In Pursuit of Offshore Wind: Financial, Political, Environmental, and Ethical Considerations

Client: Oceana

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Introduction

In today's political and ecological climate, there is a growing demand for the Biden Administration to invest in renewable energy sources. Particularly, along the Atlantic, and Pacific coasts, and in the Gulf of Mexico, offshore wind is gaining traction as a viable alternative to fossil fuels. This is due to its technical capability to supply electricity beyond consumptive needs, and its availability to major cities in these regions. Yet, in the United States, there are just seven offshore wind turbines. Thus, to meet the national demand for renewable energy it is clear the US is going to need a lot more offshore wind capital. With this, offshore wind has come to the forefront of the energy economy to help meet demand. The Bureau for Ocean Energy Management (BOEM) is working with the National Oceanic and Atmospheric Administration (NOAA) to lease and permit tracts of the ocean for offshore wind development. Although it is an exciting time to be looking into the potential of offshore wind, there are many considerations that should be addressed to ensure the offshore wind industry develops with minimum possible negative impacts to the environment and is part of a responsible and just transition to a renewable energy economy. These considerations include:

- protections and mitigations for marine mammals during offshore wind development's pre-construction, construction, and operation phase, and decommissioning
- the impact of the cost of those mitigations on the economic viability of offshore wind
- policies that determine what measures should be taken, and
- the social justice implications of offshore wind development.

In this report we hope to shed light on these and other considerations. We have conducted an analysis of:

- existing mitigation measures that are industry standard
- the impacts of construction on the North Atlantic Right Whale (NARW)
- Impact of mitigation measures on economic viability
- policies that can improve protecting for NARW
- the estimated cost of these protections,
- the economic potential of offshore wind energy (OSW)
- areas where OSW would be best suited
- future job potential
- and social justice implications.

These areas have been investigated in order to determine the best course forward for OSW develop in the United States. There is an emphasis on ensuring greatest possible protections for NARW and creating a just transition to renewables to reach President Biden's energy goals. Since policy change to improve marine mammal protections at the federal level is unlikely at this time, we have investigated potential avenues for policy action on the State level. We have also determined where OSW development is best suited in the US given available data layers.

Key Concerns

North Atlantic Right Whale Protection:

The NARW is a critically endangered baleen whale species that makes it home in the north Atlantic [1]. The known habitat of these whales' ranges from the northern most part of the Atlantic, around Maine, to as far south as the coast of Florida [1]. The North Atlantic Coast is also the forefront for OSW development in the United States, with several projects slated for construction or undergoing the leasing process [2]. The intersection of the investment in renewable energy and the protection of NARW is a hurdle that needs to be investigated and navigated to ensure a minimal amount of damage to the NARW while also advancing renewable energy. The push toward renewable energy sources have been on the forefront of the climate action debate for the last decade. While the need to make this energy transition is pressing and urgent, the question of how we balance the need to move toward renewable energy with protecting this endangered species has arisen.

Regarding offshore wind development, the impact to marine life from noise generated during construction and the operational phase of the turbines is an area of significant concern. The NARW and other marine species rely on sound to hunt, communicate, and avoid danger[3]. As part of the Environmental Impact Statement (EIS) process, the Bureau of Oceanic Energy Management (BOEM) requires a noise impact assessment during the pre-construction phase and will be continued during the construction phase[3]. Passive Acoustic Monitoring (PAM) is a common and effective way to determine what species might be in the area when construction activities take place[4]. PAM can also be used to determine the seasonality of NARW. The NARW is a migratory species which has breeding ground in the waters around southern Georgia and Florida [1]. With NARW habitat shifting northward due to warming waters and the fact that NARW don't always follow a set migration, there is a push to require PAM in a real-time format as well as in a year-round monitoring system especially in and around OSW project areas [4].

Just Transition:

Over the last decade, the rise of offshore wind jobs around the world has piqued the interest of economists wondering– what industries will be most impacted? Amidst this question there is concern for impacted workers from the oil and gas industry. However, it is debatable whether offshore wind is truly putting oil and gas workers out of a job– or if offshore wind is an economic savior to an already dying oil and gas industry.

In 2020, oil prices plummeted to approximately (-) $37.63/barrel [5]. Due to the staggering loss in revenue, many oil and gas companies made the decision to lay off much of their workforce [5]. This process sparked a conversation about what oil and gas workers might transition to, given the job insecurity within the sector. A recent survey conducted by the Campaigners Platform, found that over 50% of oil and gas workers in the United Kingdom have expressed interest in joining the offshore wind sector [6]. With this, predictions for the global offshore wind market show the industry growing exponentially. According to a publication by Research and Markets, "The global offshore wind energy market reached a value of US$ 9.14 Billion in 2021. Looking forward, the publisher expects the market to reach a value of US$ 24.71 Billion by 2027, exhibiting a CAGR of 18.03% during 2021-2027 (Wood, 2021).”

In this report, policy recommendations are given for how to achieve a just transition and increase the job potential for OSW.

Cultural Implications:

In addition to being an essential tool for greenhouse gas mitigation, renewable energy infrastructures such as offshore wind have the potential to address social inequities (i.e., disparate grid unreliability, air/water pollution, and health risks associated with fossil fuel). However, in the academic dialogue around offshore wind, the question remains on how the industry might make the transition away from fossil fuel an equitable one [7]. In considering this, socio-ecological scholars (i.e. Dr. Robert Bullard) point to the importance of remembering that the health and environmental implications of fossil fuel energy production fall disproportionately on BIPOC (Black, Indigenous, People of color) communities who have suffered at the hands of structural environmental racism [8]. These impacts include but are not limited to disproportionate exposure to air pollution, water pollution, and soil pollution via the environmental infiltration of hazardous chemicals. This is without mentioning the continuous harm of anthropogenic climate change caused by the release of greenhouse gas emissions into the atmosphere from burning fossil fuels.

With this, it is arguable that historically oppressed communities have the most to gain from offshore wind energy developments, if OSW development is approached with these inequities in mind. Notably, researchers from the University of Bergen highlight how granting benefits to the hosting communities of offshore wind developments not only increases social acceptance but also creates a sense of procedural justice. To quote the research team, “benefits could be in the form of local investments, payments to funds, scholarships, and even allowing communities to have a right of co-ownership of the facility [9].”

However, it is also important to consider the limitations of such infrastructures. For instance, a case study from Rio Grande do Norte in Brazil illuminates the concerns of Indigenous communities over procedural and distributive justice missteps regarding wind energy development on their ancestral lands [10]. This case study is important to consider in this discussion of offshore wind implementation because it highlights the cultural significance of the environment and how public perceptions of energy infrastructures differ. The further concern here is that offshore wind may exacerbate the encroachment on Indigenous and local subsistence practices—and thus should be taken into consideration when building OSW infrastructure.

Transmission

As offshore wind development grows, the need for efficient transmission plans does as well. Without proper transmission infrastructure the power we harness in the oceans cannot be used onshore and is virtually worthless. The Biden administration has vowed to push ahead with offshore wind development in the U.S., but the budding industry is confronting an issue of growing importance: how to build the huge amount of electric cabling and other infrastructure associated with transmission such as substations and two-way powerlines to deliver power obtained from the sea to the onshore grid. Coupled with this is the issue of mitigating effects on marine ecosystems and organisms, especially the NARW. The U.S. has lofty goals of installing 30 GW of offshore wind farms by the end of the decade, more than all of Europe has built to date, but there is some skepticism that it may fall short of that target if federal agencies, states, and grid operators do not coordinate on transmission plans.

The United States will need to draw on the experience of European countries as it begins to plan its own offshore wind farms, since the European power industry has already increasingly turned to offshore wind resources in the past few decades [11]. One major challenge facing offshore wind development anywhere in the world and will inevitably need to be tackled by the United States is transmission of energy from water to the grid on land. Foreseeably, it must be conducted to the onshore load centers via submarine cables. Offshore transmission has proved to be challenging and costly in Europe and will present additional challenges in the US due to the lack of domestic manufacturers of high-voltage, high-capacity submarine cable, and lack of equipment for and experience in installing this type of cable [12]. Although submarine transmission cables are common in the United States for other applications, the experience has limited applicability to wind farms.

The offshore gas and drilling industry use medium (10-100 kV) to low (under 10 kV) voltages, whereas the trend in offshore wind power is toward higher (above 100kV) voltage transmission [12]. Several medium and high voltage transmission cables have been installed in the U.S. to power islands and naval bases, for example, but submarine transmission from generation offers different problems [11]. Wind farms, for instance, usually have high reactive current demands since most wind turbines employ induction generators [13]. In electrical grid systems, reactive power is the power that flows back from a destination toward the grid in an alternating current scenario. This can cause resonance with the capacity factors of the cables, especially when economies of scale are driving up the size of offshore wind farms. Larger farms will both allow and demand more advanced electrical transmission systems, as wind power makes a greater impact on the onshore electrical grid. As power electronics are being developed, one can expect to see them play a greater role in offshore wind farm transmission and distribution designs, including the introduction of high voltage direct current (HVDC) transmission coupled with alternating current lines [12].

Furthermore, the planning and operation of OSW transmission must include thoughtful and impactful considerations and actions when laying down new lines under the ocean floors. From the coastal electricity substations and transmissions map created by our group matched to the maps that illustrate where the MPAs and the NARW's living, feeding, and breeding grounds are located, we can see that there is much conflict and overlap between the maps. Oil and gas rigs have been placed in these conflicted zones historically, but OSW must not and will not follow suit, as it strives for the most sustainable and just planet for all. The challenge is to find locations and ways to make the OSW transmission system as efficient as possible while also mitigating its impacts on the marine life and ecosystem.

There are potentially some solutions to the aforementioned logistical challenges, however. One solution is the possibility of using Ocean Grid and Power Strips for ocean transmission of electricity [11]. The idea is straightforward; rather than every individual wind farm running a cable to land, they could plug into a network of high-capacity subsea power lines that come to shore in strategic places. This would hugely diminish the demand for the high number of transmission cables which would directly mitigate the environmental impacts caused by the construction of the subsea cables. Mayflower Wind, an offshore wind project, is planning for exactly this sort of transmission system [13]. The power harnessed from 30 miles from the shore will resurface at a beach in Brayton Point in Massachusetts from where it will be incorporated in the distribution lines. Currently, the U.S. Department of Energy and the Bureau of Ocean Energy Management are assessing various offshore transmission technologies and looking at what some northern European countries are doing. They've also held public meetings to help inform the Atlantic Offshore Wind Transmission Study report [11].

Additionally, in Europe, the role of Offshore Transmission Operators (OFTOs) and Transmission System Operators (TSOs) has been critical to the development of efficient energy transmission from ocean to land. OFTOs typically have ownership of offshore electricity transmission infrastructure such as offshore substation platforms, subsea export cabling and onshore cabling, onshore substations, and the electrical equipment relating to the operation such as communication equipment and transformers. Coupled with this, the TSOs operate and regulate the actual transmission of the power itself[13]. This system has proved to be largely effective in European countries, especially Scandinavian, in regulating OWF transmissions and it has the potential to be replicated in the U.S.

Policy and Just Transition Considerations

When it comes to OSW development in the coastal United States, there are several areas of concern that should be considered. Among these concerns are the possible impacts of OSW on NARWs and communities along the Northeastern and Gulf Coasts (specifically those at the intersection of economic, racial, and environmental disenfranchisement). The most impactful areas of concern to the NARW are underwater noise, vessel traffic, and shifting habitat. The most impactful areas of concern to people being impacted workers and cultural implications. In this section of the report, we attempt to provide policy avenues to achieve best management policies and practices for OSW with the goal of increasing mitigations for endangered species and ensuring a just transition to this renewable energy

The NARW, is a critically endangered baleen whale species that makes its home in the north Atlantic [1]. The known habitat of these whales' ranges from the northernmost part of the Atlantic, around Maine, to as far south as the coast of Florida [1]. The North Atlantic Coast is also at the forefront of OSW development in the United States, with several projects slated for construction or undergoing the leasing process [2]. The push toward renewable sources of energy production have been at the forefront of the climate action debate for the last decade. While the need to make this transition is pressing and urgent, the question of how we might balance the need to move toward renewable energy with protecting this endangered species has arisen.

Additionally, the growing transition in jobs from fossil fuel (mainly offshore oil) to offshore wind has prompted a debate in local, state, and federal policy circles about what support should and/or could be given to such workers. Propositions such as the Green New Deal or Blue New Deal outline what a transition to renewable energy could look like for blue-collar workers who are looking to make the switch. However, these plans remain unpassed and unimplemented and thus, addressing these policy changes on the federal level is politically unfeasible, at this time. When, Herein, we outline two alternative policy interventions.

These interventions include State level modifications to the Request for Proposal (RFP) and Purchase Power Agreement (PPA) processes. While an RFP. is an application that OSW companies fill out in order to place a bid on the lease area available for wind development, a PPA is a contract that states enter into with the energy provider [2]. With these, we examine how changes in criteria presented in the RFPs can be used to leverage these changes. We also examine the importance of adding language to RFPs that rank protections for NARW and justice as highly as the cost of the overall project. Finally, we investigated the PPA process and its role in ensuring that these policies are enforced throughout the pre-construction phase all the way to the operational phase of OSW development.

Policy Methods:

The push toward renewable sources of energy production have been at the forefront of the climate action debate for the last decade. While the need to make this transition is pressing and urgent, the question of how we might balance the need to move toward renewable energy with protecting people, our oceans, and endangered species have arisen. Feasible policy interventions this research team recommends include evaluating current state-level legislation and the use of

Request for Proposal (RFPs) and Power Purchase Agreements (PPAs) as leverage for mitigation and justice concerns. Please note the mechanism, and term, that state governments entities use to implement offshore wind capacity varies by state; Massachusetts, Rhode Island and Connecticut use the term PPA, while New Jersey, Maryland and New York have adopted Offshore Wind Renewable Energy Certificate (OREC). Both OREC and PPA are recognized policy instruments for state-governed OSW procurement processes; for the purposes of this paper, we will use the term PPA.

One way states may approach these policy interventions is by changing their criteria when choosing projects in a RFP (Request for proposal process). This criterion should include efforts towards the wellbeing of off-shore wind laborers and critically endangered species. In addition to this, these criteria should be considered equitably by the state (i.e. holding NARW mitigation and justice concerns at the same or even greater level of importance as the cost of the project). Lastly, states should ensure the enforcement of this criteria through the power purchase agreement process once a proposal is selected. We advise these interventions as they may ensure the communities who may be the most impacted by offshore wind development be treated with care.

Policy Interventions and Recommendations

Key insights:

- Ecological and economic justice are two important themes herein.
- Industrial noise mitigation, vessel traffic, NAWR (North Atlantic Right Whale) migration patterns, as well as labor considerations should be at the center of OSW decision making.
- Priority interventions for endangered species protection of the NAWR and a just transition to offshore wind may include but are not limited to:
    - Change Request-For-Proposal language and criteria.
    - Rank Request-For-Proposal criteria equitably when choosing a proposal.
    - Integrate, operationalize, and monitor Requests-For-Proposal criteria in the Power-Purchase-Agreement.

As it stands now, most of the current requirements from NOAA (The National Oceanic and Atmospheric Association) and BOEM (The Bureau of Oceanic Energy Management) on the mitigation measures in place to protect NARW are based on seasonality [14,15]. For instance, there are seasonal requirements for when pile-driving activities, which pose the greatest threat to the NARW [3]. The seasonal restrictions are based on NARW migration patterns and are in place to help lessen the impact of construction activities on the NARW, there are areas where these recommendations are lacking and need improvement. A recent report submitted by several conservation groups in response to BOEMs first round of Environmental Impacts Statements

(EIS) regarding New York Bright's developments, makes several recommendations that should be taken into further consideration (site miles et al). The major areas that these recommendations cover are mitigations for Vessel Traffic and underwater noise in project areas, these factors pose the largest threat to marine species including the NARW [16]. Furthermore, BOEM should gather more data for the EIS and indicate where the current data is insufficient as part of the NEPA process [16]. Along with that, deploying PAM in conjunction with visual methods and reduced vessel speed would go a long way in both the pre-construction phase through the operational stage [14].

Further suggestions include adding language to the EIS that provides specific metrics when it comes to AMMM; giving specific areas and technologies such as gravity-based pile driving as well as the understanding that the project will need to take place in multiple stages to ensure maximum protections to NARW [16]. Impact Pile-driving should only commence when visibility is clear and NARW have not been spotted in the area, via the use of PAM and Protected Species Observer (PSO), and companies should utilize a "soft-start" approach to these activities. The way to address issues of vessel strikes is to reduce speed of ALL vessel speeds in the area to 10 knots and use the most up to date real time monitoring technologies to determine NAWRs in the general vicinity [16]. Current policies don't account for the shifting habitat and changing migratory patterns of NARW, sources suggest that policies should be more dynamic in regard to habitat [17,18]. Also, these policies and practices would benefit from measurable criteria into take reduction plans [19].

State-Level Opportunities to Improve Mitigation:

It is unlikely that any of these mitigation improvements from the previous sections will be made on the federal level, however, that does not mean that increased protections for the NARW during offshore wind development are out of reach. States laws like the Massachusetts 2022 Session law *An Act Driving Clean Energy and Offshore Wind* sets a precedent for state policy driving renewable energy and NAWR protections. The law has language embedded into it that states in section 62 (m),

> "a detailed description of the best management practices and any on-site or off-site mitigation the applicant shall employ, informed by the latest science at the time the plan is made, that will avoid, minimize and mitigate impacts to wildlife, including, but not limited to threatened or endangered species such as North Atlantic right whales, coastal and marine habitats; natural resources; ecosystems; and traditional or existing water-dependent uses, including, but not limited to, commercial and recreational fishing"
>
> [20].

By including language like this into bills passed on the state level, states have the ability to drive the conversation and bidding process with OSW companies looking to lease off of state waters. In conjunction with federal laws like the Endangered Species Act and the Marine Mammal Protection Act, these improved Best Management Practices (BMP) recommendations can be achieved.

While language will need to be more specific to achieve the highest level of protection, this avenue could prove to be a fruitful way of increasing BMP outside of what is required on the Federal level. Many states have already enacted policies similar to the MA 2022 Sessions Law. New York passed an act in 2019 that commits to increasing energy production from OSW by 9,000MWh by 2035 [21]. With bills like this already on the books, amending the current laws and policies would allow for these increase protections to be put in place. As it stands now, PAM is required before, during, and, after construction [15]. Adding language to make use of year-round PAM and a PSO would be able to account for that gap in federal policy. Another benefit would be that the states would be able to have more say in the vessel speeds of ships traveling to and from the construction sites. Leveraging the increased interest and need to transition to renewables like OSW with the need to protect the NARW in this way would provide a symbiotic relationship between states and OSW companies. As well as foster competition in the RFP and PPA process that fosters better mitigation.

Once the language is added to the existing state policies, then states and draw from the laws in the RFP process with OSW companies, states can also achieve this on the agency level as well by adding new requirements to existing protections. To reiterate, an RFP is an application that OSW companies fill out in order to place a bid on the lease area available for wind development [2]. In this process, States can create competition between companies and determine which company to contract with depending on how close to the requirements the company gets and how much it will cost the State. Having laws that have similar BMP language as the MA session law of 2022, states can ensure that these protections are being met as part of the contract that is signed once the company is selected. The PPA process is similar to the RFP process, however, the states have selected whom to enter the agreement with and can state any other stipulations within that contract.

In order to understand the transition from a traditional oil and gas, fossil-fuel-driven, energy market to renewable energy we must first know the power market. The power market is segmented into power generation, power transition, and power distribution. Power generation is the process of generating electrical energy from a particular source of energy. Transmission is moving this energy at a high voltage, normally over long distances, from the producer of the energy to the distributor and/or supply company; and power distribution is facilitated by distribution companies, which transport the energy using a network to its consumers (US Department of Commerce).

Expand Upon Request for Proposal Criteria:

One example of a state who has integrated a number of environmental requirements within its RFP is Massachusetts. For an OSW supplier to win the solicitation process, the OSW supplier must satisfy the minimum threshold requirements, including environmental and social standards. Kindly note that the text below is sourced from a Massachusetts RFP because it is more readily accessible, and the state includes environmental safeguards at multiple levels of its OSW procurement process. To maximize NARW protections, we propose the following language be included in RFPs.

> 2.2.2.10 Environmental and Related Impacts: “Section 83C requires that, where possible, a proposed project must demonstrate that it mitigates any environmental impacts. The proposed project must demonstrate through a fisheries mitigation plan its proposed approach to avoid, minimize and mitigate impacts on the commercial fishing industry.”
>
> 2.3.2 Qualitative Evaluation: “The qualitative evaluation will consist of the factors mandated by Section 83C as well as factors deemed important by the Evaluation Team as detailed below.
>
> > vii Environmental and Socioeconomic Impacts from Siting
> >
> > > Environmental Impacts: Extent to which a project demonstrates that it avoids, minimizes, or mitigates, to the maximum extent practicable, environmental impacts.
> > >
> > > Fishing Impacts: Extent to which the project avoids, minimizes, and mitigates impacts on commercial and recreational fishing industries.
> > >
> > > Environmental Justice Impacts: Descriptions of any potential impacts on Environmental Justice Populations and host communities.”

Further to the language above, Massachusetts’ RFP requires comprehensive environmental information, data and studies be provided in the following sections for an application to be complete.

- Appendix A: Bidders Response Package (see Appendix 2)
  - Section 7 – Environmental Assessment, Permit Acquisition Plan and Environmental Attributes Certification
  - Section 8 – Engineering and Technology; Commercial Access to Equipment
  - Section 13 – Demonstrated, Verifiable Commitment to Create and Foster Employment and Economic Development and Other Direct Benefits
- Appendix J: Environmental and Socioeconomic Impact Criteria (see Appendix 3)**.**

Additionally, we find that the Massachusetts RPF attempts to account for some cultural implications of OSW through a qualitative assessment on diversity, equity, and inclusion impacts. Though, still, the assessment mainly addresses economic and employment benefits as opposed to cultural investment and harm mitigation.

Therein the RFP states that the assessment will evaluate a:

“...Demonstrated ability and commitment to create and foster short and long-term employment and economic development in the Commonwealth, where feasible, and a commitment to diversity, equity, and inclusion, including employment and 31 procurement/contracting opportunities, for minority, women, veterans, LGBT, and persons with disabilities.

These 31 investments could include public-facing educational outreach programs to engage youth, high schools, and residents about offshore wind, clean energy, and climate topics; Utilization and investment in port facilities and infrastructure during project development, construction, and operation and maintenance of the project; Investment in offshore wind-related research and innovation initiatives or partnerships; Support for ongoing science and data collection to improve environmental, wildlife, and fisheries performance of offshore wind, including commitments to data sharing; Economic development activities and investments that directly benefit economically distressed areas, environmental justice communities, and/or low-income populations.

Commitments will be evaluated on a scale relative to project size, credibility, and firmness. Commitments that secure long-term benefits and require a robust strategy to track and report progress on promised benefits to a government agency are preferred."

In addition to economic and educational investment into "minority" communities, it is recommended herein that RFPs also include language surrounding the mitigation of social and cultural harm via the construction of OSW. This language has been conceptualized by this research team and may include but is not limited to:

1) A proposed project must demonstrate, where feasible, the mitigation of social and cultural harm against economically and racially marginalized groups who may depend on the waters of the proposed project for subsistence living or any activity of cultural significance. This process should include the consultation of communities who would be impacted by such a project in addition to adherence to the United Nations Declaration on the Rights of Indigenous Peoples (United Nations, 2007).

Rank Criteria Equitably:

In this section of the report, we continue to use the RFP as a point of policy intervention to integrate our recommendations around environmental, racial, and economic justice. Herein, we recommend that states not only include language such as that mentioned in the previous section, but also make sure to equitably rank the new criteria when making the decision on which energy provider to partner with. Take for instance this existing language from the Massachusetts' RFP on employment and economic development in the Commonwealth. Section 2.2.2.8 Contribution to Employment; Economic Development Benefits Section 83C requires that,

1) "...where feasible, a proposed project demonstrates that it creates additional employment and economic development in the Commonwealth. This requirement can be satisfied, for example, by a showing of: 1. Employment benefits associated with the proposed project; or, 2. Other economic development benefits associated with the proposed project. The Evaluation Team will consider a broad range of other economic development benefits that could be achieved by a proposed project. The proposal shall include a timeline of the short-term and long-term economic development benefits. The bidder must provide factual support for its employment and economic development projections and reflect any associated commitments in agreements with applicable governmental and nongovernmental entities."

With this, we assert that this criterion be weighted with equitable leverage in the state RFP decision-making process when compared with other criteria such as the overall cost of a proposal. It should be noted that Massachusetts's current ranking criteria were amended after receiving numerous comments from the public stressing the importance of environmental and socioeconomic factors in the selection process and requesting that the state department adjust its criteria to reflect the importance of these factors.

Further, it is recommended that states make it a point to equitably prioritize any RFP that offers workforce training at a fair rate to workers transitioning to this sector. This includes fossil fuel workers whose labor may be jeopardized with the onset of OSW construction, manufacturing, and operations (especially in the gulf coast). This, in turn, lends itself to the job potential of OSW. A report from the Workforce Development Institute (a New York state non-profit aiding in the renewable energy transition) outlines that "offshore wind development requires 74 distinct occupation types, from white-collar designers, lawyers, and engineers to myriad professions in the construction and transportation trades [22]." With these job requirements, we can infer that a great portion of the operations and manufacturing workforce can and should come from unionized fossil fuel sectors to ensure a just transition, though limited resources may be hindering this progress. According to the BOEM, workforce training credits are allocated to projects in accordance to the size of the cash bid in the RFP (see calculation below). In addition to this, it is recommended that projects with commitment to a transitioning workforce beyond the credit (which is less than 20% of the total project budget) be equitably considered in the RFP process.

Workforce Credit, BOEM, 2022

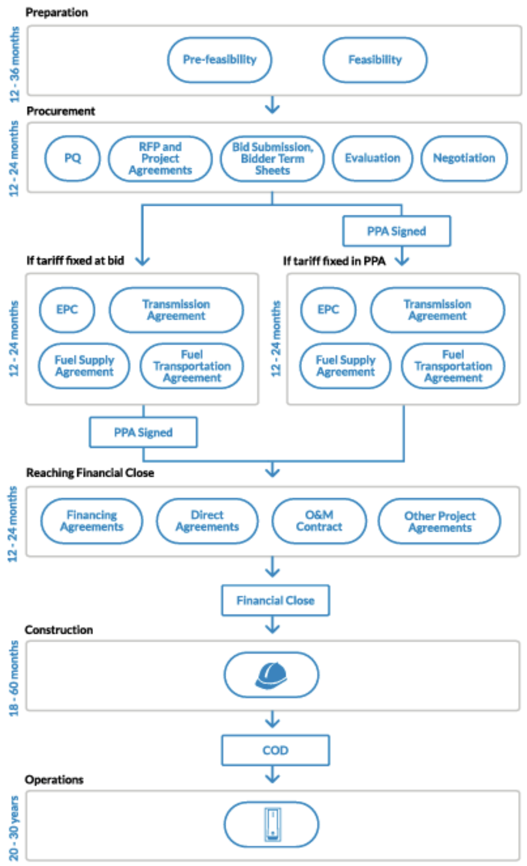
$$\text{Cash Bid} = \left\{\frac{\$31.32\text{ million}}{1 + 0.20}\right\} = \$26.1\text{ million}$$

$$\text{Credit} = \$31.32 - \$26.1 = \$5.22\text{ million}$$

$$\text{Committment} = 0.80 * \ \$5.22\text{ million} = \$4.176\text{ million}$$

Power Purchase Agreements:

The PPA is a crucial aspect in the solidification of a power project. The PPA is a formal agreement that binds the power producer and the buyer, which in many cases is the state, in a financial relationship for the life of the project (General Electric Renewable Energy).



Foundationally, a PPA is the instrument that facilitates the purchase and sale of electrical power. It also details the power company's responsibilities for finance, design, build, operation, development, and maintenance of the power plant in accordance with the PPA and applicable law. Often when a PPA is governing a renewable energy project there are special considerations, these include: speed of deployment, reduced risk and cost, security of supply, lower commissioning costs, and fewer triggers for termination. However, these considerations are not inherently environmental because as a financial mechanism the PPA primarily dictates a power project's economic ability and demand, as well as, the desired type of power generating technology.

The shift to renewable energy, particularly offshore wind, is appealing for many states because of their commitments to reducing their carbon footprint as well as their energy cost. Note that, like with any development, there are social and environmental risks associated with a project. Social impacts can occur to the local community during the transition from an oil and gas-dominated industry to a renewable industry, during construction (impeding views), and during operation (new shipping vessel routes and changes to fishing as an industry). Environmental impacts can occur both during construction and operation. State laws intended to safeguard and include environmental and social requirements that must be adhered to; additionally, the lender of the power producer may impose their own social and environmental requirements. All these considerations are intended to support the project's long-term sustainability. However, we have found in reviewing PPAs, they do not explicitly include environmental concerns and stipulations; most often the language in PPAs refers to existing legislation. The instances that do reference environmental attributes are frequently limited to financial provisions on the ownership of "environmental credits", "environmental attributes", "renewable energy credits" to the purchaser. Environmental attributes or credits are generally defined as

"1) credits, certificates, offsets or other benefits assigned to the generation in a manner which reduces, displaces or offsets air missions resulting from fuel combustion at another location or 2) aggregates the total benefits or attributes of a renewable energy marketing program, green pricing program, environmental or renewable energy trading system, renewable energy portfolio standard or other program required by federal or state law" (Yarano and Brusven, 2007).

Despite the PPA not explicitly having language that refers to socioeconomic or environmental requirements, the PPA is held to the commitments stated in the RFP. The RFP outlines an OSW supplier's eligibility for a project as the OSW supplier was selected based on their ability to balance the economic development benefits with the state's climate goals and environmental standards criteria.

Economic Analysis

Key insights:

- Current cost data on mitigation measures is scarce which limits the LCOE model
- Costs associated with added mitigation will increase the LCOE of OSW projects and increase the amount of time needed for them to become profitable
- More aggressive PPAs and federal incentives could curb the costs incurred by adding mitigation measures

Introduction to Levelized Cost of Energy

Evaluating the economic impact of adding mitigation measures to OSW projects is crucial for proving the viability of environmentally conscious projects. By using levelized cost of energy (LCOE) the potential changes in cost due to decisions made by OSW developers or mitigation required by the government can be quantified. The goal of this portion of the study is to make a case that changes in cost due to the addition of mitigation measures are negligible when compared to business-as-usual (BAU) costs for an OSW project. This section will explore findings regarding the cost of mitigation measures and discuss the results of modeling done using NREL's System Advisory Model (SAM). The LCOE model developed for this economic analysis focuses primarily on mitigation measures associated with NARW.

Capital and Operational Expenditures

The capital expenditure (CAPEX) or physical assets include infrastructure, building, construction, machinery, equipment, and vehicles whereas the operational expenditure (OPEX) includes employee salaries, rent, utilities, and taxes. In the field of OSW, these costs comprise developmental expenditure as well as upfront investments. The figure at the end of the section (BVG Associates) illustrates the contribution of each major cost element to the LCOE of OSW. As one can see, operational and maintenance costs make up most of the costs of wind energy. This is closely followed by installation costs of the turbine and its foundation in addition to the transmission cables and offshore substation development.

Mitigation Cost

There are a variety of decisions OSW developers can make to reduce the environmental impacts of their projects. Foundation structure, environmental monitoring, and vessel speed restrictions are just a few measures that can be taken to reduce the impact of OSW on NARW and other parts of the marine ecosystem. Some mitigation measures would increase the LCOE of OSW projects due to the costs incurred by their construction and operation while others such as gravity base foundations (GBFs) have the potential to lower costs due to cheaper materials. Because of this the decisions made by developers have both the potential to increase or decrease the LCOE of OSW projects. Analysis on the potential effects of these decisions is limited in the LCOE models developed for this study due to the difficulty in obtaining cost data for many of the outlined mitigation measures.

Cost of Mitigation Estimate Methods

Initially our team planned to use the cost information gathered from research on mitigation measures to build a suitable model from the ground up to perform the necessary LCOEs. However, due to the difficulty in obtaining this information it was decided that SAM would be used instead as it is already an existing modeling software that is robust enough to meet our objectives.

Using SAM, a sample project was generated to serve as the basis for the scenarios used in the LCOE analysis. This sample project uses the Southeastern MA – offshore wind resource file available in SAM to account for the wind availability in the North Atlantic region where NARWs spend most of their time. Additionally, the IEA 10MW RWT turbine available in SAM's library was selected as the turbine used in the sample project as it is assumed that turbines used in practice would have a similar rated output, and the desired output for the sample project was assumed to be 800 MW like the Vineyard Wind project. To meet this desired output eighty of the selected model turbines are necessary. A sample PPA based on the Vineyard Wind PPA was also generated to simulate the profits brought in by the power generated by the system. The sample PPA has a PPA price of .074 $/kWh, a PPA price escalation of 2.5%/year, and has an internal rate of return target of 20 years (Beiter et al., 2019). It was also assumed that the developer would claim the full 30% investment tax credit (ITC) incentive rather than a production tax credit (PTC) incentive due to the high capital costs associated with offshore wind. The analysis period was set at 25 years for all scenarios considered in this study.

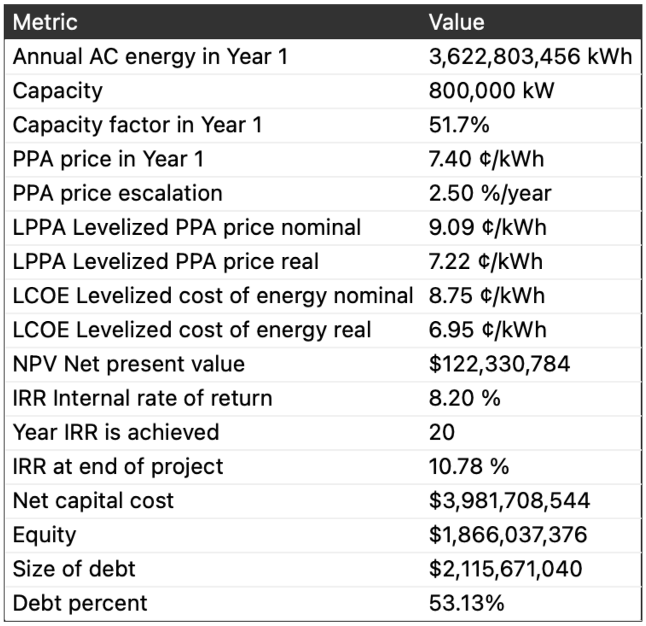
To conduct the LCOE analysis four different scenarios were developed to observe the potential effects of mitigation measures on the LCOE. Scenario 1 is representative of a control BAU case where baseline mitigation measures are taken which is used both check if assumptions made are accurate to the literature and to compare to the other scenarios. Scenario 2 switches out the monopile foundation for a jacket suction foundation without adding in additional mitigation measures. Since altering foundation type in favor of one that lessens noise pollution and causes less damage to the ocean floor is a relatively simple choice this scenario was deemed worth exploring. Due to the previously explained scarcity in findings regarding the cost of mitigation measures for OSW projects, Scenarios 3 and 4 assumed an allotted mitigation measure budget of $100 million and $200 million respectively to account for the cost of any added mitigation measures unrelated to foundation structure. The values of $100 million and $200 million were chosen as assumed additional fixed costs due to mitigation measures potentially costing tens of millions of dollars for a given project. While it may even be possible for additional mitigation measures to cost more, these assumptions exist for the purpose of outlining any trends associated with increasing additional fixed costs allocated to mitigation measures.

While SAM can perform the modeling necessary for the LCOE analysis, the software has limitations. Accounting for mitigation actions made by developers using SAM is difficult because SAM has limited parameters available that users can explicitly select. This absence is likely due to the OSW industry in the US still being in its developing phases and cost data surrounding current mitigation measures not being readily available. In addition, mitigation costs are likely not one of the main areas of cost to a developer and are therefore not prioritized in the model. Due to this limitation in both the software and the research done to develop the assumptions used in the scenarios it will be necessary to conduct further studies on the accuracy of the scenarios moving forward.

Results

Scenario 1 - BAU

The results of the simulation for the BAU scenario are shown in the table below.



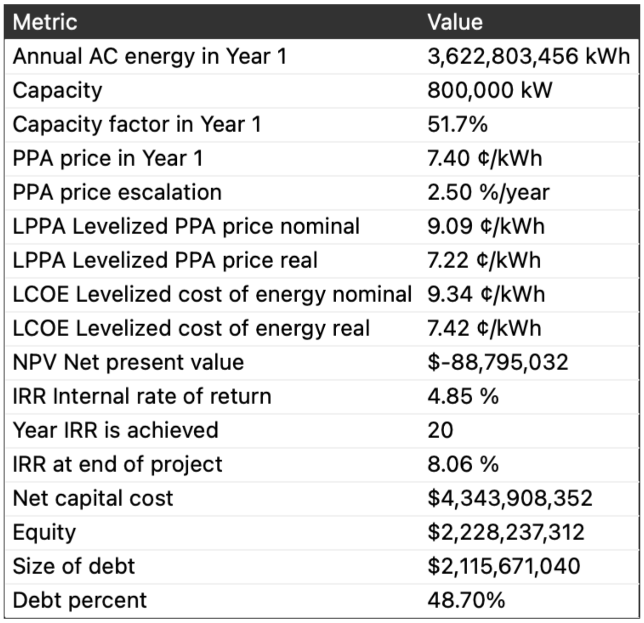
Metric	Value
Annual AC energy in Year 1	3,622,803,456 kWh
Capacity	800,000 kW
Capacity factor in Year 1	51.7%
PPA price in Year 1	7.40 ¢/kWh
PPA price escalation	2.50 %/year
LPPA Levelized PPA price nominal	9.09 ¢/kWh
LPPA Levelized PPA price real	7.22 ¢/kWh
LCOE Levelized cost of energy nominal	8.75 ¢/kWh
LCOE Levelized cost of energy real	6.95 ¢/kWh
NPV Net present value	$122,330,784
IRR Internal rate of return	8.20 %
Year IRR is achieved	20
IRR at end of project	10.78 %
Net capital cost	$3,981,708,544
Equity	$1,866,037,376
Size of debt	$2,115,671,040
Debt percent	53.13%

Table 1. Results of Scenario 1 simulation

As shown in the table the real LCOE for this scenario is 6.95 cents/kWh or $70/MWh. This falls outside the observed global LCOE range of $78/MWh to $125/MWh presented in the literature (Musial et al., 2021). This discrepancy is likely due to the assumed 30% ITC for the sample project that would not have been available at the time the referenced report was written. This scenario also resulted in a net present value (NPV) of $122.3 million, meaning that by the end of the analysis period this project is profitable under these conditions.

Scenario 2 – Jacket Suction

The results of the simulation accounting for replacing drag embedded monopile foundations for jacket suction foundations is shown in the table below.



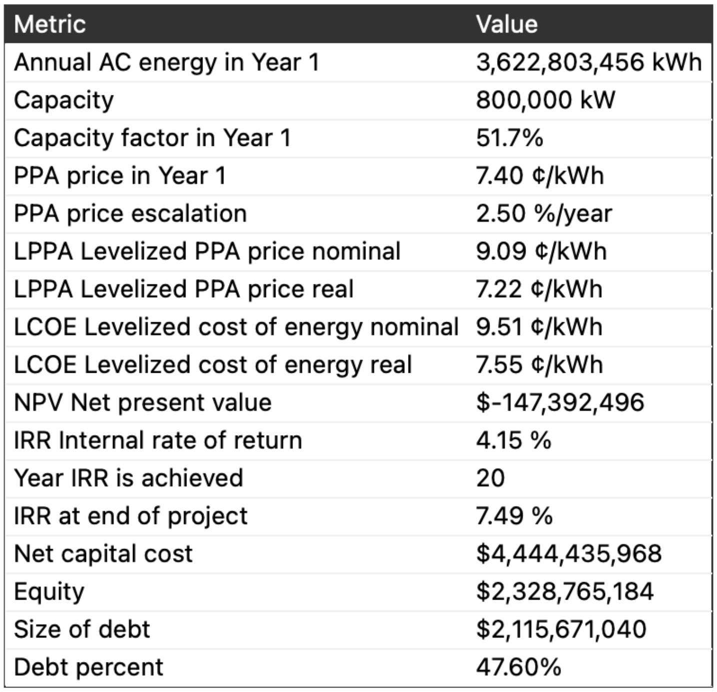
Metric	Value
Annual AC energy in Year 1	3,622,803,456 kWh
Capacity	800,000 kW
Capacity factor in Year 1	51.7%
PPA price in Year 1	7.40 ¢/kWh
PPA price escalation	2.50 %/year
LPPA Levelized PPA price nominal	9.09 ¢/kWh
LPPA Levelized PPA price real	7.22 ¢/kWh
LCOE Levelized cost of energy nominal	9.34 ¢/kWh
LCOE Levelized cost of energy real	7.42 ¢/kWh
NPV Net present value	$-88,795,032
IRR Internal rate of return	4.85 %
Year IRR is achieved	20
IRR at end of project	8.06 %
Net capital cost	$4,343,908,352
Equity	$2,228,237,312
Size of debt	$2,115,671,040
Debt percent	48.70%

Table 2. Results of Scenario 2 simulation

This simulation yielded a real LCOE of $74/MWh and a negative NPV of $88.7 million.

Scenario 3 – Jacket Suction and $100 Million Mitigation Budget

Shown below are the results of the simulation considering a $100 million mitigation budget in addition to the jacket suction foundations.



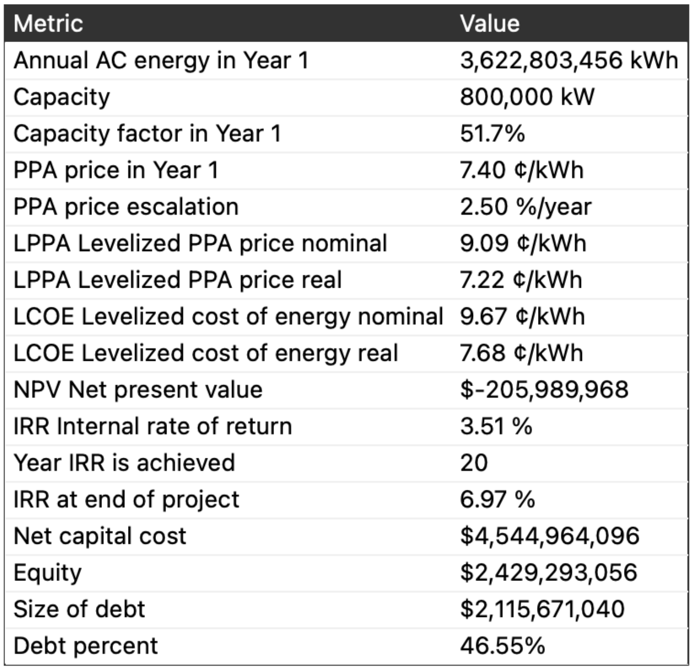
Metric	Value
Annual AC energy in Year 1	3,622,803,456 kWh
Capacity	800,000 kW
Capacity factor in Year 1	51.7%
PPA price in Year 1	7.40 ¢/kWh
PPA price escalation	2.50 %/year
LPPA Levelized PPA price nominal	9.09 ¢/kWh
LPPA Levelized PPA price real	7.22 ¢/kWh
LCOE Levelized cost of energy nominal	9.51 ¢/kWh
LCOE Levelized cost of energy real	7.55 ¢/kWh
NPV Net present value	$-147,392,496
IRR Internal rate of return	4.15 %
Year IRR is achieved	20
IRR at end of project	7.49 %
Net capital cost	$4,444,435,968
Equity	$2,328,765,184
Size of debt	$2,115,671,040
Debt percent	47.60%

Table 3. Results of Scenario 3 simulation

This simulation yielded a real LCOE of $76/MWh and a negative NPV of $147.4 million.

Scenario 4 - Jacket Suction and $200 Million Mitigation Budget

Shown below are the results of the simulation considering a $200 million mitigation budget in addition to the jacket suction foundations.



Metric	Value
Annual AC energy in Year 1	3,622,803,456 kWh
Capacity	800,000 kW
Capacity factor in Year 1	51.7%
PPA price in Year 1	7.40 ¢/kWh
PPA price escalation	2.50 %/year
LPPA Levelized PPA price nominal	9.09 ¢/kWh
LPPA Levelized PPA price real	7.22 ¢/kWh
LCOE Levelized cost of energy nominal	9.67 ¢/kWh
LCOE Levelized cost of energy real	7.68 ¢/kWh
NPV Net present value	$-205,989,968
IRR Internal rate of return	3.51 %
Year IRR is achieved	20
IRR at end of project	6.97 %
Net capital cost	$4,544,964,096
Equity	$2,429,293,056
Size of debt	$2,115,671,040
Debt percent	46.55%

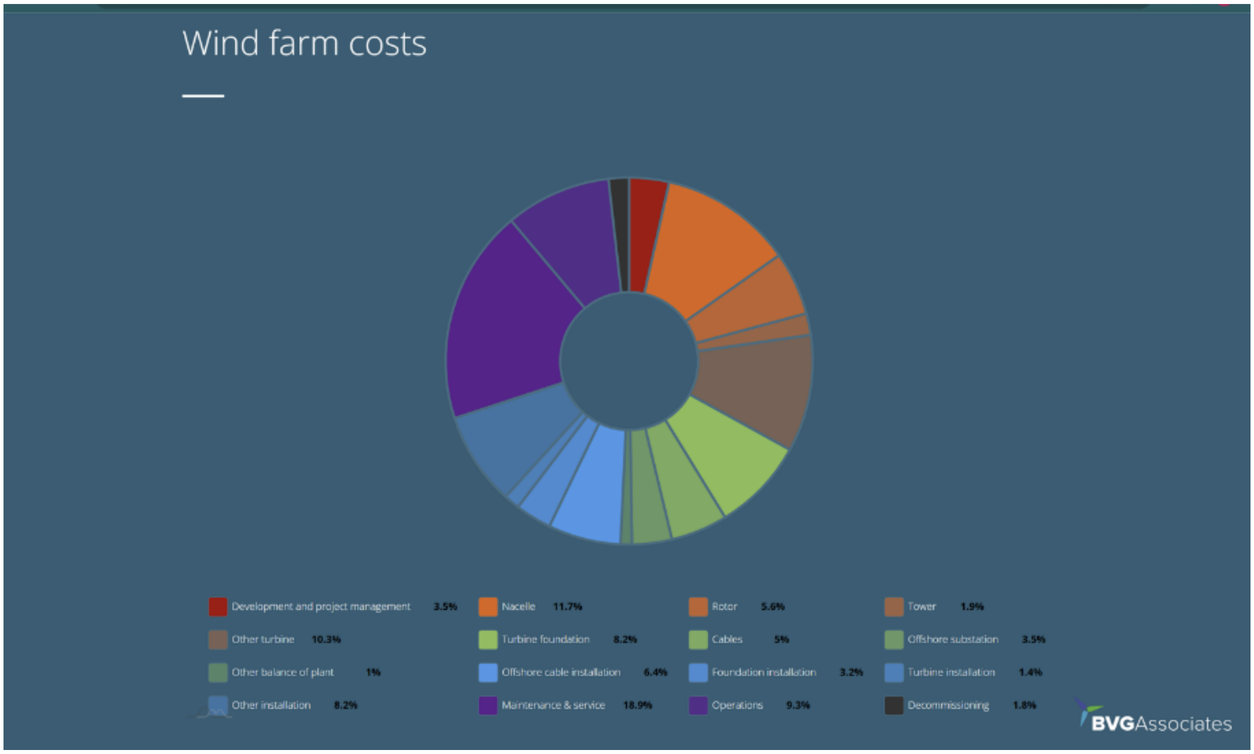
Table 4. Results of Scenario 4 Simulation

This simulation yielded a real LCOE of $77/MWh and a negative NPV of $206 million.

LCOE Discussion

Using the results from the SAM simulations it was determined that all but one of the proposed scenarios are economically viable. Scenarios 2, 3, and 4 have LCOEs that are respectively $4/MWh, $6/MWh, and $7/MWh higher than the BAU case presented in Scenario 1. The NPVs for Scenarios 2, 3, and 4 are negative indicating that these projects did not become profitable after the 25-year analysis period. Additionally, the NPV between these scenarios continues to drop as the mitigation budget increases. This indicates that without additional steps taken at the Federal and State levels, projects that include mitigation measures beyond what would be in a BAU project will take longer to pay off. The LCOE also seems to be more resistant than the NPV to changes in the mitigation budget as shown by the $1/MWh increase in LCOE in contrast to the $58.5 million decrease in NPV between Scenarios 3 and 4.

To overcome the negative NPVs in Scenarios 2, 3, 4, and in cases with a larger budget allocated to mitigation Federal and State incentives for OSW projects will be needed. More aggressive PPA agreements with greater price and price escalation conditions will help increase the revenues gained from OSW projects and offset costs from a theoretical mitigation budget. It is also important to consider that as OSW develops the price of installation will fall drastically as predicted by the US Department of Energy (Musial et al., 2021). Taking these suggestions and factors into account it is entirely possible to increase the budget associated with mitigation measures while keeping LCOE for environmentally conscious OSW projects competitive.



Source: BVG Associates: https://guidetoanoffshorewindfarm.com/wind-farm-costs

Site Suitability Analysis

Key insights:

- Initial Suitability Analysis identified areas of focus for each coastal region (East Coast, Gulf Coast and West Coast) most suitable to OSW development using four criteria: Distance to NARW Habitat, Average Wind Speed, Water Depth, and Distance to Major Ports
- Regional Suitability Analysis used to further specify regions along each coast most suitable for new OSW leases through the addition of 7 criteria spanning technical, environmental, and economic considerations.

Introduction

The question of where new OSW development should take place requires the consideration of environmental, technical, economic, and social factors. Using Geographic Information Systems (GIS) through ArcGIS Pro, we conducted a suitability analysis for OSW development for all three coastal regions of the United States (East Coast, Gulf Coast and West Coast) to identify the most suitable regions for new OSW leases.

Methods

The suitability analysis was conducted in two parts: an initial suitability analysis and a regional suitability analysis. The initial suitability analysis was conducted for each of the three coastal regions of the United States and identifies where the most suitable regions are for new OSW leases. The coastal regions were defined by the United States' Economic Exclusion Zones (EEZ) [25]. In the initial analysis, the entirety of the coastal region (using the EEZ as a limiting boundary) was classified on a suitability scale from 1 to 5. Areas classified as 1 being the least suitable for OSW and areas classified as 5 being the most suitable for OSW. The initial analysis was used to identify regional areas of focus for the second round of regional suitability analysis.

The initial analysis and regional analysis differ both in scale (the extent of the area classified) and criteria (layers used in calculating each coastal suitability). The initial analysis uses criteria defined as most important in selection of a new OSW site. The first round of criteria was chosen based on a literature review of global case studies for OSW site selection and input from Oceana regarding their focus on protection of marine species and habitats. The regional analysis was conducted for each area of focus (determined by the most suitable regions identified in the initial analysis) and uses a larger set of criteria that spans environmental, technical, and economic concerns in the selection of OSW sites. The criteria used in the regional analysis differ slightly for each area of focus, each coastal region, based on environmental differences identified in the literature review. The regional analysis uses areas classified as most suitable in the initial analysis to propose specific locations where OSW site selection should take place.

In this section, I will discuss the methods of both the initial suitability analysis and the regional suitability analysis through describing how criteria was chosen and ranked for suitability in each coastal region, how GIS was used to process and analyze raw data, and the process of weighted suitability analysis using ArcGIS Pro's Raster Calculator.

Initial Mapping

Initial Suitability Analysis Criteria

Distance to NARW Habitat: In discussions with Oceana, we identified early on that one of the most important factors in determining new locations for OSW was choosing locations outside of NARW habitat. An endangered species, the NARW has a limited habitat along the eastern coast of the United States with two main locations: coastal New England and the coastal southeast (coastal South Carolina, Georgia, and Northern Florida). A polygon shapefile from NOAA that identified the locations of NARW habitat was used to create a distance layer [26]. Using the Euclidean Distance Tool, distance from both NARW habitat polygons was calculated and rasterized. This layer, Distance to NARW Habitat, is considered the most important criteria in identifying selection sites for OSW on the East Coast. As NARWs do not inhabit the Gulf of Mexico or the West Coast, this criterion was only used in suitability analysis for the East Coast.

Average Wind Speed: The average wind speed is a crucial component in site selection of OSW as it determines functionality and energy generation capabilities of wind turbines. In the literature review, the most desirable average wind speed for wind turbine energy generation was debated. However, most case studies suggested an average wind speed above 7 m/s and below 9 m/s was most suitable for OSW. A raster layer of average wind speeds at 80 m for the continental and coastal United States from NREL was clipped to each EEZ boundary and reclassified with most suitable areas identified as 7 m/s to 9 m/s for the East Coast and West Coast and above 8 m/s for the Gulf Coast (average wind speeds in the Gulf of Mexico do not reach above 9 m/s) [27].

Water Depth: The water depth of coastal regions determines the type of wind turbine and wind turbine foundation used in construction of OSW farms. As discussed in the literature review, there are three main types of wind turbines: monopile, jacket, and floating. Each type of turbine is suitable for a different water depth. Monopile and jacket foundations are suitable for shallow water depths with monopile foundations used in depths under 30 meters, and jacket foundations typically used for depths between 30 m and 60 m [28]. Floating structures are more suitable to deeper waters and are used in water depths greater than 60 m [28]. In general, as water depth increases, technical and economic feasibility decreases. In other words, cost and maintenance increase as water depth of a selected site increases. Shallower water depths, water depths of 30 m or less, are considered most suitable in our report's suitability analysis for all three coastal regions. A raster layer of topography for the continental United States and its surround waters from NOAA was clipped to each EEZ boundary and reclassified [29].

Distance to Major Ports: Where OSW is located relative to a major port or port city is an important technical and economic criterion in the selection of OSW sites. Both the construction and maintenance of OSW turbines require transportation from the mainland. Being in closer proximity to a major port, that has the technical capabilities to easily transport large amounts of equipment and people, is important for increasing efficiency and lessening the overall cost of both construction and maintenance of OSW turbines. Also, major ports are more likely to be in largely populated areas. Selecting where generated electricity is served is also an important consideration and would be more widely used in higher population areas. A point shapefile from USGS that identified the location of major ports in the United States was used to create a distance layer [30]. Using the Euclidean Distance Tool, distance from all major ports was calculated and rasterized. This layer, Distance to Major Ports, is considered important in identifying how far an OSW site is from any major port city in each specified coastal region with areas closest to a major port deemed most suitable for OSW.

Reclassification

After all four layers used in the initial suitability analysis (Distance to NARW Habitat, Average Wind Speed, Water Depth, and Distance to Major Ports) were clipped to the EEZ boundary of each coastal region and resampled to the same cell size of 500 m, they were reclassified for use in the initial suitability analysis. Reclassification is the process of taking the original pixel values and transforming each pixel to a scale set by the user. For example, for the Average Wind Speed layer each pixel represents the average wind speed of that 500 m area and was reclassified on a suitability scale from 1 to 5. All four layers were reclassified on the same suitability scale of 1 to 5 with values reclassified as 1 being the least suitable scenario for OSW site selection and values reclassified as 5 being the most suitable scenario for OSW site selection.

Suitability Score	**Suitability Description**
1	Least Suitable
2	Less Suitable - Not Satisfactory
3	Somewhat Suitable - Acceptable but Not Ideal
4	More Suitable - Satisfactory
5	Most Suitable

The reclassification process was completed for all criteria used in the initial analysis: Average Wind Speed for all three coastal regions, Water Depth for all three coastal regions, Distance to Major Ports for all three coastal regions, and Distance to NARW Habitat for the East Coast. Reclassification tables and reclassified layers for all layers used in the initial suitability analysis are included in the appendix. See Appendix 4: Site Suitability Continued – Reclassification & Data Analysis.

Initial Suitability Analysis

The initial suitability analysis was completed for each coastal region using the Raster Calculator Tool in ArcGIS Pro. The Raster Calculator allows the user to input their own raster layers and equations to manipulate pixel values amongst multiple layers and output a new raster layer.

With the protection of NARW Habitat deemed most important in our conversations with Oceana, the Distance to NARW Habitat is ranked as the most important layer in our initial suitability analysis of the East Coast. Average Wind Speed is ranked second as it is the main determinant of whether an area is suitable for OSW energy generation. Water Depth and Distance to Major Ports are ranked third as both layers are important in determining the technical and economic feasibility of OSW construction and maintenance, but do not limit the ability for turbines to generate adequate amounts of energy. For the Gulf and West Coasts, the same ranking was applied with exception to the Distance to NARW Habitat layer which was not included as criteria for either the Gulf Coast or West Coast.

Suitability is calculated through the creation of a weighted equation with all criteria having a weight of importance based on rank. All criteria, reclassified layers, are multiplied by their assigned weight and then added together. All weights must equal to a value of 1.

East Coast Initial Suitability

The East Coast initial suitability analysis includes all four initial criteria which were ranked as followed:

1. Distance to NARW Habitat

2. Average Wind Speed

3. Water Depth

3. Distance to Major Ports

The following equation was used to calculate the initial suitability for the East Coast:

(Distance to NARW Habitat * 0.5) + (Average Wind Speed * 0.25) + (Water Depth * 0.125) + (Distance to Major Ports * 0.125)

Gulf and West Coast Initial Suitability

As the NARW does not inhabit the Gulf Coast or West Coast of the United States, the Distance to NARW Habitat criteria was not used in the initial classification of the Gulf and West Coasts. The Gulf Coast and West Coast initial suitability analysis ranked the three other initial criteria as follows:

1. Average Wind Speed

2. Water Depth

2. Distance to Major Ports

The following equation was used to calculate the initial suitability for the Gulf Coast and West Coast:

(Average Wind Speed * 0.7) + (Water Depth * 0.15) + (Distance to Major Ports * 0.15)

Regional Mapping

After the initial suitability analysis was completed, areas of focus were identified for regional suitability analysis. Areas of focus are defined as continuous areas identified in the initial suitability analysis as Most Suitable (suitability score of 5) and More Suitable (suitability score of 4).

The Area of Focus for the East Coast stretches close to the shoreline from south of Cape Cod to coastal North Carolina. The Area of Focus for the Gulf Coast is defined as coastal Texas and western coastal Louisiana. The Area of Focus for the West Coast is defined as coastal Washington State and the majority of coastal Oregon. These three areas of focus were all classified in the initial analysis with suitability scores above 3.5 (Somewhat Suitable) with the majority of the area having a suitability score equal or close to 5 (Most Suitable).

Regional Suitability Analysis Criteria

All four criteria used in the initial suitability analysis were also used in the regional suitability analysis. In addition to the original four criteria, the following criteria were also used:

Distance to Rice's Whale Habitat: Similar to the NARW, the Rice's Whale is an endangered species habituating only a small region of the coastal United States. The Rice's Whale's habitat is located in the eastern portion of the Gulf of Mexico close to the western coast of Florida. A polygon shapefile from NOAA that identified the location of Rice's Whale habitat was used to create a distance layer [31]. Using the Euclidean Distance Tool, distance from the Rice's Whale habitat polygon was calculated and rasterized. This layer, Distance from Rice's Whale Habitat, is considered important in identifying selection sites for OSW in the Gulf of Mexico with regions of the Gulf furthest from Rice's Whale deemed most suitable for OSW and for the protection of the Rice's Whale. As the Rice's Whale does not inhabit the East Coast or West Coast, this criterion was only used in suitability analysis for the Gulf Coast.

Distance to MPAs: As previously mentioned when discussing the NARW and Rice's Whale habitats, protecting marine species and their environments is the main focus of this report. In selecting a site for OSW turbines, it is crucial to consider the location of Marine Protected Areas (MPAs) in order to avoid disturbances or damages to federally protected marine environments during the construction, maintenance and existence of OSW turbines. A polygon shapefile from NOAA that identified the location of all MPAs was used to create a distance layer [32]. Using the Euclidean Distance Tool, distance from all MPAs was calculated and rasterized. This layer, Distance to MPAs, is considered important in identifying how far an OSW site is from all MPAs within each coastal region with areas farthest from MPAs deemed most suitable for OSW and for the protection of the marine life living within MPAs.

Distance to Substations: After energy is generated by OSW turbines, it is then processed and transferred to the electrical grid for distribution and use. Where OSW is located relative to electrical grid substations, the access points to electrical transmission lines which distribute electricity for public and private use, is an important technical and economic criterion in the selection of OSW sites. For example, as an electrical substation's distance from shore increases, the technical and economic feasibility of connecting OSW to electrical substations decreases. A point shapefile from NOAA that identified the locations of all substations within 20 miles of the United States coastline was clipped using a 10-mile buffer around each coastal region's shoreline to only include substations within 10 miles of the United States' shoreline [33]. A 10-mile buffer around each shoreline was chosen to identify substations more likely to be used in OSW connection due to their proximity to the shore. This clipped layer, substations less than 10 miles from the coast, was used to create a distance layer. Using the Euclidean Distance Tool, distance from all substations less than 10 miles from the shore was calculated and rasterized. This layer, Distance to Substations, is considered important in identifying how far an OSW site is from any coastal substation in each specified coastal region with areas closest to a coastal substation deemed most suitable for OSW.

Distance to Shipping Routes: In selecting a site for OSW turbines, it is important to consider the location of existing marine infrastructures and industry. One main industry within the United States' EEZ is shipping. Where OSW is located relative to existing shipping routes is an important technical criterion in the selection of OSW sites in order to avoid ship traffic during the construction, maintenance and existence of OSW turbines. In the literature review of global case studies, the appropriate distance from active shipping routes to OSW development was debated. Suggested distances used in site selection varied from allowing 200 m to 4800 m from active shipping routes to OSW development. For this suitability analysis, we decided to air on the side of caution with an ideal buffer between OSW turbines and shipping routes defined as a distance of more than 2000 m. A polyline shapefile from Living Atlas that identified all current shipping routes as of June 2020 was used to create a distance [34]. Using the Euclidean Distance Tool, distance from all shipping routes was calculated and rasterized. This layer, Distance to Shipping Routes, is considered important in identifying how far an OSW site is from any shipping route in each coastal region with areas farthest from a shipping route deemed most suitable for OSW.

Distance to Submarine Cables: In selecting a site for OSW turbines, it is important to consider the location of existing marine infrastructure and industry. Where OSW is located relative to existing submarine cables is an important technical criterion in the selection of OSW sites in order to avoid damages to submarine cables or disturb their connection to shore during the construction of OSW. In the literature review of global case studies, the appropriate distance from existing submarine cables to OSW development varied with most case studies suggesting a buffer of one or several kilometers. For this suitability analysis, we decided on an ideal buffer between OSW turbines and submarine cables defined as a distance of more than 1 km. A polyline shapefile from NOAA that identified all existing submarine cables was used to create a distance layer [35]. Using the Euclidean Distance Tool, distance from all existing submarine cables was calculated and rasterized. This layer, Distance to Submarine Cables, is considered important in identifying how far an OSW site is from any submarine cable in each coastal region with areas farthest from a submarine cable deemed most suitable for OSW.

Hurricane Density: Extreme storm events such as hurricanes and tropical storms can damage, and even collapse, OSW turbines from high wind speeds and increased wave activity. In selecting a site for OSW turbines, it is important to consider the frequency of extreme storm events of potential sites to prevent and decrease the likelihood of damage to turbines. As hurricane patterns are unpredictable and can change yearly, it is unlikely that any OSW site will be completely unaffected by hurricanes and tropical storms. However, using historical hurricane data, we can create a density layer of recent hurricane paths to understand where hurricanes have historically occurred. A point shapefile from NOAA that identified all hurricane paths from 1842 to 2023 was minimized to hurricane paths from the last 13 years, hurricanes since 2010, to better represent current hurricane trends [36]. Using the Point Density tool, the recent hurricane paths layer was used to create a density layer. This layer, Hurricane Density, is considered important in identifying the likelihood of hurricanes in each coastal region with areas of least hurricane activity deemed most suitable for OSW. As hurricanes only impact the East and Gulf Coasts of the United States, a hurricane density layer was not created or used in the suitability analysis of the West Coast.

Fault Density: Due to its location along multiple fault lines, the West Coast of the United States is prone to earthquakes and earthquake induced tsunamis. In selecting a site for OSW, understanding the location of fault lines is important in preventing potential damage to OSW turbines from earthquakes and tsunamis. As earthquakes are part of the reality of living and building on the West Coast, it is unlikely that OSW sites in the region would be completely unaffected by the effects of earthquakes. However, using fault lines data, we can create a fault density layer to understand where earthquakes and tsunamis are more likely to occur. Using the Line Density tool, a polyline shapefile from USGS that identified all fault lines along the Western Coast of the United States was used to create a density layer [37]. This layer, Fault Density, is considered important in identifying the likelihood of fault induced events along the West Coast with least fault density deemed most suitable for OSW. This layer was only created for the West Coast region of the United States and therefore was not used in the suitability analysis for the East and Gulf Coasts.

Regional Suitability Analysis

The method for reclassifying regional suitability criteria is the same as the reclassification process for initial suitability criteria. Similarly, suitability of regional criteria was also calculated using a weighted equation for each regional area of focus in the Raster Calculator tool. The only difference between methods is scale with regional suitability being calculated using a mask of the defined area of focus versus a mask of the EEZ for each coastal region. Reclassification tables and reclassified layers for all layers used in the regional suitability analysis are included in the appendix. See Appendix 4: Site Suitability Continued – Reclassification & Data Analysis.

The ranking for the regional suitability analysis differs slightly between coastal regions as criterion used in each regional analysis are slightly different. However, there are several key themes:

- Environmental Protection (Distance to NARW Habitat, Distance to Rice's Whale Habitat and Distance to MPAs) is ranked highest as our report's main focus is mitigating the impacts of OSW on marine species.
- Initial criteria (Average Wind Speed, Water Depth and Distance to Major Ports) are also ranked highly.
- After environmental protection criteria and initial criteria, Distance to Substations is the next highest ranked criteria due to its technical importance of connecting generated energy to the electrical grid.
- Following Distance to Substations is other technical criteria involving existing marine infrastructure and marine industry (Distance to Shipping Routes and Distance to Submarine Cables. These criteria are important but are not the determining factors for OSW site selection.

- Lastly, Hurricane Density and Fault Density are ranked last as their main purpose is in lessening damages to OSW turbines. As these layers are based on unpredictable natural events, they are less reliable than other criteria.

East Coast Regional Suitability

The East Coast regional suitability analysis includes all four initial criteria and all regional criteria, with exception to Fault Density and Distance to Rice's Whale Habitat, which were ranked as followed:

1. Distance to NARW Habitat

1. Average Wind Speed

2. Distance to MPAs

3. Water Depth

3. Distance to Major Ports

3. Distance to Substations

4. Distance to Shipping Routes

4. Distance to Submarine Cables

4. Hurricane Density

The following equation was used to calculate the regional suitability for the East Coast:

(Distance to NARW Habitat * 0.2) + (Average Wind Speed * 0.2) + (Distance to MPAs * 0.15) + (Water Depth * 0.1) + (Distance to Major Ports * 0.1) + (Distance to Substations * 0.1) + (Distance to Shipping Routes * 0.05) + (Distance to Submarine Cables * 0.05) +

(Hurricane Density * 0.05)

Gulf Coast Regional Suitability

The Gulf Coast regional suitability analysis includes the three initial criteria used for the Gulf Coast initial analysis and all regional criteria, with exception to Fault Density, which were ranked as followed:

1. Distance to Rice's Whale Habitat

1. Average Wind Speeds

2. Distance to MPAs

3. Water Depth

3. Distance to Major Ports

3. Distance to Substations

4. Distance to Shipping Routes

4. Distance to Submarine Cables

4. Hurricane Density

The following equation was used to calculate the regional suitability for the Gulf Coast:

(Distance to Rice's Whale Habitat * 0.2) + (Average Wind Speed * 0.2) +

(Distance to MPAs * 0.15) + (Water Depth * 0.1) + (Distance to Major Ports * 0.1) +

(Distance to Substations * 0.1) + (Distance to Shipping Routes * 0.05) +

(Distance to Submarine Cables * 0.05) + (Hurricane Density * 0.05)

West Coast Regional Suitability

The West Coast regional suitability analysis includes the three initial criteria used for the West Coast initial analysis and all regional criteria, with exception to Hurricane Density and Distance to Rice's Whale Habitat, which were ranked as followed:

1. Distance to MPAs

1. Average Wind Speed

2. Water Depth

2. Distance to Major Ports

3. Distance to Substations

3. Distance to Shipping Routes

4. Distance to Submarine Cables

4. Fault Density

The following equation was used to calculate the regional suitability for the West Coast:

(Average Wind Speed * 0.2) + (Distance to MPAs * 0.2) + (Water Depth * 0.125) +

(Distance to Major Ports * 0.125) + (Distance to Substations * 0.1) +

(Distance to Shipping Routes * 0.1) + (Distance to Submarine Cables * 0.075) +

(Hurricane Density * 0.075)

Initial Suitability Maps

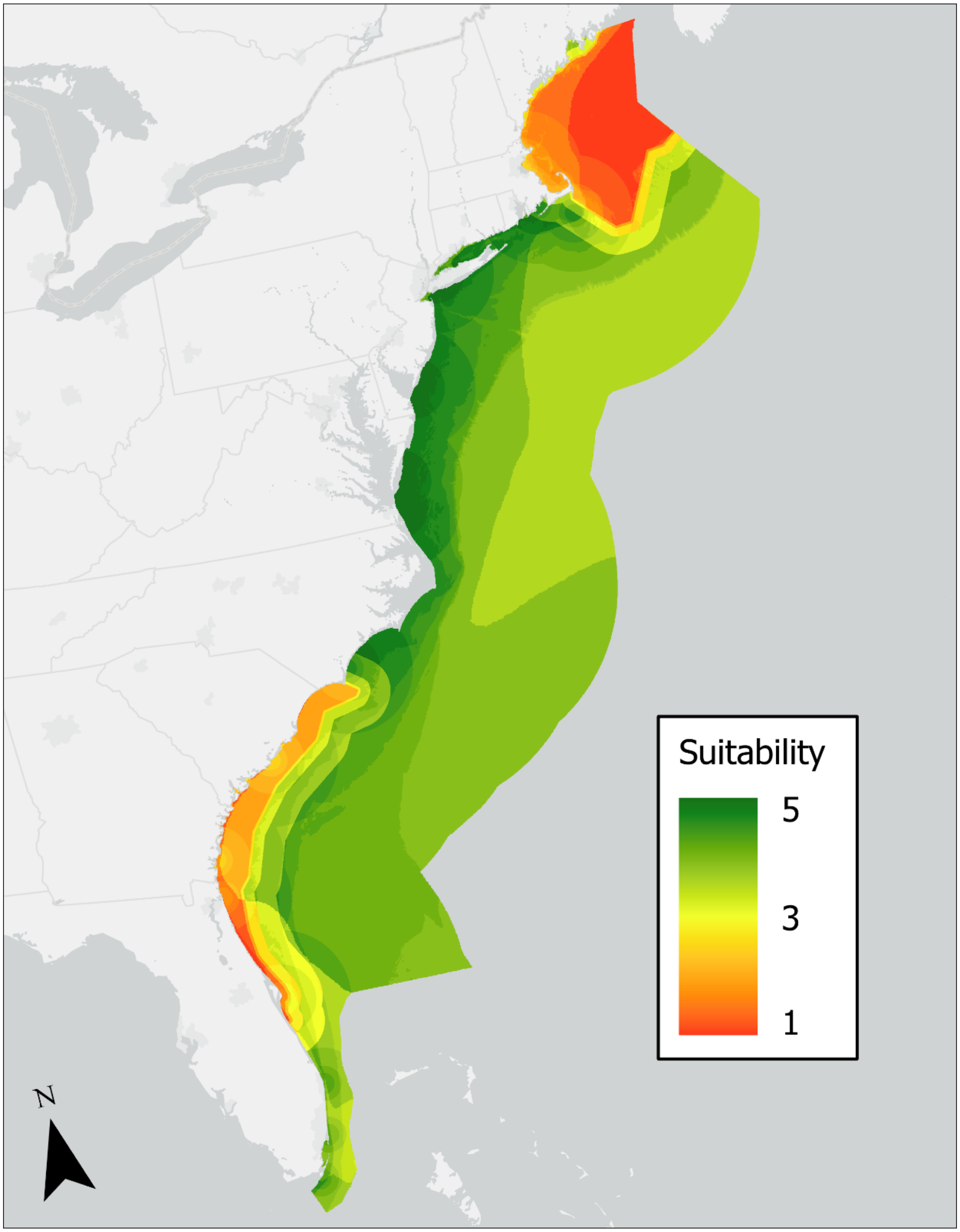


Fig. 1 Initial Suitability Map for the East Coast of the United States. Suitability was calculated on a score from 1 to 5, areas given a score of 1 are deemed least suitable and areas given a score of 5 deemed most suitable.

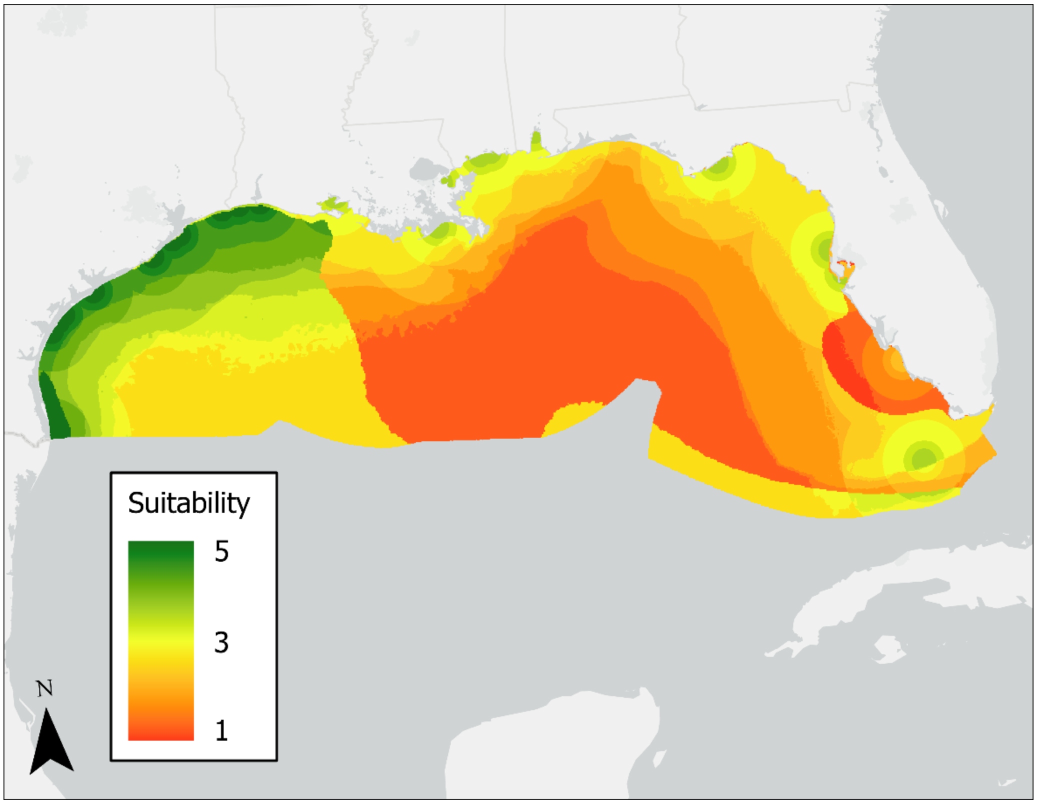


Fig. 2 Initial Suitability Map for the Gulf Coast of the United States. Suitability was calculated on a score from 1 to 5, areas given a score of 1 are deemed least suitable and areas given a score of 5 deemed most suitable.

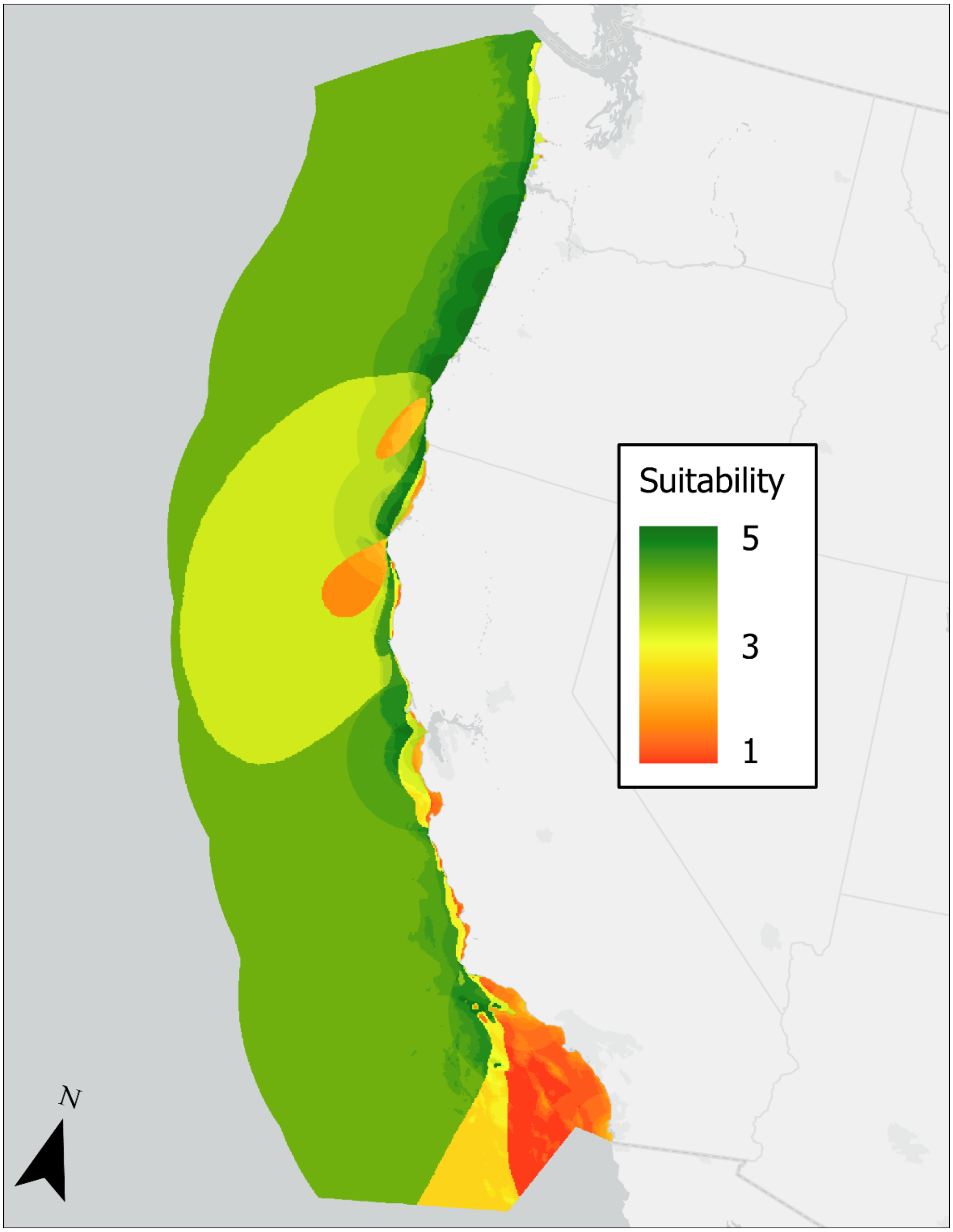


Fig. 3 Initial Suitability Map for the West Coast of the United States. Suitability was calculated on a score from 1 to 5, areas given a score of 1 are deemed least suitable and areas given a score of 5 deemed most suitable.

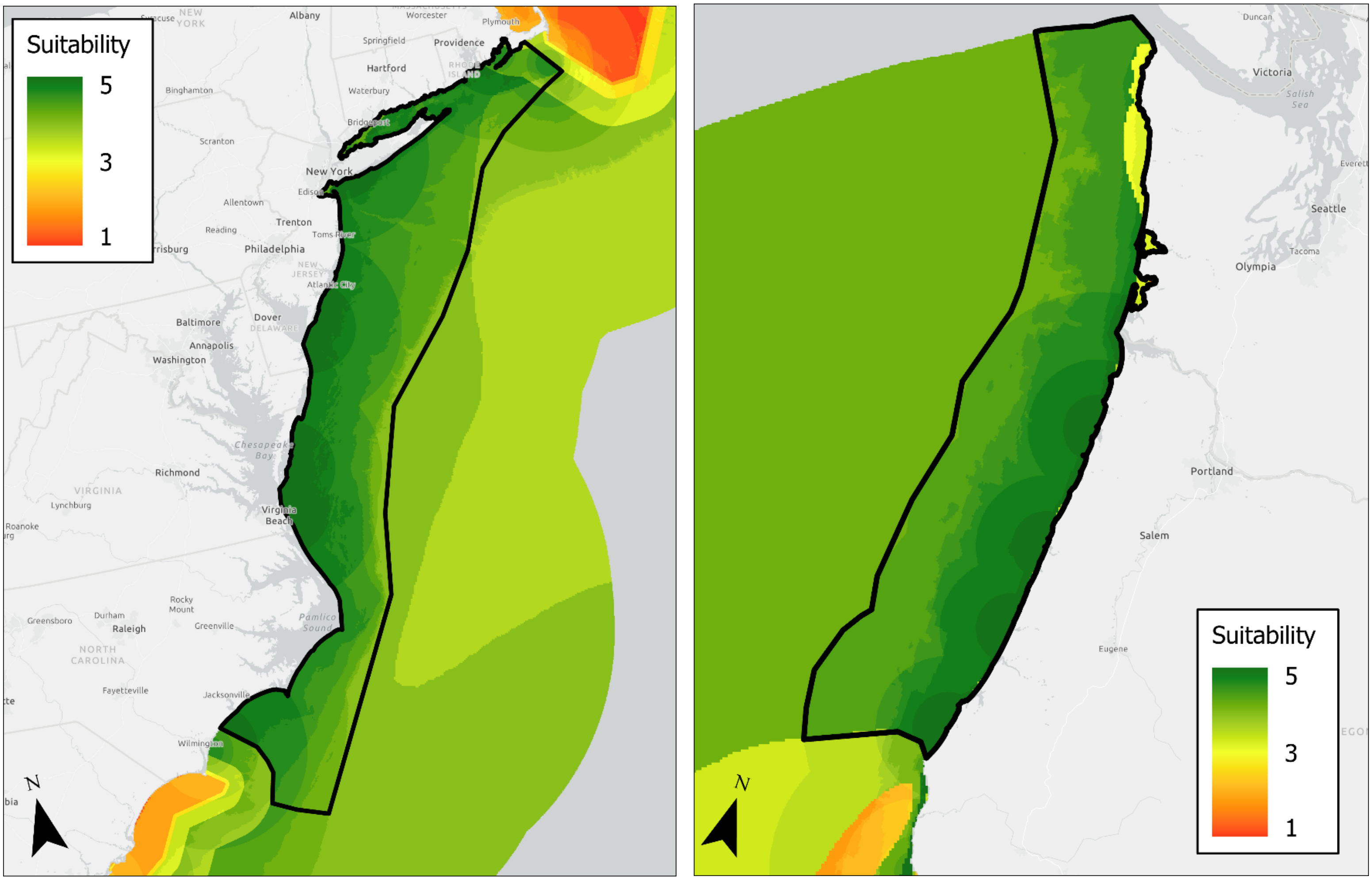


Fig 4. Initial Suitability Map for the East Coast (left image) and West Coast (right image) with highlighted Areas of Focus. Areas of Focus are defined as continuous regions, for each coastal region, with high suitability scores.

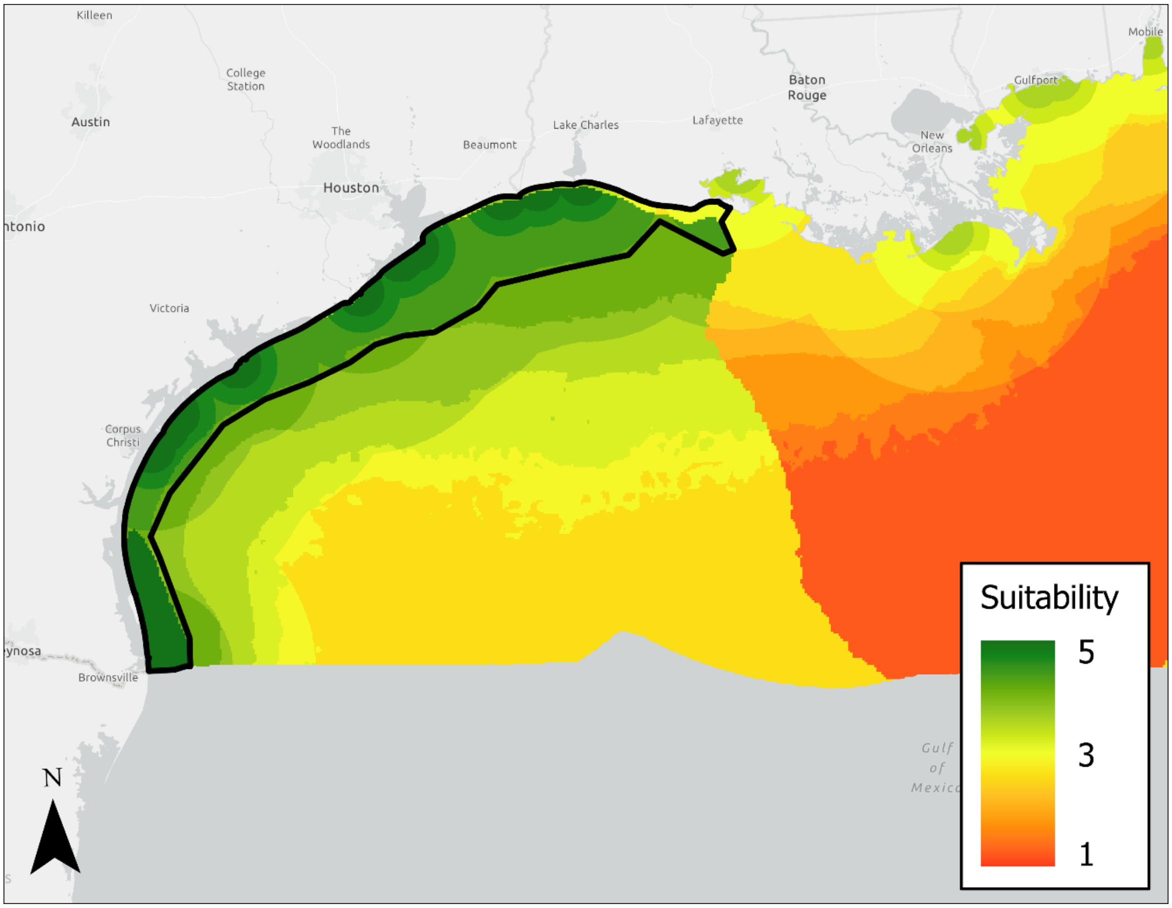


Fig 5. Initial Suitability Map for the Gulf Coast with highlighted Areas of Focus. Areas of Focus are defined as continuous regions, for each coastal region, with high suitability scores.

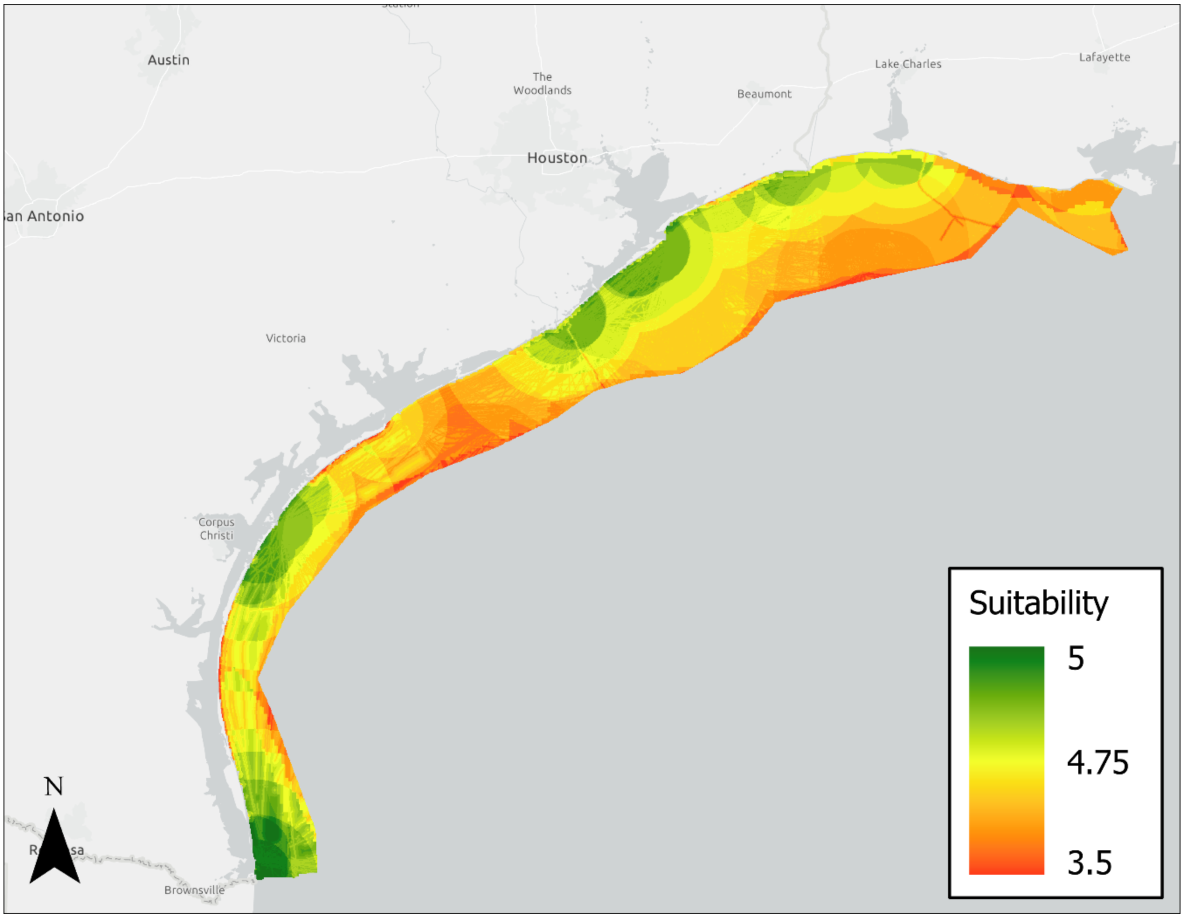


Fig 6. Regional Suitability Map for the Gulf Coast within defined Areas of Focus. The regional suitability scale differs from the initial suitability scale with all areas in the regional suitability analysis having a suitability score higher than 3.5.

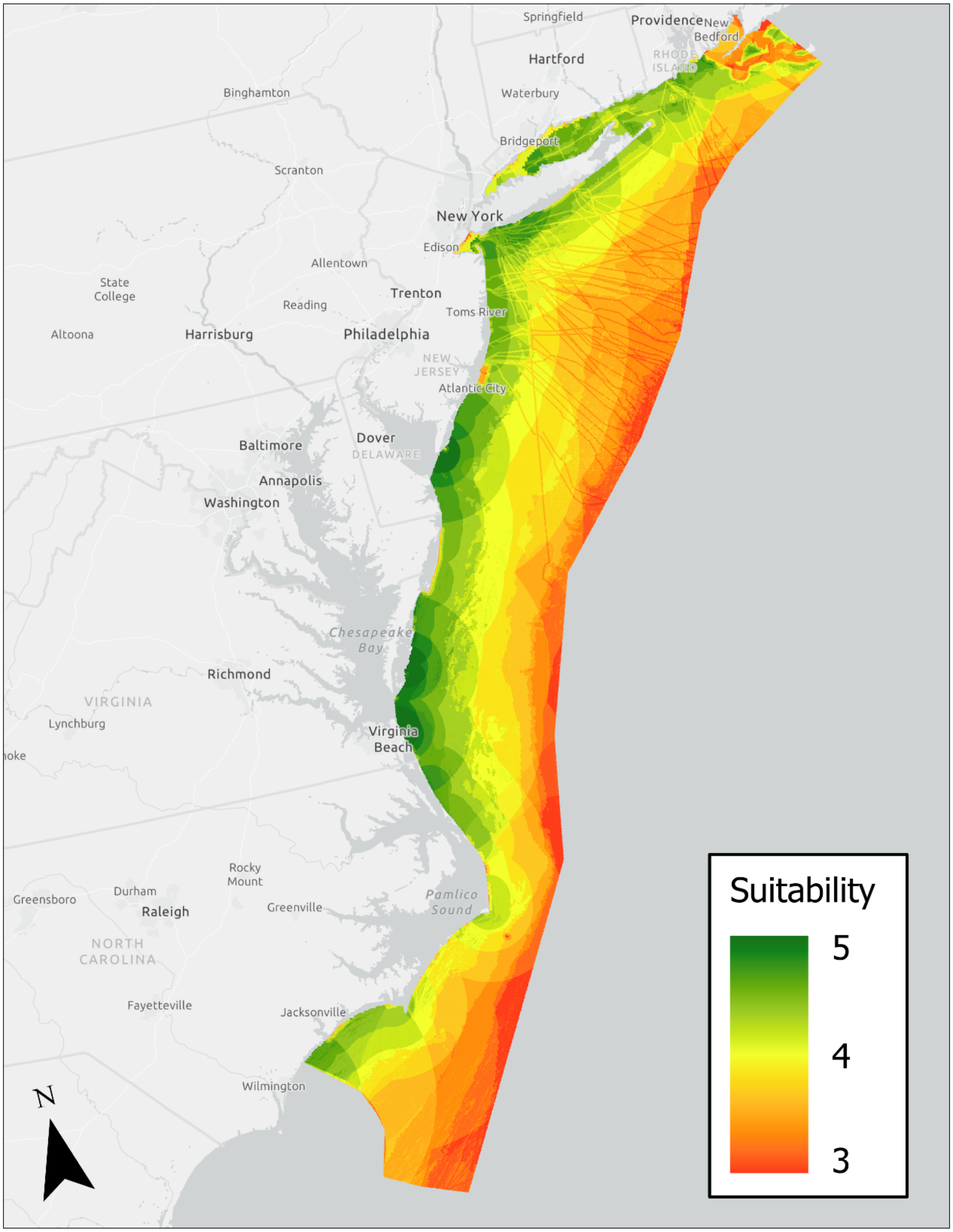


Fig 7. Regional Suitability Map for the East Coast within defined Areas of Focus. The regional suitability scale differs from the initial suitability scale with all areas in the regional suitability analysis having a suitability score higher than 3.

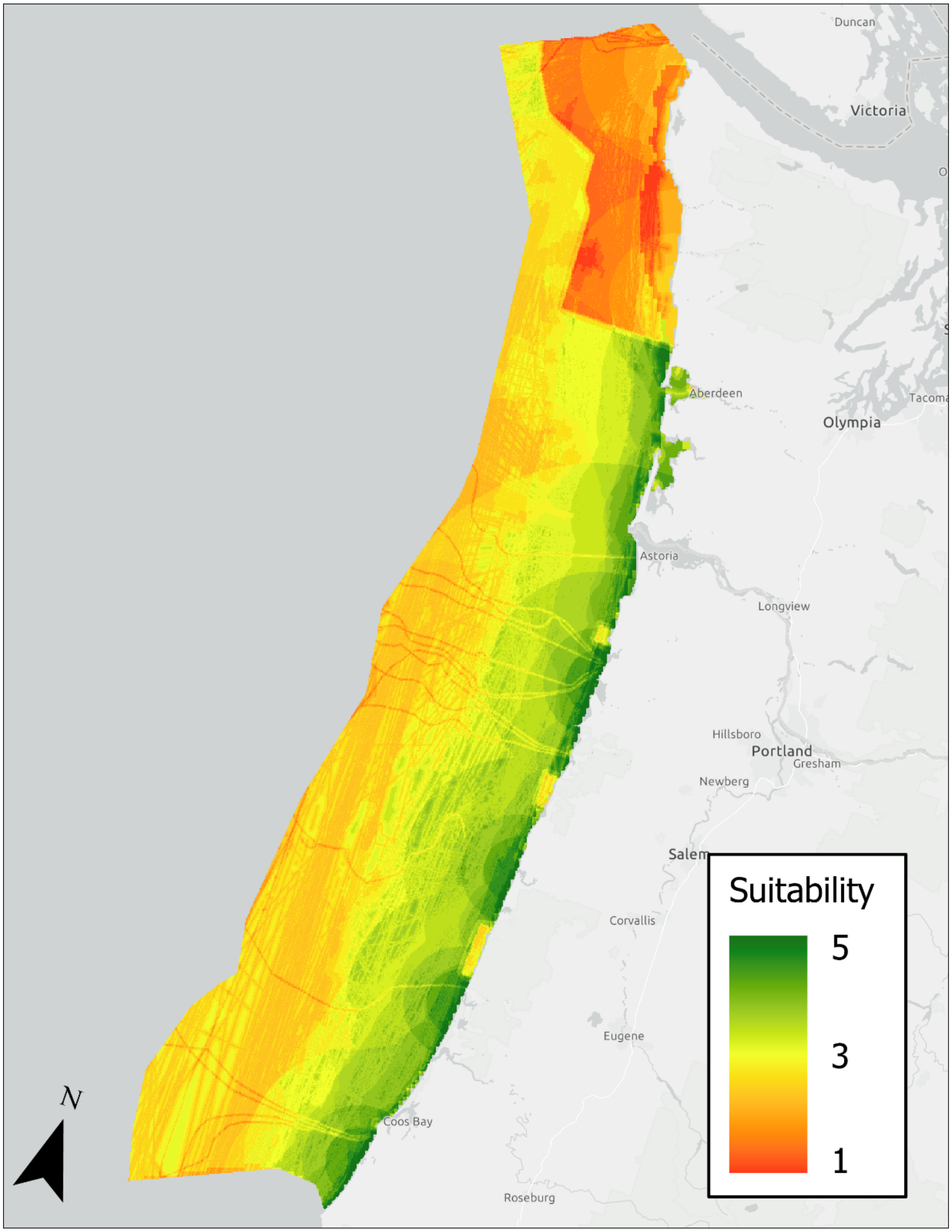


Fig 8. Regional Suitability Map for the West Coast within defined Areas of Focus. Unlike the regional suitability score for both the East and Gulf Coasts, the initial suitability scale and regional suitability scale for the West Coast are the same.

Conclusion and Discussion

Initial Suitability Map Results

The initial suitability maps identified general regions along the United States coastline where OSW would be best suited. A majority of the Eastern Coast is considered suitable for OSW. As our main criteria was the protection of NARWs, the regions outside of their limited habitat were considered suitable. With the addition of other criteria, areas outside of the NARW habitat that were in shallow waters, had a suitable wind speed (above 7 m/s) and were near major ports narrowed down the area of suitability to the coastal regions between southern Cape Cod and coastal North Carolina.

The Gulf of Mexico's most suitable regions for OSW were identified as coastal Texas and coastal western Louisiana. These coastal regions have a higher average wind speed compared to the eastern side of the Gulf which is characterized by lower speeds (averaging around and below 5 m/s). The western portion of the Gulf is also characterized by higher densities of major ports which have been historically used for other marine infrastructure such as offshore oil drilling.

The West Coast's most suitable regions for OSW were identified as coastal Washington and the majority of coastal Oregon. The West Coast has the highest average wind speeds between all three coastal regions. However, very high average wind speeds, above 10 m/s, can cause turbine failure. These pockets of higher average wind speeds along the coasts of southern Oregon and northern California make these regions less suitable for OSW. Another portion of the coast that is not suitable for OSW is the southernmost portion of California which is characterized by low average wind speeds (averaging between 5 m/s and 6 m/s).

Regional Suitability Map Results

The regional suitability maps further identified areas of best suitability for OSW by focusing on areas that were classified as most suitable in the initial analysis. In proposing where to build new OSW developments, these regional have identified smaller areas of focus based on more inclusive criteria. For the East Coast, the regional suitability analysis classified the most suitable areas for OSW, areas with a suitability score of 4.5 or higher, closest to the shore around major ports outside of the Chesapeake Bay/Virginia Beach and the southernmost tip of New Jersey.

For the Gulf of Mexico, areas with a very high suitability score of 4.75 or higher were found close to the shore and mostly found near the Texas / Louisiana border. Another spot to highlight is the southernmost tip of coastal Texas near Brownsville. However, as the regional analysis found high suitability scores for the majority of the area of focus, I think this area in general would be well suited to OSW development.

For the West Coast, similarly to the Gulf and East Coasts, the most suitable areas were found near the shore. However, one large difference between the initial suitability and regional suitability was the northernmost part of Washington State. There is a large MPA in this location and therefore was found unsuitable in the regional analysis. There are several MPAs along the Washington and Oregon coast that are seen in yellow compared to the otherwise green classification near the shoreline. The regional analysis allowed for a more detailed and fine-tuned map especially when it came to criteria protecting marine environments and species.

Conclusion

This report aims to provide a feasible trajectory for the implementation of OSW development in the United States. Throughout this report we have detailed what the key issues are regarding OSW development in the United States. While there are many considerations, the ones we found to be most important currently are protections for NARW, cultural and justice considerations, and transmission capability. We determined what policy approaches would be the most efficient and effective, best economic route for OSW and where OSW would be best suited.

For the policy approach, we investigated a three-pronged approach in which we leverage existing and amended state policy in conjunction with the RFP and PPA process. We determined that many states already have laws that incentivize renewable energy as part of a push to diversify their grids and meet the commitments towards being carbon neutral. We used the example of a 2022 Massachusetts law passed with language that mentions mitigations for the NARW. While the language is not specific in what mitigations are required, we believe that making those language changes would be a simple amendment. Language could also be added to ensure a just transition and equitable distribution of OSW benefits. With laws like this on the books, states can use this language in the RFPs and PPA process to guarantee increased mitigations and environmental protections but can also stipulate conditions for transitioning workers from across other energy industries in regions like the gulf and pacific.

We also determine the best routes economically to determine how OSW can be developed effectively and efficiently. While it was difficult to determine the full cost of mitigation for the NARW, we were able to determine that there are several avenues to ensure increased protections to NARW populations that are still profitable. Federal and State intervention in the form of incentives for OSW projects could create a more favorable environment for larger budgets allocated to mitigation measures. The use of more aggressive PPAs for OSW projects could also be a key driver in making mitigation measures more economically feasible.

Site suitability was also a focal point in this report. This suitability was based off wind speeds, water depths, distance from ports, and in the Northeast critical NARW habitat. The initial suitability analysis found that the mid-Atlantic region (from south of Cape Cod to coastal South Carolina) was best suited for OSW development for the east coast, coastal Texas and the western portion of coastal Louisiana were determined to be the most suitable regions in the Gulf, and coastal Washington and coastal Oregon the most suitable regions for the west coast.

This report is just the first step in implementing OSW in an effective, ethical, and efficient way. With President Biden’s commitment to renewables and reducing the use of fossil fuel consumption at the forefront of the climate action debate, the momentum is there to harness the wind resource of the country's coastlines. There are many other considerations that should be investigated, however, the ones listed in this report and the solutions given are stepping-stones to the greater fight for a grid built on clean energy. We hope that the information in this report can be expanded and used as a reference for Oceana and other groups interested in supporting OSW in the United States.

Appendix

Appendix 1: Literature Review

Offshore Wind Literature Review

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Date: May 2, 2022

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Introduction

In today's political and ecological climate, there is a growing demand for the Biden Administration to invest into renewable energy sources. With this, offshore wind has come to the forefront of the energy economy to satiate such a demand. In this regard, the Bureau for Ocean Energy Management (BOEM) is working with the National Oceanic and Atmospheric Administration (NOAA) to currently lease and approve tracks of the ocean for offshore wind development. Although it is an exciting time to be looking into the potential of offshore wind, there are many considerations that should be addressed to ensure the offshore wind industry develops with minimum possible negative impacts to the environment and is part of a responsible and just transition to a renewable energy economy. These considerations include

- protections and mitigations for marine mammals during offshore wind development's pre-construction, construction, and operation phase, and decommissioning
- the cost of those mitigations, economic analysis of offshore wind,
- policies that determine what measures should be taken, and
- the social justice implications of offshore wind development.

In this literature review, we aim to review where mitigations are needed most, estimate the cost of mitigation, existing policies that protect marine mammals, future job potential, and social justice implications.

Methods

A literature review was conducted on the effects of offshore wind energy development (OSW) on coastal marine environments, economy, policy, mitigation, and social justice. We reviewed around 195 sources ranging from academic journals, governmental reports (IPCC), news articles, non-profit websites, developer websites, institutional websites, and government websites. The search methods used for our research included use of the University of Michigan's library database, Science Direct, and more general Google searches. The criteria for our searches was based on our four research questions and included keywords in our searches. Words include: Biodiversity, climate change impact, dynamic management, environmental policy, floating wind, marine spatial planning, offshore wind, renewable energy, and more. This literature review covers information gathered from governmental institutions and non-profit institutions as well as from journal articles and publications.

Mitigation

Geographic Distribution of Marine Mammals

As the United States transitions to a renewable energy future, Oceana is focused on promoting a just expansion of OSW while mitigating the negative effects on marine mammals and their habitats. Specifically, our project is emphasizing the need for protection of the endangered North Atlantic Right Whale (NARW). To lessen the impacts on marine mammals, offshore wind developers can avoid construction entirely or at the relevant time of year in crucial marine mammal habitats such as migration routes and breeding grounds. In this section, we describe the geographic distribution of several of the endangered marine mammals with a focus on whale species.

North Atlantic Right Whale: The species has a limited global distribution with populations concentrated in the northern Atlantic Ocean. The NARW favors coastal waters in shallow environments such as the continental shelf of the eastern United States and Canada (Fisheries N. 2022g). Their habitat primarily ranges from the coastal waters of northern Maine to the eastern coast of Florida.

The NARW is currently one of the most endangered marine species in the world. It is estimated that there are fewer than 350 NARW left in the wild (Fisheries N, 2022g). The population has been in a steep decline in recent years with a 30% decline since 2011 (WWF, 2022). As they prefer shallow waters, where human activities such as the commercial shipping and commercial fishing industries are most present, NARWs are being actively killed by vessel strikes and entanglement with fishing equipment (Fisheries N, 2022g). The NARW is also being impacted by global climate change. As ocean temperatures increase along the Atlantic coast, the habitat range of the NARW is becoming smaller and shifting north (Fisheries N, 2022g). In 2017 the species experienced a "mass mortality event" where around 17 individuals, 12 in Canada and 5 in the US, died due to various causes, including vessel strikes and entanglement (Koubrak et al., 2021). The plight of the NARW is not uncommon to other large marine mammals, being that it is a slow-growing slow reproducing species with a small population (McDonald et al., 2016). These factors make the NARW and other species like it have a higher risk of extinction and are more sensitive to disturbance activities, including those from offshore wind development.

Sperm Whale: Sperm Whales have a large global distribution and are found in all of earth's oceans. They prefer deeper waters, at least 1000 m, and are rarely found in shallow environments (Fisheries N, 2022h). The exact population is unknown but is estimated to be around 300,000 (NWF). The Sperm Whale population became close to extinction during the 19th and 20th centuries due to the commercial whaling industry. In more recent years, with commercial whaling being internationally banned in 1986, the population has slowly started to recover (Fisheries N, 2022h). Despite the ban, Sperm Whales are still on the endangered species list

(Fisheries N, 2022h). When thinking about offshore wind farm placement, it is more likely that Sperm Whales would be found in the deeper waters of the Pacific Coast compared to the Atlantic Coast of the United States.

Blue Whale: Blue Whales have a large global distribution and are found in all of earth's oceans except the Arctic Ocean (Fisheries N, 2022a). Similar to sperm whales, Blue Whales prefer deeper waters and are rarely observed in coastal habitats (WDC, 2022a). Blue Whales also suffered from commercial fishing and their population was greatly reduced. Currently, there is an estimated population of 15,000 (MBA, 2022a).

The distribution of Blue Whales around the United States is concentrated on the Pacific Coast. Blue Whales feed in the cooler waters of the Northeast Pacific (WDC, 2022a). They have also been observed off the Atlantic Coast near Canada.

False Killer Whale: False Killer Whales prefer warmer waters and are typically found throughout the world's tropical and temperate zones (Fisheries N, 2022c). They tend to prefer deeper waters, but large populations have been inhabited in shallower waters off the coasts of Hawaii (Fisheries N, 2022c). In the contiguous United States, False Killer Whales have populations in the Gulf of Mexico and the eastern coast of Florida. The global population is unknown but there are an estimated 1,500 False Killer Whales in the coastal waters of Hawaii (Oceana, 2022a).

Fin Whale: The Fin Whale prefers deep, cool waters and is typically found in the world's temperate and polar zones (Fisheries N, 2022f). NOAA defines four distinct populations of Fin Whales in the Coastal Waters of the United States. The two populations off the contiguous United States are the Pacific Coast and North Atlantic Coast (Fisheries N, 2022f). Also drastically depleted from commercial whaling, the current estimated population is between 50,000 and 90,000 (WDC, 2022b).

Gray Whale: The Gray Whale has a limited geographic range and only inhabits the North Pacific Ocean. There are two populations of Gray Whales, one large population off the northern Pacific Coast of the United States (Washington, Oregon, and Northern California) and Canada, and one much smaller population off the eastern coast of Russia (Fisheries N, 2022e). Despite preferring cooler, shallow climates, Gray Whales migrate south to southern California and the Baja region of Mexico to calve (Fisheries N, 2022e). The current western population of Gray Whales is estimated to be 27,000 (Fisheries N, 2022e).

Humpback Whale: The Humpback has a large geographic distribution and has migration routes through all the earth's oceans. Despite its vast range, there are few consistent populations off the coast of the contiguous United States (Oceana, 2022b). Populations of humpback whales inhabit the Gulf of Maine and the Gulf of California (Oceana, 2022b). However, Humpback Whales do have migration paths along the Pacific Coast of the United States. Also experiencing great losses from commercial whaling, the Humpback whale population at its lowest was estimated between 10,000 to 15,000 (ESC, 2022). Fortunately, the population has been on the rise and is currently estimated at 80,000 (ESC, 2022).

Impacts & Technology

Wind power has been the fastest growing form of renewable energy in the past decade.[1] In the expanding market for wind energy and the limited availability of land onshore to construct wind farms, the development of OSW becomes increasingly important. With rapid technological innovation, offshore wind projects have grown rapidly in the Scandinavian region as well as other countries in Europe such as the United Kingdom, Germany, Netherlands, and Belgium, as well as countries in Asia like China, India, and South Korea. However, in the United States, there has been a lag in the push for decisive action and efficient policymaking in the field of OSW development. There are currently only seven offshore wind turbines in the U.S. and there is still an opportunity to develop and implement proper mitigation measures to protect the wildlife OSW will impact.

Impacts on Wildlife Due to OSW

The installation of man-made structures in the ocean will undeniably have effects on marine life. Of these, displacement and behavior modifications are two of the most critical effects studied. Placement of wind farms in critical habitats and sites can have negative impacts on breeding and foraging locations of marine organisms. This can result in heightened stressors and effects or simply loss of the resource due to displacement. Therefore, careful planning is imperative in the mitigation measure process. On the other hand, turbines and other infrastructure can provide increased foraging and habitat for other marine animals. Platforms provide a space for birds to perch and rest. Seals in the UK and sea lions in Australia have been observed to modify their behaviors to use wind turbine structures as foraging grounds (Maxwell et al., 2022). Much like oil rigs, wind turbine structures can act as a negative for some animals while serving as attractants to others.

Collision with vessels can result in serious injury or death to marine mammals, particularly whales. Wind energy installations will result in increased vessel presence during construction, operation, and maintenance phases. Vessels must also transit through coastal habitats to reach offshore wind installations, thereby increasing collision risks inshore as well. (Maxwell et al., 2022). However, the likelihood of collision with floating offshore wind turbines (FOWT) may be less, as most of the construction can be done on land and transported and installed at sea in a relatively short amount of time. Also, some FOWT platforms have areas large enough for helicopter access for installation and operational and maintenance requirements, which will reduce the amount of vessel traffic on water (Banister, 2017).

Collisions with moving turbine blades could pose a threat of injury and death to seabirds. This can occur at the operational phase of offshore wind development and has the potential to significantly impact population levels. Offshore environments have higher wind speeds, and researchers have shown that seabirds change their behaviors in response to these wind speeds such as relying more on gliding than flapping which gives them less control on their flight direction (Ainley et al., 2015). Because they are floating, FOWTs also have an increased range of both vertical and horizontal motion compared with stationary onshore wind turbines. This dynamic could result in the increased risk of seabird collision with turbines.

FOWT are secured to the sea floor by mooring line tension cables that create entanglement risk for diving seabirds, sea turtles, elasmobranchs, and fishes and marine mammals. The underwater infrastructure accumulates derelict gear, such as nets and hooks/lines, or plastic pollution which can pose complex issues for fish and marine species(Baulch and Perry, 2014). Further, the entanglement of these organisms can serve as bait for large predators and pose a potential risk for them being ensnared in the process of eating entangled prey (Maxwell et al., 2022). Entanglement, particularly in derelict fishing gear, represents one of the greatest threats to cetaceans worldwide (Baulch and Perry, 2014). As of 2009, 83 percent of NARW showed evidence of entanglement; 26 percent showed new entanglement scars every year, and 59 percent had been entangled more than once (Knowlton et al., 2012). With the introduction of FOWT, these numbers could increase, however, more research is needed.

Mitigation Measures/Technology

It is critical that site selection and construction consider site- and species-specific risks, and that mitigation planning and monitoring for wildlife impacts occur before, during and after development. This requires knowledge of animal distribution, breeding and foraging sites, and migration data. Placing turbines in low-impact areas, where minimal marine organisms and habitats exist is the first and foremost crucial step to reducing behavioral and displacement impacts on marine life.

Understanding co-occurrence of vessel transit routes with whale habitats is of utmost importance in mitigating vessel collisions. Therefore, limiting the number of vessels and routes as well as reducing vessel speeds has shown to reduce collision-related mortality for whales. To further reduce the potential for collision with whales, acoustic monitoring and/or aerial surveys could be used to determine presence or likelihood of presence based on environmental conditions, and vessels could be restricted or slowed during those times (Maxwell et al., 2022). This has already been used to great effect in wind projects like Vineyard Winds off the coast of Massachusetts. Furthermore, technologies such as WhaleAlert, WhaleWatch and EcoCast are already in use to reduce impacts on sensitive species in shipping and fishing industries, and a similar system could potentially be designed to meet the specific needs of the OSW sector (Hazen et al., 2018). These technologies have greatly increased the knowledge of real-time whale activity, location, and migration which can be of great benefit to OSW development and management.

A major concern with OSW development is the requirement of pile-driving foundational structures to the seafloor where marine organisms live, feed, and breed. The noise associated with these activities greatly distress and disrupt marine organisms' lifestyles and habits. The best practice to reduce impacts on aquatic wildlife is to reduce overall area and footprint of the turbine matrix, anchors, and cable arrays if applicable and to place them in locations of lower ecological importance. Large-scale spatial analysis of benthic habitat is pivotal in the assessment of potential lease areas in order to avoid regions where structure-forming organisms such as corals and sponges dwell. New technologies such as rapid deploy landers, Autonomous Underwater Vehicles (AUVs) and improvements to towed camera sleds make this work both highly feasible and affordable (Maxwell et al., 2022).

There are several land-based systems used to mitigate impacts of turbines on birds, and these can be transferred over to OSW facilities. Making rotor movement more distinguishable to birds by painting them with a bright shaded color is an efficient and simple solution. Another remedy is a concept system for continual monitoring of bird collisions using a multi-sensor array and central on-board processing systems integrated into the turbines themselves. This system uses accelerometers and microphones to detect impact, optical sensors to track moving objects, and bioacoustics recorders for use in species identification (Suryan et al., 2016). Avoidance and detection systems such as DTBird can auto-detect species of special concern in turbine areas and subsequently communicate a signal to deter birds, or to indicate the need for temporary cessation of turbine operation (Maxwell et al., 2022).

It would prove useful to monitor tension of lines and cables used in FOWT which could be used to detect both primary entanglement of large marine species and secondary entanglements if fishing gear is involved. The risk of entanglement in Tension monitors can be connected wirelessly to remotely alert to the presence of a potentially entangled species. Additionally AUVs, remotely operated underwater vessels, or wireless video can potentially be used to monitor for entanglement events in the cables (Maxwell et al., 2022). Reducing biofouling around turbine structures could also prove handy as it would reduce the potential of adherence of material to underwater infrastructure. Pingers, as used by fisheries industries to reduce bycatch, may be another method of reducing entanglement on moorings and buoyancy lines as they deter animals from entering the area of concern. Acoustic deterrents also have the potential to be enacted into the environmental mitigation actions, however, its use must be carefully planned as it can cause auditory stressors to organisms and may not prove helpful with large mammals such as whales.

Environmental Conditions

In the Anthropocene epoch human activities have exacerbated the degradation of the global environment (Crutzen, 2002). There are many direct and indirect drivers that may be attributed to the destruction of healthy ecosystems and therefore should be considered when developing mitigation strategies.

Climate Change

The 1.5˚C increase in global temperature has been predicted to increase the temperature and acidity of oceans, increase sea level rise, and alter the severity and pattern of storms and oceans (--). Climate change is causing ecosystem degradation, and biodiversity loss because climate change generates impacts and risks that can surpass the limits an organism may have to adapt, resulting in damage and loss (IPCC 2022). The effects of climate change are already present and measurable as it has already altered terrestrial, ocean and freshwater ecosystems globally, as well as adversely affected species geographic ranges, ecosystem structures and the timing of seasonal life cycles (IPCC 2022). Moreover, climate change can decrease environmental resilience when combined with other stressors such as pollution and harvesting (Hughes et al 2003), and ultimately impact the efficacy of existing conservation and mitigation measures.

Environmental Conditions of the Coastal United States

As our country plans for construction and expansion of OSW infrastructure, utilizing the expansive coast of the United States is crucial in meeting our goals. The United States has three major coastal regions: the Atlantic Coast, the Pacific Coast, and the Gulf of Mexico. Each region supports its own unique ecosystems with varying environmental conditions. In considering where to expand offshore wind, it is important to understand the environmental and ecological differences of each of the United States' coastal regions. In this section, we will define and summarize the environmental conditions relevant to offshore wind farms.

Wind Speed

One of the most important factors in deciding where new and potential offshore wind farms should be located is wind speed. Wind turbines require a minimum average wind speed to operate and generate renewable energy. Literature differs on what is the ideal or minimum wind speed for wind turbine operation. However, with optimal conditions ranging from 3 to 10 meters per second (m/s), the average obtained from the literature is an average speed of 7 m/s (See Technical Criteria section for more information). Wind speed averages for this section are based on data from (Optis et al., 2020; Schwartz et al., 2010) and (GWEC, 2021).

The Atlantic, Pacific, and Gulf coasts vary in average wind speeds. In general, the Pacific Coast has the highest average wind speeds of the coastal United states, while the Gulf Coast has the lowest average. The Atlantic Coast is somewhere in the middle, but trends to have higher average wind speeds in the northern portion of the coast near Maine and gradually decrease moving south towards the Gulf. I describe the specifics of average coastal wind speeds for each coastal region of the United States below.

Atlantic Coast: Coastal wind speeds average higher in northern Atlantic states and decrease as you move south towards the Gulf of Mexico. Average wind speeds are highest in the Gulf of Maine, averaging 9 m/s to 10 m/s. Wind speeds slowly decrease from southern Maine to the coast of the Carolinas with averages of 8 m/s to 9 m/s in New England and averages of 7 m/s to 8 m/s around the coasts of Long Island and New Jersey to Delaware and south towards the Carolinas. Slowly decreasing as you move south, lowest average wind speeds of the coastal Atlantic are found off the eastern coast of Florida, averaging between 5 m/s to 7 m/s.

Pacific Coast: Unlike the Atlantic Coast, there is not a distinct wind speed pattern along the Pacific Coast. The Washington coast has a relatively consistent wind speed. Depending on the source, wind speeds average from 6.0 m/s to 6.5 m/s at the lowest to 8 m/s to 9 m/s at the highest. All sources show the trend of increasing speeds as distance from the Washington shore increases.

Coastal Oregon has varied average wind speeds with lower average wind speeds in northern Oregon and higher average wind speeds near the border of California. Northern Oregon wind speeds average around 7 to 7.5 m/s. Wind speeds increase as you move south with a peak near the California border. Sources vary but the maximum wind speed in southern Oregon is between 9.5 m/s to 11 m/s.

Similar to coastal Oregon, average wind speeds of the California coast have a general trend of higher average wind speeds in the north and lower average wind speeds in the south. Average wind speeds in northern California range from 7 to 9 m/s with maximum wind speeds reaching 12 m/s near the Oregon border. Southern California averages 6 to 7 m/s with maximum speeds of 9 m/s. Wind speeds continue to decrease towards San Diego and the border of Mexico with average speeds 4 m/s to 7 m/s. Wind speed averages for this section are based on data from (Optis et al., 2020; Schwartz et al., 2010) and (GWEC, 2021).

Gulf of Mexico: Compared to the Pacific and Atlantic coasts, coastal wind speeds are lowest in the Gulf of Mexico. Coastal wind speeds are highest in the Gulf off the coast of Texas, averaging 7 m/s to 9 m/s. Wind speeds decrease as you move east towards the western coast of Florida. Louisiana has varied coastal wind speeds, averaging higher towards the Texas border with speeds around 6 to 7.5 m/s and lower around New Orleans, averaging from 5 m/s to 6.5 m/s. Wind speeds are consistently lower from New Orleans to the western coast of Florida, averaging around 5 m/s to 6 m/s. Wind speed averages for this section are based on data from (McCoy), (Schwartz et al., 2010) and (GWEC, 2021).

Water Depth

Similar to wind speed, water depth is another important factor in determining the optimal location for OSW. Water Depth determines the type of foundation used in the construction of offshore wind farms. There are three types of turbine foundations: monopile, jacket, and floating. Shallower waters, under 30 m in depth, are suitable for monopile foundations (Vinhoza and Schaeffer, 2021). As depths increase to 30 m to 60 m, jacket foundations are more suitable. While floating wind turbines are used for deeper waters in depths greater than 60 m (Vinhoza and Schaeffer, 2021). Average water depth varies along the contiguous, coastal United States. In general, the Pacific Coast has the deepest waters of the three coastal regions. While the Gulf of Mexico and the Atlantic Coast have a much wider continental shelf, resulting in more shallow coastal waters (Smith and Sandwell, 1997).

Atlantic Coast: The Atlantic Coast has a far-reaching continental shelf that averages around 50 miles wide with some regions extending up to 300 miles from the shore (Jarrell et al., 1992). Categorized by shallow waters, the continental shelf typically has water depths less than 100 meters which is optimal for monopile and jacket turbine foundations (South Atlantic Blueprint, 2013). The New England and Mid-Atlantic coasts have a more extensive continental shelf compared to the Carolinas and the eastern coast of Florida.

Pacific Coast: With a much thinner continental shelf, the coastal waters of the Pacific coast quickly increase in depth as distance from the shore increases. Coastal Oregon and Washington have a slightly wider continental shelf than California. Coastal water depths in Oregon and Washington average between 100 m and 300 m while California averages more than 300 m (Schwartz et al., 2010). These depths make the Pacific coast more suitable to floating turbine structures in comparison to both the Atlantic Coast and the Gulf of Mexico.

Gulf of Mexico: Similar to the Atlantic Coast, the Gulf of Mexico has an extensive continental shelf. In some regions, such as the western coast of Florida, the continental shelf extends up to 200 miles from shore. As you move west, the continental shelf decreases slightly in width. Also like the Atlantic Coast, the continental shelf has a defined water depth less than 100 meters (Hastings et al., 1999).

Extreme Storm Events

One factor in considering the lifetime of OSW is the frequency and intensity of extreme storm events. Not only can they damage wind turbines, extreme weather events prevent consistent wind generation as turbines stop operating at high wind speeds (Hartman, 2018). Using international examples and how similar offshore structures such as oil and gas rigs were affected by extreme storm events, can help predict how potential US OSW will be affected by hurricanes. For example, turbine damage caused by typhoons resulted in the loss of turbine blades and turbine tower buckling off the coast of China and Japan (Rose et al., 2013). Similarly, Hurricane Katrina, a Category 5 hurricane, resulted in the destruction of 41 and damage to 21 offshore oil and gas rigs in 2005 (Rose et al., 2013). Rose et al. created a hurricane simulation for the United States' Atlantic coast and found that Category 2 hurricanes had a 6% of causing turbine tower buckling while a jump to Category 3, 4 or 5 resulted in a 46% of turbine tower buckling.

Extreme storm events have been increasing in recent years and are predicted to continue increasing due to global climate change (Levitt and Berkowitz, 2021). To limit the potential damages and destruction to OSW it is important to understand the likelihood of these events and their geographic distribution. In this section, I will discuss past and current trends related to extreme weather events across the contiguous United States.

Atlantic Coast: In the past 20 years, the Atlantic coast has been experiencing increased hurricane events. These events occur seasonally from June to November with a peak in mid-September (NOAA, 2021). The Southern Atlantic along the coasts of the Carolinas, Georgia, and Florida experience hurricanes more frequently than the Northern Atlantic (Jarrell et al., 1992). However, as storms have also become more intense with increased wind speeds and precipitation rates, increased damages can be seen along the entirety of the coast.

Pacific Coast: The Pacific Coast experiences Atmospheric Rivers and Extratropical Cyclones. These events tend to have a greater impact on terrestrial environments such as causing mass flooding (Levitt and Berkowitz, 2021). Similar to hurricanes, atmospheric rivers and extratropical cyclones are characterized by intense precipitation and high wind speeds. However, based on the literature review, it seems they have lesser impact on marine environments and conditions compared to hurricanes experienced in the Atlantic and Gulf coasts (Dettinger et al., 2011). Therefore, these events may not impact potential OSW at the same intensity that hurricanes are expected to.

Gulf of Mexico: Similar to the Atlantic Coast, the Gulf of Mexico experiences hurricanes seasonally from June to November. However, these events occur more frequently in the Gulf than the Atlantic due to their proximity to the Caribbean (Jarrell et al., 1992). Hurricanes, also known as tropical cyclones, begin in the tropical waters of the Caribbean and travel northward. Therefore, more events reach the Gulf, with a higher intensity, as storms typically begin to dissipate moving northwards towards the Atlantic Coast

Active Fault Lines

Another factor in considering the lifetime of OSW is the frequency and likelihood of offshore or nearshore earthquakes. Destructive events that cause ground movement, increased wave height and increased wave frequency, earthquakes pose a threat to offshore wind turbines. These events also threaten the connection to power grids through the disconnection or destruction of submarine cables.

Earthquakes are caused by the movement of fault lines underneath the Earth's surface. Therefore, coastal areas with a higher concentration of offshore or nearshore active faults are more likely to experience earthquakes. Of the three coastal regions of the contiguous United States, the Pacific Coast has the highest concentration of offshore and nearshore fault lines and regularly experiences earthquakes.

Pacific Coast: The Pacific Coast is the most active area in the contiguous United States for earthquakes due its location along convergent tectonic plates. Primarily located offshore, about 20% of fault movement in the U.S. occurs within 75 miles of the Pacific coast (Brothers, 2021). There are many active faults in this region. The Hayward Fault and the Rodgers Creek Fault are in the North Pacific (Watt, 2021). The San Andreas Fault and San Gregorio-Hosgri Fault are located along the South Pacific coast (Watt, 2021). Most well-known, the San Andreas Fault extends along the majority of California for more than 1,200 km through highly populated cities such as Los Angeles and San Francisco (Pointbriand and Krezel, 2017).

Gulf of Mexico & Atlantic Coast: The Gulf of Mexico and the Atlantic Coast are located near few fault lines and rarely experience earthquakes. The Atlantic Coast has some risk of earthquake-like events such as Tsunamis caused by submarine landslides (Brink, 2009). The Gulf of Mexico does have some risk of earthquakes caused by active salt tectonics and gravity slope failures (Hart et al., 2002). However, in comparison to the Pacific Coast, there is little concern of destructive earthquake events in these regions that could cause damages to OWFs.

Coastal Ecosystems

The coastal United States is home to biologically diverse ecosystems that support the life cycles of a large variety of marine organisms. In supporting responsibly sited and operated OSW, Oceana's main goal is the protection of marine organisms and their habitats. Many of the ecosystems discussed in this section have been in decline due to ocean warming caused by human induced climate change. Fortunately, many of these communities are located within Marine Protected Areas. This section will identify the unique coastal environments of the three coastal regions of the contiguous United States.

Atlantic Coast: Ecologically important ecosystems along the Atlantic Coast include rocky coastal zones, estuaries, salt marshes, tidal flats, sandy beaches, barrier islands and seagrass beds (Wilkinson et al., 2009). Estuaries, barrier islands and seagrass beds extend from the shore into the Atlantic Ocean. Therefore, the construction of OSW could impact these communities.

Pacific Coast: Seagrass beds, tidal pools, kelp forests, sandy beaches, rocky intertidal communities, continental platform bottom communities, bays and estuaries are just a few examples of ecologically important ecosystems along the Pacific coast (Wilkinson et al., 2009). Seagrass beds, kelp forests, and estuaries are found in the shallow waters of the Pacific Coast.

Gulf of Mexico: Marine ecosystems of the Gulf of Mexico include mangroves, seagrass communities, coral reefs, coastal lagoons, estuaries, and salt marshes (Wilkinson et al., 2009). Seagrass communities, coral reefs, and estuaries

Estuaries are located along all three contiguous coastal regions of the United States. Estuaries are a unique ecosystem due to the mixing of fresh water from river basins and ocean salt water. Due to this mixing, estuaries are very biologically diverse with both fresh and saltwater organisms having adapted to these transitional waters (Seabrook, 2013). Estuaries also support the local economy of coastal communities. For example, 75% of commercial fishing occurs in estuaries (RAE, 2022). Estuaries are also characterized by other marine ecosystems such as salt marshes and tidal flats (Seabrook 2013).

Barrier Islands naturally occur through the buildup of sediment off coastal regions (Barrineau et al., 2015). In the United States, most Barrier islands occur off the Atlantic Coast. These ecosystems help to lessen the impacts of extreme weather events on coastal communities and coastal nursing habitats (NPS, 2020). They also provide habitat for endangered nesting sea turtles (NOAA, 2021). Unfortunately, barrier islands are disappearing due to human activities such as commercial shipping and dredging products (NOAA, 2021).

Seagrass beds are located along all three coasts of the contiguous United States. These diverse ecosystems provide food, refuge, and nursing habitats to a large variety of marine organisms (Reynolds et al., 2018). Similar to estuaries, these environments are also important for local coastal economies as they are used as commercial fishing grounds (Koch and Orth, 2003).

Kelp Forests are primarily located along the pacific coast of California. Kelp forests are considered one of the most productive ecosystems on earth as they provide habitat, food, and protection for a diverse range of organisms (Pfister et al., 2017). These ecosystems also help decrease wave activity on shoreline communities, reducing erosion (Fisheries N, 2021b). Unfortunately, kelp forests are disappearing due to the quickly declining population of sea otters. As sea otters keep the urchin population stable, the loss of sea otters is causing the growth of urchin populations. With a new trophic cascade, urchins are rapidly eating kelp, destroying kelp forests (MBA, 2022b).

Coral Reefs in recent years have been rapidly decreasing in size and global distribution due to increased pollution and ocean warming (Gil-Agudelo et al., 2020). Coral reefs are ecologically important ecosystems that have a highly diverse and dense distribution of marine species. These ecosystems are typically located in water depths between 30 m to 150 m (Gil-Agudelo et al., 2020). In the Gulf of Mexico, coral reefs are primarily found along the coast of Florida with some communities located off the coast of Texas and Louisiana (EPA, 2022).

Economic Considerations

Offshore Wind Turbine Components and Placement

OWFs can be placed in various locations off the coast of a shoreline. The location of a project site is characterized by the depth of the water and its distance to land. The main component of a wind farm that is affected by the depth is the foundation of the turbine. The foundation of a wind turbine is one of the most important and expensive parts of a wind farm project (Sun et al., 2012). Therefore, it is imperative to select a design that offers the greatest integrity to the structure, is as cost-efficient as possible, while also factoring in mitigation measures to the marine wildlife.

In general, the costs of offshore capacity have increased in recent years, as is the case for land-based turbines, and these increases are only partly reflected in the costs. As a result, the average costs of future offshore farms are expected to be higher. On average, investment costs for a new offshore wind farm are expected to be in the range of 2.0 to 2.2 million €/MW for a near-shore, shallow-water facility.

Offshore wind turbine foundation type and design are considerably affected by sea floor soil properties, water depth, wave heights, and currents (Sun et al., 2012). Most offshore wind projects have been or are being built in shallow waters, depths of 30 meters or less, and therefore require relatively simple monopole or gravity-based foundations with suction buckets (Musial and Ram, 2010). The design is similar to land-based turbines and its footprint on the seabed is minimal, especially the gravity-based foundation. Gravity-based foundations are oftentimes cheaper than monopole structures and overcome the pile-driving issues such as noise and surface area on seafloor related with monopoles but are more sensitive to the soil conditions at the surface (Musial and Ram, 2010). Suction buckets provide a wide base and are driven into the seabed by drawing a vacuum inside to allow the bucket to be seated by hydrostatic pressure. This technology shows promise in the lack of need of using large pile drivers to achieve tower stability. Therefore, gravity-based foundations with suction buckets should be considered as first choice in shallow water foundations as they will cause the least amount of disturbance to the marine ecosystem.

In transitional waters, depths between 30-50 meters, novel technologies have been adapted from the oil and gas industry such as multi-pile foundations and lattice substructures which also extend to the sea floor. At deeper depths with softer soil composition, a wider substructure base is required to reduce overturning forces and to correspond to turbine design requirements for integrity. Designs such as the Tripod Tube Steel, Guyed Tube, and Talisman Energy Concept are being implemented in transitional waters with success (Musial and Ram, 2010). However, these foundations generally have large seafloor footprints and take up large areas which is detrimental to the aquatic environment. Some swift and cost-efficient solutions are to incorporate ‘nature inclusive designs’ such as reef balls and an array of boulders or rocks in areas where habitat has been degraded by wind infrastructure construction (Hermans et al., 2020).

In depths extending beyond 50 meters, or deep waters, fixed seafloor structures are often not economically feasible and floating structures are required. Three idealized concepts have arisen for floating platform designs, including the semisubmersible, the spar buoy, and the tension-leg platform, each of which use a different method for achieving static stability (Musial and Ram, 2010). Presently, floating foundation designs have moved from their concept stage and prototypes to development of fully functional wind farms (Sun et al., 2012). Although not having large fixed foundational structures attached to the seafloor, FOWTs pose a threat to marine wildlife through its design mechanism of mooring tension cables which can lead to primary or secondary entanglement of aquatic species. Tension Monitors and AUVs can help mitigate such issues.

A major component of OWFs is the connectivity of the energy procured in the ocean to the grid on land. Presently, the only method available to connect the turbines to the electricity grid is through the use of underwater cables. A comprehensive analysis of the route of the grid connection is required to minimize impacts to wildlife, particularly if cables connecting turbines to onshore power are to be buried. Burying cables could potentially reduce impacts such as primary or secondary entanglement or Electromagnetic Field (EMF) impacts, but would result in impacts to benthic ecosystems (Maxwell et al., 2022). If cables are not buried and simply run along the floor of the ocean, it could have adverse impacts on mammals that use echolocation. The further the OWF is from the mainland, the further the transmission cables must travel. This obviously results in higher capital costs, greater transmission losses, and increased potential impacts on marine ecosystems.

Levelized Cost of Energy (LCOE)

An LCOE is a measure of the net cost of electricity generation for a specific generator over its lifetime. The existing literature on LCOE for offshore wind projects in the United States largely accounts for capital and operation and maintenance (O&M) expenses associated with constructing the wind turbines without getting into how specific mitigation measures for construction might influence these costs. Additionally, while there are some cost estimation categories that take environmental concerns into account it will be important to consider how the implementation of various mitigation measures could influence the costs incurred by other categories.

Previous and Current Projections

The cost of the development of offshore wind has been the subject of both annual and special reports released by organizations such as NREL and DOE in the United States in recent years. In 2017 NREL performed an assessment of the economic potential of offshore wind between 2015 and 2030. In this assessment NREL determined that the Northeast region of the country would have the greatest economic potential for offshore wind due to projected decreases in LCOE accompanied with relatively high levelized avoided cost of energy (LACE) in some areas. LACE is a measure of value that represents how much it would cost the grid to generate electricity that is displaced by new generation. Therefore when the LACE or value is greater than the LCOE or cost a project is deemed favorable. The states considered to have the highest offshore potential with these projections are Maine, Massachusetts, Rhode Island, Virginia, New Hampshire, New York, and Connecticut (Beiter et al., 2017). The assessment also recognizes that local policies and advancements in technology will be crucial in achieving the projections outlined in the assessment. As for other offshore sites such as the Great Lakes and Pacific regions the assessment recognizes that there will need to be additional technological developments to address environmental factors such as the formation of lake ice and the rapid increase in water depth respectively. In both of these cases the environmental conditions present limit the current accessibility of the wind resources in each region. Therefore, in terms of both resources available and current technological level the Northeast seems to be more ideal for offshore wind. For the LCOE in the lower range the assessment estimates there will be a decline from \$130/MWh in 2015 to \$60/MWh in 2030, in the higher range a decline from \$450/MWh in 2015 to \$190/MWh in 2030 is projected (Beiter et al., 2017). Overall, the factors that lead to a lower LCOE are sites with net capacity factors between 40% and 60%, proximity to onshore grid connection, close inshore assembly area, close to shore-based port facilities, and shallower water depths. Floating wind turbines, which would be needed in the Pacific, tend to have higher LCOEs than fixed bottom turbines, but these values are projected to converge over time. This is due to the maturation of technology involved in constructing floating turbines, which this assessment projects will lead to a significant downward shift in the supply curve by 2027 (Beiter et al., 2017). In this assessment a project is considered economically viable when its LACE exceeds its LCOE. For the Atlantic Northeast this threshold is not reached until 2027 when LCOE has fallen below the relatively high LACE values in the region. In the Pacific, Great Lakes, and Gulf regions this threshold was not projected to be cleared without significant policy intervention.

In 2021 the U.S. Energy Information Administration (EIA) published their annual energy outlook which included estimated LCOEs for projects put into service in 2027. The EIA reports an average LCOE of \$105.38/MWh with an estimated minimum of \$86.34/MWh and an estimated maximum of \$128.93/MWh in regions with available tax credits (--, 2021a). These costs fall within the projections made by the 2017 NREL report in which the lower and upper range LCOE estimates for 2022 were \$95/MWh and \$300/MWh respectively (Beiter et al., 2017). It is worth recognizing that the NREL assessment did not consider policy interventions such as tax credits while the EIA report does take these factors into account. This difference in methodology could be the factor that has resulted in the lower and upper range LCOE estimates in the EIA's report being lower than those projected by the NREL assessment in the same year. However, the EIA also made projections for regions without tax credits where the average LCOE was \$136.51/MWh with an estimated minimum of \$109.88/MWh and an estimated maximum of \$170.31/MWh. In this case the estimated maximum is still significantly below the upper estimate made in the 2017 NREL assessment which could mean that another factor outside of tax credits such as technological development is influencing the cost more than projected. Like onshore wind projects, offshore wind projects are eligible for enrollment in either Production Tax Credit (PTC) or Investment Tax Credit (ITC) incentives (--, 2021a). The EIA assumed in its projections that offshore wind projects would favor ITC incentives due to the higher upfront capital cost associated with the projects. The EIA's annual energy outlook for 2021 seems to show that the projected reduction in LCOE made by NREL's 2017 assessment is proceeding faster than anticipated. This could be the result of the tax credits, but more research will need to be done to determine to what extent tax credits have influenced this outcome as opposed to technological advancements.

For both assessments there was no significant discussion about how the implementation of mitigation measures to protect local wildlife during construction and operation would impact the LCOE of offshore wind projects. For our project we are primarily concerned with implementing protections for the North Atlantic right whale but other species in the region could be greatly affected by increased development of offshore wind in the area. It is likely that the implementation of mitigation measures will drive up the LCOE for offshore wind projects which could increase the time it takes for projects to become economically viable. This assumption is barring intervention from political forces such as tax incentives.

Current Offshore Wind Market

Using the most recent Offshore Wind Market Report published by the U.S. Department of Energy (DOE) a clearer picture of market drivers for offshore wind can be obtained. In 2021, President Biden set a goal for the installation of 30 GW of offshore wind by 2030 (Musial et al., 2021). The DOE expects that the 30 GW goal alongside a 30% ITC will give developers more confidence in the future market and spur the development of the necessary components to sustain long term growth (Musial et al., 2021). To support these goals the Bureau of Ocean Energy Management (BOEM) is aiming to complete the permitting for 16 offshore projects by 2025. The report acknowledges the importance of state level policy in driving the development of offshore wind and notes that in Virginia, Massachusetts, and North Carolina there has been an increase in policies and commitments in 2020. Additionally, in 2021 the Vineyard Wind 1 project became the first fully approved commercial-scale project in the US. The lessons learned from the 3-year review process will streamline the processes needed to rollout new commercial projects in the future. NREL estimates that the US offshore wind energy pipeline has a capacity of 35,324 MW. At the time of the DOE's 2021 report 42 MW of that capacity was in operation and 800 MW of that capacity is accounted for by projects that have been approved. Most of the estimated available capacity for offshore wind is still under a permitting or site control status (Musial et al., 2021).

There is a need for regional monitoring of the environment and wildlife. State level legislation also has a role in monitoring as some states such as New York and New Jersey require offshore developers to support regional monitoring through a contribution of $10,000/MW (Musial et al., 2021). The aim of these measures is to ensure offshore wind projects reduce risk and are environmentally responsible and cost-effective in the long run.

Balance-of-System Model

To understand the specific costs and drivers associated with offshore wind development in the United States the Balance-of-System (BOS) model developed by NREL will be used. In their explanation of the model's purpose NREL breaks up the costs associated with offshore wind into the capital expenditures (CapEx) of the turbine, the BOS costs, and O&M costs over the OSW farm's lifetime. For offshore wind projects the BOS costs which include all costs for installation and commissioning outside of CapEx, O&M, and financial costs make up approximately 70% of the total installed capital costs (ICC). These costs are broken down into six categories and given their influence on the total cost of offshore wind projects it is important to understand their impacts (Maness et al., 2017). It is worth noting that while the BOS model is made for the purpose of helping private and public entities understand the influence it is not detailed enough to be used to make project planning and budget decisions. Additionally, the model is best used on projects that have a nameplate capacity higher than 30 MW due to diminishing confidence in estimated results as nameplate capacity decreases.

Of the six cost estimation categories only the project development category explicitly mentions taking environmental impacts into account. This category accounts for expenditures developing early-stage designs. During this process the developer will conduct studies to determine a variety of factors for the chosen area such as how the environment will be affected should offshore wind be developed at the site (Maness et al., 2017). While this is the only category in the document that mentions environmental impacts, decisions made regarding this category will likely influence the other five to varying degrees. Therefore, a thorough site assessment would be the first step in determining what kind of mitigation measures might be needed during construction and operation. An environmental impact assessment would likely have the largest influence on costs incurred from the substructure and foundation, port and staging, electrical infrastructure, and assembly and installation categories. These categories are directly associated with construction so some mitigation measures that are chosen for an offshore wind project will likely fall under these categories. For example, if a developer chose to or is required to limit the speed of vessels within the site there could be potential changes in port and staging costs since they are associated with costs such as mobilization costs. In addition to these categories mitigation measures will need to be employed during operation and decommissioning as well. This could potentially lead to a need for repeated environmental impact assessments over the lifetime of an offshore wind farm.

The BOS model has over 100 parameters that can be defined by the user, but the inputs most will interact with directly are the primary input parameters (Maness et al., 2017). Similarly, to the six cost categories there is for the most part no mention of how environmental concerns will factor. Many of the primary input parameters such as turbine installation method will have differing costs based on mitigation measures chosen, but a specific parameter dedicated to decisions made regarding environmental impacts is lacking in the primary input parameters. This could prove to be a potential shortcoming in the model and is something that must be considered when it is used for the purpose of considering the impact of mitigation measures of the price of offshore wind projects. More time will need to be spent with NREL's System Advisor Model (SAM) which can be used to model the BOS costs of an offshore wind project to determine just how alterations to these parameters can influence the cost of these projects.

The BOS model is a robust tool that allows for developers in the wind industry and researchers to better understand major costs and cost drivers for offshore wind development. However, despite the model accounting for a variety of input parameters it is concerning that the impact of mitigation measures chosen to deal with potential environmental impacts is not elaborated on. Research into other parameters outside of the primary input parameters will need to be done to determine if there are parameters that better account for environmental costs more specifically.

Cost of NARW Protection

The species that is of primary concern for this project is the NARW. Offshore wind projects can pose a threat to these organisms due to noise and vessel traffic in chosen areas as well as other disturbances during operation and decommissioning. There are a variety of mitigation measures that can be chosen to deal with these issues. When determining which mitigations will be viable both effectiveness and cost must be considered.

Many of the potential mitigation measures that can be used to protect NARW populations did not have explicit prices associated with them. The reports and assessments provided by NREL, DOE, and EIA often did not adequately account for how environmental considerations might impact the cost of developing offshore wind and those provided by NOAA and BOEM focused primarily on how to use the technology we have for mitigation. Despite this some assumptions can be made about how certain mitigation measures might influence cost. Passive acoustic monitoring (PAM) is a technology that could be useful in protecting ocean ecosystems during offshore development. PAM can inform models of species distribution, soundscape, mitigating risk, and monitoring behavioral changes that result from offshore wind activities (Van Parijs et al., 2021). Being able to monitor marine mammals such as the North Atlantic right whale with PAM will allow for more effective employment of mitigation measures such as when to reduce boat speed or halt pile driving during the construction phase of offshore wind projects. Despite being such a potentially useful technology, to achieve this real-time PAM systems must be well planned and be consistent in their methods to be useful (Van Parijs et al., 2021). This will add an additional level of planning onto offshore wind developers and the costs of this planning need to be investigated further. Additionally, other mitigation methods will influence the cost of constructing offshore wind due to their potential to delay or stall construction. Using NREL's SAM model it may be possible to get an idea of just how influential delays and stalling of construction are on the LCOE of offshore wind projects.

Cost of Protection for Other Species

Various ocean species have the potential to be adversely affected by both the construction and operation of offshore wind projects. While it may be possible to mitigate these effects it is important to realize that most if not all species will be affected in their own ways. Because of this it will be the responsibility of developers and governments to determine which species they want to focus on protecting and continue the monitoring of offshore wind projects during their operation phase. The costs incurred by mitigation measures will likely depend on which and how many species developers and governments chose to focus on protecting therefore more work must be done via monitoring to determine how species of concern are affected.

Next Steps for Estimating Cost

Looking at the projections made by both NREL and EIA the cost of offshore wind is steadily declining. However, while the price per MW of building an OSW farm has declined and will likely continue to do so, it seems that the measures that need to be taken to mitigate environmental impacts have not been considered to a large degree. While it is unlikely that mitigation measures will cause offshore wind to become completely unviable from an economic standpoint it will add another dimension of cost considerations that need to be investigated. If NREL's condition of LACE exceeding LCOE for an offshore wind project is the threshold, then it may be reasonable to expect that this threshold will be met later than what was outlined by their assessment if the cost of mitigation influences overall cost to a significant degree. Using the SAM software provided by NREL will be crucial in determining how the LCOE changes when considering the price of certain mitigation measures such as environmental monitoring.

Existing and Model Policy

In this section, we will discuss existing policies that are in place to protect vulnerable marine species like the NARW and how these policies relate to the expansion of offshore wind development in the United States. We will discuss the literature on the effectiveness of mitigation measures required by these policies. We will also investigate the literature on main areas of concern and potential gaps in the existing policy. Lastly, we will make recommendations to fill gaps in policy to protect marine mammals as comprehensively as possible.

Existing Policies: Several existing federal policies in place aim to protect species and their habitat. The ESA is the most well-known of these policies, and the Marine Mammal Protection Act (MMPA) is another. These policies require various steps to recover the species and reduce "take" (Fisheries, 2022a). Another federal policy is the National Environmental Policy Act (NEPA). This policy requires an environmental impact statement (EIS) for any project and a list of alternatives and mitigation measures.

Federal Policies

Endangered Species Act (ESA): Passed in 1973, the ESA is one of the most vital pieces of legislation to protect endangered species (USFW). The goal of the ESA is to protect listed species and their habitat from human-induced activity (USFW). Marine species listed on the ESA are under the jurisdiction of NOAA. As a result, NOAA has created species recovery plans for the endangered marine life that it has jurisdiction over (Fisheries, 2022a). These species recovery plans detail the recovery goals for threatened and endangered species. For the NARW, this includes growing the population enough to reclassify the species from endangered to threatened. In order to achieve this, the species will need to have viable population growth rates that indicate population growth, not be limited by known threats, and that the population has no more than a 1% chance of quasi-extinction (Fisheries, 2021). Recovery plans also include estimated recovery costs, life-history traits, and threats. In addition, the critical habitat needs to be identified for any species listed in the ESA, which NOAA defines as the geographical area occupied by a species at the time of listing that contain physical and biological features essential to conservation of that species and can include areas outside the geographical area if the agency determines that the area is essential for conservation (Fisheries, 2022b). These protections play a critical role in influencing the mitigation activities required for any activity in critical habitat. This is one of the strengths of the ESA's ability to protect endangered species. However, there are some shortcomings in the ESA which will be discussed in more detail later.

Marine Mammal Protection Act (MMPA): The Marine Mammal Protection Act was passed in 1972 and amended twice in the 1990s (Fisheries, 2022a). The MMPA aims to protect marine stocks from declining beyond the point where they cease to be an active part of the ecosystem;

the policy is also one of the first to take an ecosystem-based approach to marine resource management (Fisheries, 2022a). One significant aspect of the MMPA is the defining "take." NOAA, which implements the MMPA, defines "take" as a means to hunt, harass, capture, or kill any marine mammal or attempting to do so (Fisheries, 2022a; McDonald et al., 2016). In addition, the agency is in charge of creating "take" reduction plans, as required by the MMPA. The goals of these plans are in the short term to reduce take within six months of implementation, and a long-term goal is to reduce take within five years and have levels of serious injury mortality approaching a zero mortality and serious injury rate (Fisheries, 2021). Once a draft of the take reduction plan is constructed, teams are formed to carry out the plan's implementation (Fisheries, 2021). We are most interested in the Atlantic Large Whale Take Reduction Plan, which focuses on stocks of large whales, including NARW and other endangered whale species.

While the MMPA aims to reduce and eliminate all forms of take, it does have exceptions to the take restrictions. The exception includes authorized incidental take applied to non-fishing activities, including offshore energy development. Under the ESA and MMPA, permits are required for any activity that might harm a protected species incidentally. The two most significant sources of take in large Cetaceans are vessel strikes and entanglement (Farr et al., 2021; Hausner et al., 2021; Koubrak et al., 2021; Maxwell et al., 2022; Silber et al., 2010). Take reduction plans help mitigate the effect of vessel strikes and entanglements by implementing speed reductions and seasonal moratoriums on commercial fishing (Federal Register, 2021). In addition, these permits help ensure that mitigation measures are implemented to reduce the impact of the activities (Fisheries, 2022c). However some shortcomings of the MMPA are that the take reduction plans do not include any measurable criteria and do not fully address the sublethal effects of noise on marine species (Dolman and Jasny, 2015; McDonald et al., 2016).

National Environmental Policy Act (NEPA): The National Environmental Policy Act was signed into law in 1970 and was one of the first national policies that ensure federal agencies consider the significant environmental consequences of proposed actions (BOEM, 2022). A significant component of NEPA is the Environmental Impact Statement (EIS). An EIS is essential in the permitting process because it allows for public input from citizens, scientists, government agencies, public interest groups, and industry supporters (BOEM, 2022). Another important part of NEPA is an environmental assessment that details the needs and purposes of the project, a list of alternatives and the impacts of the alternatives, and mitigation measures for those alternatives (US EPA, 2013).

Right Whale Coexistence Act of 2022: In February 2022, Senator Cory Booker (D-NJ) and several other Democratic senators introduced the Right Whale Coexistence Act of 2022. The bill aims to assist in the conservation of NARW by providing financial resources for NARW conservation programs and projects (Booker et al.). If passed, the bill would allocate $15 million annually to fund innovative technologies to reduce entanglement and vessel strikes (Booker et al.; Cleland, 2022). The bill would also require monitoring and continuous surveying of plankton and coordinate that information with Canada (Booker et al.).

State Policies

Massachusetts Oceans Act: The state of Massachusetts passed the Oceans Act in 2008 and required an establishment of an Ocean Management plan. In implementing an ocean management plan, the goals are to adhere to sound management practices, value biodiversity and ecosystem health, adapt to evolving knowledge and understanding of the ocean environment, and address climate change and sea-level rise, among other goals (MA, 2008). The plan includes waters and associated submerged lands of the ocean, including the seabed (MA, 2008). The Act also states that the plans will have a diverse interdisciplinary advisory commission composed of lawmakers, local interest groups, scientists, and non-profit interest groups (MA, 2008). The plans are reviewed at least once every five years, with the most recent plan finalized in 2021. The 2021 plan summarizes the core habitat of multiple marine species, including the NARW, and any updates to the habitat size and range (MA, 2021).

Massachusetts Endangered Species Act: The Massachusetts Endangered Species Act (MESA) was passed in 1990 and has similar concepts to the ESA can be found in the MESA. The Act aims to protect rare species and their habitats by prohibiting "take" of any plant or animal listed under the Act (MESA, 2020). There is a similar permitting process under MESA as there is under the ESA and MMPA and requirements and permitting for incidental take (MESA, 2020). The listing comprises three categories similar to those found in the ESA: Endangered, Threatened, and Species of Special Concern, and the criteria for listing are also very similar (MESA, 2020). Any species listed federally that is found in Massachusetts or has habitat in the state is also listed under MESA (MESA, 2020).

Areas of concern

Noise: Regarding offshore wind, noise generated during construction and the operational phase of the turbines is an area of significant concern. Many marine species rely on sound to find food, avoid danger, and communicate (BOEM, 2022). Because of this concern, sound mitigation is an integral part of the permitting process required by NOAA and BOEM through the ESA and MMPA (BOEM, 2022b). The literature on the effects of anthropogenic noise on marine mammals is broad. For this section, we focused on effects on baleen whales, like the NARW, and the mitigation practices currently in place.

Existing literature describes that marine mammals have different tolerances to noise based on their functional hearing group, whether they are high frequency, as is the case with harbor porpoises or low frequency like Humpback and NARW (Gomez et al., 2016). High-frequency cetaceans have a hearing range of about 200Hz-180kHz, while low-frequency cetaceans have a range of 7Hz-30kHz (Gomez et al., 2016b). The impacts of noise on marine mammals depends on the species and context of the sound (Dolman and Jasny, 2015). Anthropogenic noise impacts of construction activities are concerning due to potential habitat displacement and negative behavioral and stress responses from the animals (Van Parijs et al., 2021). There is also a relationship between noise frequency, noise source, and distance (Gomez et al., 2016b). Gomez et al. describes this relationship as zones of injury relative to the distance of the source of the noise. The zones are used to estimate the disturbances that marine mammals can experience at a given distance; Zone 1 (closest to the sound source) is physical disturbances such as hearing loss or damage causing permanent or temporary shifts in hearing sensitivity, Zone 2 indicates behavioral and stress responses (changes in feeding or mating etc), and Zone 3 represents areas beyond those where impacts can be expected (Bailey et al., 2014; Gomez et al., 2016b). Noise levels produced by pile-driving activities can be detected at a distance of 70km from the source, and the mid to low-frequency cetaceans could exhibit behavioral disturbances up to 50km from the disturbance (Bailey et al., 2010).

As part of the EIS mitigation process, BOEM requires that a noise impact assessment be conducted during the pre-construction phase and that continued monitoring of sound take place during construction when it comes to pile driving activities (BOEM, 2022b). The assessments typically involve determining source levels usually estimated from 1 m from sound sources and determining the reduction in sound loss with distance via modeling (Bailey et al., 2010). Passive Acoustic Monitoring (PAM) is another mitigation practice that NOAA and BOEM rely on to ensure that sensitive marine species are not present during pile-driving and other construction activities are taking place (Van Parijs et al., 2021). PAM devices can be on autonomous underwater or surface vehicles, moored to platforms, attached to buoys, or towed behind vessels (Van Parijs et al., 2021). PAM, along with the use of a Protected Species Observer (PSO), can be used to implement a "soft-start" approach to pile driving, a tactic that was used in the UK as a mitigation practice (Verfuss et al., 2016). PAM has the potential to be a valuable mitigation source which we will discuss in the additional recommendation section.

Existing literature on the noise created during offshore wind turbines' operational phase suggests a negligible negative effect on marine species during the operational phase (Farr et al., 2021; Tougaard et al., 2020; Verfuss et al., 2016). It should be noted that most of these studies have been done in and around European OFWs as well as drawing from previous literature from this region as well, the areas around these OFWs have few marine mammals that exhibit low frequency hearing. Verfuss et al. (2016) suggests that more research will need to be conducted to conclude that OFWs with hundreds of turbines have negligible effects on the underwater soundscape on all hearing groups. There is also debate on turbine size and the effects on the operational soundscape of the farm, which should be considered in the planning process (Stöber and Thomsen, 2021).

Vessel Traffic/ Shifting Critical Habitat: Vessel strikes are among the most common sources of large cetacean death, including the NARW (Koubrak et al., 2021; NOAA, 2022). The ESA and MMPA have precise requirements for reducing vessel strikes, mainly involving a reduction in vessel speed in the critical habitat of the NARW and other sensitive species, however these protections are currently only emplented seasonally when the whales are most likely to be in the area (NOAA, 2022; Silber et al., 2010). As it stands now, a vessel larger than 65ft must reduce its speed to 10knots when traveling through critical NARW habitat (NOAA, 2022). Across large cetacean species, including the NARW, these speed reductions can be a good step towards reducing the number of deaths due to vessel strikes (Johnson et al., 2020; Silber et al., 2010). Existing literature suggests that this mitigation practice, along with the use of PAM to observe whales in a given area, has successfully reduced strikes in known habitats (Johnson et al., 2020; Meyer-Gutbrod et al., 2018). However, in 2017 there was an unusual mass mortality event in which 17 NARW were killed in Canada and the US (Koubrak et al., 2021; Meyer-Gutbrod et al., 2018; NOAA, 2022). The mortality event is believed to have been caused by a shift in NARW feeding habitat in response to the effects of climate change (Meyer-Gutbrod et al., 2018). Because of this shift in habitat, the protections allotted under US and Canadian policy did not apply to the region of the St. Lawrence shelf in which 12 of the 17 NARW were found dead (Meyer-Gutbrod et al., 2018). Studies also suggest that NARW presence in the North Atlantic is not as seasonally strict as once thought, although more research is needed to establish long-term patterns (Hodge et al., 2015). NARW have been detected year-round in the North Atlantic region, and during periods it was believed they migrated south for the breeding season (Hodge et al., 2015). With the expansion of offshore wind in the North Atlantic region and the increased vessel traffic that will accompany that activity, there is question on whether existing definitions of critical habitat are sufficient to protect sensitive marine species given the warming of the ocean and the shift in habitat northward (Hausner et al., 2021; Johnson et al., 2020).

Additional Recommendations

Based on the available literature, gaps in the existing policy could be addressed to better protect sensitive marine mammals like the NARW. PAM year-round and archival and real-time recording could go a long way in predicting when marine mammals are in the vicinity of construction activities (Johnson et al., 2020). Using PAM in conjunction with visual methods can effectively track whales over large areas (Johnson et al., 2020). Because of the migratory nature of species like the NARW, PAM can help determine proximity to areas of concern. In addition to using PAM year-round, the existing policies need to reflect shifting habitat regimes. The literature suggests that there needs to be a more dynamic approach to determining critical habitat designation and taking into consideration the effects of climate change (Hausner et al., 2021;

Koubrak et al., 2021). The current policies do not consider the changing migratory patterns of marine mammals, thus leaving gaps in habitat protection they afford species like the NARW. Another recommendation that the literature suggests is incorporating measurable criteria into take reduction plans and having smaller teams with regularly monitored and enforced regulation (McDonald et al., 2016). This can be a harder push depending on the area and budget of the take reduction team. Additionally, there should be more coordination between state and federal groups regarding Marine species and habitat conservation.

Job Potential for the Offshore Wind Industry in the US

Through this literature review, we can infer that the job potential of the offshore wind market would greatly benefit from the implementation of a "Blue New Deal" (Conrad, 2021). The name Blue New Deal is a play on the Green New Deal plan proposed in 2019 by Senator Ed Markey (D-Mass) and Rep. Alexandria Ocasio Cortez. In essence, the Green New Deal calls for the revamping of the American energy market, social programs, and economic development with a particular emphasis on renewables. The Blue New Deal, formally conceptualized by Dr. Ayana Elizabeth Johnson and Senator Elizabeth Warren (D-Mass), calls for the investment in offshore renewable energy, as well as aquaculture research and the sustainability of coastal communities (Beitsch, 2019).

A case study that outlines how the Blue New Deal might be implemented (and how it would impact offshore wind development) is found in the city of Richmond, California (--). In their passing of Resolution 88-21 on July 6, 2021, they became one of the many coastal cities who have committed to a transition away from fossil fuel and towards the "blue economy." In this context, the blue economy refers to the "sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems" (World Bank, 2017).

Similarly, we also see major investment into offshore wind in the Mid-Atlantic and New England regions– who we can infer would also benefit from a Blue New Deal. From the influx of new investments (16 site leases in New England and the Mid-Atlantic for offshore wind energy facilities. Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Rhode Island, and Virginia) The Bureau of Ocean Energy Management (BOEM) established targets to procure a total of 27,812 MW of offshore wind by 2035 (Liang, 2020). Though, it is still debated whether these targets can be reached within this timeline.

Finally, in the assessment of offshore wind development in the US, it is important to consider the Gulf of Mexico as a prime location for a "just transition" away from fossil fuels. In a study conducted by the NREL (National Renewable Energy Laboratory), researchers estimated that the Gulf has the potential to generate nearly 510,000 megawatts of offshore wind energy per year–

which, according to scientists at MIT, is double the energy need of the Gulf states combined and larger capacity than both the Great Lakes and the Pacific coast (Baurick, 2022). By sheer geographic capacity alone, this makes states like Texas and Louisiana viable locations for new OWF. With this, President Biden recently announced a plan to open up more than 700,000 acres in the Gulf of Mexico to offshore wind farms (Joselow, 2022).

However, it is questioned whether this growing investment in offshore wind within the US will significantly aid in the development of the blue economy domestically (Liang, 2020). This doubt is being cast by the concern that offshore wind isn't creating any new jobs since many of the jobs and training in this sector are only supported by tax subsidies (Liang, 2020). Rather than create new jobs, it is argued that offshore wind only contributes to a loss in non-tax-incentivized jobs in other sectors (see tax credit below). This idea of job transferability will be further explored in the next section. Similarly, there is a growing push to bring manufacturing jobs back to the United States in this sector, since much of offshore wind infrastructure manufacturing currently occurs abroad (Liang, 2020).

According to the BOEM "...a winning bidder qualified for the bidding credit and meeting the asking price of \$31.32 million would receive a credit of \$5.22 million toward its winning bid in exchange for a \$4.176 million (80 percent of \$5.22 million) commitment to workforce training or development of the domestic supply chain. The bidding credit would be calculated as follows:

$$\text{Cash Bid} = \left\{\frac{\$31.32 \text{ million}}{1 + 0.20}\right\} = \$26.1 \text{ million}$$

$$\text{Credit} = \$31.32 - \$26.1 = \$5.22 \text{ million}$$

$$\text{Committment} = 0.80 * \ \$5.22 \text{ million} = \$4.176 \text{ million}$$

Workforce Credit, BOEM, 2022

Impacted Workers

Over the last decade, the rise of offshore wind jobs around the world has piqued the interest of economists wondering– what industries will be most impacted? Amidst this question there is concern for impacted workers from the oil and gas industry. However, the literature within this review conveys that it is debatable whether offshore wind is truly putting oil and gas workers out of a job– or if offshore wind is an economic savior to an already dying oil and gas industry.

In 2020, oil prices plummeted to approximately (-) $37.63/barrel (Bagchi et al., 2020). Due to the staggering loss in revenue, many oil and gas companies made the decision to lay off much of their workforce (Bagchi et al., 2020). This process sparked a conversation about what oil and gas workers might transition to given the job insecurity within the sector. A recent survey conducted by the Campaigners Platform, found that over 50% of oil and gas workers in the United Kingdom have expressed interest in joining the offshore wind sector (Richard, 2020). With this, predictions for the global offshore wind market show the industry growing exponentially. According to a publication by Research and Markets, "The global offshore wind energy market reached a value of US$ 9.14 Billion in 2021. Looking forward, the publisher expects the market to reach a value of US$ 24.71 Billion by 2027, exhibiting a CAGR of 18.03% during 2021-2027 (Wood, 2021)."

Oil and gas companies within the United States seem to be on board with this transition. In a recent article from the Washington Post, Maxine Joselow reported on an interview with Mike Moncla, President of the Louisiana Oil and Gas Association, who claimed "We're all for wind energy in the Gulf… Putting in platforms and using crew boats — those things are definitely transferrable [from offshore drilling platforms to offshore wind turbines]." Similarly, Joselow reported on Erik Milito, president of the National Ocean Industries Association, who said in an email, "Steel fabricators, heavy lift vessel operators, marine construction firms, subsea engineers, seismic surveyors, and a host of other jobs and businesses that are integral to Gulf of Mexico oil and gas development are also building out American offshore wind… There is a reason the first U.S.-built offshore wind substation is being constructed in Ingleside, Texas (Joselow, 2022)."

Include offshore oil and gas loss of gas in the Gulf

This seemingly growing transition in jobs from oil and gas to offshore wind has prompted a debate in local, state, and federal policy circles about what support should/could be given to such workers. Propositions such as the Green New Deal or Blue New Deal outline what a transition to renewable energy could look like for blue collar workers who are looking to make the switch. However, these plans still remain unpassed and unimplemented. Thus, in this literature review, it is important for us to consider case studies on how this transition is manifesting in places across the U.S.

With this, a report from the Workforce Development Institute (a New York state non-profit aiding in the renewable energy transition) outlines that "offshore wind development requires 74 distinct occupation types, from white-collar designers, lawyers, and engineers, to myriad professions in the construction and transportation trades (Gould and Cresswell, 2017)." With these job requirements, we can infer that a great portion of the operations and manufacturing workforce can and should come from unionized fossil fuel sectors.

A case study that reveals what this might look like can be found in that of the Block Island Wind Farm in Block Island, Rhode Island. It was here that over 200 trade workers were needed to complete the installation of the farm (Gould and Cresswell, 2017). These included but were not limited to electricians, heavy equipment operators, construction and assembly workers, and divers. Furthermore, the case study outlines that many of these workers came from training programs in renewable energy infrastructure offered at community colleges such as the Wind Tech Maintenance Program at Clinton Community College. With this we can see how the transition from fossil fuel jobs to offshore wind energy can be accomplished.

Cultural Implications

In the academic dialogue around offshore wind, the question remains on how the industry might make the transition away from fossil fuel an equitable one (Garcia, 2021). In considering this, socio-ecological scholars (i.e. Dr. Robert Bullard) points to the importance of remembering that the health and environmental implications of fossil fuel energy production fall disproportionately on BIPOC (Black, Indigenous, People of color) communities who have suffered at the hands of structural environmental racism (Bullard, 1993). With this, it is arguable that historically oppressed communities have the most to gain from offshore wind energy developments, if OSW development is approached with these inequities in mind.

Notably, researchers from the University of Bergen highlight how granting benefits to the hosting communities of offshore wind developments not only increases social acceptance but also creates a sense of procedural justice. To quote the aforementioned research team, "benefits could be in the form of local investments, payments to funds, scholarships, and even allowing communities to have a right of co-ownership of the facility (Herrera Anchustegui, 2020)."

However, it is also important to consider the limitations of such infrastructures. For instance, a case study from Rio Grande do Norte illuminates the concerns of Indigenous communities over procedural and distributive justice missteps regarding wind energy development on their ancestral lands (Frate et al., 2019). This case study is important to consider in this discussion of offshore wind implementation because it highlights the cultural significance of the environment and how public perceptions of energy infrastructures differ.

Site Selection for Offshore Wind Farms

Site selection for offshore wind farms requires the identification and analysis of a large variety of factors that span many fields of expertise. Selecting the optimal site for offshore wind farms is crucial for utilizing the maximum amount of wind potential for energy production, mitigating impacts on marine ecosystems, and minimizing economic costs and burdens of local communities.

Our aim in working with Oceana is analyzing the potential for offshore wind energy development while mitigating the impacts on marine mammals and their habitats with specific focus on the North Atlantic Right Whale. In the review of a variety of international case studies, the impact on marine ecosystems is just one of many criteria used in selecting the optimal potential locations for OSW. Unfortunately, environmental, and marine impacts tend to be less prioritized than technical and economic criteria (Vinhoza and Schaeffer, 2021). As we are prioritizing the protection of marine environments, the focus of this section will be on the environmental criteria. However, to best represent the methodology of OSW site selection, we will also be summarizing the other facets that impact OSW construction, lifecycle, and maintenance. Through the review of 11 case studies, we have organized selection criteria into 4 categories: Technical, Environmental, Economic, and Social & Legal.

Technical Criteria

We are defining technical criteria as criteria that impact the construction, technological and lifecycle specifications of wind turbines. Two of the most important factors in deciding where to build new OFWs exist within this category: water depth and wind velocity. Water depth determines the type of foundation and turbine structure used in offshore wind construction (Schwartz et al., 2010). There are three main types of foundations: monopile, jacket and floating structures. Monopile and jacket foundations are suitable for shallow water depths with monopile foundations used in depths under 30 meters, and jacket foundations typically used for depths between 30 m and 60 m (Vinhoza and Schaeffer, 2021). On the other hand, floating structures are more suitable to deeper waters and are used in water depths greater than 60 m (Vinhoza and Schaeffer, 2021).

Wind turbines require specific wind speeds to produce wind energy continuously and effectively. Wind speed (also known as wind velocity) is a technical limitation as only regions that experience a specific average or range of wind speeds can be considered for construction of OFWs. The literature, across case studies, had a common consensus on water depth conditions for different wind turbine foundations. However, the literature had conflicting and varied ranges for optimal wind speed criteria for wind turbine operation across wind turbine foundations. (Vinhoza and Schaeffer, 2021) & (Gil-García et al., 2022) defined optimal wind speed for OFWs as equal or greater than 7 m/s. (Argin et al., 2019) had a less strict criteria and considered coastal regions with an average wind speed greater than 3 m/s suitable for OFWs. In contrast, (Díaz and Guedes Soares, 2020) considered areas where wind speed was equal to or less than 4 m/s unsuitable for wind turbines. Between the 11 global case studies, defined optimal wind speeds for OSW ranged between 3 m/s to 10 m/s.

Other technical criteria used in the site selection of potential OFWs include, but are not limited to distance to shore, distance to high voltage electricity grids, seafloor topography (also known as bathymetry), distance to active fault lines, ocean currents, wave conditions, and frequency of extreme storm events. Distance to shore, how far a potential offshore wind farm is from the community it is planning to serve, determines the length of underwater transmission cables used in connecting wind turbines to local power grids (Zhou et al., 2022). This is an important factor to consider as increased distance from shore increases the cost and time of OSW and cable installation. It also can result in greater energy transmission loss between wind turbines and local power grids (Spyridonidou and Vagiona, 2020).

Environmental Criteria

In selecting the best potential sites for OSW, it is extremely important that we understand where crucial marine habitats are geographically located in order to lessen the impacts on the endangered species that inhabit them. In this section, we are defining environmental criteria as geographic regions to avoid in site selection of OSW that include ecologically important marine habitats and their defined protection buffers. More specifically, one of the main ways to mitigate potentially harmful effects on marine environments in the construction of OSW is to select sites that avoid habitats of endangered species and threatened ecosystems. Coastal habitats support a diverse range of organisms, and it would be nearly impossible to protect all marine animals and their habitats. To narrow down our focus, our project is focusing on the protection of endangered marine mammals including the North Atlantic Right Whale.

The NARW solely inhabits the Atlantic coastal waters of the United States from Maine to the eastern coast of Florida. To better protect the NARW at all stages of its life from the dangers of OSW construction including harmful drilling noises and potential vessel strikes from increased vessel traffic, some important considerations in site selection are the proximity to migratory paths, breeding sites, and nursing grounds. Most of the OSW site selection papers we read emphasized avoiding and creating a buffer zone around the migratory paths of marine wildlife to lessen the possibility of wildlife interacting with and being harmed by the construction of offshore wind turbines.

To better protect the NARW population from the harmful noise of drilling and potential vessel strikes, we should define the geographic locations of their migratory paths and define a protection buffer around them. However, only two papers specified a distance buffer for marine migration corridors for protection of marine wildlife from OSW construction. (Díaz and Guedes Soares, 2020) suggested defining a 1 km buffer around migration corridors to avoid in site selection. While (Spyridonidou and Vagiona, 2020) chose a larger distance, stating that sites within a 3 km buffer of migratory boundaries are unsuitable for OSW.

Other areas to avoid in the site selection of OSW are marine protected areas (MPAs). Marine protected areas are defined by the IUCN as “a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values" (Dudley et al., 2008). In other words, MPAs are protected areas of coastal habitat that are zoned for the protection of marine ecosystems and wildlife.

Unlike some of the other criteria mentioned above which propose areas that should be avoided, protected habitats are criteria that are prohibited from any built marine infrastructure. MPAs are treated as strict spatial exclusion zones in the site selection process. It is also important to note that several papers suggested defining exclusion buffers around MPAs to further protect these marine environments. A case study of the European Atlantic coastline suggested a 1 km buffer zone around MPAs, while a Greek case study suggested a larger buffer of 3 km around environmentally protected areas (Díaz and Soares, 2020; Spyridonidou and Vagiona, 2020). These buffers are designed to limit and prevent interaction between protected wildlife and the construction of OSW.

According to NOAA, 26% of United States' territorial water can be defined as marine protected areas (--). It is important to note that this figure includes the Great Lakes and waters surrounding Alaska and Hawaii which are not included in this study. The majority of MPAs are in coastal waters, versus the deep ocean, and therefore will conflict with suitable areas for monopile and jacket foundation offshore wind turbines.

Economic Criteria

We will be defining and separating economic criteria into two categories: conflicts with existing economic activities and factors that impact the cost of OSW construction and maintenance. It is important to note that even though Oceana's focus is advocating for responsible offshore wind development while protecting coastal ecosystems, many public and private organizations' first focus in implementing offshore wind is the cost and investments associated with these technologies.

As previously mentioned in the technical criteria section, distance to shore impacts the cost of construction. In addition to increased length of underwater transmission cables, as distance to shore increases, the price of construction and maintenance increases generally (Vinhoza and Schaeffer, 2021). Materials and crew members will need to be taken farther distances increasing fuel costs.

Other distances to be considered in the site selection of OSW are distance to ports and distance to airports. Like distance to shore, these distances impact construction of OSW as materials will need to be transported to coastal communities. As these distances increase, so will cost as materials and workers will need to be transported farther distances.

Another economic consideration is the location of existing marine industry and activities. It is important to define the current locations of preexisting marine infrastructure as not to interfere with already defined economic zones and boundaries. These include the definition and creation of possible buffer zones around existing commercial fishing areas, oil & gas rigs, commercial shipping routes, aquaculture, mineral extraction sites, and existing renewable energy sites.

Suggested distances from these structures vary across OSW site selection case studies. Distance to ports is defined to reduce the construction and maintenance costs as materials will be transported from these sites. A Brazilian case study suggests a 200 to 500 km distance while a Greek case study suggests turbines should be built less than 80 km from ports (Vinhoza and Schaeffer, 2021). Case studies also emphasize a buffer around underwater pipelines and submarine cables. These distances are defined to protect pipelines from damages during OWF construction. A case study focusing on the Gulf Coast defines a 100 m buffer around pipelines while a Turkish case study suggests that construction activities such as anchoring should not occur within 500 m of submarine cables (Argin et al., 2019).

Social & Legal Criteria

Other criteria to consider in site selection of potential offshore wind farms are legal boundaries and concerns from local communities. Legally, all marine infrastructure must be built within the United States' Economic Exclusion Zone (EEZ) (Wissing). NOAA defines the EEZ as "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values"(SOURCE). This area is defined along the entire U.S. coast. All offshore wind farms must be built within the EEZ. Another legal restriction when selecting OSW sites are military and naval zones. These zones, which are actively used by the United States Military, are prohibited from non-military related activity.

Visual and noise impacts from OSW are a concern for residents and visitors of local coastal communities. Distances from coastal communities are suggested across case studies to reduce visual and noise impacts. Distances range from 2 km to 30 km. A Maine case study suggests a 10-mile distance from the coast to minimize visual impacts (Gil-García et al., 2022). While a South Korean case study suggests a much smaller visual and noise buffer of 2 km from shore (Kim et al., 2018).

Methodology

Geographic Information Systems (GIS) allows researchers to define criteria boundaries, find criteria overlap and rank criteria by importance. As discussed above, site selection for offshore wind farms requires analysis of criteria across various fields of study. Also known as a complex problem, site selection for OWFs requires Spatial Multi-Criteria Decision Analysis (SMCDA) which considers the boundaries and ranking for each criterion defined by the user.

Using GIS software such as ArcGIS Pro or QGIS, the 11 site selection case studies reviewed for this section used a combination of 3 different SMCDA methodologies. I will be defining and summarizing each methodology: Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Fuzzy GIS. See references for detailed descriptions of equations and their use.

There are also several software packages that can be used for calculations related to offshore wind. Wind Atlas Analysis and Application Program (WAsP) and WindPRO can be used to calculate wind potential and energy potential based on proposed site location.

Analytical Hierarchy Process: AHP is a hierarchical comparison process that determines the relative importance of each criterion. First, using verbal descriptions, each criterion is described in importance (such as crucial, very important, somewhat important, etc.) (Zhou et al., 2022). These descriptions are placed into a decision matrix where pairwise comparison is performed between criteria (Spyridonidou and Vagiona, 2020). Every pairwise comparison (comparison of one criterion to another) is given a preference ranking value, scored on how one criterion is related in importance to the other. These values are normalized on a scale from 0 to 1 which are used to calculate the weights for each criterion (Chaudhary et al., 2016).

After each criterion is given a weight, SMCDA can be performed in GIS software through a raster calculation tool. For example, in ArcGIS Pro, the raster calculator can be used to multiply all criteria together with each criterion first being multiplied by its defined weight. Also known as a suitability analysis, this calculation produces a suitability raster that ranks pixels (typically 30 meters by 30 meters area on the ground) on how suitable landscapes are for a specific use (such as suitability for offshore wind farms).

Technique for Order Preference by Similarity to Ideal Solution: TOPSIS is a ranking system used in SMCDA to determine the relative importance of each criterion. TOPSIS and AHP are both used to determine criteria weights used in SMCDA calculations. However, TOPSIS utilizes attribute values of criteria to determine weighting while AHP is based on verbal descriptions of importance (Zhou et al., 2022). Attribute values for each criterion are placed into a decision matrix (Jozaghi et al., 2018). For example, the depth (m) attribute for the water depth criteria is defined into categories such as less than 30 m, 30 m to 60m, and greater than 60 m. The completed decision matrix is then standardized. The standardized values are used to calculate weights for each attribute value. The highest value for each criterion is considered the ideal solution (most suitable), while the lowest value is considered the negative ideal solution (least suitable) (Jozaghi et al., 2018).

The TOPSIS score for each criterion is calculated using the criteria’s ideal and negative solution values. Higher TOPSIS scores are ranked higher in importance, receiving a higher criteria weight. While, lower TOPSIS scores are ranked lower in importance, receiving a lower criteria weight (Saeidian et al., 2018). These weights are used in SMCDA calculations such as suitability analysis (discussed above).

Fuzzy GIS: Fuzzy GIS can be used within both AHP and TOPSIS methodologies. It is an alternative method to normalization or standardization of values which is utilized in the weighting process. For example, TOPSIS uses values specifically related to each criterion when defining attribute values used in its decision matrix. Fuzzy GIS uses a "fuzzy" equation that inputs real values, such as specific attribute values, and converts them into a scale from 0 to 1(Gil-García et al., 2022). In comparison, standardization and normalization convert values into varying scales based on defined matrix values. Fuzzy GIS is useful in SMCDA calculations as criteria weights must add up to 1.

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Appendix 2: Bidders Response Package

Section 7 – Environmental Assessment, Permit Acquisition Plan and Environmental Attributes Certification

SECTION 7 OF APPENDIX A TO THE RFP
ENVIRONMENTAL ASSESSMENT, PERMIT ACQUISITION PLAN AND ENVIRONMENTAL ATTRIBUTES CERTIFICATION

This section addresses environmental and other regulatory issues associated with project siting, development and operations for all aspects of the project (including generation, delivery, storage, interconnection, etc.), and in all jurisdictions (federal, all interested states, etc.).

7.1 Provide a list of all the permits, licenses, and environmental assessments and/or environmental impact statements required to construct and operate the project. Along with this list, identify the governmental agencies and States that are responsible for issuing approval of all the permits, licenses, and environmental assessments and/or environmental impact statements. If a bidder has secured any permit or has applied for a permit, please indicate this in the response.

Enter appropriate explanation in this space or reference applicable attachment(s)

7.2 Provide the anticipated timeline for seeking and receiving the required permits, licenses, and environmental assessments and/or environmental impact statements. Include a project approval assessment which describes, in narrative form, each segment of the process, the required permit or approval, the status of the request or application and the basis for projection of success by the milestone date. All requirements should be included on the project schedule in Section 10.

Enter appropriate explanation in this space or reference applicable attachment(s)

7.3 Provide information (a) demonstrating past and current productive relationship with environmental, fishing, tribal, environmental justice, and onshore stakeholders and (b) demonstrating your track record of avoiding, minimizing, and mitigating environmental, fishing, tribal, environmental justice, and onshore impacts from projects similar to the proposed project.

Enter appropriate explanation in this space or reference applicable attachment(s)

7.4 Please provide information on any fisheries mitigation measures designed to avoid, minimize and mitigate impacts on the commercial fishing industry, including but not limited to addressing all criteria specified under Fishing Impacts in Appendix J.

Enter appropriate explanation in this space or reference applicable attachment(s)

7.5 Provide a preliminary environmental characterization of the site and project, including both construction and operation. In addition, the bidder should identify environmental impacts associated with the proposed project and any potential impediments to development. A plan to avoid, minimize, or mitigate such impacts or impediments should also be included. The analysis should address all criteria specified under Environmental Impacts in Appendix J.

Enter appropriate explanation in this space or reference applicable attachment(s)

7.6 Please provide information on potential impacts on Environmental Justice Populations and host communities, including but not limited to addressing all criteria specified under Environmental Justice Impacts in Appendix J.

Enter appropriate explanation in this space or reference applicable attachment(s)

Please propose a strategy plan to track and report on the status of environmental justice impacts, and engagement and employment (training, recruitment and hiring goals) opportunities. Strategy plans may include a commitment with a government entity to share said tracking and reporting. If such a commitment is not presented, DOER will work with selected bidder after selection but before contract execution to implement an agreed-upon tracking and reporting strategy.

Enter appropriate explanation in this space or reference applicable attachment(s)

7.7 Provide documentation identifying the level of public support for the project including letters from public officials, newspaper articles, etc. Include information on specific localized support and/or opposition to the project of which the bidder is aware. Provide copies of any agreements with communities and other constituencies impacted by the project. Provide a stakeholder map and a plan for community engagement activities and targeted stakeholder outreach.

Enter appropriate explanation in this space or reference applicable attachment(s)

7.8 Provide documentation demonstrating that the project will be qualified as New Class I Renewable Portfolio Standard Eligible Resource under M.G.L. c. 25A, § 11F, and 225 CMR 14.00.

Enter appropriate explanation in this space or reference applicable attachment(s)

7.9 All bidders must include sufficient information and documentation that demonstrates that the bidder will utilize an appropriate tracking system to ensure a unit-specific accounting of the delivery of Offshore Wind Energy Generation, to enable the Department of Environmental Protection, in consultation with DOER, to accurately measure progress in achieving the commonwealth's goals under chapter 298 of the acts of 2008 or Chapter 21N of the General Laws. The RECs associated with Offshore Wind Energy Generation must be delivered into the Distribution Companies' NEPOOL GIS accounts.

Enter appropriate explanation in this space or reference applicable attachment(s)

7.10 Identify any existing, preliminary or pending claims or litigation, or matters before any federal agency or any state legislature or regulatory agency that might affect the feasibility or timing of the project or the ability or timing to obtain or retain the required permits for the project.

Enter appropriate explanation in this space or reference applicable attachment(s)

Section 8 – Engineering and Technology; Commercial Access to Equipment

SECTION 8 OF APPENDIX A TO THE RFP
ENGINEERING AND TECHNOLOGY; COMMERCIAL ACCESS TO EQUIPMENT

This section includes questions pertinent to the engineering design and project technology. This section must be completed for all aspects of a project including generation, storage (as applicable) delivery, and interconnection facilities. Bidders should provide information about the specific technology or equipment including the track record of the technology and equipment and other information as necessary to demonstrate that the technology is viable.

8.1 Provide a reasonable but preliminary engineering plan which includes the following information:

- i. Type of generation and delivery technology
- ii. Major equipment to be used (including nacelle, hub, blade, tower, foundation, delivery facilities structures and platforms, electrical equipment and cable), including the primary and alternative turbine equipment and their expected capacity rating.
- iii. Manufacturer of each of the equipment components listed above as well as the location of where each component will be manufactured.
- iv. Status of acquisition of the equipment components, including whether orders are in place and/ or production slots secured
- v. Whether the bidder has a contract for the equipment. If not, describe the bidder's plan for securing equipment and the status of any pertinent commercial arrangements
- vi. Equipment vendors selected/considered
- vii. Track record of equipment operations
- viii. If the equipment manufacturer has not yet been selected, identify in the equipment procurement strategy the factors under consideration for selecting the preferred equipment

Enter appropriate explanation in this space or reference applicable attachment(s)

8.2 If the bidder has not yet selected the major equipment for a project, please provide a list of the key equipment suppliers under consideration.

Enter appropriate explanation in this space or reference applicable attachment(s)

8.3 Please identify the same or similar equipment by the same manufacturer that are presently in commercial operation including the number installed, installed capacity and estimated generation for the past three years.

Enter appropriate explanation in this space or reference applicable attachment(s)

8.4 For less mature technologies or equipment, provide evidence (including identifying specific applications) that the technology or equipment to be employed for energy production is ready for transfer to the design and construction phases. Also, address how the status of the technology or equipment is being considered in the financial and permitting plans for the project. Provide the status of testing/ qualification for any equipment in development.

Enter appropriate explanation in this space or reference applicable attachment(s)

8.5 Please indicate if the bidder has a full and complete list of equipment needed for all physical aspects of the bid, including generation facilities, turbine support structures, electrical platforms, delivery facilities, and mandatory and voluntary transmission system upgrades. If not, identify the areas of uncertainty and when the full and complete list of equipment will be identified.

Enter appropriate explanation in this space or reference applicable attachment(s)

8.6 Please indicate if the bidder has secured its equipment for all physical aspects of the bid, including generation facilities, delivery facilities, and mandatory and voluntary transmission system upgrades. If not, identify the long-lead equipment and describe the timing for securing this equipment.

Enter appropriate explanation in this space or reference applicable attachment(s)

Section 13 – Demonstrated, Verifiable Commitment to Create and Foster Employment and Economic Development and Other Direct Benefits

SECTION 13 OF APPENDIX A TO THE RFP
DEMONSTRATED, VERIFIABLE COMMITMENT TO CREATE AND FOSTER EMPLOYMENT AND ECONOMIC DEVELOPMENT AND OTHER DIRECT BENEFITS

13.1 Please provide an estimate of the number of jobs to be created directly during project development and construction, and during operations, and a general description of the types of jobs created, duration of employment, estimated annual compensation, the employer(s) for such jobs, and the location. Employment impacts should be broken out by state and the region as a whole and highlight any impacts in economically distressed areas. Please treat the development, construction, and operation and maintenance periods separately in your response. All information provided must be measurable.

Enter appropriate explanation in this space or reference applicable attachment(s)

Please describe the status of any contractual commitments with respect to direct job creation and provide any pertinent agreements that have been executed.

Enter appropriate explanation in this space or reference applicable attachment(s)

13.2 Please provide a diversity, equity and inclusion plan that that includes a Workforce Diversity Plan and the Supplier Diversity Program Plan as outlined in Section 2.3.2.i of the RFP. Describe consultation with the Massachusetts Supplier Diversity Office, as applicable.

Enter appropriate explanation in this space or reference applicable attachment(s)

13.3 Please describe and quantify any other economic activity or development expected to result directly from the proposed project. Impacts should be broken out by state and the region as a whole and highlight any impacts in economically distressed areas. Direct economic activity/development will be evaluated based on scale relative to project size, credibility and firmness. Commitments that secure long-term benefits are preferred. Commitments will be evaluated by the degree or extent to which the asserted benefits are contractually committed to by the bidder. Specific commitments to economic activity or development may include (but are not limited to):

- Investment in supply chain improvements to support the offshore wind industry.
- Investment in workforce development to support the offshore wind industry, which may include partnerships with vocational and technical schools, community colleges, labor groups, and community-based organizations to create paid training, internship, apprenticeship programs. These investments could include public-facing educational outreach programs to engage youth, high schools, and residents about offshore wind, clean energy, and climate topics.
- Utilization and investment in port facilities and infrastructure during project development, construction, and operation and maintenance of the project.
- Investment in offshore wind-related research and innovation initiatives or partnerships
- Support for ongoing science and data collection to improve environmental, wildlife, and fisheries performance of offshore wind, including commitments to data sharing.
- Economic development activities and investments that directly benefit economically distressed areas, environmental justice communities, and/or low-income populations.

13.4 Please describe the status of any contractual commitments with respect to economic development and provide any pertinent agreements that have been executed. Please indicate how any economic benefits with specific commitments that are not already subject to contractual agreements will be covered by such agreements prior to executing Long Term Contracts under this solicitation (see RFP Sec. 2.2.2.8.) and your plan and timetable to negotiate and execute such agreements.

Enter appropriate explanation in this space or reference applicable attachment(s)

Please specify the administrator of any funds (i.e. fund administered by a third-party or by the Bidder).

Enter appropriate explanation in this space or reference applicable attachment(s)

Please propose a strategy to track and report on any applicable commitments, including progress in achieving promised economic benefits and the goals in the diversity, equity and inclusion plan. Such a strategy may include a commitment with a government entity to share said tracking and reporting. If such a commitment is not presented, DOER will work with selected bidder after selection but before contract execution to implement an agreed-upon tracking and reporting strategy.

Enter appropriate explanation in this space or reference applicable attachment(s)

13.5 Please describe any tracking or reporting mechanisms, such as an annual report(s) of milestones achieved and jobs created to verify the contributions to employment and economic development identified in 13.1, 13.2.

Enter appropriate explanation in this space or reference applicable attachment(s)

13.6 To the extent not already specified elsewhere in your response, please address the factors listed in RFP Section 2.3.2.i and describe any benefits or impacts associated with the proposed project.

Enter appropriate explanation in this space or reference applicable attachment(s)

13.7 Please demonstrate any benefits to low-income ratepayers in the Commonwealth, including, but not limited to: projects that reduce the energy burden for low-income ratepayers through energy efficiency or renewable energy upgrades; direct funding of rate relief through grant programs, support of existing community programs or other funding opportunities. Describe the impact, if any, those benefits will have on the cost to the project. Please provide any agreements to effectuate those benefits.

Enter appropriate explanation in this space or reference applicable attachment(s)

13.8 The Section 13 Addendum: Economic Development Summary Sheet is a Microsoft Excel workbook provided on MACleanEnergy.com. Please fill out and submit the Section 13 Addendum to accompany responses in this section.

Attachments:

Copy of completed Section 13 Addendum in Excel format (.xls or .xlsx file): ☐

Appendix 3: Massachusetts's RFP – Environmental and Socioeconomic Impact Criteria

Appendix J
Environmental and Socioeconomic Impact Criteria

This Appendix J provides additional details on the Environmental and Socioeconomic Impact criteria to be considered in the Qualitative Evaluation (RFP section 2.3.2).

- **Stakeholder and Mitigation Experience**: Demonstrated past and current productive relationship with environmental, fishing, tribal, environmental justice, and onshore stakeholders and track record of avoiding, minimizing, and mitigating environmental, fishing, tribal, environmental justice, and onshore impacts from projects similar to the proposed project.
- **Environmental Impacts:** Extent to which a project demonstrates that it avoids, minimizes, or mitigates, to the maximum extent practicable, environmental impacts. Factors to be considered may include:
  - Preliminary characterization of the potential environmental impacts (onshore and offshore) from the wind farm array, transmission cabling, substations and other infrastructure from pre-construction through the duration of the project, including but not limited to:
    - Impacts on species protected under the Endangered Species Act, including the North Atlantic Right Whale.
    - Description of how sensitive habitat areas (e.g. areas with long-lived and easily damaged epifauna, spawning areas, and areas where demersal eggs are deposited) have been or will be identified.
    - Description of environmental baseline and monitoring data that will be collected beginning from pre-construction through the duration of the project and plans for the use of that data in project development.
    - Expected environmental impacts to onshore coastal beaches and ecosystems from port infrastructure construction and operation.
  - A preliminary plan that highlights the approach to avoid, minimize, or mitigate environmental impacts (onshore and offshore) from the wind farm array, transmission cabling, substations and other infrastructure from pre-construction through the duration of the project based on best management practices, including but not limited to:
    - Description of operational protocol to avoid, minimize, and mitigate impacts to fish, invertebrates, marine mammals, birds and bats, including mitigation of sound exposure on marine mammals like the North Atlantic Right Whale.
    - Impact of planned cable burial depth, use of protective materials, and monitoring of cables to avoid, minimize, and mitigate continuous impacts on marine species.
    - Use of co-location or siting with compatible existing infrastructure.
    - Minimizing the number of transmission cables used, reducing the area of seafloor or shoreline disturbance, and/or reducing the number of cable landfalls.

        - Plan to avoid, minimize, or mitigate impacts on the National Marine Fisheries Service (NMFS) surveys.
        - Description of any cooperation and efforts with other developers or regional entities to avoid and minimize potential cumulative impacts across the MA/RI Wind Energy Areas.
    - Plan for compliance and consistency with the Massachusetts Ocean Management Plan and other state and regional ocean management plans.
    - Plan for compliance with Massachusetts Coastal Zone Management federal consistency review process, including any plans for voluntary federal consistency filing.
    - Plan for timely data sharing with relevant environmental and fisheries stakeholders and ongoing, transparent communication with stakeholders regarding data availability.
    - Description of participation in and any commitments (time, staff, and/or financial) to existing and ongoing regional regulatory, research, and science organizations regarding environmental assessment, monitoring, and mitigation, including but not limited to direct funding to the Responsible Offshore Science Alliance and the Regional Wildlife Science Entity.
    - Extent to which the project avoids, minimizes, and mitigates potential impacts of the project to cultural and tribal resources and viewsheds from the Massachusetts shoreline, including through thoughtful siting and engagement with local stakeholders.
    - Any additional information that may demonstrate mitigation of environmental impacts.
- **Environmental Justice Impacts:** Descriptions of any potential impacts, both positive and negative, including assessments of cumulative environmental impacts, on Environmental Justice Populations[1] and host communities.
    - Demonstrated plans or investments to avoid, minimize, and mitigate environmental burdens and other negative impacts from the project on affected groups and Environmental Justice populations.
    - Plans to engage with affected communities through targeted outreach and education events, including identified partnerships with existing Environmental Justice organizations.
    - Strategy plan to track and report on the status of environmental justice impacts, engagement and employment (training, recruitment and hiring goals) opportunities. Strategy plans may include a commitment with a government entity to share said tracking and reporting. If such a commitment is not presented, DOER will work with selected bidder after selection but before contract execution to implement an agreed-upon tracking and reporting strategy.
- **Fishing Impacts:** Extent to which the project avoids, minimizes, and mitigates impacts on commercial and recreational fishing industry. Factors to be considered may include but are not limited to:

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[1] Defined and outlined in the EEA 2017 Environmental Justice Policy, see: https://www.mass.gov/files/documents/2017/11/29/2017-environmental-justice-policy_0.pdf

Appendix 4: Site Suitability Continued – Reclassification & Data Analysis

Appendix 4: Site Suitability Continued – Reclassification & Data Analysis

For each criteria used in the suitability analysis, a reclassification layer, ranked on a suitability scale from 1 (least suitable) to 5 (most suitable) was created. The following appendix section details the steps in creating each reclassification layer. Maps of raw data, distance layers, density layers and reclassification layers are included. In addition, a reclassification table detailing the values identified as least to most suitable for each criteria are defined.

Initial Suitability Analysis

Distance to NARW Habitat

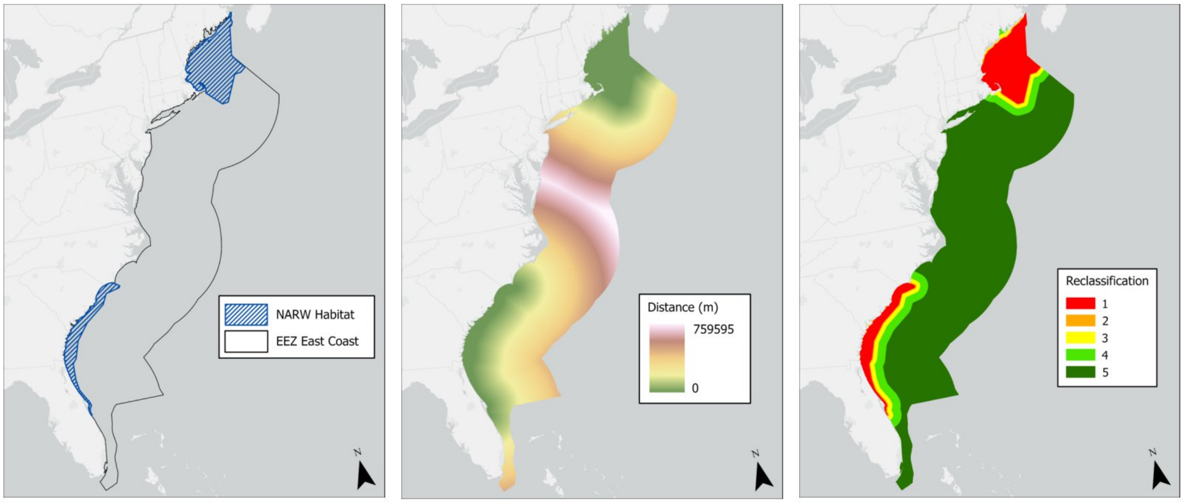


Fig. 1 Three maps (from left to right) showing the process of reclassification for the Distance to NARW Habitat on the eastern coast of the United States: Raw Data (NMFS, 2023), Distance (in meters) to NARW Habitat layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m)	Reclassified Value
0 - 1500	1
1000 - 8000	2
8000 - 32000	3
32000 - 80000	4
80000 +	5

Fig. 2 Reclassification table for Reclassification of Distance to NARW Habitat layer with areas of the eastern coast furthest (in meters) from NARW Habitat ranked as most suitable for OSW

Average Wind Speed

As each coastal region differs slightly in average wind speed range and frequency, each coastal region was reclassified using a unique reclassification table. Most suitable average wind speeds for OSW energy generation are defined in this report as average speeds between 7 m/s to 9 m/s, so each coastal region's most suitable reclassification values are within this range.

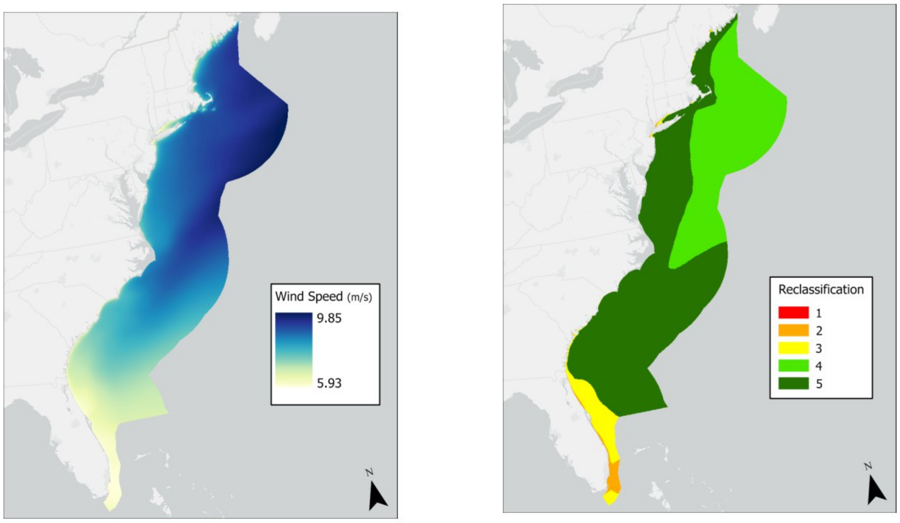


Fig. 3 Two maps (from left to right) showing the process of reclassification for the Average Wind Speed on the eastern coast of the United States: Average Wind Speed layer clipped and resampled to 500 m cell

size (Draxl et al., 2015) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m/s)	**Reclassification Value**
5.93 - 6	1
6 - 6.5	2
6.5 - 7	3
9 - 9.85	4
7 - 9	5

Fig. 4 Reclassification table for Reclassification of Average Wind Speed layer for the east coast. Areas of the eastern coast with an average wind speed from 7 m/s to 9 m/s are ranked as most suitable for OSW

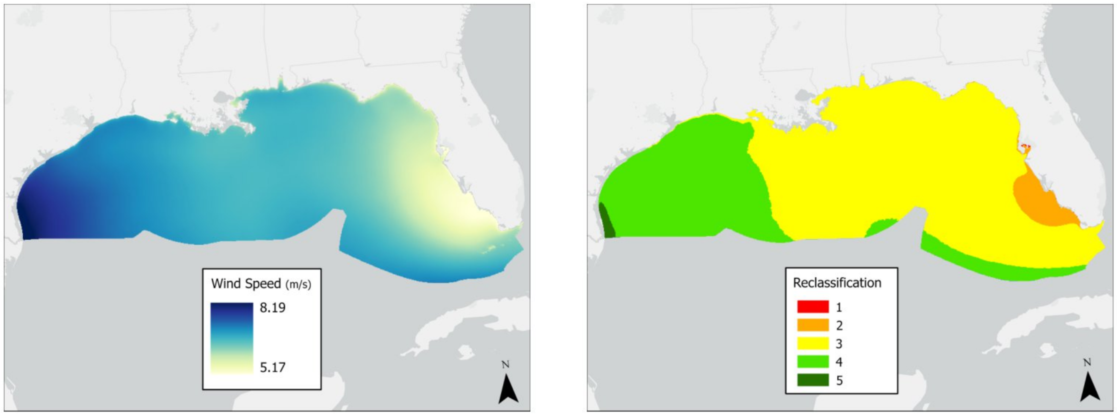


Fig. 5 Two maps (from left to right) showing the process of reclassification for the Average Wind Speed on the gulf coast of the United States: Average Wind Speed layer clipped and resampled to 500 m cell size (Draxl et al., 2015) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m/s)	**Reclassified Value**
5.16 - 5.5	1
5.5 - 6	2
6 - 7	3
7 - 8	4
8 +	5

Fig. 6 Reclassification table for Reclassification of Average Wind Speed layer for the gulf coast. Areas of the gulf coast with an average wind speed higher than 8 m/s are ranked as most suitable for OSW

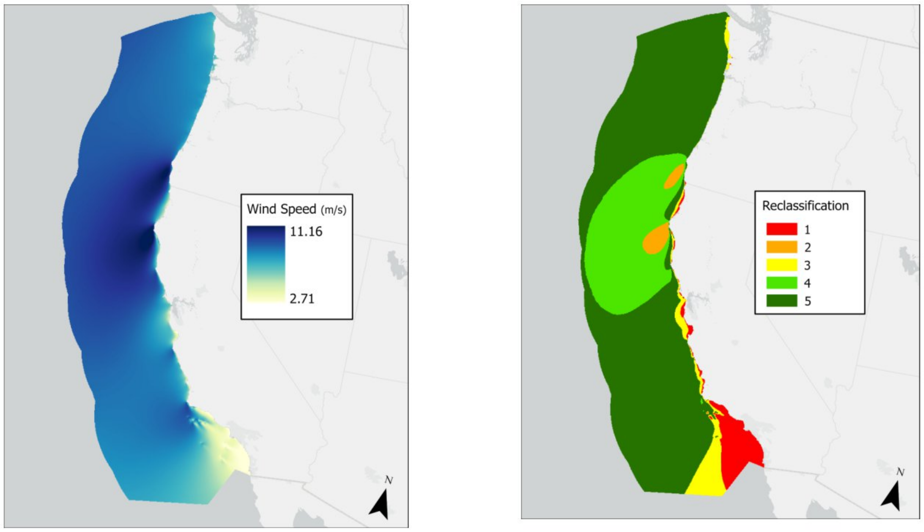


Fig. 7 Two maps (from left to right) showing the process of reclassification for the Average Wind Speed on the west coast of the United States: Average Wind Speed layer clipped and resampled to 500 m cell size (Draxl et al., 2015) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m/s)	Reclassified Value
2.71 - 5.5	1
10 - 11.16	2
5.5 - 7	3
9 - 10	4
7 -9	5

Fig. 8 Reclassification table for Reclassification of Average Wind Speed layer for the west coast. Areas of the west coast with an average wind speed between 7 m/s to 9 m/s are ranked as most suitable for OSW

Distance to Major Ports

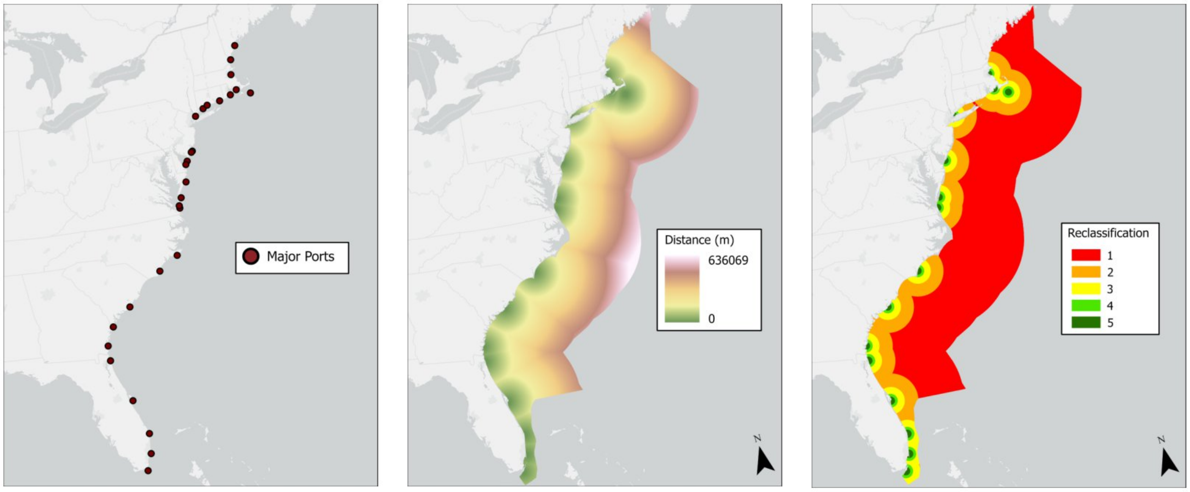


Fig. 9 Three maps (from left to right) showing the process of reclassification for the Distance to Major Ports on the eastern coast of the United States: Raw Data (LCC, 2012), Distance (in meters) to each Major Port layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

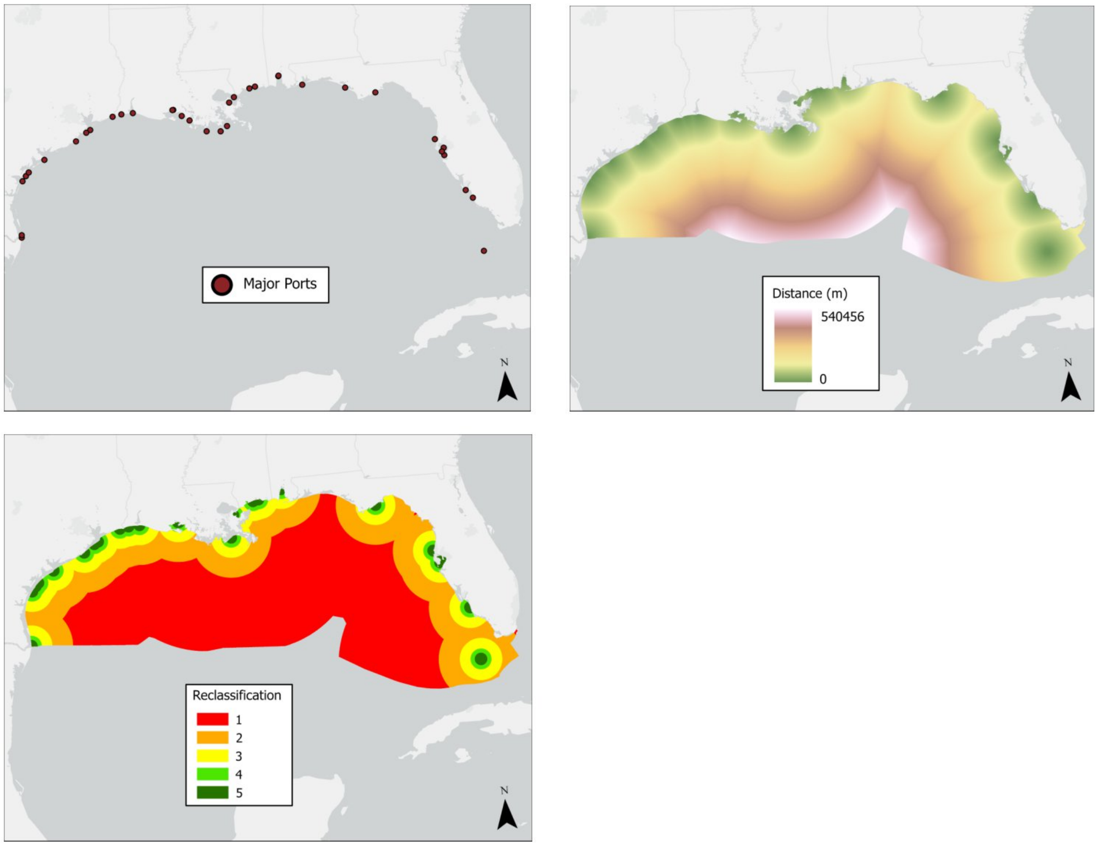


Fig. 10 Three maps (from left to right) showing the process of reclassification for the Distance to Major Ports on the gulf coast of the United States: Raw Data (LCC, 2012), Distance (in meters) to each Major Port layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

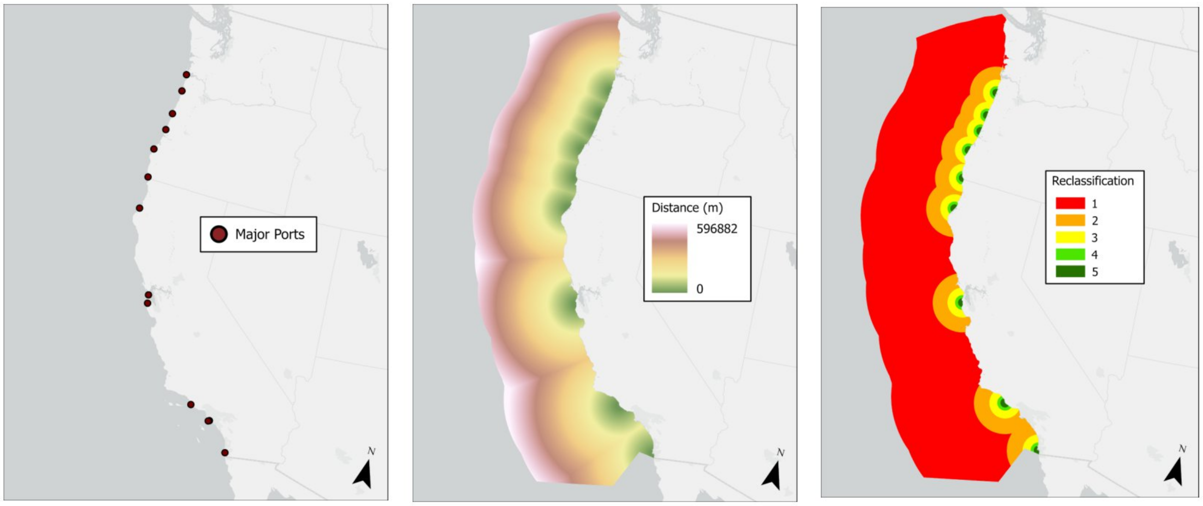


Fig. 11 Three maps (from left to right) showing the process of reclassification for the Distance to Major Ports on the western coast of the United States: Raw Data (LCC, 2012), Distance (in meters) to each Major Port layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m)	**Reclassified Value**
160000 +	1
80000 - 160000	2
40000 - 80000	3
24000 - 40000	4
0 - 24000	5

Fig. 12 Reclassification table for Reclassification of Distance to Major Ports. Areas of the each coastal region (east coast, gulf coast and west coast) in close distance, less than 24000 m (15 miles) from a major port are ranked as most suitable for OSW

Water Depth

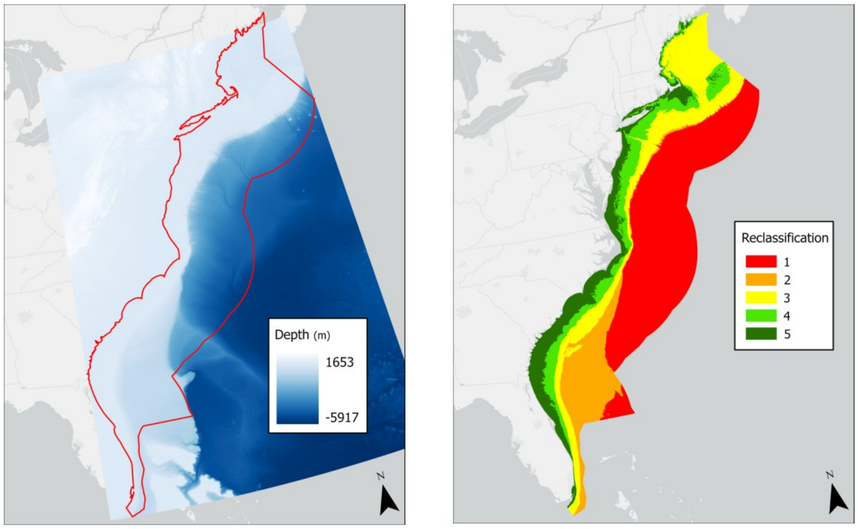


Fig. 13 Two maps (from left to right) showing the process of reclassification for Water Depth on the east coast of the United States: Water Depth layer clipped and resampled to 500 m cell size (NOAA NCEI, 2022) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

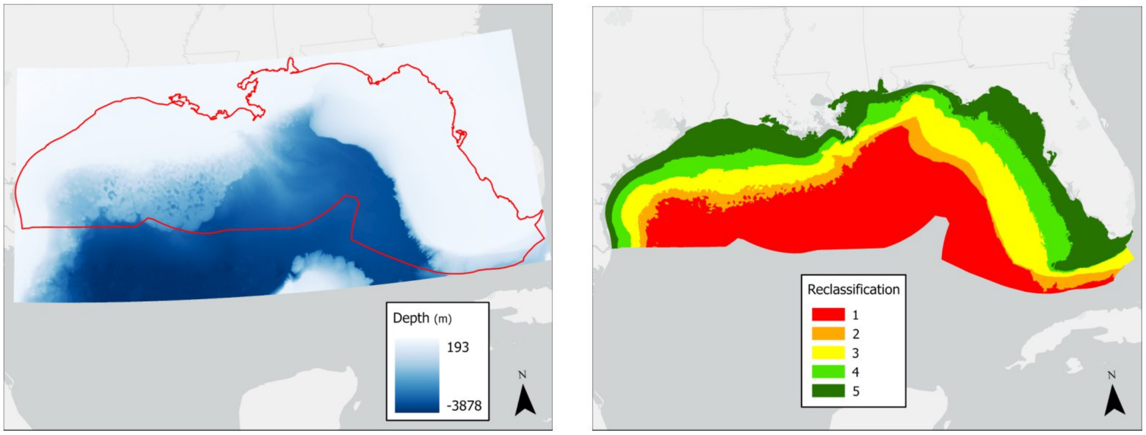


Fig. 14 Two maps (from left to right) showing the process of reclassification for Water Depth on the gulf coast of the United States: Water Depth layer clipped and resampled to 500 m cell size (NOAA NCEI,

2022) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

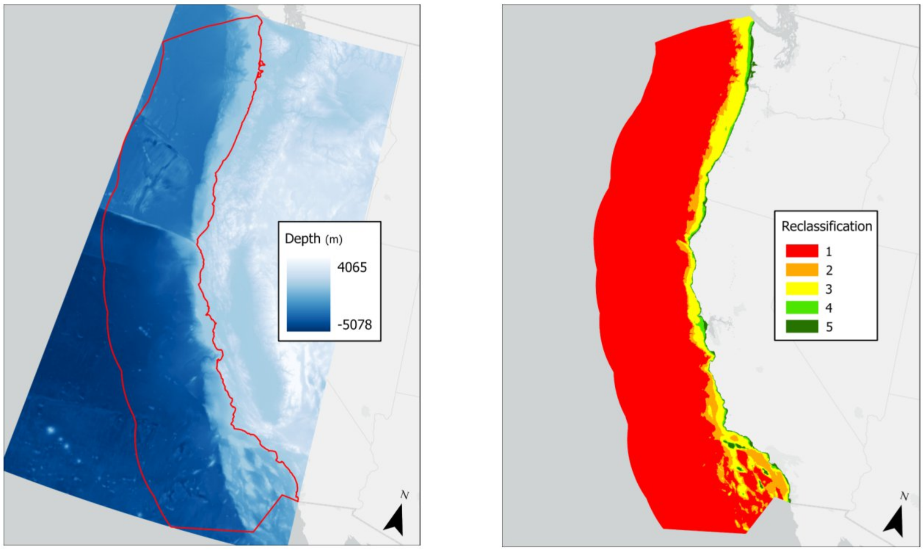


Fig. 15 Two maps (from left to right) showing the process of reclassification for Water Depth on the west coast of the United States: Water Depth layer clipped and resampled to 500 m cell size (NOAA NCEI, 2022) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m)	**Reclassified Value**
-1000 +	1
-1000 - -500	2
-500 - -60	3
-60 - -30	4
-30 - 0	5

Fig. 16 Reclassification table for Reclassification of Water Depth. Areas of the each coastal region (east coast, gulf coast and west coast) with a depth less than 30 meters (shallow waters suitable for monopile foundations used in the construction of wind turbines) are ranked as most suitable for OSW

Distance to Rice's Whale Habitat

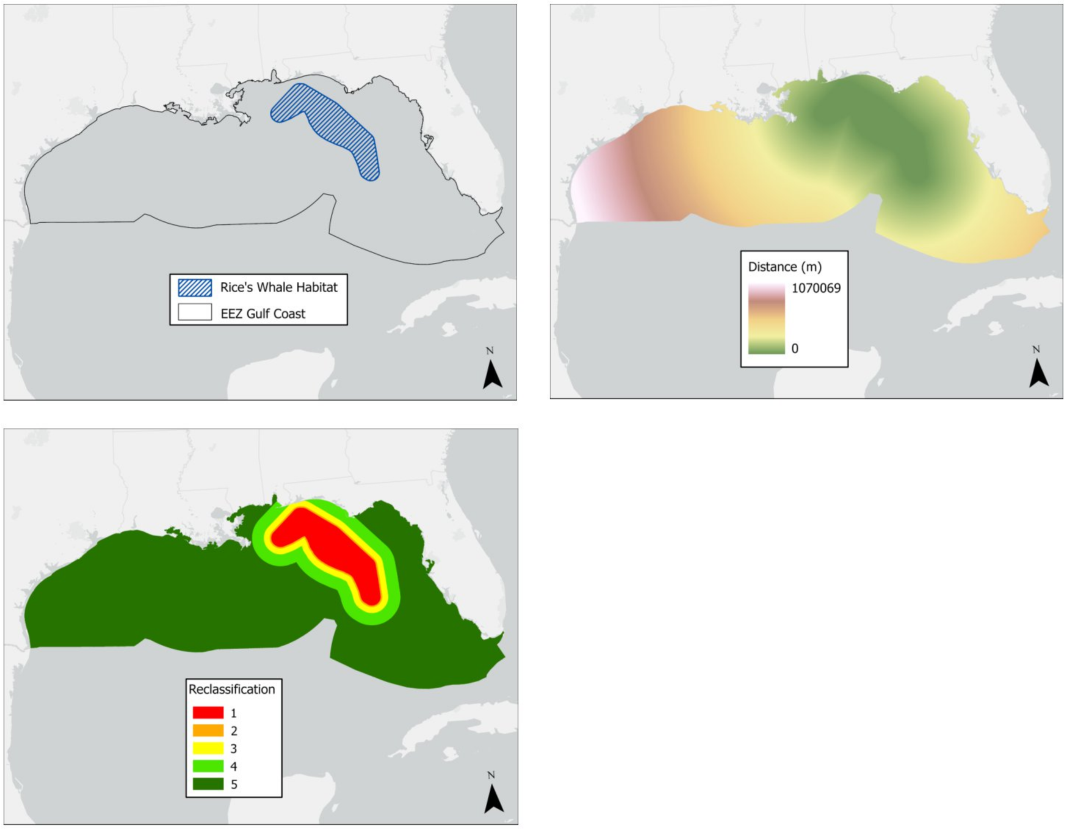


Fig. 17 Three maps (from left to right) showing the process of reclassification for the Distance to Rice's Whale Habitat on the gulf coast of the United States: Raw Data (Garrison, 2019), Distance (in meters) to Rice's Whale Habitat layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m)	Reclassified Value (m)
0 - 1500	1
1500 - 8000	2
8000 - 32000	3
32000 - 80000	4
80000 +	5

Fig. 18 Reclassification table for Reclassification of Distance to Rice's Whale Habitat. Areas of the gulf coast with furthest from Rice's Whale Habitat, greater than 80000 m from Rice's Whale Habitat, are ranked as most suitable for OSW

Distance to MPAs

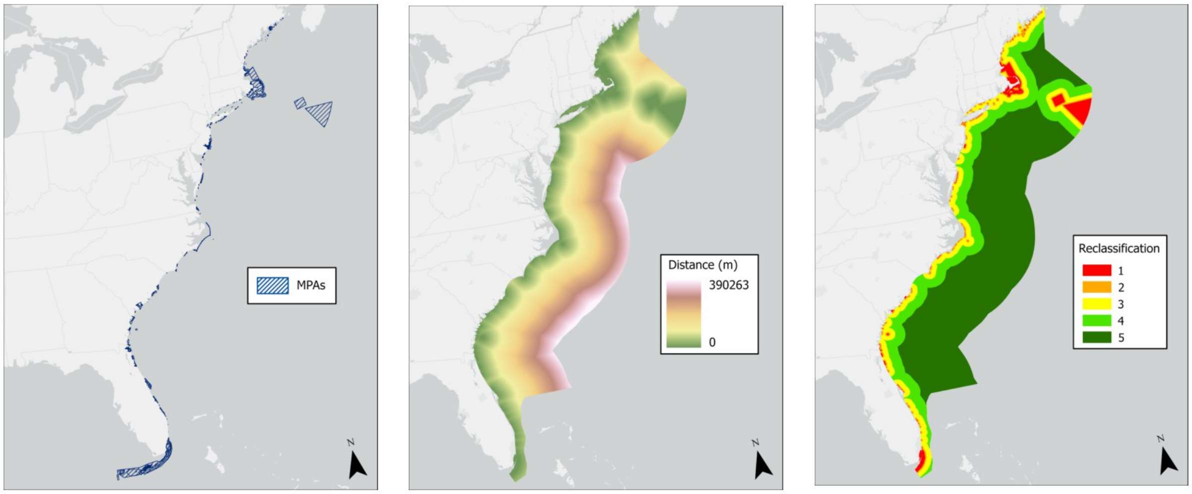


Fig. 19 Three maps (from left to right) showing the process of reclassification for Distance to MPAs for the east coast of the United States: Raw Data from (NOAA MPAC, 2020), Distance (in meters) to each MPA layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

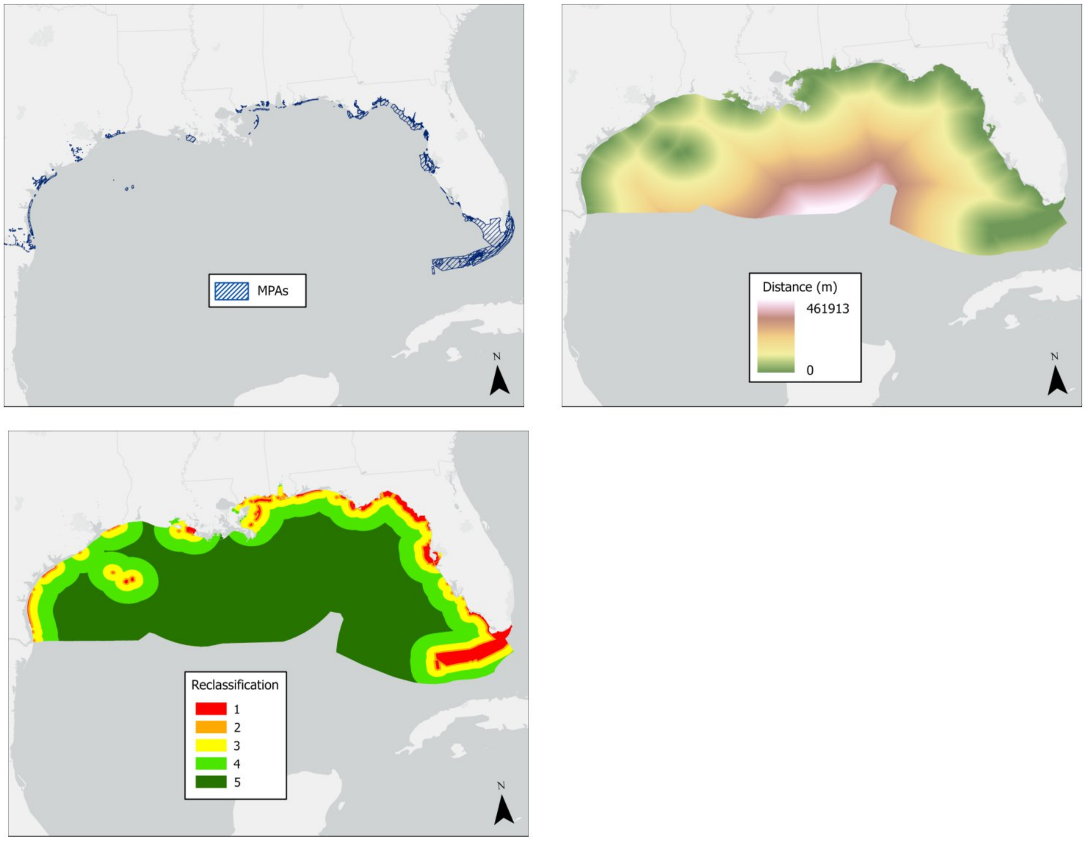


Fig. 20 Three maps (from left to right) showing the process of reclassification for Distance to MPAs for the gulf coast of the United States: Raw Data (NOAA MPAC, 2020), Distance (in meters) to each MPA layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

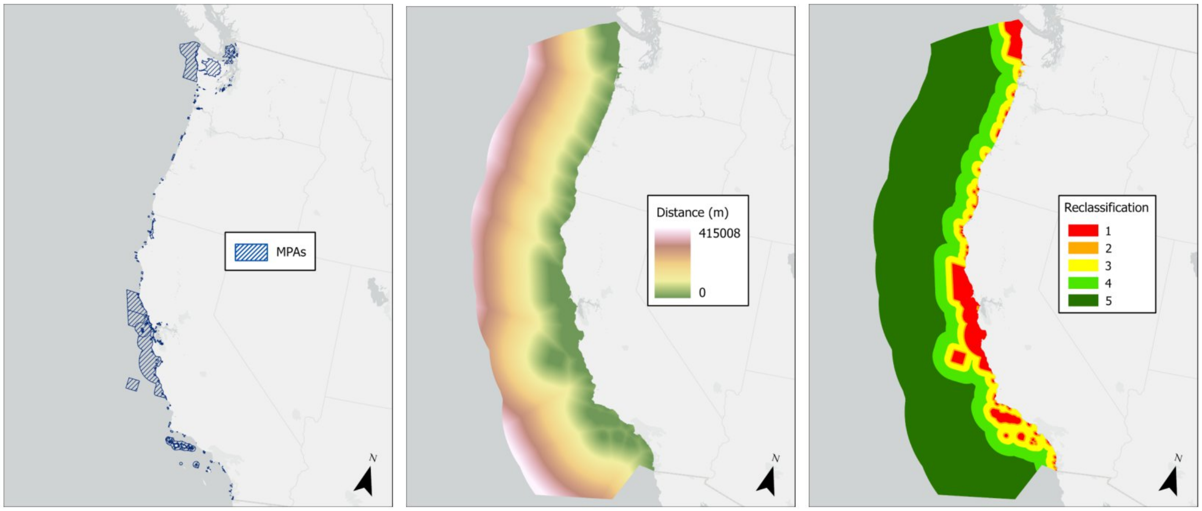


Fig. 21 Three maps (from left to right) showing the process of reclassification for Distance to MPAs for the west coast of the United States: Raw Data (NOAA MPAC, 2020), Distance (in meters) to each MPA layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m)	**Reclassified Value**
0 - 1500	1
1500 - 8000	2
8000 - 32000	3
32000 - 80000	4
80000 +	5

Fig. 22 Reclassification table for Reclassification of Distance to MPAs. Areas of each coastal region (east coast, gulf coast and west coast) furthest from MPAs, greater than 80000 m from any MPA, are ranked as most suitable for OSW

Distance to Substations

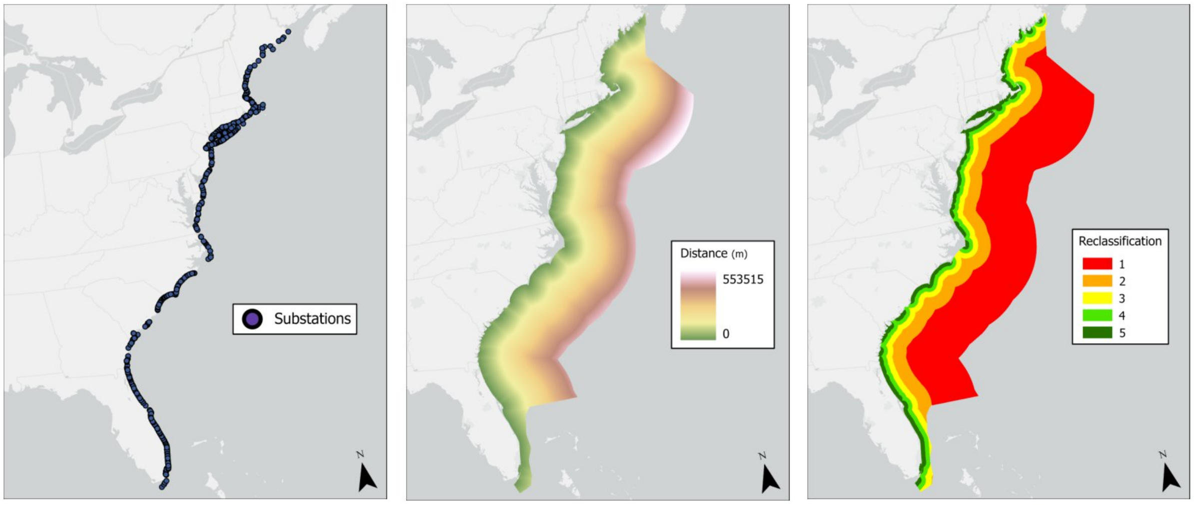
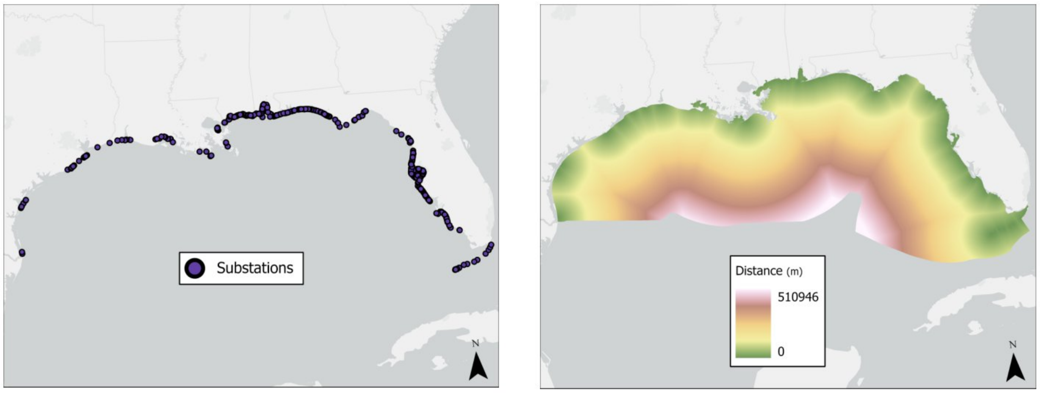


Fig. 23 Three maps (from left to right) showing the process of reclassification for Distance to Substations for the east coast of the United States: Raw Data (Office for Coastal Management, 2023), Distance (in meters) to each Substation layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)



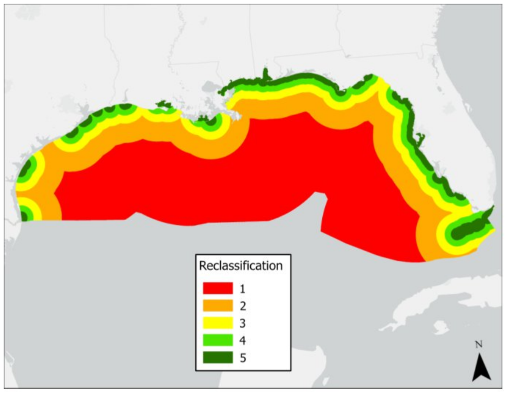


Fig. 24 Three maps (from left to right) showing the process of reclassification for Distance to Substations for the gulf coast of the United States: Raw Data (Office for Coastal Management, 2023), Distance (in meters) to each Substation layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

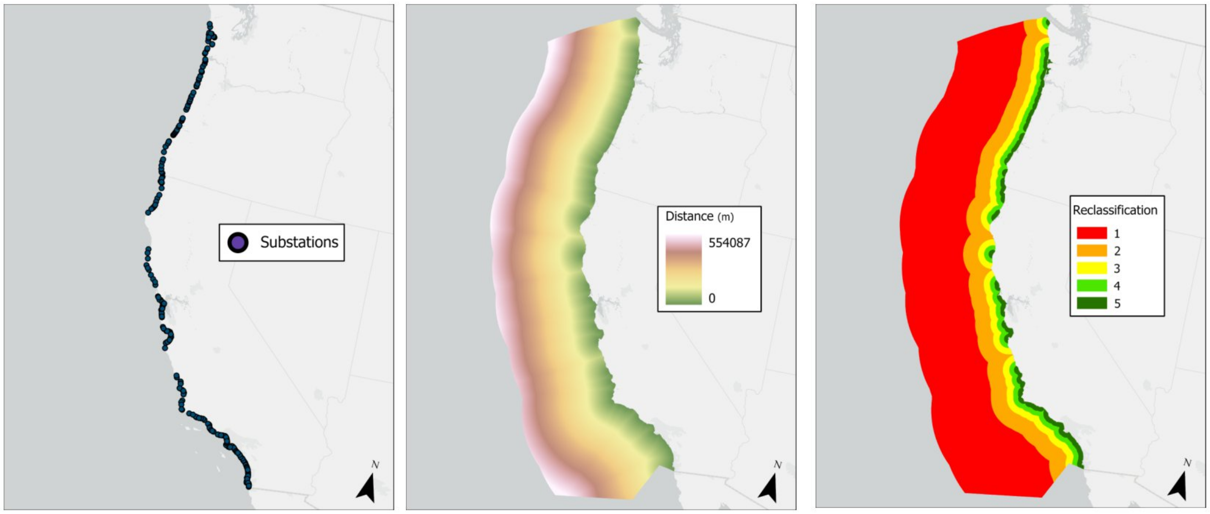


Fig. 25 Three maps (from left to right) showing the process of reclassification for Distance to Substations for the west coast of the United States: Raw Data (Office for Coastal Management, 2023), Distance (in meters) to each Substation layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m)	**Reclassified Value**
160000	1
80000 - 160000	2
48000 - 80000	3
24000 - 48000	4
0 - 24000	5

Fig. 26 Reclassification table for Reclassification of Distance to Substations. Areas of each coastal region (east coast, gulf coast and west coast) close to Substations, less than 24000 m (15 miles) from any substation, are ranked as most suitable for OSW

Distance to Shipping Routes

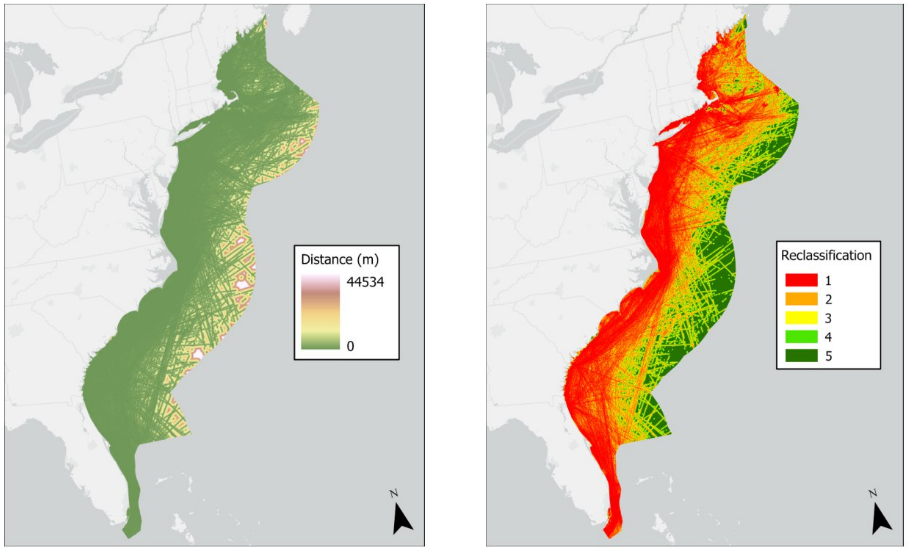


Fig. 27 Two maps (from left to right) showing the process of reclassification for the Distance to Shipping Routes on the east coast of the United States: Distance (in meters) to each Shipping Route layer (Living Atlas, 2022) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

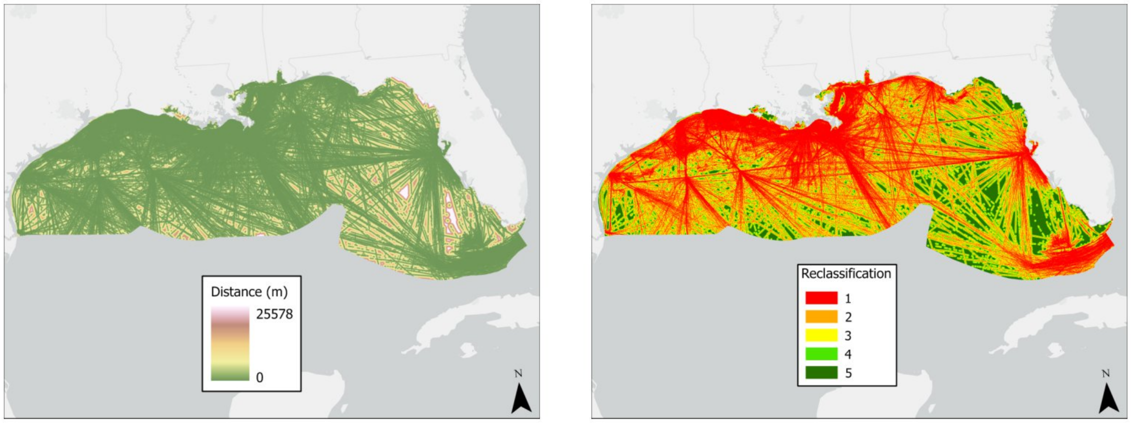


Fig. 28 Two maps (from left to right) showing the process of reclassification for the Distance to Shipping Routes on the gulf coast of the United States: Distance (in meters) to each Shipping Route layer (Living Atlas, 2022) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

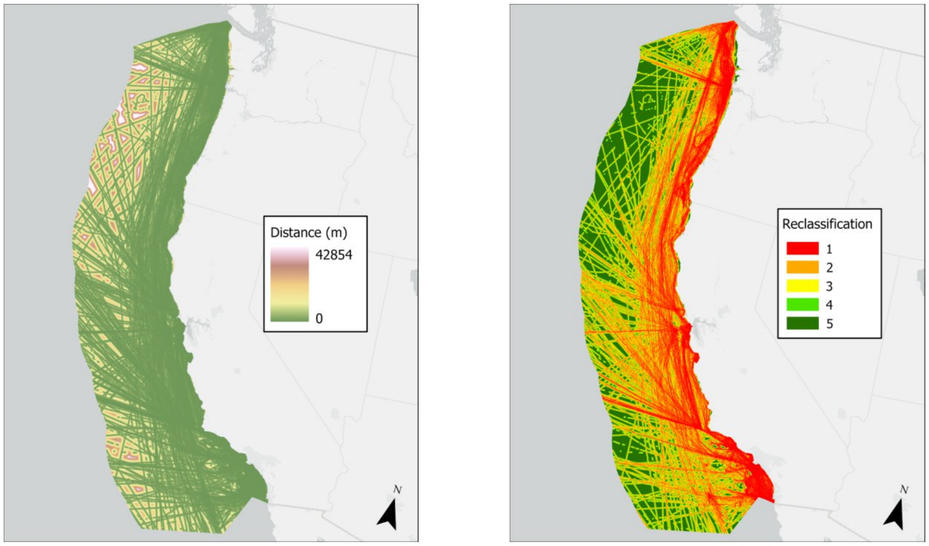


Fig. 29 Two maps (from left to right) showing the process of reclassification for the Distance to Shipping Routes on the west coast of the United States: Distance (in meters) to each Shipping Route layer (Living Atlas) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m)	Reclassified Value
0 - 200	1
200 - 500	2
500 - 2000	3
2000 - 4000	4
4000 +	5

Fig. 30 Reclassification table for Reclassification of Distance to Shipping Routes. Areas of each coastal region (east coast, gulf coast and west coast) furthest from Shipping Routes, greater than 4000 m from any Shipping Route, are ranked as most suitable for OSW

Distance to Submarine Cables

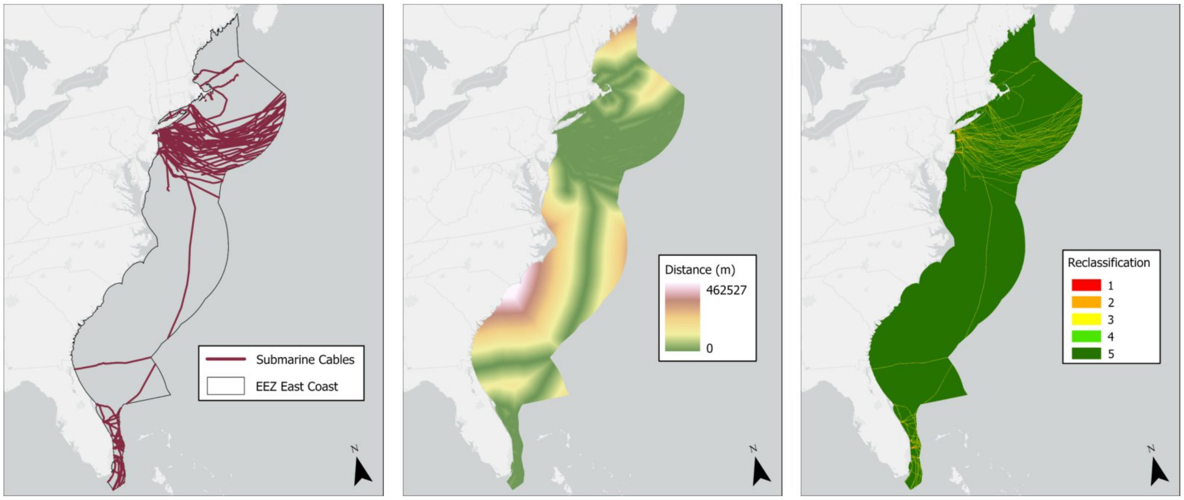


Fig. 31 Three maps (from left to right) showing the process of reclassification for Distance to Submarine Cables for the east coast of the United States: Raw Data (Office for Coastal Management, 2023), Distance (in meters) to each Submarine Cable layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

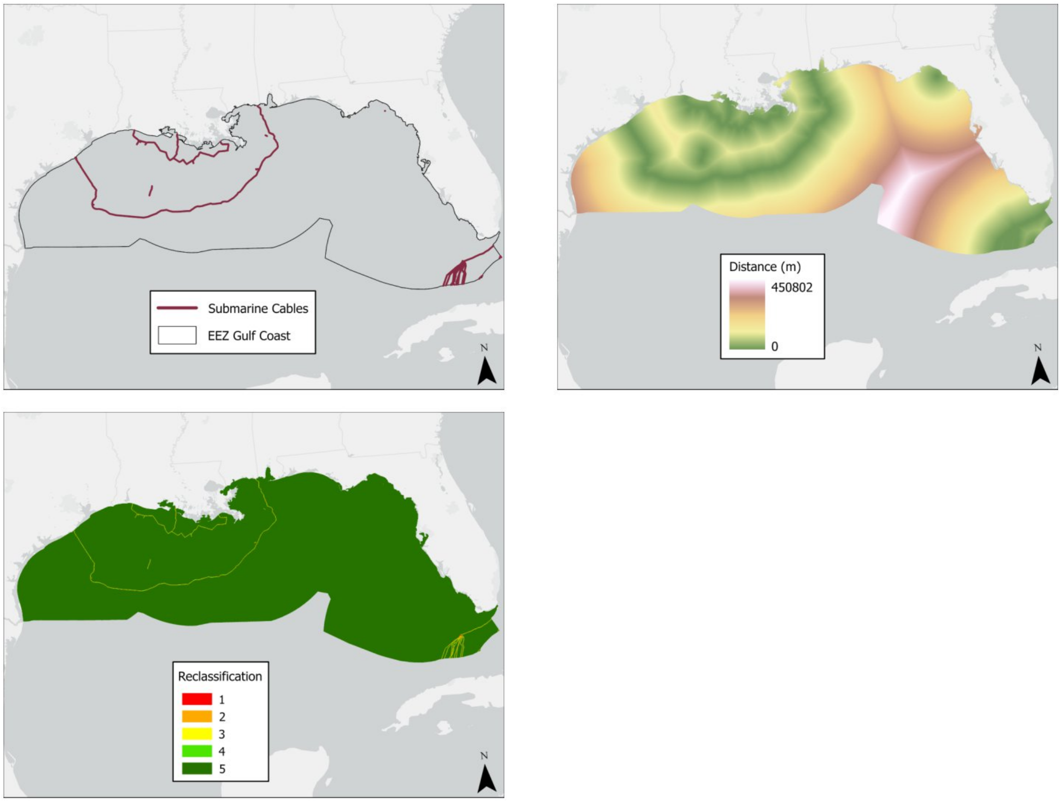


Fig. 32 Three maps (from left to right) showing the process of reclassification for Distance to Submarine Cables for the gulf coast of the United States: Raw Data (Office for Coastal Management, 2023), Distance (in meters) to each Submarine Cable layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

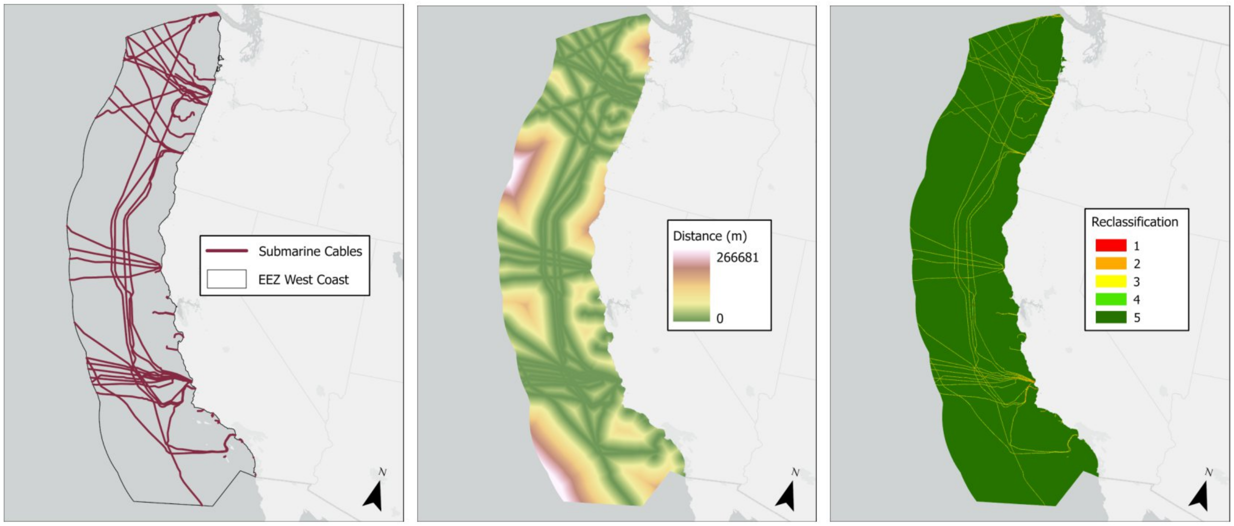


Fig. 33 Three maps (from left to right) showing the process of reclassification for Distance to Submarine Cables for the west coast of the United States: Raw Data (Office for Coastal Management, 2023), Distance (in meters) to each Submarine Cable layer and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value (m)	Reclassified Value
0 - 50	1
50 - 100	2
100 - 500	3
500 - 1000	4
1000 +	5

Fig. 34 Reclassification table for Reclassification of Distance to Submarine Cables. Areas of each coastal region (east coast, gulf coast and west coast) furthest from Submarine Cables, greater than 1000 m from any Submarine Cable, are ranked as most suitable for OSW

Hurricane Density

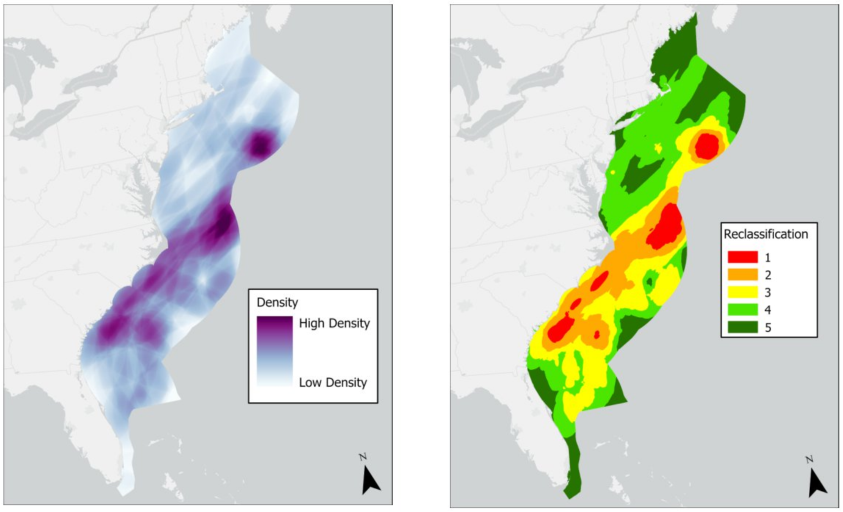


Fig. 35 Two maps (from left to right) showing the process of reclassification for Hurricane Density on the east coast of the United States: Density of Hurricanes layer (Knapp et al., 2018) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value	**Reclassified Value**
0.12 - 0.16	1
0.089 - 0.12	2
0.061 - 0.089	3
0.036 - 0.061	4
0 - 0.036	5

Fig. 36 Reclassification table for Reclassification of Hurricane Density. Areas of the east coast identified as least likely to be affected by Hurricanes, least dense with a density value of 0 to 0.036, are ranked as most suitable for OSW

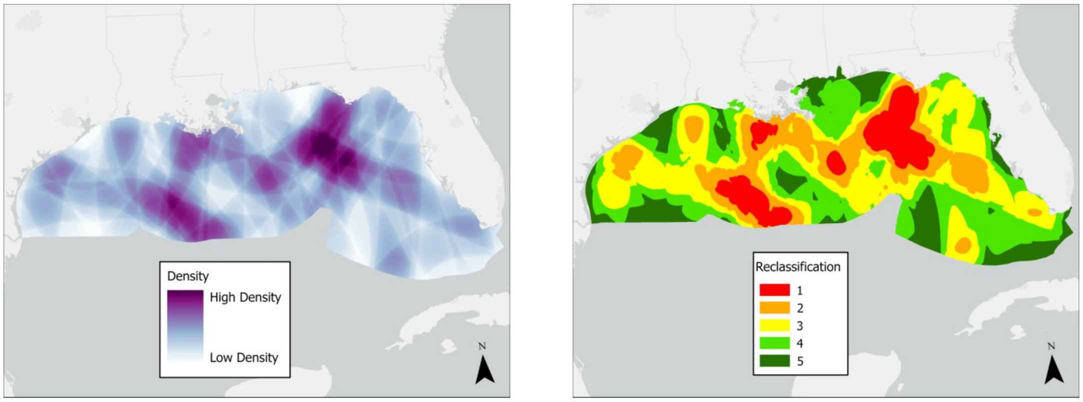


Fig. 37 Two maps (from left to right) showing the process of reclassification for Hurricane Density on the east coast of the United States: Density of Hurricanes layer (Knapp et al., 2018) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value	**Reclassified Value**
0.074 - 0.12	1
0.053 - 0.074	2
0.036 - 0.053	3
0.02 - 0.036	4
0 - 0.02	5

Fig. 38 Reclassification table for Reclassification of Hurricane Density. Areas of the gulf coast identified as least likely to be affected by Hurricanes, least dense with a density value of 0 to 0.02, are ranked as most suitable for OSW

Fault Density

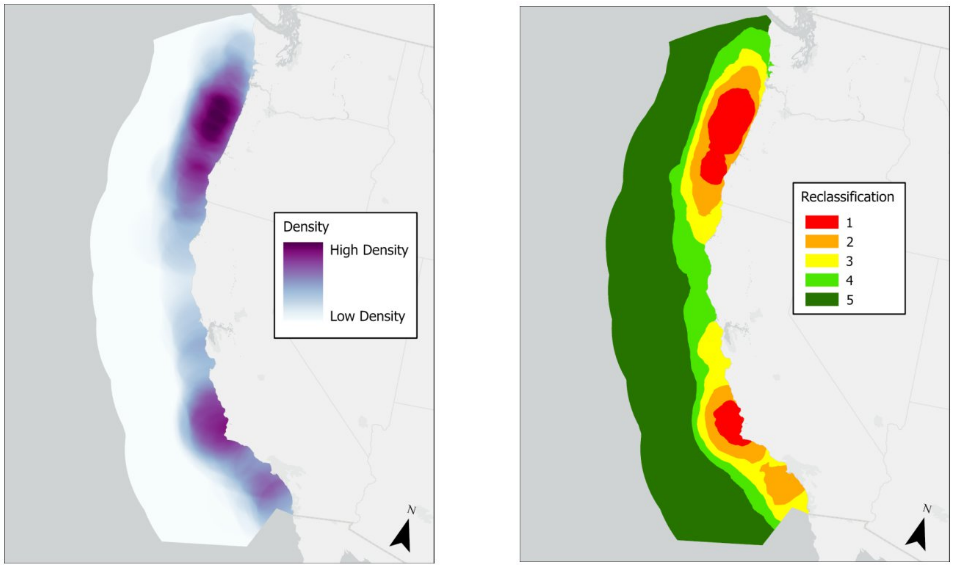


Fig. 39 Two maps (from left to right) showing the process of reclassification for Fault Density on the west coast of the United States: Density of Faults layer (USGS, 2019) and Reclassification layer used in suitability analysis ranked on a scale from 1 (least suitable) to 5 (most suitable)

Original Value	**Reclassified Value**
0 - 6E-06	1
6E-06 - 1.6E-05	2
1.6E-05 - 2.6E-05	3
2.6E-05 - 3.7E-05	4
3.7E-05 - 5.3E-05	5

Fig. 40 Reclassification table for Reclassification of Fault Density. Areas of the west coast identified as least likely to be affected by Faults, least dense with a density value of 0 to 6E-06, are ranked as most suitable for OSW

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