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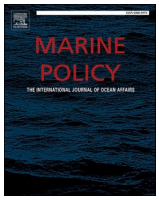

Offshore wind farms in New Jersey, USA: Stakeholder concerns and anticipated impacts on recreational fishing

Kripa Shrestha [a,b,*], Pankaj Lal [a,b], Meghann Smith [b]

[a] Clean Energy and Sustainability Analytics Center, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, USA
[b] Department of Earth and Environmental Studies, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, USA

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ABSTRACT

Offshore wind farms (OWFs) are being developed to generate renewable, carbon-free electricity for the grid; however, the development of OWFs faces resistance, especially from marine recreational fishers. This research explores charter boat captains' and owners' perspectives toward OWF development in New Jersey, USA, based on responses from 87 participants in an online survey, including 10 who also participated in follow-up telephone interviews. The research identifies widespread opposition to OWFs (91 % of respondents), rooted in concerns over ecological disruption, navigation safety, access restrictions, and economic impacts. Respondents reported observed shifts in fish migration patterns, increased marine mammal stranding, and anticipated operational risks tied to OWF infrastructure. Many also expressed dissatisfaction with stakeholder engagement processes and skepticism regarding promised economic benefits. While some participants acknowledged the potential of OWF structures to function as artificial reefs, the prevailing sentiment emphasized a need for stronger safeguards, transparent planning, and inclusive governance. By providing a nuanced understanding of these concerns and the factors shaping them, this research equips policymakers and OWF developers with the knowledge to pursue targeted mitigation strategies, build trust with fishing communities, and ensure that the needs and perspectives of recreational fishers are meaningfully incorporated into the planning and implementation of OWF projects.

1. Introduction

In response to the pressing issues of energy scarcity and environmental degradation, sustainable and alternative sources of energy are being sought out globally. As a result, wind power has gained significant attention as an abundant, clean, and renewable energy source. In line with this trend, the Intergovernmental Panel on Climate Change (IPCC) suggests that renewable sources, including wind energy, could meet up to 80 % of the world's energy demand by 2050 [1]. With the onshore market for wind energy expanding and land becoming scarce, the development of offshore wind farms (OWFs) is crucial to sustain this growth [2]. Exploitation of offshore wind energy (OWE) can reduce greenhouse gas emissions and ease pressure on the power supply in economically developed coastal regions. Therefore, offshore wind has become one of the fastest-growing energy technologies and a future focus for many countries worldwide [3].

OWF development serves as a powerful catalyst for job creation, renewable energy access, and broader socio-economic benefits within regions where implemented. The global offshore wind capacity has scaled up substantially over the past two decades, reaching over 63 GW despite the disruptions caused by the COVID-19 pandemic [4,5]. The top five global markets for offshore wind include China (41 GW), the United Kingdom (UK) (13.9 GW), Germany (8.1 GW), the Netherlands (2.8 GW), and Denmark (2.3 GW) [5]. In line with global trends, interest and investments in OWFs have recently expanded in the United States (U.S.) [6]. According to the Department of Energy's (DOE) National Renewable Energy Laboratory (NREL), meeting the national target of 30 GW in offshore wind by 2030 will help the U.S. avoid up to 78 million metric tons of carbon dioxide (CO_2) [7]. New Jersey (NJ) is positioning itself as a contributor to OWF development in the U.S., with the ambitious goal of generating nearly 50 percent of its electricity needs (i.e. 11, 000 megawatts (MW) by 2040. With three awarded OWF projects and several additional lease areas proposed, offshore wind is expected to play a vital role in the state's energy transition, supporting its goal of achieving a 100 percent clean energy economy by 2050 [8].

As a coastal state, boating and recreational fishing are popular activities for residents and tourists. The Recreational Boating and Fishing Foundation reports that the number of U.S. anglers aged six and older

* Corresponding author at: Clean Energy and Sustainability Analytics Center, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, USA.
E-mail addresses: shresthak2@montclair.edu (K. Shrestha), lalp@montclair.edu (P. Lal), smithmeg@montclair.edu (M. Smith).

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has steadily increased in recent years, reaching 50.1 million in 2019 [9]. This means that approximately one out of every six Americans enjoys fishing. The economic impact of recreational fishing is substantial, with anglers spending over $51 billion annually on equipment, licenses, trips, and other fishing-related expenses [10]. In NJ, over 1 million recreational anglers spent $867.6 million on fishing, supporting 7410 jobs and contributing $1.1 billion to the state's economy [11]. Likewise, NJ's recreational boating sector generates $6.6 billion annually, directly supporting 20,177 jobs and 1193 businesses [12]. With 164,911 boats registered, NJ boasts a thriving boating community, including $677.6 million annual new boat, engine, trailer, and accessory sales [12,13].

The State of NJ estimates that on average, each OWF is expected to create over 4000 jobs and contribute an additional $700 million to the state's economy [14]. While the potential environmental and economic impacts of OWFs are substantial, the recreational fishing community has voiced concern and opposition to its development [15,16,17]. Despite these concerns, empirical studies assessing the impact of OWFs on recreational fisheries remain limited [16,18], with a notable gap in research specifically examining the impacts on the boating sector. By taking a stakeholder-centered approach, OWF developers can better integrate social complexities into their development plans to better meet the needs of the communities they serve [19,20]. This paper aims to address this gap by investigating charter boat captains' and owners', who serve as recreational fishers, attitudes, preferences, and perceptions of OWFs in NJ, U.S. In this study, the term recreational fishing specifically refers to boat-based recreational fishing activities, and does not encompass the broader boating sector, which includes sailing, cruising, or other non-fishing boating uses.

2. Literature review

The need to decarbonize the energy sector in response to climate change and achieve national and global emissions reduction targets has catalyzed the expansion of renewable energy technologies. OWFs have gained increasing traction in recent years as a key component of this transition due to their high energy-generating potential and technological developments for deeper water and more efficient turbine installations. Compared to onshore wind, OWFs offer several advantages: access to stronger and more consistent wind resources, vast maritime spaces that reduce land-use conflicts, and the ability to deploy larger turbines that improve efficiency while minimizing visual and noise impacts on populated areas [21,22].

Despite these advantages, OWFs also present unique environmental, economic, and social challenges. These include concerns about ecological destruction [23,24,25], questions of economic feasibility [26,27], and issues of social acceptance, especially among coastal communities wary of impacts on seascapes, recreational uses, and traditional maritime activities [16,28,29]. Environmental concerns include noise pollution, habitat disruption, and altered migratory patterns of marine species and birds during site assessment, construction, operation, and maintenance [30–35]. A growing body of research highlights the complex and sometimes contradictory ecological and socio-economic outcomes associated with OWF development. For instance, Lüdke et al. [36] found that offshore wind infrastructure in Germany's North Sea produced both benefits - such as benthic habitat enhancement - and drawbacks, including harm to fish and bird populations. These findings spurred mitigation efforts like noise reduction technologies and fisheries compensation programs. Likewise, Mavraki et al. [37] found that while some fish species used OWF structures as feeding habitats, others did not benefit from these artificial environments, underscoring variability in ecological responses.

Perspectives within the recreational fishing community also reflect this complexity. In the UK, Hooper et al. [16] found that angers often viewed OWFs positively as artificial reefs supporting fish abundance, though the opinions were mixed on whether catch rates improved. In the U.S., the Block Island Wind Farm (BIWF) serves as a prominent case study of how OWFs intersect with local community dynamics. Recreational anglers near BIWF reported increased fish diversity and abundance near turbine structures [17,18,38], with research showing changes in species composition and the formation of new habitats [39–41]. Beyond ecological outcomes, OWFs also shape local economies and public perceptions. Studies found that Rhode Island residents, including those on Block Island, generally supported the BIWF, citing its aesthetics, local job creation, and perceived tourism benefits as notable contributions to the region [42,43].

While ecological and economic impacts are central to OWF assessments, stakeholder engagement and public perception are equally critical. Effective participatory planning, as demonstrated during the BIWF's development, helped build trust and community buy-in [44,45]. However, gaps remain in our understanding of how specific user groups, especially recreational marine stakeholders experience and perceive OWFs. Although commercial fishing impacts are frequently studied, the implications for recreational fishing and boating are under explored [46]. Conditional support from these groups often hinges on factors such as continued access, perceived crowding, and proximity of turbines to the shore [47]. Visual impacts are also a recurring concern, with support generally increasing as turbine distance from the shore increases [48,49], while opposition may be rooted in perceived procedural injustice or emotional attachment to coastal landscapes [28,50].

Despite these challenges, public support for OWFs often stems from their symbolic value as a step toward climate change mitigation and long-term energy equity [51,52]. Still, more comprehensive assessments are needed to understand the nuanced responses of marine resource users such as recreational boaters, ferry riders, and conservationists [33,53]. While most studies suggest neutral or positive effects on recreational boating [29], empirical research remains limited.

This study contributes to the growing body of OWF literature by focusing on a specific but underrepresented stakeholder group: charter boat captains and owners within NJ's recreational fisheries industry. By examining their experiences with and perceptions of OWF development, this research highlights the importance of engaging affected stakeholders to inform equitable planning processes, promote sustainable development, and enhance the understanding of OWF impacts on recreational fisheries.

3. Methodology

3.1. Study sites

The study area includes three awarded OWF projects in NJ coastal waters that are still in the planning and development phase and have not yet been constructed. This distinction is essential to contextualize the results presented in this study, which are based on the attitude and perceptions of the future anticipated impacts. As of January 2025, several offshore wind projects in the US have been paused or halted, with no official timeframe established for resumption of activities or regulatory approvals.Fig. 1 shows a detailed map of the Bureau of Ocean Energy Management (BOEM) awarded and proposed lease areas, artificial reefs, and prime fishing grounds. Information on the OWF projects, including anticipated power generation, is listed in the Table 1.

3.2. Data collection and analysis

This study employed a mixed-methods approach, combining both

Table 1
Offshore Wind Project in NJ.

Lease Area	Project	Award Date	Power (MW)
OCS-A 0499	Atlantic Shores	July 2021	1510
OCS-A 0538	Attentive Energy Two	July 2021	1342
OSC-A 0542	Leading Light	January 2024	2400

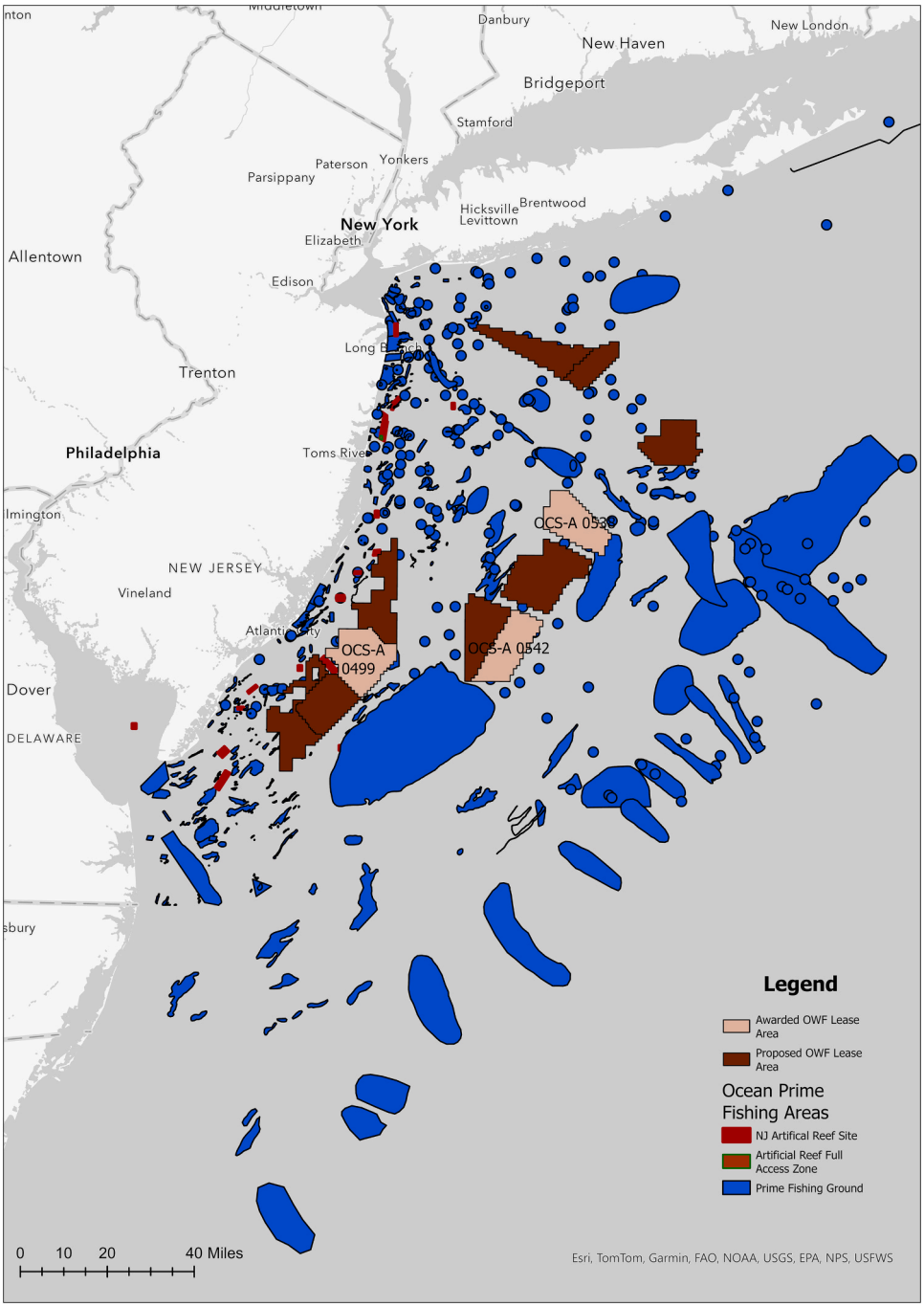

Fig. 1. Prime fishing grounds of NJ OWF lease areas (Data source: NJDEP Bureau of GIS).

quantitative and qualitative techniques to gather comprehensive insights into the perceptions and experiences of charter boat captains and owners regarding OWFs within their operational areas, as well as their boating activities. The survey was developed based on a comprehensive review of existing literature [17,23,33,38,43,45,47,51,54–60] and local newspaper articles exploring this subject. The survey was broken into four sections, which included closed- and open-ended questions related to Recreational Fishing (including boating), OWF Development, Perceived Impacts and Recommendation, and Socio-demographic information. To complement the survey, a set of open-ended interview questions were designed to explore key survey themes in greater depth, which would allow participants to give deeper context for their survey responses. Following institutional review board approval (IRB Study No. FY23–24–3238), online surveys were disseminated via Qualtrics survey software between February and April 2024, targeting charter boat captains and owners registered and operating in NJ. The contact information for 573 registered boat captains and owners was sourced from the New Jersey Department of Environmental Protection's (NJDEP) NJ DEP boat captains/owner database Agency, Bureau of Marine Fisheries. At the end of the survey, participants were given the option to volunteer their contact information to participate in a follow-up telephone interview. Survey responses took approximately 15–20 min to complete.

Interviews were conducted via telephone in May 2024 with a subset of respondents who opted in the survey. The interviews provided a more flexible and conversational format for participants to elaborate on their survey responses or raise new issues. Each interview lasted approximately 10–15 min, was audio-recorded with consent, and transcribed for analysis. Researchers referred to the completed survey during each

call to guide the conversation and seek clarification where needed.

Quantitative data were analyzed using JMP Pro software, employing descriptive statistics to summarize participants' responses. To further support the interpretation of qualitative data, we applied inductive thematic analysis to systematically identify, analyze and report patterns (themes) within the open-ended survey responses and interview transcripts [61]. Inductive thematic analysis allows the data to determine the themes rather than being driven by pre-existing assumptions. After reviewing the survey responses and interview transcripts, we identified broad themes (e.g., ecological concerns) which were further refined to include more specific sub-themes (e.g., whale beaching, migratory animals). We coded each theme and sub-theme, and recorded the frequency with which each theme and subtheme was mentioned, calculating the proportion of participants who expressed each concern relative to the total sample. This allowed us to assess not only the diversity but also the relative salience of different issues raised by participants. Representative quotes from both the interviews and open-ended survey responses are included in the results section to illustrate key themes and give voice to the participant perspectives, thereby grounding our interpretations in the data.

4. Results and discussion

4.1. Profile of the respondents

Altogether 87 complete responses were received from the online survey, resulting in a 15.2 % response rate. 10 of those respondents consented to participate in audio-recorded telephone interviews.

19.5 % of respondents identified as charter boat captains, and 80.5 % indicated they were both charter boat captains and owners. Among them, 78.2 % reported over 10 years of experience operating in NJ waters, indicating a high level of familiarity with the study's greater region. In addition, 96.6 % of respondents were identified as recreational fishers. The majority of the respondents (90.7 %) were residents of NJ, and many provide their services near Atlantic City (17.7 %), Ocean City (12.4 %), Long Island (5.3 %), among other major hubs for recreational boating and fishing in the region (Fig. 2). Most respondents were male (93.6 %), high-earning (80 % earning $100,000 + per year), and highly educated (53.1 % with a bachelor's degree or higher); however, only 36.8 % indicated that charter boating was their primary source of income.

4.2. Recreational marine fishing in NJ

Charter boat captains and owners play a key role in facilitating access to offshore fishing grounds for both residents and tourists, and contribute notably to local economic vitality. Drawing from their long-standing experience, many respondents shared detailed observations of changes in fish populations and distributions over time. According to the respondents, the major species targeted by recreational fishers in the region include black sea bass, tuna, fluke, striped bass, summer flounder, bluefish, and striper (Fig. 3). While some respondents acknowledged that natural fluctuations in fish populations occur over annual and decadal periods, others perceived a marked decline in the abundance of certain species observed within the past 10–20 years. Specifically, respondents noted a decrease in summer flounder (*Paralichthys dentatus*), weakfish (*Cynoscion regalis*) and Atlantic mackerel (*Scomber scombrus*), while observing an increase in stripers/striped bass (*Morone saxatilis*), bluefin tuna (*Thunnus thynnus*), jellyfish (*Cassiopea xamachana*), and Atlantic menhaden (*Brevoortia tyrannus*). These species trends are not only ecologically significant but also economically consequential, as they directly affect trip planning, catch success rates, and customer satisfaction among recreational fishers. For example, according to the Atlantic States Marine Fisheries Commission [62], summer flounder are highly valued in the recreational fishery, with the 2022 recreational harvest reaching 8.6 million pounds, an increase from 6.8 million pounds in 2021. Similarly, Atlantic mackerel plays a critical ecological role by linking different trophic levels in the marine food web and serving as a nutrient rich food for many predator fish such as bluefish, weakfish, bluefin tuna, whale, dolphins etc [63]. Respondents also noted changes in striped bass migration patterns due to coastal disturbances like dredging and beach replenishment projects. It is important to note that the economic importance of striped bass is substantial. In 2016, recreational angling for this species supported 18,624 jobs and

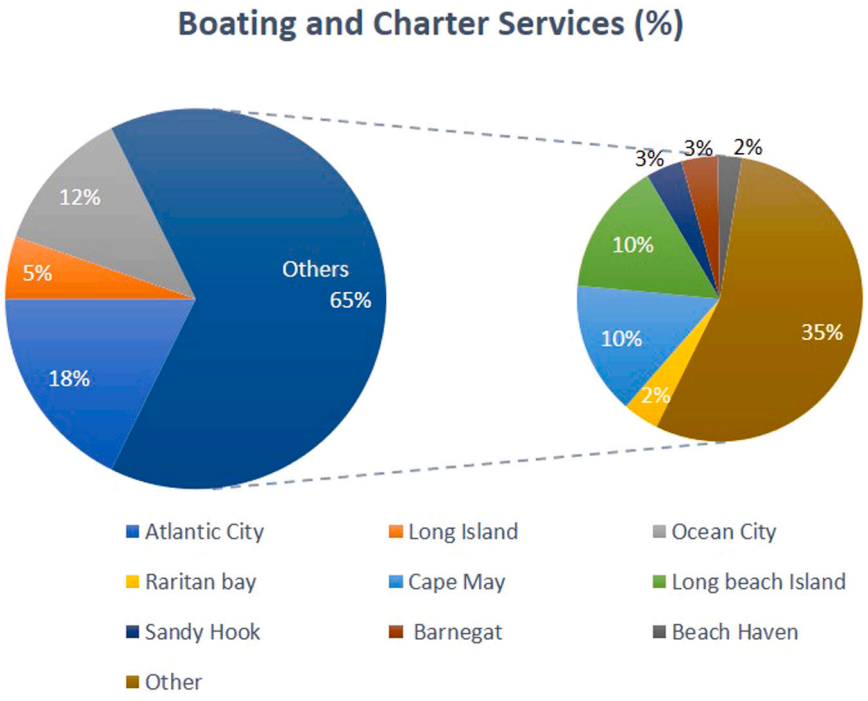

Fig. 2. Area of Boating and charter services provided by the respondents (Others: Sandy hook, NY and NJ Bight, Point Pleasant, Northern Jersey shores, Belmar, Shark river NJ etc.).

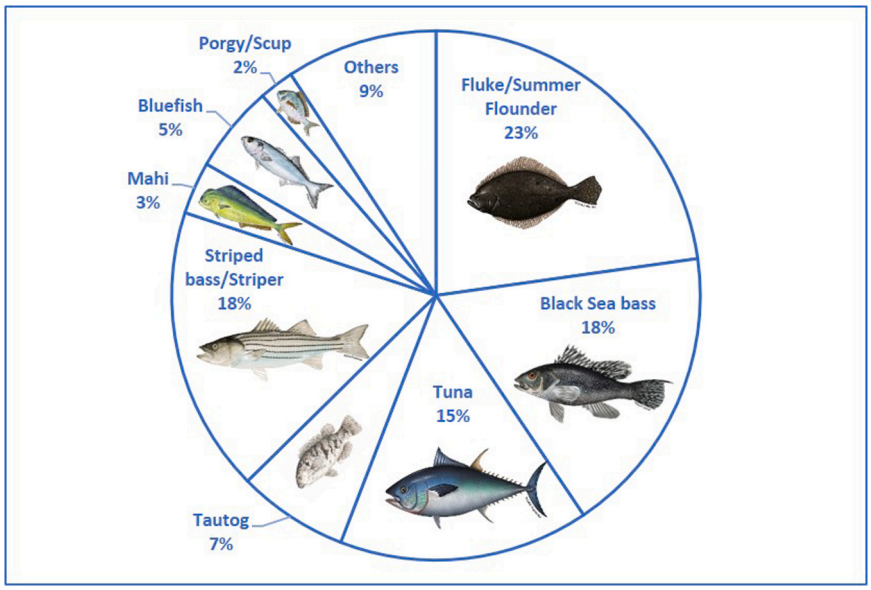

Fig. 3. Recreational marine fish species in NJ (*Others: Blue Marlin, Bonito, False albacore, Weakfish, Triggerfish, Sheepshead, Swordfish, Wahoo, Cod, Tilefish, ling*) (Fish photos source: NOAA Fisheries).

contributed over $1.6 billion to NJ's GDP [64]. These examples highlight the ecological sensitivity of these species and its role in sustaining coastal economies, underscoring the need to balance habitat preservation with sustainable recreational fisheries.

Concerns were also raised regarding the potential impacts of OWE development activities, with some respondents reporting a decline in fish abundance and an increase in marine mammal mortality (whale stranding) during periods of offshore developers' survey vessel activity, such as sonar testing. These concerns are also supported by the studies that have shown that beach nourishment projects can have a variety of environmental impacts, as the dredging and transport activities involved can directly disturb marine mammals and turtles [65–67]. Furthermore, BOEM [68] has acknowledged that the noise generated from these surveys can cause injury, hearing loss, or trigger behavioral changes to certain marine species. This information provides a foundation for understanding the intersection of environmental change, regulatory development and stakeholder experiences within marine resource management.

4.3. Charter boat operation for recreational fishing

Understanding the activities and cost flows associated with charter boat operations is essential for assessing how OWF development might impact the recreational fishing sector. For the majority of boat captains and owners (63.2 %), recreational fishing is a seasonal endeavor rather than a primary source of income, leading them to pursue various other occupations during the offseason. This finding aligns with a 2023 report on fishing which revealed that 55 % of U.S. saltwater anglers fish occasionally, while 41 % identify as avid anglers [69]. Our study showed that the saltwater recreational fishing in the region generally occurs between March and November, with a peak season during the summer months of June through August (Fig. 4). Most fishing expeditions (33.8 %) involve traveling more than 60 miles offshore, highlighting the industry's reliance on access to offshore fishing grounds (Fig. 4). Any disruptions to established routes such as those that might arise from OWF constriction or operational zones might pose potential risks to operational cost and customer satisfaction. These potential issues, among others, were acknowledged as key areas of concern by study

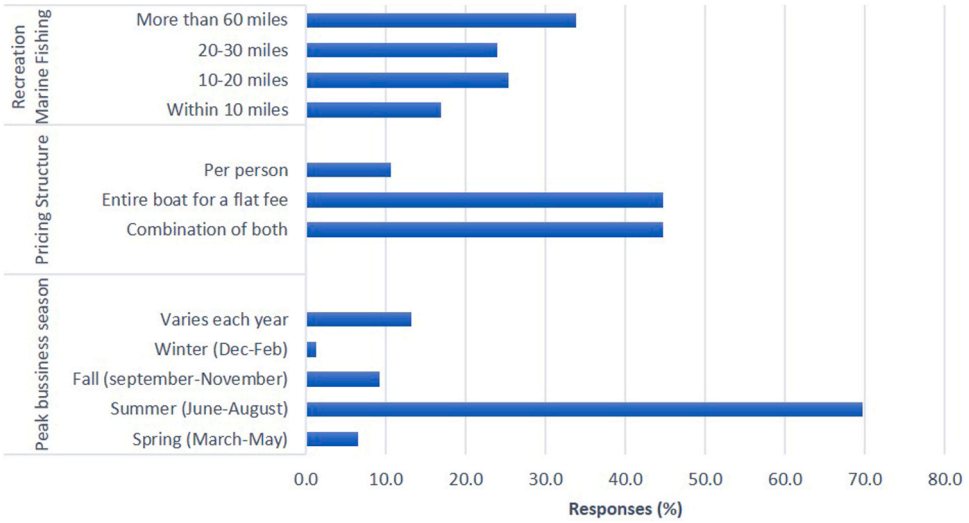

Fig. 4. Graph showing distance travelled for Recreational marine fishing, pricing structure for boating service and peak business season for recreational fishing in NJ.

participants as detailed in the following section. This concern is compounded by the nature of pricing models in the sector. Most operations use either a flat fee (44.7 %) or a combination of flat fee and per-person rates (44.7 %), with only 10.6 % using per-person pricing exclusively. Rates vary widely depending on trip length and passenger numbers, with hourly rates ranging from $75 to $250, half-day trips from $95 to $2000, and full-day excursions reaching up to $5100. These price structures leave operators vulnerable to fluctuations in fuel prices and operational constraints factors that could be exacerbated by OWF-related restrictions. In addition, the presence of these structures in navigable waters creates a risk of collision hazard, potentially resulting in vessel damage, environmental pollution, and, in severe cases, fatalities [70].

4.4. Perceived impacts of OWF development

Respondents shared a wide range of perspectives on the potential impacts of OWF development on the recreational fishing and boating industry. The survey findings revealed deep concerns among the party/charter boat operators regarding the potential impacts of OWF development on their businesses and the broader recreational fishing sector. 91 % of respondents opposed the development of OWF in NJ within their operational areas, citing a range of anticipated negative effects (Fig. 5).

When asked to agree or disagree with a list of perceived impacts of OWF development on the recreational fishing and boating sectors, the majority of respondents expressed strong agreement with negative impacts while largely rejecting potential positive outcomes (Fig. 5). Respondents largely disagreed that OWFs would create new jobs (44.3 %), produce a clean form of energy (56 %), support energy independence (69 %), enhance natural beauty or aesthetics (88 %), increase recreational (58 %) and commercial (78 %) fish catches, improve NJ's recreational fishing appeal (74 %), attract more tourists or residents (69 %), and improve the local economy (75 %) Conversely, respondents largely agreed that OWFs would negatively affect the marine environment (76 %), lead to overcrowding and restrictions (60 %), reduce NJ's appeal for recreational fishing (68 %), disturb marine species (78 %), force longer travel distances (82 %), and industrialize the ocean undesirably (87 %) (Fig. 5). We applied regression analysis to explore whether there were any significant factors contributing to respondents' opposition to OWFs; however, due to a high degree of response homogeneity there was limited variation in responses, and the statistical tests did not yield significant results.

The introduction of OWFs into marine environments underscores the need for careful planning and management to avoid detrimental consequences for both the ecosystem and maritime industries [71]. The concerns expressed by study participants are further explored in the following section, leveraging qualitative data from open-ended survey questions and interview quotes. This qualitative data draws on responses from a total of 87 participants, including quotations from 10 individuals who also took part in follow-up interviews. The data was then categorized into seven themes (subheadings to follow), where we utilize proportion of responses and direct quotations to the discussion of OWF support and opposition. Using these insights, we discuss pathways for mitigation efforts to balance clean energy goals with the sustainability of charter boat operations and marine recreational fishing (Table 2).

Table 2
Thematic analysis of perceived impacts of offshore wind farms (OWFs) based on participant responses (*Respondents were able to write or mention multiple concerns in open ended questions, so percentages do not total 100 %*).

Perceived impacts (Theme)	Total (%)
Ecological Impact on marine ecosystem (Overall)	78 %
- Whale stranding	26 %
- Migratory birds	3 %
Electromagnetic Field	10 %
Noise/Vibration	9 %
Navigational hazard and safety	12 %
Turbine as artificial reef	3 %
Access after construction	15 %
Visual impacts	5 %
Negative impact on economic development	75 %

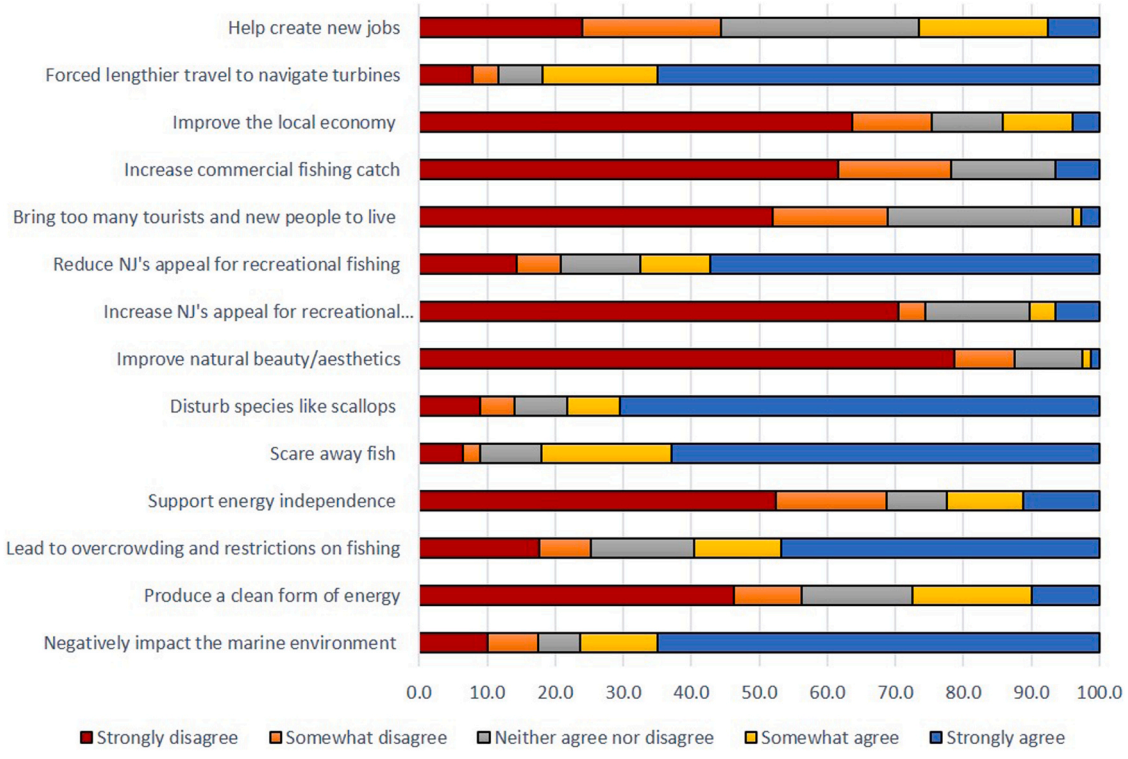

Fig. 5. Response to "In your opinion, how much do you agree/disagree with the following impact of the Offshore Wind Project statements?".

4.4.1. Ecological impact on marine ecosystem

A considerable proportion of respondents (78 %) voiced concerns about the potential for OWF development to disrupt fish habitats and migration patterns (Table 2). Some respondents reported observed declines in certain fish species during offshore survey activities, raising concerns about possible long-term changes to the local marine ecosystem. Respondents highlighted that migrating fish traveling from the south to northern NJ might avoid these areas entirely, potentially eliminating access to key fishing grounds in the northern region. Additionally, 26 % of respondents pointed to the reported increase of dead humpback whales stranded in NJ as a cause for concern. The following quotes from the survey captures these sentiments:

S-8: "*Most of the Whales we observed the past two years have been found dead, I believe it's over 25 now! When they stopped the sonar, the Whales stopped dying. This is a huge scam.*"

S-12: "*The dead whales & dolphins washing up onshore which are being blamed on by vessel strikes, which is false.*"

S-15: "*There is the issue with the boats out there doing the surveys killing the whales and not having the proper inspectors (marine life monitors) onboard while conducting surveys. I have two friends who scallop, both have dragged their gear through areas where the research boats recently surveyed and everything they pulled up was dead or dying (scallops, clams, fish, conch, and more)*."

Research indicates that OWF construction and operation can have both positive and negative effects on marine wildlife, with impacts varying based on local conditions and environmental management goals [72,73]. A study on UK anglers' perceptions of OWFs found divided opinions on the impact of future developments: 44 % believed their recreational angling activities would be affected, while 37 % felt there would be no impact. Among respondents to an open-ended question, 23 % anticipated positive changes, while 16 % expressed concerns about negative effects, such as harm to wildlife or electromagnetic field impacts [16]. Likewise, a survey on the Cape Wind OWF project found that respondents believed marine mammals' feeding habits would be most affected during construction, as most species would avoid the area due to pile-driving noise and deterrent measures. Respondents identified construction as the most impactful phase, scientists noted minimal impacts during operation, which could potentially benefit marine mammals [58]. There are many negative direct or indirect impacts on several marine species such as cetaceans (whales, dolphins, and porpoises), fish, marine turtles, and invertebrates that have been reported to date [55]. However, the National Oceanic and Atmospheric Administration (NOAA) stated that there are no known links between large whale deaths and ongoing offshore wind activities in NJ [74]. The impact of OWFs extends beyond marine mammals to bird and marine species migration [32,35]. While research on bird vulnerability and mortality related to wind farms has advanced, much of the current understanding is based on terrestrial data. Collecting direct mortality data from OWFs remains challenging due to the difficulty of locating bird carcasses at sea [98]. This underscores the need for further research to comprehensively assess the ecological impacts of OWF development and inform effective mitigation strategies.

4.4.2. Electromagnetic fields and noise

One of the concerns of the respondents (10 %) is the electromagnetic field that is generated by the subsea cables connecting the wind turbines to the onshore grid and noise/vibration (9 %) during and after construction. One respondent argued (S-18), "*The environmental disturbance from the sonic testing, construction, and continued maintenance far outweigh the possible benefits of destroying thousands of acres of prime scallop bedding areas*." Studies have shown that these fields can potentially disrupt the migration patterns and behaviors of certain marine species [76–79], such as sharks and rays, that rely on the earth's natural electromagnetic fields for navigation and prey detection. Likewise, the introduction of underwater noise throughout the lifecycle of an OWF, from installation and operation to decommissioning, presents a serious concern [75]. The construction of offshore wind turbines, specifically the pile driving of monopiles, generates substantial underwater noise pollution, reaching up to 228 decibels for a 1.5 MW turbine [80], and there is evidence from studies stating the injury to fish species due to pile driving sounds [81–83]. This intense sound can travel tens of kilometers underwater, potentially impacting marine mammals in various ways. These impacts range from temporary to permanent hearing damage and behavioral changes, such as displacement from the area to avoid the noise, and masking of communication signals [23,84].

4.4.3. Navigational hazard and safety

In addition to the potential impacts on marine habitats and fish populations, respondents also expressed concerns over the navigational challenges (12 %) posed by OWFs. The placement of large, fixed structures in key fishing and boating areas was seen as a major navigational hazard, particularly for smaller recreational vessels that may have difficulty maneuvering around the turbines. One interviewee (I-3) explained, "*Navigational hazards are a huge concern, as the turbines will be placed in the middle of prime fishing and boating areas, creating a maze for vessels to try to navigate through.*" This sentiment was echoed by many of the party/charter boat operators, who feared that the OWFs could severely disrupt their ability to access productive fishing grounds and lead to serious safety risks due to radar interference. While some expressed their concerns regarding the safety issue, some also responded (S-7) saying "*Without the project being completed it is difficult to answer but I feel that recreational anglers and boaters will not be permitted close to the turbine structures for fear that they will be vandalized or have accidental collisions. If that were to be the case, it would destroy the argument that the turbines would be good for fishing because fish are attracted to the underwater structures. It's not beneficial if we cannot fish near or around them.*" Some also stated (I-9) "*The concern is sooner or later, somebody's going to bang one of those and the impact would be irreversible.*" These statements and concerns are also supported by many studies that stated the turbines can interfere with radar systems, modify wind and tidal behaviors, and lengthen transit times for essential shipping and ferry routes [85]. Many studies conclude that the shipping and navigation impact of OWF is one of the high-level constraints [86,87].

4.4.4. Turbine structure to be an artificial reef

Some respondents envisioned OWF as potential tourism hotspots, suggesting that the artificial reefs created by turbine structures could attract sightseeing anglers and ecotourists, thereby boosting the recreational fishing industry and offsetting any economic drawbacks. Respondent (S-89) said "*Turbines could create an interest for sightseeing plus structure will help recreational fishing as an artificial reef*". Similar findings of turbine being artificial reef attracting fish species were observed in the other studies [17,72,73,88–92] and increased fish assemblages [72,73]. However, it's important to acknowledge that while some studies highlight the positive effects of wind farms on fish populations, others suggest potential negative impacts on pelagic productivity and food web dynamics [93]. Further research is needed to fully understand these complex interactions. Interestingly, a study on the Block Island Wind, the first OWF built in North America, found that most fishers, both recreational and commercial, observed an increase in recreational fishing in the area after the turbines were constructed [38].

4.4.5. Concern about access after construction

Respondents also expressed concerns about the potential for restricted access to fishing grounds after wind farm construction as the fishing area is all around the OWF lease areas (Fig. 1). Echoing this apprehension, when asked about the expected impact of OWF in the business/work, one respondent (S-31) shared, "*I will be restricted from the fishing grounds where I normally fish where these offshore wind turbines will be constructed. In addition, the species which I regularly target will be negatively affected by the construction in the local waters, which we have already seen by the survey boats in the area.*" They fear the introduction of

additional regulations and limitations on fishing around the turbines, ultimately hindering their ability to fish in these productive areas. This restricted access, they argue, would negate any benefits of the artificial reefs created by the turbine structures, rendering them pointless if fishing is prohibited. The reduction of available fishing areas and displacement of fishing activities can negatively impact the income of the fishing communities. While the UK and potentially France permit bottom trawling within offshore wind farms, most other countries prohibit this practice. However, passive and transit fishing, subject to certain limitations, are permitted within OWFs in the UK, Germany, Belgium, and the Netherlands. However, Denmark maintains a policy against all types of fishing within these areas [94]. Likewise, OWFs in Belgium are strictly off-limits to all vessels, with the exception of those required for wind farm maintenance or government research. This restriction has resulted in the loss of access to certain fishing grounds for both commercial and recreational fishing activities [34].

4.4.6. Visual impacts (Beauty and aesthetics)

In addition to the navigational and ecological concerns, some respondents expressed worries about the potential visual impacts of OWFs in the seascape. The prospect of seeing large, industrial-scale structures on the horizon was seen as an aesthetic detriment that could diminish the recreational appeal of the coastline and offshore areas. As one interviewee (I-5) said, "*The view from the beach will be ruined due to turbines, that will impact tourism.*"

The perceptions of visual impacts from OWF development vary widely in literature. A study on coastal residents' preferences along the U.S. East Coast found that those living on the coast often preferred wind farm projects located beyond 15 nautical miles (27.8 km) from shore, a preference not shared by frequent visitors to the coast [95]. Some anglers, while optimistic about the wind farm's effects on catch, were less enthusiastic about its impact on non-catch aspects of their experience, such as boat traffic and visual effects in BIWF, U.S [47]. Community acceptance studies commonly emphasize visual impacts, with a recurring finding that the public generally prefers turbines to be sited farther offshore, though only up to a certain distance [48,49].

Conversely, some studies highlight more positive perspectives. For instance, a study conducted in the Netherlands [96] found that people were still willing to visit beaches despite the presence of wind farms. Similarly, research in Delaware revealed that nearly 84 % of respondents were willing to visit a beach with wind turbines at least once, with 55.8 % indicating a high likelihood of doing so. This interest in experiencing wind farms firsthand suggests potential opportunities for tourism, such as recreational boat tours of the wind farm, dedicated visitor centers, and innovative marketing strategies for nearby beaches [97]. These findings underscore the diverse perspectives on visual impacts and highlight the potential for integrating OWFs into tourism and recreational activities.

4.4.7. Impact on economic development

Almost 75 % respondent disagreed that OWFs would improve the local economy of NJ. Adding to these concerns, respondents also pointed out the high costs associated with offshore wind farms, emphasizing that they are expensive to construct, maintain, and operate, ultimately leading to higher electricity prices for consumers. When asked about the additional perceived impact of OWF, one of the respondents (S-17) articulated, "*If the 'electric' company were to significantly reduce or make electricity for free for those that are affected by the wind farm construction, I would fully support the project.*" However, respondents painted a stark picture of the economic fallout they fear from the OWF development. They reported that fish have already moved out of their usual waters, likely due to sonar activity related to the OWF development. This has forced them to travel further for fewer catches, a change that hasn't gone unnoticed by customers. As word spreads about the dwindling catches, the respondents worry that customers will go elsewhere to fish, leading to a decline in chartered trips, increased fuel costs, and a severe blow to their income potentially even putting them out of business. The respondents believe this decline in fish populations will also impact those seeking to fish or scuba dive recreationally, further compounding the economic repercussions.

These concerns are also addressed by a study on the economic impact of OWF development in the Atlantic region of the U.S., which outlined four primary economic concerns regarding the potential impacts of offshore wind development on the fishing industry i.e., increased fuel expenses for fishing vessels, potential reductions in fishing revenue, income, and livelihoods, rising insurance costs, and negative consequences for businesses that support the fishing industry [60]. A similar study in the UK revealed that OWFs led to increased steaming times, longer distances to fishing grounds, and consequently higher fuel consumption, ultimately impacting fishing effort due to fuel costs [98]. However, the U.S. administration anticipates a surge in job creation within the offshore wind farm sector as a result of these new developments. Projections indicate the potential for 25,000 jobs in development and construction between 2022 and 2030, along with up to 4000 annual positions in operations and maintenance along the coastal region spanning Long Island to NJ [99]. Between 2014 and 2018, the economic contribution of U.S. seaports experienced a notable 17 % increase, reaching $5.4 trillion. This accounted for a substantial portion of nearly 26 % of the nation's total GDP of $20.5 trillion (in 2021 dollars) [60].

4.5. Stakeholders involvement in decision making process

The OWF infrastructure in coastal and offshore areas carries substantial implications for various stakeholders, given the potential for both direct and indirect consequences. This reality underscores the need for stakeholder involvement throughout the planning and decision-making process. As mandated by the National Environmental Policy Act, the BOEM is obligated to conduct a comprehensive environmental impact assessment before any development decisions can be made. This assessment must encompass a thorough evaluation of all potential socioeconomic impacts, including direct, indirect, and cumulative effects. Furthermore, as highlighted by Portman [100] and Chen et al. [3], the decision-making process for both environmental policy and the environmental impact assessment should prioritize the inclusion of stakeholder perceptions. These perceptions, encompassing both positive and negative viewpoints, are essential to consider as they directly influence the level of stakeholder acceptance.

Despite the recognized importance of stakeholder engagement, our survey results revealed a pronounced degree of dissatisfaction with the current approach. Most respondents (79.6 %) reported participating in various forms of OWF development engagement, including research surveys (22 %), discussions and debates (17.8 %), and meetings with developers (12.7 %); however, a substantial 20.3 % of respondents indicated they abstained from participation entirely (Fig. 6). Despite their involvement, about 20 % respondents felt that their concerns were neither adequately addressed nor resolved. When asked about the role local communities and stakeholders should play in the decision-making process for OWD in NJ, one of the respondents said (S-1), "*It doesn't matter because the government is going to do whatever they want, but since you are asking, the decision should be made by the residents of the state, not the governor*". Likewise, another respondent (S64) writes, "*There should be public meetings held to discuss the way that local fishermen feel but we know it's all about the money and not about us*". This sentiment underscores a prevailing sense of marginalization among recreational fishing groups and other stakeholders regarding OWF development decisions.

4.6. Stakeholder perspectives on OWF development in NJ

Boat captain and owner's perspectives on OWF development in NJ varied widely, reflecting the complexity and high stakes of the issue.

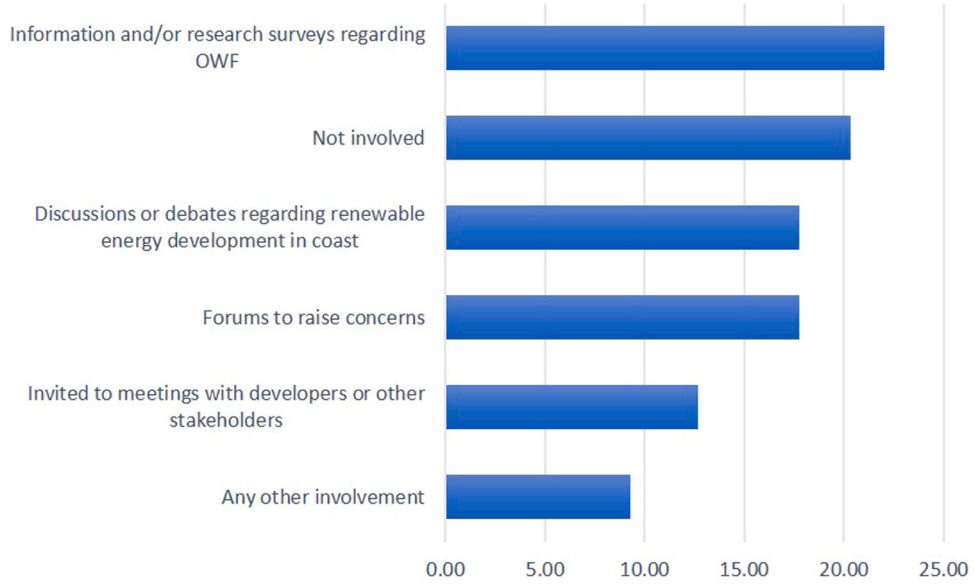

Fig. 6. Level of respondents' involvement in decision making process.

When asked, "Do you believe that some specific measures or practices can be implemented to mitigate any potential negative impacts of offshore wind development on the recreational marine fishing and boating sector?" 64 % of respondents answered "No." Some respondents advocated for a cautious, phased approach, proposing a demonstration project with a single, smaller wind farm to assess potential impacts before proceeding with larger-scale developments. These individuals also emphasized the importance of comprehensive environmental monitoring and genuine community engagement through public hearings and transparent communication from the outset. Conversely, some respondents expressed strong opposition to the project, arguing that the environmental and economic risks outweigh any potential benefits. They cited concerns about damage to marine ecosystems, navigation hazard, fishing access, visual impact, and the potential for increased energy costs. These respondents called for halting wind farm construction altogether, prioritizing the long-term health of the ocean and safeguarding the livelihoods of those who depend on it.

When asked about the role of local communities and stakeholders in the decision-making process, one respondent (S-73) stated, *"We should be at the forefront. Our fishing communities, along with the small and large businesses that have thrived on them for over a hundred years, should have the biggest say. We have made countless sacrifices due to ongoing fishing regulations."* This sentiment underscores the connection these communities feel to their marine environment and their rightful demand for a central role in shaping its future. These contrasting viewpoints highlight the urgent need for robust environmental impact assessments, transparent cost-benefit analyses, and inclusive stakeholder engagement processes that amplify diverse voices and address community concerns. Respondents have called for rigorous scientific evidence demonstrating that wind turbines pose minimal risk to marine mammals and could even serve as fish-attracting ecosystems. While these types of studies are required from OWF developers as a part of the planning process, results should be more widely disseminated with a focus on effective scientific communication. Additionally, respondents stress the importance of guaranteed and continued fishing access near wind farms, noting the need to (S-87) "*Reassure the public that anglers will have complete access and ability to fish the wind farms*"; and (S-39), "*…access to fish around the structures*"; and (S-13) "*Guarantee fishing access in proximity" to OWF*, advocating for a vision where renewable energy projects coexist harmoniously with vital, long-standing industries.

Research exploring stakeholder perspectives on offshore wind farm development reveals a complex interplay of demographics, experiences, and values. Studies consistently show that experienced fishers and aquaculture farmers tend to hold more negative or neutral views towards OWFs [29], while younger, less experienced, and more educated individuals demonstrate higher acceptance rates [3,29]. This pattern, however, is not without exception. While some studies find a positive correlation between age, income, and OWF acceptance, the influence of education remains mixed [49]. Furthermore, research highlights the critical role of place attachment, demonstrating that individuals with similar socioeconomic backgrounds can hold vastly different opinions on OWFs depending on their connection to the proposed development area [43,51,56]. Echoing these complex dynamics, our study finds a predominantly negative sentiment towards OWF development, despite the range in participants' age and experience.

4.7. *Effective communication, participation, and recommendations*

Effective communication and inclusive stakeholder participation are crucial for navigating the complexities of OWF development in NJ. The findings from this study highlight the need for tailored communication strategies, to disseminate clear, accessible information on environmental, economic, and operational impacts of OWF throughout various stages of planning, development, and operation. Inclusive engagement processes, such as public hearings, community advisory boards, and regular progress updates, are critical for fostering trust and collaboration, especially amongst opposing groups such as the majority of the study's participants. A phased development approach, suggested by respondents, could allow for real-time evaluation and adjustment, demonstrating responsiveness to community feedback.

Research suggests that public acceptance of wind projects often follows a U-shaped trajectory [101–104], where initial support dips during planning and construction but rebounds once the project is operational. Learning from the European experience, [29] stakeholder engagement, transparent processes and integrated marine spatial planning has proven to help mitigate conflicts. Further, incorporating incentives such as financial benefits [105], tax breaks [106], streamlined permitting for environmentally sound projects, or voluntary "green pricing" programs can encourage community buy-in. By integrating local knowledge, fostering transparent communication, and aligning incentives with community priorities, NJ can harmonize renewable energy goals with the preservation of coastal livelihoods and ecosystems, setting a precedent for sustainable large-scale OWF development in the U.S. When stakeholders feel heard and respected, and are invested

in the process, the path toward a sustainable OWE future becomes clearer.

5. Conclusions

OWE in NJ has emerged as a complex and contentious issue, with diverse stakeholders voicing a range of perspectives. While some respondents recognize the potential benefits of OWE such as advancing renewable energy transitions and creating economic opportunities, many raised substantial concerns regarding its environmental and socioeconomic impacts on recreational fisheries, coastal communities, and maritime navigation. Balancing these competing interests requires a careful and adaptive approach to ensure that renewable energy goals align with sustainable development and public acceptance.

To support more equitable and informed development, policymakers and OWF developers must prioritize transparent and inclusive stakeholder engagement efforts that value local knowledge and address community concerns throughout all stages of planning and implementation. An adaptive and evidence-based approach to OWE development grounded in rigorous scientific research, comprehensive marine ecosystem assessments, and meaningful stakeholder participation offers a pathway to balance environmental, economic, and social considerations. Furthermore, transparent sharing of results and evidence with stakeholders in a format that effectively communicates scientific evidence and data is essential for building public trust and increasing acceptance of change. Previous work has shown that incentives such as revenue-sharing agreements, tax breaks, and direct compensation for impacted stakeholders can foster community buy-in and mitigate resistance. For charter boat captains and owner's needs, efforts to ensure continued access to fishing grounds, protect marine ecosystems, safe navigation and uphold the safety of maritime activities must be prioritized.

While this study offers valuable insights into the stakeholder perspectives, the findings reveal a high degree of alignment in responses, with most participants expressing concern or opposition to OWF development. Charter boat captains and owners' livelihoods are closely tied to marine resources, so it is understandable why this stakeholder group may be hesitant to support OWE. While this pattern provides a clear view into the sentiments of this stakeholder group, it highlights the need for future research to include recreational boaters and fishers to capture the full spectrum of these communities' perspectives surrounding OWE in NJ. A broader population could allow for effective inferential statistical analysis to identify correlations and inform best practices for bolstering OWF acceptance. This study leverages quantitative survey data, thematic coding of qualitative data, and direct quotes from interviews and survey responses to effectively capture the perspectives and concerns of charter boat captains and owners. As a result, this study highlights critical concerns and provides a foundation for future investigations into long-term ecological impacts, fish population dynamics, and socioeconomic outcomes. With thoughtful planning and sustained community engagement, NJ has the opportunity to become a model for responsible offshore wind development.

CRediT authorship contribution statement

Kripa Shrestha: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Dr. Pankaj Lal:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Dr. Meghann Smith:** Writing – review & editing, Methodology, Data curation.

Ethics statement

This study received ethical approval from the Montclair State University Institutional Review Board (Study No. FY23–24–3238).

Disclaimer

Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not reflect the views of the Montclair State University.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests Kripa Shrestha reports financial support was provided by New Jersey Economic Development Authority. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The data that has been used is confidential.

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