scallops** over the region
- However, spatial persistence of the change **may be relevant to local scale patches** of sea scallops and any local fisheries they may support.



Recommendations for further study

Recommendations for Further Study

Localized analyses:

- Develop area and species-specific impact **threshold limits** for acceptability of changes in larvae settlement
- Extend the ABM analyses for **juvenile stages** of target species development

Use/collect dedicated local observational data / knowledge plus localized and more temporally refined ABM result post-processing for:

- Sea Scallop - New Jersey / Delmarva areas to better understand conditions causing the observed changes .
- Monitoring/surveys could be focused in the **hotspot areas** identified in this study

Inclusion of the artificial reef effect

- Monopiles and their scour protection armor may act as a suitable habitat for certain species

Acknowledgements

Acknowledgements

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- More than 80% of commissioned offshore wind farms include DHI input (excluding the Peoples Republic of China).
- DHI methods, data and ecological modelling tools allow identification of potential impacts early and throughout the project cycle to ease approval processes and reduce scheduling and investment risks.

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