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Perceptions of Commercial and Recreational Fishers on the Potential Ecological Impacts of the Block Island Wind Farm (US)

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Offshore wind is gaining momentum in the United States as a viable source for meeting domestic energy needs. Although offshore wind farms have been developed in Europe and Asia, the Block Island Wind Farm (BIWF) is the first offshore wind farm built in North America. To improve marine resource management, it is critical to understand the impacts of the wind farm on marine resource users in context. Little is known about the impacts of offshore wind farms on marine resource users in the United States. This study investigates recreational and commercial fishers' perceptions of the impacts of the BIWF on the local marine ecosystem. Semi-structured interviews were conducted with 25 fishers, mostly based out of Block Island or Point Judith, Rhode Island (US), in the summer and fall of 2017. During the interviews, fishers were asked about their perceptions of changes in the marine ecology of the wind farm area during and after the offshore wind turbines were constructed, and how their activities in the area have changed since the wind farm was installed. Results indicate that there were perceived impacts of the BIWF on the local ecosystem and the behavior of the marine resource users. For some recreational fishers, the wind farm functioned as a destination or target and served as an artificial reef for spearfishing. For some commercial fishers, the increase in recreational fishing due to the establishment of the BIWF crowded out commercial fishers in these areas. As the offshore wind farm industry expands within US waters, findings from this study and others like it can provide valuable insights on the potential impacts of these wind farms on marine resource users.

Keywords: offshore wind, commercial, recreational, perceptions, artificial reef, marine resource user, fishing, offshore energy

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INTRODUCTION

Use of offshore wind turbines are gaining momentum in the United States as a viable option for meeting domestic energy needs. Knowledge of the impacts of offshore wind turbines on other local marine uses and resources in the United States is limited. Although studies have been conducted on proposed offshore wind farms in the US (Kimmell and Stolfi Stalenhoef, 2011), there is currently only one offshore wind farm operating in US waters, the Block Island Wind Farm (BIWF). BIWF consists of five turbines located about 16 miles south of mainland Rhode Island.

Past research on active offshore wind farms outside of the US has found several positive and negative impacts on marine biota, habitats, and ecological function. Impacts include the creation of an "artificial reef," (Wilhelmsson and Malm, 2008; Lindeboom et al., 2011; Langhamer, 2012; Bergström et al., 2014), increased fish assemblages (Wilhelmsson and Malm, 2008; Bergström et al., 2014); and disturbance of existing ecosystems (Wilhelmsson et al., 2006; Bergström et al., 2014). Impacts on birds and mammals have also been recorded (Bergström et al., 2014).

The impact of offshore wind farms on marine resource users has not been extensively studied. Marine resource users can include recreational boaters, ferry riders, sightseers, conservationists, fishers, and beachgoers. Some studies (e.g., Firestone and Kempton, 2007; Krueger et al., 2011; Firestone et al., 2012a; Landry et al., 2012) have examined impacts of wind farms on on-shore recreational activities such as beachgoing. This project focuses on recreational and commercial fishers that transit wind farm areas by boat. Lüdeke (2017) looked at the impacts of German North Sea offshore wind turbines on marine resource users and found that the turbines had a large environmental impact, both positive and negative, through creation of benthic habitat and protected areas, as well as injury to fish during construction and birds during operation. He proposed mitigation of some construction impacts through noise mitigation systems, and compensation to fishers for loss of fishing grounds. Lüdeke (2017) determined that 60% of their surveyed experts in the offshore wind farm industry want to exclude biological hotspots from future wind farm areas. Hooper et al. (2015) discussed how offshore wind farms could potentially disrupt important European fisheries through poor placement and noted that, "the lack of reported experience of potting within OWFs was not related to stock concerns but to uncertainty around safety, gear retrieval, insurance and liability" (p. 16).

The transferability of these impact study findings may be sensitive to differences in physical, cultural, and economic settings in disparate locations (Maar et al., 2009; Lindeboom et al., 2011). Although other pre-construction studies for offshore wind have been conducted, such as in the case of Cape Wind (Brownlee et al., 2015), the BIWF is the first offshore wind farm to be fully constructed and operational in North America.

This study uses a qualitative approach to examine recreational and commercial fishers' perceptions of the impacts of the BIWF on the local marine ecosystem and human activities in and around the wind farm area. A qualitative approach is useful for revealing how fishers understand the wind farm and their relationship to it (Lüdeke, 2017) and for providing rich insights about feelings, thoughts, and emotions that do not always emerge through more quantitative research methods (Bernard, 2006). In qualitative studies, participants may speak in their own terms (Bernard, 2006). The local ecological knowledge derived from fishers' recreational and work practices and their place-based knowledge of biotic dynamic interactions can provide valuable insights (Richmond, 2013; Garavito-bermúdez and Lundholm, 2017) about changes in the area around the BIWF.

To better understand perceptions of the Block Island Wind Farm project, it is necessary to understand the process of its development. The state of Rhode Island (RI) has policies that set out goals for uses of coastal waters and for power generation. Previously, an effort in nearby Massachusetts to build an offshore wind farm, called Cape Wind, had failed due to local opposition (Firestone et al., 2012b). In 2008, a Rhode Island state renewable mandate decreed that by 2020, 15% of the state's energy should be from renewable sources. Deepwater Wind (DW) was selected as the developer for an offshore wind farm in RI state waters and promised a power cable to Block Island. DW submitted permit applications for the Block Island Wind Project, a 5-turbine project that would serve as a demonstration project for offshore wind development in the US. State officials from the Coastal Resources Management Council (CRMC) decided that, instead of siting the offshore wind farm through a leasing process based on the BOEM model and NEPA processes, they would use a planning/zoning model that would result in a special area ocean management plan (SAMP) around the optimal site for offshore wind turbines. The planning, data collection and mapping process, including wind, bathymetry, and bird activity, were completed in 2 years and included many stakeholder meetings (McCann et al., 2013). Once the SAMP was finalized, the federal NEPA process for the offshore wind project progressed, including a federal environmental impact statement.

By 2015, the BIWF had received the required permits from the US Army Corps of Engineers, Federal Aviation Administration, US Fish and Wildlife Service, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, US Environmental Protection Agency, US Coast Guard, Rhode Island Coastal Resources Management Council, Rhode Island Department of Environmental Management, US Department of the Interior's Bureau of Ocean Energy Management (BOEM) and Rhode Island State Historic Preservation Office (Block Island Times, 2014). The permits reflected that there were some limits to the data available. The developers were required to respond to complaints from boaters on navigational safety impacts caused by the construction process of the BIWF project and detail their responses in a report to the US Army Corps of Engineers (Block Island Permit, U.S. Army Corps permit, Permit Number: NAE-2009-789, September 14, 2014).

Transmission cables connect the wind farm to Block Island and to the mainland shore of Rhode Island. Before the construction of the BIWF, Block Island electricity was running on a local diesel generator. The BIWF provided an opportunity to local Island stakeholders for Block Island to be connected to the mainland electrical grid (United States Army Corps of Engineers., 2012). The BIWF was designed to link Block Island to the mainland electricity grid, so that when the turbines were not running, the electricity would flow in a stable and potentially less expensive manner from the electrical grid on the mainland of Rhode Island.

Rules for Mariners were issued in July 2015 to close off areas around the turbines during construction. The areas that were closed off due to construction (in 2015 and from May 15 to October 31, 2016) varied according to the construction activity (United States Coast Guard, 2018). Pile driving lasted from July to October 2015 and cable laying and turbine construction lasted from October 2015 to August 2016. Wind farm construction was completed in December 2016. At the time of our study, the BIWF had been operational for about 8 months and the data were collected in the first summer season after operation.

METHODS

Study Area

The study area includes the area in and around the BIWF as well as the area around the transmission cables connecting the wind farm to Block Island and to the mainland shore of Rhode Island. Location of the BIWF is shown in **Figure 1**.

The five turbines of the BIWF are located about 3 miles off of Block Island, Rhode Island in the northeastern part of the United States. The turbines themselves are located just inside Rhode Island State Waters (**Figure 1**). The turbines are about 600 feet tall and rest on four-pile jacket foundations that were drilled into the bedrock (**Figure 2**). The turbines are placed about half a mile from each other in an arc and have an electrical generation capacity of 30 megawatts (MW).

The BIWF is located near Rhode Island's largest commercial fishing port, the Port of Galilee in Pt. Judith, and other smaller ports like Block Island (Tetra Tech Environmental Consultant., 2012). However, only a small portion of the 189 federally-permitted commercial fishing vessels based in these ports in 2009 historically fished the area in and around the BIWF. At about 6 mi^2, the BIWF area has supported a limited amount of lobster fishing, gill netting, and trawling (Tetra Tech Environmental Consultant., 2012). Recreational fishing has also taken place in the BIWF area. There were 73 party/charter vessels based in Pt. Judith and Block Island in 2009 and tens of thousands of individuals participating in recreational ocean fishing in and around Block Island waters (McCann et al., 2013).

The sediment type under the turbines is mainly coarse sand. Turbines 1, 3, and 5 were surveyed (Bartley et al., 2017). Turbines 1 and 3 stand on coarse sand, while Turbine 5 stands on coarse sand and pebble, gravel, and coarse sand sediment types (Bartley et al., 2017). One section of the cable lays over a clay, fine sand, and fine silt mix (Deepwater Wind., 2012). Block Island is a popular summer tourist destination, with 70% of the houses on the island categorized as vacant or seasonal/recreational (Block Island Times., 2001). A ferry service links Block Island to the mainland in Point Judith in Narragansett, Rhode Island. Marine resource users can currently access the area where the wind turbines are located; there are currently no navigational restrictions around the turbines. An image of the BIWF is shown in **Figure 2**.

Data Collection

We conducted in person semi-structured interviews (summer/fall 2017) with 25 fishers, mainly based out of the towns of New Shoreham (Block Island) or Narragansett, Rhode Island. Each interview lasted 30–90 min. Purposive sampling was used to recruit interview respondents. Purposive sampling is a commonly used sampling technique in qualitative studies where individuals are selected based on their characteristics and the objective of the study and are studied in depth (Bernard, 2006; Guest et al., 2006). Interview respondents had to meet the following criteria: (1) recreational or commercial fishers; (2) used the area in and around the BIWF; and (3) over 18 years old. To ensure that a wide range of perspectives was captured in the interviews, we tried to recruit fishers from across a diversity of commercial and recreational gear types and different home ports. Because there is no list of recreational and commercial fishers using the waters in and around the BIWF, we used snowball sampling techniques to identify potential study participants. In snowball sampling, respondents and other individuals knowledgeable about a topic suggest the names of possible study participants (Bernard, 2006).

We first consulted with staff at the state coastal and fisheries management agencies in Rhode Island to identify commercial fishers who had historically fished in the BIWF area. These fishers were contacted for potential interviews, and were also asked to provide the names of others who fished in the area. We stopped recruiting commercial fishers when we had reached out to all of the commercial fishers identified through this process. To recruit recreational fishing respondents, we contacted charter boat captains in Pt. Judith and Block Island as well as spearfishing captains and other individual recreational fishers. As with commercial fishers, we used snowball sampling to identify recreational fishers who used the BIWF area. We continued recruiting recreational fishers until data saturation was achieved, which is the point at which no new information is observed in the data (Guest et al., 2006).

The goal of the interviews was to understand past and current uses and perceptions of change before and after the wind turbines were constructed and operational. To ensure the collection of reliable, comparable qualitative data, we developed an interview guide (**Supplementary Material**). Interviews asked respondents about: (1) their fishing experience and prior use of the study area before the construction of the BIWF; (2) their use of the area and any ecological changes in the area during construction of the BIWF; (3) their perceptions of any changes in the area and uses of the area after the BIWF was constructed; and (4) how their individual behaviors in the area changed as a result of the BIWF.

The interviews were audio-recorded and transcribed. They were coded for themes using NVivo 11. Applied thematic analysis and a structural coding approach were used to segment different sections of text that correspond to themes or research questions (Guest et al., 2012). Themes were first identified, and then coded as behavioral or ecological impacts. An impact was considered to be a human use/behavioral impact if it referred to the activity of humans, while an impact was considered to be an ecological impact if it referred to a physical or biological impact on the natural ecosystem.

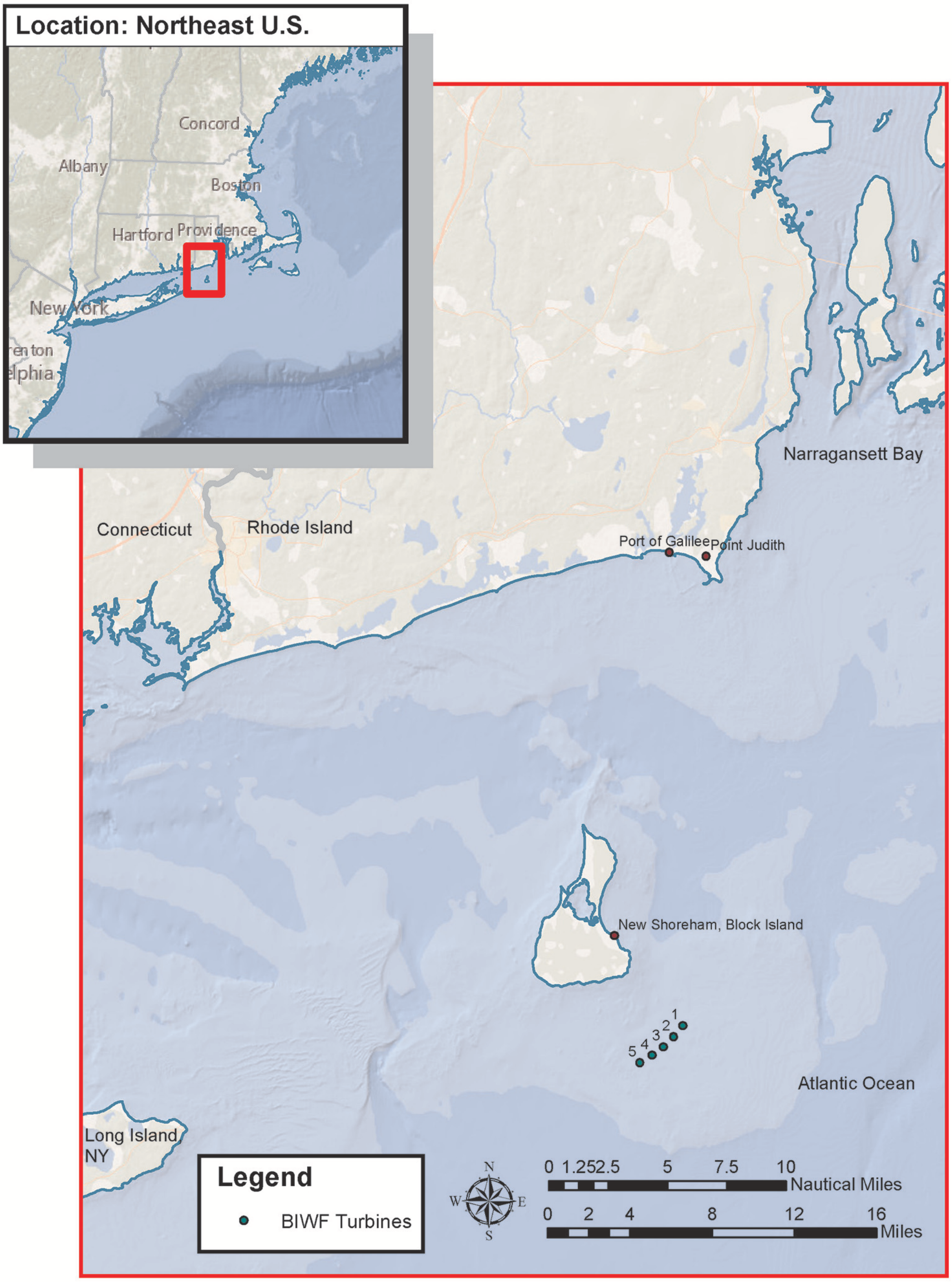


FIGURE 1 | Location of turbines of Block Island Wind Farm (source: Rhode Island Geographic Information System data).

RESULTS

Characteristics of Respondents

All the interview respondents were male and most were year-round residents of Rhode Island. Some charter and recreational fishers were summer residents of Rhode Island. We interviewed seven commercial fishers. Four mainly used gillnets, one mainly used lobster traps, one was a scallop dredger and one was a trawler for other species.

We interviewed 18 recreational fishers, seven of whom were based out of Block Island. Of the recreational fishers, 12 were charter captains. Two of the charter captains were also spearfishers. There were an additional four spearfishers. The gear used by the recreational fishers who did not use spearguns was rod and reel (i.e., hook and line). All of the spearfishers interviewed also fished by rod and reel, although they were categorized as spearfishers because their main fishing activity used spearfishing gear.

FIGURE 2 | Block Island Wind Farm (photo by A. Calianos).

It is worth commenting on the relatively small sample size of commercial fishers in this study. As noted earlier, limited commercial fishing took place within the BIWF area prior to wind farm construction. We attempted to recruit as many commercial fishers as possible who had fished in and around the BIWF. According to the interview respondents, the fishers participating in this study comprised much of the active commercial fishing going on in the BIWF area.

Perceived Impacts

Numerous perceived impacts of the BIWF on the marine ecology and the behavior of fishers emerged through the interview analysis. Key impacts, grouped into human/behavioral and ecological impacts, are described below. Thirteen themes related to behavioral impacts (or non-impacts) were described by respondents, with an additional eight themes related to ecological impacts (**Table 1** and **Graph 1**). Of the 13 human/behavioral themes, 10 related to existing conditions, while 3 focused on uncertainty about future conditions. In the following sections, perceived human/behavioral and ecological impacts are described in more detail, using the language of the respondents where possible.

Human/Behavioral Impacts

More recreational fishing in the area than before the wind farm

Most fishers (22), including both recreational and commercial, noted that there was increased recreational fishing in the area since the turbines were constructed. This impact of the BIWF was discussed by more fishers than any other impact.

Some felt it was because the turbines functioned as a landmark. One fisher said, "Some days, when the fluking was really good out there, you'd see 50, 60 boats out there; where years ago, you might only see 20. So word gets out: Go to the wind farm, there's good fluking. And then everybody runs. And I don't know if anybody credits the wind farm for it, or it's just that the wind farm happens to be there."

Others noted that the turbines provided the ability to catch targeted species of fish. A spearfisher described catching codfish around the wind turbines, stating, "That winter [2015], for about 2 months, starting in December right through January, whenever we went out, we'd catch codfish. Nice ones too. Like 15 pounds. Right in front of the windmills. I've never experienced that before."

New audio-visual-kinetic experience of the turbines

Fourteen fishers, including recreational and commercial, noted that being around the turbines and having them in the horizon was a new experience. One charter boat captain found that the experience of being around the wind farm was negative, saying, "To me they [turbines] are an eyesore. To customers, it's something to gawk at. You know, cause they're very, very impressive when you get up to them. They're massive. But to me… I'd rather not see them out there."

Another fisherman had a positive visual-kinetic experience, noting that "It's pretty neat. You know, I mean you're looking at a man-made structure that's six hundred feet high. That's the height of two football fields put together stacked up."

At least two charter fishers had taken people out on wind farm tours, and one charter fisherman said, "Just depends on what's going on… we stopped fishing this year because I'm doing these windmill charters. There's a lot of call for that, so we pretty much stopped charter fishing and [started] running tours." Another fisherman noted that the demand for wind farm tours was less than he had expected and the majority of his charters were for fishing.

Navigational concerns that boats could run into the turbines

Many fishers (10), mostly commercial, thought that the turbines could be a navigation hazard. One charter boat fisherman said he thought that the impact of the wind farm as a navigation hazard was more important than its impact on fishing; "I don't think they [turbines] are going to harm the fishing at all, [but] I'm waiting for the first dragger to hit 'em." He explained that fishers may run into the offshore wind farm because of fog or exhaustion, noting that commercial fishing boats are often understaffed. He explained "Cause those guys [commercial fishers] work hard… it's exhausting and… you could fall asleep very easily. People don't realize it's easy to do. Sooner or later, somebody's going to bang one… I think they're a hazard to navigation."

TABLE 1 | Perceived offshore wind farm impacts described during the interviews with fishers.

Impacts on humans and ecological system	Identified themes	No. of Respondents (out of 25 total fishers)	No. Commercial (out of 7)	No. Recreational (out of 18)
Human use/Behavioral	More recreational fishing in the area	22	5	17
	New Audio-Visual-Kinetic experience of the turbines	14	3	11
	Navigational concerns of running into the turbines	10	6	4
	Loss of access to the area during construction	10	6	4
	Lost fishing ground and gear (varied reasons)	8	6	2
	Turbines as landmark or target	8	2	6
	Compensation for negative impacts of wind farm	7	6	1
	More commercial rod and reel fishers in the area	5	0	5
	Created new area for spearfishing	5	0	5
	Benefit of not using diesel generator for electrical power on the island	4	1	3
	Only 5 turbines (concerned about more)	4	3	1
	Concern about access after construction	3	2	1
	Concern about decommissioning the turbines	3	2	1
Ecological system	“Structure” or “reef” or “fish aggregating” as rationale for fish behavior	20	3	17
	Additional fish species noticed in the area	11	0	11
	Fewer fish during construction	11	2	9
	Little to no impact on fisheries	11	2	9
	Some turbines more ecologically beneficial than others	11	4	7
	Establishment of ’mussels’ and other habitat	9	1	8
	Sound issues during construction	7	2	5
	More cod in the area (personal and indirect experience)	5	0	5

While some fishers felt that the idea of themselves hitting the turbines was laughable, some felt that fog, wind, or exhaustion could cause themselves or other individuals to hit the turbines. Two commercial fishers invested in additional navigational radar technology in order to navigate around the turbines and other boats in the dark.

Although many respondents were concerned about running into or being blown into the turbines, one felt that the turbines served as a navigational aid and three others were not concerned at all about navigating around the turbines.

Loss of access to the area during construction

Ten fishers discussed the access to the area that was lost during construction of the turbines. In the interviews, almost all of the commercial fishers described how DW provided some funding to fishers who could prove that they fished in the areas that would be closed for construction to compensate for their lost time fishing when those areas were closed. Some fishers noted that the construction of the cable had been delayed, resulting in additional lost fishing time for which they were not compensated. Recreational fishers were not compensated for any loss of access during construction.

Lost fishing ground and gear (varied reasons)

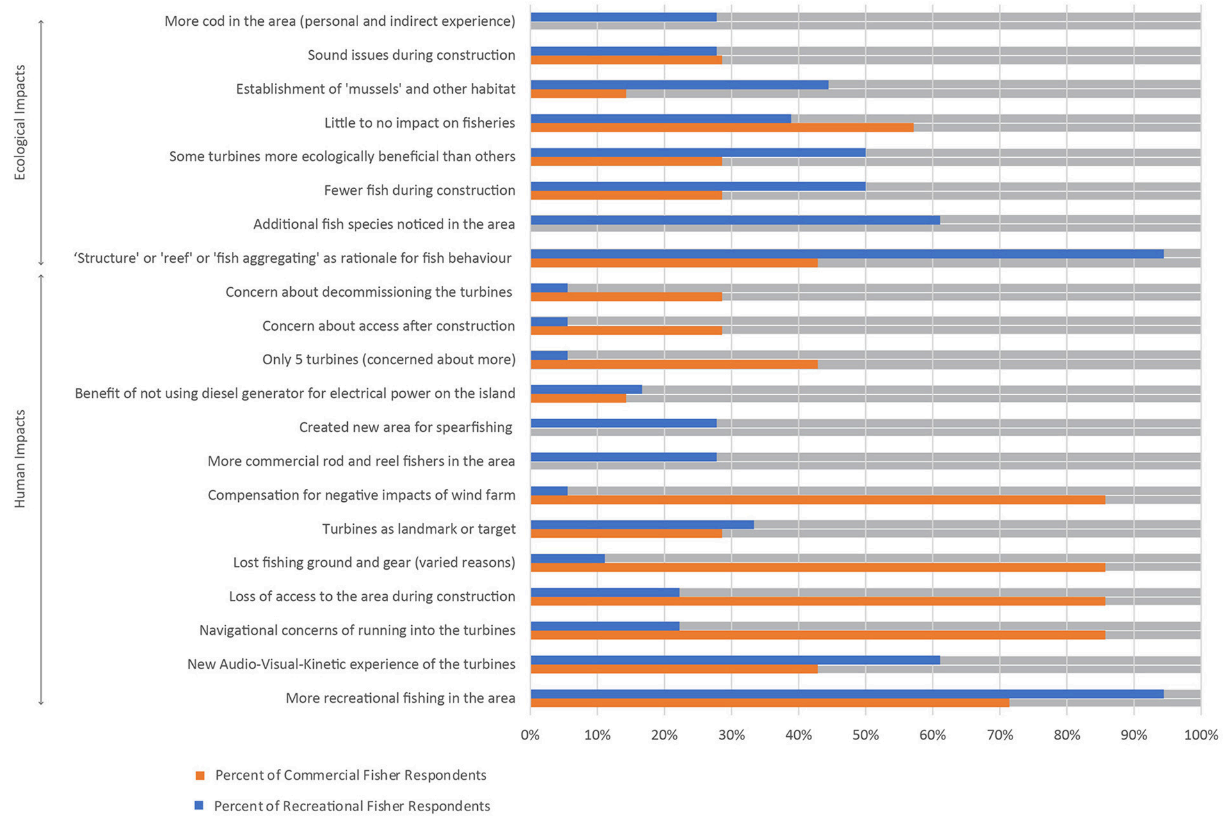
Several respondents (8) also discussed how the offshore wind farm resulted in displacement and crowding of fishing vessels which made them feel like they had lost productive fishing ground. This concern was discussed at length by all but one commercial fisher. As one commercial fisherman explained, “We went to a different area, tried a different spot, which was less productive, I mean, less money. Sometimes a lot of guys lost gear.” Six out of seven commercial fishers discussed lost fishing grounds or gear due to crowding. One fisherman who lost a net during construction due to a misunderstanding about the time and area of construction was compensated by the wind farm developer.

The influx of recreational fishers around the wind farm caused displacement of commercial fishers. One commercial gillnetter explained, “There are a lot of places we can’t get to. If you do go there, let’s say you gillnet there, when you go to haul it, [recreational fishers] don’t really know what is going on because it [gillnet] has two ends on it. [...] They’ll go get fish hooks and weights and lures caught in the net [...] You spend half a day pulling all this fishing gear out of your twine. So a lot of spots–if they’re fishing there–we can’t go anymore.”

Because the BIWF had become a new destination for recreational fishers, the commercial gillnetters interviewed felt that they were displaced or crowded out by the increase in recreational fishers. The physical establishment of the offshore wind farm also necessitated a change in the angle of the layout of the gillnet gear.

Turbines as landmark or target

Several respondents (8), including six recreational fishers, noted that they considered the wind farm to be a destination or



Graph 1 | Perceived offshore wind farm impacts described during the interviews with fishers.

target for recreational fishers. It was considered a destination for fishing; as one recreational fisherman said, "If there was nothing out there, I certainly would not have gone out there otherwise. It definitely has the bug to a lamp effect."

While recreational fishers generally felt that the wind farm's role as a destination or target was beneficial, the two commercial fishers who brought up this impact described it as negative because it increased the amount of activity going on in their fishing grounds.

Compensation for negative impacts of wind farm

Six commercial fishers discussed compensation in the event of negative impacts on their fishing. One fisherman did not think that it was necessary for him to get any compensation because he only transited through the area. One recreational fisherman wanted assurance that a commercial fisherman who had a historic fish trap would be reimbursed for relocating his trap to accommodate the cable.

More commercial rod and reel fishers in the area

Commercial rod and reel fishers fish with the same technique and gear as recreational and charter boat fishers, but have a commercial license to sell the fish. Respondents noted that it is difficult to tell what license other fishers were using, but some respondents (5) felt that there were more commercial rod and reel licenses being used in the area than in the previous years.

Establishment of new spearfishing grounds

Five of the spearfishing respondents felt that the wind farm provided new grounds for spearfishing. Spearfishers described how they sometimes went to the wind farm to target rarer fish species, like tropical fish. The wind farm area also attracted spearfishers that were beginners because of the novel experience of being around the turbines. One charter spearfisherman described how he now "can take beginners to it [the BIWF], because they can just float around and look at it… I mean it's incredible looking.… And the amount of fish-life's unbelievable. […] People want to see it [the BIWF]. Gives them something to look at besides the norm."

He continued, "Within two or three months [of construction of the BIWF] it was loaded with fish. And this year it has even more. So now it's not only structure to hide them but there's a food source on it. […] I think it will keep getting better [for spearfishing]. But there's mussels all over it, the scup [a common pelagic fish in the region] are eating the mussels… there's bass on it eating the scup… there's uh there's all kinds of small marine life… minnows and shiners that are hanging around it for protection. And of course, that brings in the pelagics."

Benefit of not using diesel generator for electrical power on the island

Several fishers (4) discussed the benefit of not using the diesel generator on the island. Some of the fishers lived on the island and felt that the benefit of not using the diesel generator for electrical power outweighed any other concerns. One recreational fisherman residing on the island noted, "The wind mills are not that offensive. They're not saving us any money at this point, but as my wife is quick to point out, we're getting a constant flow of electricity. With the generators, it was always going up and down. . . Nobody on Block Island, when they were running the diesel generators, could use an electric clock, because it would not keep time... That also wore heavy on your appliances..... and now it [electricity] is consistent."

Concerns about future wind farms, access to the area after construction, and decommissioning the turbines

Three respondents were concerned about future wind farm projects, their access to those areas, and how turbines would be decommissioned. One fisherman explained, "this particular farm isn't the end all, be all [. . .]. They are going to put something like 200 turbines here and the whole ocean, you know, is going to be carved up."

Another commercial fisherman noted, "This is just 5 wind turbines. Five in a row. If it was 15 or 20 in a block, or 50, that would be a whole different story. Now, this little demonstration project is not a big deal, and really doesn't have a big impact so to say."

He continued, "I mean, it [BIWF project] is minimal, but still, there they are. It's offensive that they are there on the water. Here is the radar [shows interviewer a photo on his cell phone of his boat's radar]. I took quick pictures of [the turbines], for the radar. . . . The blue dot there is [my boat], see how these sweeps, now that's on a 6 mile range out there, see how it's [the turbines are] just obliterating the opportunity to see any other target on there." To this fisherman, the wind farm was a physical symbol of his concerns about the future, dislike of many different aspects of the project, and navigational issues with the turbines.

Ecological Impacts

Structure" or "reef" or "fish aggregating" as rationale for fish behavior

Most respondents (20), including 17 recreational fishers, noted that the wind turbines created a new structure for fish habitat and served as an artificial reef. Many fishers (9) also noticed mussel growth and fish attraction as a description of the artificial reef, as one recreational fisherman noted, "the fish were on the structure within a month of them putting it in. . . it was incredible. [. . .] These had growth, they had small mussels on 'em within a couple months. . . It was unbelievable!"

Another fisherman explained that the wind farm structure created a deep vertical ecosystem: "Coming up from the bottom almost all the way up, you could almost see them from above, like a vertical ecosystem, of just like, scup. [. . .] So it's definitely acting as sort of an artificial reef. It's definitely benefiting the fishing."

One recreational and one commercial fisherman discussed how the turbines did not provide a new long-term habitat, noting that the artificial reef would not create a richer area for fishing, but just serve as a temporary attraction for fish.

Additional fish noticed in the area, including cod, a target species

The fish species found at the BIWF are a mix of in-shore and offshore species. Many recreational fishers (11) noticed additional fish species in the area. Some of the fish species that have been noticed around the turbine by respondents include scup (*Stenotomus chrysops*), summer flounder or fluke (*Paralichthys dentatus),* black sea bass (*Centropristis striata*), striped bass (*Morone saxatilis),* tautog (*Tautoga onitis),* bluefish (*Pomatomus saltatrix*), mako shark (*Isurus oxyrinchus*), triggerfish (*Balistidae spp.),* Almaco jack (*Seriola rivoliana*), cobia (*Rachycentron canadum*), mahi mahi (*Coryphaena hippurus*), bonito (*Sardini* spp.), false albacore (*Euthynnus alletteratus),* banded rudderfish (*Seriola zonata*), sea robin (*Triglidae spp.)* and cod (*Gadus morhua*). Five fishers noted that the wind turbines attracted cod, a targeted fish rarely seen in waters near the wind farm, and one said that he personally caught cod there in 2016, after the turbines were installed. In fact, respondents brought up cod more than any other species when describing changes in fish populations near the turbines.

One spearfisherman noted, "I think, we're seeing a wholesale change of the whole area. Oh yeah, because I see this whole ecosystem developing out there. This whole thing with the codfish and the herring, that just blew my mind. I mean, like, I was pulling up the codfish and they had herring like this big [uses hands to show interviewer the size of the fish] in them. And there was a reason that the herring were hanging out in that area. And like I said, that was not last year but the winter before. Winter of'16. I mean, just the number of bluefish that I've seen..."

He explained that he likes to fish near the wind turbines to catch different types of fish, both in-shore and offshore, "We definitely dive [turbine numbers] 5 & 4, shoot a couple blackfish [tautog] off of it. . . . Shoot another semi-tropical thing. You go out and try to target a big blackfish because there are big ones there, up to ten pounds and over."

Sounds issues and fewer fish during construction

Respondents also described how turbine construction negatively impacted water quality and underwater noise. One fisherman noticed murky water quality, sound, and vibrations during the 3 weeks of drilling, saying, "The whole side of the [Block] island was just a big mud plume. . . . And then as the tide switched, it would generally dissipate. But when they were using the lancers to drive it, there was just silt everywhere. And the pounding, you could hear the pounding on Watch Hill Reef in the water. . . you could hear the pounding of the pilings being driven."

Many fishers (11) felt that there were fewer fish in the area of the wind turbines during construction. Some described the fish as being "chased" into other areas that were further away from the wind farm and noted that there seemed to be more fish in other areas around the island. Two spearfishers noted that the sound of drilling negatively impacted fish on the southeast side of the island; that there were fewer striped bass on the side of Block Island closest to the turbines during construction and more of them in other areas around the island. This short-term impact of noise pollution was the primary negative environmental impact of the turbines and discussed by seven respondents, although the fishers felt that the fish quickly recovered after the noise disturbance.

One spearfisherman explained, "I'll tell you what used to scare the fish.... When they built them [turbines]. When they were putting them in, when they were driving those things down in the ground, we could hear it underwater on Block Island in the shallows... almost 3 miles away. I mean loud! It scared all the fish in the area, we had really bad fishing in that area in that season... once they were in... once they laid up driving the pilings, then the fish would return. So, it would just make them nervous for a short period of time."

Ecological differences among turbines

Eleven fishers perceived slight ecological differences around each of the turbines, indicating that they preferred fishing at certain turbines. A few other respondents (3) felt that even when the turbines were located on different substrate (e.g., mud, rock), the ecosystems around each turbine were identical.

One spearfisherman explained that his favorite turbine to fish was Turbine 5 (see **Figure 1**), saying, "I've been on the other turbines, it hasn't been quite as good in the past on [turbine] 1. What's happening, I think the ecosystem is growing this way, and maybe it has to do with the incoming tide, but they all seem to be covered with the base layer of mussels now. And that's what they need. The base layer ecosystem that they need, which will promote other growth, which will promote growth for the other fish. I haven't spent enough time to say it's not good there. [...]. Oh yeah, definitely, [turbine] 5 has the densest mussels, 5 is definitely the leading edge of the ecosystem, that's what I think, that's my impression."

BIWF has no impact on fish

Many fishers (11) felt that the wind farm had no major ecological impacts. They felt that fish stocks had natural variability, and that the wind farm had not had a discernably large impact on fishing. One charter fisherman explained, "This year [2017] has been a crazy year, so I don't know if it's because of the wind farm, or it's just a crazy year."

His comments illustrate the variable nature of local fisheries, further noting, "I mean, we had a really lousy spring, and we haven't had much of a summer either. And we have had a lot of bait. There is more bait around this year than there ever was. And I don't know why that's happening, but I think the fish are just getting so full of the bait, that you know, unless they are hungry, they are not going to come eat our lures. That is why I think the fishing is a little off this year. The bottom fishing is fine. Bottom fishing is good. But bass fishing... and bluefishing is off. There is hardly any bluefish around. When they show up, it's like, crazy. And then the next day they are gone."

Establishment of "mussels" or other habitat

When describing the turbines as an artificial reef, many (9) also mentioned mussel growth and fish attraction, as one recreational fisherman noted, "So that's what I've seen diving there... the explosion of the mussel population, the mussels up near the top are smaller... as you descend down past 15-20 feet, the mussels get to be, I'd say they're in the range of 2.5-3 inches right now. And they are densely packed onto it [the turbine]... there's mussels growing on mussels now. So, I don't know how they're going to address that ... I'm sure there's an industrial way of removing these mussels. They must do it all over the world. But I mean, the biomass of mussels on these things has got to be in the hundreds of tons... it's got to be. It's unbelievable."

DISCUSSION

Twenty-one different impacts associated with the Block Island Wind Farm were identified by individuals who fish the area in and around the BIWF. Most of the impacts were discussed by both recreational and commercial fishers. A few impacts were described by only recreational fishers. For instance, only recreational fishers said they had seen changes in cod abundance or noticed other fish species in and around the BIWF. In contrast, many commercial fishers said that the BIWF was having little to no impact on fisheries. While commercial fishers discussed some ecological impacts during the interviews, they focused more attention on human impacts. Human impacts garnering the most attention from commercial fishers included compensation, lost ground and gear, lost access during construction, and navigational concerns. Several commercial fishers (3) also expressed concerns about future impacts (i.e., decommissioning, access after construction, larger projects in the future), while these impacts got little attention from recreational fishers during the interviews.

Ecological impacts highlighted by respondents included short-term impacts on fish during construction to potentially longer-term impacts on mussel growth and new habitat around the turbines. The noise of pile driving during construction was perceived as a negative impact on the ecology of the area. Some respondents noted that there were fewer striped bass on the side of Block Island closest to the turbines during construction and more of them in other areas around the island. Other studies have also highlighted that animals have left a wind farm area during construction (Bergström et al., 2014; Vallejo et al., 2017). For instance, Vallejo et al. (2017) reported that harbor porpoise abundance decreased in the area of a wind farm during construction but that there was no change in porpoise abundance in the area pre-construction and post construction (i.e., during operation of the wind farm). Lindeboom et al. (2011) found that seals stayed away from an offshore wind farm during pile driving. Two studies (Lindeboom et al., 2011; Wilber et al., 2018) determined that although drilling for offshore wind farm turbines was audible in reference areas, it did not seem to have a major impact on fish abundance.

Findings from this study are consistent with prior research indicating that offshore wind farms have positive impacts by serving as "artificial reefs," enhancing habitat and attracting fish after they are constructed (e.g., Wilhelmsson and Malm, 2008; Lindeboom et al., 2011; Bergström et al., 2014). According to individuals who fish around the BIWF, the primary change (to date) at the BIWF has been at a lower trophic level (i.e., mussels), which aligns with existing studies. Petersen and Malm (2006) suggested that the ‘reef effect’ through the addition of hard substratum through turbine foundations and pilings would have the largest impact on the ecology of the area. In a study of offshore turbines in the Baltic Sea, Wilhelmsson et al. (2006) found that there was a greater abundance of fish around the turbines, and the community structure of the fish on the monopoles was different than it was before the wind farm was constructed. They also identified that mussels and barnacles were covering the turbines, noting that offshore wind farms serve as artificial reefs and potentially fish aggregating devices. In a study of the first offshore wind farm off the Dutch coast, Lindeboom et al. (2011) reported that the new hard substrate of the turbines enhanced biodiversity by acting as new type of habitat. Bergström et al. (2014) also found that there was habitat gain from offshore turbines that often increased local species abundance in an artificial reef effect, potentially resulting in changes to higher trophic levels.

Observations from individuals fishing around the BIWF suggest that there are already some changes in higher trophic levels occurring near the turbines, such as increases in certain species abundance (i.e., cod and black sea bass). These changes are consistent with findings by Raoux et al. (2017), whose model predicted that total ecosystem activity increased after construction of an offshore wind farm and that higher trophic levels such as marine mammals, birds, and piscivorous fish would increase, and Lindeboom et al. (2011), which showed that cod stayed around an offshore wind farm and seemed to find food and shelter at their bases for at least 9 months continuously. However, there is some evidence that black sea bass along the northeast US coast are migrating due to changes in climate (NOAA Fisheries Service NEFSC, 2018). More study is needed to better understand if observed changes in species abundance near the turbines are due to the wind farm or to broader environmental changes.

While fishers noticed some ecological changes in the area, the most significant changes were associated with human use of the BIWF. The perceived function of the wind turbines as artificial reefs or fish aggregating devices greatly affected recreational use of the area. Perceptions of greater fish abundance around the turbines will likely have future positive impacts on the recreational, commercial rod and reel, and spearfishing sectors in southern New England. These findings are not surprising, as a similar study of recreational fishers in the United Kingdom found that they had positive perceptions of the artificial reef effects of wind farms and 73% of anglers surveyed said they would be willing to fish around the perimeter or within a wind farm (Hooper et al., 2017). Although increased abundance of fish can aid fisheries and tourism sectors (Bergström et al., 2014), the increased activity could negatively affect resources and lead to overfishing (Giglio et al., 2018). For instance, Coleman et al. (2004) found that recreational fisheries landings comprised 23% of the total landings in the United States in 2002, and for some valued overfished species, recreational landings were greater than commercial landings. It will be important to monitor changes in fishing pressure, particularly recreational fishing pressure, around the turbines in the coming years.

As some fishers suggested in the interviews, changes in fishing around the turbines could also affect the fishing experience. Commercial fishers are already observing conflicts in use around the turbines. There could be crowding issues among recreational fishers as well, as the wind farm attracts more users over time. The growing popularity of wind farm tours seems to have increased the overall number of boats in the area, yet this increase in use might only be a short-term impact resulting from the novel experience of viewing offshore wind farms. Levels of use around the wind farm could eventually exceed social carrying capacity, or levels deemed acceptable to commercial fishers, recreational fishers, tour operators, and other users, affecting user experience and possible future use of the area (e.g., Dalton et al., 2017). More research on the effects of offshore wind farms on user crowding and social carrying capacity is needed to better understand longer-term impacts of offshore wind farms.

As an artificial reef, the turbines provided a new site for spearfishers, a subcategory of recreational fishers who use spearfishing gear underwater to target fish, often trophy fish (Young et al., 2015). Spearfishing is historically popular in Rhode Island, especially on Block Island (Korden, 2013), where spearfishers fish along rocky shorelines or other shallow reef areas. The BIWF gives spearfishers a novel experience in deeper waters and can potentially have positive impacts on the recreational spearfishing industry in Rhode Island. Alternatively, an increase in spearfishing might have some positive impacts on wind farm activities. Because they are able to make close observations about underwater ecology, spearfishers can provide early warnings of change in fish and habitat (e.g., Young et al., 2015). Videos captured by spearfishers in the Mediterranean provided a valuable tool for assessing the structure of fish assemblages on rocky reefs (Bulleri and Benedetti-Cecchi, 2014). It is possible that spearfishers around the BIWF could serve as citizen scientists, helping to monitor ecosystem changes over time (e.g., Bonney et al., 2014). Spearfishing has not yet been discussed in the literature as an impact of offshore wind farms in the North Sea; this may be due to the siting of the wind farms further offshore or in colder waters. More research on the potential impact of offshore wind farms on the recreational spearfishing industry, and the opportunity for spearfishers to provide information about the ecology of the area, is recommended.

Fishers around the BIWF have observed a variety of offshore wind farm impacts, yet these impacts seem to be unevenly distributed among different fishing sectors. Commercial fishers who historically used the BIWF tended to describe its impacts in a negative way (**Graph 1**). For instance, increased recreational fishing in the area resulted in gear loss, crowding, and reduced access to their fishing ground. They also highlighted navigational concerns about transiting the area. Recreational fishers, on the other hand, described more positive impacts of the wind farm related to increases in fish habitat and abundance, leading to an improved fishing experience. As noted earlier, it is possible that changes in ecology and use will negatively affect the experience of recreational fishers around the BIWF, but for now, negative impacts of the BIWF are most strongly felt by commercial fishers who had historically used the area. Our findings support the suggestion by Hooper et al. (2017) to consider co-locating recreational fisheries with offshore wind farms, and providing compensation to commercial fishers who have historically fished there.

CONCLUSION

Through interviews with commercial and recreational fishers, this study demonstrates how local or traditional ecological knowledge can highlight perspectives of people who are closely connected to a resource (e.g., Berkes et al., 2007). There have been numerous ecological, physical, and engineering studies of wind farms, but only a few social science studies focusing on human impacts at sea. Improved understanding of the perceptions, values, and experiences of local stakeholders in the marine environment sheds light on how resources will be impacted and can provide additional context for biological studies (Diogo et al., 2017). Local knowledge of BIWF fishers that was gathered through this study can supplement the findings from ecological studies of the BIWF and contribute to a more holistic understanding of the impacts of offshore wind farms.

Several larger wind farms are being proposed along the Atlantic coast of New England. Rhode Island selected DW to plan a 50 turbine project with 400 MW capacity, Massachusetts awarded a contract to a 100 turbine project with 800 MW capacity, and New Jersey passed a law requiring 3500 MW of energy be generated from offshore wind power (Coren, 2018). The findings of studies like this one can be used to inform how decisions on where, how, and if offshore wind farms can be placed to aid fishers (e.g., Rigano and Delle Fave, 2017). High quality environmental impact assessments of offshore renewable energy projects are needed, yet lacking (Maclean et al., 2014; Willsteed et al., 2017). Findings from this study will inform on-going environmental impact assessments of offshore wind farm projects in the US and elsewhere. It is important to note that the BIWF was developed in state waters, <3 miles from shore, and has only five turbines, so there is still some uncertainty associated with the impacts of larger-scale wind farm projects further offshore in the US. More research on this is needed.

Energy production from offshore wind farms will contribute to broader efforts to integrate renewable energy sources into climate change mitigation and sustainable livelihoods. The Intergovernmental Panel on Climate Change (IPCC) found that renewable energy sources could reduce CO_2 emissions by more than half the estimated amount between 2011 and 2050, since the majority of greenhouse gas emissions were due to consumption of fossil fuels (Edenhofer et al., 2011). The IPCC Report and other studies note that these estimates depend on the technologies, system behaviors, site-specific conditions and types of energy sources being replaced, but potential benefits of renewable energy include social and economic development, access to energy, more secure energy supply, reduced air pollution, and lower fatality rates (Edenhofer et al., 2011; Esteban et al., 2011; Saidur et al., 2011; Leung and Yang, 2012; Bruckner et al., 2014). While offshore wind has the potential to meet energy needs more sustainably than fossil fuel consumption, the impacts of renewable energy projects must be better understood. Local knowledge of the fishers in this study have provided valuable insights on the impacts of offshore wind farms on recreational and commercial fishers. Policymakers, developers and users can use these insights to more effectively plan and develop offshore wind projects.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of Institutional Review Board. The protocol was approved by the Institutional Review Board, University of Rhode Island Office of Research Integrity, Division of Research, and Development. All subjects gave written informed consent in accordance with the Declaration of Helsinki.

AUTHOR CONTRIBUTIONS

TtB: contribution to the paper through data collection, analysis, and interpretation, manuscript writing, and serving as corresponding author; TD: contribution to the paper through development of the project, oversight on data collection, analysis, interpretation, and manuscript writing.

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SUPPLEMENTARY MATERIAL

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