Fisheries Oceanography

WILEY

SPECIAL ISSUE ARTICLE OPEN ACCESS

Assessing Impacts of Offshore Wind Development: An Analysis of the Minimization of Economic Exposure of the Scallop Fishery Through the Regulatory Process

Marina Chaji[1] | Greg Ardini[2] | Melanie Harsch[3] | Alan Haynie[4] | Min-Yang Lee[2] | Bryce McManus[3] | Tammy Murphy[2] | Lisa Pfeiffer[5] | Eric Thunberg[6]

[1]ECS Federal, Fairfax, Virginia, USA | [2]Northeast Fisheries Science Center, NOAA Fisheries, Woods Hole, Massachusetts, USA | [3]Pacific States Marine Fisheries Commission, Portland, Oregon, USA | [4]International Council for the Exploration of the Sea (ICES), Copenhagen, Denmark | [5]Northwest Fisheries Science Center, NOAA Fisheries, Seattle, Washington, USA | [6]Office of Science and Technology, NOAA Fisheries, Silver Spring, Maryland, USA

Correspondence: Marina Chaji (marina.chaji@boem.gov)

Received: 5 April 2024 | **Revised:** 5 August 2024 | **Accepted:** 14 November 2024

Funding: Research Funding was provided by the National Oceanic and Atmospheric Administration, and publication funding was provided by the Bureau of Ocean Energy Management, https://doi.org/10.13039/100012475.

Keywords: development | fishery | impact | interaction | wind

ABSTRACT

Offshore wind energy has expanded as a source of clean energy in the United States since the first US offshore wind farm began operations off the coast of Rhode Island in 2016. The emergence of offshore wind has increased the need to manage ocean use across multiple stakeholder groups, a difficult and contentious process. We use 15 years of scallop (*Placopecten magellanicus*) fishery data to describe how offshore wind may expose one of the most valuable commercial fisheries in the United States to economic risks. Our analysis shows that the current configuration of approved offshore wind lease areas off the northeastern coast of the United States is expected to result in relatively small economic exposure for the scallop fishery. We also illustrate how the measured development process, which includes ample opportunity for stakeholder input, has mitigated exposure through *minimization* or *avoidance* by characterizing the change in impacted activity through two case studies. We find moderate to strong levels of exposure mitigation across our three scallop fleet métiers within the Central Atlantic (CA) region. In contrast, exposure mitigation was more variable in the New York Bight (NYB) region suggesting mitigation methods in the NYB are not as effective for the scallop fishery as the CA. The open development process that allowed for early stakeholder engagement has largely mitigated the potential for economic risk of offshore wind on the scallop industry by approving the siting of offshore wind development in less utilized or less productive scalloping areas.

1 | Introduction

Over 16 million acres of the ocean within the United States territorial waters are designated as Offshore Wind Planning Areas, and over 2.2 million acres have been leased and are close to construction (as of Aug 2023, Bureau of Ocean Energy Management 2023a). The pace of offshore wind lease issuance within the Northeastern United States has increased markedly over the last 15 years (Figure 1[1]) and is expected to grow to meet the Biden administration's offshore wind energy goal of 30 gigawatts of capacity by 2030 (The White House Briefing Room 2022). Offshore wind developers would prefer to site wind turbines in locations that supply energy to the grid at comparatively lower costs. In the Northeastern United States, these locations are close to the coast in relatively shallow water, with other site-specific conditions like water depth, seabed geology, and

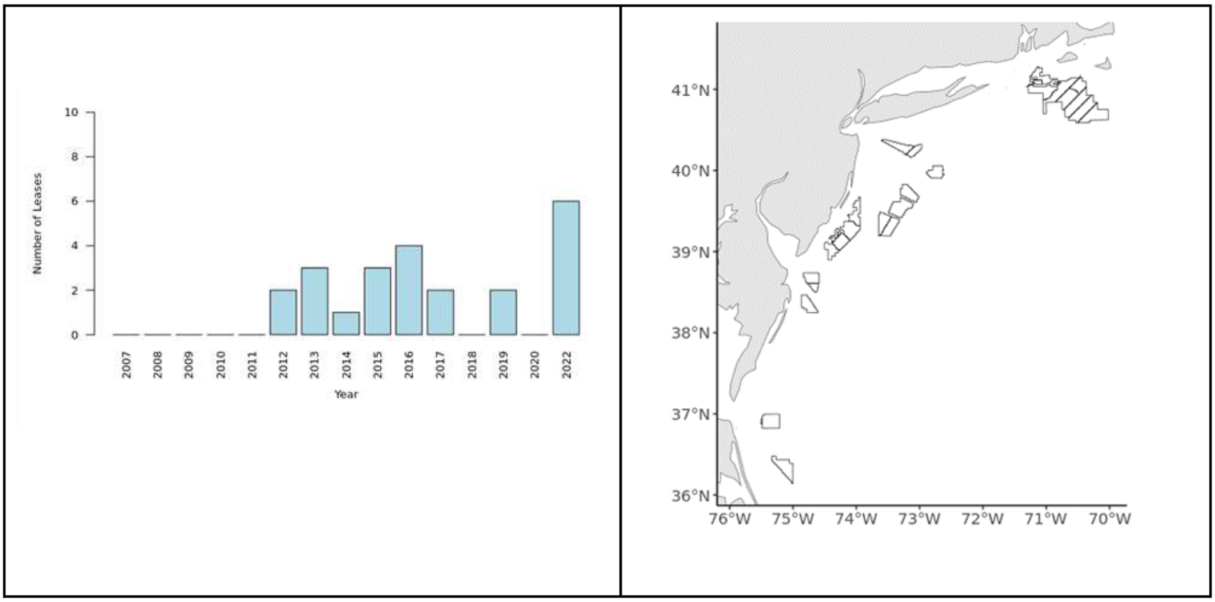

FIGURE 1 | Number of new offshore wind lease areas approved and location within federal waters of the northeast region of the United States.

wave loading that are conducive to turbine placement. Other users of ocean resources, like the fishing industry, would prefer siting in areas of the ocean that they do not use. These preferences will inevitably conflict.

The Outer Continental Shelf Lands Act (OSCLA) and the National Environmental Policy Act (NEPA) establish the basis for a deliberative and consultative process for the Bureau of Ocean Energy Management (BOEM) to balance multiple interests, including those of the fishing industry, environmental sustainability, and the technical and economic feasibility of offshore wind. This involves learning about and mitigating the impacts of proposed wind areas on the human environment to achieve environmentally preferred outcomes. Stakeholder input in this process is important and there are many reasons why policy should be responsive to stakeholder input. First, a high-quality process that integrates information and preferences from a wide range of impacted stakeholders should lead to more informed decision-making. This consequentialist utilitarian philosophy is at the heart of the 91st Congress's intention to “use all practicable means and measures … in a measure calculated to foster and promote the general welfare” (National Environmental Policy Act 1970). Second, a transparent and inclusive process can increase the perception of decisions as legitimate, increasing the regulatory buy-in necessary for effective ocean and coastal management (Hannah 1995, 1999). These two reasons are “narrow,” “consequentialist” views of good governance: good governance promotes good outcomes. A third reason is that a procedurally just process for collective decision-making can directly affect the well-being of people (Hahn 1982; Sen 1997; Dolan et al. 2007). Dolan et al. (2007) shows that processes that are accurate, consistent, and give meaningful voice to stakeholders are valued.

This research investigates how the development of offshore wind in the Northeastern United States may impact the economically and culturally important Atlantic Sea scallop fishery (NOAA Fisheries 2021) by analyzing economic exposure. Economic exposure, henceforth referred to as exposure, refers to the potential risks and vulnerabilities that the scallop fishery faces due to changes in valuation metrics as a result of offshore wind development. There are two ways that adverse impacts on the scallop fishery from wind development can be mitigated during the siting process. First, regulators could *avoid* impacts on the scallop fishery by removing all or part of an area from consideration. Second, impacts can be minimized by siting wind farms in less productive areas where revenues, landings, or operating profits are lower. We use 15 years (2007–2021) of fishery catch, revenue, cost, and location data to characterize impacts among three distinct métiers. Each of the three métiers, limited access (LA)–days at sea (LA-DAS), LA–access area (LA-AA), and general category–individual fishing quota (GC-IFQ), has a unique management structure. Five key metrics are used to characterize exposure: trips, ex-vessel scallop revenue, scallop landings, operating profit, and revenue per day. We characterize economic exposure to each fishery métier from approved lease areas in the Northeastern United States and find that a relatively small amount of the scallop fishery occurs in the lease areas.

Furthermore, we evaluate two case studies of the offshore wind regulatory approval process in the New York Bight (NYB) and Central Atlantic (CA) regions to illustrate how exposure is minimized as a result. We find that the regulatory process mitigated the exposure of the three métiers in different ways. In the NYB, the regulatory process removed areas that were relatively close to shore, which resulted in a disproportionately large (relative to the reduction size of the wind development areas) reduction in impacted trips on the nearshore GC-IFQ scallop métier. In contrast, in the CA, the regulatory process to date has removed areas that were further from shore: The GC-IFQ métier saw a disproportionately smaller reduction in impacted trips, whereas the LA métiers saw a disproportionately larger one.

2 | Setting

2.1 | Offshore Wind Development Process in the United States

BOEM informs and advises developers on how to efficiently develop energy while protecting ocean resources. This process entails environmental analysis, stakeholder engagement, and technical review for all renewable energy developments in the United States' Outer Continental Shelf (OCS). A wide range of criteria is used to determine whether to approve offshore wind areas, including geographical, biological, and socioeconomic factors. Design and engineering dependencies, including water depth, seabed geology, wave loading, wind speeds, and ocean floor depths, are also important (BOEM 2023b).

The leasing process consists of four mandatory phases necessary for the development of an offshore wind farm: (1) planning and analysis, (2) leasing, (3) site assessment, and (4) construction and operations (Figure 2). During the planning and analysis phase, potential wind development areas are identified by BOEM through three mandatory and two optional steps (Figure 3). BOEM may optionally designate planning areas and request for information areas. Call areas are identified as locations potentially suitable for offshore wind. After gauging developer commercial interest and public input, BOEM designates the high-potential parts of the call areas as wind energy areas (WEAs). BOEM further refines the WEAs to lease areas if all needs in environmental assessments for lease issuance and site assessment activities are met.

In addition to OCSLA, NEPA shapes the planning and development process.[2] One requirement of NEPA is that federal agencies must assess the environmental impacts of their proposed action(s). These impacts include ecological, aesthetic, historic, cultural, economic, social, or health effects, whether direct, indirect, or cumulative, prior to decision-making (Protection of Environment 2020). With this information, well-informed decisions about the appropriate measures to mitigate adverse impacts can be made (Table 1). When adverse impacts cannot be further reduced, developers of offshore wind may compensate firms for reductions in fishing revenues and increases in costs due to wind siting. Understanding the levels and distribution of these impacts is important to ensure the compensation systems are fair and equitable.

The potential impacts of offshore wind are wide-ranging (Methratta et al. 2020). Offshore wind structures may act as fish aggregating devices, altering ecosystems, stocks, and catch rates (Hogan et al. 2023). Development may affect commercial and recreational fishing, fishing-related businesses, tourism, and housing prices (Smythe et al. 2020). There may also be changes to fishing and coastal community values, dependence, attitudes, perceptions, and stakeholder engagement (Hogan et al. 2023).

The increase in offshore wind development has provided a need to further understand possible impacts on other ocean users (Tsai et al. 2022; Haggett et al. 2020; Gill et al. 2020; Methratta et al. 2020), including fisheries within the northeastern region

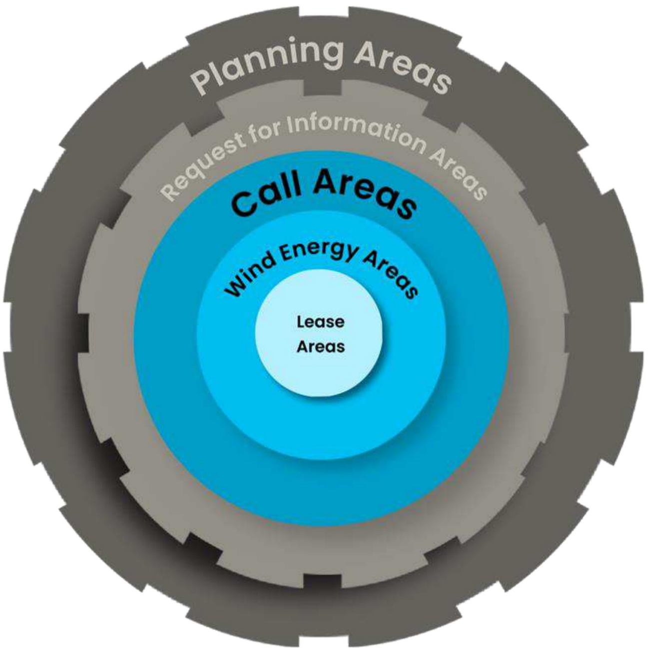

FIGURE 3 | Comparison of the relative potential wind development areas for each decision-making phase defined by BOEM. Notches in a circle represent a step that is not mandatory in the BOEM process.

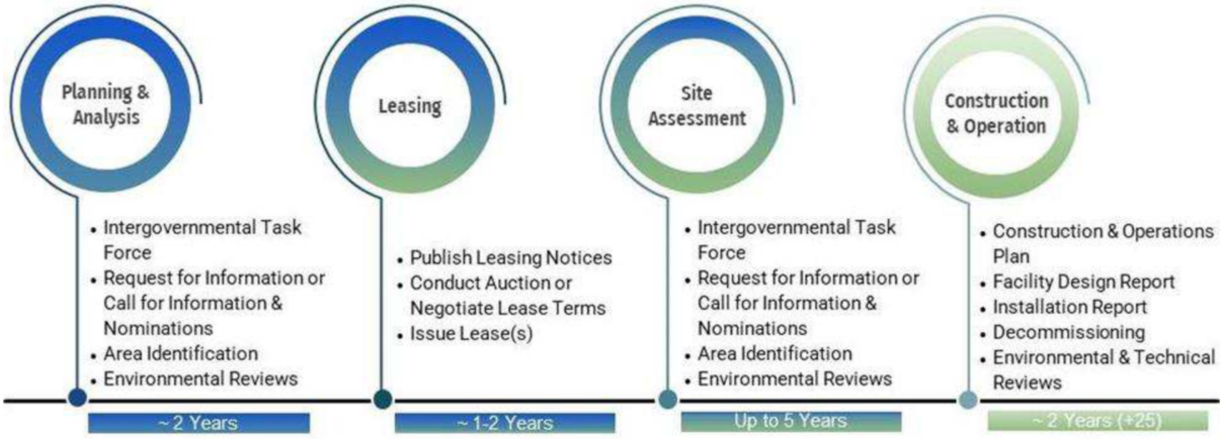

FIGURE 2 | BOEM regulatory roadmap for offshore wind development.

of the United States (Kirkpatrick et al. 2017; Munroe et al. 2022; Hogan et al. 2023). For example, the participants in the Atlantic clam fishery are expected to earn less revenue and relocate to less profitable areas (Scheld et al. 2022) in response to wind energy development. Impacts may vary by user group, for example, pilings for wind turbines create structure and can aggregate fish, leading to improved outcomes for the recreational sector (Hooper, Beaumont, and Hattam 2017; ten Brink and Dalton 2018; Smythe, Bidwell, and Tyler 2021). New offshore wind projects are expected to create notable challenges for commercial fisheries including disruptions to fishing operations (ten Brink and Dalton 2018), increased competition for fishery resources among vessel operators, heightened navigation risk, congestion, and higher operating costs (Hogan et al. 2023).

TABLE 1 | Forms of mitigation as defined under NEPA (Protection of Environment 2020).

Forms of mitigation	
Mitigation type	**Definition**
Avoid	Avoiding impact(s) altogether by not taking a certain action or parts of an action
Minimize	Minimizing impact(s) by limiting the degree or magnitude of the action and its implementation
Rectify	Rectifying the impact by repairing, rehabilitating, or restoring the affected environment
Reduce	Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action
Compensate	Compensating for the impact by replacing or providing substitute resources or environments

Case studies of the planning and analysis phase in the NYB and CA provide a way to understand how BOEM used stakeholder and cooperating agency input to shape areas considered for the development of offshore wind, creating knock-on effects that can mitigate potential impacts of wind development on the fishing industry by assessing exposure. Wind development in the NYB region has moved through all three steps, from call areas to WEAs and finally lease areas (Figure 4). The NYB call areas covered 1,733,470 acres and the final lease areas covered 487,843, which is just 28% of the size of the call areas. Wind development in the CA region has only progressed through the first two steps (Figure 5). The CA call areas covered 4.7M acres and the WEA covers 350,000 acres, which is just 8% of the size of the CA call areas.

2.2 | Scallops and the Scallop Fishery

Fishing is culturally and economically important in many communities in the Northeastern United States. Cod and other groundfish have been targeted in New England waters for over 400 years (Kurlansky 1998), and the colorful lobster buoys of Maine's iconic lobster fishery can be found along much of the state's coastline. A few hundred kilometers south, the Atlantic Sea scallop fishery is one of the most valuable commercial fisheries in the United States, with ex-vessel revenues exceeding $500 million (2021 USD) per year (NEFMC 2023). Sustained fishery value has been driven by healthy stock biomass (NEFSC 2018), management efforts,

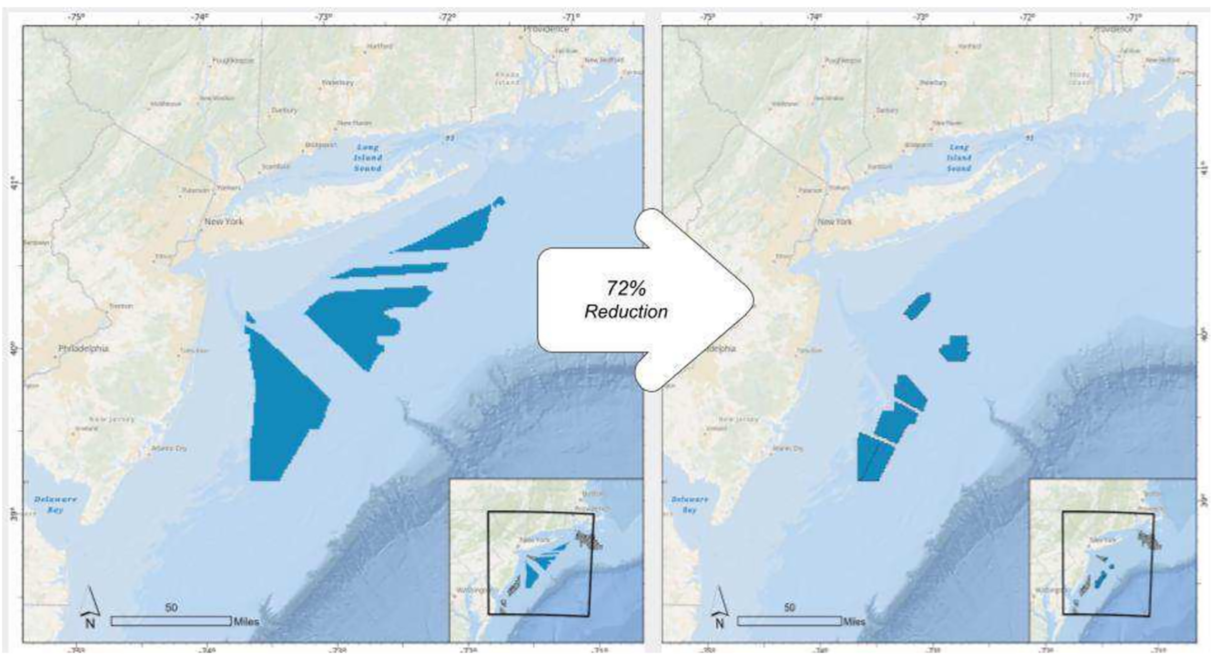

FIGURE 4 | Map of New York Bight call areas and lease areas. The New York Bight (NYB) mitigation phase consists of trips that take place within the bounds of NYB call areas but not within lease areas.

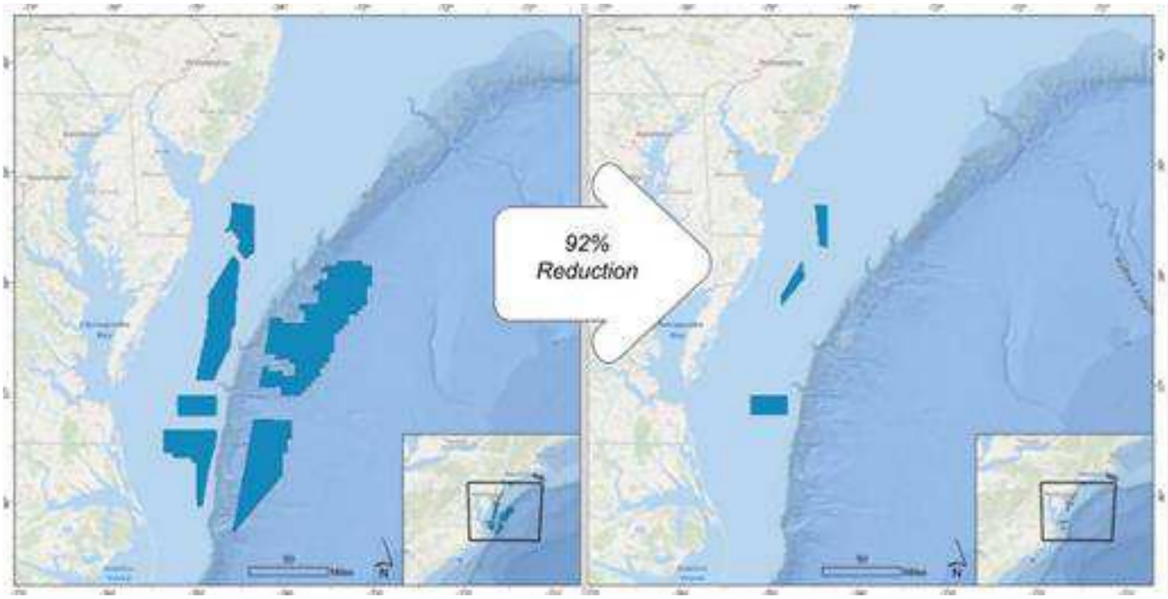

FIGURE 5 | Map of Central Atlantic (CA) call areas and wind energy areas. The Central Atlantic mitigation phase consists of trips that take place within the bounds of CA call areas but not within wind energy areas (WEAs).

and high ex-vessel prices (NEFMC 2023). Large scallops receive a significant price premium relative to smaller scallops (Ardini and Lee 2018), and the success of the access area management system, in which portions of the ocean are closed to scallop fishing to allow scallops to grow to large sizes, has greatly increased the profitability of the fishery (Walden, Lee, and O'Donnell 2021).

Scallops are found at depths of 18–110 m and have historically been caught in two areas: Georges Bank, which lies east of Massachusetts, and the Mid-Atlantic Bight, which extends from southern Massachusetts to Virginia. Climate change is expected to negatively impact the scallop resources in these two regions. Suitable habitat is likely to shift northward and contract in Georges Bank and the Mid-Atlantic Bight (Tanaka et al. 2020). Warmer bottom temperature (Zang et al. 2023) and ocean acidification (Rheuban et al. 2018) are expected to reduce the productivity of the scallop resource. Wind development may directly alter bivalve habitats (Lindeboom et al. 2011), larval dispersal, and larval settlement (Chen et al. 2024).

The scallop fishery has been managed by the New England Fishery Management Council (NEFMC) under the Atlantic Sea Scallop Fishery Management Plan (FMP) since 1982. The New Bedford dredge is commonly used to harvest scallops (NOAA Fisheries 2018); however, a small number of vessels use bottom trawls. The fishery has been divided into two components since 1994, when most of the fishery transitioned to LA based on historical landings. Fishing efforts by LA vessels have been primarily managed through nontransferrable limits on days at sea (DAS) and limits on crew and gear. Because the user rights are nontransferrable, the number of active LA vessels has been relatively constant over time. Taking advantage of the high growth rates of Atlantic Sea scallops, the NEFMC initiated area-based management in 1999, which was formalized in 2004 with Amendment 10 to the Scallop Fishery Management Plan. Amendment 10 also increased the minimum dredge ring size to 4 in., improving selectivity for large scallops and reducing contact time with the ocean floor through improved catch efficiency. Areas with a high abundance of small scallops are closed until those scallops grow, at which time the access areas are opened to fishing. Upon opening, LA vessels are allocated trips to access areas. At the start of a scallop trip, vessel operators must declare into either a DAS or AA trip. When fishing in an access area, LA vessels are subject to a possession limit on scallops; these limits are not applicable on DAS trips. These relatively large (80–100 ft in length) vessels typically take long, multi-day trips and are responsible for the vast majority (~95%) of scallop landings. These vessels derive nearly all of their fishing revenues from the scallop fishery (Kitts et al. 2020). We treat vessels fishing on LA-DAS and LA-AA trips as distinct métiers because they are subject to different regulations, face different incentives, and operate in different areas of the ocean.

Our third métier is the GC-IFQ. Vessels that did not qualify for an LA permit could obtain an open-access general category (GC) permit. From 1994 to 2007, the GC portion of the scallop fishery was open access and managed primarily through trip limits. The GC fishery expanded from less than 5% to 10% of overall landings. Wanting to stave off further increases, managers imposed Limited Access and quickly transitioned the fishery from quarterly fleet-level quotas (2008–2009) to individual fishing quota (IFQ) in 2010. The total allocation for the GC-IFQ fleet was set at 5% of the projected total annual scallop landings. A possession limit of 400 lbs of scallop meats was set; this limit was increased to 600 lbs in 2011. The vessels in the GC-IFQ métier are typically smaller in size and take shorter, nearshore trips. These trips are typically up to 2 days in duration although our findings show they are usually under 24 h. Because quota is transferable, the number of active vessels had declined over time. The GC-IFQ fleet is more diversified in terms of species-level fishing revenue compared to the LA fleet (Kitts et al. 2020).

3 | Data and Methods

The primary data used in our analysis is a comprehensive dataset maintained by the Greater Atlantic Regional Fisheries Office that combines information on the location fished, gear used, landings, revenue, and a pretrip declaration of the type of trip from a collection of primary sources. We include data from scallop fishing years 2007–2021, covering March 2007 through March 2022.[3] Fishing vessel operators file one vessel trip report (VTR) per combination of statistical area (Figure 6) and gear fished on a trip. Over 95% of LA and 99% of GC-IFQ trips in our dataset contain only one VTR record; for trips with multiple VTR records, we use the coordinates (latitude and longitude) corresponding to the record with the plurality of scallop revenue. We use the pretrip declaration to assign records to one of the three métiers and our dataset contains approximately 108,000 GC-IFQ, 26,600 LA-AA, and 19,000 LA-DAS trips. Trips are mapped and added to an overlay of shapefiles using the sf package in R (Pebesma 2018). These publicly available shapefiles contain polygons corresponding to call areas, WEAs, and lease areas.[4]

Using the raw spatial data in the VTRs implicitly allocates all fishing effort to a single location, introducing two types of errors. Some trips may spend part of their time fishing inside an area, but all of the trip's fishing effort is classified as outside of the area. Conversely, some trips may spend part of their time fishing outside an area, but all of the trip's fishing effort is classified as inside the polygon. An alternative source of spatial data comes from models that allocate effort. Palmer and Wigley (2009) and Muench, DePiper, and Demarest (2017) illustrate how to classify VMS polls as fishing or not fishing, although it is unclear how to allocate catch or revenue. DePiper (2014) and Benjamin, Lee, and DePiper (2018) use the output of a statistical model to probabilistically assign effort over space based on the distance between VTR points and observer hauls. Because this model does not account for directionality, the true geographic extent of fishing is typically overestimated. Allen-Jacobson et al. (2023) test and validate a solution for a pelagic fishery using extremely high-frequency data, but such data does not exist for the scallop fishery, precluding our use of this method.

We use five metrics measuring exposure to understand the potential effects of wind energy generation on the scallop fishery: the number of trips, landings per trip, scallop revenue per trip, operating profit per trip, and revenue per day (Table 2). Trips are simply the number of trips inside a particular set of polygons at each relevant point of the decision-making process. We apply an unpaired, two-tailed *t*-test to four of our metrics to determine whether fishing inside each corresponding

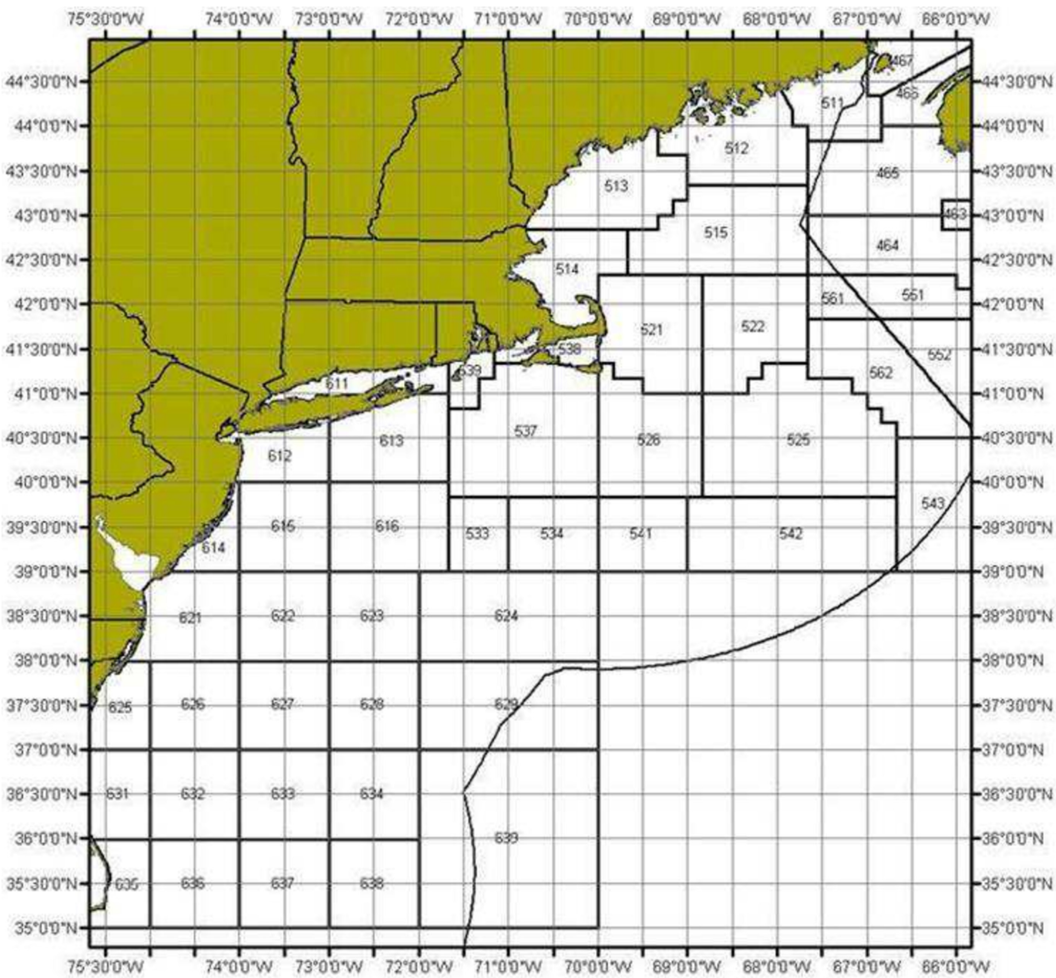

FIGURE 6 | Northeastern United States statistical areas. From NOAA Fisheries (2023) accessed December 18, 2023.

TABLE 2 | Summary statistics for scallop trips, revenue, landings, operating profit, and revenue per day including totals, averages, and standard deviations across LA-AA ($n = 26,595$), LA-DAS ($n = 19,092$), and GC-IFQ ($n = 107,846$) métiers.

	Totals			Averages (st. dev.)		
Métier	GC-IFQ	LA-DAS	LA-AA	GC-IFQ	LA-DAS	LA-AA
Trip length (days at sea)	91,516	164,292	180,228	0.85	8.61	6.78
				(0.49)	(3.72)	(2.8)
Scallop Revenue	$569M	$3924M	$3967M	$5273	$205,510	$149,166
				(2816)	(137,313)	(73,941)
Landed pounds	46M	327M	343M	427	17,126	12,887
				(168)	*(10,900)*	*(5794)*
Operating profit	$481M	$3723M	$3729M	$4459	$195,027	$140,211
				(3313)	*(145,744)*	*(81,042)*
Revenue per day	N/A	N/A	N/A	$7237	$22,887	$22,737
				(4537)	*(11,785)*	*(11,005)*

TABLE 3 | Scallop trips, average scallop revenue, average landings, average operating profit, and average revenue per day across LA-AA, LA-DAS, and GC-IFQ métiers.

Métier	Area designation	Number of trips	Average scallop revenue per trip	Average landed pounds per trip	Average operating profit per trip	Average revenue per day
LA-AA	Inside lease areas	73	$121,177***	10,788***	120,313*	$19,020***
LA-AA	Outside lease areas	26,522	$149,243	12,892	$140,266	$22,747
LA-DAS	Inside lease areas	1374	$196,618***	18,021***	$182,322***	$21,060***
LA-DAS	Outside lease areas	17,718	206,200	17,057	$196,012	$23,028
GC-IFQ	Inside lease areas	6605	$5762***	458***	$4410	$6640***
GC-IFQ	Outside lease areas	101,241	$5421	425	$4462	$7276

*,
**, and
***represent the rejection of the null hypothesis that the metric in the inside lease areas is equal to the corresponding metric in the subsequent row at the 10%, 5%, and 1% confidence levels, respectively. Averages computed over trips.

mitigation phase is statistically different from trips inside wind development areas. Landings are the weight of scallops, in meat pounds, corresponding to those trips. Scallop revenues are gross receipts derived from scallop landings. Operating profits are gross receipts (from all species) minus variable operating costs. Variable operating costs are predicted at the trip level using the econometric models in Werner et al. (2020) and are winsorized at the first and 99th percentiles by gear group. Revenue per day is calculated by dividing gross revenues (from all species caught) by the length of the trip in days. All economic values were normalized to the second quarter of 2022 using the GDP Implicit Price Deflator.[5] To ensure data is not affected by outliers, the revenue, landings, and revenue per trip for each métier were winsorized at the first and 99th percentiles. We calculate these metrics aggregated over all of the approved lease areas in the northeastern region (Figure 1) for each of the GC-IFQ, the LA-DAS, and LA-AA métiers.

For our case studies of the regulatory process, we also compute our metrics at different phases in the offshore wind decision-making process (Figure 3). These phases correspond to discrete checkpoints in the regulatory process in the CA and NYB regions. We introduce mitigation phases that represent specific steps in the decision-making process (Figure 3). The mitigation phases represent 1. Trips inside call areas but not inside a WEA and 2. Trips inside call areas but not inside lease areas. In the NY Bight, we compute our metrics for the call areas, lease areas, and a mitigation phase. In the CA, we compute these metrics for the call areas, WEAs, and a mitigation phase; lease areas have not been announced for the CA. If the regulatory process is effective at avoiding impacts on a métier, we expect the number of trips that remain impacted by wind to decrease faster than the size of the areas themselves. If the regulatory process is effective at minimizing the impacts of offshore wind on a métier, we expect the trips located in the mitigation phase to be more productive than trips impacted by a wind area. We apply an unpaired, two-tailed *t*-test to our four metrics to determine whether fishing inside each corresponding mitigation phase is statistically different from trips inside potential offshore wind areas.

4 | Results

4.1 | Scallop Fishing in the Wind Lease Areas in the Northeastern United States

We find minimal overlap between the scallop fishery and the approved offshore wind lease areas. For the GC-IFQ métier, 6% of trips (6605) and scallop revenues are inside the lease areas. Mean scallop revenues and landings from trips inside the lease areas are slightly higher than outside the lease areas at conventional significance levels (Table 3). However, mean revenue per day inside the lease areas is slightly lower.

We find almost no overlap between the access area métier and the lease areas. Just 73 trips in our dataset, representing well under 1% of LA-AA trips and LA-AA scallop revenue, are inside the lease areas (Table 3). In general, LA-AA trips inside the lease areas are less productive than trips outside the lease areas: mean values of revenue, landed pounds, and revenue per day are lower inside the lease areas than outside at conventional significance levels.

We find a bit more overlap between trips within the LA-DAS métier and lease areas with 1374 trips, representing 7% of all LA-DAS trips and scallop revenue, inside the lease areas (Table 3). In general, LA-DAS trips inside the lease areas are slightly less productive than trips outside the lease areas: mean values of revenue, operating profit, and revenue per day are lower inside the lease areas than outside at conventional significance levels. However, mean landed pounds inside the lease areas is slightly higher. This is broadly consistent with the findings from the LA-AA trips.

4.2 | The Adaptive Wind Development Processes

4.2.1 | New York Bight

As the development process in the NYB progressed from call areas to lease areas, the footprint considered for wind development shrunk substantially, the NYB lease areas are 28% of the size of the call areas (Figure 5). The wind development process in the NYB area resulted in lease areas that were further from the coast.

Nearly 20% (19,781) of all trips taken by the GC-IFQ métier were inside the NYB call areas, a relatively inshore location accessible to the smaller fishing vessels in this métier. The number of impacted trips and scallop revenue decreased disproportionately: Just 21% of GC-IFQ trips and 24% of GC-IFQ scallop revenue that were contained in the call areas are found in the lease areas. For two of our metrics (scallop revenue and landed pounds), GC-IFQ trips that took place during the mitigation phase[6] were worse than trips that did not (Table 4). For example, 4148 trips took place inside the NYB lease areas and averaged $63,810 in revenue, 483 pounds of scallop landings, and $5056 of operating profit; 15,633 trips took place in the mitigation phase, trips that were inside the bounds of the NYB call areas but not inside the NYB lease areas; these trips selected averaged $5310 in revenue, 446 pounds of scallop landings, and $4481 in operating profit. These differences were statistically different at a 1% confidence level.

Nearly 20% (3789) of all trips taken by the LA-DAS métier were inside the NYB Call Area. The number of impacted trips and scallop revenue decreased disproportionately: Just 32% of LA-DAS trips and scallop revenue that were inside the call areas were also inside the lease areas. We find evidence that LA-DAS trips inside the mitigation phase landed more scallops than trips in areas that remained (Table 4). Average revenue, operating profit, and revenue per day on trips in the mitigation phase are statistically indistinguishable. We find the same is true for

TABLE 4 | Scallop trips, average scallop revenue, average landings, average operating profit, and average revenue per day in the New York Bight region across LA-AA, LA-DAS, and GC-IFQ métiers.

Métier	New York Bight phase	Number of trips	Average scallop revenue per trip	Average landed pounds per trip	Average operating profit per trip	Average revenue per day
LA-AA	Call areas	85	$116,007	9598	$106,076	$18,133
LA-AA	Mitigation phase	59	$111,509	9192	$102,296	$17,466
LA-AA	Lease areas	26	$126,213	10,521	$114,654	$19,647
LA-DAS	Call areas	3789	$191,460	17,014	$180,170	$20,997
LA-DAS	Mitigation phase	2618	188,957*	16,481***	$179,647	$20,976
LA-DAS	Lease areas	1171	$197,055	18,205	$181,339	$21,044
GC-IFQ	Call areas	19,781	$5535	454	$4602	$7784
GC-IFQ	Mitigation phase	15,633	$5310***	446***	$4481***	$7899***
GC-IFQ	Lease areas	4148	$6381	483	$5056	$7350

*,
**, and
***represent the rejection of the null hypothesis that the metric in the mitigation phase is equal to the corresponding metric in the subsequent row at the 10%, 5%, and 1% confidence levels, respectively. Averages computed over trips.

LA-AA trips (Table 4). We note our sample sizes for the LA-AA métier are quite small (85 trips in the call areas and just 26 in the lease areas).

4.2.2 | Central Atlantic

As the development process in the CA moved from call areas to WEAs, the footprint considered for wind development shrank by 92% (Figure 5). The wind development process in the CA excluded areas from wind development that were farther from the coast.

Approximately 2% (2136) of all trips taken by the GC-IFQ métier were inside the CA call areas. Although the CA WEAs are 92% smaller than the corresponding call area, 43% of GC-IFQ trips and 37% of GC-IFQ scallop revenue that were contained in the call areas were found in the lease areas. According to all four of our metrics, GC-IFQ trips in the mitigation phase and trips that were inside the CA Call areas but not inside the CA wind energy areas were more productive than WEAs (Table 5).

Well under 1% (62) of all trips taken by the LA-DAS métier were inside the CA call area; 39% of the LA-DAS trips and 35% of the LA-DAS scallop revenue that were contained in the call areas were found in the lease areas. There is weak evidence that revenue per day was higher in the mitigation phase[7] compared to trips inside the WEAs (Table 5). Average revenue, landed pounds, and operating profits inside the mitigation phase and the WEA are statistically indistinguishable, likely due to the relatively small sample sizes.

Just under 3% (666) of all trips taken by the LA-AA métier were inside the CA call area. 3% of LA-AA trips and 2% of LA-AA scallop revenue that were contained in the call areas were found in the corresponding WEA. We find evidence that average revenue per day and operating profits are higher in the mitigation phase relative to the WEA (Table 5).

5 | Discussion and Conclusions

As offshore wind grows in the northeastern region of the United States, understanding and managing space use conflicts becomes increasingly necessary. Our analysis uses 15 years of data from the high-valued Atlantic Sea scallop fishery and contains two components. The first component examines the economic exposure of the scallop industry in the awarded lease areas. The second component illustrates how the regulatory process decreased the potential adverse impacts on the scallop fishery from offshore wind development.

The first form of mitigation takes place when decisions are made during the regulatory process that *avoid* the scallop fishery by siting offshore wind in areas where there has historically been limited fishery activity. We find that approximately 6% of the trips for the GC-IFQ and LA-DAS métiers and well under 1% of LA-AA trips would be impacted by offshore wind lease areas. These low percentages are indicative that the wind siting processes largely avoided introducing exposure to much of the scallop fishery.

The second form of mitigation considered in this analysis is *minimizing exposure* by developing offshore wind in areas where fisheries are comparatively less productive. We find mixed evidence of exposure minimization. The LA-AA and LA-DAS métiers show lower productivity within lease areas for most metrics. Scallop revenue and landed pounds per trip are slightly higher inside the lease areas for the GC-IFQ métier.

TABLE 5 | Scallop trips, average scallop revenue, average landings, average operating profit, and average revenue per day in the Central Atlantic region across LA-AA, LA-DAS, and GC-IFQ métiers.

Métier	Central Atlantic phase	Number of trips	Average scallop revenue per trip	Average landed pounds per trip	Average operating profit per trip	Average revenue per day
LA-AA	Call areas	666	$142,442	12,646	$131,853	$22,099
LA-AA	Mitigation phase	648	$143,433**	12,707	$132,942**	$22,115
LA-AA	Wind energy areas	18	$106,760	10,447	$92,622	$21,495
LA-DAS	Call areas	62	$101,950	10,540	$85,397	$12,860
LA-DAS	Mitigation phase	38	$108,532	10,983	$94,320	$14,137*
LA-DAS	Wind energy areas	24	$91,529	9839	$71,270	$10,838
GC-IFQ	Call areas	2136	$3908	404	$2504	$5327
GC-IFQ	Mitigation phase	1213	$4348***	418***	$2957***	$5787***
GC-IFQ	Wind energy areas	923	$3330	386	$1909	$4722

*,
**, and
***represent the rejection of the null hypothesis that the metric in the mitigation phase is equal to the corresponding metric in the subsequent row at the 10%, 5%, and 1% confidence levels, respectively. Averages computed over trips.

The results of our case studies indicate that potential exposure to the scallop fishery was reduced for the NYB and CA areas at aggregate levels but was mostly disproportional to a reduction in the size of the area slated for offshore wind. In the NYB, as potential offshore wind areas became smaller, no distinguishable changes were observed in the per-trip metrics for the LA métiers. For the GC-IFQ métier, the average operating profit increased in value as the regulatory process progressed through every phase. In the mitigation phase, average revenue and landings decreased in value before sequentially increasing, surpassing values in the call areas, whereas the opposite was observed in revenue per day. The CA, a historically important region for scallop harvest, underwent a transformative change in areas considered for offshore wind, marked by area reductions of > 90% between the call areas and WEAs stages. The GC-IFQ métier, with a higher trip frequency of trips in the CA compared to the LA métiers, had a statistically significant decrease in average per-trip revenues, landed pounds, and operating profits, as well as revenue per day within potential development areas. For the LA métiers, the reduction in area from the call areas to the WEAs meant that far fewer trips were overlapping; this reduction in trips was mainly driven by the LA-AA métier. Although comparisons between WEA trips and mitigation phase trips yielded few significant results for the LA-DAS métier, LA-AA trips showed relatively large negative differences in average revenue per trip and average operating profit per trip in the transition from call areas to WEAs.

Our research finds that (a) the current configuration of lease areas results in minimal exposure of the scallop fishery to wind development and (b) the adaptive leasing process has reduced fishery exposure to wind development. However, there are a few caveats regarding offshore wind effects on fishing dynamics. First, vessels using scallop dredges and other mobile bottom-tending gear have a higher likelihood of entanglement and damage or loss when interacting with offshore cables and wind turbines compared to static gear types (Hogan et al. 2023). Second, vessels may have to avoid transiting through wind areas, raising the cost of fishing; this will likely impact the LA-AA and LA-DAS métiers, which take longer trips farther from shore than the GC-IFQ métier. Offshore wind is expected to increase transit times on some scallop trips, particularly for ports in close proximity to offshore wind. Third, our analysis assumes that no fishing activity will occur within potential offshore wind areas. While fishing activity is not explicitly prohibited in most areas, many of these locations in the Northeastern United States are near one another (Figure 1), exasperating challenges coinciding with spatial constraints. Lastly, vessel operators are likely to reallocate efforts to less profitable fisheries or areas in response to explicit spatial closures and de facto hesitance to fish within offshore wind development areas (Vasquez Caballero, Sylvia, and Holland 2023; Stafford 2018; Bockstael and Opulach 1983). The first two caveats imply that we have underestimated the true exposure of wind development on the scallop fishery; the final two caveats imply that we have overestimated them.

As renewable energy initiatives become more ambitious, additional leases may be identified in areas once excluded from consideration, complicating future assessments of impacts.[8] Climate change is also likely to affect scallop populations, potentially causing them to move or decrease in productivity (Lucey and Nye 2010; Hare et al. 2016), potentially leading to future shifting and contracting of suitable habitats in areas of overlap analyzed in this study (Tanaka et al. 2020) affecting fisheries and their communities (Colburn et al. 2016). These variations can lead to over or underestimations of projected impacts and underscores the need for adaptive planning at all stages of development.[9]

Planning for new uses of marine space in already busy waters is a complex challenge and necessitates a variety of approaches. Marine spatial planning strives to quantify the spatial needs of existing uses and allocate space to new uses (Stelzenmüller et al. 2022). Suitability modeling attempts to minimize conflicts between existing and new uses (Farmer et al. 2023). Bioeconomic modeling works toward assessing the interactions between ecological systems and economic activities (Munroe et al. 2022; Scheld et al. 2022). Ecosystem-based management aims to quantify tradeoffs among ocean use sectors (Pezy et al. 2020), and the study of ecosystem services provides a structure to analyze how pressures from human activities may affect the goods and services provided to humans by the marine ecosystem (van de Pol et al. 2023; Hooper, Hattam, and Austen 2017). To date, most countries rely on environmental impact assessments (of varying extent and comprehensiveness, depending on legal requirements) (Willsteed et al. 2017). Each of these approaches involves first collecting, mapping, and analyzing historical data, as well as involvement from stakeholders, regulatory agencies, and industry experts to better understand the relevant issues and potential impacts within the region in question. In the United States, lessees must provide information on social and economic conditions (in addition to environmental conditions) that could be affected by wind development on the OCS (Renewable Energy on The Outer Continental Shelf 2023). BOEM's mitigation guidance encourages lessees to partner with commercial and recreational fishing communities before beginning development.[10] This can facilitate avoiding, minimizing, rectifying, reducing, and compensating for adverse impacts of offshore wind. The offshore wind regulatory process takes time but allows for participation to reduce impacts on stakeholders. A good understanding of the impacts of wind development on the fishing industry can provide policymakers with valuable insights into how future fishing behavior will be affected over the next few decades as offshore wind continues to expand.

Acknowledgments

The authors wish to acknowledge Angela Silva (NEFSC) for sharing her offshore wind policy expertise. Travis Ford (GARFO) and Jonathan Peros (NEFMC) provided valuable insight on scallop fishing and regulations. Rockne Rudolph (BOEM) contributed the maps in Figures 4 and 5. Anna Mercer (NEFSC) provided valuable insight into risk aversion of scallop fishing vessels in relation to offshore wind. Research Funding was provided by the National Oceanic and Atmospheric Administration, and publication funding was provided by the Bureau of Ocean Energy Management. The findings and

conclusions of this article are those of the authors and do not necessarily reflect the views or opinions of their corresponding institutions.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available upon request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Endnotes

[1] A summary of the status of planning efforts and active leases can be found using the following BOEM interactive map (https://www.boem.gov/renewable-energy/offshore-renewable-activities).

[2] Other relevant laws include the Marine Mammal Protection Act, Endangered Species Act, Magnuson-Stevens Fishery Conservation and Management Act, and the Fish and Wildlife Coordination Act (NOAA Fisheries 2022).

[3] The scallop fishing year currently runs from April through March. Prior to 2017, the fishing year ran from March to February, and although effort does occur year-round, harvest is considerably higher in late spring through summer.

[4] Lease area shapefiles were collected using BOEM's Renewable Energy GIS Data site. Locations for future development can also be found on BOEM's offshore renewable activities site (https://www.boem.gov/renewable-energy/offshore-renewable-activities). Shapefiles used in case studies were collected by downloading historic shapefiles from BOEM's New York Bight & Central Atlantic project pages.

All shapefiles were accessed in September 2023.

[5] Collected from https://fred.stlouisfed.org/series/GDPDEF, accessed on October 17, 2022.

[6] Trips that are inside the bounds of the NYB call areas but not inside the NYB lease areas.

[7] Trips that were inside the bounds of the CA call areas but not inside the CA WEAs.

[8] A summary of planning efforts and active leases can be found using this BOEM interactive map https://www.boem.gov/renewable-energy/offshore-renewable-activities.

[9] (1) Planning and analysis, (2) leasing, (3) site assessment, and (4) construction and operations.

[10] Including but not limited to site assessment plans and construction and operations plans.

References

Allen-Jacobson, L. M., A. W. Jones, A. J. Mercer, et al. 2023. “Evaluating Potential Impacts of Offshore Wind Development on Fishing Operations by Comparing Fine- and Coarse-Scale Fishery-Dependent Data.” *Marine and Coastal Fisheries* 15, no. 1: 1.

Ardini, G., and M. Lee. 2018. “Do IFQs in the US Atlantic Sea Scallop Fishery Impact Price and Size?” *Marine Resource Economics* 33, no. 3: 263–288. https://doi.org/10.1086/698199.

Benjamin, S., M. Y. Lee, and G. DePiper. 2018. “Visualizing Fishing Data as Rasters.” NEFSC ref doc 18-12; 24. https://repository.library.noaa.gov/view/noaa/23030.

Bockstael, N. E., and J. J. Opulach. 1983. “Discrete Modeling of Supply Response Under Uncertainty: The Case of the Fishery.” *Journal of Environmental Economics and Management* 10: 125–137. https://doi.org/10.1016/0095-0696(83)90021-9.

ten Brink, T., and T. Dalton. 2018. “Perceptions of Commercial and Recreational Fishers on the Potential Ecological Impacts of the Block Island Wind Farm (US).” *Frontiers in Marine Science* 5: 5–9. (Sec Marine Affairs and Policy). https://doi.org/10.3389/fmars.2018.00439.

Bureau of Ocean Energy Management. 2023a. *Renewable Energy GIS Data*. Washington, DC: Bureau of Ocean Energy Management. Retrieved September 2023, from https://www.boem.gov/renewable-energy/mapping-and-data/renewable-energy-gis-data.

Bureau of Ocean Energy Management. 2023b. *Regulatory Framework and Guidelines*. Washington, DC: Bureau of Ocean Energy Management. Retrieved December 19, 2023, from https://www.boem.gov/renewable-energy/regulatory-framework-and-guidelines.

Chen, C., L. Zhao, H. Lin, et al. 2024. “Potential Impacts of Offshore Wind Energy Development on Physical Processes and Scallop Larval Dispersal Over the US Northeast Shelf.” *Progress in Oceanography* 224: 103263. https://doi.org/10.1016/j.pocean.2024.103263.

Colburn, L. L., M. Jepson, C. Weng, T. Seara, J. Weiss, and J. A. Hare. 2016. “Indicators of Climate Change and Social Vulnerability in Fishing Dependent Communities Along the Eastern and Gulf Coasts of the United States.” *Marine Policy* 74: 323–333. https://doi.org/10.1016/j.marpol.2016.04.030.

DePiper, G. 2014. “Statistically Assessing the Precision of Self-Reported VTR Fishing Locations.” NOAA Technical Memorandum NMFS-NE-229; 22. https://repository.library.noaa.gov/view/noaa/4806.

DePiper, G. S. 20 C.E. *Statistically Assessing the Precision of Self-Reported VTR Fishing Locations*, 22. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. https://doi.org/10.7289/V53F4MJN.

Dolan, P., R. Edlin, A. Tsuchiya, and A. Wailoo. 2007. “It Ain't What You Do, It's the Way That You Do It: Characteristics of Procedural Justice and Their Importance in Social Decision-Making.” *Journal of Economic Behavior & Organization* 64, no. 1: 157–170.

Farmer, N. A., L. P. Garrison, J. A. Litz, et al. 2023. “Protected Species Considerations for Ocean Planning: A Case Study for Offshore Wind Energy Development in the U.S. Gulf of Mexico.” *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 00: e10246. https://doi.org/10.1002/mcf2.10246.

Gill, A. B., S. Degraer, A. Lipsky, N. Mavraki, E. Methratta, and R. Brabant. 2020. “Setting the Context for Offshore Wind Development Effects on Fish and Fisheries.” *Oceanography* 33, no. 4: 118–127. https://www.jstor.org/stable/26965755.

Haggett, C., T. ten Brink, A. Russell, et al. 2020. “Offshore Wind Projects and Fisheries: Conflict and Engagement in the United Kingdom and the United States.” *Oceanography* 33, no. 4: 38–47. https://doi.org/10.5670/oceanog.2020.404.

Hahn, F. 1982. “On Some Difficulties of the Utilitarian Economist.” In *Utilitarianism and Beyond*, edited by A. Sen and B. Williams, 187–198. New York, NY: Cambridge University Press.

Hannah, R. W. 1995. “Variation in Geographic Stock Area, Catchability and Natural Mortality of Ocean Shrimp (*Pandalus jordani*): Some New Evidence for a Trophic Interaction With Pacific Hake (*Merluccius productus*).” *Canadian Journal of Fisheries and Aquatic Sciences* 52: 1018–1029.

Hannah, R. W. 1999. “A New Method for Indexing Spawning Stock and Recruitment in Ocean Shrimp, *Pandalus jordani*, and Preliminary Evidence for a Stock-Recruitment Relationship.” *Fishery Bulletin* 97: 482–494.

Hare, J. A., W. E. Morrison, M. W. Nelson, et al. 2016. “A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the

Northeast U.S. Continental Shelf." *PLoS ONE* 11, no. 2: e0146756. https://doi.org/10.1371/journal.pone.0146756.

Hogan, F., B. Hooker, B. Jensen, L. Johnston, A. Lipsky, E. Methratta, A. Silva, and A. Hawkins. 2023. *Fisheries and Offshore Wind Interactions: Synthesis of Science*. NOAA Technical Memorandum NMFS-NE-291, 388. Silver Spring, MD: NOAA Institutional Repository. https://doi.org/10.25923/tcjt-3a69.

Hooper, T., N. Beaumont, and C. Hattam. 2017. "The Implications of Energy Systems for Ecosystem Services: A Detailed Case Study of Offshore Wind." *Renewable and Sustainable Energy Reviews* 70: 230–241. https://doi.org/10.1016/j.rser.2016.11.248.

Hooper, T., C. Hattam, and M. Austen. 2017. "Recreational Use of Offshore Wind Farms: Experiences and Opinions of Sea Anglers in the UK." *Marine Policy* 78: 55–60. https://doi.org/10.1016/j.marpol.2017.01.013.

Kirkpatrick, A. J., S. Benjamin, G. S. DePiper, T. Murphy, S. Steinback, and C. Demarest. 2017. *Socio-Economic Impact of Outer Continental Shelf Wind Energy Development on Fisheries in the U.S. Atlantic*. Vol. II—Appendices. Atlantic OCS Region, Washington, D.C.: U.S. Dept. of the Interior, Bureau of Ocean Energy Management OCS Study BOEM 2017-012. 191 pp.

Kitts, A., R. Van Anrooy, S. Van Eijs, et al. 2020. *Techno-Economic Performance Review of Selected Fishing Fleets in North and South America*. FAO Fisheries and Aquaculture Technical Paper No. 653/2. Rome: FAO.

Kurlansky, M. 1998. *Cod: A Biography of the Fish That Changed the World*. Toronto, Ontario, Canada: Vintage Canada.

Lindeboom, H., H. Kouwenhoven, M. Bergman, et al. 2011. "Short-Term Ecological Effects of an Offshore Wind Farm in the Dutch Coastal Zone; a Compilation." *Environmental Research Letters* 1341: 35101–35113. https://doi.org/10.1088/1748-9326/6/3/035101.

Lucey, S. M., and J. A. Nye. 2010. "Shifting Species Assemblages in the Northeast US Continental Shelf Large Marine Ecosystem." *Marine Ecology Progress Series* 415: 23–33. https://doi.org/10.3354/meps08743.

Methratta, E. T., A. Hawkins, B. R. Hooker, A. Lipsky, and J. A. Hare. 2020. "Offshore Wind Development in the Northeast US Shelf Large Marine Ecosystem: Ecological, Human, and Fishery Management Dimensions." *Oceanography* 33, no. 4: 16–27. https://www.jstor.org/stable/26965746.

Muench, A., G. S. DePiper, and C. Demarest. 2017. "On the Precision of Predicting Fishing Location Using Data From the Vessel Monitoring System (VMS)." *Canadian Journal of Fisheries and Aquatic Sciences* 75, no. 7: 1036–1047. https://doi.org/10.1139/cjfas-2016-0446.

Munroe, D., D. Haidvogel, C. Caracappa, et al. 2018. "Modeling Larval Dispersal and Connectivity for Atlantic Sea Scallop (*Placopecten magellanicus*) in the Middle Atlantic Bight." *Fisheries Research* 218: 7–15. https://doi.org/10.1016/j.fishres.2018.06.020.

Munroe, D. M., E. N. Powell, J. M. Klinck, et al. 2022. "The Atlantic Surfclam Fishery and Offshore Wind Energy Development: 1. Model Development and Verification." *ICES Journal of Marine Science* 79, no. 6: 1787–1800. https://doi.org/10.1093/icesjms/fsac108.

National Environmental Policy Act, 42 U.S.C. § 4331(a) (1970). https://www.fsa.usda.gov/Internet/FSA_File/nepa_statute.pdf.

NEFMC. 2023. *Framework Adjustment 36 to the Atlantic Sea Scallop Fishery Management Plan*. Newburyport, MA: New England Fishery Management Council (NEFMC).

NOAA Fisheries. 2018. *Fishing Gear: Dredges*. Silver Spring, MD: NOAA Fisheries. Retrieved December 5, 2023, from https://www.fisheries.noaa.gov/national/bycatch/fishing-gear-dredges.

NOAA Fisheries. 2021. *The Atlantic Sea Scallop: A Fishery Success Story*. Gloucester, MA: NOAA Fisheries Retrieved May 2, 2022, from https://www.fisheries.noaa.gov/story-map/atlantic-sea-scallop-fishery-success-story.

NOAA Fisheries. 2022. *Offshore Wind Energy*. Silver Spring, MD: NOAA Fisheries. Retrieved March 31, 2022, from https://www.fisheries.noaa.gov/topic/offshore-wind-energy.

NOAA Fisheries. 2023, June 7. *Resources—Greater Atlantic Region Statistical Areas*. Gloucester, MA: NOAA Fisheries. Retrieved December 18, 2023, from https://www.fisheries.noaa.gov/resource/map/greater-atlantic-region-statistical-areas.

Northeast Fisheries Science Center (NEFSC). 2018. *65th Northeast Regional Stock Assessment Workshop (65th SAW) Assessment Report*. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 18–11; 659 p. Woods Hole, MA: NOAA Fisheries Northeast Fisheries. http://www.nefsc.noaa.gov/publications/.

Palmer, M. C., and S. E. Wigley. 2009. "Using Positional Data From Vessel Monitoring Systems to Validate the Logbook-Reported Area Fished and the Stock Allocation of Commercial Fisheries Landings." *North American Journal of Fisheries Management* 29, no. 4: 928–942. https://doi.org/10.1577/M08-135.1.

Pebesma, E. 2018. "Simple Features for R: Standardized Support for Spatial Vector Data." *R Journal* 10, no. 1: 439–446. https://doi.org/10.32614/RJ-2018-009.

Pezy, J.-P., A. Raoux, and J.-C. Dauvin. 2020. "An Ecosystem Approach for Studying the Impact of Offshore Wind Farms: A French Case Study." *ICES Journal of Marine Science* 77, no. 3: 1238–1246. https://doi.org/10.1093/icesjms/fsy125.

van de Pol, L., K. van der Biest, S. E. Taelman, et al. 2023. "Impacts of Human Activities on the Supply of Marine Ecosystem Services: A Conceptual Model for Offshore Wind Farms to Aid Quantitative Assessments." *Heliyon* 9, no. 3: 1. https://doi.org/10.1016/j.heliyon.2023.e13589.

Protection of Environment, 40 C.F.R § 1508.1 (2020). https://www.ecfr.gov/current/title-40/chapter-V/subchapter-A/part-1508/section-1508.1.

Renewable Energy On The Outer Continental Shelf, 30 C.F.R. § 585 (2023).https://www.ecfr.gov/current/title-30/chapter-V/subchapter-B/part-585?toc=1.

Rheuban, J. E., S. C. Doney, S. R. Cooley, and D. R. Hart. 2018. "Projected Impacts of Future Climate Change, Ocean Acidification, and Management on the US Atlantic Sea Scallop (*Placopecten magellanicus*) Fishery." *PLoS ONE* 13, no. 9: e0203536. https://doi.org/10.1371/journal.pone.0203536.

Scheld, A., J. Beckensteiner, D. Munroe, et al. 2022. "The Atlantic Surfclam Fishery and Offshore Wind Energy Development: 2. Assessing Economic Impacts." *ICES Journal of Marine Science* 79, no. 6: 1801–1814. https://doi.org/10.1093/icesjms/fsac109.

Sen, A. 1997. "Maximization and the Act of Choice." *Econometrica* 65, no. 4: 745–779.

Smythe, T., D. Bidwell, A. Moore, H. Smith, and J. McCann. 2020. "Beyond the Beach: Tradeoffs in Tourism and Recreation at the First Offshore Wind Farm in the United States." *Energy Research & Social Science* 70: 101726.

Smythe, T., D. Bidwell, and G. Tyler. 2021. "Optimistic With Reservations: The Impacts of the United States' First Offshore Wind Farm on the Recreational Fishing Experience." *Marine Policy* 127: 104440. https://doi.org/10.1016/j.marpol.2021.104440.

Stafford, T. 2018. "Accounting for Outside Options in Discrete Choice Models: An Application to Commercial Fishing Effort." *Journal of Environmental Economics and Management* 88: 159–179. https://doi.org/10.1016/j.jeem.2017.10.006.

Stelzenmüller, V., J. Letschert, A. Gimpel, et al. 2022. "From Plate to Plug: The Impact of Offshore Renewables on European Fisheries and the Role of Marine Spatial Planning." *Renewable and Sustainable Energy Reviews* 158: 112108. https://doi.org/10.1016/j.rser.2022.112108.

Tanaka, K. R., M. P. Torre, V. S. Saba, C. A. Stock, and Y. Chen. 2020. "An Ensemble High-Resolution Projection of Changes in the Future Habitat of American Lobster and Sea Scallop in the Northeast US Continental Shelf." *Diversity and Distributions* 26, no. 8: 987–1001. https://doi.org/10.1111/ddi.13069.

The White House. 2022. *FACT SHEET: Biden-Harris Administration Announces New Actions to Expand U.S. Offshore Wind Energy*. Washington, DC: White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/15/fact-sheet-biden-harris-administration-announces-new-actions-to-expand-u-s-offshore-wind-energy/.

Tsai, H.-H., H.-S. Tseng, C.-K. Huang, and S.-C. Yu. 2022. "Review on the Conflicts Between Offshore Wind Power and Fishery Rights: Marine Spatial Planning in Taiwan." *Energies* 15, no. 22: 8768. https://doi.org/10.3390/en15228768.

Vasquez Caballero, S., G. Sylvia, and D. S. Holland. 2023. "Fishery Participation and Location Choice Models: The West Coast Salmon Troll Commercial Fishery." *Canadian Journal of Fisheries and Aquatic Sciences* 80, no. 11: 1170–1194.

Walden, J., M. Lee, and C. O'Donnell. 2021. "Profits, Prices, and Productivity in a Common Pool Fishery." *Agricultural & Applied Economics Association* 1: 1–21. https://doi.org/10.1111/ajae.12280.

Werner, S., G. DePiper, D. Jin, and A. Kitts. 2020. "Estimation of Commercial Fishing Trip Costs Using Sea Sampling Data." *Marine Resource Economics* 35, no. 4: 379–410. https://doi.org/10.1086/710668.

Willsteed, E., A. B. Gill, S. N. R. Birchenough, and S. Jude. 2017. "Assessing the Cumulative Environmental Effects of Marine Renewable Energy Developments: Establishing Common Ground." *Science of the Total Environment* 577: 19–32. https://doi.org/10.1016/j.scitotenv.2016.10.152.

Zang, Z., R. Ji, D. R. Hart, et al. 2023. "Effects of Warming and Fishing on Atlantic Sea Scallop (*Placopecten magellanicus*) Size Structure in the Mid-Atlantic Rotationally Closed Areas." *ICES Journal of Marine Science* 80, no. 5: 1351–1366. https://doi.org/10.1093/icesjms/fsad063.