Environmental Studies Program: Ongoing Study

Field	Study Information
Title	Offshore Wind Farm Impacts on Pacific Upwelling, Nutrients, and Productivity (NT-23-09)
Administered by	Office of Environmental Programs
BOEM Contact(s)	Thomas Kilpatrick (thomas.kilpatrick@boem.gov)
Procurement Type(s)	Interagency Agreement
Conducting Organization(s)	NOAA Southwest Fisheries Science Center
Total BOEM Cost	$500,000
Performance Period	FY 2023–2025
Final Report Due	August 13, 2025
Date Revised	October 25, 2023
Problem	The California Current is a highly productive Eastern Boundary Upwelling System (EBUS). A recent modeling study indicates that offshore wind farms planned for the Pacific coast may have a modest impact on upwelling and nutrient supply, raising stakeholder concerns about offshore wind impacts to the California Current ecosystem.
Intervention	A coupled hydrodynamic-biogeochemical modeling study is proposed to evaluate the impact of proposed offshore wind farms on biogeochemistry, including primary productivity, in the California Current region.
Comparison	Analyses of model outputs will be compared to a control simulation without wind turbines and associated wind wakes, in the context of the strong interannual and decadal variability (i.e., El Nino cycle and climate change) in the California Current EBUS.
Outcome	The study will provide BOEM with: quantitative estimates of the impacts of proposed offshore wind farms on California Current productivity, necessary for future NEPA analyses; and information to guide future Pacific coastal monitoring efforts.
Context	Pacific

BOEM Information Need(s): To support the sustainable development of offshore wind (OSW) farms over the Pacific Outer Continental Shelf (OCS), BOEM must be able to estimate environmental impacts. The strong wind resource of the Pacific OCS drives coastal upwelling and a highly productive marine ecosystem. The modeling experiments proposed here would help BOEM estimate OSW farm impacts on primary productivity (which supports fisheries, seabirds, and marine mammals); assure stakeholders; and guide discussion of potential mitigations.

Background: The federal government and state of California have both set ambitious goals for renewable energy development, including OSW farms. BOEM needs to assess the environmental impacts of OSW farms for energy planning and to make leasing and management decisions.

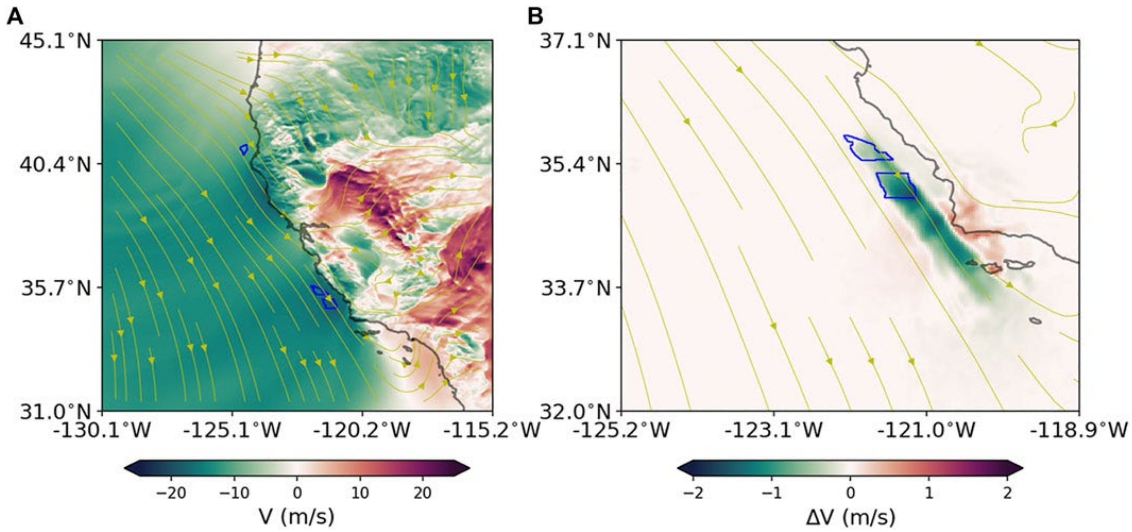

***Figure 1**. (A) Hub-height wind field on 15 Apr 2000; and (B) change in wind wake (green) due to one scenario of future wind farms. Note the O(1-2 m/s) wind speed reduction behind the Morro Bay wind energy area of interest, which would potentially reduce upwelling. From Raghukumar et al. (2022).*

OSW wind farms draw energy from the surface winds, thereby creating a "wake" of reduced wind speed (Raghukumar et al. 2022; Fig. 1). OSW farm structures will alter oceanic turbulence, and therefore vertical mixing, of currents flowing past the turbine structures (Dorrell et al. 2022). Both of these effects may alter local and regional ocean circulation enough to impact the marine ecosystem. Since OSW development is still in the nascent stage in the US, BOEM has relied on computer modeling experiments to assess OSW farm impacts to Mid-Atlantic ocean circulation and larval dispersal (Chen et al. 2016, Johnson et al. 2021).

The mid-Atlantic OCS is a different oceanographic regime from the Pacific OCS, which is an eastern boundary upwelling system, where equatorward winds drive upwelling of cool water and nutrients. These nutrients support a highly productive ecosystem. A recent study funded by the state of California has shown a modest reduction to upwelling near the Morro Bay wind energy area of interest (Raghukumar et al., 2023). This study has raised concerns among stakeholders about impacts to ocean biogeochemistry and marine life, which were not directly simulated in the experiments. That study also did not incorporate potential effects of the structure and cabling on turbulence and vertical mixing.

The study proposed here would therefore address an important knowledge gap for BOEM and the state of California, namely OSW farm impacts on biogeochemistry and the marine ecosystem. Results will help inform potential mitigations (if necessary).

Objectives: The primary objective of this study is to determine, via computer modeling experiments, the impacts of Pacific offshore wind farms on biogeochemistry, including nutrient availability and primary productivity, and therefore vulnerability of marine species.

Secondary objectives are to partner with the state of California, a vital partner for the buildout of Pacific offshore wind farms; and to support open-source modeling tools that will be portable to BOEM.

Methods: A regional computational modeling approach will be used. The spatial domain will cover the California OCS, inclusive of the Morro Bay and Humboldt wind lease areas. Experiments with simulated wind impacts from offshore wind farms (i.e., wind wakes, Fig. 1) will be compared to a control scenario without offshore wind farms. The model will simulate hydrodynamical and biogeochemical aspects of the California Current response to the wind farms.

One candidate model is the Regional Ocean Modeling System (ROMS), which has been used heavily to study the California Current System, including nutrient-phytoplankton-zooplankton-detritus (NPZD) dynamics. The recent California state-funded study, Raghukumar et al. (2023), has utilized ROMS for hydrodynamic modeling only (i.e., no NPZD biogeochemical modeling).

ROMS is open-source and has packages available to simulate NPZD biogeochemistry (Song et al. 2016), which will help answer the question of how OSW-induced upwelling changes will impact the marine ecosystem.

One goal of this study is to support open-source modeling tools, whether ROMS or an unstructured grid model such as FVCOM or Delft3D. Open-source means that the model codes are publicly available; BOEM would be able to re-run the model simulations internally in the future or provide the code base and model configuration to future vendors/contractors to build upon. Open-source modeling therefore provides greater value to the taxpayer, while aligning with the concept of Open Science, which aims to make the fruits of scientific investment available to the wider public (White House memo, 2022).

Specific Research Question(s):

1. Recent modeling experiments (Raghukumar et al., 2023) indicate offshore wind farms could result in a modest reduction in upwelling in the vicinity of wind energy areas of interest (e.g., Morro Bay). How will these changes in upwelling impact biogeochemistry, including nutrient availability and primary productivity?
2. What are the magnitude, spatial footprint, and seasonal expression of OSW farm-induced changes in biogeochemistry?
3. How does the magnitude of the simulated OSW farm-induced changes to biogeochemistry compare to the large interannual variability (Jacox et al. 2015) in this region? (Option: How does it compare to projected climate change scenarios?) Would OSW farm-induced changes to biogeochemistry be detectable given the large interannual variability in the northeast Pacific?
4. How can we optimize hydrodynamic and biogeochemical monitoring efforts around Pacific OSW farms to detect potential changes to upwelling?
5. How might potential mitigations, such as a reduced buildout (80%, 60%, etc.) or alternative siting, limit OSW farm impacts to biogeochemistry?

Current Status: Kickoff meeting was held 13 Oct 2023. Dr. Kilpatrick and BOEM Pacific office staff sent the research team updated information about realistic turbine layouts for the Humboldt and Morro Bay lease areas.

Publications Completed: None

Affiliated WWW Sites: Regional Ocean Modeling System (ROMS) web site: https://myroms.org

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White House memo on Multi-Agency Research & Development Priorities, 22 July 2022, https://www.whitehouse.gov/wp-content/uploads/2022/07/M-22-15.pdf