Spatial Modeling to Support Sustainable Offshore Wind Energy Development for California



Conservation Biology Institute

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Credits

Degagne, R., Gough, M., Joseph, G., Pizzino, D., Smith, C. and Strittholt, J. 2022. Spatial Modeling to Support Sustainable Offshore Wind Energy Development for California. CBI Technical Report 2022. 70 pp.

For more info please contact: Rebecca.degagne@consbio.org

Table of Contents

Executive Summary

Offshore wind energy developed in federal ocean waters off California is poised to help the state achieve its 100% renewable and zero-carbon energy goals. Since 2016, the State has coordinated with governmental partners, including the Bureau of Ocean Energy Management (BOEM) and the BOEM-California Renewable Energy Intergovernmental Task Force, to identify areas off the state's coast suitable for potential offshore wind energy development. To support this effort, the Conservation Biology Institute (CBI) used data from the California Offshore Wind Energy Gateway to produce a robust set of spatial models, designed to synthesize information to help stakeholders and decision-makers assess the suitability of offshore wind energy development in federal waters off the coast of California. These models, created using the Environmental Evaluation Modeling System (EEMS) with 239 input datasets, provide a transparent and data-driven means for assessing a range of considerations at a given location, such as energy potential, deployment feasibility, ocean uses, fisheries, and marine life occurrence. Together, these models can be used to inform planning processes for offshore wind energy development, to maximize renewable power generation and to help avoid or minimize potential impacts to existing ocean uses and the environment.

The California Offshore Wind Energy Modeling Platform, powered by EEMS Online technology, provides an interface where stakeholders and decision-makers can interact with and explore the models and their data sources to help support decision-making processes. However, it is also important to understand these do not provide a sensitivity or vulnerability evaluation and should not be used to identify or assess project-level impacts. Additionally, they reflect available data, expert opinion, and currently understood geographic distributions of species and ocean use, without taking potential shifts due to climate change into account.

In the future, CBI's modeling approach could be extended geographically, (e.g. to California's state waters or to Oregon for regional planning efforts), and/or enhanced with additional data, based on agency and stakeholder priorities. This work could be leveraged to further support strategic planning by combining the thematic models into a least-conflict analysis to highlight areas most suited for exploration of OSW development, under different scenarios. There is a need for continued investment, to keep the analysis current and relevant throughout the different stages of offshore wind energy planning in California.

Background

Marine offshore wind energy is poised to play a vital role in helping the State of California achieve its one hundred percent renewable energy goals by 2045 (Assembly Bill 525; Gill et al. 2021), but this technology has not yet been deployed for the West Coast of the United States. California's offshore wind (OSW) energy resource potential is excellent and includes areas with some of the highest wind speeds among all waters of the United States (Optis et al. 2020). However, the deep ocean waters off the West Coast require floating offshore wind systems, a different technology than the fixed-bottom systems already deployed on the East Coast of the United States. Floating offshore wind is an emerging technology that is quickly advancing toward commercial status (Musial et al. 2020). This exceptional renewable energy source has the potential to create new industry jobs, provide critical power at times when solar is unavailable, and reduce air pollution from fossil-fuel power generation (Rose et al. 2021). However, implementation of OSW energy must be carefully balanced with the following considerations:

- Preserving existing ocean uses, such as fishing and recreation.
- Engaging and responding to the needs of local communities.
- Minimizing impacts to marine life dependent on the unique ecosystem off California's coast that supports numerous endangered and protected species.

To facilitate responsible offshore wind energy deployment, the State of California is continuing its proactive approach to strategic renewable energy planning by utilizing advanced spatial analysis and online tools to enhance objective decision-making and increase stakeholder engagement. For over 10 years, the California Energy Commission (CEC) has invested in science-based tools to help identify and explore a wide range of potential opportunities and constraints to developing renewable energy resources to meet the State's climate and energy goals (Davis et al. 2013; Pearce et al. 2016). The benefits of using strategic planning approaches for renewable energy planning include early identification and resolution of significant issues or barriers to development, increased transparency in decision making, understanding and evaluating potential tradeoffs, heightened agency collaboration, and more certainty in the development of environmentally responsible renewable energy projects. Such objective and transparent approaches to finding optimal solutions can address a range of stakeholder concerns, and potentially lower planning and permitting costs (Pearce et al. 2016; Tegen et al. 2016).

The State of California is carrying out offshore wind energy planning activities in close coordination with the BOEM-California Intergovernmental Renewable Energy Task

Force, (a partnership of state, local, federally-recognized tribal governments, and federal agencies), and the Bureau of Ocean Energy Management (BOEM), the federal permitting agency that leases offshore areas for energy development with a goal to responsibly manage resources in the interest of environmental sustainability, economic development, and national security (About BOEM 2022; BOEM CA Activities 2022).

The CEC and BOEM have been engaged in outreach and data gathering for the past several years. In 2018, the CEC and BOEM co-funded and collaborated to launch the California Offshore Wind Energy Gateway, an authoritative platform to support OSW planning efforts by assembling geospatial information on ocean wind energy potential, ecological and natural resources, ocean commercial and recreational uses, and community values (Figure 1). The California Offshore Wind Energy Gateway receives dozens of user visits per day and is powered by Data Basin technology; it contains over 800 spatial datasets, organized into thematic galleries and topical maps. This platform allows decision makers and stakeholders to access, view, map, collate, and contribute data. It also supports public and private collaboration and integration with online tools.

Figure 1. The California Offshore Wind Energy Gateway is the authoritative platform to support OSW planning efforts by assembling geospatial information on ocean wind energy potential, ecological and natural resources, ocean commercial and recreational uses, and community values.

The CEC and BOEM used publicly available information in the Gateway as a source of information to identify areas for potential OSW development; these became the Wind Energy Areas shown in the map below (Figure 2; BOEM CA Activities 2022).

Figure 2. The CEC and BOEM have identified two Wind Energy Areas for potential OSW development, (BOEM CA Activities 2022).

The Conservation Biology Institute (CBI) was funded by the Ocean Protection Council (OPC), with additional support from the Resources Legacy Fund, to utilize the rich archive of data in the Gateway and undertake modeling to provide insight on considerations around offshore wind energy development in California. These models, developed using the Environmental Evaluation Modeling System (EEMS), synthesize key data and provide a transparent and data-driven means for examining a range of factors at a given location, such as wind energy potential, OSW infrastructure deployment feasibility, ocean uses, fisheries, and marine life occurrence (Sheehan and Gough 2016). They are designed to allow stakeholders and decision-makers to access and evaluate a multitude of datasets and to help assess the suitability of offshore wind energy development in federal waters (between 3 and ~70 nautical miles) off the coast of California. Together, these models can be used to raise awareness of the uses and resources in a given area, inform planning processes for offshore wind energy development, and help avoid or minimize potential impacts to existing ocean uses and the environment.

The Conservation Biology Institute's open-source EEMS modeling platform offers several advantages for renewable energy planning. The location-based framework integrates numerous and diverse data into a transparent system that provides a nuanced view of activities and resources at a given location. It can consume complex geospatial datasets, such as analytical and statistical modeling outputs, alongside more general information provided by experts and stakeholders, and summarize everything to multiple levels of detail. It is particularly well suited to enable data-driven decision making to answer complex questions. It has an interactive online interface that allows people to visualize analysis components with a graphic diagram, alongside the mapped results. The maps and analysis can be queried to examine input data sources, as well as to determine what factors contribute to a score at any given location. Lastly, the EEMS modeling framework is flexible and adaptable; it provides a baseline that can be updated and expanded to support the OSW planning process long-term to address emerging needs of agencies and stakeholders.

We worked closely with multiple California state agencies, BOEM, and independent subject matter experts during data acquisition and model development. Staff from OPC and CEC were involved in model design and met regularly with the CBI team to provide input and guidance. OPC and CEC staff reviewed and approved modeling-related decisions, (e.g., selection of input data and how datasets were treated in modeling). Other State agencies, including the California Coastal Commission, State Lands Commission, and California Department of Fish and Wildlife were involved in the project and decisions made along the way, to ensure maximum alignment of CBI's models with agency activities. BOEM staff and subject matter experts provided critical input and data, and BOEM staff were invited to review and comment on the spatial models before they were released to stakeholders. Finally, experts from federal agencies, (esp. NOAA), and universities provided essential information on input data and recommended model structure in the EEMS analytical framework.

Model Overview

The Conservation Biology Institute created models showing offshore wind energy planning considerations, using BOEM's aliquots to ensure maximum alignment with the leasing process, for the four themes described below. Each model has a hierarchical structure with multiple components and data that can be examined in detail on the California Offshore Wind Energy Modeling Platform, the interactive EEMS Online website: https://osw.eemsonline.org/. Models depict where any given location falls on a continuum of values generated for federal waters off the coast of California, based on normalized input data; scores range from "Low" (False, -1) to "High" (True, +1). Please see the `About' page in the online interface, if you need more details on the scoring process. Essentially, each of the models depicts a composite index and individual scores for all components, based on the available input data.

1. Wind Energy Potential - This model estimates energy potential by considering annual, monthly, and evening components of the offshore wind energy resource.

2. OSW Infrastructure Deployment Feasibility - This model estimates OSW infrastructure deployment feasibility by considering proximity to ports and electrical grid connections, physical constraints of seafloor slope and depth, and infrastructure avoidance.

3. Ocean Use - This model estimates the amount of ocean use at a given location by considering commercial fishing activity, vessel traffic and navigation, recreation, cultural and historic resources, and ocean disposal sites.

4. Environmental Considerations - This model estimates an index of marine life presence at a given location by considering the occurrence, activity, density, and/or habitat of sensitive marine species, including whales, seabirds, and leatherback sea turtles. Species with a higher protected status, (e.g. endangered), were weighted more heavily in the model.

Methodology

Workflow Overview

Spatial models were generated using the EEMS fuzzy logic modeling system, working through an iterative analysis process in close coordination with OPC, CEC, BOEM, and subject matter experts.

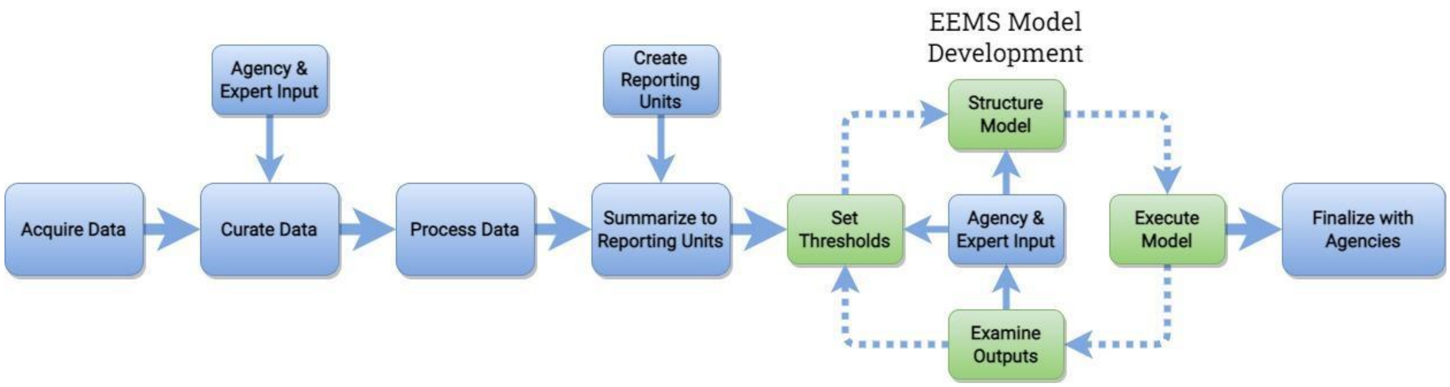


Figure 3. Modeling workflow diagram.

To create each of the models, we implemented the following workflow (Figure 3):
1. Acquired spatial data from authoritative sources; 2. Curated data with agency and expert input to identify the best available data to meet State planning needs; 3. Processed selected model input data, deriving new inputs to represent planning considerations where applicable; 4. Summarized processed data to aliquot reporting units; 5. Carried out iterative EEMS model development to optimize model parameters; 6. Worked with independent experts and agency staff to review outputs and modify, as recommended.

Reporting Units & Study Area Boundary

BOEM aliquots were selected as the reporting units for CBI's analysis and EEMS models, to provide appropriate spatial resolution for examining regional patterns and to maximize alignment with the leasing process (Figure 4; Appendix 1). BOEM Outer Continental Shelf (OCS) lease blocks serve as the legal definition for federal leasing and administrative purposes; aliquots nest within these blocks, subdividing each into 16ths to allow for more detailed boundary delineation in offshore energy leasing. An aliquot measures 1200 x 1200 meters.

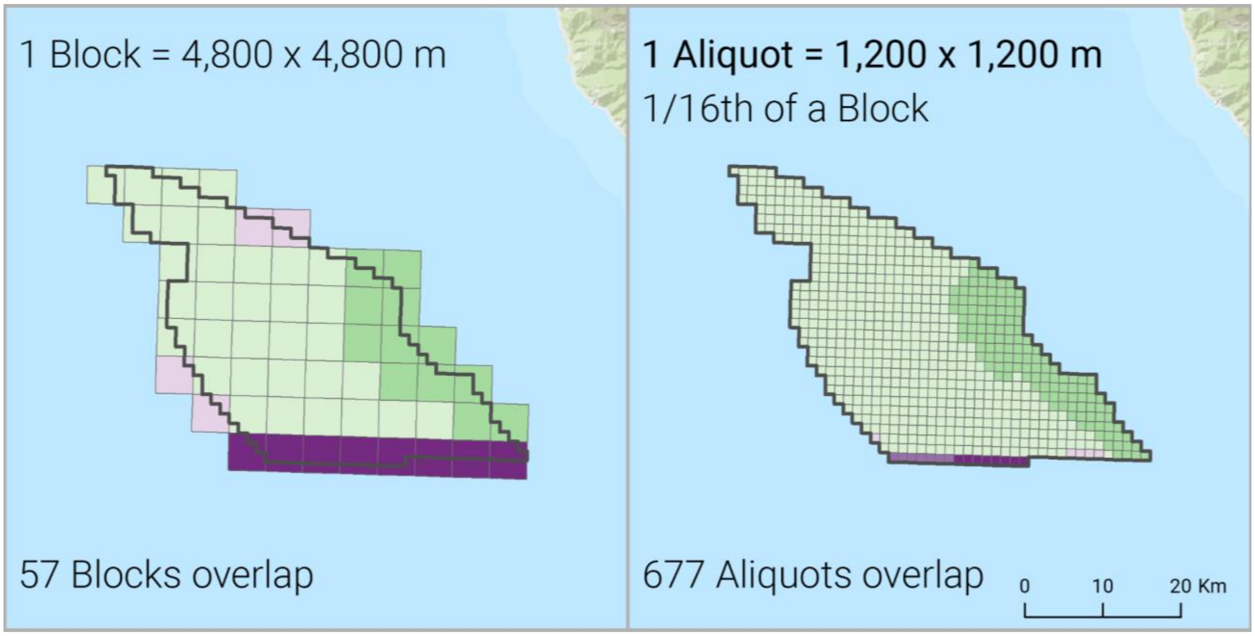


Figure 4. BOEM OCS lease blocks (left) and aliquots (right) intersecting the Morro Bay Wind Energy Area. Aliquots were utilized as the analysis reporting units to provide enhanced resolution and to maximize alignment with the leasing process.

The study area for CBI's analysis encompasses federal waters off the California coast, and follows several logical and legal boundaries (Figure 5; Appendix 1). Analysis reporting units begin three nautical miles from the coastline at the Submerged Lands Act (SLA) boundary, (which delineates State and Federal jurisdiction over natural resources), and extend approximately 70 nautical miles offshore, which represents the extent of NREL wind data provided by BOEM. Reporting units extend northward to the Pacific Administrative Boundary for California and southward to the edge of the U.S. Pacific Exclusive Economic Zone.

The State of California selected this study boundary to facilitate examination of OSW planning considerations across all waters off the State's coast, to understand the full spectrum of energy potential, deployment feasibility, ocean use, and marine life present. The analysis was not limited to designated Wind Energy Areas, to allow for the possibility of future additional OSW development beyond those boundaries, (especially relevant to AB 525 planning). Note, jurisdictions and exclusions could be overlaid with analysis results to better understand where OSW development may be feasible or legal.

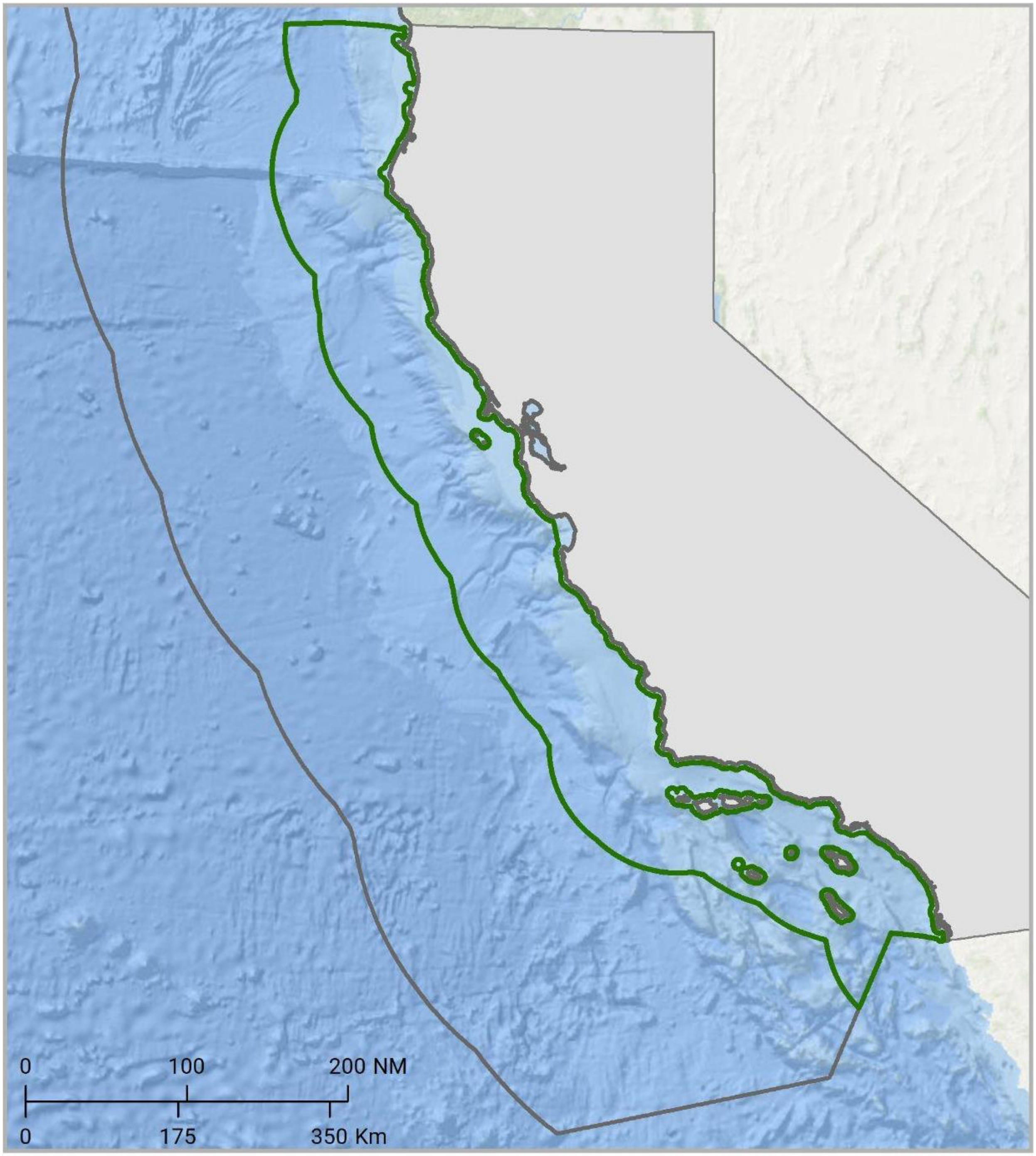


Figure 5. The study area (delineated in green) for CBI's OSW analysis encompasses federal waters off California's coastline, beginning at the Submerged Lands Act boundary, 3 nautical miles from shore. U.S. Pacific EEZ shown in gray.

Input Data

Input data were acquired from many authoritative sources, including the California Offshore Wind Energy Gateway, Marine Cadastre, BOEM, NOAA, NREL, BSEE, ORNL, U.S.

Coast Guard, CEC, CDFW, CDFG, and academic researchers or other data providers. See appendix for tables showing input data for each of the four models (Appendix 3). In total, 239 datasets were selected for inclusion in the models.

Data Processing

Once data was acquired, it was projected to the California (Teale) Albers NAD83 coordinate system, clipped to the study boundary, and then summarized to aliquot reporting units. For input data representing discrete features, such as submarine cables or critical habitat, Euclidean distances were derived from relevant features and resulting distance values were summarized to the reporting units. Software and tools used for data processing included ArcMap v10.6, R v4.1, and the R packages arcgisbinding, rgdal, raster, sf, and exactextractr.

EEMS Modeling Approach

EEMS Model Framework

Spatial models depicting wind energy potential, OSW infrastructure deployment feasibility, ocean use activity, and marine life presence were created using the Environmental Evaluation Modeling System (EEMS), a fuzzy-logic modeling system developed by CBI as an open source alternative to the Ecosystem Management Decision Support (EMDS) software package (Sheehan and Gough 2016, Reynolds 1999). Modeling was executed using the EEMS ArcGIS Model Builder interface and custom Python scripts.

A logic model represents the logical relationships among a network of spatial data components. They are especially suited to evaluating and characterizing complex topics, such as those related to offshore wind energy planning. Unlike conventional GIS applications that use Boolean logic (1s - true and 0s - false) or scored input layers, EEMS models rely on fuzzy logic. Simply put, fuzzy logic allows the user to assign shades of gray to concepts rather than being restricted to black (false) and white (true) determinations. All data inputs (regardless of the type - ordinal, nominal, continuous) are assigned relative values between -1 (false) and +1 (true). This framework can incorporate diverse data inputs, such as statistical model outputs as well as more general vector layers, combining them to characterize nuanced patterns in data, normalized across the study area.

There are many advantages to this modeling approach: (1) it is highly interactive and flexible; (2) it is easy to visualize the data sources and analysis structure; (3) the components are modular, making it easy to add or exclude information; (4) the model parameters can be adjusted using a number of different mechanisms; and (5) numerous data sources of different types can be included into a single integrated analysis.

EEMS models are hierarchical — that is, data flows from the bottom up in order to answer a primary question. Each component in the hierarchy represents a proposition, and these individual components provide valuable information in their own right. A proposition is simply a statement that can either be true (+1), false (-1), or somewhere in-between at any given location. For example, if the model proposition is "High Wind Energy Potential", a value of +1 at a specific location would indicate that this statement is totally true at that location (i.e., that there is high wind energy potential there). A value of -1 at a different location would indicate that this statement is totally false, (i.e., that there is low wind energy potential there). Values in between -1 and +1 simply represent degrees along the continuum (the gray areas). For example, a value equal to zero indicates the proposition is neither true nor false (neutral), i.e., wind energy potential is of an intermediate value there, in the context of the study area and model parameters.

To reiterate, all of the models have output map scores ranging from -1 to +1, which can essentially be interpreted as a range of low (-1), to moderate (0), to high (+1) for each theme: wind energy potential, OSW infrastructure deployment feasibility, ocean use activity, and marine life presence.

EEMS Thresholds

Using fuzzy logic as the core modeling principle, model performance and optimization are achieved in several ways. The values of every input dataset included in the model are scaled from -1 to +1 using thresholds, which determine how the range of input data is normalized along the continuum. Thresholds can be set in multiple ways, including: 1. Using the full range of input data (minimum and maximum values); 2. Expert opinion/heuristics; 3. Guided by statistical distribution of the input data; 4. Taken from previously published studies and literature.

Setting model thresholds is an iterative process, and during model development we worked to make sure data input values were represented in a balanced fashion across the study area. To do so, we considered each factor individually, relying on expert input, literature, and statistically driven approaches when necessary, to ensure display of informative gradients across the study area with nuanced representation of model components and subtle patterns. Often, a statistical approach to setting thresholds, based on standard deviations from the mean as calculated from the input data's distribution, best represented subtle patterns across the study area; this was especially useful for fishing activity and species density data. In situations where input data featured proximity to features of interest, we consulted agency experts to determine appropriate distances for thresholds. Lastly, we used published data related to offshore wind turbine power curves from NREL's report (Beiter et al. 2020) to determine appropriate thresholds for model components. See Appendix 3 for a complete list of thresholds for all input data layers.

EEMS Operators

Spatial data inputs and derived layers are integrated together using EEMS logic operators. Table 1 describes the logic operators utilized in the four models produced by CBI. Certain operators are best suited to different situations. For instance, the UNION (average) operator highlights places where considerations co-occur, e.g. activity in multiple fisheries; the OR (maximum) operator can ensure features that do not overlap are represented in the output, e.g., endangered toothed whales; and the AND (minimum) operator can be used to identify where multiple criteria must be met, e.g. OSW deployment feasibility is highest at locations with low physical constraints that avoid existing infrastructure.

Table 1. EEMS modeling system logic operators used to combine inputs and derived data in California OSW thematic models.

EEMS Tool	EEMS Command	Input Data Type	Description
CONVERT TO FUZZY	CvtToFuzzy	Raw	Converts input values into fuzzy values using linear interpolation, normalizing input data values to -1 and +1, based on chosen thresholds.
Fuzzy AND	FuzzyAnd	Fuzzy	Takes the fuzzy And (minimum) of fuzzy input variables.
Fuzzy OR	FuzzyOr	Fuzzy	Takes the fuzzy Or (maximum) of fuzzy input variables.
Fuzzy SELECTED UNION	FuzzySelectedUnion	Fuzzy	Takes the fuzzy Union (mean) of N Truest or Falsest fuzzy input variables.
Fuzzy UNION	FuzzyUnion	Fuzzy	Takes the fuzzy Union (mean) of fuzzy input variables.

Fuzzy WEIGHTED UNION	FuzzyWeightedUnion	Fuzzy	Takes the weighted fuzzy Union (mean) of fuzzy input variables.

EEMS Modeling Process Summary

As shown in the workflow overview diagram, EEMS modeling is an iterative process that includes input at multiple stages to optimize parameters (Figure 3). In summary, the steps are as follows: 1. Process input data and summarize layers to aliquot reporting units; 2. Set thresholds and convert raw data values into normalized fuzzy space (values ranging from -1 to +1); 3. Create hierarchical model structure, combining inputs with EEMS logic operators into components relevant to OSW planning; 4. Execute model code and examine results; 5. Adjust parameters and structure, creating multiple variations to optimize outputs; 6. Obtain and incorporate feedback from agency and subject matter experts; adjust models based on their inputs; 7. Review the models with the OSW agency core group, including representatives of CEC, OPC, CCC, CDFW, SLC, and BOEM.

Model Structure & Input Data

Wind Energy Potential

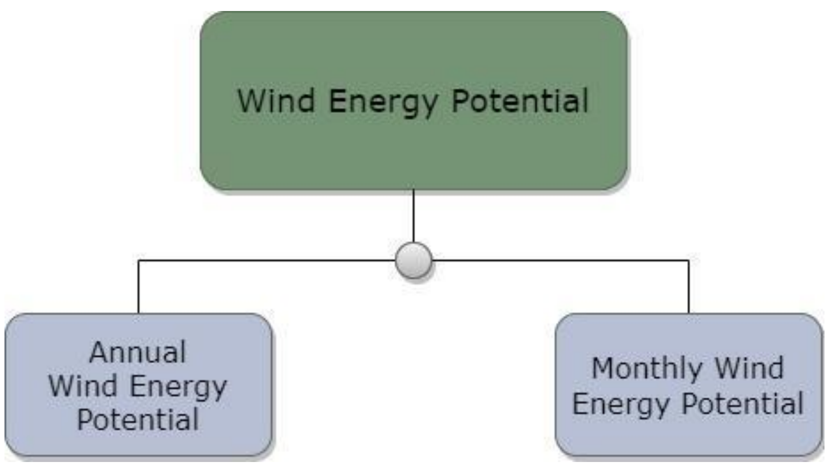


Figure 6. Wind Energy Potential EEMS model structure.

The Wind Energy Potential EEMS model integrated measures of annual and monthly wind energy (Figure 6). There were a total of four inputs, all NREL products provided by BOEM, representing various facets of offshore wind energy resources: annual average wind speed, annual average evening (5 - 9 p.m. Pacific Time) wind speed, number of months with average wind speed greater than 7 meters/second, and number of months with average evening wind speed greater than 7 meters/second. Evening wind speed is an important consideration for evaluation of wind energy resources, since this is when solar energy production drops and energy demand peaks (Rose et al. 2021).

The thresholds for annual average wind speed inputs were set using NREL documentation for offshore wind turbine power curves (Beiter et al. 2020). The annual average wind speed false threshold (-1) was set to the minimum input data value, while the true threshold (+1) was set to 10 meters/second, when turbine power generation reaches its maximum (Beiter et al. 2020; Appendix 2). Monthly wind speed inputs were set with the false threshold at the minimum input data value and the true threshold at the maximum input data value. Details of the model's components, input data, and thresholds are shown in Appendix 3, Figure 1 and Tables 1 & 2.

OSW Infrastructure Deployment Feasibility

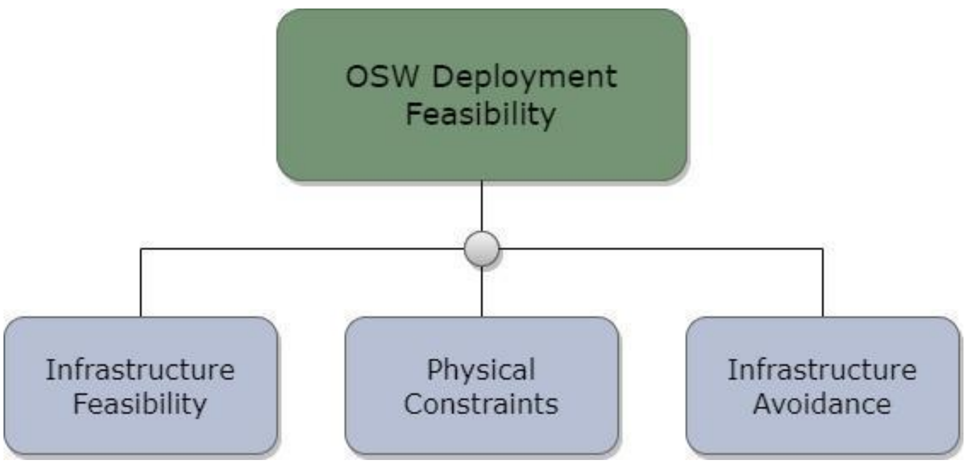


Figure 7. OSW Deployment Feasibility EEMS model structure.

The OSW Infrastructure Deployment Feasibility EEMS model combined 15 total inputs, representing Infrastructure Feasibility, Physical Constraints, and Infrastructure Avoidance (Figure 7). Inputs for the Infrastructure Feasibility component were calculated distances to the nearest coastal substation with an operating voltage greater than 110kV, (based on CEC's selected grid connection locations), and distance to California ports. Considerations for Physical Constraints were water depth and slope of the seafloor. Infrastructure Avoidance inputs included distances to existing physical infrastructure such as submarine cables, oil and gas pipelines, and navigational hazards like buoys or other obstructions.

The thresholds for Infrastructure Feasibility were set with a false threshold at the minimum input data value and a true threshold at the maximum, (i.e., locations closer to electrical grid connections and port infrastructure were assigned higher deployment feasibility). Physical Constraints thresholds were set with input and feedback from

BOEM, CEC, and OSW industry representatives. The false threshold for depth was set to target a fuzzy value of 0 at -1,300 m, indicating deployment feasibility values become increasingly lower in water deeper than 1,300 meters, which is the current, theoretical depth limit for OSW infrastructure deployment, (BOEM, pers. comm.) The false threshold for slope was set to target a fuzzy value of -0.25 at 10 degrees slope, indicating moderately low with decreasing deployment feasibility at locations with slopes greater than 10 degrees. The true threshold for slope was set to the minimum (0 degrees). All Infrastructure Avoidance thresholds were set with a false threshold of 1 km and a true threshold of 3 km, based on guidance from BOEM and CEC. Details of the model's components, input data, and thresholds are shown in Appendix 3, Figure 2 and Tables 3 & 4.

Ocean Use

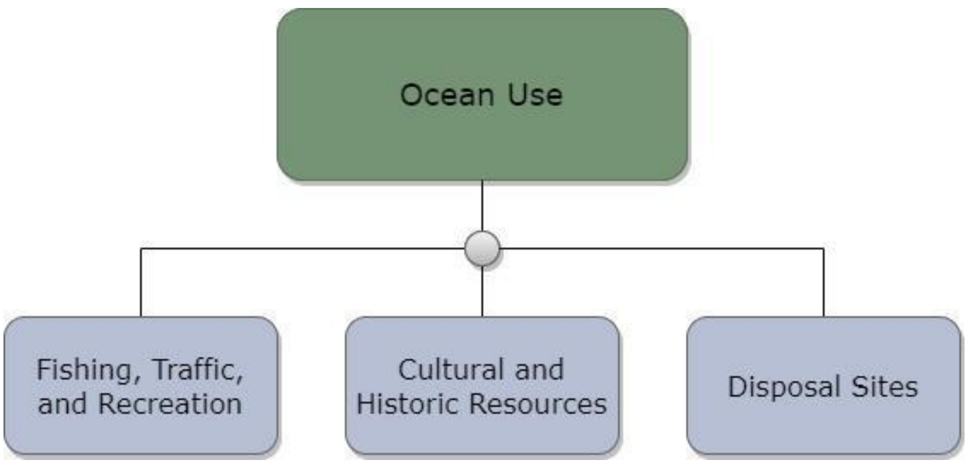


Figure 8. Ocean Use EEMS model structure.

The Ocean Use EEMS model included a total of 48 inputs, representing fishing activity, vessel traffic, recreation, historic and cultural resources, and disposal sites (Figure 8). The State prioritized fishing as a key focus of CBI's data acquisition and modeling efforts; other elements of ocean use represented are less mature in this phase of work. Fishing activity data, quantifying effort and density, included bottom trawl for halibut, sea cucumber, pink shrimp, and groundfish or other fish; midwater trawl for Pacific whiting (hake) or other fish, trolling for albacore and salmon, hook-and-line fishing for sablefish and other fish, pot gear fishing for sablefish, Dungeness crab, and other fish. Historic fishing catch and value for groundfish was also included per recommendation of experts at CDFW. Vessel traffic included vessel transit counts and distances to regulated vessel areas such as shipping lanes, anchorage areas, and pilot boarding stations. Recreation activity included distance to dive sites. Cultural resources combined distance to shore (to capture visual impact concerns) with potential archaeological sites (also of potential relevance to Indigenous communities) and shipwrecks. These aspects of the model should be refined in the future, in line with State needs. Finally, disposal sites inputs were dredge disposal and unexploded ordnance areas.

Fuzzy thresholds for fishing and vessel traffic inputs were set based on the statistical distributions of input datasets, with all false thresholds set at the minimum input value and true thresholds set to four standard deviations from the mean, except for albacore trolling, which was set to two standard deviations from the mean, to better capture nuance in activity patterns. Regulated vessel areas, dive sites, shipwrecks, and disposal sites were all set using a false threshold of 3 km and true threshold of 1 km. Distance to shore and submerged lands probability were both set to a false threshold at the minimum value and true threshold at the maximum value. Details of the model's components, input data, and thresholds are shown in Appendix 3, Figures 3 & 4 and tables 5 & 6.

Environmental Considerations

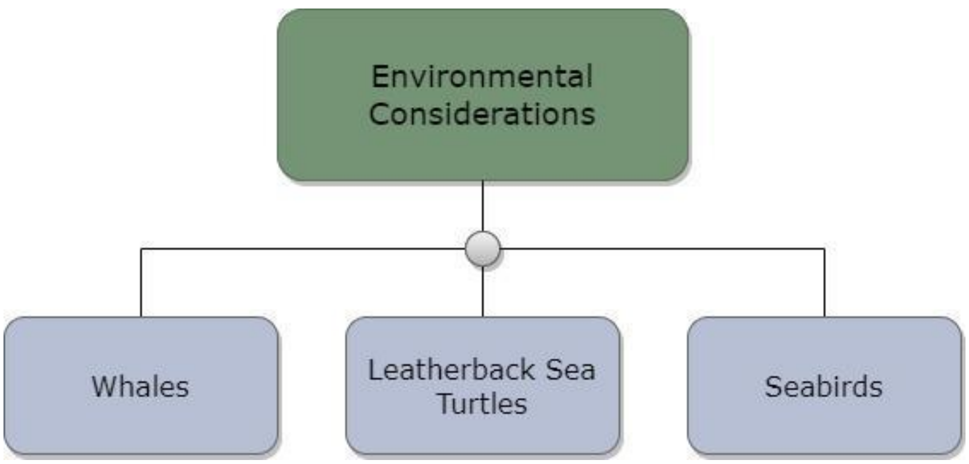


Figure 9. Environmental Consideration EEMS model structure.

The Environmental Considerations EEMS model included 172 inputs representing important and sensitive species of whales, sea turtles, and seabirds (Figure 9). Data inputs included species' predicted densities, habitat suitability, utilization distributions, biologically important areas, and critical habitat. This extensive set of biological data was combined into components based on species' taxa, listing status, and/or population threat status. Baleen whale species included blue, humpback, fin, gray, and minke whales, while toothed whales included Southern Resident killer whale, sperm whale, seven dolphin species, several beaked whales, and Dall's porpoise. The leatherback sea turtle is the sole sea turtle species represented since it is the only one with a potentially significant presence in the study area, based on available data (Maxwell et al. 2013; NOAA pers. comm.). Seabirds included species of alcids, cormorants, grebes, gulls & terns, jaegers & skuas, loons, brown pelican, phalaropes, scoters, and tubenoses (albatrosses, storm-petrels, and petrels & shearwaters).

Fuzzy thresholds for predicted densities, utilization distributions, and habitat suitability were all set based on the statistical distributions of the input data. All whale predicted density and utilization distribution inputs were set to a false threshold at the minimum value and true threshold at 1.5 standard deviations from the mean. Biologically important areas (BIAs) for whales were set to a false threshold of 20 km and true threshold of 1 km from the area, except for gray whale, which was set to a false threshold of 15 km and true threshold targeting a fuzzy value of -0.25 at 1 km, to keep the species representation constrained to the broad BIA.

All whale critical habitat inputs were set to a false threshold of 15 km and true threshold of 1 km. Seabird predicted density and utilization distribution inputs were set to a false threshold at the minimum value and true threshold at 2 standard deviations from the mean. Leatherback sea turtle critical habitat thresholds were set to a false threshold of 15 km and true threshold of 1 km, while the utilization distribution was set at the minimum value and true threshold at 1.5 standard deviations from the mean. Details of the model's components, input data, and thresholds are shown in Appendix 3, Figures 5 & 6 and Tables 7 & 8.

Study Results and Findings

The Conservation Biology Institute created models showing offshore wind energy planning considerations, summarized to BOEM's aliquots, for the following themes: 1. Wind Energy Potential, 2 OSW Infrastructure Deployment Feasibility, 3. Ocean Use, 4. Environmental Considerations. The analysis structure of each model, input data, and the model's mapped outputs can be examined and visualized in detail on the California Offshore Wind Energy Modeling Platform.

Models have output map scores ranging from -1 to +1, which can essentially be interpreted as a composite index with a range of low (-1), to moderate (0), to high (+1) at a given location for each theme and its components: wind energy potential, OSW infrastructure deployment feasibility, ocean use activity, and marine life presence. Note, jurisdictions and exclusions could be overlaid on analysis results to better understand where OSW development may be feasible or legal.

Modeling Results

The outputs for the top level of each model are depicted below (Figures 10, 11, 13, and 15) and the main findings reported. Note, all maps show the relative score for each location, on a continuum of values generated for federal waters off the coast of California. The top level score takes all lower components (i.e., "model ingredients" and input data) into account; however, it is important to use the online interface to explore the scores for the different components contributing to the theme, since each of these are valuable outputs in their own right and can be used to understand what factors are influencing a given outcome. In the maps below and on the interactive website, dark green areas have the highest scores, (i.e., are locations with the highest energy resources, deployment feasibility, ocean use activity, or marine life presence), and dark purple areas have the lowest scores, (i.e., are locations with the lowest energy resources, deployment feasibility, ocean use activity, or marine life presence).

1. Wind Energy Potential

The Wind Energy Potential model results show that high to very high wind energy potential exists across the majority of federal ocean waters off of the California Coast. Waters off of the North Coast have very high wind energy potential, and waters off of Southern California have the lowest wind energy potential, with areas shown in purple generally considered to be less ideal for offshore wind energy development (Figure 10). In the future, this model could be refined with further input from the CEC, BOEM, NREL, and OSW experts.

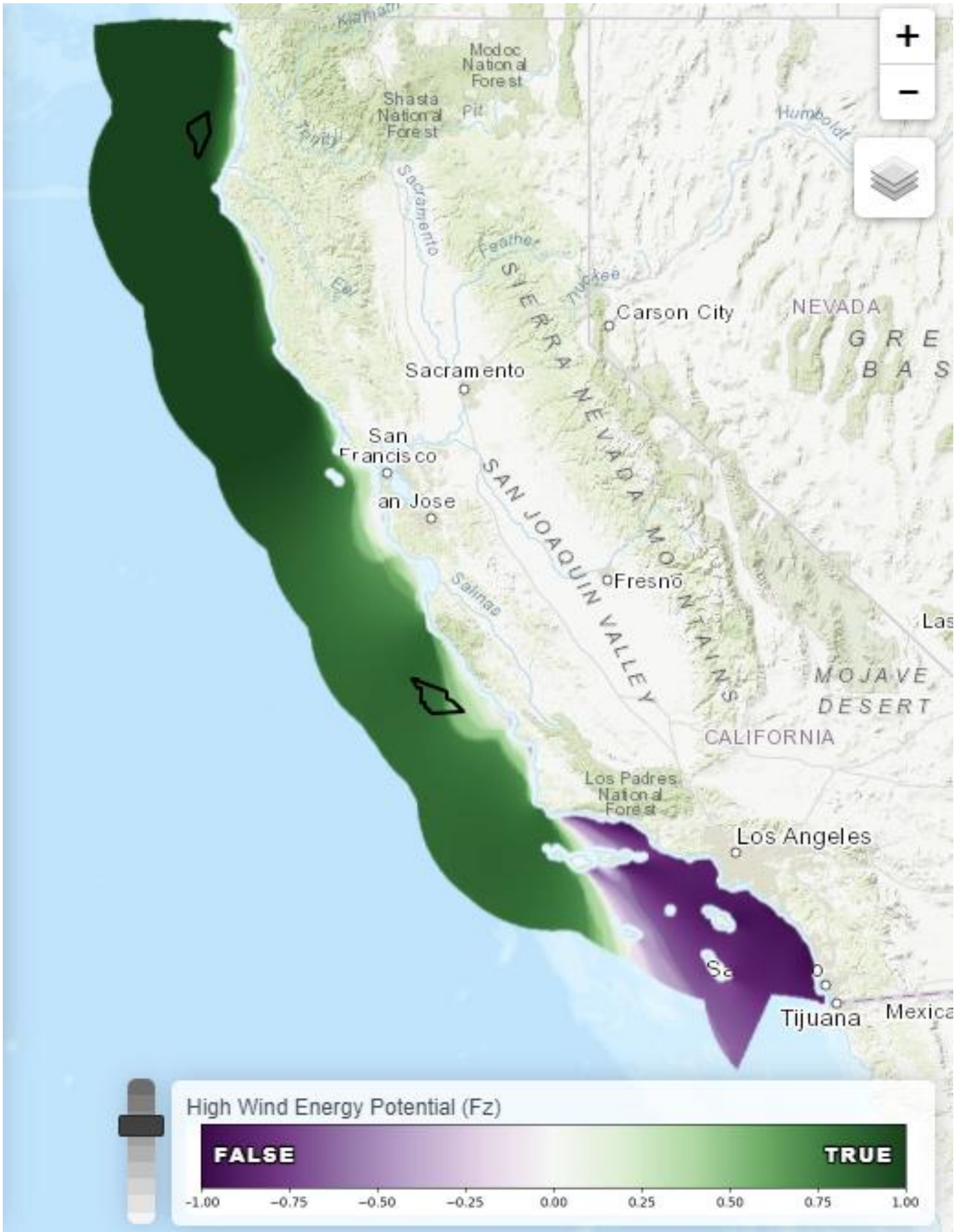


Figure 10. Wind Energy Potential model results show the relative score for each location, for federal waters off the coast of California. Scores range from “Low” (False, -1) to “High” (True, +1). Dark green areas have the highest wind energy potential and dark purple areas have the lowest.

2. OSW Infrastructure Deployment Feasibility

The OSW Infrastructure Deployment Feasibility model results show that deployment feasibility in federal waters increases with proximity to the California Coast (Figure 11). Areas nearer to shore provide better access to ports and power grid connections. Water depth, influenced by the sharp seafloor drop-off off the West Coast is a major consideration for deployment of OSW infrastructure. Our model depicts OSW deployment feasibility becoming lower as water becomes deeper than 1,300 meters; however, a hard cutoff is not implemented in the model.

Since concentrations of existing ocean use and marine biota occur nearer to shore, it could be beneficial to deploy OSW infrastructure as far from the coast as is feasible, to minimize potential interactions. Floating OSW technology is evolving quickly (Beiter et al. 2020; Figure 12), so it may be useful to consider deeper areas, (with appropriate constraints as advised by OSW experts and industry), for long-term time horizons. Note that seismic activity is not currently factored into this model, though could be in subsequent iterations. In the future, this model could be refined with additional input from the CEC, BOEM, NREL, and OSW experts.

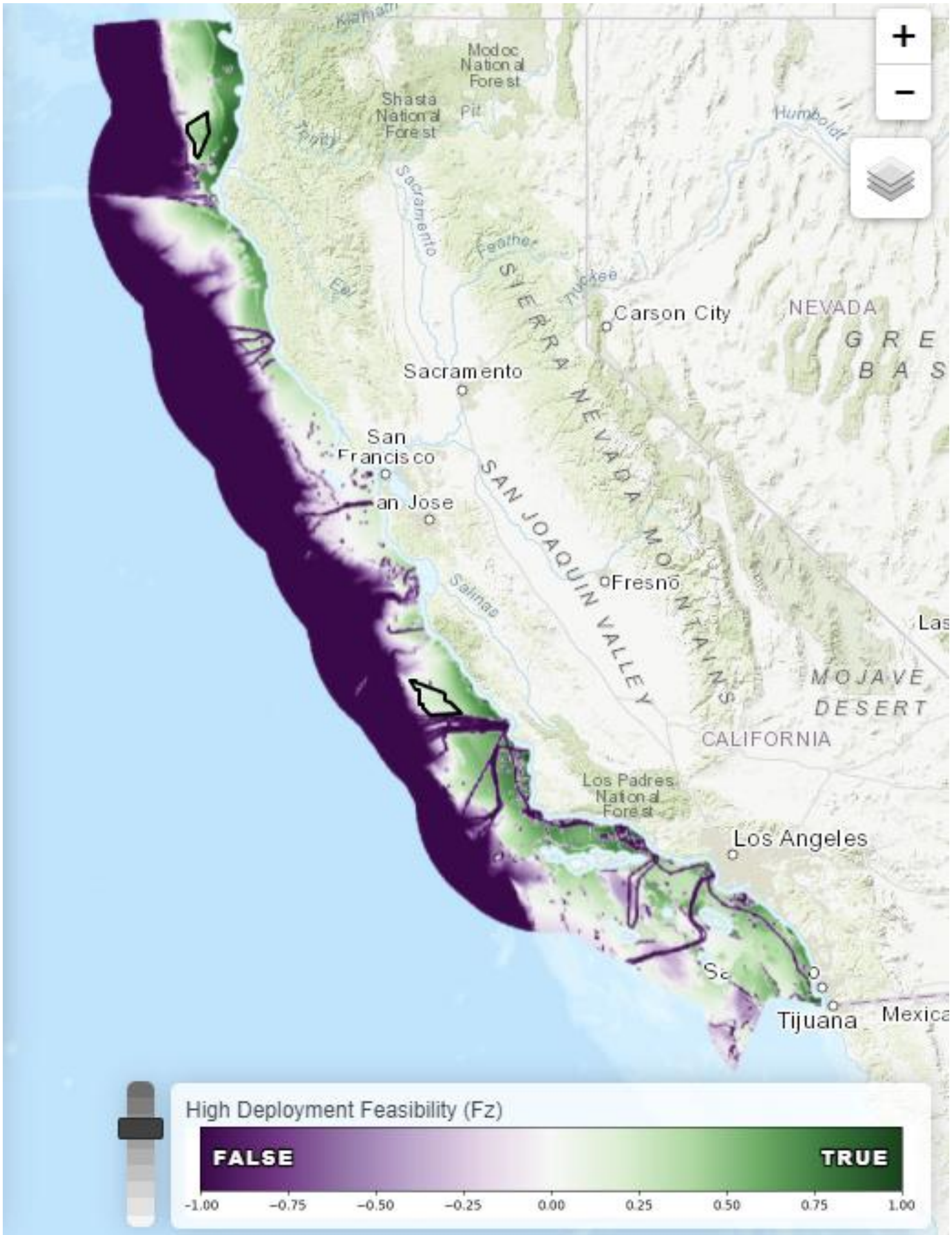


Figure 11. OSW Deployment Feasibility model results show the relative score for each location, for federal waters off the coast of California. Scores range from "Low" (False, -1) to "High" (True, +1). Dark green areas have the highest deployment feasibility and dark purple areas have the lowest.

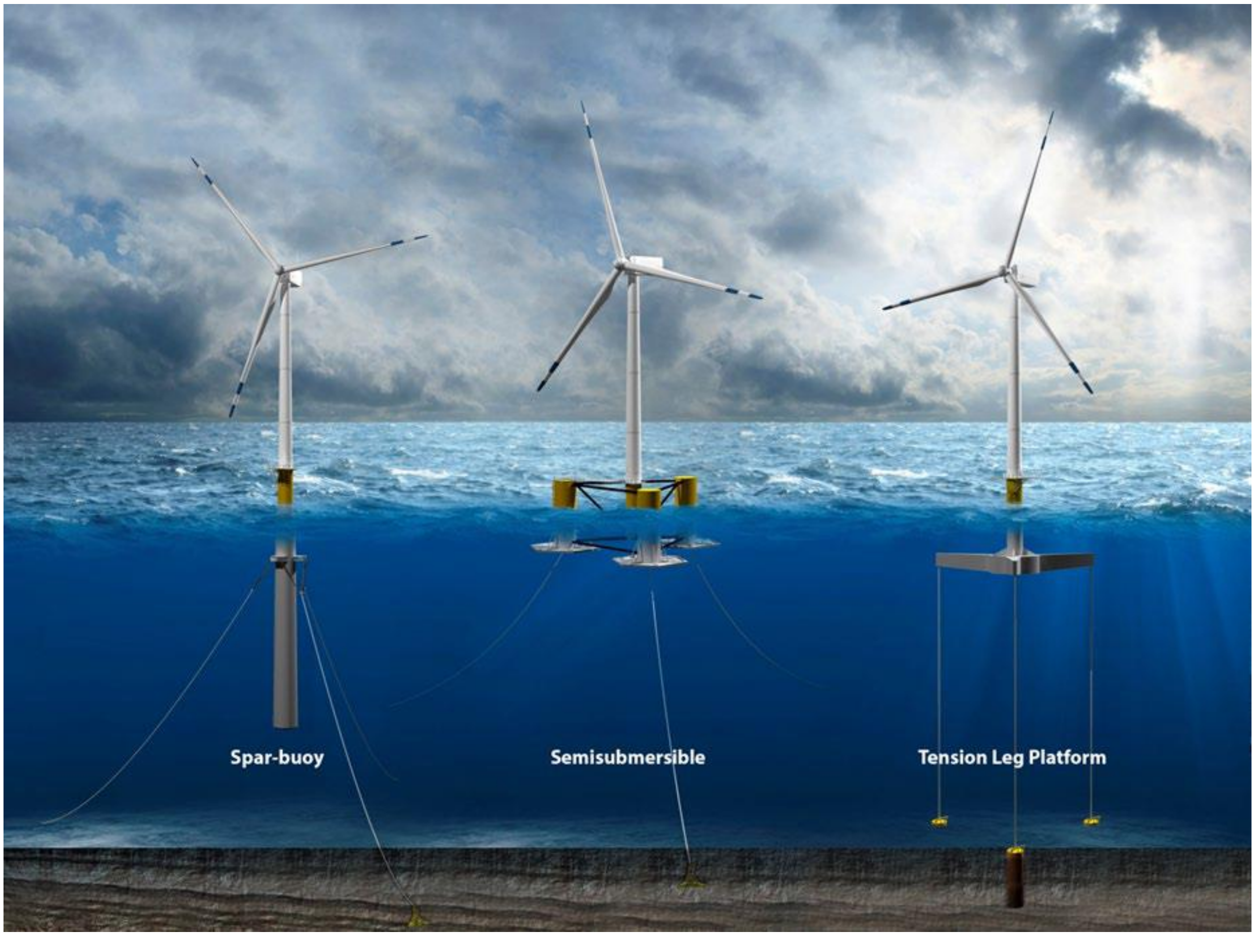


Figure 12. Three designs for floating offshore wind turbine technology being developed. Each of these substructure archetypes have evolved or been adapted from deep-water oil and gas production platforms, (Beiter et al. 2020). *Illustration by Josh Bauer, NREL*.

3. Ocean Use

The Ocean Use model reiterates that federal waters off California have a wealth of existing ocean uses. Ocean use activity (including commercial fishing, vessel transit, and recreation activities, as well as cultural & historic resources and ocean disposal sites) is generally highest in federal waters near the California Coast, within ~20 miles of shore (Figure 13). However, use of deeper waters does occur, especially for certain types of commercial fishing.

The Ocean Use model's fishing component shows that both Wind Energy Areas (WEAs) avoid places with the highest fishing activity (Figure 14). However, some fishing activity takes place in each WEA - bottom trawl occurs in the Humboldt WEA and trolling and pot trap fishing in the Morro Bay WEA. Note that the primary measures of fishing activity captured by the model include fishing effort and density, not financial value or catch of the fishery resource, (though catch and value are represented in the historical groundfish component, which was included based on feedback from agency experts).

In the future, this model could be refined as new data becomes available, especially to include better representation of fisheries targeting highly migratory species and local activities not well-captured by current data, as well as to represent forecast shifts in activity patterns based on changes in climate. The recreation and cultural value components could also be enhanced, (particularly with local and Indigenous community feedback). Continuation of ongoing engagement with stakeholders is recommended to gain additional understanding around commercial fishing and other important ocean uses, to ensure valuable perspectives not represented by spatial data are taken into account during the OSW planning process.

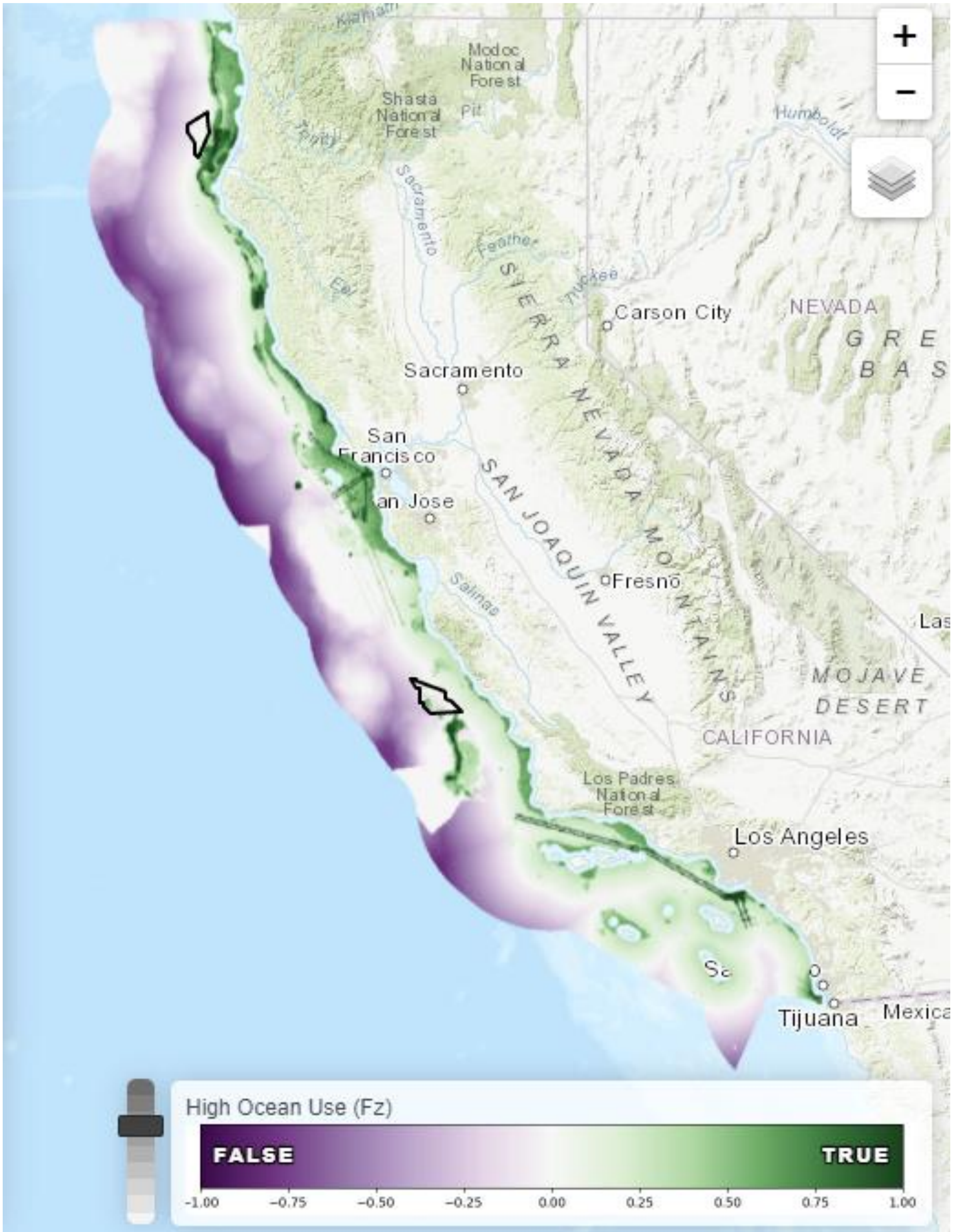


Figure 13. Ocean Use model results show the relative score for each location, for federal waters off the coast of California. Scores range from “Low” (False, -1) to “High” (True, +1). Dark green areas have the highest ocean use activity and dark purple areas have the lowest.

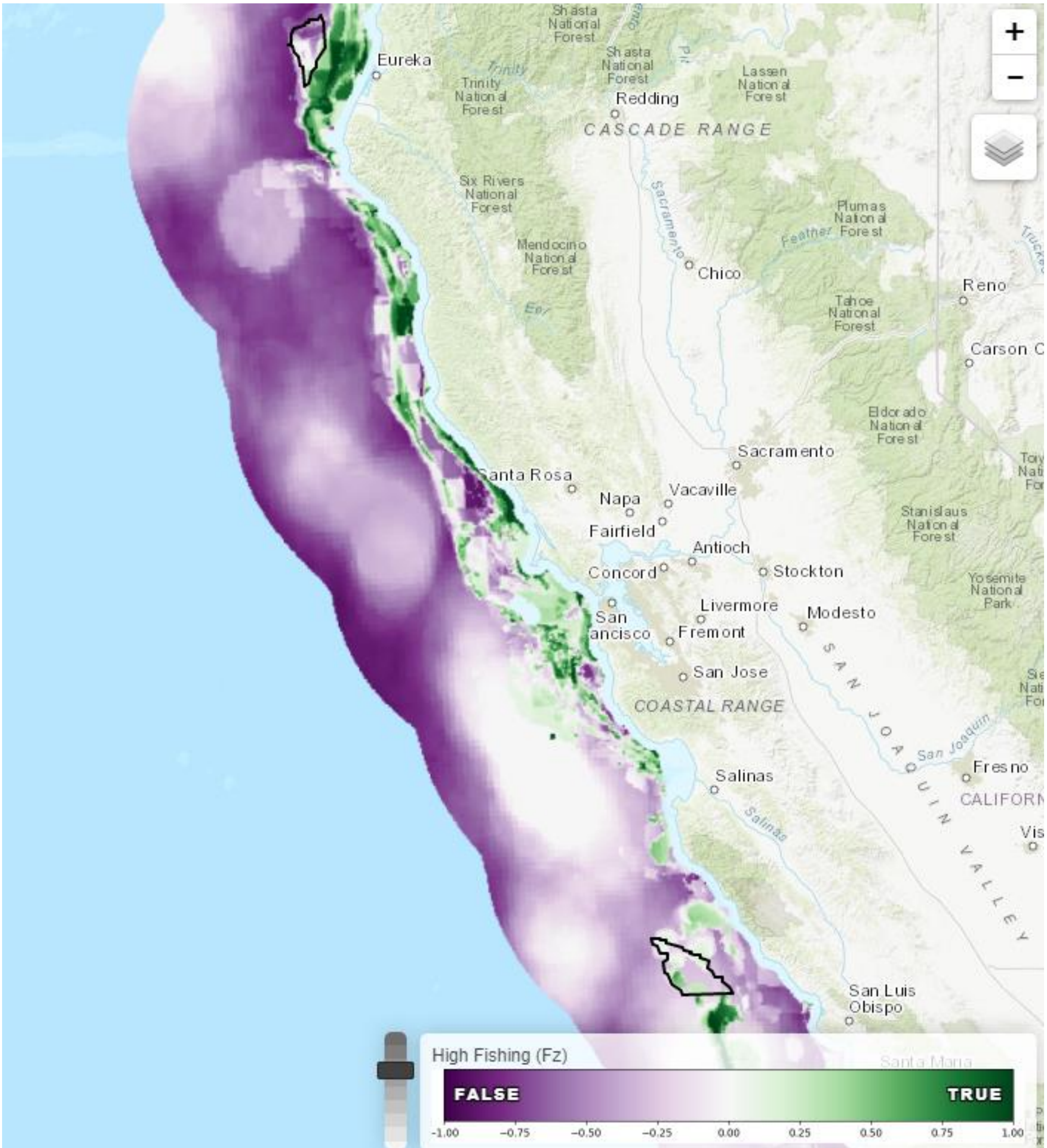


Figure 14. The Ocean Use model's fishing component shows that the Wind Energy Areas avoid places with the highest fishing activity (dark green). However, some fishing activity takes place in each WEA - bottom trawl in the Humboldt WEA and trolling and pot trap fishing in the Morro Bay WEA. Green areas have higher fishing activity and purple areas lower activity.

4. Environmental Considerations

The Environmental Considerations model illustrates that federal waters off the California Coast support a rich ecosystem with diverse marine life, including protected whales, seabirds, and turtles. Recall that species with a higher threat or protected status, (e.g. endangered), were weighted more heavily in the model.

In general, marine life presence, (as represented by a composite index of species occurrence, activity, density, and/or habitat), is higher in federal waters near the California Coast (Figure 15). The very highest concentrations occur in waters off the Bay Area (roughly from Mendocino to Point Sur) and south from San Luis Obispo to Lompoc. The composite index shows moderate to high concentrations of species occur in waters less than ~20 miles off the North Coast, whereas moderate to high species concentrations extend to ~40 miles off the greater Bay Area, Central Coast, and further south.

The Environmental Considerations model shows both Wind Energy Areas (WEAs) avoid places with the highest concentrations of protected species. However, based on the data incorporated into the model, some protected species have the potential to occur in each WEA. For example, endangered humpback, fin, and blue whales show moderately high presence in the Morro Bay WEA and blue whales show moderately high presence in the Humboldt WEA. The endangered leatherback sea turtle shows a moderate level of activity in the Morro Bay WEA, which overlaps the species' critical habitat. Seabirds with high threat status that may occur in the WEAs during at least one season, (showing moderate values based on normalized predicted densities), include marbled murrelet, tufted puffin, ashy storm-petrel, and pink-footed shearwater. Of these, pink-footed shearwater is the only species with a high threat status to show high concentrations in a Wind Energy Area (Morro Bay).

Many other species were included in this model and should be examined on an individual basis using the interactive online interface to evaluate where areas of concentrated species activity may occur. Of particular interest is the rich spatial data on seabirds, depicting the relative density of species and species groups across multiple seasons. It should be noted that the documentation for model input datasets and application caveats should be carefully read and understood when using these models (Leirness et al. 2021).

In the future, this work could be expanded to include additional species, (such as seals, sea otters, sea lions, bats, and krill), and to add ecological characteristics, (such as productivity and upwelling), that play an important role in the California Current System.

Data on forecast shifts in species' ranges based on changes in climate and dynamic products could also be added as these become available. Continuation of ongoing engagement with experts is recommended to ensure valuable information not represented by spatial data is taken into account during the OSW planning process.

Lastly, individual species sensitivity and vulnerability to OSW deployment are not factored into the current analysis. Results identify where species may be present and potential interactions might occur, not where impacts will occur. Of note, a recent review of potential environmental effects of floating OSW highlighted that many factors (physical, acoustic, electromagnetic, and infrastructure) appear to have low potential for major impact or could be mitigated. - Monitoring data from pilot facilities could be invaluable in helping understand actual environmental effects in-situ (Farr et al. 2021).

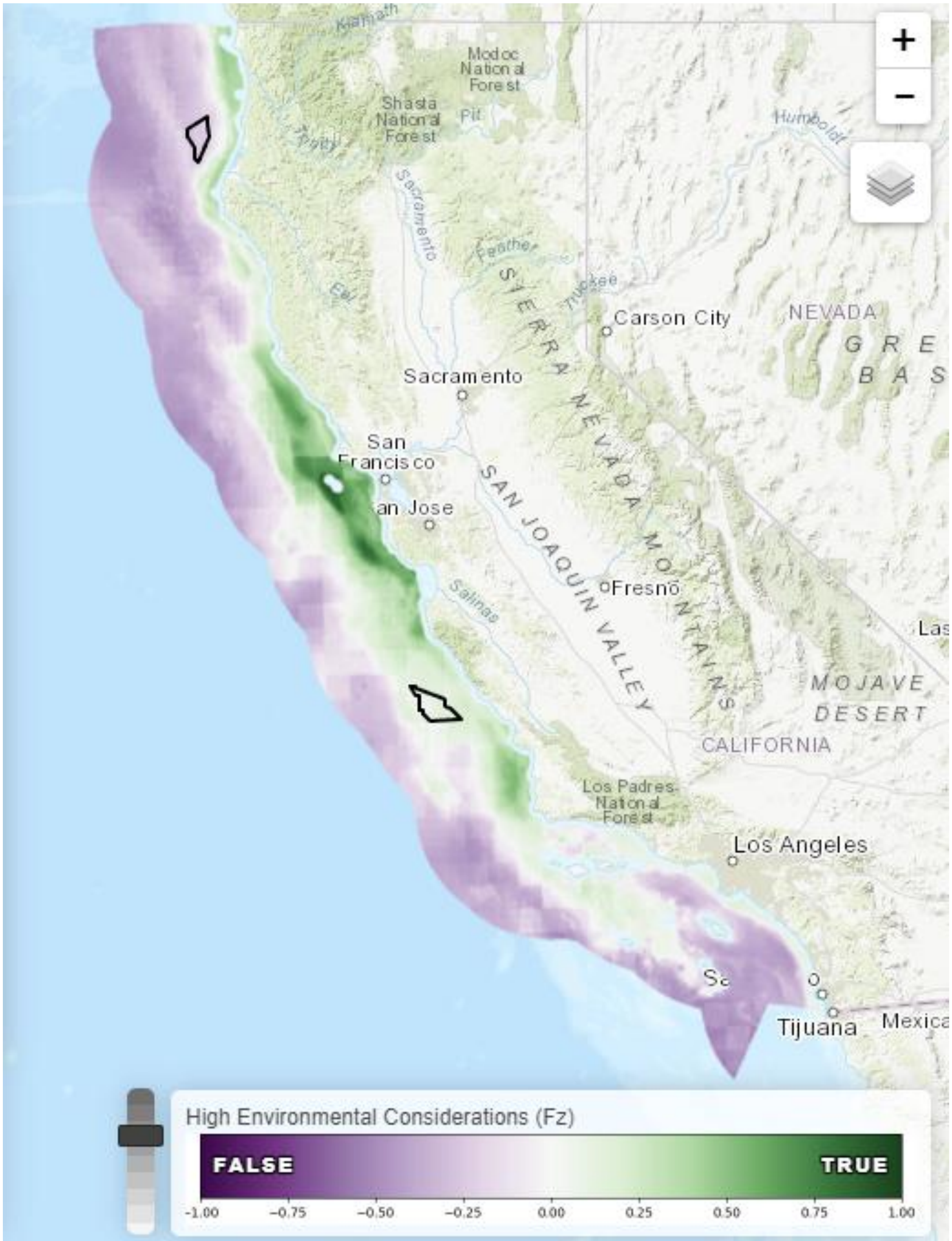
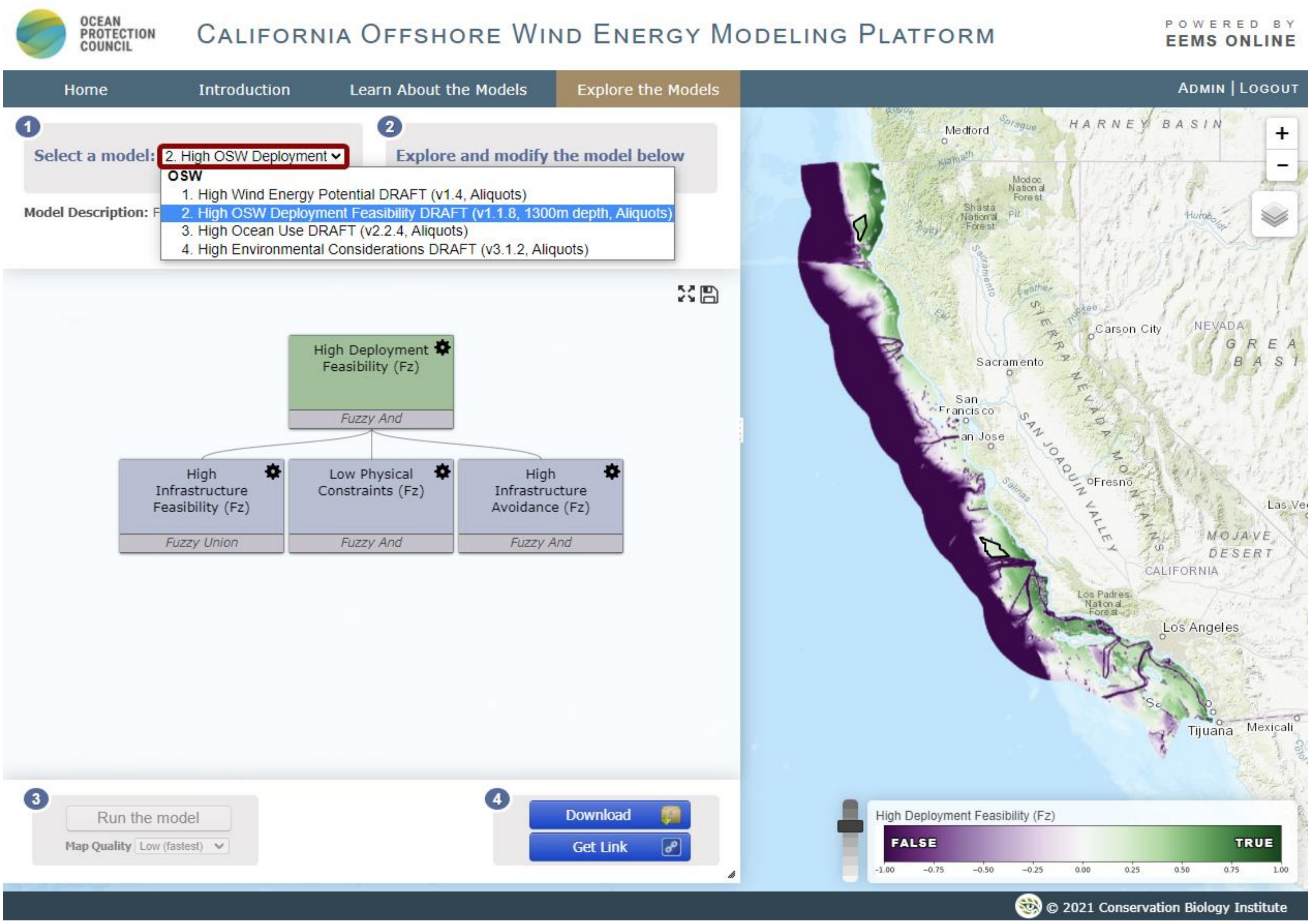


Figure 15. Environmental Considerations model results show the relative score (a composite index of marine life presence, represented by species occurrence, activity, density, and/or habitat) for federal waters off the coast of California. Scores range from “Low” (False, -1) to “High” (True, +1). Dark green areas have the highest species (whales, seabirds, turtle) presence and dark purple areas have the lowest, weighted to emphasize species with a higher threat or protected status.

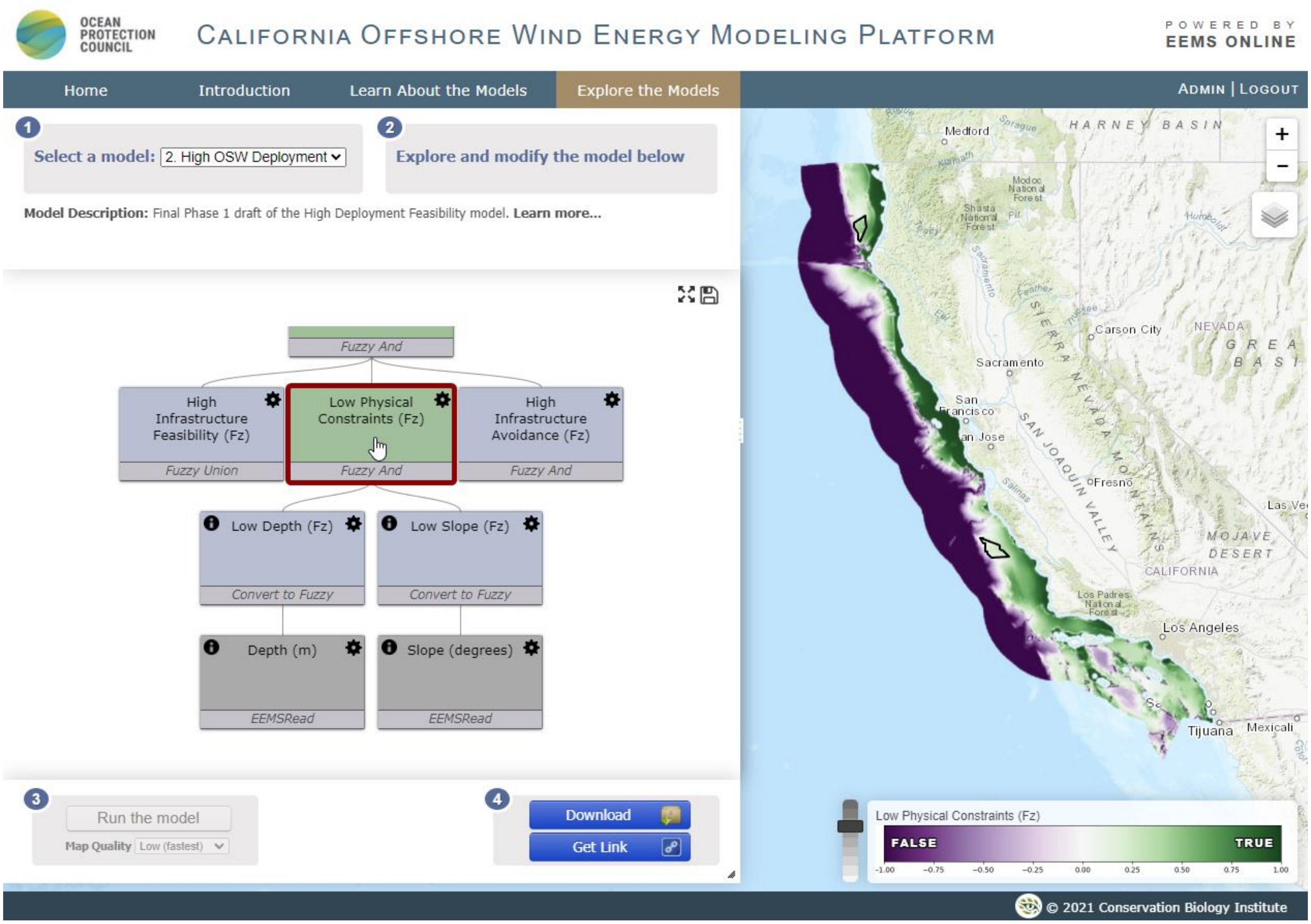
Exploring Results with [EEMS Online]

The model outputs and all components can be examined and visualized in detail on the [California Offshore Wind Energy Modeling Platform], using EEMS Online interactive technology.

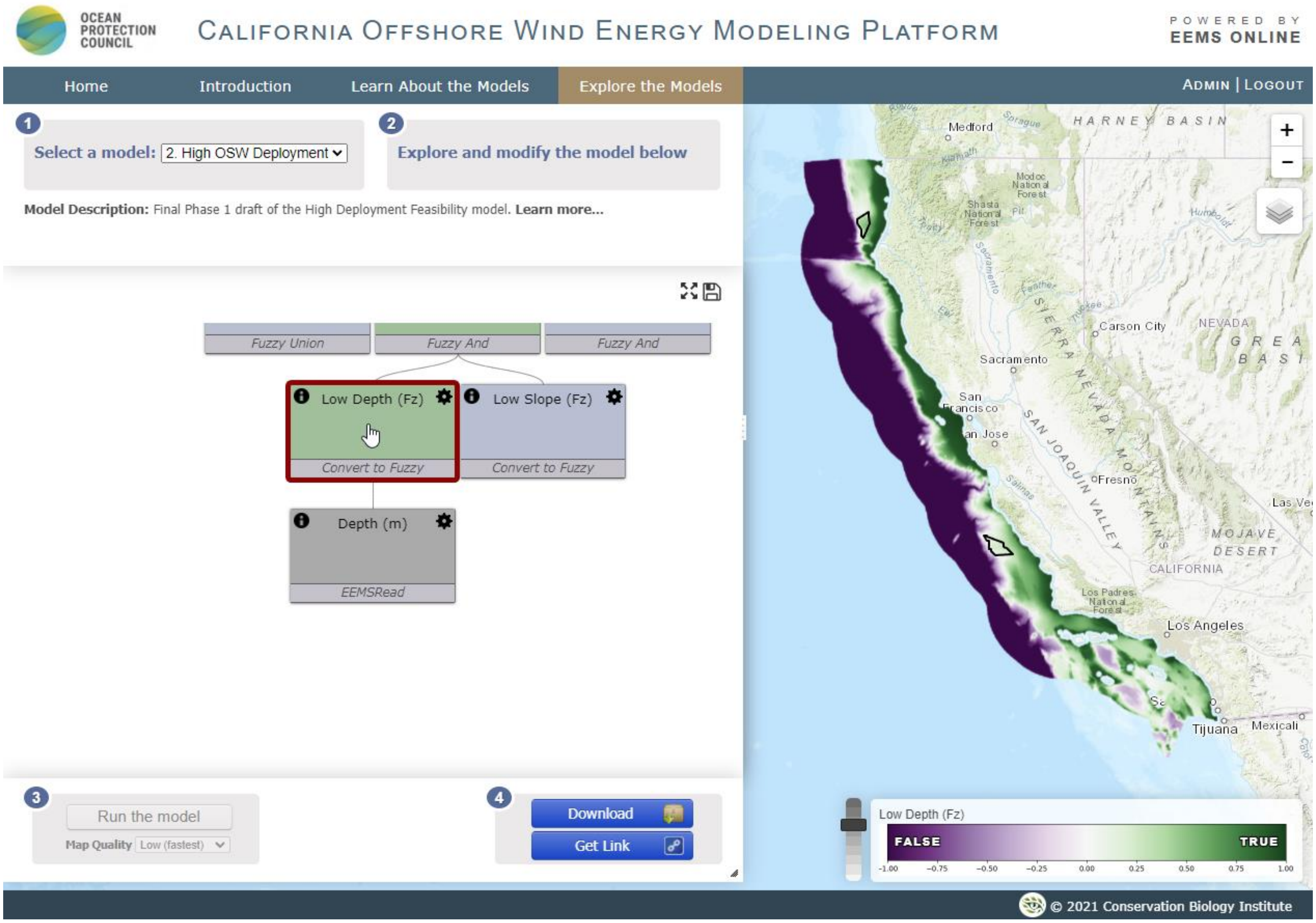
To explore the models, first pick the model of interest from the dropdown on the left.



Then, click on the model component you're interested in. For this example, we're interested in physical constraints to offshore wind development. For all models, green is higher (true) and purple is lower (false) on the fuzzy value continuum for the given statement, which in this case is "Low Physical Constraints". Recall that model components have output scores ranging from -1 to +1, which can essentially be interpreted as a composite index with a range of low (-1, false), to moderate (0, neutral), to high (+1, true) at a given location for each theme.

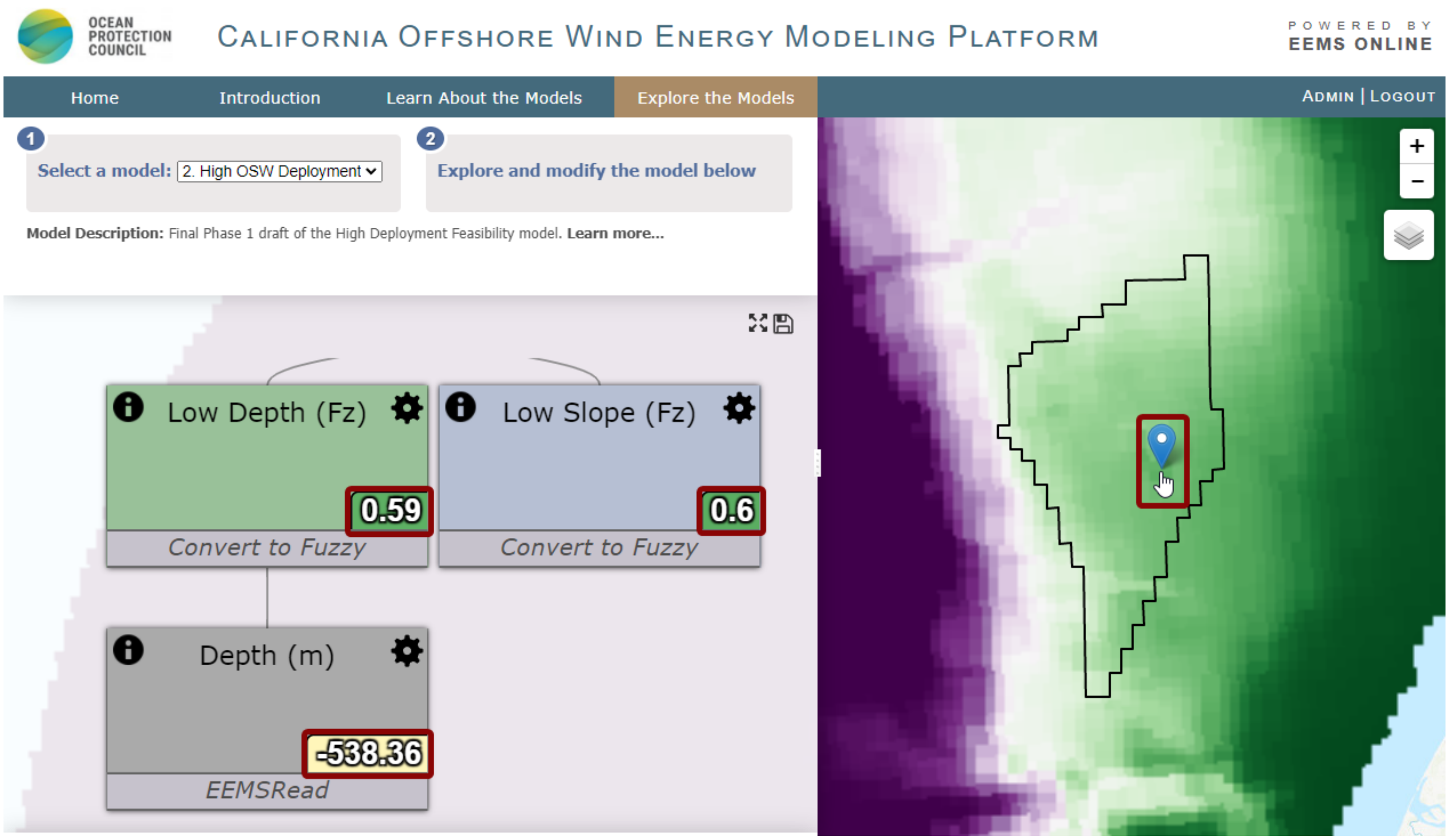


Note how the map on the right updates to display the output for the specific model component you've selected.

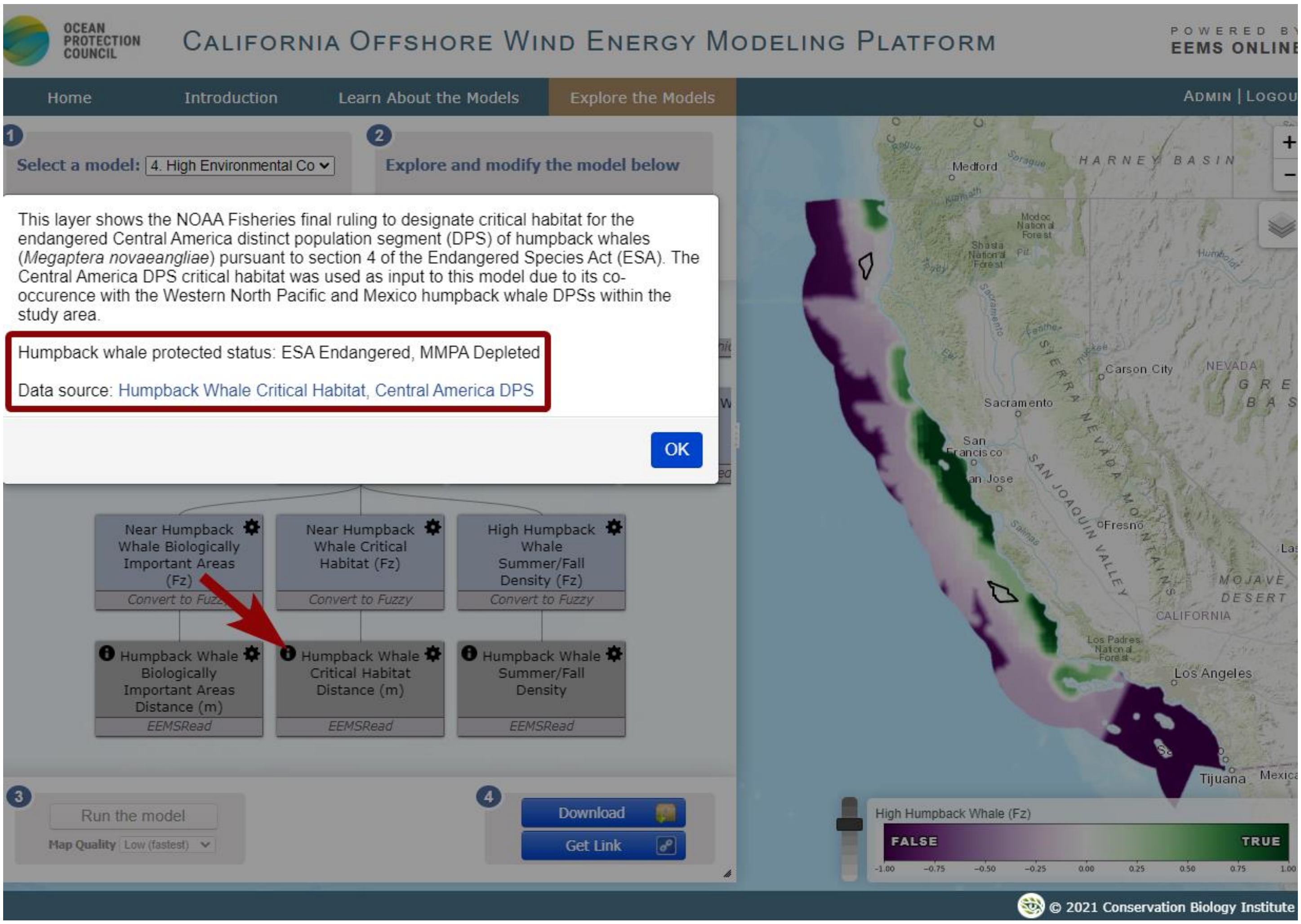


It is important to use the online interface to explore the scores for the different components contributing to the theme, since each of these is valuable in its own right and can be used to understand what factors are influencing a given outcome.

To examine model output values, click on the map in your location of interest. EEMS Online will show the scores for all components of the model in the location you selected.



All input data can be explored, as well. Navigate to the bottommost node and click the "i" symbol to open the information pop-up. Click the data source link to open a new browser window displaying the source data page in the CA Offshore Wind Energy Gateway. For select sensitive marine species, information on their threat or protected status is included in this interface, along with source data information.



Appropriate Use

The Conservation Biology Institute's set of models is a powerful tool to visualize key data to provide information on geographic distribution of species occurrence and ocean use, relevant to offshore wind energy deployment in California. It is a useful line of evidence to highlight areas with maximum offshore wind energy potential and infrastructure deployment feasibility, as well as areas with high existing ocean uses and marine life occurrence relative to input data values across the statewide range. Values and patterns indicate where there might be interactions, but not impacts related to offshore wind energy deployment.

It is also important to understand the limitations of these models, in part dictated by data availability. The models do not provide a sensitivity or vulnerability evaluation and should not be used to identify or assess project-level impacts, including NEPA or CEQA analyses. Additionally, datasets reflect currently understood geographic distribution of species occurrence and ocean use and do not take into account climate change and species' shifting ranges. The focus of the project was on federal waters off California and should not be used to assess activities in state waters (within 3 nautical miles of shore) or areas beyond California. Note, jurisdictions and exclusions can be overlaid with analysis results to better understand where OSW development may be feasible or legal.

Applications & Path Forward

The Conservation Biology Institute is providing findings to support the State of California in using the spatial data and modeling outcomes of this project as a source of information for strategic planning, energy resource and transmission planning, engaging with stakeholders, and other decision-making. These thematic EEMS models offer one source of information the State can consider during offshore wind energy planning.

In the future, CBI's modeling approach could be extended geographically, (e.g. to California's state waters or to Oregon for regional planning efforts), and/or enhanced with additional data, based on agency and stakeholder priorities. Note, if analysis of state waters is pursued, we suggest coverage be undertaken with a separate modeling effort rather than expansion of the current set of models, since multiple gaps for marine species data exist near the shoreline; a potential solution is creation of custom models for state waters using different input data for pelagic species, facilitating inclusion of additional near-shore species, as well.

Lastly, the Conservation Biology Institute's current work could be leveraged to further support CEC's strategic planning for AB 525 by combining the thematic models into a robust least-conflict analysis to highlight areas most suited for exploration of OSW development, under different scenarios.

There is a need for continued investment, to keep the analysis current and relevant throughout the different stages of offshore wind energy planning in California.

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Appendix

A1. Reporting Units and Study Area

BOEM Aliquots

Aliquots are generated from full Outer Continental Shelf (OCS) blocks by subdividing each block into 16ths to allow for more detailed boundary delineation in offshore energy leasing. OCS lease blocks serve as the legal definition for BOEM offshore boundary coordinates used to define small geographic areas within an Official Protraction Diagram (OPD) for leasing and administrative purposes. OCS blocks relate back to individual Official Protraction Diagrams and are not uniquely numbered. Aliquots use a letter designation in addition to their parent protraction number and OCS block number (i.e. NK-1802, 6822F). A full OCS block is 4800 x 4800 meters, while an aliquot measures 1200 x 1200 meters. Smaller, clipped aliquots are found along the Fed/State OCS boundary and along UTM zone borders.

Table A1-1. Description of study area geographic boundaries.

Boundary	Description
North	Pacific Admin Boundary for California
East	Fed-State SLA Boundary (3 NM from shoreline)
South	U.S. Pacific EEZ
West	67.06 nautical miles from SLA Boundary

A2. Wind Turbine Power Curves

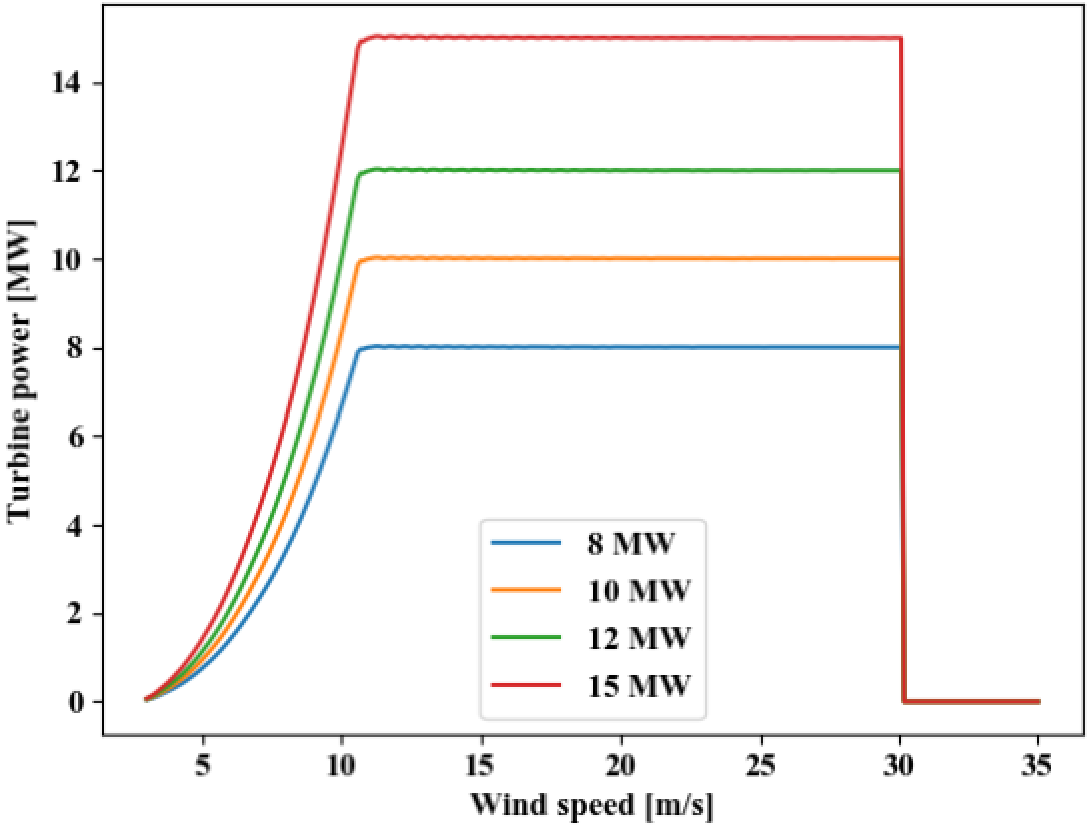

Figure A2-1. Offshore wind turbine power curves from Beiter et al. 2020. Power curves correspond to 2019, 2022, 2027, and 2032 technology assumptions.

A3. Model Input Data and Thresholds

Table A3-1. Wind Energy Potential EEMS model input data. Model structure shown below.

Input	Data Description	Data Provider(s)	Gateway Link
Annual Avg Wind Speed	Annual average wind speed, in meters per second.	California State University Northridge, BOEM, NREL; Optis et al. 2020	[Offshore Wind Variables Summarized By Aliquot]
Annual Avg Evening Wind Speed	Annual average wind speed, in meters per second, between 5:00 - 9:00 pm Pacific Time.		
Num Months Avg Wind Speed > 7 m/s	Annual number of months with an average wind speed greater than 7 meters per second.		
Num Months Avg Evening Wind Speed > 7 m/s	Annual number of months with an average wind speed greater than 7 meters per second, between 5:00 - 9:00 pm Pacific Time.		

Table A3-2. Wind Energy Potential EEMS model fuzzy thresholds.

Input	Input theme (units)	False Threshold	True Threshold
Annual Avg Wind Speed Annual Avg Evening Wind Speed	Annual Wind Speed (m/s)	Min	10
Num Months Avg Wind Speed > 7 m/s Num Months Avg Evening Wind Speed > 7 m/s	Monthly Wind Speed (number of months)	Min	Max

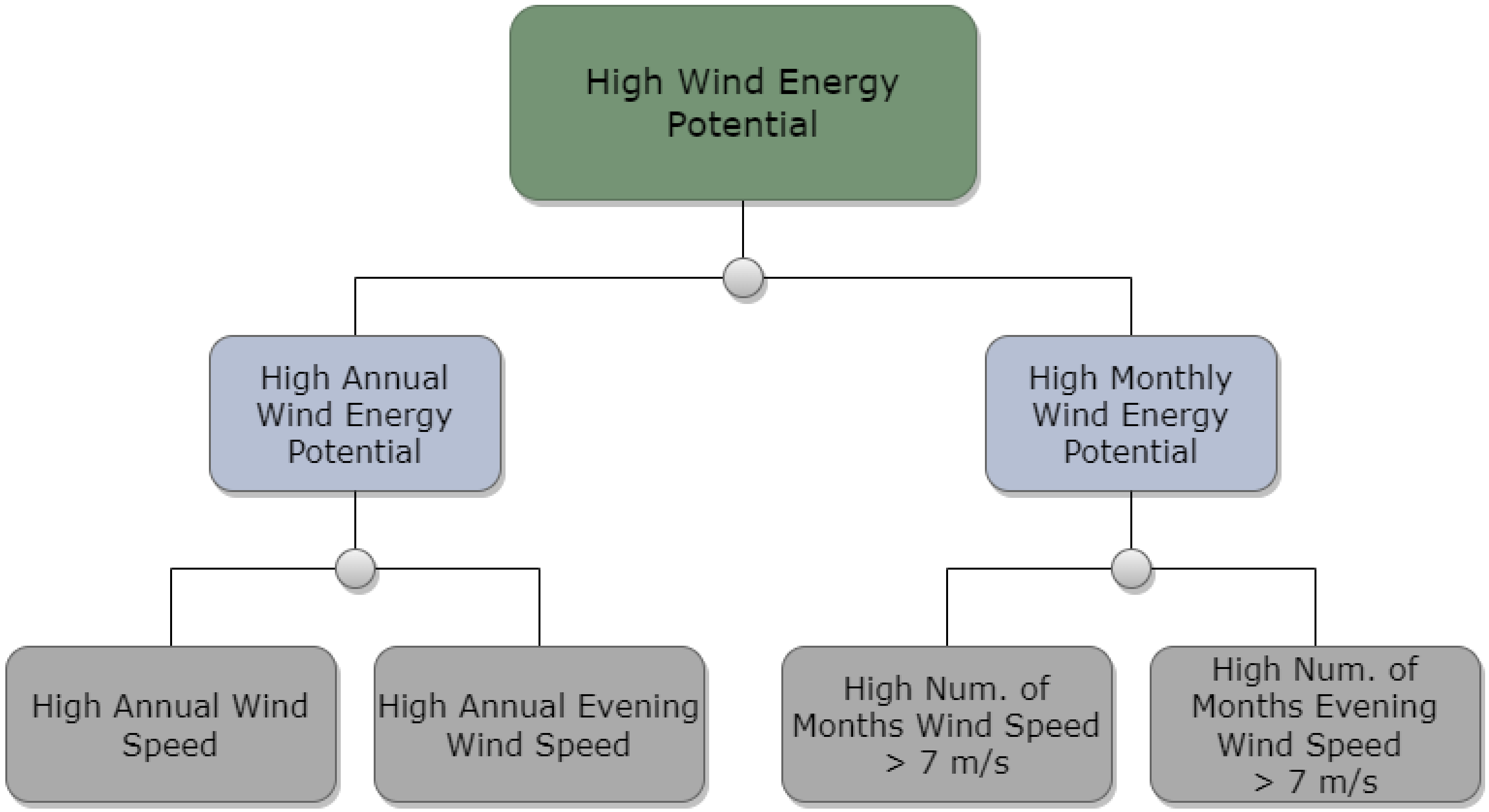

Figure A3-1. Wind Energy Potential EEMS model detailed structure. This model estimates energy potential by considering annual, monthly, and evening components of the offshore wind energy resource. For complete interactive components see interactive models on osw.eemsonline.org.

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Table A3-3. OSW Deployment Feasibility EEMS model input data. Model structure shown below.

Input	Data Description	Data Provider(s)	Gateway Link
Offshore Wind Energy Potential Substations [>110kV]	Grid connections are represented by all potentially viable substations with an operating voltage greater than 110 kilovolts. The following substations were excluded from this analysis: Moss Landing, San Mateo, Martin, Ignacio.	Oak Ridge National Laboratory, HIFLD Subcommittee, BOEM, CEC	Offshore Wind Energy Potential Substations [>110kV]
California Ports	Coastal California ports.	CDFG Marine Region GIS Lab, Chad King, 2001	California Ports
GEBCO 2020 Bathymetric Grid, Pacific EEZ	Depth of the ocean floor, in meters. The GEBCO 2020 Grid is the latest global bathymetric product released by the General Bathymetric Chart of the Oceans (GEBCO) and has been developed through the Nippon Foundation-GEBCO Seabed 2030 Project.	GEBCO Compilation Group	GEBCO 2020 Bathymetric Grid, Pacific EEZ
GEBCO 2020 Slope, OPC OSW Study Area	Slope of the ocean floor, in degrees. Derived from the GEBCO 2020 Bathymetric Grid.	GEBCO Compilation Group	GEBCO 2020 Slope, OPC OSW Study Area
Coastal Cable Submarine line - NOAA	Coastal cable submarine lines. Nautical chart features contained within a NOAA ENC provide a detailed representation of the U.S. coastal and marine environment. ENC Direct to GIS data is organized by scale band, and there are six scale bands available: Overview, General, Coastal, Approach, Harbor, and Berthing.	NOAA	Coastal Cable Submarine line - NOAA
Submarine Cables	The source data depicts the occurrence of submarine cables in and around U.S. navigable waters. Source geometry and attributes were derived from 2010 NOAA Electronic Navigation Charts and 2009 NOAA Raster Nautical Charts.	NOAA Office for Coastal Management	Submarine Cables
Coastal Cable Area - NOAA	Submarine Cable Areas may contain one or more submarine cables. The geographic scope of that area is governed by local conditions but shall include the immediate area which overlies a cable. Nautical chart features contained within a NOAA ENC provide a detailed representation of the U.S. coastal and marine environment. ENC Direct to GIS data is organized by scale band, and there are six scale bands available: Overview, General, Coastal, Approach, Harbor, and Berthing.	NOAA	Coastal Cable Area - NOAA

Harbor Cable Area - NOAA	Submarine Cable Areas may contain one or more submarine cables. The geographic scope of that area is governed by local conditions but shall include the immediate area which overlies a cable. Nautical chart features contained within a NOAA ENC provide a detailed representation of the U.S. coastal and marine environment. ENC Direct to GIS data is organized by scale band, and there are six scale bands available: Overview, General, Coastal, Approach, Harbor, and Berthing.	NOAA	Harbor Cable Area - NOAA
Approach Pipeline Area - NOAA	Pipeline areas are any area which contains one or more types of pipelines. Within protected waters such as harbors, rivers, bays, estuaries or other inland waterways, the location of pipelines is indicated as "Pipeline area" on NOAA nautical charts and maps. Nautical chart features contained within a NOAA ENC provide a detailed representation of the U.S. coastal and marine environment. ENC Direct to GIS data is organized by scale band, and there are six scale bands available: Overview, General, Coastal, Approach, Harbor, and Berthing.	NOAA	Approach Pipeline Area - NOAA
Approach Pipeline Submarine on Land - NOAA	Pipeline submarine on land line. Nautical chart features contained within a NOAA ENC provide a detailed representation of the U.S. coastal and marine environment. ENC Direct to GIS data is organized by scale band, and there are six scale bands available: Overview, General, Coastal, Approach, Harbor, and Berthing.	NOAA	Approach Pipeline Submarine on Land - NOAA
BOEM Pacific Oil and Gas Pipelines - 2011	This dataset contains the locations of oil and gas pipelines in the Bureau of Ocean Energy Management Pacific OCS Region.	BOEM	BOEM Pacific Oil and Gas Pipelines - 2011
Outer Continental Shelf Oil and Natural Gas Wells, Pacific OCS Region	This dataset contains surface locations for oil and gas wells located in the Pacific Coast federal waters.	Bureau of Safety and Environmental Enforcement	Outer Continental Shelf Oil and Natural Gas Wells, Pacific OCS Region
NOAA Wrecks and Obstructions	The Office of Coast Survey's Wrecks and Obstructions database contains information on the identified submerged shipwrecks and obstructions within the U.S. maritime boundaries.	NOAA Office of Coast Survey	NOAA Wrecks and Obstructions

Marine Observation Stations - National Data Buoy Center	This dataset includes buoys and fixed platform stations as provided by the National Data Buoy Center.	NOAA National Data Buoy Center	Marine Observation Stations - National Data Buoy Center
Aids to Navigation	Structures intended to assist a navigator to determine position or safe course, or to warn of dangers or obstructions to navigation. This dataset includes lights, signals, buoys, day beacons, and other aids to navigation.	NOAA Office for Coastal Management	Aids to Navigation

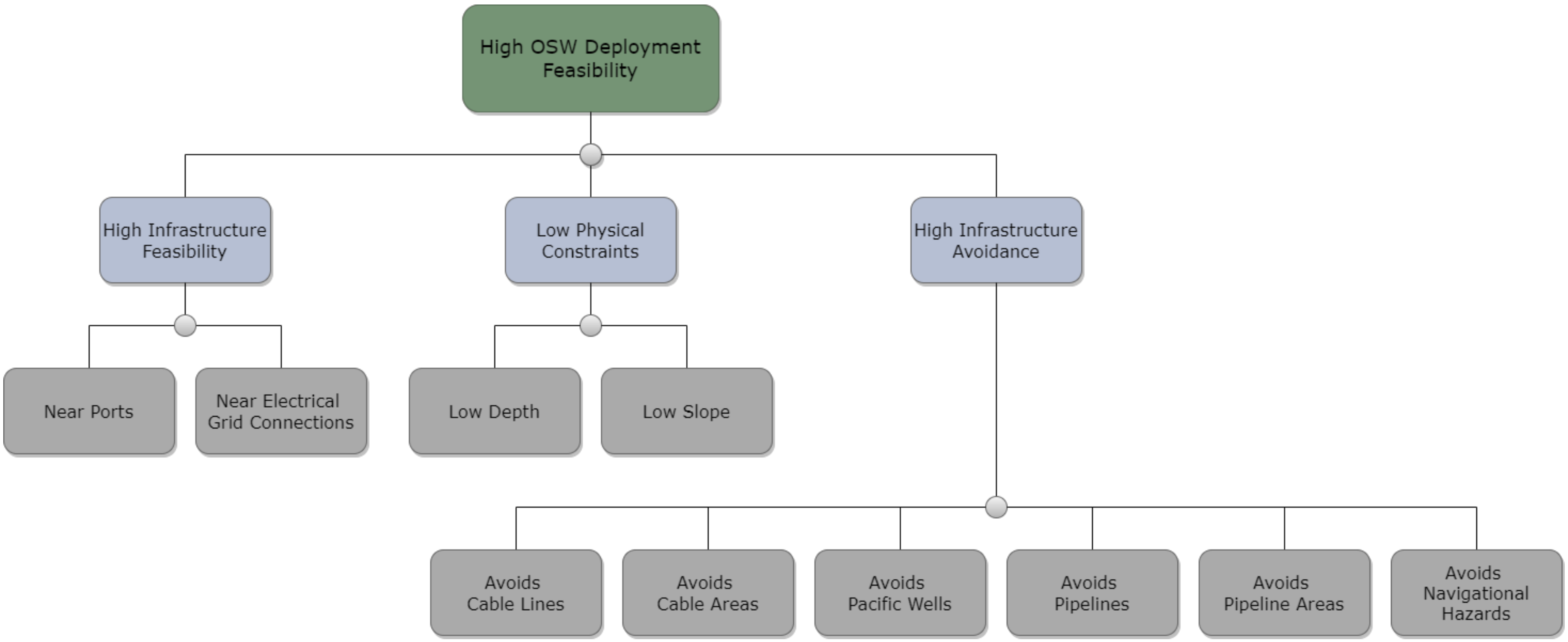

Figure A3-2. OSW Deployment Feasibility EEMS model detailed structure. This model estimates OSW infrastructure deployment feasibility by considering proximity to ports and electrical grid connections, physical constraints of seafloor slope and depth, and infrastructure avoidance. For complete interactive components see interactive models on osw.eemsonline.org.

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Table A3-4. OSW Deployment Feasibility EEMS model fuzzy thresholds.

Input	Input Theme (units)	False Threshold	True Threshold
Offshore Wind Energy Potential Substations [>110kV]	Electrical Grid Distance (m)	Max	Min
California Ports	Port Distance (m)	Max	Min
GEBCO 2020 Bathymetric Grid, Pacific EEZ	Depth (m)	-2,592.22 (fuzzy value target of 0 @ -1,300)	Max
GEBCO 2020 Slope, OPC OSW Study Area	Slope (degrees)	16 (fuzzy value target of -0.25 @ 10)	Min
Coastal Cable Submarine line - NOAA Submarine Cables	Cable Line Distance (m)	1,000	3,000
Coastal Cable Area - NOAA Harbor Cable Area - NOAA	Cable Area Distance (m)	1,000	3,000
Approach Pipeline Area - NOAA	Pipeline Area Distance (m)	1,000	3,000
Approach Pipeline Submarine on Land - NOAA BOEM Pacific Oil and Gas Pipelines - 2011	Pipelines Distance (m)	1,000	3,000
Outer Continental Shelf Oil and Natural Gas Wells, Pacific OCS Region	Pacific Wells Distance (m)	1,000	3,000
NOAA Wrecks and Obstructions Marine Observation Stations - National Data Buoy Center Aids to Navigation	Navigational Hazards Distance (m)	1,000	3,000

Table A3-5. Ocean Use EEMS model input data.

Input	Data Description	Data Provider(s)	Gateway Link
Point Density of North Pacific Albacore Trolling Fleet Logbook (1995-1999)	This logbook is maintained to track catch and effort of albacore using hook and line gear, particularly by trolling. The logbook data records catch and effort at discrete latitude/longitude points for each set made. Using the discrete points, a raster layer was created using the Point Density tool in ArcGIS to create a map of where the points reported in logbooks are more and less dense.	CDFW	Point Density of North Pacific Albacore Trolling Fleet Logbook (1995-1999)
Point Density of North Pacific Albacore Trolling Fleet Logbook (2000-2005)			Point Density of North Pacific Albacore Trolling Fleet Logbook (2000-2005)
Point Density of North Pacific Albacore Trolling Fleet Logbook (2006-2010)			Point Density of North Pacific Albacore Trolling Fleet Logbook (2006-2010)
Point Density of North Pacific Albacore Trolling Fleet Logbook (2011-2016)			Point Density of North Pacific Albacore Trolling Fleet Logbook (2011-2016)
CA Halibut Trawl Density, 1997-2017	Summarizes logbook records from the CDFW Marine Log System (MLS) showing the density of trawls targeting California halibut from 1997 to 2017.		CA Halibut Trawl Density, 1997-2017
Groundfish Trawl Density, 1997-2017	Summarizes logbook records from the CDFW Marine Log System (MLS) showing the density of trawls targeting groundfish from 1997 to 2017.		Groundfish Trawl Density, 1997-2017
Sea Cucumber Trawl Density, 2010-2017	Summarizes logbook records from the CDFW Marine Log System (MLS) showing the density of trawls landing sea cucumbers from 2010 to 2017.		Sea Cucumber Trawl Density, 2010-2017
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Limited Entry Bottom Trawl (2002-2010)	The main purpose of these data layers is to help inform the National Marine Fisheries Service Biological Opinion on Continuing Operation of the Pacific Coast Groundfish Fishery. In the shoreside bottom trawl fishery, permit holders with IFQ and a trawl endorsement can use multiple gear types (although not within the same trip), including bottom trawl,	NOAA Fisheries, Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring Division; Somers et al. 2020	NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Limited Entry Bottom Trawl (2002-2010)
NOAA Observed Fishing Effort			NOAA Observed Fishing Effort

in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Catch Shares Bottom Trawl (2011-2017)	midwater trawl, hook-and-line gear, and pot gear. These management changes could impact fishing effort in trawl sectors, as well as alter fixed gear fishing effort by providing a new opportunity for fixed gear fishing activity and potential competition between IFQ and other fixed gear sectors. This data layer displays fishing effort to assess these potential changes. NOAA fishing effort layers are limited in scope and spatial extent.		in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Catch Shares Bottom Trawl (2011-2017)
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: At-Sea Midwater Trawl Mothership (2002-2017)			NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: At-Sea Midwater Trawl Mothership (2002-2017)
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Shoreside Midwater Trawl for Hake (2011-2017)			NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Shoreside Midwater Trawl for Hake (2011-2017)
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Non-Catch Shares Hook-and-Line (2002-2017)			NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Non-Catch Shares Hook-and-Line (2002-2017)
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Catch Shares Hook-and-Line (2011-2017)			NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Catch Shares Hook-and-Line (2011-2017)
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Non-Catch Shares Pot (2002-2017)			NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Non-Catch Shares Pot (2002-2017)
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries:			NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries:

Catch Shares Pot (2011-2017)			Catch Shares Pot (2011-2017)
VMS Bottom Trawl 2010-2017 (BOEM)	Vessel Monitoring System (VMS) data were used from the NOAA Office of Law Enforcement to create this fishing effort dataset for the U.S. West Coast. The dataset was generated using VMS points at fishing speeds to create fishing tracks. Tracks were joined to the BOEM aliquot grid (1.2x1.2 km) to create heat maps of fishing effort for various fisheries based on individual and combined declaration codes.	BOEM, California State Polytechnic University	VMS Bottom Trawl 2010-2017 (BOEM)
VMS Dungeness Crab 2010-2017 (BOEM)			VMS Dungeness Crab 2010-2017 (BOEM)
VMS Groundfish 2010-2017 (BOEM)			VMS Groundfish 2010-2017 (BOEM)
VMS Midwater Trawl 2010-2017 (BOEM)			VMS Midwater Trawl 2010-2017 (BOEM)
VMS Pink Shrimp 2010-2017 (BOEM)			VMS Pink Shrimp 2010-2017 (BOEM)
VMS Salmon 2010-2017 (BOEM)			VMS Salmon 2010-2017 (BOEM)
VMS Whiting 2010-2017 (BOEM)			VMS Whiting 2010-2017 (BOEM)
Catch of California commercial groundfish fisheries 1931-2005	This layer summarizes California Fish and Wildlife commercial groundfish catches from 1931-2005 in metric tons per kilometer squared. Catches are reported on landing receipts (also known as fish tickets) and are recorded by fish dealers or processors at the port of landing.	Miller, R.R.; Miller et al. 2017	Catch of California commercial groundfish fisheries 1931-2005
Value (ex-vessel) of California commercial groundfish fisheries 1931-2005	This layer summarizes California Fish and Wildlife groundfish fisheries ex-vessel value from 1931-2005. Monetary value, expressed as every USD per kilometer squared, was derived from commercial fisheries catches reported on landing receipts (also known as fish tickets) and are recorded by fish dealers or processors at the port of landing.		Value (ex-vessel) of California commercial groundfish fisheries 1931-2005
Vessel Transit Counts 2017	Automatic Identification Systems (AIS) are a navigation	U.S. Coast Guard	Vessel Transit Counts 2017

Vessel Transit Counts 2018 All Vessels Vessel Transit Counts 2019 All Vessels	safety device that transmits and monitors the location and characteristics of many vessels in U.S. and international waters in real-time. This dataset represents annual vessel transit counts summarized at a 100 m by 100 m geographic area. A single transit is counted each time a vessel track passes through, starts, or stops within a 100 m grid cell.	Navigation Center, BOEM, NOAA Office for Coastal Management	Vessel Transit Counts 2018 All Vessels Vessel Transit Counts 2019 All Vessels
Recommended Vessel Tracks Monterey Bay NMS	Monterey Bay National Marine Sanctuary Recommended Vessel Tracks. In 1997, the United States Coast Guard (USCG) and the National Oceanic and Atmospheric Administration (NOAA) established a workgroup of key stakeholders in the issue of vessel traffic, including representatives from federal, state and local governments, environmental groups and industry to review existing practices and risks, and recommend a package of strategies which would maximize protection of Sanctuary resources while allowing for the continuation of safe, efficient and environmentally sound transportation.	Monterey Bay National Marine Sanctuary; De Beukelaer et al. 2014	Recommended Vessel Tracks Monterey Bay NMS
Shipping Lanes CA 2016	Shipping zones delineate activities and regulations for marine vessel traffic. Traffic lanes define specific traffic flow, while traffic separation zones assist opposing streams of marine traffic. Shipping Lanes and Regulations layer was created by extracting ENC (.000) files published by NOAAs Office of Coast Survey, Marine Chart Division (NOAA OCS).	BOEM, NOAA Office of Coast Survey	Shipping Lanes CA 2016
Regulated Navigation Areas	Regulated Navigation Areas (RNAs) (outlined in 33 CFR Part 165) are water areas within a defined boundary for which regulations for vessels navigating within the area have been established. RNAs are usually created where a more permanent solution to a safety or environmental concern is required. They principally regulate the operation of vessels permitted inside the area, but also may establish control of access to an area if necessary.	NOAA Office for Coastal Management	Regulated Navigation Areas
Pilot Boarding Areas	Pilot boarding areas are locations at sea where pilots familiar with local waters board incoming vessels to navigate their passage to a destination port. Pilots can rendezvous with	NOAA Office for Coastal Management	Pilot Boarding Areas

	ships anywhere within a Pilot Boarding Area.		
Pilot Boarding Stations	Pilot boarding stations are specific point locations depicted on NOAA navigational charts where pilots rendezvous with ships. It represents precise locations depicted on NOAA navigational charts or described in United States Coastal Pilots where pilots rendezvous with ships. This dataset does not contain information regarding the hazards and considerations necessary to approach each port.	NOAA Office for Coastal Management	Pilot Boarding Stations
Dive Sites	A collection of various SCUBA dive sites along the California coast were compiled for Marine Protected Area planning purposes during the Marine Life Protection Act. Sources include PISCO, REEF, www.wannadive.net and www.scubadiving.com.	CDFG, Marine Region GIS Lab	Dive Sites
Distance to the California Coast, OPC OSW Study Area	Distance to the California shoreline as a stand-in for coastal viewshed considerations.	Conservation Biology Institute with data from NOAA National Geodetic Survey	Distance to the California Coast, OPC OSW Study Area
Submerged Landforms Model, California	This dataset was developed as a predictive model for locating potential archaeological sites along the California coastline. The model is based on NOAA's National Geophysical Data Center's (NGDC) high-resolution digital elevation models (DEMs) created for select U.S. coastal regions. Submerged lands probability is on a scale of 1-6, low to high.	BOEM, National Geophysical Data Center, NOAA; ICF International et al. 2013	Submerged Landforms Model, California
NOAA Wrecks and Obstructions	The Office of Coast Survey's Wrecks and Obstructions database contains information on the identified submerged shipwrecks and obstructions within the U.S. maritime boundaries.	NOAA Office of Coast Survey	NOAA Wrecks and Obstructions
Ocean Disposal Sites	In 1972, Congress enacted the Marine Protection, Research, and Sanctuaries Act (MPRSA, also known as the Ocean Dumping Act) to prohibit the dumping of material into the ocean that would unreasonably degrade or endanger human	NOAA Office for Coastal Management	Ocean Disposal Sites

	health or the marine environment. Virtually all material ocean dumped today is dredged material (sediments) removed from the bottom of waterbodies in order to maintain navigation channels and berthing areas. Ocean dumping cannot occur unless a permit is issued under the MPRSA.		
Unexploded Ordnance Areas	Unexploded ordnances (UXO) are explosive weapons (bombs, bullets, shells, grenades, mines, etc.) that did not explode when they were employed and still pose a risk of detonation. Ocean disposal of munitions was also an accepted international practice until 1970, when it was prohibited by the Department of Defense. This dataset represents known or possible former explosive dumping areas and UXOs. This is NOT a complete collection of unexploded ordnances on the seafloor, nor are the locations considered to be accurate.	BOEM, NOAA Office for Coastal Management	Unexploded Ordnance Areas
Formerly Used Defense Sites (Unexploded Ordnances)			Formerly Used Defense Sites (Unexploded Ordnances)

Table A3-6. Ocean Use EEMS model fuzzy thresholds.

Input	Input Theme (units)	False Threshold	True Threshold
Point Density of North Pacific Albacore Trolling Fleet Logbook (1995-1999)	Albacore Trolling (density)	Min	2 st dev
Point Density of North Pacific Albacore Trolling Fleet Logbook (2000-2005)			
Point Density of North Pacific Albacore Trolling Fleet Logbook (2006-2010)			
Point Density of North Pacific Albacore Trolling Fleet Logbook (2011-2016)			
CA Halibut Trawl Density, 1997-2017	CA Halibut Trawl (density)	Min	4 st dev
Groundfish Trawl Density, 1997-2017	Groundfish Trawl (density)	Min	4 st dev
Sea Cucumber Trawl Density, 2010-2017	Sea Cucumber Trawl (density)	Min	4 st dev

NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Limited Entry Bottom Trawl (2002-2010)	Bottom Trawl, NOAA (density)	Min	4 st dev
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Catch Shares Bottom Trawl (2011-2017)			
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: At-Sea Midwater Trawl Mothership (2002-2017)	At-Sea Midwater Trawl Mothership, NOAA (density)	Min	4 st dev
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Shoreside Midwater Trawl for Hake (2011-2017)	Midwater Trawl for Hake, NOAA (density)	Min	4 st dev
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Non-Catch Shares Hook-and-Line (2002-2017)	Hook-and-Line Fishing, NOAA (density)	Min	4 st dev
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Catch Shares Hook-and-Line (2011-2017)			
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Non-Catch Shares Pot (2002-2017)	Pot Fishing, NOAA (density)	Min	4 st dev
NOAA Observed Fishing Effort in the 2002-2017 U.S. Pacific Coast Groundfish Fisheries: Catch Shares Pot (2011-2017)			
VMS Bottom Trawl 2010-2017 (BOEM)	VMS Bottom Trawl (density)	Min	4 st dev
VMS Dungeness Crab 2010-2017 (BOEM)	VMS Dungeness Crab (density)	Min	4 st dev
VMS Groundfish 2010-2017 (BOEM)	VMS Groundfish (density)	Min	4 st dev
VMS Midwater Trawl 2010-2017 (BOEM)	VMS Midwater Trawl (density)	Min	4 st dev

VMS Pink Shrimp 2010-2017 (BOEM)	VMS Pink Shrimp (density)	Min	4 st dev
VMS Salmon 2010-2017 (BOEM)	VMS Salmon (density)	Min	4 st dev
VMS Whiting 2010-2017 (BOEM)	VMS Whiting (density)	Min	4 st dev
Catch of California commercial groundfish fisheries 1931-2005	Historic Groundfish Catch (tons/km^2)	Min	4 st dev
Value (ex-vessel) of California commercial groundfish fisheries 1931-2005	Historic Groundfish Value ($10k/$km^2$)	Min	4 st dev
Vessel Transit Counts 2017			
Vessel Transit Counts 2018 All Vessels	Vessel Transit (count)	Min	4 st dev
Vessel Transit Counts 2019 All Vessels			
Recommended Vessel Tracks Monterey Bay NMS			
Shipping Lanes CA 2016			
Regulated Navigation Areas	Regulated Vessel Areas Distance (m)	3,000	1,000
Pilot Boarding Areas			
Pilot Boarding Stations			
Dive Sites	Dive Site Distance (m)	3,000	1,000
Distance to the California Coast, OPC OSW Study Area	Shore Distance (m)	Max	Min
Submerged Landforms Model, California	Submerged Lands Probability (0-6, low-high)	Min	Max
NOAA Wrecks and Obstructions	Shipwreck Distance (m)	3,000	1,000
Ocean Disposal Sites	Ocean Disposal Site Distance (m)	3,000	1,000

Unexploded Ordnance Areas	Ordnance Site Distance (m)	3,000	1,000
Formerly Used Defense Sites (Unexploded Ordnances)			

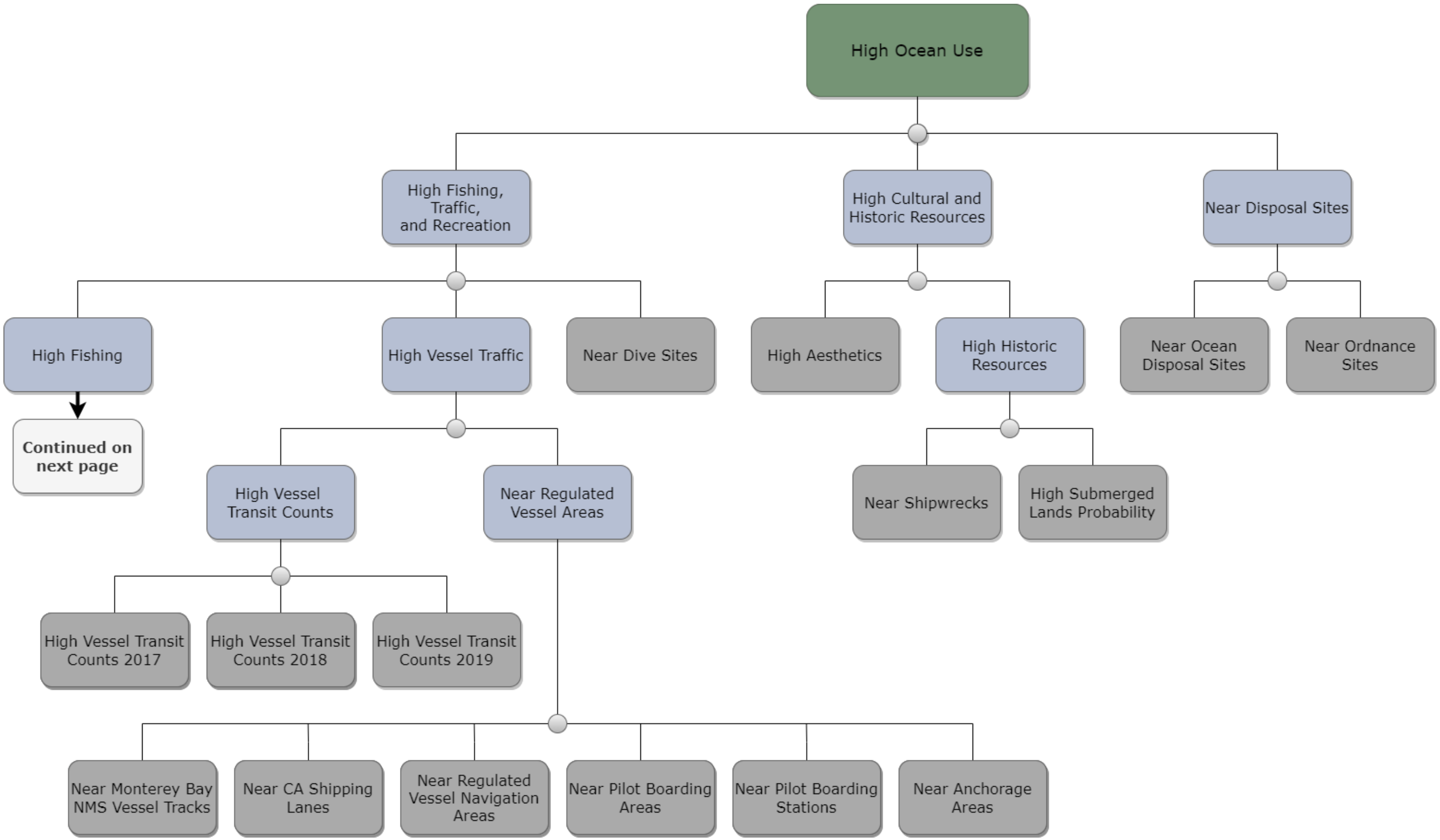

Figure A3-3. Ocean Use EEMS model detailed structure. This model estimates the amount of ocean use at a given location by considering commercial fishing activity, vessel traffic and navigation, recreation, cultural and historic resources, and ocean disposal sites. For complete interactive components see interactive models on osw.eemsonline.org.

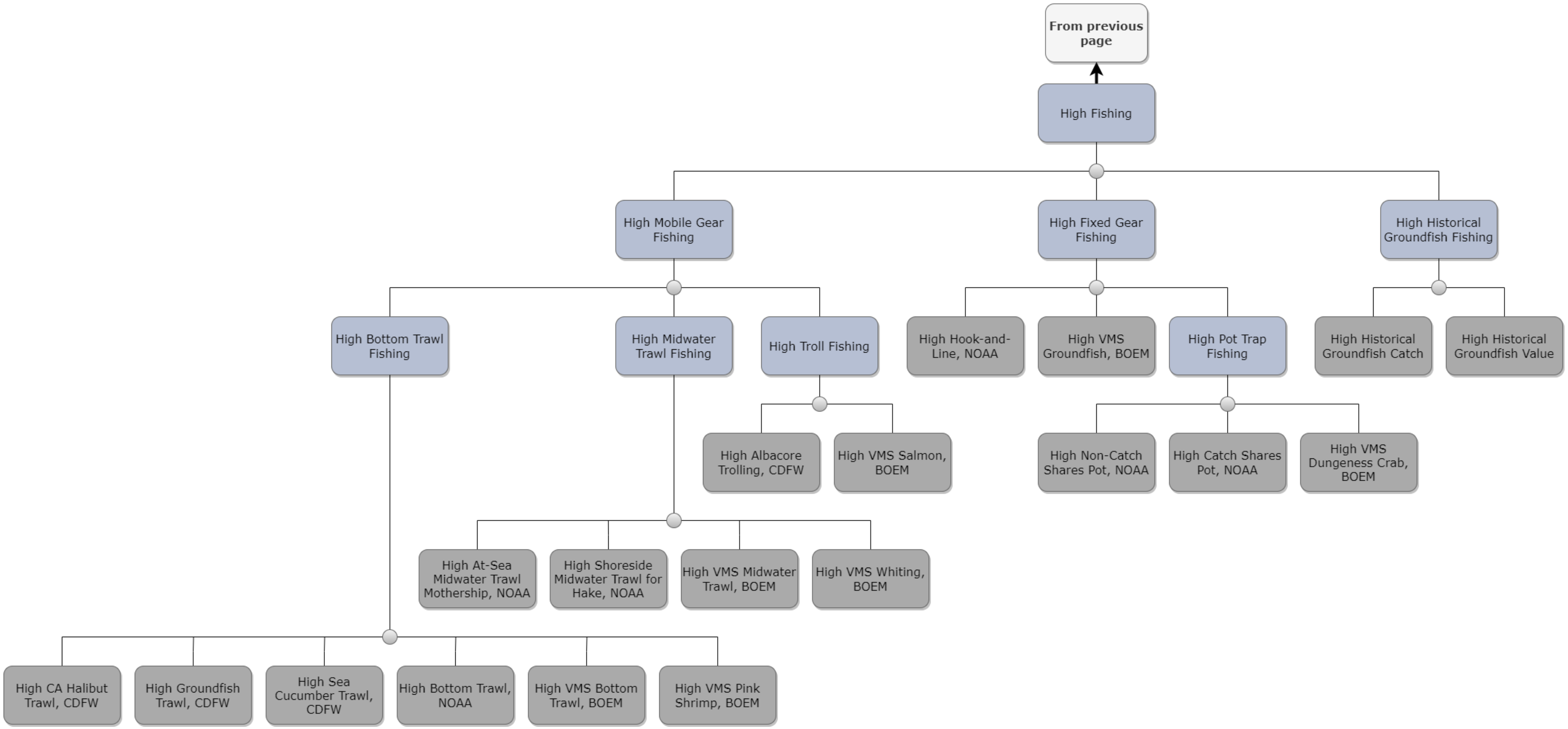

Figure A3-4. Fishing component of the Ocean Use EEMS model detailed structure.

Table A3-7. Environmental Considerations EEMS model input data.

Input	Data Description	Data Provider(s)	Gateway Link
Blue Whale Utilization Distribution, California Current	Blue Whale (*Balaenoptera musculus*) utilization distribution (UD) in the California Current. Utilization Distribution is the probability of an animal being found in a given location. In this study, satellite and light-based geolocation tracking data from the Tagging of Pacific Predators (TOPP) project were used to determine the distribution and key habitats of eight protected predator species across three taxa groups within the US waters of the California Current System (CCS).	Sara Maxwell, TOPP (Tagging of Pacific Predators) Program; Maxwell et al. 2013	Blue Whale Utilization Distribution, California Current
Biologically Important Areas for Blue Whales on the US West Coast	The Cetacean Density and Distribution Mapping Working Group identified Biologically Important Areas (BIAs) for 24 cetacean species, stocks, or populations in seven regions within US waters. BIAs are reproductive areas, feeding areas, migratory corridors, and areas in which small and resident populations are concentrated.	Marine Geospatial Ecology Lab, Duke University; Van Parijs et al. 2015; Calambokidis et al. 2015	Biologically Important Areas for Blue Whales on the US West Coast
Blue Whale Summer/Fall Habitat-based Density, California Current	Blue Whale (*Balaenoptera musculus*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Blue Whale Summer/Fall Habitat-based Density, California Current
Fin Whale Summer/Fall Habitat-based Density, California Current	Fin Whale (*Balaenoptera physalus*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild	Elizabeth A. Becker, NOAA; Becker et al. 2020	Fin Whale Summer/Fall Habitat-based Density, California Current

	(Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.		
Fin Whale Relative Habitat Suitability, West Coast	This layer models the influence of biophysical conditions on habitat suitability for endangered fin whales (*Balaenoptera physalus*), with a view to informing management in a heavily impacted ocean region. Biophysical conditions in the southern CCS generate productive foraging habitats that can support the fin whale population year-round and allow for extended periods of residency in localized areas. High-use habitats for fin whales are co-located with areas of intense human use, including international shipping routes and a major naval training range. Seasonal habitat suitability maps presented here could inform the management of anthropogenic threats to endangered baleen whales in this globally significant biodiversity hotspot.	Kylie L. Scales; Scales et al. 2017	Fin Whale Relative Habitat Suitability, West Coast
Biologically Important Areas for Gray Whales on the US West Coast	The Cetacean Density and Distribution Mapping Working Group identified Biologically Important Areas (BIAs) for 24 cetacean species, stocks, or populations in seven regions within US waters. BIAs are reproductive areas, feeding areas, migratory corridors, and areas in which small and resident populations are concentrated.	Marine Geospatial Ecology Lab, Duke University; Van Parijs et al. 2015; Calambokidis et al. 2015	Biologically Important Areas for Gray Whales on the US West Coast
Biologically Important Areas for Humpback Whales on the US West Coast	The Cetacean Density and Distribution Mapping Working Group identified Biologically Important Areas (BIAs) for 24 cetacean species, stocks, or populations in seven regions within US waters. BIAs are reproductive areas, feeding areas,	Marine Geospatial Ecology Lab, Duke University; Van Parijs et al. 2015; Calambokidis et al. 2015	Biologically Important Areas for Humpback Whales on the US West Coast

	migratory corridors, and areas in which small and resident populations are concentrated.		
Humpback Whale Summer/Fall Habitat-based Density, California Current	Humpback Whale (*Megaptera novaeangliae*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Humpback Whale Summer/Fall Habitat-based Density, California Current
Humpback Whale Critical Habitat, Central America DPS	This layer shows the NOAA Fisheries final ruling to designate critical habitat for the endangered Central America distinct population segment (DPS) of humpback whales (*Megaptera novaeangliae*) pursuant to section 4 of the Endangered Species Act (ESA). The Central America DPS critical habitat was used as input to this model due to its co-occurrence with the Western North Pacific and Mexico humpback whale DPSs within the study area.	NOAA Fisheries	Humpback Whale Critical Habitat, Central America DPS
Minke Whale Summer/Fall Habitat-based Density, California Current	Minke Whale (*Balaenoptera acutorostrata*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Minke Whale Summer/Fall Habitat-based Density, California Current

Baird's Beaked Whale Summer/Fall Habitat-based Density, California Current	Baird's Beaked Whale (*Berardius bairdii*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Baird's Beaked Whale Summer/Fall Habitat-based Density, California Current
Common Bottlenose Dolphin Summer/Fall Habitat-based Density, California Current	Common Bottlenose Dolphin (*Tursiops truncatus*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Common Bottlenose Dolphin Summer/Fall Habitat-based Density, California Current
Dall's Porpoise Summer/Fall Habitat-based Density, California Current	Dall's Porpoise (*Phocoenoides dalli*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Dall's Porpoise Summer/Fall Habitat-based Density, California Current

Long-beaked Common Dolphin Summer/Fall Habitat-based Density, California Current	Long-beaked Common Dolphin (*Delphinus delphis bairdii*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Long-beaked Common Dolphin Summer/Fall Habitat-based Density, California Current
Northern Right Whale Dolphin Summer/Fall Habitat-based Density, California Current	Northern Right Whale Dolphin (*Lissodelphis borealis*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Northern Right Whale Dolphin Summer/Fall Habitat-based Density, California Current
Pacific White-sided Dolphin Summer/Fall Habitat-based Density, California Current	Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Pacific White-sided Dolphin Summer/Fall Habitat-based Density, California Current

Risso's Dolphin Summer/Fall Habitat-based Density, California Current	Risso's Dolphin (*Grampus griseus*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Risso's Dolphin Summer/Fall Habitat-based Density, California Current
Short-beaked Common Dolphin Summer/Fall Habitat-based Density, California Current	Short-beaked Common Dolphin (*Delphinus delphis delphis*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Short-beaked Common Dolphin Summer/Fall Habitat-based Density, California Current
Small Beaked Whale Guild Summer/Fall Density, California Current	Small Beaked Whales in the genus (*Mesoplodon* spp.) and Cuvier's Beaked Whale (*Ziphius cavirostris*) density map created by the California Current Marine Mammal Assessment Program at NOAA's Southwest Fisheries Science Center. Predictive habitat-based models of cetacean density were developed based on seven shipboard cetacean surveys conducted during summer and fall between 1991 and 2009 in the California Current Ecosystem.	Elizabeth A. Becker, NOAA; Becker et al. 2016	Small Beaked Whale Guild Summer/Fall Density, California Current
Southern Resident Killer Whale Critical Habitat	A geospatial dataset depicting the boundaries of marine areas designated as critical habitat under the Endangered Species	NOAA, National Marine Fisheries Service, West	Southern Resident Killer Whale Critical Habitat

	Act (ESA) for Southern Resident killer whales (SRKW). The layer displays SRKW critical habitat as the area from the US-Canada Border in the north to just below Point Sur, approximately 20 miles south of Monterey, CA., and between the -6.1 meter (-20 ft.) isobath, relative to mean higher water (MHW) and the -200 meter (-656 ft.) isobath.	Coast Region	
Sperm Whale Summer/Fall Density, California Current	Sperm Whale (*Physeter macrocephalus*) density map created by the California Current Marine Mammal Assessment Program at NOAA's Southwest Fisheries Science Center. Predictive habitat-based models of cetacean density were developed based on seven shipboard cetacean surveys conducted during summer and fall between 1991 and 2009 in the California Current Ecosystem.	Elizabeth A. Becker, NOAA; Becker et al. 2016	Sperm Whale Summer/Fall Density, California Current
Striped Dolphin Summer/Fall Habitat-based Density, California Current	Striped Dolphin (*Stenella coeruleoalba*) habitat-based density estimates in the California Current Ecosystem. Habitat-based density models were developed for 14 species and one guild (Mesoplodonts and Cuvier's beaked whale) using 92,214 km of on-effort survey data collected between 1991 and 2018 within the CCE study area. To generate average density surfaces, predictions were made on daily grids encompassing the 1996-2018 surveys (late June - early December). Models thus provide "multi-year average density surfaces" representative of the summer/fall period.	Elizabeth A. Becker, NOAA; Becker et al. 2020	Striped Dolphin Summer/Fall Habitat-based Density, California Current
Pelagic Important Bird Areas	Important Bird Areas (IBAs) are based on an established program that uses standardized criteria to identify essential habitats, which are areas that hold a significant proportion of the population of one or more bird species. To qualify as a globally significant IBA, a proposed site must hold a significant number of a globally threatened species, or a significant percentage of a global population, as evidenced by documented, repeated observation of substantial	Audubon California	Pelagic Important Bird Areas

	congregations in an area. This layer represents individual colony locations. The following species are represented in this dataset: Ashy Storm-Petrel, Black-footed Albatross, Brandt's Cormorant, Elegant Tern, Pink-footed Shearwater, Sooty Shearwater, Western Gull.		
Black-footed Albatross Utilization Distribution, California Current	Black-footed Albatross (*Phoebastria nigripes*) utilization distribution (UD) in the California Current. Utilization Distribution is the probability of an animal being found in a given location. In this study, satellite and light-based geolocation tracking data from the Tagging of Pacific Predators (TOPP) project were used to determine the distribution and key habitats of eight protected predator species across three taxa groups within the US waters of the California Current System (CCS).		Black-footed Albatross Utilization Distribution, California Current
Laysan Albatross Utilization Distribution, California Current	Laysan Albatross (*Phoebastria immutabilis*) utilization distribution (UD) in the California Current. Utilization Distribution is the probability of an animal being found in a given location. In this study, satellite and light-based geolocation tracking data from the Tagging of Pacific Predators (TOPP) project were used to determine the distribution and key habitats of eight protected predator species across three taxa groups within the US waters of the California Current System (CCS).	Sara Maxwell, TOPP (Tagging of Pacific Predators) Program; Maxwell et al. 2013	Laysan Albatross Utilization Distribution, California Current
Sooty Shearwater Utilization Distribution, California Current	Sooty Shearwater (*Puffinus griseus*) utilization distribution (UD) in the California Current. Utilization Distribution is the probability of an animal being found in a given location. In this study, satellite and light-based geolocation tracking data from the Tagging of Pacific Predators (TOPP) project were used to determine the distribution and key habitats of eight protected predator species across three taxa groups within the US waters of the California Current System (CCS).		Sooty Shearwater Utilization Distribution, California Current
Ancient Murrelet Predicted At-Sea Density, U.S. West Coast	This dataset provides seasonal spatial rasters of predicted long-term (1980-2017) density throughout the Pacific Outer Continental Shelf (OCS) and adjacent waters off of the	Jeffery B. Leirness, CSS Inc., NOAA, BOEM; Leirness et al. 2021	Ancient Murrelet Predicted At-Sea Density, U.S. West Coast

Ashy Storm-Petrel Predicted At-Sea Density, U.S. West Coast	contiguous United States at 2-km spatial resolution. The maps represent model-derived spatial predictions of long-term average density, in units of individuals per km^2. The maps do not provide predictions of the actual number of individuals of a given species or taxonomic group that would be expected in a given area; they only indicate where a given species/group may be more or less abundant.		Ashy Storm-Petrel Predicted At-Sea Density, U.S. West Coast
Black Storm-Petrel Predicted At-Sea Density, U.S. West Coast			Black Storm-Petrel Predicted At-Sea Density, U.S. West Coast
Black-footed Albatross Predicted At-Sea Density, U.S. West Coast			Black-footed Albatross Predicted At-Sea Density, U.S. West Coast
Black-legged Kittiwake Predicted At-Sea Density, U.S. West Coast			Black-legged Kittiwake Predicted At-Sea Density, U.S. West Coast
Black-vented Shearwater Predicted At-Sea Density, U.S. West Coast			Black-vented Shearwater Predicted At-Sea Density, U.S. West Coast
Bonaparte's Gull Predicted At-Sea Density, U.S. West Coast			Bonaparte's Gull Predicted At-Sea Density, U.S. West Coast
Brandt's Cormorant Predicted At-Sea Density, U.S. West Coast			Brandt's Cormorant Predicted At-Sea Density, U.S. West Coast
Brown Pelican Predicted At-Sea Density, U.S. West Coast			Brown Pelican Predicted At-Sea Density, U.S. West Coast
Buller's Shearwater Predicted At-Sea Density, U.S. West Coast			Buller's Shearwater Predicted At-Sea Density, U.S. West Coast
California Gull Predicted At-Sea Density, U.S. West			California Gull Predicted At-Sea Density, U.S. West Coast

Coast		
Caspian Tern Predicted At-Sea Density, U.S. West Coast		Caspian Tern Predicted At-Sea Density, U.S. West Coast
Cassin's Auklet Predicted At-Sea Density, U.S. West Coast		Cassin's Auklet Predicted At-Sea Density, U.S. West Coast
Common Loon Predicted At-Sea Density, U.S. West Coast		Common Loon Predicted At-Sea Density, U.S. West Coast
Common Murre Predicted At-Sea Density, U.S. West Coast		Common Murre Predicted At-Sea Density, U.S. West Coast
Common, Arctic Tern Predicted At-Sea Density, U.S. West Coast		Common, Arctic Tern Predicted At-Sea Density, U.S. West Coast
Cook's Petrel Predicted At-Sea Density, U.S. West Coast		Cook's Petrel Predicted At-Sea Density, U.S. West Coast
Cormorant Spp. Predicted At-Sea Density, U.S. West Coast		Cormorant Spp. Predicted At-Sea Density, U.S. West Coast
Double-crested Cormorant Predicted At-Sea Density, U.S. West Coast		Double-crested Cormorant Predicted At-Sea Density, U.S. West Coast
Fork-tailed Storm-Petrel Predicted At-Sea Density, U.S. West Coast		Fork-tailed Storm-Petrel Predicted At-Sea Density, U.S. West Coast

Heermann's Gull Predicted At-Sea Density, U.S. West Coast		Heermann's Gull Predicted At-Sea Density, U.S. West Coast
Herring, Iceland Gull Predicted At-Sea Density, U.S. West Coast		Herring, Iceland Gull Predicted At-Sea Density, U.S. West Coast
Jaeger Spp. Predicted At-Sea Density, U.S. West Coast		Jaeger Spp. Predicted At-Sea Density, U.S. West Coast
Laysan Albatross Predicted At-Sea Density, U.S. West Coast		Laysan Albatross Predicted At-Sea Density, U.S. West Coast
Leach's Storm-Petrel Predicted At-Sea Density, U.S. West Coast		Leach's Storm-Petrel Predicted At-Sea Density, U.S. West Coast
Loon Spp. Predicted At-Sea Density, U.S. West Coast		Loon Spp. Predicted At-Sea Density, U.S. West Coast
Marbled Murrelet Predicted At-Sea Density, U.S. West Coast		Marbled Murrelet Predicted At-Sea Density, U.S. West Coast
Murphy's Petrel Predicted At-Sea Density, U.S. West Coast		Murphy's Petrel Predicted At-Sea Density, U.S. West Coast
Northern Fulmar Predicted At-Sea Density, U.S. West Coast		Northern Fulmar Predicted At-Sea Density, U.S. West Coast
Parasitic, Long-tailed Jaeger Predicted At-Sea		Parasitic, Long-tailed Jaeger Predicted At-Sea Density, U.S.

Density, U.S. West Coast		West Coast
Pelagic Cormorant Predicted At-Sea Density, U.S. West Coast		Pelagic Cormorant Predicted At-Sea Density, U.S. West Coast
Phalarope Spp. Predicted At-Sea Density, U.S. West Coast		Phalarope Spp. Predicted At-Sea Density, U.S. West Coast
Pigeon Guillemot Predicted At-Sea Density, U.S. West Coast		Pigeon Guillemot Predicted At-Sea Density, U.S. West Coast
Pink-footed Shearwater Predicted At-Sea Density, U.S. West Coast		Pink-footed Shearwater Predicted At-Sea Density, U.S. West Coast
Pomarine Jaeger Predicted At-Sea Density, U.S. West Coast		Pomarine Jaeger Predicted At-Sea Density, U.S. West Coast
Red-throated Loon Predicted At-Sea Density, U.S. West Coast		Red-throated Loon Predicted At-Sea Density, U.S. West Coast
Rhinoceros Auklet Predicted At-Sea Density, U.S. West Coast		Rhinoceros Auklet Predicted At-Sea Density, U.S. West Coast
Royal, Elegant Tern Predicted At-Sea Density, U.S. West Coast		Royal, Elegant Tern Predicted At-Sea Density, U.S. West Coast
Sabine's Gull Predicted At-Sea Density, U.S. West Coast		Sabine's Gull Predicted At-Sea Density, U.S. West Coast

Scoter Spp. Predicted At-Sea Density, U.S. West Coast			Scoter Spp. Predicted At-Sea Density, U.S. West Coast
Scripps's, Guadalupe, and Craveri's Murrelet Predicted At-Sea Density, U.S. West Coast			Scripps's, Guadalupe, and Craveri's Murrelet Predicted At-Sea Density, U.S. West Coast
Short-tailed, Sooty, Flesh-footed Shearwater Predicted At-Sea Density, U.S. West Coast			Short-tailed, Sooty, Flesh-footed Shearwater Predicted At-Sea Density, U.S. West Coast
South Polar Skua Predicted At-Sea Density, U.S. West Coast			South Polar Skua Predicted At-Sea Density, U.S. West Coast
Tufted Puffin Predicted At-Sea Density, U.S. West Coast			Tufted Puffin Predicted At-Sea Density, U.S. West Coast
Western, Clark's Grebe Predicted At-Sea Density, U.S. West Coast			Western, Clark's Grebe Predicted At-Sea Density, U.S. West Coast
Western, Glaucous-winged Gull Predicted At-Sea Density, U.S. West Coast			Western, Glaucous-winged Gull Predicted At-Sea Density, U.S. West Coast
Leatherback Sea Turtle Critical Habitat	This dataset depicts designated critical habitat for the leatherback sea turtle (*Dermochelys coriacea*) in California as designated by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, under the Endangered Species Act.	NOAA Office for Coastal Management	Leatherback Sea Turtle Critical Habitat
Leatherback Sea Turtle Utilization Distribution,	Leatherback Sea Turtle (*Dermochelys coriacea*) utilization distribution (UD) in the California Current. Utilization	Sara Maxwell, TOPP (Tagging of Pacific	Leatherback Sea Turtle Utilization Distribution,

California Current	Distribution is the probability of an animal being found in a given location. In this study, satellite and light-based geolocation tracking data from the Tagging of Pacific Predators (TOPP) project were used to determine the distribution and key habitats of eight protected predator species across three taxa groups within the US waters of the California Current System (CCS).	Predators) Program; Maxwell et al. 2013	California Current

Table A3-8. Environmental Considerations EEMS model fuzzy thresholds.

Input	Input Theme (units)	False Threshold	True Threshold
Blue Whale Utilization Distribution, California Current	Blue Whale Utilization Distribution (presence probability)	Min	1.5 st dev
Biologically Important Areas for Blue Whales on the US West Coast	Blue Whale Biologically Important Areas Distance (m)	20,000	1,000
Blue Whale Summer/Fall Habitat-based Density, California Current	Blue Whale Summer/Fall Density (predicted density)	Min	1.5 st dev
Fin Whale Summer/Fall Habitat-based Density, California Current	Fin Whale Summer/Fall Density (predicted density)	Min	1.5 st dev
Fin Whale Relative Habitat Suitability, West Coast	Fin Whale Relative Habitat Suitability (Habitat Suitability Index, 0-1)	Min	Max
Biologically Important Areas for Gray Whales on the US West Coast	Gray Whale Biologically Important Areas Distance (m)	15,000	-7,400 (fuzzy value target of -0.25 @ 1km)
Biologically Important Areas for Humpback Whales on the US West Coast	Humpback Whale Biologically Important Areas Distance (m)	20,000	1,000
Humpback Whale Summer/Fall Habitat-based Density, California Current	Humpback Whale Summer/Fall Density (predicted density)	Min	1.5 st dev
Humpback Whale Critical Habitat, Central America DPS	Humpback Whale Critical Habitat Distance (m)	15,000	1,000
Minke Whale Summer/Fall Habitat-based Density, California Current	Minke Whale Summer/Fall Density (predicted density)	Min	1.5 st dev
Baird's Beaked Whale Summer/Fall Habitat-	Baird’s Beaked Whale Summer/Fall Density (predicted density)	Min	1.5 st dev

based Density, California Current			
Common Bottlenose Dolphin Summer/Fall Habitat-based Density, California Current	Common Bottlenose Dolphin Summer/Fall Density (predicted density)	Min	1.5 st dev
Dall's Porpoise Summer/Fall Habitat-based Density, California Current	Dall's Porpoise Summer/Fall Density (predicted density)	Min	1.5 st dev
Long-beaked Common Dolphin Summer/Fall Habitat-based Density, California Current	Long-beaked Common Dolphin Summer/Fall Density (predicted density)	Min	1.5 st dev
Northern Right Whale Dolphin Summer/Fall Habitat-based Density, California Current	Northern Right Whale Dolphin Summer/Fall Density (predicted density)	Min	1.5 st dev
Pacific White-sided Dolphin Summer/Fall Habitat-based Density, California Current	Pacific White-sided Dolphin Summer/Fall Density (predicted density)	Min	1.5 st dev
Risso's Dolphin Summer/Fall Habitat-based Density, California Current	Risso's Dolphin Summer/Fall Density (predicted density)	Min	1.5 st dev
Short-beaked Common Dolphin Summer/Fall Habitat-based Density, California Current	Short-beaked Common Dolphin Summer/Fall Density (predicted density)	Min	1.5 st dev
Small Beaked Whale Guild Summer/Fall Density, California Current	Small Beaked Whale Guild Summer/Fall Density (predicted density)	Min	1.5 st dev
Southern Resident Killer Whale Critical Habitat	Southern Resident Killer Whale Critical Habitat Distance (m)	15,000	1,000
Sperm Whale Summer/Fall Density, California Current	Sperm Whale Summer/Fall Density (predicted density)	Min	1.5 st dev
Striped Dolphin Summer/Fall Habitat-based Density, California Current	Striped Dolphin Summer/Fall Density (predicted density)	Min	1.5 st dev
Pelagic Important Bird Areas	Pelagic Important Bird Areas Distance (m)	20,000	1,000

Black-footed Albatross Utilization Distribution, California Current	Black-footed Albatross Utilization Distribution (presence probability)	Min	2 st dev
Laysan Albatross Utilization Distribution, California Current	Laysan Albatross Utilization Distribution (presence probability)	Min	2 st dev
Sooty Shearwater Utilization Distribution, California Current	Sooty Shearwater Utilization Distribution (presence probability)	Min	2 st dev
All Seabird Predicted At-Sea Densities	Seabird Density (predicted density)	Min	2 st dev
Leatherback Sea Turtle Critical Habitat	Leatherback Sea Turtle Critical Habitat Distance (m)	15,000	1,000
Leatherback Sea Turtle Utilization Distribution, California Current	Leatherback Sea Turtle Utilization Distribution (presence probability)	Min	1.5 st dev

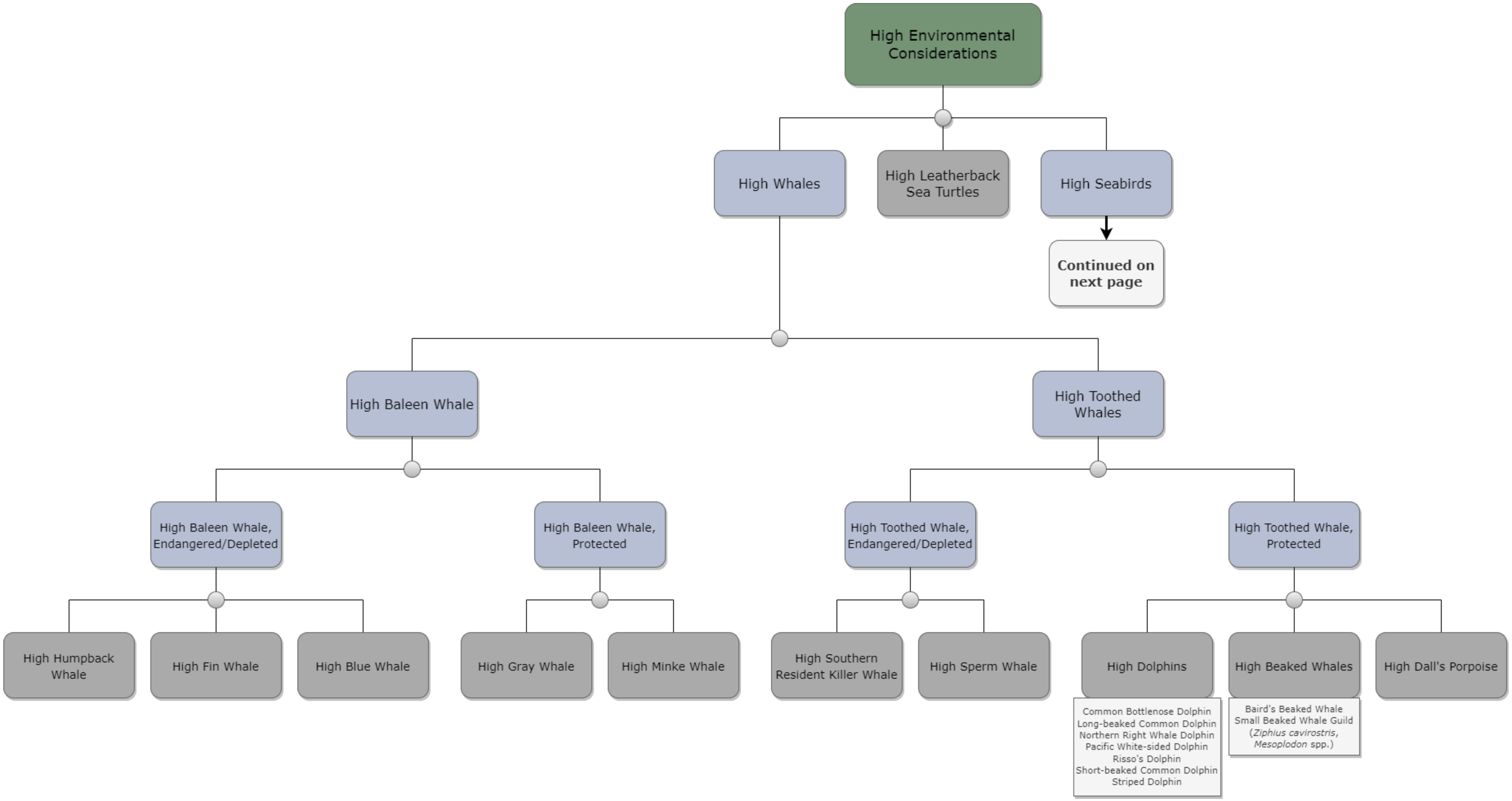

Figure A3-5. Environmental Consideration EEMS model detailed structure. This model estimates an index of marine life presence at a given location by considering the occurrence, activity, density, and/or habitat of sensitive marine species, including whales, seabirds, and leatherback sea turtles. Species presence is represented by numerous types of data as shown in Appendix 3, Table 7. Species with a higher protected status, (e.g. endangered), were weighted more heavily in the model. For complete interactive components see interactive models on osw.eemsonline.org.

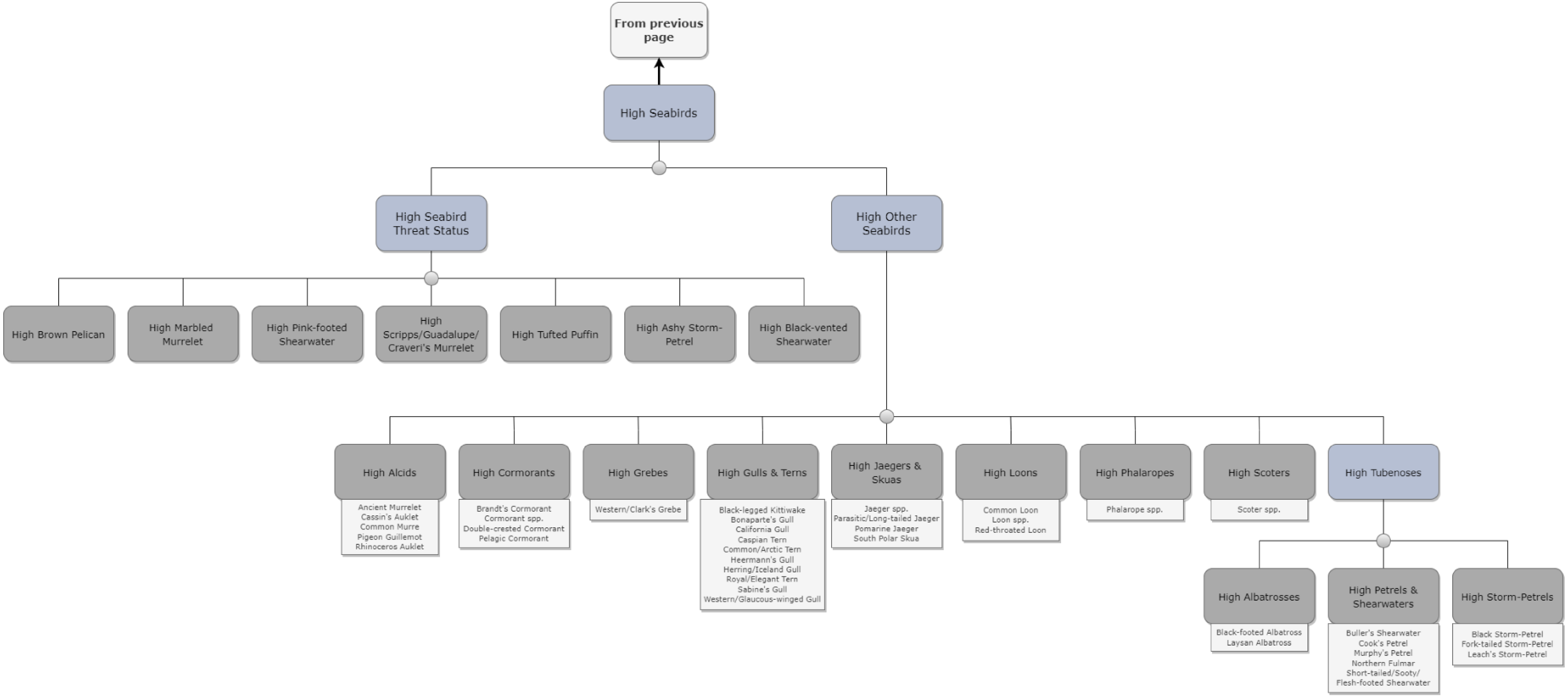

Figure A3-6. Seabirds component of the Environmental Consideration EEMS model detailed structure.