Offshore Habitat Assessment for US Wind Energy

Benjamin D. Best

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Contents

# Preface

This report was funded by the [Resources Legacy Fund](https://resourceslegacyfund.org/).

# 1. Abstract

Development of offshore wind energy will be essential for providing renewable energy to mitigate climate change impacts, yet should be responsibly sited to minimize impacts on sensitive species and habitats. The Bureau of Ocean Energy Management (BOEM) manages the federal offshore leasing of wind energy for the United States (U.S.) and has defined regions, zones and individual lease blocks, which were used to evaluate differences in species and habitats for the federal waters of the U.S. lower 48 states (excluding Alaska and Hawaii). Species distributions were collated from a variety of sources and rescaled (0 to 100) according to a preferred hierarchy of response terms: 1) density surface models (response: # individuals / km2; 151 species of marine mammals, seabirds and sea turtles across 4 datasets); 2) habitat probability models (response: 0 to 1; 9,639 species from AquaMaps); 3) and expert range maps (response: 0 or 1; 342 species from IUCN Red List). All data layers were downscaled to a common grid of roughly 15 arc-seconds (each pixel ranging in area 0.16 to 0.31 km2) aligned with the GEBCO high resolution global bathymetry in order to calculate differences between individual lease blocks (ranging in area 0.67 to 23.09 km2). Species richness and species abundance were calculated per pixel along with an aggregate extinction risk for those species having an IUCN Red List category assigned. An overall conservation score also incorporated primary productivity, hydrothermal vents and seamounts with equal weighting for each layer.

[ TODO: next - + Tables - Spatial Scoring: Zone Average - Zones with Blocks - move to Appendix

* future
  + app to change weights
  + app to extract species with extinction risk per AoI / pixel / block / zone ]

Key habitats of hydrothermal vents and seamounts were also

In contrast, many more thou

Species distributions were collated into a common response across

Species distribution models were collated across the

# 2. Introduction

Development of offshore wind energy will be essential for providing renewable energy to mitigate climate change impacts, yet should be responsibly sited to minimize impacts on sensitive species and habitats. Acoustic impacts from construction and operation may negatively impact some species (Mooney, Andersson, and Stanley 2022). Hard substrate provided by the platforms may actually benefit other species (Wilson and Elliott 2009). Although only 42 megawatts (MW) of offshore wind energy capacity is operational (in Rhode Island and New York) as of May 31 2022, the pipeline of potential generating capacity is estimated to be 40 gigawatts (GW) – enough to power 13 million homes (Musial et al. 2022).

Wind energy areas are under active development by the Bureau of Ocean Energy Management (BOEM) throughout the United States. This study will assess habitats for sensitivity throughout strategic parts of the US.

A couple fundamental questions driving this analysis are:

1. *How different are existing lease areas from the rest of the region?* (***intra-region***)  
   Areas not already slated for the offshore wind leasing impact species and habitats less, so could be candidates for alternative future planning. Areas with designated military use and outside BOEM’s authority (e.g., National Marine Sanctuaries) need to be further excluded from consideration.
2. *How different are existing lease areas from each other within a given region?* (***inter-lease***)  
   Within the leasing process the most oversight can be exercised within existing lease areas, especially ones in the earlier stages of Proposed Sale Notices and Call Areas. Identifying less impacted lease areas may lend greater stakeholder support for development.

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While density surfaces are most preferable, especially for determining number of individuals impacted by human activity (e.g., for Potential Biological Removal as mandated by the Marine Mammal Protection Act), the distributions of relatively few taxa have been described by these models for the .

* Essential Fish Habitat (EFH) is too coarse, not preferred by (Friedland et al. 2021) (see [methods notes | offhab - Google Docs](https://docs.google.com/document/d/1JSJMBqqL4c44c8fx01I-elx7gK8dNyuABjLinaxC95k/edit#bookmark=id.sky4lrftqqq8))

# 3. Methods

## 3.1 Spatial Hierarchy: Regions > Zones > Blocks

Determination of regions for which to assess offshore habitat was based on BOEM activity and representativeness of habitats across the continental United States ([Figure 3.1](#fig-map-zones)). The first (and presently only commercially in production) US wind farm at Block Island, NJ is in the North Atlantic where $4.4 billion was paid in offshore wind bids earlier this year ([DOE news](https://poweralliance.org/2022/02/25/boem-sets-offshore-energy-records-with-4-37-billion-in-winning-bids-for-wind-sale/)). The Atlantic seaboard slopes gradually making it appropriate for fixed platforms, whereas the Pacific coast drops off quickly into deeper depths making floating platforms more suitable. These technological differences therefore affect the bottom habitats differently. Whereas fixed platforms involve pile driving and addition of additional hard surfaces for habitats, the floating platforms leave only the benthic footprint of moorings and submarine cables.

### 3.1.1 Regions and Zones

|  |
| --- |
| Figure 3.1: Regions (Atlantic, Gulf of Mexico, and Pacific) are subdivied into Zones corresponding to BOEM Planning Areas in federal waters clipped to the U.S. Exclusive Economic Zone (except Alaska and Hawaii). To prevent overcrowding of labels only abbreviations are shown for Central (CGM), Eastern (EGM) and Western (WGM) Gulf of Mexico.. Please also see the [online interactive figure](https://offshorewindhabitat.info/report/methods.html#fig-map-zones). |

### 3.1.2 Blocks

| Zone | # of Blocks | Block Area (km<sup>2</sup>) |
| --- | --- | --- |
| Atlantic | | |
| Mid Atlantic | 2,165 | 16,534 |
| North Atlantic | 342 | 859 |
| South Atlantic | 801 | 3,448 |
| Gulf of Mexico | | |
| Central Gulf of Mexico | 33 | 762 |
| Western Gulf of Mexico | 96 | 2,215 |
| Pacific | | |
| Central California | 16 | 23 |
| Northern California | 237 | 535 |
| Southern California | 673 | 2,590 |
| Washington/Oregon | 753 | 4,684 |

## 3.2 Datasets

|  |  |  |  |  |  | Regions | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Key | Name | Type | Taxa | # Taxa | Year | Pacific | Atlantic | GoMex |
| am | AquaMaps Global Probabilities | probability | All | 9,639 | 2021 | ✓ | ✓ | ✓ |
| rl | IUCN Global RedList Ranges | range | All | 342 | 2022 | ✓ | ✓ | ✓ |
| du | Duke Atlantic Marine Mammal Densities | density | Marine mammals | 48 | 2022 |  | ✓ | ✓ |
| sw | SWFSC Pacific Cetacean Densities | density | Marine mammals | 13 | 2020 | ✓ |  |  |
| gm | NOAA GoMex Cetacean & Sea Turtle Densities | density | Marine mammals, sea turtles | 11 | 2022 |  |  | ✓ |
| nc | NCCOS Atlantic & Pacific Seabird Densities | density | Seabirds | 79 | 2021 | ✓ | ✓ |  |
| sm | SOEST Pacific Seamount Occurrences | occurrence |  |  | 2011 | ✓ |  |  |
| ve | InterRidge Pacific Hydrothermal Vent Occurrences | occurrence |  |  | 2020 | ✓ |  |  |
| vg | OregonState Global Productivity | productivity |  |  | 2021 | ✓ | ✓ | ✓ |

## 3.3 Processing Steps

1. **Download dataset**  
   As raster or vector.
2. **Convert dataset layers to common raster format**  
   In order to calculate quickly across a wide range of spatial data based on different formats (vector or raster), spatial units of analysis and projections, a common study area and grid was generated from the **GEBCO** elevation map and projected to Web Mercator for readily displaying in “slippy” maps online. The area-based distortion of Web Mercator was compensated for by calculating the true area per cell as a separate multiplicative layer for use in calculations.
3. **Average within dataset-species layers**  
   Some datasets include seasonally (e.g., [du]) or regionally (e.g., [nc]) distinct density surfaces. These get averaged (for seasonal) and mosaicked (for regional) together to produce a single average per dataset and species.
4. **Rescale dataset-species layers 0 to 100% for all model types**  
   While this analysis is detailed spatially, it is coarse in terms of abundance, since the best available spatial distribution information is combined across disparate dataset types, i.e. expert ***range*** maps (i.e., [rl]), ***probability*** of occurrence (i.e., [am]) and ***density*** surface models (e.g., [du], [sw], [nc], [gm]). Model values were rescaled 0 to 100%, i.e. normalized to the existing probability of occurrence range of values (i.e., [am]). For instance, the original maximum ***density*** surface model value for common dolphins (*Delphinus delphis*) in the Atlantic from [du] is 286 individuals per km2, whereas for the minke whale (Balaenoptera acutorostrata) in the Pacific from [sw] is 0.00491 individuals per km2. Both of these maxima are converted to 100, since we are not comparing relative abundance between species but rather within species. Since expert ***range*** maps are binary in nature, i.e. in or out of range, a single value of 50% is applied within the range. Converting the stored values to single unsigned integers (INT1U for the range [0, 100]) enables a significant reduction of individual raster file sizes. Furthermore zeros were converted to NA (not available) for the sake of calculating the species range. A similar hierarchy was taken for [Biologically Important Areas to Cetaceans](https://oceannoise.noaa.gov/biologically-important-areas) in the US (LaBrecque et al. 2015).
5. **Mosaic to single taxa across datasets, taxa**  
   Since some datasets were not present in all regions, a mosaic approach was taken whereby different datasets could contribute to different regions, based on which had the most preferred data type (***density*** > ***probability*** > ***range*** > ***occurrence***) most recently collected (***newer*** > ***older***). Of 10,061 species, only 41 had multiple datasets contributing to different regions.
6. **Aggregate layers to use as inputs to scoring**  
   **Species Richness** was calculated as the sum of the presence of taxa in a given pixel. **pecies Abundance** was the normalized abundance (ranging 1 to 100) within the pixel. **Extinction Risk** was based on species having an IUCN RedList Category and converted to a score: 0 for Least Concern (LC), 1 for Near Threatened (NT), 2 for Vulnerable (VU), 3 for Endangered (EN) and 4 for Critically endangered (CR) (Juslén et al. 2016). In future, endemism, trophic level, [MarineSpecies.org/Traits](https://MarineSpecies.org/Traits), <FishBase.org>, …
7. **Score with input layers**  
   Calculate the score per pixel with the input aggregate layers using [Equation 3.1](#eq-scoring).
8. **Extract across spatial hierarchies**  
   Zonal statistics were then captured across the full spatial hierarchy of Study, Regions, Zones and Blocks.
9. **Make scores relative to spatial hierarchy**  
   Normalize pixel and Block scores per Zone by subtracting the mean and dividing by the standard deviation ([Equation 3.2](#eq-normalizing)). This way pixels and Blocks equal to the mean will be 0, positive values containing higher conservation scores, negative values lower conservation scores.

## 3.4 Scoring Conservation Value

By combining disperate layers with weights we can arrive at a fundamental conservation index (O’Hara and Halpern 2022).

The and layers are presence-only (i.e., binary, 1 or 0), so convert to a value of 0.5 where present, whereas the other layers have a range from 0 to 1.

A naive weighting approach is taken in which all weights are given an identity value of 1. To allow different value sets among users, a useful future application would calculate new scores on the fly with a slider for weight value applicable to each of the layers.

## 3.5 Normalizing within Zone for Block Comparison

In order to evaluate conservation value within a given Zone, we normalized the score for each pixel by subtracting the Zone average () and dividing by the standard deviation () of the scores in the given Zone:

# 4. Results

|  |  |  |  | Species | | | | | | Habitats | | | | | |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Region | Zone | Score |  | Richness |  | Abundance |  | Extinction Risk |  | 1º Productivity |  | Hydrothermal Vents |  | Seamounts |  | Area (km²) |  |
| Atlantic | ALL | 31.5 |  | 1,840.1 |  | 126,838.2 |  | 8,542.5 |  | 777.9 |  | – |  | 1 |  | 866,082.4 |  |
| Atlantic | Mid Atlantic | 25.8 |  | 1,447.9 |  | 101,259.9 |  | 7,790.5 |  | 588.0 |  | – |  | – |  | 323,451.1 |  |
| Atlantic | North Atlantic | 27.1 |  | 1,507.5 |  | 89,085.2 |  | 7,066.8 |  | 1,101.1 |  | – |  | 1 |  | 306,210.9 |  |
| Atlantic | South Atlantic | 41.1 |  | 2,507.6 |  | 182,516.7 |  | 10,984.1 |  | 655.6 |  | – |  | – |  | 198,772.0 |  |
| Atlantic | Straits of Florida | 64.7 |  | 4,391.2 |  | 359,686.3 |  | 14,115.1 |  | 425.4 |  | – |  | – |  | 37,648.4 |  |
| Gulf of Mexico | ALL | 38.9 |  | 2,468.8 |  | 176,382.8 |  | 9,313.6 |  | 815.1 |  | – |  | – |  | 627,105.6 |  |
| Gulf of Mexico | Central Gulf of Mexico | 30.9 |  | 1,878.9 |  | 126,988.5 |  | 7,549.6 |  | 911.9 |  | – |  | – |  | 257,622.8 |  |
| Gulf of Mexico | Eastern Gulf of Mexico | 45.4 |  | 2,923.2 |  | 215,881.9 |  | 11,054.2 |  | 672.4 |  | – |  | – |  | 254,654.9 |  |
| Gulf of Mexico | Western Gulf of Mexico | 42.7 |  | 2,784.5 |  | 199,604.4 |  | 9,410.9 |  | 914.2 |  | – |  | – |  | 114,827.9 |  |
| Pacific | ALL | 15.5 |  | 698.6 |  | 42,241.0 |  | 4,428.1 |  | 922.0 |  | 1 |  | 1 |  | 794,098.2 |  |
| Pacific | Central California | 14.1 |  | 569.2 |  | 33,341.2 |  | 3,935.6 |  | 1,046.7 |  | – |  | 1 |  | 143,978.4 |  |
| Pacific | Northern California | 13.6 |  | 638.4 |  | 37,967.7 |  | 3,955.9 |  | 810.0 |  | 1 |  | 1 |  | 138,500.5 |  |
| Pacific | Southern California | 18.2 |  | 806.6 |  | 52,071.2 |  | 5,465.5 |  | 938.6 |  | – |  | 1 |  | 275,850.4 |  |
| Pacific | Washington/Oregon | 14.2 |  | 686.6 |  | 38,685.0 |  | 3,792.6 |  | 892.2 |  | 1 |  | 1 |  | 235,768.9 |  |

[TODO: format table as Calibri size 8. R-click: Insert caption, borders, merge cells, swap state codes like example.

Table [tbl-zones]. Average pixel values across Regions and Zones for overall Score as well as input layers. Values are colored per column highest to lowest: red, orange, yellow, green, blue, violet. Sortable table is [online](https://offshorewindhabitat.info/report/results.html#tbl-zones). ]

See [Table [tbl-zones]](#tbl-zones).

# 5. Discussion

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# References

Friedland, Kevin D., Elizabeth T. Methratta, Andrew B. Gill, Sarah K. Gaichas, Tobey H. Curtis, Evan M. Adams, Janelle L. Morano, Daniel P. Crear, M. Conor McManus, and Damian C. Brady. 2021. “Resource Occurrence and Productivity in Existing and Proposed Wind Energy Lease Areas on the Northeast US Shelf.” *Frontiers in Marine Science* 8.

Juslén, Aino, Juha Pykälä, Saija Kuusela, Lauri Kaila, Jaakko Kullberg, Jaakko Mattila, Jyrki Muona, Sanna Saari, and Pedro Cardoso. 2016. “Application of the Red List Index as an Indicator of Habitat Change.” *Biodiversity and Conservation* 25 (3): 569–85. <https://doi.org/10.1007/s10531-016-1075-0>.

LaBrecque, Erin, Corrie Curtice, Jolie Harrison, Sofie M. Van Parijs, and Patrick N. Halpin. 2015. “3. Biologically Important Areas for Cetaceans Within US Waters-Gulf of Mexico Region.” *Aquatic Mammals* 41 (1): 30.

Mooney, T Aran, Mathias H Andersson, and Jenni Stanley. 2022. “ACOUSTIC IMPACTS OF OFFSHORE WIND ENERGY ON FISHERY RESOURCES.” *Oceanography*, 15.

Musial, Walter, Paul Spitsen, Patrick Duffy, Philipp Beiter, Melinda Marquis, Rob Hammond, and Matt Shields. 2022. “Offshore Wind Market Report: 2022 Edition.”

O’Hara, Casey C., and Benjamin S. Halpern. 2022. “Anticipating the Future of the World’s Ocean.” *Annual Review of Environment and Resources* 47 (1): null. <https://doi.org/10.1146/annurev-environ-120120-053645>.

Wilson, Jennifer C., and Michael Elliott. 2009. “The Habitat-Creation Potential of Offshore Wind Farms.” *Wind Energy* 12 (2): 203–12. <https://doi.org/10.1002/we.324>.