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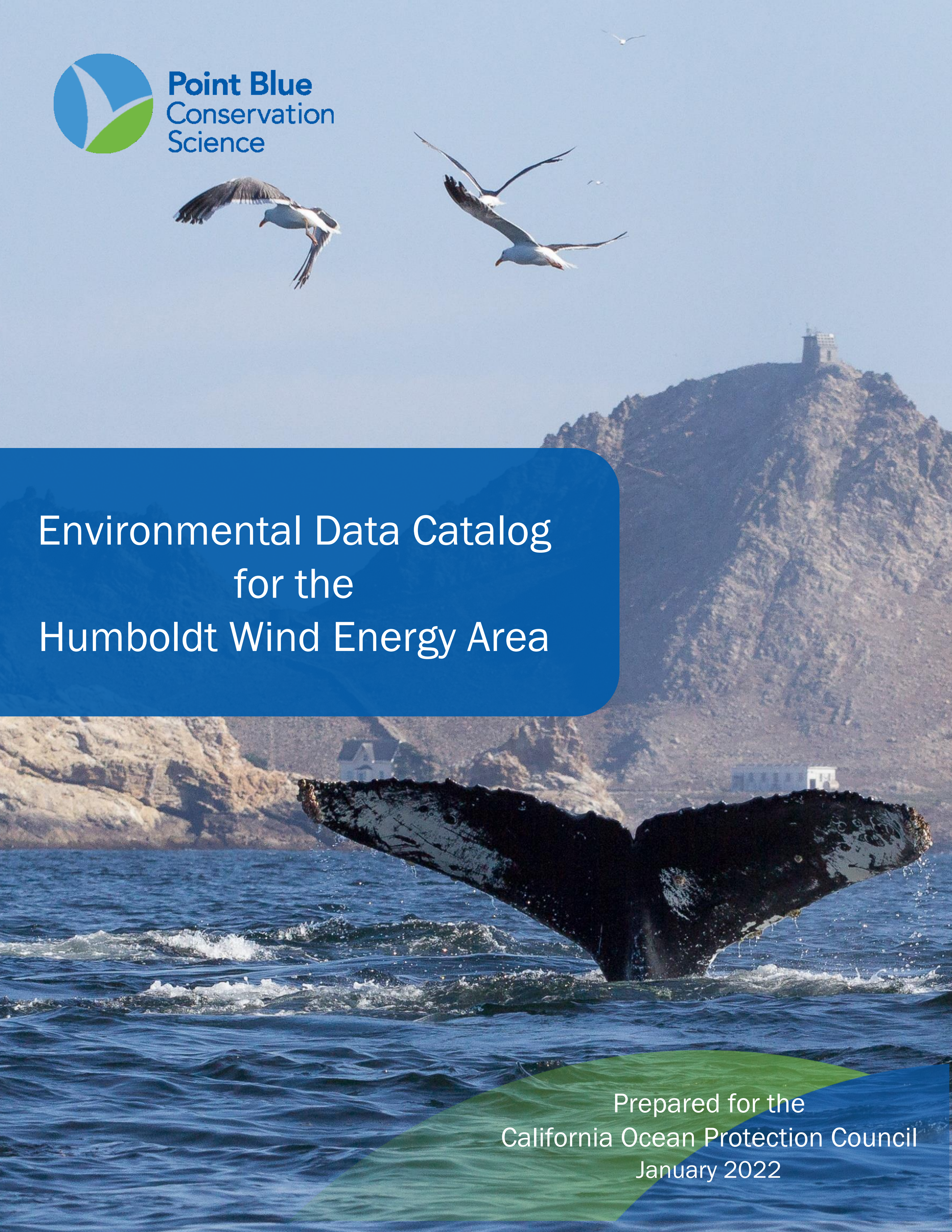

Environmental Data Catalog for the Humboldt Wind Energy Area

Prepared for the
California Ocean Protection Council
January 2022

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Cover photo: Humpback whale and western gulls near Southeast Farallon Island; Mike Johns/Point Blue Conservation Science

Point Blue Conservation Science – Point Blue's 160 scientists work to reduce the impacts of climate change, habitat loss, and other environmental threats while developing nature-based solutions to benefit both wildlife and people.

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LIST AND DEFINITIONS OF ACRONYMS[1]

Anadromous…..describes fish that move from marine waters back to natal freshwater rivers and streams to spawn; salmon is an anadromous species

ASV……………….. Autonomous Surface Vehicle

AUV……………….. Autonomous Underwater Vehicle

BIAs……………….. Biologically Important Areas are based on expert opinion of the best available science to help inform regulatory and management decisions

BOEM……………. Bureau of Ocean Energy Management, which is responsible for energy and mineral resources (including renewable resources such as offshore wind) in federal Outer Continental Shelf waters (i.e., beyond 3 nautical miles [**nm**] or 5.6 km from shore)

CESA……………... California Endangered Species Act is a state law of California that conserves and protects plant and animal species at risk of extinction

CCS………………... California Current System is a cold-water Pacific Ocean current that moves southward along the western coast of North America, beginning off southern British Columbia and ending off southern Baja California Sur

CDFW…………….. California Department of Fish and Wildlife, formerly known as the California Department of Fish and Game (CDFG)

CPS………………... Coastal Pelagic Species

Critical Habitat..specific areas that have physical or biological features essential to the conservation of the species and which may require special management considerations or protection, as s defined by the **Endangered Species Act** as

CSMP…………….. California Seafloor Mapping Program

CV………………….. Coefficient of Variation for modeling is a way to measure how spread out data values are relative to the mean and how well the model fits the data; a lower CV means that the predicted values are closer to the actual data

DDT……………….. Dichlorodiphenyltrichloroethane was developed as an insecticide in 1939, but was banned by many countries by the 1970s because of its environmental impacts

Deepwater…….Generally defined by **BOEM** as waters greater than 300 m (1,000 ft); other agencies (such as **NOAA Fisheries**) may consider 200 m (656 ft) to be deepwater.

DOI………………... United States Department of the Interior; **BOEM** and **USFWS** are agencies within DOI

DSCRTP………….. Deep-Sea Coral Research and Technology Program

EEZ………………... The Exclusive Economic Zone offshore California extends from 12 **nm** (22 km) to 200 **nm** (370 km), and grants the U.S. sovereign rights to the exploration and use of marine resources such as fisheries, as well as energy production from water and wind resources

[1] Additional emboldened words found in the descriptions are also defined in this list.

EFH………………….. Essential Fish Habitat

EFHCA…………….. Essential Fish Habitat Conservation Area

ENSO……………... El Niño-Southern Oscillation is a large-scale climate event that occurs when sea surface temperatures in the eastern equatorial Pacific region along the coasts of Peru and Ecuador increase significantly above the average temperature for three or more months; the ENSO phase has a return period of every four to five years resulting in a slowdown of the prevailing winds and increased rainfall off the West Coast

ESA………………….. Endangered Species Act is a federal law of the United States to conserve and protect endangered and threatened species and the ecosystems upon which they depend

EXPRESS……….. Expanding Pacific Research and Exploration of Submerged Systems

FAO……………….. Food and Agriculture Organization of the United Nations

FMP……………….. Fishery Management Plan

FRAM…………….. Fishery Resource Analysis and Monitoring Division within **NOAA**

HAPC……………... Habitat Areas of Particular Concern

HMS……………….. Highly Migratory Species

High Seas……….. All parts of the sea that are not included in the jurisdictional waters of a state and which are open to all nations

Hotspots…………Ecologically significant areas with persistently elevated biomass

HWEA…………….. Humboldt **Wind Energy Area** is an area that **BOEM** is considering holding a commercial lease sale for some or all of this 206 mi^2 or 534 square-kilometers km^2 area, which would grant exclusive rights to the lessee(s) to submit a construction and operations plan on their particular leasehold

IATTC……………... Inter-American Tropical Tuna Commission

IODE………………. International Oceanographic Data and Information Exchange

IUCN………………. International Union for the Conservation of Nature

La Niña…………...A La Niña event is the return of colder ocean temperatures that is the opposite phase of an **El Niño-Southern Oscillation**

LiDAR…………….. Light Detection and Ranging is a remote sensing technology that uses pulsed laser from an aircraft to measure distance (range) to the earth's surface, which are then combined with position and orientation data to obtain accurate, three dimensional spatial maps

Live Bottom…….Marine habitat areas that consist of biological assemblages such as seagrass beds, sponges, and coral attached to exposed hard substrate

MPA………………. Marine Protected Area

MSA………………. Magnuson-Stevens Conservation and Management Act

NEPA……………... National Environmental Policy Act

nm………………….. nautical mile; one NM is equal to 1.85 km or 1.15 mi

NMFS…………….. National Marine Fisheries Service (also known as **NOAA Fisheries**)

NMS………………. National Marine Sanctuary

NOAA Fisheries…National Oceanic and Atmospheric Administration (NOAA) Fisheries or **NMFS**

NREL……………... National Renewable Energy Laboratory

PacFIN……………. Pacific Fisheries Information Network

PCBs……………….polychlorinated biphenyls are man-made organic chemicals that were used in a variety of industrial and commercial applications (such as transformers and cable insulation) that were manufactured from 1929 until they were banned in 1979

PFMC…………….. Pacific Fishery Management Council is one of eight regional entities that manages fisheries for approximately 119 species of salmon, groundfish, coastal pelagic species (sardines, anchovies, and mackerel), and highly migratory species (tunas, sharks, and swordfish) on the West Coast of the U.S.

PSMFC…………... Pacific States Marine Fisheries Commission

ROV……………….. Remotely Operated Vehicle

SAFE………………. Stock Assessment and Fishery Evaluation

SMCA…………….. State Marine Conservation Area

SSH………………... Sea Surface Height

SST………………….. Sea Surface Temperature

USFWS…………... United States Fish and Wildlife Service

WCPFC……………Western and Central Pacific Fisheries Commission

WEA………………. Wind Energy Area is an offshore location that **BOEM** has assessed as most suitable for commercial wind energy leasing and possible development

YOY……………….. Young-of-the-Year (or Age-0) refers to animals that are younger than one year old within the population

SECTION 1. INTRODUCTION

The Bureau of Ocean and Energy Management (BOEM) is preparing an Environmental Assessment pursuant to the National Environmental Policy Act (NEPA) to assess a proposed Humboldt Wind Energy Area (HWEA) related to offshore wind leasing, and potentially, development activities. The HWEA is a 131,840-acre (534 km^2 /206 mi^2) open ocean area being considered by BOEM to conduct an offshore wind lease sale in fall 2022 (BOEM 2021). The HWEA is in federal jurisdictional waters beginning approximately 34 km (21 mi) offshore west of the city of Eureka in Humboldt County, California, extending seaward to 56 km (35 mi) offshore, and stretching approximately 45 km (28 mi) from north to south (Figure 1.1).

The California Coastal Commission, through its consultation responsibilities under Section 307 of the Coastal Zone Management Act, is to decide on whether to concur with the federal consistency determination that will be prepared by BOEM as part of the issuance of the Environmental Assessment and the proposed action to hold a lease sale. The Coastal Commission will assess and base its decision on whether the consistency determination, as well as other information and data provided, meet the state's enforceable policies, which are documented in Chapter 3 of the California Coastal Act of 1976.

To help the Coastal Commission in this review and assessment process, Point Blue Conservation Science (Point Blue) was tasked with developing a data catalogue and to synthesize the most relevant environmental datasets that are known within the HWEA or vicinity, including the nearshore coastal areas offshore Humboldt County. The intent of this report is to identify the best sources of data currently available on California's offshore resources, particularly in and around proposed wind energy areas. An important next step that would enhance this data catalogue effort is to identify and develop a single repository for West Coast data. Ideally, this would include regular updates of the datasets and a process to ensure that information has been peer-reviewed and verified.

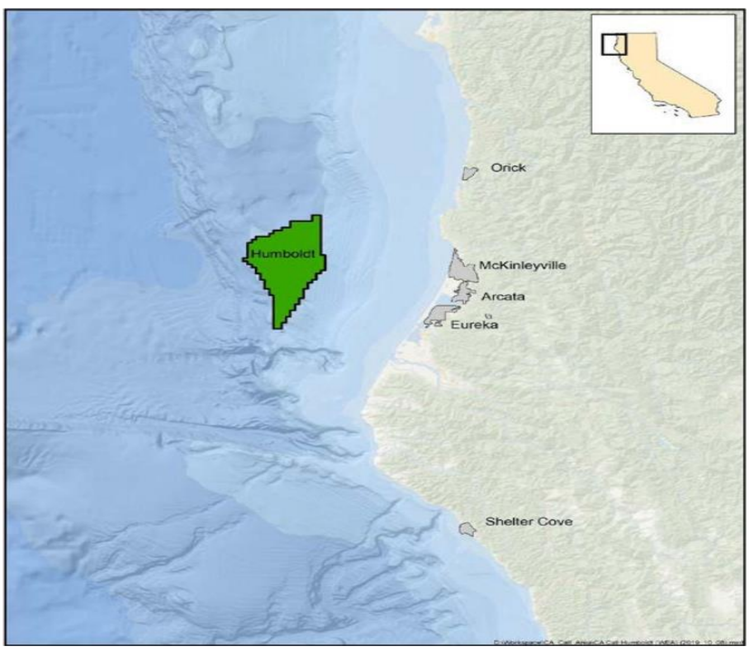

Figure 1.1. Location of Humboldt Wind Energy Area in relation to the California Coast (BOEM 2021).

This report describes certain marine resources and associated datasets that are available for the region. The report also includes information on potential gaps in the current knowledge base on data associated with these resources.

Understanding Dynamic Marine Systems

While datasets are static, the animals in this system are not. Many factors affect species and their movements along the length of California's 1,770 km (1,100 mi) coastline and marine ecosystem. The

California Current System defines this ecosystem. In simple terms, the California Current System acts as a conveyor belt bringing cold, nutrient-rich waters of the California Current that interact with the warmer counterflow of the Davidson Current (Figure 1.2). Predominantly northwesterly winds put stress on surface waters and with the earth's rotational pull, this creates the energy and motion needed to force upwelling of deep, cold waters toward the coast. The upwelling influences food resources and larval transport thereby affecting one of the most productive marine systems in the world. The upwelling helps to sustain a wide range of marine predators, including whales, seals, sharks, tuna, and pelagic seabirds. This ecosystem, in turn, supports socioeconomic goods and services from managed fisheries to tourism.

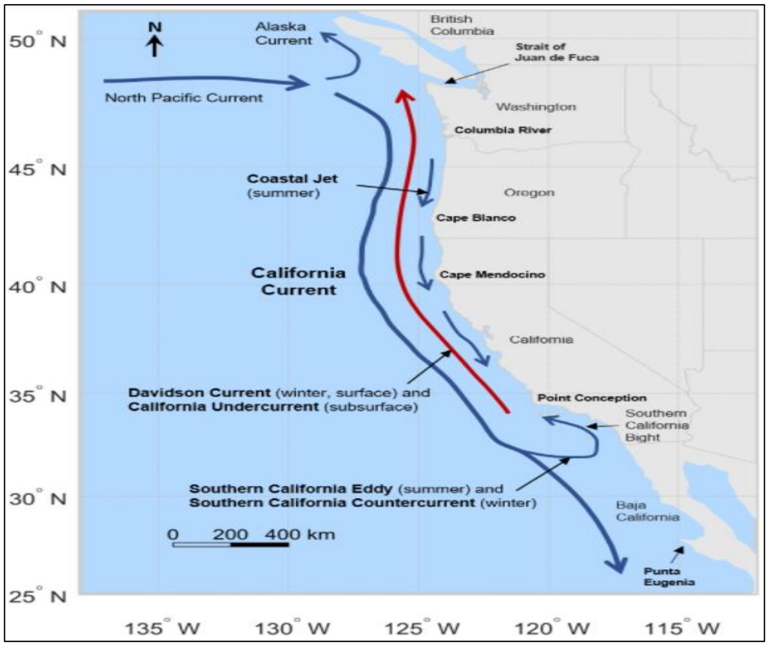

Figure 1.2. Schematic of the California Current System

Changes to the intensity and magnitude of this upwelling have corresponding significant effects (both positive and negative) on ocean productivity. The upwelling tends to be stronger and colder during spring and summer months, then weaker in the fall and winter when offshore winds subside. Other factors that are linked to marine productivity include chlorophyll-a concentration, dissolved oxygen levels, nitrogen, water temperature, and salinity. Depth, grain size, sediment composition, and presence of methane gas (also called "cold seeps") are some of the factors that influence the benthic biota.

Phytoplankton (diatoms) is the key to this trophic food chain supporting a diverse array of marine life from microscopic zooplankton (e.g., krill and copepods) to the largest whales. Its productivity can be measured by satellites based on the color intensity (i.e., concentration) of chlorophyll in the system. Phytoplankton productivity varies widely depending on many factors from climate variability to seabed topographic features.

In addition to the location and abundance of food sources, the physical properties of the seabed and water depth are also helpful predictors of species' habitat preferences. The HWEA lies west of the continental shelf break over the shelf slope in water depths ranging from 500 - 1,150 m (1,640 - 3,770 ft, Figure 1.3).

Modeling Efforts to Track Species Preferences

Predictive seafloor habitat mapping efforts of the continental slope and shelf between Trinidad Head and Cape Mendocino suggest that the HWEA and adjacent seafloor area consist of sand interspersed with rocky reef habitat. Two deepwater trenches, the Trinidad Canyon (also called Trinity Canyon) and Eel

Canyon, are located to the north and south of the HWEA. These submarine canyons are also helpful indicators of species presence based on benthic habitat types and water depth preferences.

Humboldt Bay is a significant feature along the Humboldt County coastline. The bay contains important tidal mudflats, eelgrass beds, salt marsh, and wetland habitats covering more than 195 km^2 (75 mi^2). While this report does not include this coastal lagoon area, it is worth noting that Humboldt Bay contains among the largest eelgrass beds between Willapa Bay, Washington and Baja California, Mexico (Western Hemisphere Shorebird Reserve Network 2021). Humboldt Bay also provides significant habitat for many species of marine and estuarine fish and invertebrates (particularly in their juvenile stages) that become prey for other species, and which may be targeted for commercial and recreational purposes.

Because fish cannot be easily observed in place, data must be routinely collected from various sources of information to assess commercial and recreational catch effort on the managed populations (called “fisheries dependent surveys”). Data are also routinely collected from standardized scientific surveys along specific transects at certain times of the year, which are called “fisheries independent surveys.”

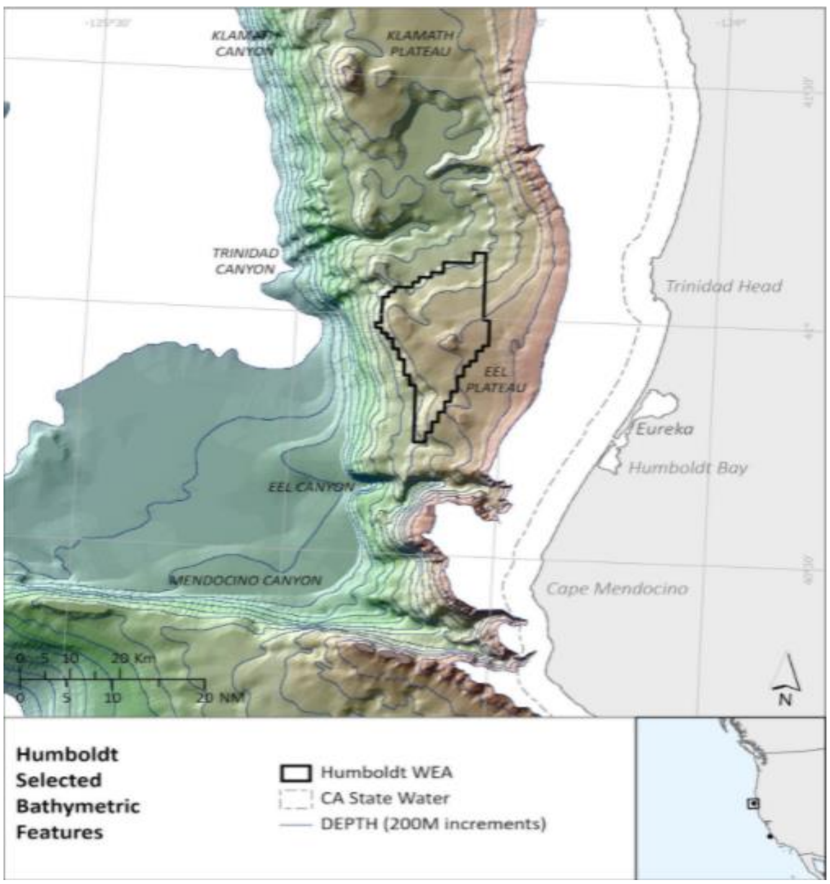

Figure 1.3. Selected bathymetric features within and around the HWEA.

Through the aggregation of this information along with other data that is collected, such as from satellite tracking of certain fishing vessels, interviews with fishermen, and other information, an understanding of habitat preferences and abundances emerges that allows for an assessment of the health and status of these managed populations of marine fish, sharks, and invertebrates. These efforts are described in Section 2.

Nearshore marine areas generally out to the 200-m isobath (656 ft) have been well characterized over the years, but site-specific benthic surveys of the HWEA have not yet been required or conducted. Information is available, however, that can be used to conduct preliminary assessments of the potential macrofauna that are likely to exist in the area. BOEM funded a predictive modeling study that indicates the likely distribution of deep-sea corals and sponges in the HWEA and vicinity (see Section 3). Corals and sponges are considered the most important groups of benthic organisms to form biogenic (“live bottom”) habitats in deep ocean waters. These predictive maps can be used to infer patterns in habitat suitability across taxa in depths from 50 to 1,200 m (164 to 3,937 ft).

The HWEA area also contains numerous invertebrates such as crab, shrimp, and squid (Section 3) and bony fish and shark and ray species, from resident rockfish to migratory tuna (Section 4). Many of these are important to commercial and recreational fishing, which are described in their relevant Fishery Management Plans, available online (Pacific Fishery Management Council [PFMC] 2021). Additional information on the best available data of managed stocks and fisheries can be found in the Stock Assessment and Fishery Evaluation (SAFE) documents, which are also available at the Pacific Fishery Management Council's website (PFMC 2021).

There are, however, difficulties in using fishery information for other purposes such as trying to combine datasets that cover varying spatial and temporal scales. These surveys have also been designed to answer specific fishery management questions (such as how much of each species is being landed to measure catch totals) and this information can be limited in their usefulness for other purposes or questions.

Section 5 describes many species of marine mammals that could occur in or adjacent to the HWEA. One method to assess their possible likelihood in the region is the use of species density models. These models are based on the collection of shipboard and aerial observer data as well as extrapolating information collected from observational surveys to help determine habitat preferences. This type of modeling has been done for many of the marine mammals listed in Section 5, which is based on a current understanding of life history traits that are known for these species.

Many pelagic bird species could also potentially occur in the vicinity of the HWEA. These include highly abundant populations of common murres and sooty shearwaters as well as less common pelagic seabirds that remain at sea for long periods of time. Section 6 describes the current understanding of those species that are likely to occur in the region. Seabird density models have also been developed from seabird observational data to predict habitat preferences when fine-scale, long-term, monitoring data are not yet available.

Predictive models are a way to assess potential anthropogenic pressures on many species that can be difficult to survey, where it may not be possible to count every animal, and where information about uncommon species is lacking. However, biodiversity of marine species is extremely complex and there are inherent uncertainties in any modeling system that need to be understood when using predictive models for planning and management decisions. For example, the biggest uncertainty in any modeling effort is capturing the dynamic nature of the marine environment in conjunction with often highly mobile species. The level of effort during observational surveys, as well as when and where these surveys were conducted, can create gaps in the underlying data that the models must fill. Modeling accuracy is also affected by the spatial resolution of the grid that is used for analysis and presentation of the results.

Real-time data on oceanic and atmospheric conditions is becoming more widely available with greater use of satellite technology, remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), and autonomous surface vehicles (ASVs). These technologies will eventually allow for greater collection of biotic and abiotic information that can be conducted more frequently, in deeper waters, and during times of the year when crewed vessels do not venture offshore. Different methods between human observers and autonomous devices still need to be evaluated to determine how information can best be integrated, especially with existing, long-term datasets. A new tool called baited remote underwater video systems (BRUVS) can be used on the seabed or in mid-water as a non-lethal sampling method to identify species, determine relative abundance and, when stereo-BRUVS are used, measure length. FishBase, which provides information on 33,000 fish species (Froese and Pauly 2021), has a new BRUVS tool feature that provides publicly available geo-referenced data from global fish surveys that are based on these baited remote underwater video systems, although none is available at this time from marine locations of the United States. Other technologies such as passive acoustic monitoring, infrared cameras, floating multi-instrument arrays, and high-definition digital imaging are also becoming more frequently used in offshore studies to obtain more information, and often more accurate information, which is particularly useful for rarely seen or difficult to observe species.

Science-based Mapping and Analysis Platforms

As competing demands for ocean resources rise and climate change creates greater uncertainty for predictions of habitat preferences, the need for collating marine data into large spatial databases becomes ever more important. Ideally, these datasets would be accessible in a single repository, but this is useful only if the datasets are maintained and updated regularly, particularly to incorporate new biological information and protected habitat designations. There are nearly 700 datasets currently in the California Offshore Wind Energy Gateway mapping tool; however, some are incomplete or need to be updated. All portals have varying levels of data and ease of use. Many thousands of datasets can be found for West Coast resources in portals from organizations and national and international bodies. Hourigan et al. (2015) describe a process and schema toward the development of an integrated database for deep-sea corals. This is an example of the type of guide that might be useful in developing a system for standardizing data collection efforts, ensuring the continuity of collected data, and developing an interface for data visualization.

Ocean marine resources do not obey state, national, or international jurisdictional boundaries. Many species in the California Current System might also be found latitudinally between Alaska and Mexico or longitudinally from the West Coast to Asia; some species migrate as far as the Antarctic. The main concern about the various data aggregation sites and portals is the need to have continuous updates with current data and information, as well as a constant review to ensure that invalid links or corrupted files are corrected. The inaccessibility of information, sub-optimal user interfaces, as well as the presence of outdated data diminishes the user's experience and limits the accuracy and usefulness of these products. In general, these sites and associated datasets can be: a) difficult to navigate for the general public, b) not regularly updated, and c) scattered and not accessible in one website/URL.

Overall synthesis of environmental variables

Predictive models can be used to describe habitat properties and species distributions in areas beyond the exact sampling locations. Biodiversity of marine species is extremely complex and there are inherent uncertainties in any modeling approach. Water depth and seafloor structure are among the key attributes that affect marine species' habitat preferences. Data that can be accessed to visualize the efforts that have been taken to conserve and minimize effects on important seafloor habitats and the water column are provided in Dataset Table 2.1, which describes a tool to show where Essential Fish Habitat (EFH) is located. Dataset Table 2.2 also shows depth-based fishing closure areas off the West Coast. Nearly all federal waters are considered EFH along with some areas that have specific fishing gear or seasonal restrictions. Predictive seafloor habitat mapping efforts of the continental slope and continental shelf suggest that the seafloor in the region consists of sand interspersed with cobble and rocky reef habitat. This information can be found in Dataset Table 2.3, which is a unified database that provides an understanding of the geologic sedimentary character of the continental margins of the United States. Dataset Tables 2.4 and 2.5 provide bathymetry data, which not only offers information on important benthic habitats, but can also be used to map the locations of offshore geohazards including faults, submarine landslides, sediment transport pathways, and seafloor seeps.

In general, the nearshore seafloor out to about the 200-m isobath (656 ft) has been well characterized, but site-specific benthic surveys of the HWEA and the surrounding deepwater region are not yet available. There are assessments that can be used to provide a basic understanding of potential macrofaunal resources that are likely to exist in the area; however, site-specific qualitative and quantitative information is generally lacking for deep-sea benthic ecosystems. Deepwater corals and sponges are considered important benthic and biogenic habitat features because of their complex structures that provide sources of vertical relief on the seabed of the deep ocean that is mainly composed of mud and sand. Dataset Table 3.1 is a source of information as to where observations have been made of deepwater corals and sponges. One drawback is that the mapping scale of these observations is extremely large and does not accurately represent site-specific benthic values and the areal extent of these features. Potential impacts to krill and other forage species from changing environmental and climate variables can be graphed as shown in Dataset Table 3.2, which offers access to invertebrate data taken from trawl nets conducted at set stations. It is known that large-scale water transport and the location and abundance of krill are top factors that influence ecosystem productivity. When this type of sampling is done over many years and at regular times of the year, then the emerging patterns help connect the linkages between the physical and biological processes, which are critical toward understanding what drives abundance and diversity in this large and dynamic marine ecosystem. Dataset Table 3.3 is one way to bring together both the remotely sensed environmental or biological variables, (e.g., chlorophyll-a/phytoplankton), with the consumers (e.g., krill, forage fish), to depict hotspots or areas of enhanced species abundance, diversity, and/or trophic interactions. Understanding food source abundance and availability through their response to oceanic conditions might also be useful for making basic assumptions about changes to the system because of anthropogenic inputs.

Small pelagic and larval fish form critical food web links between phytoplankton and krill and higher trophic marine predators. Understanding fish life histories and their ecological traits can help predict habitat preferences and spatial distribution. This information is also used to support management efforts to maintain sustainable populations for exploitation of this resource, which can be depicted in the “landings” of commercially and recreationally harvested fish and other species. Dataset Table 4.1 is the NOAA Fisheries Landings database that shows how much of each species was caught in California during certain years and the value of those fisheries at the docks (with certain caveats on the data). Groundfish, which include more than 60 rockfish species, lingcod, Pacific whiting, flounders and sole, are one of the important commercially and recreationally targeted species in federal offshore waters of California. Dataset Table 4.2 describes long-term trawl data (similar to Dataset Table 3.2) that gives fisheries managers an indication of the number of young-of-the-year rockfish in the system, which can be used to monitor trends and changes in the ecosystem. Another way to compile this information is shown in Dataset Table 4.3, a “fishing intensity” map from twenty years of aggregated data on groundfish that was made available through vessel trip information reported by fishermen along with what they caught and where. Dataset Table 4.4 is information to access the nation’s first regional fisheries data network, called PacFIN, which combines federal and state fishery data to provide accurate estimates of commercial catch and value for West Coast fisheries. How this dataset can be used to show fishing intensity across all fisheries is provided in Dataset Table 4.5, *Catch of California commercial marine fisheries*, but this dataset has not been updated since 2005, which makes it less useful when assessing current activities. This is especially true because fisheries management changes over the last decade have led to new quota systems and significant changes in the species composition of landings and spatial patterns of fishing that have not been captured by this dataset.

Forty-five species of marine mammals are known to occur in the California Current System between Canada and Mexico that have a presence off California, from the largest cetaceans to sea otters. Because many marine mammal species prefer deep, offshore waters, and can be difficult to observe, predictive models are also used to determine abundance and range. By combining oceanic variables with observational data on marine mammals, predictions can be made about where they are likely to be seen. Dataset Table 5.1 is the most current and best available information on these species and sources, although it is limited to cetaceans. In addition to observation-based models, more general habitat use areas have been identified as Biologically Important Areas (BIAs) for cetaceans, described in Dataset Table 5.2. Based on the distribution models, cetacean species most likely to occur in or near the HWEA are Dall's porpoise, northern right whale dolphin, and Pacific white-sided dolphin. Humpback, blue, and fin whales are also broadly and seasonally distributed in the region but have lower predicted densities due to lower overall population numbers and distribution patterns. The highest density of baleen whales in the vicinity of the HWEA is most likely to occur in the summer and fall. For pinnipeds, spatially explicit distribution data is limited in availability and have not been utilized to create discrete distribution models although some tagging data is available upon request to the researchers.

Predictive density and distribution modeling efforts have been made for seabirds, which number at least 80 species off California from nearshore to far offshore. Dataset Table 6.1 includes survey data from multiple cruises combined with predictor variables derived from bathymetric and remotely sensed oceanographic data as well as climate indices. This modeling efforts predicted densities of 30 seabird species, some of which are well represented in the dataset (i.e., frequently observed) while others are less representative because they are rare or infrequently seen when the at-sea surveys were conducted. Dataset Table 6.2 is a mapping effort that shows model-derived spatial predictions with long-term average density to provide an indication of where certain species or groups of seabirds may be more or less abundant. Dataset Table 6.3 is a comprehensive database that can be used (and modified or updated) to quantify marine bird vulnerability to offshore renewable energy developments. In very general terms, jaegers, skuas, pelicans, terns, and gulls have high vulnerability to collision with offshore wind infrastructure, whereas loons, grebes, sea ducks, and alcids have high habitat displacement vulnerability.

Sea turtle observational data have been collected from aerial surveys, nesting beach surveys, and in water capture efforts to estimate marine turtle abundance, stock structure, habitat use, and movement patterns. Access to this data is described in Dataset Table 7.1. Similarly, Dataset Table 7.2 describes leatherback turtle occurrence based on a deductive process of their habitat preferences. Dataset Table 7.3 is another predictive modeling effort but uses satellite and light-based geolocation data from the tracking of tagged leatherback sea turtles to determine their distribution and habitat preferences. Dataset Table 7.4 provides an index of how sensitive certain areas might be along the California shoreline, in case there is an accident such as from an oil spill. This dataset includes sea turtle sensitivity.

In general, obtaining data on environmental resources in the HWEA region is difficult because of the remoteness of this northern California area and the site's location far offshore (at least 27 km [17 mi]). Because winter conditions can be dangerous for at-sea observation and conditions frequently preclude data collection, the available information on species distribution is significantly skewed toward summer and fall months and may be reduced or lacking in winter months. The data that are available may also be limited in accessibility (e.g., geographic information system [GIS] software and analysts are needed to manipulate the data) or requests must be made to state agencies or researchers to obtain the datasets. For the portals that do exist, they are scattered in numerous online sites, have varying levels of updated information, and different levels of ease of use.

Overall synthesis of science gaps

Gaps and deficiencies in available data fall into several broad categories including temporal weaknesses, spatial coverage shortfalls and quality or applicability issues. These different types of gaps are distributed unevenly across the various classes of data covered in this report. Deficiencies also stem from different root causes including technical hurdles, funding shortfalls and disparity in historical drivers of research for different taxa and physical components of the marine environment. Here we first describe some of the overarching differences and drivers of data quantity and quality, we then identify patterns of temporal, spatial and data applicability gaps specific to each data type covered in the report. We finish with a discussion of three key research gaps that are poorly addressed across nearly all data types covered in this report: 1) prediction of future change especially resulting from climate change scenarios, 2) quantification of sensitivity to offshore wind impacts, and 3) development of a well-organized, easily accessible, well-maintained data repository with maintained links to source data.

Data quality and quantity

One key disparity in data quality and quantity is availability driven by the logistics of data collection. The surface and near-surface ocean are sampled using visual methods and remote sensing, so significantly more upper-ocean data is available covering a greater area and finer time steps. In comparison, midwater and bottom data are largely collected at widely spaced, specific sampling points by research cruises or automated systems such as vertical profiling floats. These focused point data lead to a relatively poor picture of mid-, deep- and benthic physical and biological processes because they are limited in spatial and temporal extent. The lower coverage and availability of subsurface marine data limits the understanding of ecosystem level interactions between species and their environment. It also increases the difficulty in constructing good models of species that spend the majority of their time in deeper waters. For example, the authors of Dataset Table 5.1 state that the two lowest-performing models of marine mammals are for sperm whales and the small beaked whale guild, partially due to limited environmental data in their most frequented habitat.

Another broad pattern of data disparity is between abundant versus rare species. Distributions of abundant species are more readily studied and modeled, frequently leaving gaps in information covering rare (and often at-risk) species such as the north Pacific right whale, Guadelupe fur seal, California least tern, or leatherback sea turtle. Solving these deficiencies may require targeted approaches such as tagging and tracking to better understand the distribution and habitat use patterns of species that might be at disproportionate risk of population impacts.

Third, because most at-sea studies cover broad areas and are conducted seasonally or annually at best, there is a lack of site-specific data on the variability of presence and abundance of species in the development area. Given the high levels of strong interannual physical and biological variation in the California Current system, multi-year and cross-season data is usually important for a comprehensive assessment of impact. In addition, because of longer-term changes (e.g., the increase in warm water events in recent years or changes in fisheries regulations) it is important to have recent data that represents current conditions to compare with historical patterns that may no longer be relevant. For example, one of the key fisheries data sets (Dataset Table 4.5) does not include data from the last 15 years, a time period of known extreme marine heat events which likely affected fish populations. High resolution seasonal data is most important for very mobile species like seabirds, marine mammals or highly migratory fish. Solid interannual data is key for mobile species that may alter habitat use annually as well as for shorter-lived species like krill, forage-fish, or squid that can have large population fluctuations over relatively short timeframes.

Habitat and Species-Specific Gaps

The inherent nature of the **benthic environment** leads to difficulty in understanding it. Data collection and processing requires highly specialized equipment, high levels of training, complex logistics, and large quantities of time and server capacity to store and manage. In general, benthic data is collected at two scales: extremely fine spatial scale over a small area, or as a series of well-dispersed points from which unsampled areas are extrapolated. Both result in limited spatial coverage of data, which restricts applicability for site-specific projects like offshore wind development. Focused, fine-scale data collection in the project area will improve the understanding of the importance of these features and their biological associations. Developments in automated sampling platforms like subsurface gliders and continuing improvements to three-dimensional ocean models like the Regional Ocean Modeling System (ROMS) are beginning to increase data availability for sub-surface habitats, offering the prospect for improved understanding and modeling of deeper waters and the species that reside there. Increased use of high-resolution acoustic sampling and new analytical techniques are also improving quantification of midwater species distributions and benthic features. However, based on this review, it does not appear that hydrographic data is being collected for temperature, salinity, oxygen, phosphate, and nutrients in or near the HWEA. Regular sampling would allow categorization of faunal groups across deepwater habitats that exist beyond the shelf.

Marine invertebrates are one of the most difficult groups of organisms to investigate. Monitoring changes in invertebrate communities requires collecting multiple samples at several locations and across seasons, and post-cruise laboratory work to identify and quantify the species caught. Obtaining ship time and the appropriate gear for sampling can be expensive, and sampling is often deficient at both spatial and temporal scales. For example, sampling benthic invertebrates on the seafloor is logistically challenging and is focused on small areas and species groups (e.g., deepwater corals and sponges). Sampling pelagic invertebrates is also inadequate, as spatial coverage is poor, and sampling is not frequent enough to capture the dynamic nature of these populations that fluctuate rapidly with changing ocean conditions. Ample time and expertise is needed for laboratory analysis of the samples collected. Site-specific sampling is necessary to understand the invertebrate communities that inhabit the HWEA site. Benthic invertebrate communities identified could be linked to the benthic data and features, and this would be helpful in modeling approaches for this and future potential offshore wind sites.

Fish and fishery data are some of the most complex datasets that are least available in high or specific spatial or temporal detail. Studies that collect data on fish are often species or group specific, tend to focus on species that have an economic value, and are highly localized. Exclusion of less-studied fish species may skew analysis of data to the point of overlooking the influence those species have on the ecosystem. The highly mobile and wide-ranging nature of some fish species increases challenge of collecting population and distribution data. Fishery data can be used as a proxy for fish population information, but the intrinsic lack of random spatial and temporal sampling will lead to bias. In addition, fishery information is not easily available to the public mainly because of legal restrictions that preclude reporting of individually identifiable data. There are certain types of vessels or vessels targeting certain species that are required to carry tracking devices called Automatic Identification System (AIS) or Vessel Monitoring System (VMS). AIS and VMS data that are currently available are problematic because they are not standardized across the whole fishing fleet, especially the smaller vessels or those targeting less sensitive species. VMS information would be particularly useful data because it would more precisely allow an assessment of the location and duration of fishing activity, and it would be in near real-time because the data are automatically transmitted every two hours to satellites. Such precise spatial information on fishing activities could be used to create bio-economic models that would allow better understanding of the dependencies between coastal communities and their fishing grounds.

Marine mammals are one of the better studied and data-rich groups, although they can be difficult to monitor due to variability in their spatial and temporal distribution, as well as the fact they spend most of their time at sea underwater and out of view. The strong legal protections and regulatory monitoring requirements for marine mammals have led NOAA to collect long-term data that spans two and a half decades. These data underlie the high-quality models in Dataset Table 5.1, most of which have strong statistical fits and have been thoroughly validated with independent data. Since the predictions represent the average densities over the dataset timeframe, they are an excellent representation of long-term patterns. Spatial coverage is good, though because the shipboard surveys cover the whole EEZ, models may be weaker in nearshore areas. With the exception of pinnipeds, there is good taxonomic coverage of marine mammals, though the statistical strength of the sperm and beaked whale model predictions is low and needs to be considered when assessing model strength, especially at the scale of the HWEA. Species distribution models of pinniped species that have good tracking data would offer a way to improve data for that group. In addition, recent advances in acoustic monitoring are likely to improve data on beaked and sperm whales, as well as for other vocal species during seasonal periods where coverage is currently lacking. While long-term coverage is good for marine mammals overall, seasonal representation is lacking, with most species only having models for summer/fall.

Datasets for **seabirds** are the most complete for spatial, temporal, seasonal, and taxonomic coverage of all the habitat and species groups. Their need to breed on land, propensity to be more readily observed at-sea, and large populations of most species allow for the collection of robust data in all environments they utilize. As with other species, however, the logistics of collecting data at sea limits the quantity of data available. Also, these data tend to be coarse, generalized over large areas and time scales of many months. For the purposes of wind energy development, it would be beneficial to have more information on the differential species reaction to and potential interaction with offshore wind infrastructure, including seasonality of habitat use, flight behavior, and local foraging habits. Rare, threatened, endemic, and locally breeding species all deserve extra attention, in that they may be disproportionately affected by changes in the local environment. Studies that provide fine spatial and temporal scale data on seabird movement patterns and habitat utilization in and around the HWEA itself are important for understanding the potential impacts of offshore wind energy development and operation.

Sea turtles are one of the more data-poor groups, lacking in spatial, temporal and taxonomic coverage. The highest-quality data available is for leatherback turtles and derives from tracking studies. These have been processed into kernel utilization densities (KUDs, Dataset Table 7.2), but the tracked animals were not representative of the broader population and there were known behavioral effects of the tagging process. For these reasons, the KUDs are only suitable as a general indication of where leatherback turtles may be found but should be treated with caution because some areas that species actually uses may be missing. While potentially of some use, the GAP models only identify areas of potentially suitable habitat and thus should not be treated as a reliable indicator of presence or absence. Green and loggerhead turtles have no distribution data available. While current data is lacking, there is research underway to construct a statistical model fit to an expanded tracking dataset of leatherback turtles and this data should be more useful for evaluating offshore wind conflicts once available.

Key Research Gaps

There is a growing field of study following the impact of changes in climate and the increasing frequency of marine heat waves. These events will cause changes in distribution and migratory patterns, potentially deviating from model predictions that are widely used to assess distribution and abundance. Abrupt shifts in oceanic conditions can cause a cascade of changes in distribution and migratory patterns for different species, many of which are described in this report. This is a recently expanding area of intense study and new research findings. Publicly available data on ocean heat content and temperature anomalies over different time scales going back to 1955 can be found at the National Oceanic and Atmospheric Administration (NOAA) National Center for Environmental Information (NOAA NCEI 2021). This can be useful when trying to compare whether population shifts in marine species might be due to oceanic and climatic conditions or anthropogenic inputs. Also, an International Working Group on Marine Heatwaves tracks marine heat waves and consolidates publications on this topic (Marine Heatwaves International Working Group 2021). Improving the information on likely future scenarios will be important to effective and durable assessments of offshore wind development impacts.

Another important information gap for most of the resources covered in this report is a thorough understanding of the vulnerability each species or habitat to offshore wind development and operation impacts. Though generally not spatial in nature, this data plays a key role in translating exposure (as determined by spatial and temporal patterns) into impact. The sensitivity of seabirds to collision and displacement has been evaluated (Dataset Table 6.3) and there is some research quantify noise impacts for marine mammals. However, sensitivities for most of the species and habitats at risk are not well known, especially to floating turbine development which is relatively new and un-studied.

Lastly, the challenges of data accessibility for impact analysis are daunting. Some data are not available because they have not been released for general use. Other data must be requested directly from their sources, which may be complicated by difficulty in making contact or timeliness of response. For data that are publicly available online, the vast variety of data gateways and repositories in which data are stored can increase the effort required to find and acquire the data. Online data may also not be updated regularly or at all, web addresses may be changed, outdated, or broken, and the data itself may not be clearly linked to peer-reviewed studies. Once acquired, data may not be in a useful format, or may require specialized analysis software or skills. All of these factors apply to data described in this document and influence the quality and usefulness of data for project-specific purposes such as offshore energy development.

SECTION 2. GEOLOGY, BATHYMETRY, AND HABITAT

Marine benthic habitats are often defined by their geological structure as well as depth (or bathymetry) and chemistry. For this reason, geophysical techniques (high-resolution seismic and sub-bottom profiling, side scan sonar, multibeam surveying) are critical in determining bathymetric features, habitat structure, and rock type. Depth is often a feature of habitat preference from the intertidal areas to the deep ocean. The continental shelf (from 0 to 200 m [656 ft]) delineates the submerged part of the continental landmass that extends from the coastline to the shelf break. From the 200-m (656 ft) isobath, which delineates the shelf break, a long continuous continental slope (from approximately 200 to 2,000 m [656 to 6,562 ft]) descends slowly to the ocean floor. Deep trenches form at the areas of subduction that occur between tectonic plates, while submarine canyons (formed by ancient fluvial processes during lower sea levels) are common across both the continental shelves and slopes. Submarine canyons have complex bathymetry with high, ridge-like features, which provide habitat for a variety of species, and can affect local bottom currents. Steep topographic structures and rock provide exposed relief above the seabed that serve as important habitats for both pelagic and benthic species. Deepwater branching corals and sponges also create structural habitat.

Geological and Bathymetric Conditions in the HWEA or Vicinity

Regional Tectonics

The continental shelf off Eureka is a relatively narrow (about 20 km/12 mi), flat, and topographically smooth feature with large, continuous inputs of sediment from the Eel and Mad Rivers (Friedlander et al 1999). The continental slope in this area also marks the approximate eastern boundary of the Gorda Plate, which is a segment of the southern Juan de Fuca tectonic plate that is being subducted beneath the southeastward-moving North American tectonic plate (Field et al. 1980). Movement of the North American Plate against the northeastward-moving Pacific Plate creates the active San Andreas Fault Zone (Figure 2.1). Where these three tectonic plates converge is called the Mendocino Triple Junction, which is south of the HWEA. The Mendocino fault, which trends east to west, forms the boundary between the Gorda Plate to the north and the Pacific Plate to the south.

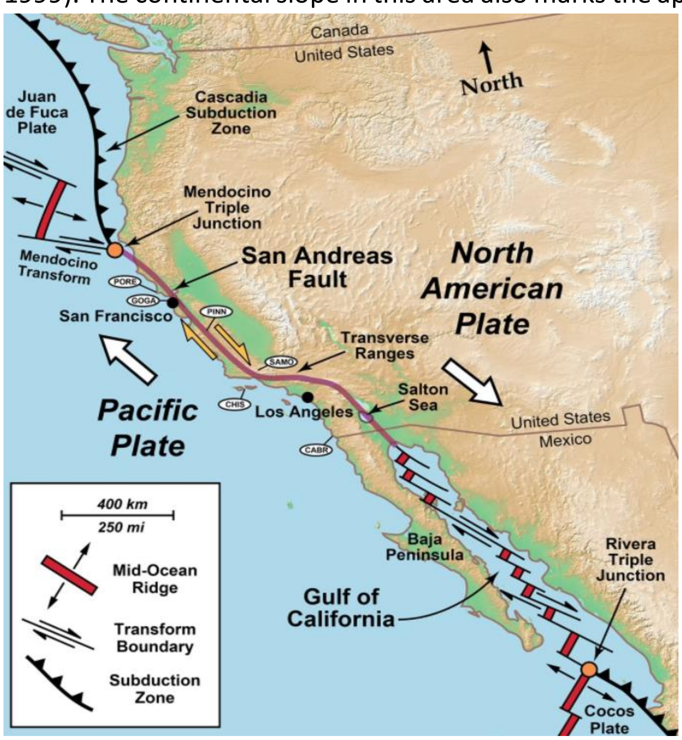

Figure 2.1. Major tectonic plates along the U.S. West Coast

Typically located in the deeper continental slope region, seamounts are underwater ridges that can rise more than 1,000 m (3,300 ft) above the seafloor. Other, smaller features of knolls, hills, and mounds, often a result of volcanic activity, also exist here. Seamounts and other features are often productive areas of the continental slope because they create structure and a regionalized upwelling that are beneficial for benthic and pelagic marine life.

As part of their efforts to protect fish populations, federal and state agencies have taken measures to protect, enhance, and restore a variety of habitats, including inshore and offshore areas. Offshore habitats that have been determined to be particularly important for fish are protected under numerous designations with different regulations. Some areas are off limits to fishing entirely, sometimes all year but often on a seasonal basis or in certain fishing blocks at certain times to avoid critical spawning or migration, or other factors. Other areas are off limits to certain gear types, most often commercial bottom trawling that directly contacts the seafloor. The National Marine Fisheries Service (NMFS or NOAA Fisheries) and the Pacific Fishery Management Council identify, map, and manage certain fish-specific habitat designations along the West Coast.

Submarine Canyons and Seamounts

Slumps and slides occur from rapid sedimentation, particularly from submarine rivers flowing over the continental shelf. These conditions tend to be common near submarine canyons because of gravity flows and seismic activity (Nittrouer and Kravitz 1996). Dominant geologic features in the area are the Eel River Canyon approximately 7 km (4 mi) to the south of the HWEA, and the Trinidad Canyon (also called the Trinity Canyon) approximately 9 km (6 mi) to the north (refer to Figure 1.3 and to CSA Ocean Sciences Inc. et al. 2019).

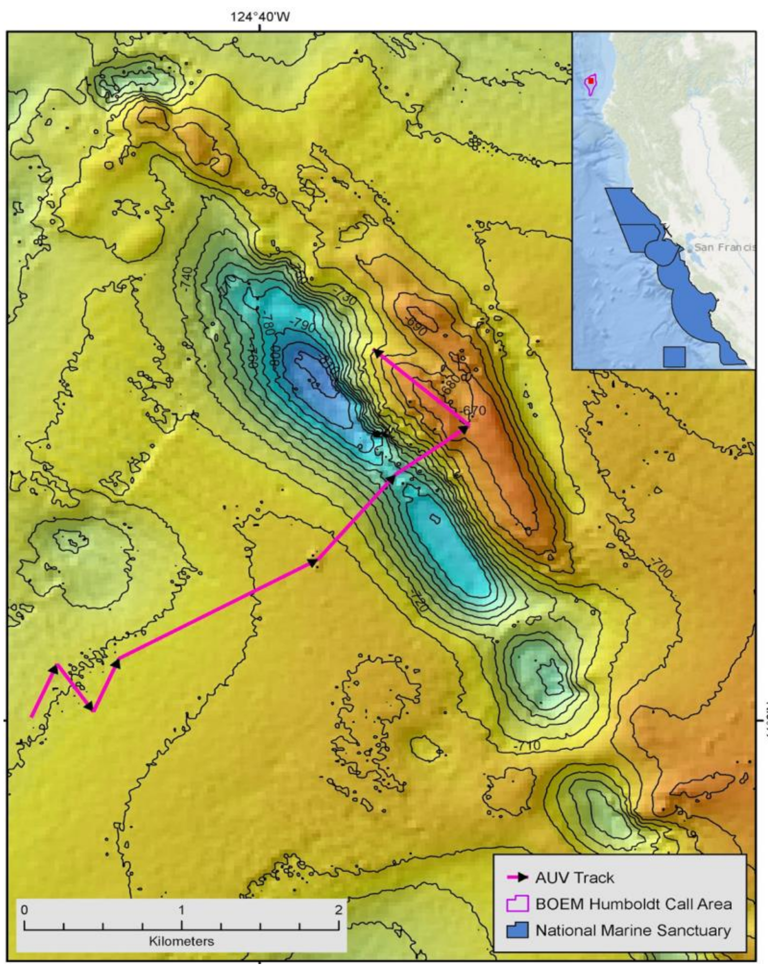

Figure 2.2. Location of large ridge feature in the HWEA (image from: NOAA, BOEM, and USGS 2019).

Within the HWEA exists a large and prominent seamount located approximately 40 km (25 mi) from shore (Marine Conservation Institute 2020; Figure 2.2). The feature is about 8 km (5 mi) long with a peak rising hundreds of feet above the seabed. Because of its bathymetry, this seamount may enhance local upwelling and provide a source of food and habitat structure for deepwater species.

The HWEA is also known to contain rocky reef structures. These features do not appear to have been fully described or mapped yet, but current side scan sonar and multibeam surveying efforts might provide higher resolution depth data and still images that could be used to evaluate these areas in more detail. Currently, the reefs are broadly categorized as Essential Fish Habitat. Deepwater corals, which can settle on hard substrate and are also considered EFH habitat, are described in Section 3 on invertebrates.

Hydrothermal Vents and Cold Seeps

Hydrothermal vents, often located at seafloor spreading centers, are deep-sea features that form due to the venting of hot, mineral-rich fluids into the water column. Temperatures at these vents can exceed 400°C (750°F). Hydrothermal vents occur when fractures in the seafloor allow seawater and magma to meet. Vent fluids are hot enough to cause minerals such as silica, sulfide, and heavy metals to leach from the surrounding rocks. When these fluids hit the cold seawater, minerals precipitate into a cloud of particles consisting of either black (iron sulfide) or white (calcium and silicon) plumes that look like smoke. This precipitation of minerals eventually solidifies into large chimney-like structures. Hydrothermal vents create ecosystems that support a wide array of benthic organisms that rely on these venting fluids as their sole source of energy. Due to the western divergent boundary of the Juan de Fuca and Gorda Plates, the deep ocean offshore the U.S. Pacific Northwest and the Northern California Coast remains an area that is abundant with hydrothermal vents and supported deep-sea habitat.

When organic matter reaches the seafloor and is buried in the sediments over time, methane gases can develop from the activity of anaerobic bacteria. Frozen methane is stored in marine sediments as gas hydrates in water depths greater than 300-600 m (985-1,970 ft). Once destabilized and released, gasses then bubble up through the ocean and are released into the atmosphere. This is called a cold seep. Off Eureka, seafloor characteristics indicate the presence of shallow gas fields (Field et al. 1980). The presence of methane gas is variable throughout the Eel River Basin region. Areas containing the most gas are correlated with seafloor failure (Syvitski et al. 1996). Research in Monterey Bay has also found that cold seeps occur more often on steep slopes, which are commonly areas of recent erosion and sharpened geochemical gradients (Paull et al. 2005).

Habitat Areas in the HWEA or Vicinity

Essential Fish Habitat

Essential Fish Habitat (EFH) is a designation under the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to protect waters and substrate that are necessary for spawning, breeding, feeding, or growth to maturity of fish. Groundfish and Highly Migratory Species EFH, which are overlap, are within and around the proposed HWEA (Figure 2.3). An EFH designation does not regulate fishing activity specifically, but it is the regulatory standard requiring action to minimize adverse effects. EFH is determined, described, and mapped based on the array of available species information. There is an EFH designation for nearly all federally managed species, and this habitat can be thought of as being essential to the survival of those fish. EFH locations and information can be found in the relevant Fishery Management Plans, as well as in the EFH Mapper tool (Dataset Table 2.1). Currently, EFH is available as a data layer in the California Offshore Wind Energy Gateway tool. All waters within and around the HWEA are designated as EFH. For example, in areas north of Point Conception, salmon EFH extends from the extreme high tide line in nearshore and tidal submerged environments, within state waters out to the full extent of the exclusive economic zone (EEZ; PFMC 2016).

Figure 2.3. Essential Fish Habitat for groundfish and swordfish in and near the HWEA.

Habitat Areas of Particular Concern

Habitat Areas of Particular Concern (HAPC) are a subset of EFH in which spatially discrete habitat areas are known to exhibit one or more of the following traits: rare, stressed by development, provides important ecological functions for federally managed species, or are especially vulnerable to anthropogenic degradation. HAPCs offshore California are designated through actions by the Pacific Fishery Management Council, but they do not convey additional restrictions or protections on an area. HAPCs can cover a specific location (e.g., a bank or ledge, or a spawning location) or cover habitat that is important for a specific function that is found at many locations (e.g., nearshore nursery areas or pupping grounds). They are intended to focus increased scrutiny, study, or mitigation planning compared to surrounding areas because they represent high priority areas for conservation, management, or research and are necessary for healthy ecosystems and sustainable fisheries (NOAA Fisheries 2021a). On the west coast, HAPCs have been designated for Pacific coast groundfish and salmon. There are several HAPCs for Pacific Coast groundfish located in and near the HWEA (shown in dark green Figure 2.4). These features consist of rocky reefs, which are associated with hard substrate and seamounts. The California Offshore Wind Energy Gateway tool has an “area estimation” function that can be used to estimate the size of these areas. Using this tool results in roughly 4,775 acres (7.5 mi^2) of groundfish HAPC within the HWEA. Additionally, there is an HAPC immediately adjacent and inshore of the HWEA, both in and near Samoa Deepwater and Mad River Rough Patch Essential Fish Habitat Conservation Areas (see below), as well as along the coast (Figure 2.4). Humboldt Bay is designated as HAPC for groundfish.

Other Conservation Areas Closed to Fishing

Essential Fish Habitat Conservation Areas (EFHCAs) are a component of EFH that are recommended by the Pacific Fishery Management Council and designated by rulemaking in which NOAA Fisheries may prohibit fishing with certain gear types (NOAA Fisheries 2019a). There are six discrete EFHCAs within and/or adjacent to the HWEA. These were created by Amendments 19 (2006) and 28 (2020) in the Pacific Coast Groundfish Fishery Management Plan for the purpose of contributing to the protection of West

Coast groundfish habitat. West Coast groundfish fisheries and fisheries that may take groundfish incidentally are managed with a variety of closed areas intended to either minimize the bycatch of overfished groundfish species or to protect groundfish habitat. Many of the closed areas are gear-specific, meaning they are closed to some gear types, but not others.

Within the following EFHCAs in or near the HWEA (Figure 2.4), fishing is not allowed with any bottom trawl gear other than demersal seine gear, a type of bottom trawl designed to encircle fish on the seabed (NOAA Fisheries 2015). The EFHCAs include the closure of waters deeper than 1,280 m (4,200 ft) to bottom trawl and the prohibition of large footrope trawl shoreward of the 100 fathom (183m, 600 ft) depth contour.

- Samoa Deepwater EFHCA is a 12,170-acre site[2] (19 mi^2) that straddles the HWEA. This EFHCA also overlaps with Pacific Coast Groundfish HAPC.
- Mad River Rough Patch EFHCA is a 3,257-acre (5.1 mi^2) site appearing to be located just to the east of the HWEA. This EFHCA is characterized by rocky ridge, complex topography, diverse habitats, and fauna including corals, sponges, and sea pens (Gorelnik 2021). It also overlaps the Pacific Coast Groundfish HAPC.
- Trinidad Canyon EFHCA is a 56,244-acre (87.9 mi^2) site that is north and slightly west of the HWEA.
- Eel River Canyon EFHCA is the large, triangular-shaped area south of and close to the HWEA. Its total area is 219,978 acres (343.7 mi^2).
- Blunts Reef EFHCA is estimated to be a 20,150-acre (31.5 mi^2) area south and east of the HWEA.
- Mendocino Ridge EFHCA is a 472,185-acre (737.8 mi^2) area, extending east to west along the ridge, south of HWEA.

Figure 2.4 was generated using the California Offshore Wind Energy Gateway tool (2021), with additional labels added manually in an image editor, for clarity. The figure was generated by selecting the following layers within the Gateway tool:

- "Humboldt Wind Energy Area"
- "Habitat Areas of Particular Concern (HAPC) for Pacific Coast Groundfish"
- "NOAA National Marine Fisheries Service: Essential Fish Habitat Areas Protected From Fishing"
- "Oceans" as the base map

Other conservation areas that pertain to protection of groundfish around the HWEA region are Rockfish Conservation Areas, Yelloweye Rockfish Conservation Areas, and Deep-Sea Ecosystem Conservation Areas. These are areas in which certain vessels may fish for other flatfish using hook and line gear only as long as they do not also have other gear on board the vessel that is unlawful to use for fishing within the groundfish conservation area. These and other conservation areas are also partially defined by depth-based boundary lines that are intended to approximate particular depth contours. These boundary lines are typically defined coast-wide and around islands, with a few exceptions, but may be used to define a closed area off just a part of the coast (Dataset Table 2.2).

[2]Table 4 of the NOAA Fisheries data sheet: https://www.habitat.noaa.gov/application/efhinventory/docs/pfmc_datasheet.pdf, refers to these areas in square miles, which is incorrect and has resulted in the EFH Mapper and the California Wind Energy Data Basin also incorrectly referencing the areal size of these sites.

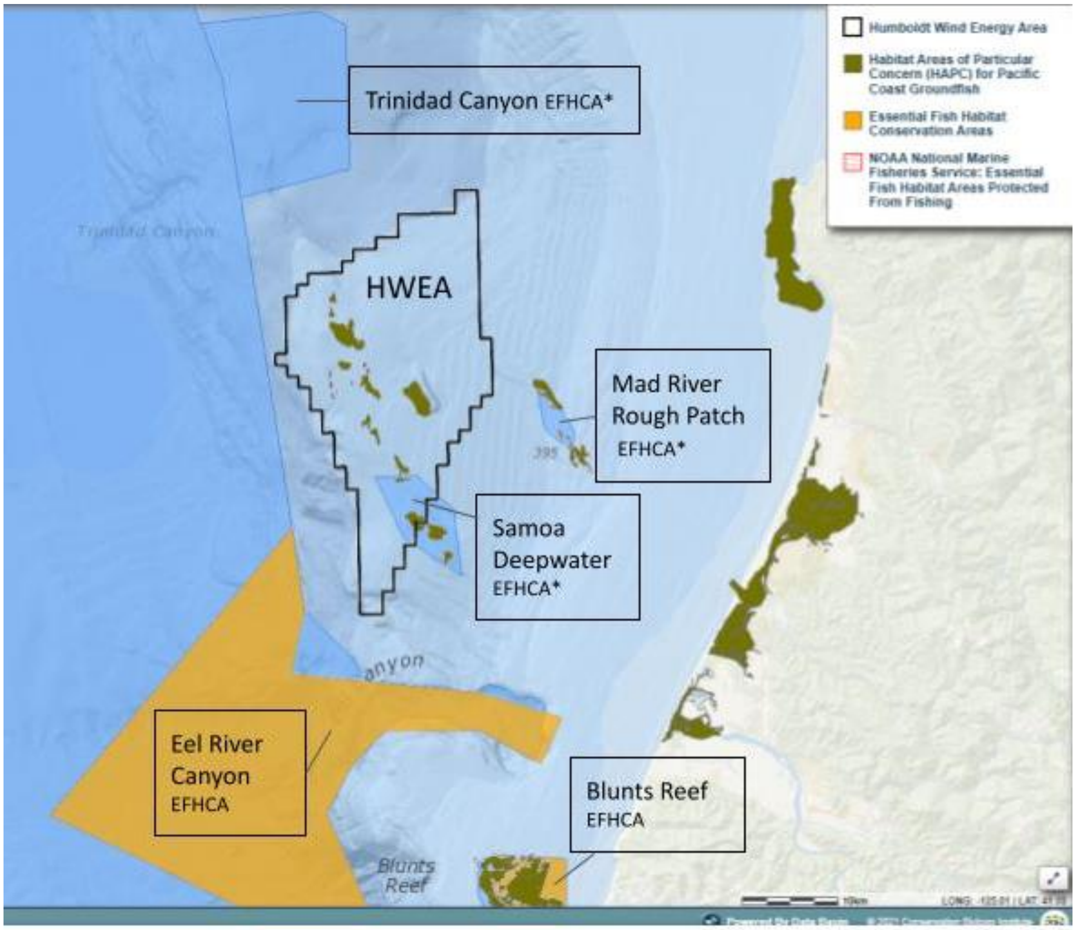

Figure 2.4. Five of the six EFHCAs located in or near the HWEA (the sixth is Mendocino Ridge EFHCA, which lies to the south of Eel River Canyon EFHCA).

Critical Habitat

Critical habitat is a designation under the Endangered Species Act, defined by NOAA Fisheries as, "areas that contain essential physical or biological features important to the conservation of listed species and that may require special management and protection." Critical habitat may also be designated in areas outside of the geographic boundaries of a species if the agency determines that these are also necessary for conservation. Federal agencies must consult with NOAA Fisheries if they are to undertake or allow any action (e.g., the development of offshore wind infrastructure) that may affect listed species or their designated critical habitat. Critical habitat has been designated for the southern resident killer whale from Cape Mendocino and southward, for the Steller sea lion at Sugarloaf Island and Cape Mendocino (Section 5), and for leatherback sea turtles from Point Arena and southward (Section 7).

Marine Protected Areas

Under the California Marine Life Protection Act, there is one Marine Protected Area (MPA) designated in state waters (within 3 nm or 5.5 km from shore) just north of Arcata/Humboldt Bay in Humboldt County. This is the Samoa State Marine Conservation Area. Its designation as a State Marine Conservation Area (SMCA) means that some recreational and/or commercial take of marine resources may be allowed.

Availability of Geologic, Bathymetric, and Habitat Data

The U.S. Geological Survey (USGS) through its National Geological and Geophysical Data Preservation Program (NGGDPP) maintains a geological repository of U.S. lands and waters, containing samples, logs, maps, and data. For example, core samples from the Humboldt continental shelf region were collected as part of the STRATAFORM project (Minasian et al. 2001). This type of data allows an understanding of how sedimentation and sediment transport processes might influence seafloor deposits. The data sources have been compiled into a robust database called usSEABED, which contains textural, statistical, geochemical, geophysical, and compositional data and information from surveys on the U.S. Pacific Coast continental margin (Dataset Table 2.3).

Additional mapping of the seafloor near the HWEA has recently begun as part of a collaborative research program called the Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS). EXPRESS studies involve conducting multibeam surveys and collecting sediment samples to help inform ocean energy and mineral resource decisions and improve offshore hazard assessments. The data are being used to create seamless bathymetric maps of the southern Cascadia Margin that lies offshore Northern California. Figures 2.2 and 2.3 are examples of the type of high-resolution bathymetry that is being mapped with depth indicated by various colors. Certain sonar and seismic scanning equipment are also being used to produce images of the geological structures beneath the seafloor or of the water column above. At present, EXPRESS data are not available except for southern California (Kennedy et al. 2021), but multibeam bathymetry data of the southern Cascadia Margin offshore northern California are available (Dartnell et al. 2021; Dataset Table 2.4). High-resolution figures of the HWEA and vicinity are also available online (USGS 2021).

Earthquakes, landslides, liquefaction, tsunamis, slope instability, and biogenic gas are some of the hazards that can impact the HWEA site. The risks associated with these geologically hazardous and active regions are mainly to the mooring and anchorage systems, as well as buried cables that would transmit power to shore. Visualizations of the potential earthquake, landslide, tsunami, and geo-hazards of the HWEA have been prepared by BOEM through an interactive online portal (Bakhsh et al. 2020; Dataset Table 2.5).

In coastal waters, which extend out to 3 nm (5.6 km), the California Seafloor Mapping Project has been using sonar, light detection and ranging (LiDAR), and video mapping technologies to create similar multi-layer maps of California's seafloor and coastal geology. The effort includes an online, publicly accessible data repository for use in ecological modeling, coastal conservation, and baseline habitat maps (Dataset Table 2.6).

General Status and Threats to Geology, Bathymetry, and Habitats

Submarine canyons and other deep-sea habitats are potentially vulnerable to a variety of human activities. From monitoring that has been conducted in the Monterey Submarine Canyon, deep-sea fish were found to have elevated concentrations of persistent organic pollutants, such as polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT), when compared with fish collected from surface waters. This is believed to have been caused by the bioaccumulation of these pollutants from more highly concentrated flow of sediments and pollutants into the submarine canyons. These same processes may also lead to accumulation of marine debris, such as abandoned fishing gear, plastics, and other man-made items into the canyons (Sanctuary Integrated Monitoring Network [SIMON] 2021). In a ranking of human-caused impacts on benthic habitats worldwide, Harris (2020) found the greatest threat from fishing, followed by pollution and litter, aggregate mining, oil and gas, coastal development, tourism, cables, shipping, invasive species, climate change, and construction of wind farms.

Data Gaps and Limitations

Seabed sediment boundaries have not been defined and correlated to known benthic communities. Proposed wind energy projects would also need to collect core samples to assess the ability of various substrates to retain anchor systems and other mooring configurations. Any rocky terrain or steep slopes (greater than 10 degrees) would be difficult for anchor placements. These areas are often found in the transition between the 1,000 m (3,281 ft) and 2,000 (6,562 ft) isobaths.

Chemistry data is an important component of understanding the benthic habitat system. Other than the California Seafloor Mapping Project in state waters, it does not appear that hydrographic data is being collected for temperature, salinity, oxygen, phosphate, and nutrients in or near the HWEA. Regular sampling would allow categorization of faunal groups across deepwater habitats that exist beyond the shelf.

Figure 2.4, which shows the results of the “Essential Fish Habitat Conservation Areas” dataset from the California Wind Energy Gateway, does not include three of the known EFHCAs near the HWEA (Samoa, Mad River, and Trinidad) although they can be found in the “NOAA National Marine Fisheries Service: Essential Fish Habitat Areas Protected From Fishing” dataset. All current EFH data appear to be regularly updated and available in the NOAA Fisheries’ EFH Mapper tool (Dataset Table 2.1).

Within the California Offshore Wind Energy Gateway tool, it would also be helpful to set the HAPCs in the data portals as polygons or enable the ‘identify’ function to treat HAPCs as polygons to be able to discern the acreage of each HAPC and other relevant information.

There are also two “West Coast Rockfish Conservation Areas, 2015” datasets provided in the California Offshore Wind Energy Gateway. One was last updated May 2021 by the Conservation Biology Institute although the title remains dated as of 2015 and the “content date” is listed as 2006. The original metadata cannot be confirmed because the link is no longer accessible. The other dataset in the California Offshore Wind Energy Gateway that is also called “West Coast Rockfish Conservation Areas, 2015” was last updated by Eli Harland in 2017, but selecting this dataset results in an error message that it did not load correctly or that access is not allowed.

Summary Tables of Selected Geological, Bathymetric, and Habitat Datasets

Dataset Table 2.1. Essential Fish Habitat and Other Protected Areas

Dataset Title	Essential Fish Habitat (EFH) Mapper
Species/Resource	Habitat areas essential for fish and areas protected from fishing
Abstract	This mapping application provides an interactive platform for viewing spatial boundaries of EFH, or those habitats that NOAA Fisheries and the regional fishery management councils have identified and described as necessary to fish for spawning, breeding, feeding, or growth to maturity. Data layers available for viewing in the EFH Mapper include: • Essential Fish Habitat (EFH) • Habitat Areas of Particular Concern (HAPCs) • EFH areas protected from fishing This data uses methodologies that reflected regional differences in both source data and management needs. Because of the variability in quality and intended use of these GIS data layers, each should be considered individually when interpreting the accuracy and utility of the information they provide. Please be sure to view the EFH data inventory and read the information under Data Quality, to fully understand the usage constraints for each data layer and the completeness and accuracy of the information the EFH Mapper provides.
Strength/Weakness	The EFH Mapper contains areas of EFH and other areas that are protected from fishing as well as certain base maps, but it does not appear to have a method for uploading other datasets, such as the wind energy areas, into the EFH Mapper. The EFH Mapper includes other data disclaimers such as that data for the Pacific Region are based on previous compilation efforts (e.g., groundfish data are from 2006) and do not necessarily reflect current habitat conditions. It is especially important to be aware of the data limitations when viewing HAPC boundaries. As a result, the data as represented in the Mapper, should not be relied upon for impact assessments related to individual projects.
File Name	https://www.habitat.noaa.gov/application/efhinventory/index.html (click on the download button under the West Coast region)
Data Type	SHP file
Spatial Extent	The boundaries of each area are defined by straight lines connecting a series of latitude and longitude coordinates and other regulatory boundaries.
Time Scale	Not specified
Contact/Source	EFH.Mapper@noaa.gov
License/Use Restrictions	Publicly available information as long as information obtained from the use of the site is used for general reference purposes only
Citation Info	NOAA Fisheries, 2021. Essential Fish Habitat.

	https://www.fisheries.noaa.gov/national/habitat-conservation/essential-fish-habitat.
Online Link	https://www.habitat.noaa.gov/apps/efhmapper/
Metadata Link	XML documents containing the metadata are located at: https://www.habitat.noaa.gov/application/efhinventory/index.html. Then click on the "download data" button for the West Coast region.

Dataset Table 2.2. West Coast Fishery Closed Areas

Dataset Title	Depth-Based Boundary Lines on the West Coast
Species/Resource	Closed areas
Abstract	Several types of closed areas, including Rockfish Conservation Areas and Block Area Closures, are at least partially defined by depth-based boundary lines. Depth-based boundaries are lines that connect a series of latitude and longitude coordinates and are intended to approximate particular depth contours. These boundary lines are typically defined coast-wide and around islands, with a few exceptions, but may be used to define a closed area off just a part of the coast.
Strength/Weakness	The coordinates must be input by the user, but the data seem to be updated whenever necessary. There are also two West Coast Rockfish Conservation Areas datasets provided in the California Offshore Wind Energy Gateway. One was last updated May 2021 by the Conservation Biology Institute although the title remains dated as of 2015 and the "content date" is listed as 2006. The original metadata cannot be confirmed because the link is not accessible (https://caoffshorewind.databasin.org/datasets/f55d62c191eb4bd5b67172a48a55790d/layers/956ccfd7c01e49bd88e3aafcee6d0156/metadata/original/). The other dataset entitled, "West Coast Rockfish Conservation Areas, 2015" in the California Offshore Wind Energy Gateway, was last updated by Eli Harland in 2017, but selecting this dataset results in an error message that it did not load correctly or that access is not allowed.
File Name	2021-22HarvestSpecifications-FinalDepthContourLats&Longs_03162021.zip
Data Type	Microsoft Excel Comma Separated Files
Spatial Extent	Coastwide California
Time Scale	Current to March 16, 2021; seems to be updated as needed
Contact/Source	NOAA Fisheries West Coast Region; (503) 230-5400
License/Use Restrictions	Publicly available
Citation Info	NOAA Fisheries. 2021b. Depth-Based Boundary Lines on the West Coast (website last updated by West Coast Regional Office on 03/16/2021)

Online Link	https://media.fisheries.noaa.gov/2021-03/2021-22HarvestSpecifications-FinalDepthContourLats%26Longs_03162021.zip?null=
Metadata Link	https://www.fisheries.noaa.gov/resource/data/depth-based-boundary-lines-west-coast

Dataset Table 2.3. Sediments and Seafloor of the U.S. Continental Shelf

Dataset Title	usSEABED: Offshore Surficial-Sediment Database for Samples Collected within the United States Exclusive Economic Zone (Edition: 1.0)
Species/Resource	Geological information
Abstract	Since the second half of the 20th century, there has been an increase in scientific interest, research effort, and information gathered on the geologic sedimentary character of the continental margins of the United States. Data and information from thousands of sources have increased our scientific understanding of the geologic origins of the margin surface, but rarely have those data been combined into a unified database. Initially, usSEABED was created by the USGS in cooperation with the Institute of Arctic and Alpine Research at the University of Colorado Boulder, for assessments of marine-based aggregates and for studies of sea-floor habitats by the USGS. Since then, the USGS has continued to build up the database as a nationwide resource for many uses and applications. Previously published data derived from the usSEABED database have been released as three USGS data series publications containing data covering the U.S. Atlantic margin, the Gulf of Mexico and Caribbean regions, and the Pacific coast (Reid and others, 2005; Buczkowski and others, 2006; and Reid and others, 2006). This expanded USGS data release unifies the data from these three publications and includes an additional 54 data sources added to usSEABED since the original data series, provides revised output files, and expands the data coverage to include usSEABED data from all areas within the U.S. Exclusive Economic Zone (EEZ) as of the time of publication (including Alaska, Hawaii, and U.S. overseas territories). The usSEABED database was created using the most recent stable version of the dbSEABED software available to the USGS at the time of release (specifically, dbSEABED software [NMEv, version date 4/23/2010] using the dbSEABED thesaurus [db9 dict.rtf, version date 8/21/2009], the component setup file for U.S. waters [SET ABUN 2016.txt, version date 5/29/2016], and the facies setup file for U.S. waters [SET FACI.txt, version date 3/16/2012]). The USGS Open-File Report "Sediments and the sea floor of the continental shelves and coastal waters of the United States: About the usSEABED integrated sea-floor-characterization database, built with the dbSEABED processing system" (Buczkowski and others, 2020) accompanies this data release and provides information on the usSEABED database as well as the dbSEABED data processing system. Users are encouraged to read this companion report to learn more about how usSEABED is built, how the data should be interpreted, and how they are best used.
Strength/Weakness	It is better to turn on only single layer at a time or subsequent data layers may not be visible.

	It is assumed that usSEABED incorporates earlier USGS data (such as https://data.cnra.ca.gov/dataset/pac_fac-seabed-facies-data-combined-components-for-the-continental-margin-of-the-u-s-pacific-co from 2006) even though these older databases remain available and likely contain outdated information.
File Name	usSEABED_EEZ.zip (https://cmgds.marine.usgs.gov/data/whcmsc/data-release/doi-P9H3LGWM/)
Data Type	Vector digital data
Spatial Extent	West_Bounding_Coordinate: -180.000000 East_Bounding_Coordinate: 180.000000 North_Bounding_Coordinate: 74.709763 South_Bounding_Coordinate: 31.75000
Time Scale	1880-2016; data were processed in 2019-2020
Contact/Source	Brian J. Buczkowski, Physical Scientist, Woods Hole Coastal and Marine Science Center, (508) 548-8700 x2361; bbuczkowski@usgs.gov.
License/Use Restrictions	The public domain data from the U.S. Government are freely redistributable with proper metadata and source attribution. Please recognize the U.S. Geological Survey as the originator of the dataset.
Citation Info	Buczkowski, B.J., Reid, J.A., Schweitzer, P.N., Cross, V.A., and Jenkins, C.J., 2020, usSEABED—Offshore surficial-sediment database for samples collected within the United States Exclusive Economic Zone: U.S. Geological Survey data release. *Over 300 sources, both published and unpublished, are used as the sources of information for usSEABED. Full list of data sources: https://pubs.usgs.gov/ds/2006/182/pac_sources.html*
Online Link	https://doi.org/10.5066/P9H3LGWM
Metadata Link	https://cmgds.marine.usgs.gov/data/whcmsc/data-release/doi-P9H3LGWM/usSEABED_EEZ_meta.txt

Dataset Table 2.4. Composite Multibeam Bathymetry Offshore Northern California

Dataset Title	Composite multibeam bathymetry surface and data sources of the southern Cascadia Margin offshore Oregon and northern California
Species/Resource	Bathymetry
Abstract	Bathymetry data from various sources, including newly released 2018 and 2019 multibeam data collected by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS), were combined to create a composite 30-m resolution multibeam bathymetry surface of the southern Cascadia Margin offshore of Oregon and northern California. The bathymetry data are available as a 30-m resolution geoTIFF file, accompanied by a polygon shapefile describing the data sources used to create the

	composite bathymetry surface. This bathymetric surface was created as part of a cooperative project between the U.S. Geological Survey, Pacific Coastal and Marine Science Center and NOAA. The surface was generated to assist research projects studying offshore geohazards including mapping faults, submarine landslides, sediment transport pathways, and seafloor seeps. These data are not intended to be used for navigation.
Strength/Weakness	The bathymetry data were collected over a span of nearly 24 years using a variety of models of multibeam echosounders, GPS systems, position and motion compensation systems, sound velocity profilers, and tide measurements. The attribute table in the bathymetry source shapefile (SouthernCascadia_bathy_sources.shp), also included in this data release provides links to the survey page for each dataset. Some of the datasets provide metadata and reports that describe mapping procedures and data quality including uncertainty measurements and comparisons with other bathymetry data. The horizontal accuracy of bathymetry data in this data release may be lower than stated in the reports due to further processing of the data.
File Name	SouthernCascadia_30m_bathy_UTM10_NAD83.zip
Data Type	GeoTIFF
Spatial Extent	West_Bounding_Coordinate: -125.570471 East_Bounding_Coordinate: -124.072995 North_Bounding_Coordinate: 43.415421 South_Bounding_Coordinate: 40.159820
Time Scale	1994-2020; progress complete
Contact/Source	U.S. Geological Survey, Pacific Coastal and Marine Science Center (PCMSC) Science Data Coordinator (831) 427-4747; pcmsc_data@usgs.gov
License/Use Restrictions	USGS-authored or produced data and information are in the public domain from the U.S. Government and are freely redistributable with proper metadata and source attribution. Please recognize and acknowledge the U.S. Geological Survey as the originators of the dataset and in products derived from these data. Portions of the map used data provided by the Ocean Exploration Trust's Nautilus Exploration Program, Cruises NA072, NA078, NA080, NA082, NA122. This composite bathymetry grid is intended for research purposes only, studying the seafloor morphology of the southern Cascadia margin. The bathymetry grid is not intended to be used for navigation.
Citation Info	Dartnell, P., Conrad, J.E., Watt, J.T., and Hill, J.C., 2021, Composite multibeam bathymetry surface and data sources of the southern Cascadia Margin offshore Oregon and northern California: U.S. Geological Survey data release, https://doi.org/10.5066/P9C5DBMR
Online Link	https://cmgds.marine.usgs.gov/data-releases/datarelease/10.5066-P9C5DBMR/
Metadata Link	https://cmgds.marine.usgs.gov/data-releases/media/2021/10.5066-P9C5DBMR/dc813b73e32f440c853f4c4282db1df4/SouthernCascadia_30m_bathy_UTM10_NAD83_metadata.txt

Dataset Table 2.5. Potential Earthquake, Landslide, Tsunami and Geo-hazards

Dataset Title	Potential Earthquake, Landslide, Tsunami and Geo-hazards for the U.S. Offshore Pacific Wind Farms
Species/Resource	Benthic geo-hazards
Abstract	This study/website was developed by RPS and was funded by the Bureau of Ocean Energy Management (BOEM), U.S. Department of the Interior, Washington, D.C., under Contract 140M0119C0004. Earthquakes, landslides, liquefaction, tsunamis, slope instability, and biogenic gas are some of the hazards that can impact the floating offshore wind farms located off the coasts of California, Oregon, and Hawaii, as they are located in geologically hazardous and active regions. The risks are mainly to the mooring and anchorage systems, as well as buried cables that transmit the power to shore. The BOEM funded Solicitation No. E17PS00128 to assess the potential threats to wind energy development off the U.S. Pacific coast, including catastrophic geohazards (e.g., seismic activities, landslides, and tsunamigenic earthquakes), gas plumes, liquefaction, and turbidity currents, and the effect on the mooring and anchorage system and buried cable due to geohazards. This evaluation of geohazards is designed to aid in selecting suitable sites for Floating Offshore Wind Farms (FOWF) with the focus on areas already designated as potential lease sites using the best available science, so that potential impacts are understood to the greatest extent possible. The main goal of the study is to provide an understanding of geohazards risks in areas under analysis for the development of FOWF using a geospatial planning approach by providing a guideline on most important geohazards and how they might affect the performance of FOWF. This website provides publicly available datasets of geological and geophysical seabed and soil conditions, ground acceleration and bathymetry slope in the region that are analyzed in form of geospatial raster maps and used in the study. These spatially varying datasets are then weighted and overlaid to determine suitability of the area and define exclusive area that might have more risk for installation of FOWF. It should be noted these maps serve just as a guideline based on publicly available datasets. BOEM strongly encourages review of the full report including current practices regarding the geologic hazards posing risks to components of FOWF, a literature review on approaches and standards applicable to the siting and engineering processes associated with floating offshore structures, and the geohazards off the U.S. West Coast and Hawaii that may directly or indirectly affect the FOWF, and the data analysis for developing geospatial indexing of suitability maps.
Strength/Weakness	No legend appears on the mapping product, so the color-coding schema is not known for geology and seabed type.
File Name	N/A
Data Type	The geospatial data are not available, but visualizations of the different wind energy areas can be generated online through BOEM’s interactive mapping interface.
Spatial Extent	Five floating offshore wind farm areas in Hawaii (Oahu North and Oahu South) and California (Humboldt, Morro Bay and Diablo Canyon).

Time Scale	Various dates depending on the data source. See Appendix A in: http://boem-oceansmap.s3-website-us-east-1.amazonaws.com/reports/final_report.pdf
Contact/Source	Jennifer Miller, BOEM Office of Renewable Energy Program; (805) 384-6306; jennifer.miller@boem.gov
License/Use Restrictions	Publicly accessible
Citation Info	Bakhsh T, Monim M, Simpson K, Lapierre T, Dahl J, Rowe J, Spaulding M. 2020. Potential earthquake, landslide, tsunami, and geohazards for the U.S. offshore Pacific Wind Farms. Kingstown, RI: U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2040-040. 127 p.
Online Link	http://boem-oceansmap.s3-website-us-east-1.amazonaws.com/
Metadata Link	Various sources. See Appendix A in: http://boem-oceansmap.s3-website-us-east-1.amazonaws.com/reports/final_report.pdf

Dataset Table 2.6. California Seafloor Mapping Program

Dataset Title	Block H11977 / Vicinity of Humboldt (BG)
Species/Resource	Geological information
Abstract	In 2007, the California Ocean Protection Council initiated the California Seafloor Mapping Program (CSMP), designed to create a comprehensive seafloor map of high-resolution bathymetry, marine benthic habitats, and geology within the 3-nautical-mile limit of California's State Waters. The CSMP approach is to create highly detailed seafloor maps and associated data layers through the collection, integration, interpretation, and visualization of swath sonar data, acoustic backscatter, seafloor video, seafloor photography, high-resolution seismic-reflection profiles, and bottom-sediment sampling data. CSMP has divided coastal California into 110 map blocks, each to be published individually as USGS Scientific Investigations Maps (SIMs) at a scale of 1:24,000. The map products display seafloor morphology and character, identify potential marine benthic habitats, and illustrate both the seafloor geology and shallow (to about 100 m) subsurface geology. This CSMP data catalog contains much of the data used to prepare the SIMs in the California State Waters Map Series. Other data that were used to prepare the maps were compiled from previously published sources (for example, onshore geology) and, thus, are not included herein.
Strength/Weakness	The links leading to “seafloor.csumb.edu” are no longer valid so the data have to be accessed through the individual USGS reports
File Name	seafloor.otterlabs.org/csmp/csmp_datacatalog.html#help
Data Type	TIF files

Spatial Extent	High-resolution 1:24,000 scale geologic and habitat base map series covering all of California's state waters out to the three-mile limit
Time Scale	2009
Contact/Source	Carrie Bretz, California State University Monterey Bay, (831) 582-4197; cbretz@csumb.edu
License/Use Restrictions	All data are publicly available
Citation Info	Golden, N.E., compiler, 2013, California State Waters Map Series Data Catalog: U.S. Geological Survey Data Series 781, and Beeson, J.W., and Johnson, S.Y., 2019, Offshore shallow structure and sediment distribution, Punta Gorda to Point Arena, northern California: U.S. Geological Survey Open-File Report 2019–1072, 2 sheets, scales 1:100,000 and 1:200,000
Online Link	https://pubs.usgs.gov/ds/781/, https://doi.org/10.3133/ofr20191072
Metadata Link	https://cmgds.marine.usgs.gov/data/csmp/PuntaGordaToPointArena/data_catalog_PuntaGordaToPointArena.html

SECTION 3. INVERTEBRATES INCLUDING LIVE BOTTOM HABITAT

Information on invertebrates can be surmised from biological assessments that have been conducted for fiber optic cables in the Northern California region and surveys of deepwater habitat in the expanded areas of Cordell Bank and Greater Farallones National Marine Sanctuaries. BOEM has also begun funding modeling efforts to help assess habitat suitability across the deeper parts of the continental slope. Depth is considered the primary variable to determine macrofaunal invertebrate species distribution with subsequent distinctions related to grain size, while the number of species per grab (richness) and the number of organisms per grab (abundance) also declined with depth (Henkel et al. 2020). Generally occurring macrobenthic fauna found in water depths to at least 306 m (1,004 ft) include sea pens (*S. elongata*, *Virgularia* spp.), crabs (*Cancer* spp.), spot prawns (*Pandalus platyceros*) and other shrimp, sea slug (*Pleurobranchea californica*), sea stars (*Mediaster aequalis, Ceramaster patagonicus, Rathbunaster californicus, Petalaster (luidia) foliolata*, and other *Asteroidea*), sea anemones (*Urticina* spp.,*Corallimorphus pilatus* and other *Actiniaria*), fireworm (*Chloeia pinnata*), sea urchin (*Strongylocentrotus* [or *Allocentrotus] fragilis*), brittle star (*Amphiodia* sp. and *Ophiuroidea*), and California sea cucumber (*Pleurobranchea californicus*; Applied Marine Sciences 2018; Graiff et al. 2016).

Deep-sea corals and sponges form important but sparse live bottom habitats in deep oceanic waters. Octocorals, black corals, and sponges off the West Coast create structure for numerous invertebrate species and are strongly associated with rockfishes (Poti et al. 2020). Bottom trawl surveys conducted from 2001 to 2012 found more than 25% with deep-sea sponges (Porifera) and 23% containing sea pens (*Pennatulacea*) along with other corals and sponges. The tows were in water depths from 55 to 1,280 m (180 to 4,199 ft; Clarke et al. 2017). Sea pens are the most abundant group of deep-sea corals in the region because they are adapted to live in soft substrates. There are 28 species of pennatulaceans known to occur along the U.S. West Coast such as *Stylatula elongata* that are in very shallow waters to *Umbellula lindahli*, which are in water depths to 4,000 m (13,123 ft; Poti et al. 2020).

Euphausiid crustaceans (krill) form the key food source for much of the marine life along the U.S. West Coast. Two species of krill (*Euphausia pacifica* and *Thysanoessa spinifera*) form particularly large aggregations, while another six species are typically more dispersed. Krill growth and reproduction are closely linked with changes in upwelling and large-scale transfer of ocean waters to the shelf (Fiechter et al. 2020). Areas along the shelf break and within submarine canyons have been found to be krill “hotspots,” primarily for *E. pacifica* (Santora et al. 2018).

Pink shrimp (*Pandalus jordani*), also called ocean shrimp, are generally found in depths of 46 to 366 m (150 to 1,200 ft), aggregating near the bottom during the day and ascending the water column at night to feed. High concentrations of pink shrimp annually occur in well-defined areas, or beds, which are generally characterized by muddy-sand bottoms. It is believed that high fluctuations of pink shrimp abundance are largely caused by environmental conditions (CDFW 2021a).

Dungeness crab (*Metacarcinus magister*) is typically found on sand or mud bottoms from the intertidal zone to 30 m (98 ft). They are fished only in state waters from Crescent City to the Morro Bay-Avila area. Larvae are pelagic until March, at which time they move closer inshore and settle on the seabed. Growth rates are slower in colder waters, which is why Dungeness crabs are managed at different times in the central and northern areas of California, demarcated by the Sonoma-Mendocino County line (CDFW 2013).

Squid are important prey for many fish, seabirds, and marine mammals in the California Current Ecosystem. Important pelagic squid include the families of Cranchiidae, Gonatidae, Histioteuthidae, Octopoteuthidae, and Ommastrephidae, Onychoteuthidae, and Thysanoteuthidae. These groups contain numerous genera and species mostly with poor distributional records. Like many animals in the open ocean, squid make vertical (diel) migrations with some swimming to depths of 1,200 m (3,937 ft) or more during the day, and then returning near the surface (at or above 200 m [656 ft]) at night. Other species are more mixed throughout the water column (Roper and Young 1975).

California market squid (*Doryteuthis (Loligo) opalescens*) is a small, short-lived (six to nine months) mollusk that ranges throughout California from the continental shelf to depths of 700 m (2,300 ft). These are coastal species with adults that move into deeper water during the day, then return to the upper 90 m (295 ft) of the water column at night to feed. Adults and juveniles are most abundant at temperatures between 10 to 16 ^{o}C (50 to 61 ^{o}F). Market squid are extremely sensitive to warm water conditions during El Niño-Southern Oscillation (ENSO) conditions, resulting in decreases of fishery catches, but they rebound during La Niña phases when colder water increases upwelling intensity (California Department of Fish and Game [CDFG] 2005). Different spawning seasons between central and southern California are likely due to variations in ocean bottom temperatures than biological differences.

Humboldt squid (*Dosidicus gigas*) are most likely to occur in water temperatures of 12-14 ^{o}C (54-57 ^{o}F) and over water depths of approximately 1,000 m (3,281 ft). Their core range is typically from southern California south but during strong ENSO events, they have expanded their range as far as southern Alaska (Litz et al. 2011) They are opportunistic predators and are known to feed on sardine, whiting, mackerel, anchovy, and salmon (Litz et al. 2011).

Sea cucumbers are echinoderms related to sea stars, sea urchins, and sand dollars. They live in sandy habitats and serve as a resource for divers and fishermen. Two species of sea cucumbers are fished in California: the California sea cucumber (*Parastichopus californicus*), also known as the giant red sea cucumber, which occurs throughout California in water depths out to 75 m (249 ft), and the warty sea cucumber (*Apostichopus parvimensis*), which occurs from Monterey Bay and southward in water depths to 30 m (98 ft). The warty sea cucumber is fished almost exclusively by divers, while the California sea cucumber is caught principally by trawling in southern California and occasionally targeted by divers in northern California (CDFW 2013).

Invertebrates and Live Bottom Habitat Potential in the HWEA or Vicinity

Deep-Sea Corals and Sponges

Whitmire et al. (2020) provide a listing of deep-sea coral taxa known to occur off California along with their depth distributions. Deep-sea corals and sponges have been observed in and within the vicinity of the HWEA including sea pens, sponges, and coral species such as black coral (Order Antipatharia, Figure 3.1). Due to the spatial resolution of the map, specific geophysical assessments would be needed before the full extent of suitable habitat for deep-sea corals and sponges can be determined.

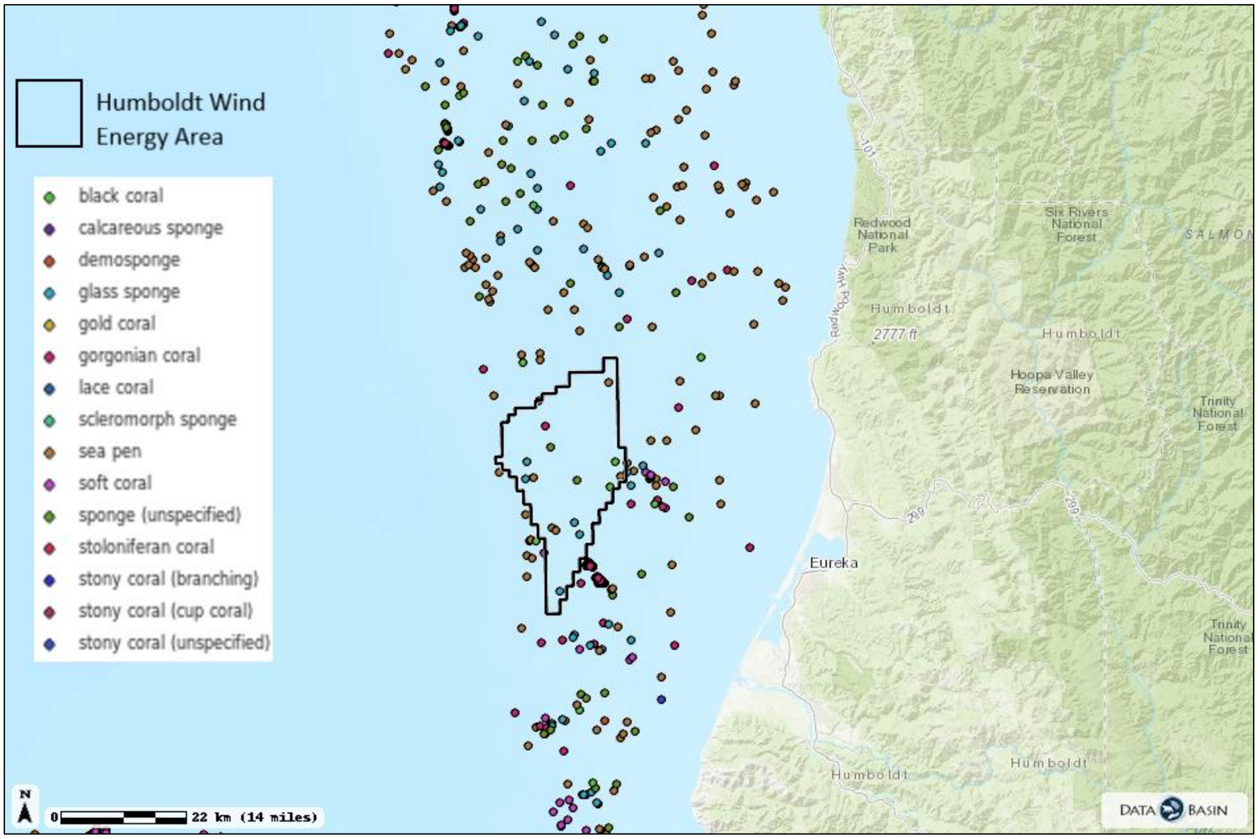

Figure 3.1. Deep-sea corals and sponges in relation to the HWEA (figure created on the California Offshore Wind Energy Gateway 2021; refer to Dataset Table 3.1)

Other Invertebrates

Market squid are targeted in nearshore waters of California, typically over sandy bottom habitats from Monterey Bay and southern California (CDFW 2021b); however, it is believed these squid inhabit deeper waters and may extend farther north (PFMC 2020a). Humboldt squid may also occasionally occur in the HWEA during strong ENSO periods.

Pink shrimp are widely distributed along the U.S. West Coast, but the majority of the fishery is concentrated around Eureka. Trawling is only allowed to occur in federal waters. Based on reported fishing data, pink shrimp are generally caught in water depths between 91 and 183 m (300 and 600 ft; CDFW 2021a).

In addition to market squid and pink shrimp, numerous other invertebrate species have been collected from mid-water trawls that are conducted annually in water depths of 2,804 m (9,200 ft) at a station called Trinidad Head (reported as West -124.27° and North 41.0°), which appears almost midway between the town of Eureka and the nearest eastern boundary of the HWEA (Figure 3.2). The list presented here are those species that were caught at this deepwater station during a six-year period (2013-2018) either during the month of May or June. The invertebrates are: spot prawn (*Pandalus platyceros*), red shrimp (*Bentheogennema burkenroadi*), mysid shrimp (Mysidacea), mantis shrimp (Stomatopoda), glass shrimp

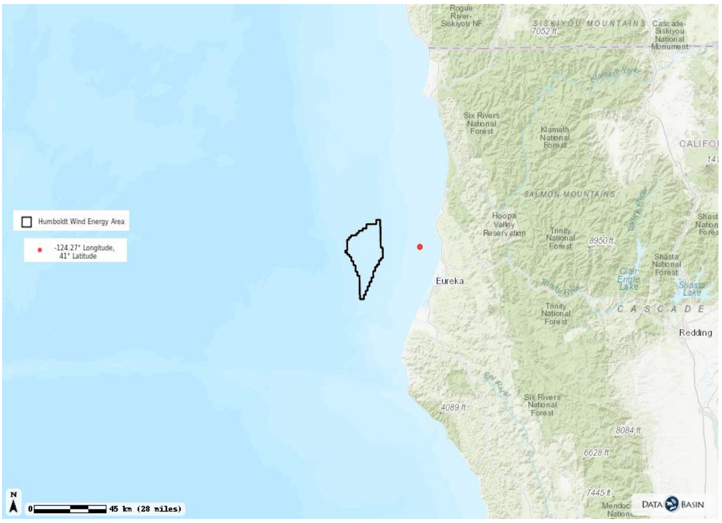

Figure 3.2. Location of a mid-water trawl station in water depths of 9,200 ft (2,804 m) that is annually surveyed by NOAA Fisheries.

(*Pasiphaea pacifica*), crangon shrimp (*Crangon spp.*), bay ghost shrimp (*Neotrypaea californiensis*), and other types of shrimp (Natantia; Sergestidae; Caridea); Humboldt squid (*Dosidicus gigas*), stubby squid (*Rossia pacifies*); robust clubfoot squid (*Onykia robusta*), Octopoteuthis squid (*Octopoteuthis deletron*), fire squid (Pyroteuthidae), boreal clubhook squid (*Onychoteuthis borealijaponica*), blacktip squid (*Abraliopsis fells*), berryteuthis squid (*Berryteuthis* spp.), baseball squid (*Cranchia scabra*), armhook squid (*Gonatus* spp.), and other unidentified Teuthida; tuberculate pelagic octopus (*Ocythoe tuberculata*), and other octopus (Octopoda; Alloposidae); pelagic red crab (*Pleuroncodes planipes*); and spiny lobster larvae (*Palinuridae*). Krill species (Euphausiacea) were also found in the trawls, but not from every year's survey (Southwest Fisheries Science Center, Fisheries Ecology Division 2021).

Availability of Invertebrate Data

Information that can be used to understand invertebrate presence in or near the HWEA includes NOAA's Deep-Sea Coral Research and Technology Program (DSCRTP), which has developed a national database of observation data, images, and technical reports on deep-sea corals and sponges (Hourigan et al. 2015; Dataset Table 3.1). In addition to being able to map general locations from observations, the data have been used to develop maps of predicted probability to show where deep-sea corals might be located (Poti et al. 2020; Figure 3.3). These predicted habitat suitability maps for 46 West Coast coral and sponge species included figures that showed the coefficient of variation (CV) associated with the modeling effort. The CV figures are used to indicate the level of uncertainty for the confidence in the predictions of the grid cells. The use of CV maps (or values) with maps of predicted probability of occurrence allows for a better understanding of when there are low values in the probability of occurrence (i.e. higher CV values) while high probability of occurrence with corresponding low CV values suggest a good fit of the model (Poti et al. 2020). This is illustrated in a set of predicted habitat maps for the soft coral (*Heteropolypus ritteri*), one of the species that is frequently found offshore in water depths to 1,200 m (3,937 ft, Figure 3.3). The low CV values reflect high confidence that the results shown in the figure depicts good potential habitat areas for *H. ritteri*. (Refer to Figure 3.49b in Poti et al. [2020] for areas within the HWEA that were predicted to have high habitat suitability.) Generally, the highest habitat potential is found on the shelf and upper slope around offshore banks, submarine canyons, and other areas of topographic complexity.

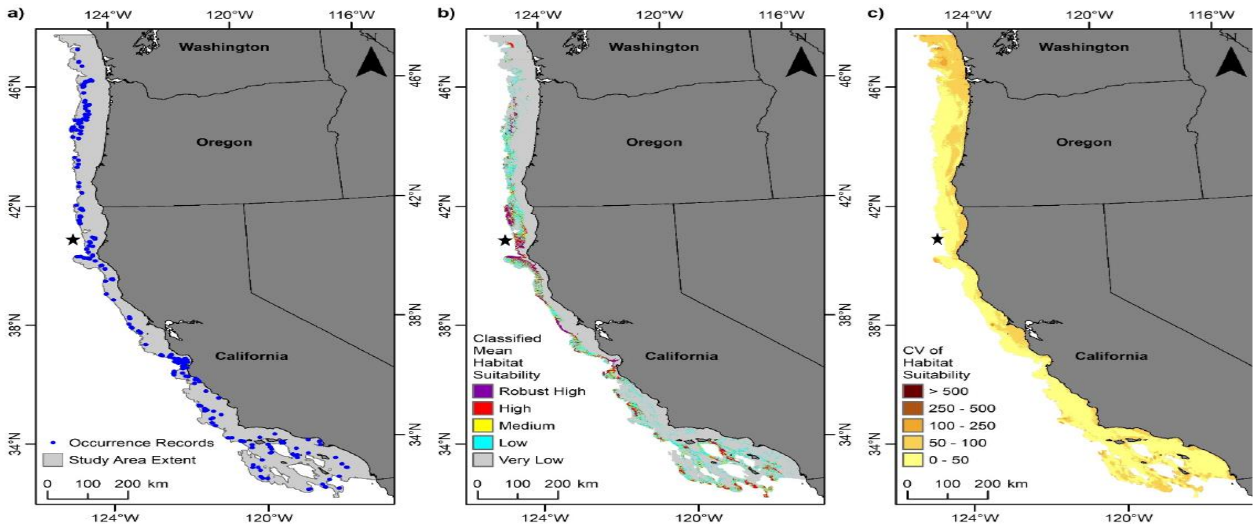

Figure 3.3. Predicted habitat suitability for the soft coral Heteropolypus ritteri (Alcyonacea, Alcyoniidae). (a) Records of H. ritteri occurrence from the NOAA National Database for Deep-Sea Corals and Sponges within the study area offshore to 1,200 m depth; (b) classified mean habitat suitability for H. ritteri; and (c) coefficient of variation of the mean habitat suitability for H. ritteri. (Figure reproduced from Poti et al. 2020; star indicates general location of the Humboldt Wind Energy Area)

Poti et al. (2020) also provide a comprehensive listing of the datasets that were available (as of 2017) in NOAA's National Database for Deep-Sea Corals and Sponges. The list includes the total number of observations (248,020) of deep-sea corals and sponges in the datasets. Information currently in the National Deep-Sea Coral and Sponge Database indicates that it was last updated in 2021, and it seems to be continually updated as more information from deep-sea surveys are received.

NOAA's Southwest Fisheries Science Center, Fisheries Ecology Division has been conducting annual midwater trawls off central California since 1983 to better understand rockfish recruitment. Because the trawls collect numerous other species, a long-term database is available that lists all fish and select invertebrates caught in these trawls (Dataset Table 3.2). Beginning in 2002, krill were identified to species, but the Trinidad Head station itself near the HWEA was not added until 2013. Limited information from this data can also be visualized in the Central and Northern California Ocean Observing System (CeNCOOS) data portal, which is primarily for nearshore species.

Understanding the location of hotspots (i.e., oceanic processes that concentrate zooplankton and forage fish) is an important factor in potentially locating areas of enhanced species abundance, diversity and/or trophic interactions. Messié et al. (in prep) recently completed a project that combined remote sensing products, ecosystem models, and in situ data to investigate zooplankton hotspots along the U.S. West Coast and their relationship with environmental forcing, and lower and higher trophic levels. The simulations were evaluated against in situ observations of krill from fisheries surveys and distributions of krill predators (e.g., seabirds and marine mammals). The results show the importance of the upwelling process and oceanic circulation in shaping mesoscale distribution of biological hotspots (Dataset Table 3.3).

General Status and Threats to Invertebrates and Live Bottom Habitat

Benthic macroinvertebrates are the types of communities that would most likely be directly impacted by offshore energy development because of disturbances to the seafloor (Poti et al. 2020). Deep-sea corals can be affected by anthropogenic effects because some species grow very slowly and can live for thousands of years. Because of their distance from shore, deep-sea benthic communities have not been as heavily exploited as shelf and coastal habitats.

Population dynamics of krill and other zooplankton are affected by climate variability. Hotspots of krill over the continental shelf are also directly linked with hotspots of other wildlife, particularly for blue whales, although this linkage was more variable for humpback (Rockwood et al. 2020). Predicting hotspots is important for vessel traffic management along routing corridors, which tend to be static, while krill hotspots are dynamic. If real-time forecasting can be developed to better predict where these hotspots might occur, this could help in establishing temporary and dynamic management areas for vessel traffic routing to reduce environmental effects. The U.S. Coast Guard is currently conducting a Port Access Route Study (PARS) to evaluate safe access routes for the movement of vessel traffic proceeding to or from ports or places along the U.S. western seaboard of the United States to determine whether routing measures should be established, adjusted, or modified. The study was initiated because of the current forecasted development of aquaculture farms, offshore renewable energy, commercial spaceports/re-entry sites, expansion of marine sanctuaries, development of ports supporting Panamax vessels, potential liquefied natural gas (LNG) facilities, and increasing commercial traffic.

Data Gaps and Limitations

Qualitative and quantitative information such as abundance, density, size, and condition remain lacking for most deep-sea benthic ecosystems such as corals and sponges. This information is necessary to understand differences in habitat quality or vulnerability such as large, healthy aggregations versus small, marginal, or already impacted deep-sea biota (Hourigan et al. 2015).

Another gap is the need to define “associated taxa” when conducting surveys on deep-sea corals and sponges. There is no consensus among researchers about what types of associations should be included or how to measure associations. Currently, researchers are not recording associated taxa in the deep-sea coral and sponge database. A null value does not reliably indicate that no associated taxa were present, which is information that could help ascertain their habitat value for other species (Hourigan et al. 2015).

No reliable estimates are available of the California market squid population mainly because the entire population replaces itself annually (CDFG 2005). Other poorly understood biological parameters include life history strategies concerning spawning frequency, the duration of time spent on spawning grounds, and the period of time from maturation to death (PFMC 2020a).

The California Offshore Wind Energy Gateway has a dataset entitled, “Krill Hotspots Along California Coast, 2004–2009.” The webpage was last modified Sep 7, 2017. Notes available in the dataset states that the authors have new data on krill hotspots (surveys from 2010-17) that are not published yet and will be made available after publication. This is an example of the need to continue to maintain the integrity of these datasets.

Summary Tables of Selected Invertebrate Datasets

Dataset Table 3.1: Deep-Sea Corals and Sponges

Dataset Title	Observations of Deep-Sea Coral and Sponge Occurrences from the NOAA National Deep-Sea Coral and Sponge Database, 1842-Present (NCEI Accession 0145037)
Species/Resource	Various corals, cnidarians, anthozoans
Abstract	NOAA's Deep-Sea Coral Research and Technology Program (DSC-RTP) is compiling a national geodatabase of the known locations of deep-sea corals and sponges in U.S. territorial waters and beyond. The database will be comprehensive, standardized, quality controlled, and networked to outside resources. The database schema accommodates both linear (trawls, transects) and point (samples, observations) data. The structure of the database is tailored to occurrence records of all the azooxanthellate corals, a subset of all corals, and all sponge species. Records shallower than 50 m are generally excluded in order to focus on predominantly deepwater species – the mandate of the DSC-RTP. The intention is to limit the overlap with light-dependent (and mostly shallow-water) corals. The database fulfills NOAA's requirements under the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to identify and map locations of deep-sea corals and to submit this information for use by regional fishery management councils. Given the authorities outlined in MSA, NOAA's DSC-RTP will serve as a central data aggregator and distributor. The DSC-RTP geodatabase will represent a baseline of historical observations from samples archived in museums, research institutions, and scientific literature augmented by observations collected during deepwater in situ surveys conducted as part of regional fieldwork initiatives.
Strength/Weakness	This is the only database of coral and sponge observation data.
File Name	145037.3.3.tar.gz (NCEI Accession 0145037 v3.3 published 2021-08-06T20:32:17Z)
Data Type	TAR.gz
Spatial Extent	N: 76.12 S: -77.8664 E: 179.994 W: -180
Time Scale	August 1, 1842, to October 15, 2021 (data complete and updated as needed)
Contact/Source	Deep-Sea Coral Data Manager, (228) 688-2936; deepseacoraldata@noaa.gov
License/Use Restrictions	Publicly available. NOAA and NCEI make no warranty, expressed or implied, regarding these data, nor does the fact of distribution constitute such a warranty. NOAA and NCEI cannot assume liability for any damages caused by any errors or omissions in these data. If appropriate, NCEI can only certify that the data it distributes are an authentic copy of the records that were accepted for inclusion in the NCEI archives.

Citation Info	Alaska Fisheries Information Network (AKFIN); Bishop Museum, Invertebrate Zoology Collection; Bureau of Ocean Energy Management; National Oceanic and Atmospheric Administration; California Academy of Sciences; Dauphin Island Sea Lab; University of Alabama; Hall-Spencer, J.; Harbor Branch Oceanographic Institute; Hawaii Undersea Research Laboratory; Monterey Bay Aquarium Research Institute; NOAA Alaska Fisheries Science Center; NOAA Center for Coastal Environmental Health and Biomolecular Research; NOAA Cordell Bank National Marine Sanctuary; NOAA Flower Garden Banks National Marine Sanctuary; NOAA Gulf of Farallones National Marine Sanctuary; NOAA Northeast Fisheries Science Center; NOAA Northwest Fisheries Science Center; NOAA Office of Ocean Exploration and Research; NOAA Office of Response and Restoration; NOAA Olympic Coast National Marine Sanctuary; NOAA Southwest Fisheries Science Center, La Jolla; NOAA Southwest Fisheries Science Center, Santa Cruz; National Museum of Natural Science, Taichung, Taiwan (NMNS); National Undersea Research Center; Ocean Biogeographic Information System, USA; Oceana; Oculina Banks Geographic Information System; Quattrini, Andrea M.; Ross, Steve; Santa Barbara Museum of Natural History; Schmidt Ocean Institute; SeamountsOnline (Seamount Biota); Smithsonian Institution, National Museum of Natural History; Texas A&M, Biodiversity Research and Teaching Collections; Tu, Qiang; USGS; Wagner, Daniel; Washington State University; Yale University Peabody Museum (2016). Observations of Deep-Sea Coral and Sponge Occurrences from the NOAA National Deep-Sea Coral and Sponge Database, 1842-Present (NCEI Accession 0145037). NOAA National Centers for Environmental Information (https://www.ncei.noaa.gov/archive/accession/0145037).
Online Link	https://www.ncei.noaa.gov/archive/archive-management-system/OAS/bin/prd/jquery/accession/download/145037
Metadata Link	https://www.ngdc.noaa.gov/docucomp/23e89380-4a72-11e5-b970-0800200c9a66

Dataset Table 3.2: Mid-Water Invertebrates off Trinidad Head

Dataset Title	Rockfish Recruitment and Ecosystem Assessment Survey, Catch Data
Species/Resource	Armhook squid, baseball squid, bay ghost shrimp, blacktip squid, blob octopus, boreal clubhook, caridean shrimp, crangon shrimp, fire squid, fried egg jelly, glass shrimp, Humboldt squid, krill total, mantis shrimp, market squid, moon jelly, mysid, octopoteuthis, octopus, pandalid shrimp, pelagic red crab, purple-striped jelly, pyrosoma, red shrimp, robust clubhook squid, sea nettle, shrimp, spiny lobster larvae, spot prawn, squid, stubby squid, swordtail squid, and tuberculate pelagic octopus
Abstract	The Fisheries Ecology Division of the Southwest Fisheries Science Center (SWFSC) has conducted a midwater trawl survey off central California since 1983 with the primary goal of developing pre-recruit indices for YOY rockfish (*Sebastes spp*.). The survey also samples numerous other components of the epipelagic micronekton, including other YOY groundfish (such as Pacific hake (whiting), *Merluccius productus*, and sanddab, *Citharichthys* spp), coastal pelagic fishes (such as Pacific sardine, *Sardinops sagax*, and northern anchovy, *Engraulis mordax*) and other forage species. Additional details regarding the survey methods and results are described in Ralston et al. (2015) and Sakuma et al. (2016).
Strength/Weakness	The parameters (such as date range, latitude and longitude, species name or common

	name) need to be set by the user.
File Name	For the HWEA, "Trinidad Head" was used to specify the area
Data Type	Point
Spatial Extent	21 area locations in California
Time Scale	1990-2018 (annual surveys; ongoing)
Contact/Source	John Field, NOAA Fisheries Ecology Division, (831) 420-3900; John.Field@noaa.gov
License/Use Restrictions	The data may be used and redistributed for free but is not intended for legal use, since it may contain inaccuracies. Neither the data Contributor, ERD, NOAA, nor the United States Government, nor any of their employees or contractors, makes any warranty, express or implied, including warranties of merchantability and fitness for a particular purpose, or assumes any legal liability for the accuracy, completeness, or usefulness of this information.
Citation Info	Ralston, S., J.C. Field and K.S. Sakuma. 2015. Long-term variation in a central California pelagic forage assemblage. Journal of Marine Systems 146: 26-37. (https://dx.doi.org/10.1016/j.jmarsys.2014.06.013). Sakuma, K.M., J.C. Field, B.B. Marinovic, C.N. Carrion, N.J. Mantua, and S. Ralston. 2016. In revision. Anomalous epipelagic micronekton assemblage patterns in the neritic waters of the California Current in spring 2015 during a period of extreme ocean conditions. CalCOFI Report, Vol. 57, 2016 (http://calcofi.org/publications/calcofireports/v57/Vol57-Sakuma_pages.163-183.pdf)
Online Link	https://coastwatch.pfeg.noaa.gov/erddap/tabledap/FED_Rockfish_Catch.html
Metadata Link	https://coastwatch.pfeg.noaa.gov/erddap/info/FED_Rockfish_Catch/index.html https://researchworkspace.com/api/metadata/export/5adfa63f30c49e00088113b4/19115

Dataset Table 3.3: Krill Hotspots in the California Current

Dataset Title	Krill hotspots in the California Current
Species/Resource	Euphausiids (krill)
Abstract	Oceanic processes that concentrate zooplankton and forage fish in so-called hotspots (areas of enhanced species abundance, diversity and/or trophic interactions) have remained elusive. Zooplankton including euphausiids (krill) and copepods are important grazers of phytoplankton and prey species for a diverse array of predators; therefore, they represent a key link in marine food webs. The distribution of zooplankton is patchy and often decoupled from phytoplankton in space and time. Consequently, it has been difficult to predict the abundance and distribution of fish, seabirds and marine mammals, which depend directly on zooplankton for growth and reproduction, from remotely sensed variables such as chlorophyll or primary production. A NASA-funded project (80NSSC17K0574) combined remote sensing products, ecosystem models and in

	situ data to investigate zooplankton hotspots along the U.S. West Coast and their relationship with environmental forcing, lower and higher trophic levels. We simulated the distribution of hotspots using two different, complementary approaches: 1) a high-resolution coupled biophysical model (Fiechter et al., 2020), and 2) a simple combination of satellite-based winds and currents with plankton growth and grazing equations (Messié et al., in prep). Our simulations were evaluated against in situ observations of krill from fisheries surveys and distributions of krill predators (e.g., seabirds and marine mammals). Our results highlight the importance of the upwelling process and oceanic circulation in shaping the mesoscale distribution of biological hotspots. Here we present routine products for the prediction of zooplankton hotspots along the U.S. West Coast from remotely sensed variables.
Strength/Weakness	None noted
File Name	California CCMP
Data Type	NetCDF
Spatial Extent	California from 28°N to 48°N
Time Scale	1983 to present
Contact/Source	Monique Messié, Monterey Bay Aquarium Research Institute (MBARI); monique@mbari.org
License/Use Restrictions	Refer to the listed publications when using these products. For use in publications, authors should obtain written permission from MBARI's Director of Information and Technology Dissemination Heidi Cullen. MBARI should be acknowledged as the data source in those publications and reprints should be provided to the MBARI library.
Citation Info	Messié Monique, Francisco Chavez, Jerome Fiechter, and Jarrod Santora (in prep)
Online Link	https://www.mbari.org/science/upper-ocean-systems/biological-oceanography/krill-hotspots-in-the-california-current/
Metadata Link	https://www3.mbari.org/science/upper-ocean-systems/biological-oceanography/Nsupply/Nsupply_California_CCMP.nc

SECTION 4. BONY AND CARTILAGINOUS FISH

Bony fish and cartilaginous fish (sharks, skates, and rays) occur widely throughout the California Current System as well as inshore in bays and river systems during different stages of their life cycles. Habitat preferences and locations during each life history stage vary based on the species' morphology and physiology. Fish eggs and larvae of many groups (particularly anchovy, herring, jacks, sculpins, and sand lances) may spend days to a year or more adrift as plankton that are driven far offshore by coastal winds. Other fish that produce eggs attached to substrate are more likely to be closely associated with the areas in which they were spawned while other fish species give birth to live young that may also drift as plankton for long periods.

The peak period of spawning for most species in the California Current ecosystem is winter, which generally supports retention of larvae near the coastal zone (Doyle 1992). Some fish larvae will settle out in estuarine and nearshore waters where they remain their whole lives. At a certain size class, typically after one year or more, juveniles of other species such as rockfish will move offshore and/or to deeper water where they mature into adults. Variations in these life history stages and locations are dependent on the species and are also influenced by oceanographic conditions such as upwelling intensity, wind-driven currents, water temperature, and other drivers. Other fish, namely salmon, are anadromous, moving from freshwater streams out to the ocean and then back to the freshwater to spawn.

Small pelagic fish and the larvae of larger fish form critical food web links between phytoplankton and other marine predators. Understanding fish life histories and their ecological traits can help predict their habitat preferences. This type of information is also used to support management efforts to maintain sustainable populations. Growth rate, fecundity, feeding strategy, mobility, and size at maturity are some of the data that are routinely collected to help understand and manage important marine fish populations.

For this report, fish have been generally categorized in the same format as they are listed in the Fishery Management Plans that are used to manage commercially and recreationally important species as well as those species that are considered significant for the ecosystem. The Pacific Fishery Management Council manages fisheries for groundfish (including rockfish, sole, whiting, shark, and various skates), coastal pelagic species (sardines, anchovies, and mackerel), highly migratory species (tunas, other sharks, and swordfish), and salmon in the exclusive economic zone, which occurs from 5-322 km (3-200 mi) off the coasts of California, Oregon, Washington. The Pacific Fishery Management Council also works with the International Pacific Halibut Commission to manage Pacific halibut fisheries, which have been included in the groundfish group in this report. The following sections describe the life histories of some of these managed species.

Pacific Coast Groundfish

There are more than 90 different species of managed Pacific Coast groundfish including more than 64 rockfish species such as bocaccio (*Sebastes paucispinis*), yelloweye (*Sebastes ruberrimus*), thornyheads (*Sebastolobus* spp.); six species of roundfish including lingcod (*Ophiodon elongatu*s), Pacific whiting, and sablefish (*Anoplopoma fimbria*); 12 species of flatfish such as flounder, Dover sole (*Microstomus pacificus*), and Pacific sanddab (*Citharichthys sordidus*); leopard shark (*Triakis semifasciata*) and skates. Other species of groundfish include the ratfish, grenadiers, and finescale codling, which are being monitored but are not actively managed such as with catch limits (PFMC 2020b). With a few exceptions, Pacific Coast groundfish live on or near the bottom of the ocean in sandy bottom habitats, sometimes adjacent to rock or other structures. Rattails, of which there are approximately 300 species, are the dominant fish on continental slopes.

Rockfish

Many rockfish species are vulnerable to exploitation because they do not begin to reproduce until they are five to 20 years old, and few of their young survive to adulthood. However, because of their large size and age at reproduction, rockfish benefit from what is known as the "storage effect" in which they can outlive periods that are not favorable for reproduction, but then have strong periods of successful recruitment during good environmental conditions (Gertseva and Cope 2017). Rockfish are further managed by the habitat in which they are most frequently encountered (i.e., shallow nearshore, deeper nearshore, shelf, and slope).

Bocaccios are one of the largest Pacific coast rockfish. They are moderately slow growing, late to mature, and long-lived. Bocaccios are most common between Oregon and northern Baja California with adults found over rocky reefs to depths of 476 m (1,562 ft) but also common on open bottoms to about 320 m (1,050 ft). Juveniles are pelagic and settle in nearshore nursery areas then move to deeper habitats (Froesse and Pauly 2021). Bocaccios mature and begin to reproduce between four and seven years old and can live to be 50 years old. Off northern California, they spawn from January to May and peak in February. Most commercial fishery landings are reported to occur from May to November (CDFW 2020).

Yelloweye rockfish are among the longest-lived rockfish with a maximum reported age of 147 years (Love 2011). This species also is very slow growing and late to mature. Adults are found along the continental shelf, generally shallower than 400 m (1,312 ft). They are typically found in deeper, rocky-bottomed areas although smaller yelloweye tend to occur in shallower water. They are large, slow growing, and mature late in life (50% reported mature at 22 years old; Gertseva and Cope 2017). A small amount of yelloweye are reported in the commercial fishery landings from July through October (CDFW 2020).

Shortspine thornyhead (*Sebastolobus alascanus*) and **longspine thornyhead** (*S. altivelis*) grow and mature relatively slowly and may live for 80 to 100 years. They are generally found in deep, soft bottom habitats. Shortspine thornyheads spawn between December and late May along the West Coast, while longspine generally spawn during February, March, and April (Fay 2020). Unlike rockfish in the genus *Sebastes* that give birth to live young, *Sebastolobus* thornyheads are oviparous, producing a gelatinous mass consisting of 20,000-450,000 eggs (NOAA Fisheries 2021c) that are fertilized at depth. The mass then floats to the surface where final development and hatching occurs (Fay 2020). Juvenile longspine settle on the continental slope at depths between 600 and 1,200 m (1,969 and 3,937 ft). Longspine are better adapted to deep water than shortspine. Thornyheads are often captured with Dover sole and sablefish (Fay 2020) and are targeted throughout the year (CDFW 2020).

Lingcod

Lingcod occur from the western Gulf of Alaska to northern Baja California but are most abundant from north of northern California because of their preference for colder waters of 7 to 10 ^{o}C (44 to 50 ^{o}F). They are typically taken from water depths of 305 m (1,000 ft) or less but occur from the intertidal zone out to 494 m (1,620 ft). In more southerly or warmer waters, they do not typically occur in water depths less than 30 m (100 ft). Small juveniles (less than 8 cm [3 in]) are pelagic and can be attracted to the surface by lights at night, while larger juveniles live on the bottom in nearshore waters out to 61 m (200 ft). Adults are bottom dwelling and mostly solitary. Spawning varies by location, generally taking place from November to April in California, peaking in late December to early February. Lingcod are voracious predators, and feed on almost any fish within their vicinity, along with squid and octopus (Love 2011). They are commercially targeted throughout the year (CDFW 2020).

Pacific Whiting

Pacific whiting, also known as Pacific hake, are abundant throughout most of their range from the Bering Sea to Baja. They are the most abundant commercial species on the Pacific coast. Whiting form large, dense schools and are most often found in water depths of 46 to 183 m (150 to 600 ft) but occur in a large depth range from 11 to 1,335 m (35 to 4,380 ft) and up to 322 km (200 mi) offshore (NOAA Fisheries 2021c). The population offshore California makes extensive annual migrations, and the stock is bilaterally managed between the U.S. and Canada. Adult whiting occurs in southern waters during the winter spawning season and migrate to coastal areas between northern California and northern British Columbia during the spring, summer, and fall when the fishery is conducted. In years with warmer water, the stock tends to move farther to the north during the summer (Johnson et al. 2021). Eggs and larvae are found as far as 644 km (400 mi) offshore in depths from 40 – 101 m (130 - 330 ft). Open-water whiting are not adapted to living around structures. Young Pacific whiting are found in nearshore waters off southern to central California, and make their way north as they mature, reaching San Francisco by early March and likely up to the area surrounding the HWEA by mid to late March. Most whiting would be gone by winter as they make their way back to the southern spawning grounds. Young Pacific whiting feed largely on krill, and all Pacific whiting feed on krill to some extent. YOY may also come into shallow water to feed. Feeding often occurs at night, leading whiting towards the surface as they follow their prey. A very small amount is reportedly caught off Eureka during September and October (CDFW 2020).

Sablefish

Sablefish (commonly called blackcod) are schooling fish that typically live on or near the seafloor, usually over sand or mud. They are sedentary, not making extensive movements, with exceptions. Sablefish eggs and larvae have been found as far as 278 km (173 mi) offshore, but YOY are found near the surface along the coast, especially in summer. Juveniles usually occur shallower than 182 m (600 ft), including sheltering within floating kelp rafts, while adults are typically found from 182 to 1,000 m (600 to 3,000 ft). They have been known to shift downslope into cooler waters on a seasonal basis, seeming to prefer 3 to 8 ^{o}C (37 to 46 ^{o}F) temperatures. Sablefish occur from east-central Honshu Island, Japan north into the Bering Sea and southeast along the U.S. West Coast down to Baja. Historically, they are abundant from at least southern California northward with the largest concentrations north of Cape Mendocino (Love 2011). Sablefish spawn in batches, three to four times per season. The spawning season tends to be highly variable; one study indicated August to November along the Washington to California coast; another off Central California indicated October to February (Love 2011). Commercial harvest of sablefish occurs during all months of the year off Eureka (CDFW 2020).

Skates

Of all the skate species off California, **longnose skates** (*Beringraja rhina*) comprise the majority of fishery and survey catches. No directed commercial fishery for longnose skate occurs in California but they are taken incidentally as bycatch and sold when fishing for other groundfish species, primarily sablefish and Dover sole. They are commonly found at depths ranging from 150 to 400 m (492 to 1,312 ft). Although found over a wide range of habitats, they are most often found over mixed cobble and sandy sediment on the seafloor. As with most skates, they are slow growing, late to mature, have low fecundity, and have a relatively long lifespan compared to other fish. Longnose skates are oviparous with egg cases deposited onto the sea floor. They may live to at least 30 years; age at maturity can range from 5-14 years. When market demand peaked from 1995 to 2001, an average of 75% of skates were landed in the Crescent City and Eureka port complexes. In 2010 and 2011, there was a southern shift in landings with the majority coming from Eureka and Fort Bragg that was likely due to changes in the trawl fishery and market demand (CDFW 2013). A little more than 97,522 kg (215,000 pounds) of longnose skates were landed in Eureka in 2020 (PacFIN 2021). Commercial harvest of longnose skates occurs during all months of the year off Eureka (CDFW 2020).

Pacific Halibut

The **Pacific halibut** (*Hippoglossus stenolepis*) is migratory, crossing state boundaries off the U.S. West Coast as well as internationally from Japan to Russia. Halibut occur from Santa Barbara, California to Nome, Alaska, along the edge of the continental shelf at depths from about 182 to 488 m (600 to 1,600 ft). Adults congregate on spawning grounds in British Columbia and Alaska from November to March (International Pacific Halibut Commission 2021). Commercial harvest of Pacific halibut occurs during the months of June and July (CDFW 2020).

Coastal Pelagic Species

Pelagic refers to the whole water column of the open ocean. Pelagic fish encompass species that live in the water column, but not near or on the bottom. The coastal pelagic species offshore California are found throughout the water column from the surface down to 1,000 m (3,281 ft), and generally above the continental shelf. These species, which are also referred to as forage fish, include Pacific sardine (*Sardinops sagax caerulea*), Pacific (or chub) mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), and northern anchovy (*Engraulis mordax*). These small coastal pelagics are a critical part of the food web in the California Current ecosystem for many other species of fish, marine mammals, and seabirds.

The **Pacific sardine** is a small, fast growing, schooling fish that typically lives for five years or so, though can reach up to 13 years. They occur from southeastern Alaska to Baja and possibly off Peru and Chile. Sardine spawning season is usually from late winter through summer, though has been shown to extend into fall, and individuals spawn multiple times per season. A large amount of spawning occurs near shore, while some takes place out to 483 km (300 mi) or more (Love 2011). The highest concentrations of sardine larvae occur in warmer, more southern waters. Sardine feed on phytoplankton and zooplankton, and like many other small schooling fish, are an important food source for seabirds, larger fish, and marine mammals, such as the harbor porpoise. The population size varies naturally, which leads to large fluctuations in abundance – a phenomenon known as a boom-bust population cycle, which is typical of small pelagic species that have relatively short life spans and high reproduction rates.

Pacific (chub) mackerel are fast-growing fish that can live up to 18 years but are able to reproduce by age four, and sometimes as early as one year. Although the stock ranges from southeastern Alaska to southern Baja California, they are more common from Monterey Bay to Cabo San Lucas. Over the last few decades, Pacific mackerel are occurring more often in the northernmost portions of its range in response to warmer oceanographic conditions during El Niño events. Pacific mackerel usually occur within 30 km (19 mi) of shore but have been captured as far as 400 km (249 mi) offshore, and from the surface to 300 m (984ft) depth. Adults are commonly found near shallow banks. Juveniles are found off sandy beaches, around kelp beds, and in open bays. They often school with other small pelagic species, particularly jack mackerel and Pacific sardine (Crone et al. 2019). Pacific mackerel also naturally experience boom-bust cycles of abundance. A very small amount of Pacific mackerel is commercially landed during July off Eureka (CDFW 2020).

Highly Migratory Species

While many types of fish tend to spend most of their lives in one general location (such as reef fish on hard bottom habitat, many groundfish in sandy areas, or other fish in kelp forests), highly migratory species are open water fish that travel vast distances across oceans and along coastlines generally making seasonal migrations between temperate waters where they feed, and tropical waters where they spawn. Some of the highly migratory species that occur in the California Current System include tunas, many sharks, mahi-mahi (or dolphinfish; *Coryphaena* spp.), swordfish (*Xiphias gladius*), marlin (*Tetrapturus* spp. and *Makaira* spp.), and sailfish (*Istiophorus* spp.). These fish are known to have extensive ranges, often crossing international borders. Although they predominantly live in the open ocean, they may also spend part of their life cycle in nearshore waters.

Tunas

Tunas are fast-moving pelagic fish that often form large schools. Tunas that occur off California include **North Pacific albacore** (*Thunnus alalunga*), **bigeye** (*T. obesus*), **Pacific bluefin** (*T. thynnus* and *T. orientalis*), **skipjack** (*Katsuwonus pelamis*), and **yellowfin** (*T. albacares*). Yellowfin and bigeye are found mid-ocean while albacore, skipjack, Pacific bluefin are found in both coastal and mid-ocean areas (FAO 2021). Tunas can thermoregulate through a process in which arterial blood is warmed by venous blood that flows through red swimming muscles. This enables them to repeatedly forage in deep, cold waters and then ascend to rewarm their tissues. Thermoregulation also allows them to maintain high activity levels with some of the fastest swimming speeds of all fish.

At least for bigeye tuna, this thermoregulatory mechanism develops as body size increases, which affects vertical distribution as the fish become more cold tolerant (Hino et al. 2021). Larger size is also more effective in retaining heat. Skipjack and yellowfin can be found in waters where the temperature is greater than 18° C (64 °F) although they can dive in colder waters. Albacore and Pacific bluefin tend to be found in more temperate waters as cold as 10 °C (50 °F) though albacore also migrate to tropical waters. Bigeye is intermediate to these temperature regimes.

Tunas spend a lot of time relatively near the surface (above 50 m [165 ft]), but dive to depths of hundreds of feet, often in very short amounts of time (FAO 2021). Juveniles have also been reported spending more time around floating objects at shallower depths during the daytime (Hino et al. 2021). Vertical distribution is also influenced by dissolved oxygen levels, and so tunas may concentrate along the edges of continental shelves and deeper water canyons, depending on the species. With varying sea surface temperatures, migration may vary seasonally and from year to year, with some tuna much more abundant in northern California waters in the summer during warm waters years (PFMC 2018).

Albacore tuna tend to concentrate on the warm sides of upwelling fronts, on the seaward edge (Love 2011). Albacores make their way northward feeding along the West Coast upwelling front. Their offshore range is approximately 16 to 322 km (10 to 200 mi) off the Pacific coastline. Total landings of albacore tuna have decreased in recent years from peaks in the mid to late 1990s (Figure 4.1, Dataset Table 4.1). Some of the peaks in the catches tend to correspond with broadly accepted warm water ENSO events (NOAA Physical Sciences Laboratory 2021). Commercial landings at the Eureka Port Complex of albacore occur during the months August, September, and October (CDFW 2020).

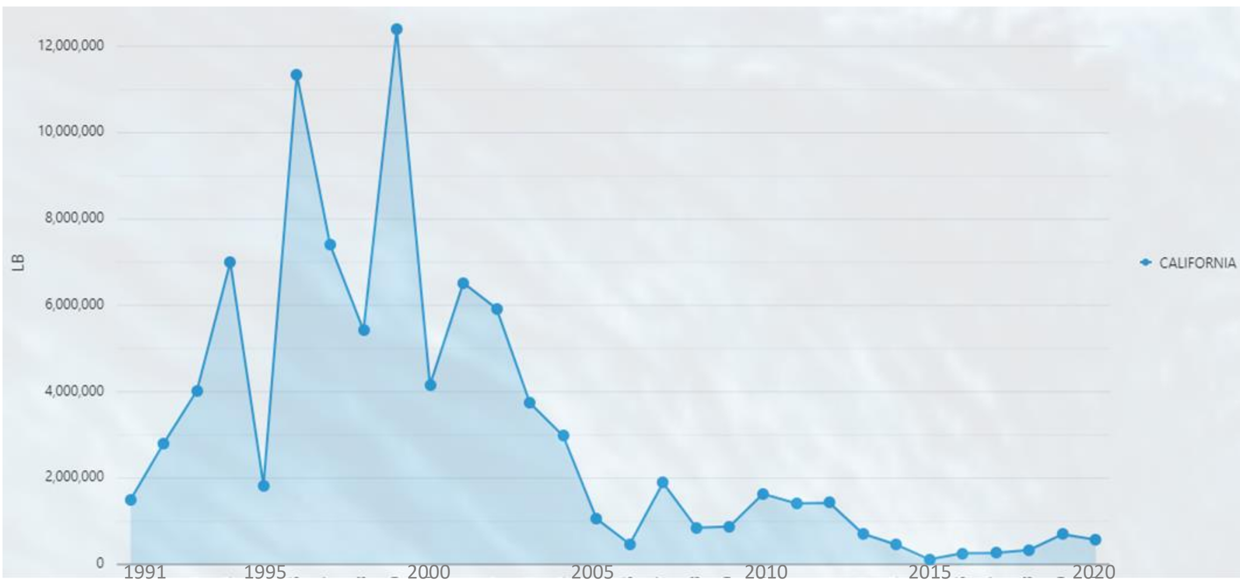

Figure 4.1. State of California landings (in pounds) of albacore tuna from 1991 to 2020 (NOAA Fisheries Landing Data 2021)

Oceanic Sharks

Migratory, oceanic sharks (as opposed to bottom-dwelling sharks described in the section on Pacific Coast Groundfish) are **common threshers** (*Alopias vulpinus*), **bigeye threshers**, and **pelagic threshers**; **shortfin mako** (*Isurus oxyrinchus*); **blue shark** (*Prionace glauca*); **great white shark** (*Carcharodon carcharias*), **megamouth** (*Megachasma pelagio*), **basking shark** (*Cetorhinus maximus*), among others. Managed shark species that are fished offshore California are common thresher, shortfin mako, and blue shark. Thresher, mako, and blue sharks are targeted by the drift gillnet fishery, which has approximately 14 participants, at varying distances from shore depending on the season. October to December are the months when most of the drift gillnet fishing effort occurs (NOAA Fisheries 2021b). Other shark species that cannot be actively targeted but occur in California state and federal waters include the great white shark, basking shark, and megamouth shark. These sharks tend to occur in greatest numbers in the Eastern Pacific in autumn and winter months. The north Pacific stock of basking shark is also listed as endangered by the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2021).

Swordfish

Swordfish (*Xiphias gladius*) have round bodies and long, flat, pointed bills. Adults do not have scales and may grow up to 4.5 m (15 ft) in length and weigh up to 536 kg (1,182 lb), although the average size caught in the fishery is much smaller (PFMC 2018). Swordfish are mid-ocean fishes that can be found from surface level (around 100 m [328 ft]) during the night then diving to depths of 600 m (1,969 ft) with occasional descents below 900 m (2,953 ft), and sometimes deeper, for prolonged periods during the day. These depths are habitats that contain very low oxygen and temperature (Abascal et al. 2010). It is believed that swordfish can control their rate of heat loss or gain during these vertical movements by altering the route of blood flow supplying the red muscle, which allows them to prey on species that are not accessible for most other active, pelagic fish (Stoehr et al. 2018). Historically, swordfish were more commonly caught in waters off central and especially southern California, but they have been recently caught offshore of the San Francisco region. As water temperatures warm, distribution and habitat preferences for the swordfish and many other species are expected to change.

Other predatory fish

Another type of billfish that occurs off California is the **striped marlin** (*Kajikia audax*), which ranges as far north as Oregon, but is more common south of Point Conception. Striped marlins prefer water temperatures between 20 to 25 °C (68° and 78 °F). Their prey sources include northern anchovy, Pacific sardine, jack mackerel, and squid (PFMC 2018). Other highly migratory species include **dolphinfish** (also called mahi-mahi; *Coryphaena hippurus*), which occurs in the more tropical waters of southern California. Dolphinfish are highly productive and widely distributed throughout the tropical/subtropical Pacific. They are mostly commercially taken on the high-seas, outside of U.S. waters, but are recreationally taken in California primarily in the Southern California Bight (CDFW 2020).

Salmonids

Salmon are anadromous fish that begin their lives in streams, tributaries, and rivers, emigrate down river through estuaries and out to sea, then return to spawn in their natal freshwater streams. Juvenile and young salmon migrate to sea after spending time feeding in rivers and estuaries. They grow to maturity in saltwater. Time spent in fresh and estuarine (brackish) waters varies significantly by species and by population groups. The main ocean salmon species found in California are **Chinook** or king (*Oncorhynchus tshawytscha*), **coho** or silver (*O. kisutch*), and **steelhead** (*O. mykiss irideus*), which is the anadromous form of rainbow trout. Small numbers of **pink salmon** (*O. gorbuscha*) are caught on occasion in California, but **chum** (*O. keta*) and **sockeye** (*O. nerka*) are rarely encountered (CDFW 2013). California Chinook stocks generally spend two to five years at sea before returning to spawn in their natal streams. Most coho spend two years at sea, but some return to spawn after the first year. Pacific salmon are most abundant offshore of California in the summer months of June, July, and August. Between Point Sur and Point Arena, Chinook salmon are primarily targeted in depths of 3 to 110 m (10 to 361 ft); it is prohibited to retain ocean coho or steelhead salmon. Stock statuses vary widely; some stocks of Chinook are above target levels, whereas others are listed as threatened or endangered under the Endangered Species Act (ESA). Other California coastal and riverine salmon stocks are listed as either threatened or endangered under the ESA and the California Endangered Species Act (CESA). Chinook salmon are primarily landed by commercial fisheries during the months of June through August, with much smaller amounts during other months of the year (CDFW 2020).

Fish Potential in the HWEA or Vicinity

Many species of fish are likely to occur in and around the HWEA including those that are actively targeted in fisheries and others that are not. Based on known population distribution data (life history data), the landings data provided by the State of California, some of the survey data available within the California Offshore Wind Energy Gateway, and other information, Table 4.1 depicts a short list of key fish and the depth ranges at which they are likely to occur. This list is by no means exhaustive but serves as a useful base for the types of fish that may be considered for further assessment within the HWEA or in the region.

Table 4.1. Depth Preferences and Range of Select Fish Species Likely or Known to Occur In or Near the HWEA

Type	Name	Depth and/or Offshore Range (for adults)*
Pacific Coast Groundfish Fishery Management Plan		
Rockfish	Yelloweye	Commonly in 137 to 182 m (450 to 600 ft) water depths but ranges widely from 45 to 365 m (150 to 1,200 ft) deep
	Bocaccio	Found in depths from 20 to 475 m (66 to 1,558 ft), but tend to be most abundant from 95 to 225 m (312 to 738 ft) in depth
	Thornyheads	From 26 - 1,524 m (85 to 5,000 ft) or more
Groundfish	Sablefish (blackcod)	Occurs in water depths from 57 to 1,524 m (187 to 5,000 ft)
	Lingcod	From 0 to 494 m (0 to 1,620 ft) deep
	Pacific whiting (hake)	Commonly at depths of 45 to 182 m (148 to 597 ft); full range is 10 to 1,335 m (33 to 4,380 ft)
Flatfish	Dover sole	In water depths from 27 - 914 m (89 to 3,000 ft)
	Petrale sole	In water depths from 18 - 460 m (59 to 1,509 ft)
	California halibut	Usually between 1.5 and 54 m (5 and 180 ft), but also as deep as 83 m (600 ft)
Skate	Longnose skate	From 9 to 1,069 m (29 to 3,507 ft)
International Pacific Halibut Commission		
Flatfish	Pacific halibut	Summer feeding grounds on the continental shelf in water depths to 500 m (1,640 ft); occurs farther offshore during winter spawning
Pelagic Fisheries of the Western Pacific Region		
Coastal Pelagic	Pacific sardine	Spawns from surface waters to at least 50 m (165 ft); ranges up 483 km (300 mi) offshore
	Pacific (chub) mackerel	Surface oriented, but retreats down to 300 m (990 ft); spawns up to 322 km (200 mi) offshore
	Pacific herring (a state-managed fishery)	Depth varies with season, generally surface oriented to 478 m (1,568 ft)
	Northern anchovy	Surface to 305 m (1,000 ft) and usually within 161 km (100 mi) of shore, but can be found out to 483 km (300 mi)
Highly Migratory Species		
Tuna	Albacore tuna	Within 16-24 km (10 to 15 mi), sometimes closer; generally, ranges more than 55 km (34 mi) from shore
Shark	Shortfin mako	Occurs primarily near surface, down to 152 m (500 ft)
	Common thresher	Occurs from the surface down to 368 m (1,208 ft) or more, ranging offshore to 80 km (50 mi) or more
	Blue shark	From the surface to 350 m (1,150 ft) and extremely wide ranging
Salmonids		
Salmon	Chinook Salmon	Occurs from 3 - 110 m (10 - 361 ft) and ranges 46 km (0 to 28 mi) from shore

*Approximate depth and offshore ranges for individual species listed above were based on life history information obtained from Froese and Pauly (2021) and Love (2011).

Availability of Fisheries Data Near and Within the HWEA

Based on the records from six years of surveys by the Southwest Fisheries Science Center, which are conducted to assess recruitment of juvenile rockfish and other economically and ecologically important species, at least 30 rockfish species have been identified from mid-water trawls in the Trinidad Head region in water depths to 2,804 m (9,200 ft; Dataset Table 4.2). Twenty-seven of these are specifically listed in the Pacific Coast Groundfish Fishery Management Plan, many of which are further defined as “slope rockfish,” because they are typically found in deeper waters of the shelf and continental slope (Sinclair 2020). These include aurora (*Sebastes aurora*), bank (*S. rufus*), blackgill (*S. melanostomus*), and darkblotched (*S. crameri*) rockfish. All *Sebastes* species, whether they are specifically listed in the plan or not, are managed in the fishery. The other three that have been found in surveys but are not listed in the plan are squarespot (*S. hopkinsi*), Puget Sound (*S. emphaeus*), and shortbelly (*S. jordani*) rockfish. Figure 4.2 depicts rockfish richness (number of species present) from surveys in the Trinidad Head region from 2009 to 2018 (Dataset Table 4.2).

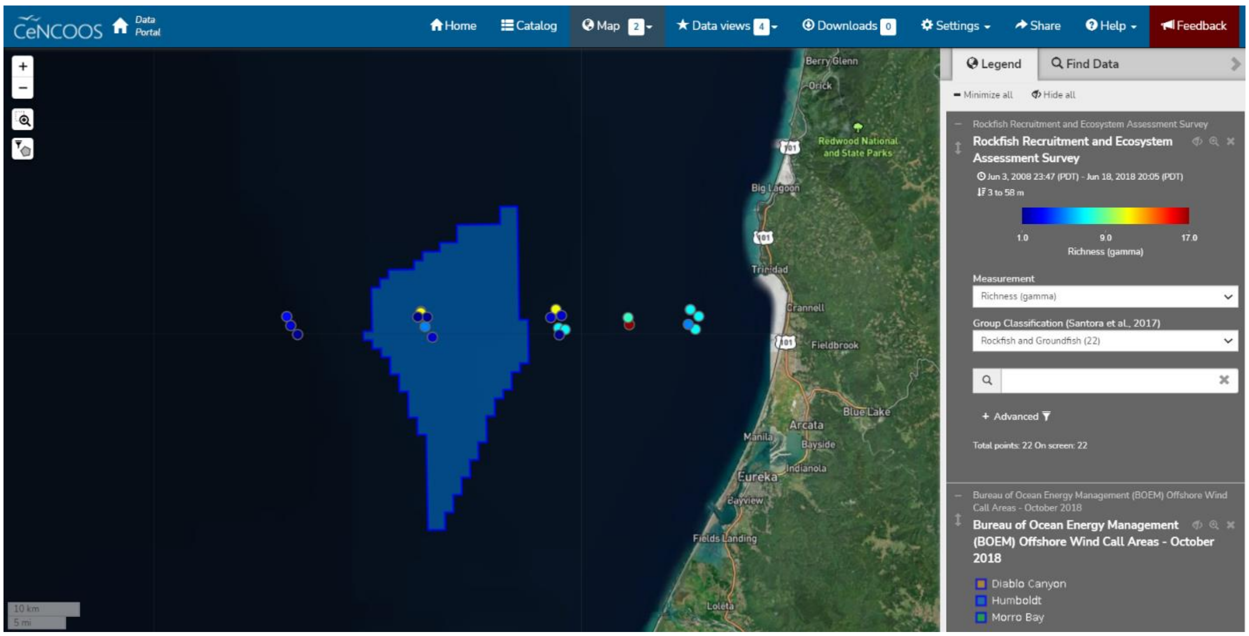

Figure 4.2. Rockfish richness from surveys conducted along the Trinidad Head stations. Created using the CeNCOOS data portal.

Flatfish found during the surveys at the Trinidad Head deepwater stations include managed species such as turbot (*Scophthalmus maximus*), starry flounder (*Platichthys stellatus*), and Pacific sanddab, as well as speckled sanddab (*Citharichthys stigmaeus*), slender sole (*Lyopsetta exilis*), and California halibut (*Paralichthys californicus*).

Other important groundfish occurring in or near the area included lingcod, wolfeel (*Anarrhichthys ocellatus*), sablefish, and Pacific whiting. Figure 4.3 depicts groundfish trawl density (1997-2017) as one method to assess abundance and habitat preferences for groundfish species in and adjacent to the HWEA, but the site needs to be updated to include data from more recent years (Dataset Table 4.3). Certain fish found in these trawl surveys, such as Pacific sand lance (*Ammodytes hexapterus*) are currently considered “Ecosystem Component” species that are not actively targeted.

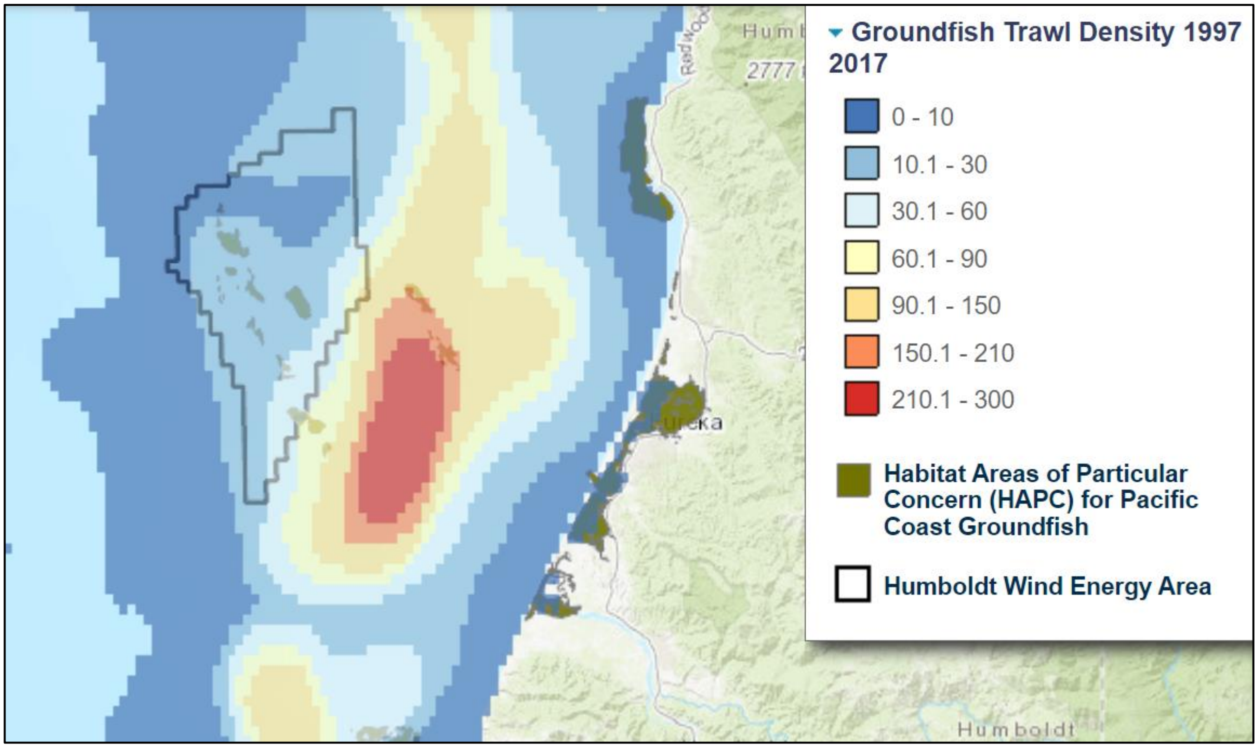

Figure 4.3. Groundfish Trawl Density (1997 to 2017). Prepared from information in the California Offshore Wind Energy Gateway (2021).

Other fish from the surveys in the deepwater region of the Trinidad Head station include predominantly deepwater species and oceanic fish such as Pacific bonito (*Sarda chiliensis*), lamprey (Petromyzontidae), blue lanternfish (*Tarletonbeania crenularis*), hatchetfish (Sternoptychidae), California headlight fish (*Diaphus theta*), sunbeam lampfish (*Lampadena urophaos*), common mola (*Mola mola*), and barracudinas (Paralepididae). In addition to the sharks and rays such as blue shark and spiny dogfish, the deep midwater trawl surveys found big skate (*Raja binoculata*), pelagic stingray (*Dasyatis violacea*), Pacific electric ray (*Torpedo californica*), and bluntnose sixgill shark (*Hexanchus griseus*).

Commercial Fisheries Data and Tools

The Pacific Fisheries Information Network (PacFIN) is a collaboration between state and federal fishery agencies that supply the information needed to effectively manage fish stocks on the U.S. West Coast. The PacFIN APEX reporting system provides summary data based on landings ("trip tickets") reported by fishermen (i.e., species caught, total weight) as well as other information such as revenue estimates and price per pound of commercially caught species (Dataset Table 4.4). The data can be sorted by certain landings type (groundfish, albacore, all highly migratory species, or all fisheries), by the gear type used, by the port where the landings were reported, by the catch area (such as "40 30' N TO 42 00' N; CAPE MENDOCINO TO OREGON-CALIFORNIA BORDER"), and other categories. Customized queries can also be developed from the raw (non-aggregated, non-confidential) data in PacFIN (Edwards 2020).

One example using this data is the information presented in Table 4.2, which shows landings (by value) of each management fishery group reported to the ports in Humboldt County ("Eureka Port Complex") and

Crescent City in Del Norte County. Based on these records, by far the most important fishery in this region is Dungeness crab, which is generally targeted inside of state waters. Other landings in the Eureka Port Complex and Crescent City are sablefish, Pacific whiting, lingcod, bocaccio, certain types of rockfish (canary, black, blue, yellowtail, quillback, copper, vermillion), Pacific mackerel, longnose skate, and albacore. Included in the totals for Eureka groundfish landings in 2020 were 6.6 metric tons of unspecified slope rockfish with a total value of $11,400 and a small amount (less than a metric ton) of unspecified shelf rockfish landed in Crescent City with a total value of $454. In 2019, only 4.0 metric tons of unspecified slope rockfish with a value of $7,220 were reported landed in the Eureka Port Complex.

Notably, more than half of the total landings in Eureka and 23% of the landings in Crescent City in 2020 were not publicly reported because of confidentiality concerns (Table 4.2). This happens when there are fewer than three vessels or three dealers reporting.

Commercial fisheries are also monitored using self-reported logbook data to assess catch levels and fishing activity. The logbook data contain three main types of features: a) characteristics specific to a fishing trip (such as departure and return port), b) characteristics specific to a tow (such as set and retrieval locations of the gear), and c) characteristics specific to a particular species or market grade (Mamula et al. 2020). The logbooks are required as soon as the catch is landed at port to verify that the fish were caught with appropriate methods and in approved areas. This information is then compiled so each fishery has a complete data set of all the fishing locations reported for a given time with detailed information on hot spots of fishing activity and high catch areas. NOAA Fisheries receives these logbooks and then compiles the data into an in-house database. This is an important source of data on commercial fishing effort and species. The logbooks can also provide a long historical record of the spatial distribution of fishing effort. This type of data has been compiled for public use in the California Offshore Wind Energy Gateway, but it has not been regularly updated (Miller et al. 2017; Dataset Table 4.5). There are a number of other spatially discrete datasets related to commercial fishing in the California Offshore Wind Energy Gateway, which will need to be updated to reflect current data. The most recent are from 2017.

Table 4.2. Total Landings and Revenue at Eureka Port Complex and Crescent City.

Total Landings and Revenues at Eureka (2019 and 2020)					
Management Group	**Species Caught**	**Total Landings (metric tons)**		**Total Revenue**	
Crab	Dungeness	1,477.6	857.4	$10,472,511	$6,499,826
Groundfish	Bocaccio, canary rockfish, black rockfish, yellowtail rockfish, longnose skate, shortspine thornyhead, etc.	2,933.5	756.2	$4,564,029	$1,316,937*
Flatfish	Dover sole (74% of total), petrale sole, rex sole, English sole	1,656.9	1.9	$2,283,409	$7,759*
Roundfish	Sablefish, lingcod	449.9	426.5	$1,401,959	$935,929*
Highly Migratory Species	Albacore	79.1	93.2	$331,996	$382,256
Shrimp	Pacific pink shrimp	214.6	---	$307,359	---
Other	Other species (no management group)	153.3	190.6	$301,805*	$441,314*
Salmon	Chinook	17.6	1.5	$226,545	$19,823
Coastal Pelagic Species	Pacific (chub) mackerel	0	0.4	0*	$1,563*
Not publicly reported because of confidentiality	Unknown (data in the revenue columns marked with an asterisk were withheld for confidentiality)	395.6	2,216.5	$455,296	$2,218,301
Total Landings and Revenue at Crescent City (2019 and 2020)					
Management Group	**Species Caught**	**Total Landings (metric tons)**		**Total Revenue**	
Crab	Dungeness	2,550.8	1,203.6	$19,199,374	$9,297,813
Shrimp	Pacific pink shrimp and other shrimp	941.6	41.5	$1,923,197	$569,292*
Groundfish	Black rockfish, quillback rockfish, copper rockfish, vermillion, etc. rockfish, canary rockfish, blue rockfish, yellowtail rockfish	107.6	45.9	$485,206*	$228,515*
Roundfish	Lingcod	---	12.4	---	$78,923*

Management Group	Species Caught	Total Landings (metric tons)		Total Revenue	
Highly Migratory Species	Albacore	85.3	0	$286,823	0*
Salmon	Chinook	17.6	---	$226,545	---
Coastal Pelagic Species	Market squid	126.7	---	$139,714*	---
Not publicly reported because of confidentiality	Unknown (data in the revenue columns marked with an asterisk were withheld for confidentiality)	8.2	393.1	$55,062	$468,466

*Data withheld for confidentiality purposes

General Status and Threats to Fish

Primary threats to bony and cartilaginous fish include habitat loss, water quality degradation, and climate change. Over-harvesting is also a threat to some species, though U.S. Fishery Management has enabled the recovery of most stocks to sustainable levels.

Many shark species, as well as some groundfish and deepwater bony fish species have a later maturation age and lower reproductive rates, which may contribute to their vulnerability. Other impacts such as the bioaccumulation of mercury is a particular threat to fish that feed higher on the food chain such as pelagic sharks and tunas.

Primary threats to salmon have been associated with the degradation and loss of fresh and brackish water spawning, rearing, and feeding habitats (PFMC 2016). Effects on long-term ocean temperature trends due to climate change are also expected to alter fish habitat preferences and abundance levels both positively and negatively, depending on species and location.

Data gaps and Limitations

NOAA Fisheries, the Pacific Fishery Management Council, and the Pacific States Marine Fisheries Commission, along with numerous academic and research institutions, collect, maintain, and analyze data regarding fish. Much of the raw data (e.g., survey data and geo-spatial data for individual species occurrence and abundance), is not easily available to the public. There are, however, detailed Stock Assessment and Fishery Evaluation (SAFE) reports that contain information on abundance, population trends, landings, and more. SAFE documents summarize the most recent biological condition of a species, social and economic factors of industries, including the fish processing sector.

For other fisheries, relatively little area-specific data are available such as for sharks and billfish, of which there is limited knowledge about stock distribution, status, and habitats at different life stages. Information is also needed to identify important habitat areas such as for thresher and mako shark pupping areas, key migratory routes, feeding areas, and areas where large adult female sharks congregate (PFMC 2018). Some of these data deficiencies are changing as more tuna, billfish, and sharks are electronically tagged and monitored remotely such as with the Tagging of Pelagic Predators program at Stanford University Hopkins Marine Station. This type of dataset can provide a baseline for monitoring and forecasting seasonal patterns and assessing shifts in abundance for highly migratory species.

Overall, this fish section is able to provide only a partial list of what is likely to occur in and near the HWEA. Species presence and abundance will vary seasonally, and on a yearly basis depending on oceanic conditions. Some species ranges may shift northward as ocean waters follow a warming trend. To obtain a better understanding of what fish occur within and near the HWEA, when, and at what abundance levels, site-specific, standardized pelagic and benthic surveys will be necessary. Surveys conducted in and near the area would allow for a more complete assessment of fish that are likely to occur within and around the HWEA.

For fishery landings data, the summaries will show only non-confidential landing statistics. Federal statutes prohibit public disclosure of landings (or other information) that would allow identification of the data contributors and possibly put them at a competitive disadvantage. Most summarized landings are non-confidential, but whenever confidential landings occur, they have been combined with other landings and usually reported as "Withheld for Confidentiality." Total landings by state include confidential data and will be accurate, but landings reported by individual species may, in some instances, be misleading due to data confidentiality. Further, it appears that 2020, the first year of the coronavirus (COVID-19) pandemic, the significant increase in confidentiality reporting may have been due to fewer processing facilities open for business compared to 2019 (Table 4.2).

Except for certain fisheries with required reporting requirements, landings data do not indicate the physical location of harvest but the location at which the landings either first crossed the dock or were reported from. Data queries on landings represent the most currently available data.

Summary Tables of Selected Fish Datasets

Dataset Table 4.1. NOAA Fisheries Landings

Dataset Title	NOAA Fisheries Landings
Species/Resource	Commercially and recreationally harvested fish and shellfish
Abstract	The NOAA Fisheries Landings database allows users to query the data to summarize domestic fishery landings—that is, fish and shellfish that are landed and sold in the 50 states by U.S. fishermen. (Domestic fishery landings do not include landings made in U.S. territories or by foreign fishermen.) You can summarize the pounds and dollar value of commercial landings by years, months, states, or species for 1990 onwards. For 1950 onwards, you can get a summary of the volume and value of landings by years, states, and species.
Strength/Weakness	Aggregated by state or major port so the data are not as useful for small port complexes such as Eureka or at Crescent City. Landings data do not indicate the physical location of harvest but the location at which the landings either first crossed the dock or were reported from.
File Name	Not applicable

Data Type	The raw data are not available
Spatial Extent	State and federal waters of all 50 states
Time Scale	Annually
Contact/Source	NOAA Fisheries
License/Use Restrictions	This is an automated program that anyone can use to get a quick summary of U.S. commercial fisheries landings
Citation Info	NOAA Fisheries Commercial Fisheries Landings
Online Link	https://www.fisheries.noaa.gov/foss/
Metadata Link	https://www.fisheries.noaa.gov/foss/f?p=215:240:7979717421101::NO:::

Dataset Table 4.2. Mid-Water Rockfish Trawls in the Trinidad Head Area

Dataset Title	Rockfish Recruitment and Ecosystem Assessment Survey
Species/Resource	Rockfish, Pacific whiting, sanddab, Pacific sardine, northern anchovy, and others
Abstract	The Fisheries Ecology Division of the Southwest Fisheries Science Center (SWFSC) has conducted a midwater trawl survey off central California since 1983 with the primary goal of developing pre-recruit indices for YOY rockfish (Sebastes spp.). The survey also samples numerous other components of the epipelagic micronekton, including other YOY groundfish (such as Pacific hake (whiting), *Merluccius productus*, and sanddab, *Citharichthys* spp), coastal pelagic fishes (such as Pacific sardine, *Sardinops sagax*, and northern anchovy, *Engraulis mordax*) and other forage species. Additional details regarding the survey methods and results are described in Ralston et al. (2015) and Sakuma et al. (2016).
Strength/Weakness	Query parameters (such as date range, latitude and longitude, species name or common name) need to be set by the user in the data server called ERDDAP. For example, for the HWEA, "Trinidad Head" was used to specify the area.
File Name	FED_Rockfish_Catch
Data Type	The data are available through the CeNCOOS data portal, where it can be viewed using interactive visualizations. Data files are also available for download from three unique access points: Web Mapping Service (WMS); Web Feature Service (WFS); and File Downloads (PNG, Shapefile, CSV)
Spatial Extent	21 survey locations in California
Time Scale	1990-2018 (annual surveys; ongoing)
Contact/Source	John Field, NOAA Fisheries Ecology Division, (831) 420-3900; John.Field@noaa.gov
License/Use Restrictions	The data may be used and redistributed for free but is not intended for legal use, since it may contain inaccuracies. Neither the data Contributor, ERD, NOAA, nor the United States

	Government, nor any of their employees or contractors, makes any warranty, express or implied, including warranties of merchantability and fitness for a particular purpose, or assumes any legal liability for the accuracy, completeness, or usefulness of this information.
Citation Info	Ralston, S., J.C. Field and K.S. Sakuma. 2015. Long-term variation in a central California pelagic forage assemblage. Journal of Marine Systems 146: 26-37. (https://dx.doi.org/10.1016/j.jmarsys.2014.06.013).
Online Link	https://coastwatch.pfeg.noaa.gov/erddap/info/FED_Rockfish_Catch/index.html and also https://data.cencoos.org/#metadata/8672e1f4-90df-4d9a-8533-37dbea59431e/2b5a4999-286b-4fd5-a4ba-fc3bef82b990
Metadata Link	https://coastwatch.pfeg.noaa.gov/erddap/info/FED_Rockfish_Catch/index.html

Dataset Table 4.3. Groundfish Trawl Density (1997 to 2017)

Dataset Title	Groundfish Trawl Density, 1997-2017
Species/Resource	Aurora rockfish, arrowtooth flounder, bank rockfish, bocaccio, blackgill rockfish, bottom rockfish-shelf, bottom rockfish-slope, brown rockfish, chilipepper rockfish, canary rockfish, darkblotched rockfish, Dover sole, spiny dogfish, Dover-thornyheads-sablefish, deepwater Dover (focus on Dover sole), English sole, grenadiers, greenspotted rockfish, lingcod, longspine thornyheads, nearshore flatfish mix, other flatfish, Pacific sanddab, petrale sole, Pacific whiting, rex sole, rock sole, sablefish, shortbelly rockfish, scorpionfish, sanddabs, sharpchin rockfish, splitnose rockfish, sand sole, shortspine thornyhead, starry flounder, shelf rockfish, slope rockfish, widow rockfish, yellowtail rockfish
Abstract	This feature collection summarizes logbook records from the CDFW Marine Log System (MLS) showing the density of trawls targeting groundfish from 1997 to 2017. Data from CDFW Marine Log System (MLS) were extracted to determine the start position, end position, vessel ID, tow or drag number ID, date, target species, and species landed. Records were transformed and plotted to create straight line trawl tracks attributed with date and targets. Lines were filtered to remove records plotted on land and track lines greater than 25km in length. Records were selected for groundfish targets (species list provided by T. Larinto - see supplemental info) and summarize by the ArcGIS line density function. Results are presented by a 1 km cell GRID representing a 5km search radius. Units are reported as total length of trawls (Km) within the search area.
Strength/Weakness	Has not been updated since 2017; the logbook data are confidential and can only be presented in summarized form to the public. However, researchers with appropriate clearance can access the more detailed data.
File Name	Groundfish Trawl Density, 1997-2017
Data Type	Logbook records
Spatial Extent	California

Time Scale	Not specified
Contact/Source	CDFW Marine Region GIS; mr_gis@dfg.ca.gov
License/Use Restrictions	This work is licensed under Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/). Using the citation standards recommended for BIOS datasets (https://www.wildlife.ca.gov/Data/BIOS/Citing-BIOS) satisfies the attribution requirements of this license. Disclaimer: The State makes no claims, promises, or guarantees about the accuracy, completeness, reliability, or adequacy of these data and expressly disclaims liability for errors and omissions in these data. No warranty of any kind, implied, expressed, or statutory, including but not limited to the warranties of non-infringement of third party rights, title, merchantability, fitness for a particular purpose, and freedom from computer virus, is given with respect to these data.
Citation Info	Data provided by the California Department of Fish and Wildlife, Marine Region GIS lab with post-processing by the Conservation Biology Institute
Online Link	https://caoffshorewind.databasin.org/maps/new/#datasets=209cacc1981e421e94dd908a5e2e2eeb
Metadata Link	Not available

Dataset Table 4.4. Pacific Fisheries Information Network (PacFIN)

Dataset Title	Pacific Fisheries Information Network (PacFIN) APEX reporting system
Species/Resource	Managed fisheries
Abstract	The nation's first regional fisheries data network, PacFIN is a joint federal and state data collection and information management project. Cooperative agency and industry partners supply data from commercial fisheries off the coasts of Washington, Oregon, and California. PacFIN combines the collected information to provide accurate estimates of commercial catch and value for the West Coast. Member agencies include California Department of Fish & Wildlife, Oregon Department of Fish & Wildlife, Washington Department of Fish & Wildlife, National Oceanic and Atmospheric Administration, Pacific States Marine Fisheries Commission, Pacific Fisheries Management Council
Strength/Weakness	Landing summaries are compiled from databases that overlap in time and geographic coverage and come from both within and outside of NOAA Fisheries. Although numerous checks have been made to verify their completeness and accuracy, discrepancies are always possible.
File Name	Varies based on data downloaded
Data Type	.csv or .xml
Spatial Extent	California, Oregon, and Washington
Time Scale	Depending on the type of data received, the information is updated weekly, monthly, or annually. The California fish ticket data are updated twice each month (refer to:

	https://pacfin.psmfc.org/data/faqs/).
Contact/Source	A "contact us" form is available at: https://pacfin.psmfc.org/contact/contact-us/
License/Use Restrictions	Not described
Citation Info	Pacific Fisheries Information Network (PacFIN) 2021
Online Link	https://reports.psmfc.org/pacfin/
Metadata Link	https://reports.psmfc.org/pacfin/f?p=501:826:11678925069201:INITIAL:::F_SELECTED_NODE:146&cs=3IQ4bqnVRHobEHev2_B88HsOtSCZtHfuqBv_4SsO5JilSQnRNmLS8HO-R7dOifVlUA33bW0pZXi-dQUwzs4wrTQ The "metadata" is only the fishery codes, but custom queries can be created from the raw data (see Edwards 2020).

Dataset Table 4.5. Catch of California commercial marine fisheries 1981-2005

Dataset Title	Catch of California commercial marine fisheries 1981-2005
Species/Resource	Commercial marine fisheries
Abstract	This data summarizes California Fish and Wildlife commercial fisheries catches from 1981-2005. The purpose of the dataset was to identify historically important fishing grounds and quantify an associated relative ecosystem service and benefit measured over time and space for a suite of commercially important species. Catches are reported on landing receipts (also known as 'fish tickets') and are recorded by fish dealers or processors at the port of landing. Summary catch statistics include market category, year, pounds landed, and spatial block. The time series includes species that are historically and/or currently important to the California fisheries economy and were binned into 10 broad taxonomic groups: groundfish, coastal pelagic species, salmonids, game fish, highly migratory species, abalone, market squid, echinoderms, Dungeness crab and other crustaceans. To improve the spatial accuracy of the catches, a bathymetric criterion was used for each taxonomic group based on depth range in which the species is most often encountered. For all taxonomic groups, total catch for 25 years for each block was summarized and converted pounds to metric tons. To normalize the catch, the total catch was divided by the area of the grid block or depth contour. Note that no catch-related effort information available with this dataset.
Strength/Weakness	The latest data, which are collected annually from logbook data, were last updated in 2005; the dataset was scientifically peer reviewed
File Name	Catch of California commercial marine fisheries 1981-2005
Data Type	Raster data layer
Spatial Extent	California
Time Scale	1981-2005

Contact/Source	Rebecca Miller, National Marine Fisheries Service Fisheries Ecology Division Groundfish Analysis Team, Santa Cruz, CA 95060; (831) 420-3966; rebecca.miller@noaa.gov
License/Use Restrictions	This work is licensed under a Creative Commons Attribution 3.0 License.
Citation Info	Miller, R.R., J. Field, J. Santora, Monk, M.H., R. Kosaka, C. Thomson. 2017. Spatial valuation of California marine fisheries as an ecosystem service. Canadian Journal of Fisheries and Aquatic Sciences. doi.org/10.1139/cjfas-2016-0228
Online Link	https://caoffshorewind.databasin.org/maps/new/#datasets=49ad0ad50e5b49339b8f0774f039a774
Metadata Link	Not available

SECTION 5. MARINE MAMMALS

Forty-five species of marine mammals are known to occur in the California Current System between British Columbia, Canada and Baja California Sur, Mexico. Marine mammals discussed in this section fall into two taxonomic groups: cetaceans (whales, dolphins, and porpoises) and pinnipeds (seals and sea lions). Cetaceans are further divided into two groups consisting of baleen whales (mysticetes) and toothed whales (odontocetes). Seven species of baleen whales are known to occur off California. Toothed whales known to occur offshore California include sperm whales (three species), orca (also known as "killer whales" from three morphologically distinct groups), beaked whales (15 species that are difficult to distinguish at sea), dolphins (19 species), and porpoises (two species). Pinnipeds include the eared seals (otariids) and the earless or true seals (phocids). Southern sea otters (*Enhydra lutris nereis,* mustelids) inhabit a limited portion of the CCS from Pigeon Point to Gaviota State Beach. All marine mammals in U.S. waters are protected under the Marine Mammal Protection Act, and some have additional protections such as under the U.S. ESA and the International Convention on Trade in Endangered Species of Wild Fauna and Flora (CITES).

The nutrient-rich upwelling season of the California Current is strongest in spring and summer, which is when prey is likely to be most abundant. When the California Current upwelling relaxes from August to October, whales and pinnipeds will follow the warmer surface waters. The northward flowing Davidson Current dominates in winter, and from November to February warm water species such as dolphins will move north from Southern California. The distribution of cetaceans and pinnipeds is also influenced by the edge of the continental shelf at the 200-m (656-ft) isobath along the West Coast (Becker et al. 2020).

Many of the baleen whale species that are seen in California waters in the spring and then later in the fall are passing through to their foraging or breeding and calving grounds. In the summer, they can be found in cold water feeding areas north of Oregon (Würsig, 1988; Calambokidis et al. 2009). In winter, most baleen whales are found in tropical waters off Mexico, Costa Rica, and Hawaii where they mate and calve (Würsig, 1988; Heithaus and Dill 2009). Baleen whale foraging locations and patterns can change depending on oceanographic conditions in their search for better feeding areas (Calambokidis et al. 2009).

Toothed whales occur in a diverse range of habitats from nearshore to far offshore in a variety of temperature regimes and bottom structure preferences. Some examples include Dall's porpoise (*Phocoenoides dalli*), which occurs in upwelling-modified waters along the shelf-slope break. Risso's dolphins (*Grampus griseus*) prefer bathymetrically complex regions with warm water. Short-beaked common dolphins (*Delphinus delphis delphis*) are found in warmer offshore waters while Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) are found on the cooler shelf-slope areas. Harbor porpoises (*Phocoena phocoena*) concentrate nearshore on the shelf in areas of cool ocean temperatures (Pelagic Working Group 2002; Allen et al. 2011).

Because of their connection to land, pinnipeds follow a predictable and synchronous annual cycle between terrestrial sites for hauling out and rearing young, and ocean foraging sites. They often exhibit breeding site fidelity, returning to the same site annually. Haul out site selection and overall seasonal distribution may be driven by proximity to foraging opportunities. Otariids are also known to float on the surface of the ocean to warm themselves, sometimes in large rafts. The sea lion species are more likely to remain closer to shore, as they haul out frequently to rest and thermoregulate. Fur seals utilize habitat in a similar fashion to the phocids, in that they spend most of their lives at sea, hauling out primarily for breeding. The phocids depend on their higher levels of subcutaneous fat stores to thermoregulate while at sea, allowing them to spend less time on land.

Based on distinct habitat preferences that are generally closely linked to seasonal oceanic conditions, cetacean distribution models have been developed to help assess which animals might be in an area and at which time. Becker et al. (2020) created predicted density distribution models for several species of cetaceans (Table 5.1). These models combine information on animal observations in the field with the ocean's physical and chemical attributes (e.g., topography, temperature, salinity, depth, chlorophyll concentration, etc.) to determine how environmental drivers influence the distribution of marine species. Known information about habitats and food sources can be used to predict their preferences and form a picture of where marine animals are likely to occur at different times of their biological life histories. The seasonal patterns between cold and warm water, which create generally predictable occurrences in the food web, are altered during abrupt climatic shifts. The shift to an ENSO event occurs about every four to ten years, when the usual westerly trade winds cease, and upwelling is reduced. This affects the whole food chain with corresponding impacts to marine mammal distribution and health.

Table 5.1. Cetacean species commonly observed in the California Current System. Abundance estimates are based on Barlow and Forney (2007).

Common Name	Scientific Name	Abundance Estimate for N. California (38° - 42° N)	IUCN Status; Global Population Trend
Mysticetes (Baleen Whales)			
Blue whale	*Balaenoptera musculus*	115	Endangered; increasing
Humpback whale	*Megaptera novaeangliae*	90	Least Concern; increasing
Gray whale	*Eschrichtius robustus*	-----	Least Concern; stable
Common minke whale	*Balaenoptera acutorostrata*	102	Least Concern; unknown
Fin whale	*Balaenoptera physalus physalus*	448	Vulnerable; increasing
Bryde's whale	*Balaenoptera edeni*	0	Least Concern; unknown
Sei whale	*Balaenoptera borealis*	47	Endangered; increasing
Odontocetes (Toothed Whales)			
Sperm whale	*Physeter macrocephalus*	736	Vulnerable, unknown
Dwarf or pygmy sperm whale	*Kogia sp.*	130	Least Concern; unknown
Orca (or killer whale)	*Orcinus orca*	142	Data Deficient; unknown
Baird's beaked whale	*Berardius bairdii*	200	Least Concern; unknown
Cuvier's beaked whale	*Ziphius cavirostris*	784	Least Concern; unknown

Common Name	Scientific Name	Abundance Estimate for N. California (38° - 42° N)	IUCN Status; Global Population Trend
Other beaked whales	*Mesoplodon sp. and Ziphiid sp.*	172	Data Deficient; unknown
Bottlenose dolphin (offshore)	*Tursiops truncatus*	133	Least Concern; unknown
Dall's porpoise	*Phocoenoides dalli*	27,410	Least Concern; unknown
Long-beaked common dolphin	*Delphinus capensis*	0	Least Concern; unknown
Northern right whale dolphin	*Lissodelphis borealis*	1,652	Least Concern; unknown
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	4,137	Least Concern; unknown
Risso's dolphin	*Grampus griseus*	1,036	Least Concern; unknown
Striped dolphin	*Stenella coeruleoalba*	4,040	Least Concern; unknown

Marine Mammals With Potential to Occur in the Wind Energy Area or Vicinity

Based on the distribution models of Becker et al. (2020), the cetacean species most likely to occur in or near the HWEA are Dall's porpoise, northern right whale dolphin, and Pacific white-sided dolphin. Humpback, blue, and fin whales are also broadly and seasonally distributed in the region but have lower predicted densities due to lower overall population numbers and distribution patterns. The highest density of baleen whales in the vicinity of the HWEA is most likely to occur in the summer and fall.

Baleen Whales

The current best estimate on the number of **humpback whales** that occur along the U.S. West Coast is 2,900 animals in the California/Oregon/Washington stock (Carretta et al. 2020). They are most abundant off California from spring to fall although a small number remain to feed along the Pacific coast between Kodiak Island, Alaska, and northern California. Becker et al. (2020) estimates that the highest density of humpback whales in the HWEA occurs in the summer/fall, which is considered low compared to the maximum density in the CCS (Figure A.1). Based on density modeling data and survey sightings, a Biologically Important Area (BIA) for feeding has been delineated from Fort Bragg to Point Arena between July and November (Calambokidis et al. 2019; Dataset Table 5.2).

The best estimate of the number of **blue whales** in the eastern North Pacific is between 1,767 and 2,038 individuals (Calambokidis and Barlow, 2020). Recent modelling efforts have found that blue whale habitat preferences are strongly influenced by water temperature, seafloor topography and subsurface water properties (Abrahms et al. 2019). Blue whale abundance estimates from line-transect surveys over the years have been highly variable, which is attributed to a more recent northward shift in their distribution to waters off Oregon and Washington because of warming ocean temperatures (Calambokidis et al. 2009). Blue whales are most likely to be found off California between summer and fall after which they leave U.S.

West Coast waters from November to March (Carretta et al. 2020). Becker et al. (2020) estimates that the highest density of blue whales in the HWEA occurs in the summer/fall, which is considered low relative to the CCS (Figure A.2). The distribution pattern indicates that the whales concentrate over the shelf and shelf break, and more offshore in the southern California area. BIAs for blue whales have also been predicted through similar modeling efforts. The northernmost BIA for blue whales is an area along the shelf edge from Point Arena north to Fort Bragg (Calambokidis et al. 2015; Dataset Table 5.2).

The California/Oregon/Washington stock of **fin whales** is estimated to be 9,029 individuals, but this is probably an underestimate because it excludes some fin whales that could not be identified during the surveys, so they were recorded as “unidentified rorqual” or “unidentified large whale” (Carretta et al. 2020). The population structure and movements of fin whales are not well known, but they are generally present year-round off California, occurring both nearshore and offshore, with the highest densities in the summer and fall. High densities have been predicted in modeling efforts in offshore waters centered about 185 km (115 miles) west of the Gulf of the Farallones (Calambokidis et al. 2015). Not all fin whales undergo long-range seasonal migrations with some making only short-range seasonal movements in spring and fall (Calambokidis et al. 2015). Becker et al. (2020) estimates that the highest density of fin whales in the HWEA could occur in the summer/fall, but these densities are low compared to areas well offshore, as well as to central California between the Channel Islands and Morro Bay, where densities are predicted to be highest (Figure A.3). Local density values have been predicted to be higher to the south of the HWEA along Eel Canyon, a steep, narrow meandering canyon (Field et al. 1980). In research conducted in the North Atlantic, fin whale distribution was likely influenced by depth and more complex bottom topography. More information is needed to better estimate the likelihood for fin whales in the area around the HWEA.

Two distinct populations of **gray whales** inhabit the Pacific Ocean, with the Eastern North Pacific population’s range extending from Alaska to Baja California, Mexico. Recent abundance estimates for this population indicate there are 26,960 individuals (Carretta et al. 2020). Gray whales are in greatest abundance off California from spring to fall but can be observed almost year-round (Calmbokidis et al. 2015). The migration corridors for most gray whales are within 10 km (6 mi) of the U.S. West Coast although some may deviate farther offshore. This proximity to shore makes them relatively easy to count using land-based observers. These numbers show there is a spike in the number of individuals seen per day from December to March when they are on their southbound migration and again from April to July when they are traveling northward. After these peaks, the numbers moderate for a few weeks until slowly tapering off (Calambokidis et al. 2015). Given their nearshore foraging and travel habitat preferences, gray whales are considered unlikely to be in the vicinity of the HWEA. Because of the lack of at-sea observation data due to their seasonality and nearshore migration tendencies, there is currently no known California Current-wide predictive distribution model for gray whales.

Toothed Whales

The largest member of the toothed whale family is the **sperm whale**. They are also one of the large whales that cannot go without feeding for long periods of time. They routinely dive to depths of 610 m (2,000 ft) for up to 40 minutes or longer in search of squid, their primary prey, and have been known to dive as deep as 3,048 m (10,000 ft; NOAA Fisheries 2021d). Female groups migrate up to 683 mi (1,100 km) as part of a strategy for surviving in a variable habitat with low local food abundance and poor foraging success. It is believed this tactic may be the reason that female sperm whales form permanent social bonds as they may benefit from the experience of older females during migrations (Heithaus and Dill 2009). The 2,000-m isobath is a potential predictor of sperm whale habitat, generally delineating the shift from the continental slope to the continental rise (Becker et al. 2020). Becker et al. (2020) also reports that the habitat-based density model for sperm whales showed “some of the worst model metrics among all species and predicted distribution patterns that match poorly to actual sightings.” It is believed this is because there has been limited sampling of deep offshore waters where sperm whales are usually found. The model predicted low to moderate densities of sperm whales in the HWEA compared to the CCS as a whole, but there is a substantial increase in predicted density immediately west of the HWEA along and beyond the shelf slope (Figure A.4). It is expected that sperm whales can be found in California waters year-round, with higher abundance in mid-May and mid-September off Central California due to migration patterns (Allen et al. 2011). Given the water depths and distance from shore, it is expected that sperm whales are likely to occur west of the HWEA and potentially within the HWEA.

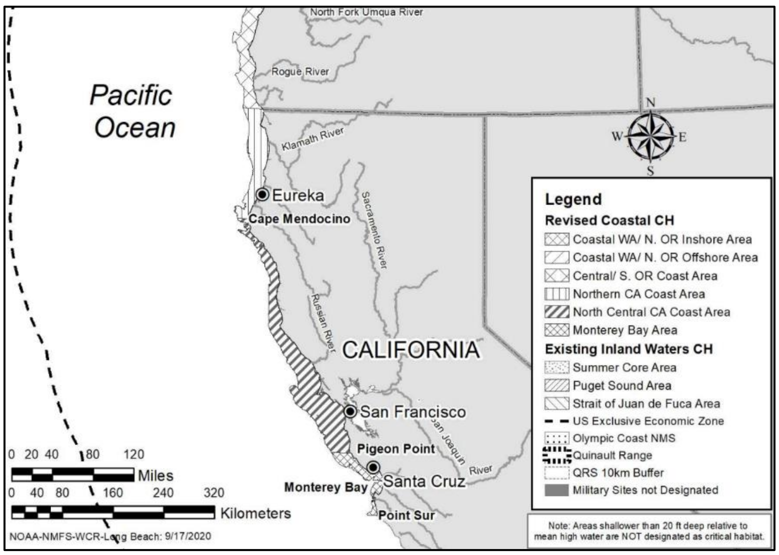

Figure 5.1. Southern resident killer whale DPS critical habitat (NOAA Fisheries 2021d).

Southern resident killer whales spend nearly all their time on the continental shelf within 34 km (21 mi) from shore in water less than 200 m (656 ft) deep (Hanson et al. 2017). They depend on different prey species and habitats throughout the year, but their movements also seem to be influenced by the seasonal timing of salmon returns to different river systems (NOAA Fisheries 2021d). In August 2021, NOAA Fisheries revised critical habitat of the Southern Resident Killer Whale Distinct Population Segment (DPS). In addition to the original inland waters of Washington State that are listed as critical habitat, the new rule included marine waters in depths of 6 to 200 m (20 to 656 ft) from the U.S. border with Canada south to Point Sur (Figure 5.1; NOAA Fisheries 2021d). There is currently no known California Current-wide predictive distribution model for killer whales.

Because **Baird’s beaked whales** are larger than other beaked whales, and are also more social, they are the most easily identified species of the beaked whale family during at-sea surveys. They are commonly found in deep, cold waters but are also occasionally observed over the continental slope and shelf along the California Current System in summer and fall (NOAA Fisheries 2021d). The California/Oregon/Washington stock population abundance estimate is 2,697 whales (Carretta et al. 2020). Becker (et al. 2020) indicated that predicted densities of Baird’s beaked whales in the HWEA in spring and summer are low compared to the CCS. Densities were predicted to be much higher well offshore over the shelf slope south of Cape Mendocino as well as to the northwest off central Oregon (Figure A.5).

The **small beaked whale guild** offshore California includes **Cuvier's beaked whale** (*Ziphius cavirostris*) and six species of Mesoplodonts: **Blainville's beaked whale** (*Mesoplodon densirostris*), **Perrin's beaked whale** (*M. perrini*), **lesser beaked whale** (*M. peruvianus*), **Stejneger's beaked whale** (*M. stejnegeri*), **gingko-toothed beaked whale** (*M. gingkodens*), and **Hubb's beaked whale** (*M. carlhubbsi*). These species are grouped into a guild because they are difficult to distinguish at sea and are rarely observed, resulting in insufficient sighting records to create accurate estimates of distribution and density for any given species (Carretta et al. 2020). The 2014 California/Oregon/Washington stock of mesoplodont whale abundance is estimated to be 3,044 animals (Carretta et al. 2020). Becker et al. (2020) reported that when these small beaked whales were modeled, they showed "some of the worst model metrics among all species and predicted distribution patterns that match poorly to actual sightings." It is believed this is due to limited sampling of offshore waters where small beaked whales are typically found (Becker et al. 2020). These models indicated higher predicted density well beyond the shelf-slope, with low values in and near the HWEA compared to the CCS as a whole (Figure A.6). The 2,000-m (6,562-ft) isobath is a useful predictor for beaked whale habitat preference because this depth represents the transition from the continental slope to the continental rise (Becker et al. 2016).

The **Dall's porpoise** is a common and easily identifiable cetacean in California offshore waters. Although much of its life history is not known, it is reasonably abundant (NOAA Fisheries 2021d) in temperate to boreal waters that are more than 183 m (600 ft) deep and with temperatures between 2 and 17 ºC (36 and 63 °F). They can be found in offshore, inshore, and nearshore oceanic waters. Dall's porpoises occur in higher abundance near the shelf break. Their migration patterns are based on geography and seasonality (NOAA Fisheries 2021d) and may be linked to movement of prey (Allen et al. 2011). The average abundance estimate for the outer coast of California, Oregon, and Washington waters is 17,954 (Carretta et al. 2020). Becker et al. (2020) estimates that the highest density of Dall's porpoise in the HWEA could occur in the summer/fall months (Figure A.7), a high density compared to the CCS overall.

Pacific white-sided dolphins are offshore pelagic species that are unlikely to be found close to shore. Individuals are most common over the continental shelf and along the shelf break to 1,000 m (3,281 ft) or in areas of submarine canyons (Allen et al. 2011). Changes in their distribution off California are likely in response to seasonal and interannual oceanographic changes. The minimum population estimate for the California, Oregon, and Washington stock of Pacific white-sided dolphins is believed to number 21,195 individuals (Carretta et al. 2020). Becker et al. (2020) estimates that the highest density of Pacific white-sided dolphins in the HWEA could occur in the summer/fall, a high value compared to the CCS overall (Figure A.8).

Northern right whale dolphins range from deep, cold water to warm temperate waters of the Pacific Ocean. They usually travel in groups of 100 to 200 individuals but sometimes travel in groups of up to 3,000. There are an estimated 26,000 individuals in the California/Oregon/Washington stock (Carretta et al. 2020). They are most common on the continental shelf and shelf break to depths of 1,000 m (3,300 ft). Based on stomach contents of four carcasses found on California beaches, the most common prey (75%) was lanternfish (Myctophidae), a small mesopelagic fish, followed by California smoothtongue (*Leuroglossus stilbius*), a deep-sea smelt that occurs from the surface to 690 m (2,300 ft; Allen et al. 2011). Becker et al. (2020) estimates that the highest density of Northern right whale dolphins in the HWEA could occur in the summer/fall, a high value compared to the overall CCS average density (Figure A.9).

The population of **short-beaked common dolphins** that inhabit offshore waters from California to Washington is believed to number 969,861 (Carretta et al. 2020). At sea, short-beaked common dolphin co-occurs with Pacific white-sided dolphin, striped dolphin, and common bottlenose dolphin, which can be confused by observers. These dolphin species commonly ride the bow wakes of vessels. During the day, they are known to form large schools of 2,000 to 10,000 individuals that break into smaller feeding groups of 20 to 200 later in the afternoon and nighttime. This behavior is believed to be in response to the patchy distribution of prey in oceanic waters when they feed at night on fish, squid, and some crustaceans, and then mostly rest and socialize during the day. They usually forage at 9 to 50 m (30 to 164 ft) but will pursue prey down to 280 m (920 ft; Allen et al. 2011). It is likely that short-beaked common dolphins would be uncommon to rare in the HWEA. Becker et al. (2020) estimates that the highest density of short-beaked common dolphins in the HWEA could occur in the summer/fall but this value is very low compared to areas offshore to the south, as well as in the Southern California Bight where densities are predicted to be highest (Figure A.10).

Long-beaked common dolphins often mix with other species including common bottlenose dolphin and Pacific white-sided dolphin. They will form small schools of ten to 30 during the night and larger schools of up to several thousand, but more often 100 to 500, during the day. A regional concentration occurs from Central California to Baja generally in water depths to 183 m (600 ft) and in areas of high relief and local upwelling. They are rarely seen in Northern California, preferring warm temperate and tropical coastal waters (Allen et al. 2011). It is likely that long-beaked common dolphins would be uncommon to rare in the HWEA. Becker et al. (2020) estimates that the highest density of long-beaked common dolphins in the HWEA could occur in the summer/fall months, but this value is very low compared to areas offshore to the south, where densities are predicted to be highest (Figure A.11).

Common bottlenose dolphins are found offshore, beyond and over the continental shelf, as well as nearshore, including in bays, estuaries, and harbors. They prefer tropical or temperate waters and consume a wide range of prey including crustaceans, squid, and fish. They travel and hunt in small groups, using cooperative behavior and sound to concentrate and capture prey (Allen et al. 2011). Becker et al. (2020) estimates that the summer/fall density of bottlenose dolphins in the HWEA is very low compared to offshore areas well to the south, where densities are predicted to be highest (Figure A.12).

Risso's dolphins are often seen off California on the continental shelf edge and slope, in deeper offshore temperate waters. These dolphins are visually distinct, with prominent white scars covering their gray or nearly white bodies. They travel in small groups of tens of animals, although are sometimes observed in pods of hundreds of animals. While foraging, they can dive more than 333 m (1,000 ft) to hunt cephalopods, especially squid, as well as fish and krill (Allen et al. 2011). Becker et al. (2020) estimates that the summer/fall density of Risso's dolphins in the HWEA is very low compared to areas to both the north and south, where densities are predicted to be highest (Figure A.13).

The habitat preferences for **striped dolphin** (*Stenella coeruleoalba*) fluctuate substantially because of changing ocean conditions, which results in large fluctuations of the number of animals that may be sighted in the study area in any single year (Becker et al. 2020). Becker (et al. 2020) predicted very low densities of striped dolphins in the HWEA compared to the overall CCS (Figure A.14). These models indicate this species is distributed very far offshore in the southwest portion of the CCS.

Rare or Data Deficient Marine Mammal Species

Baleen Whales

North Pacific right whales were distributed broadly throughout California before being decimated by whaling operations. Their habitat preferences are cool temperate waters in depths ranging from 100 to 225 m (328 to 738 ft). Despite this, almost all observations of North Pacific right whales south of Canada over the past 30 years have occurred close to shore (Allen et al. 2011). They are listed as Endangered throughout their range under the U.S. ESA, and there are no reliable estimates of current abundance or population trends (NOAA Fisheries 2021c).

Whaling records suggest **sei whales** occurred in nearshore California waters from March to May, then traveled offshore to more than 100 km (62 mi) from July to September. It is not known if this pattern still exists today. Sightings are extremely rare, but when they do occur, they are from aerial observations in pelagic waters between California and Washington (Allen et al. 2011).

Pinnipeds

Spatially explicit distribution data for pinnipeds is limited in availability, often restricted to local scales. Some at-sea surveys, both boat-based and aerial, collect pinniped observation data as well as cetaceans and seabirds, but these data have not been utilized to create discrete distribution models. Telemetry studies have also provided data on individual animals, but the volume of data is potentially insufficient for distribution analysis.

Northern fur seals (*Callorhinus ursinus*) are small, solitary, pelagic species that spend 80% of their time at sea, coming ashore primarily to breed (NOAA Fisheries 2021c). These eared seals forage on fish and cephalopods in deep waters over and beyond the continental shelf (Allen et al. 2011). Only two sites support breeding rookeries off the coast of California: Southeast Farallon Island and San Miguel Island. However, their pelagic range extends from Baja California, Mexico to Alaska and west to Japan. They have additional protections under the Fur Seal Act (NOAA Fisheries 2021c).

California sea lions (*Zalophus* californianus) are also eared seals. This charismatic species is well-known due to its propensity to haul out on rocks, beaches, docks, and buoys, and their boisterous, vociferous nature. They eat fish and cephalopods, and are known for interacting with commercial and recreational fishing vessels. They are commonly observed in shallow waters over the continental shelf, especially in areas where upwelling has concentrated their prey. Unlike Steller sea lions, California sea lions do not breed in Humboldt County, as their breeding range extends south from the Channel Islands to Mexico (NOAA Fisheries 2021c). However, they do utilize haul out sites in the Humboldt area that they share with other pinniped species.

The largest of the otariids, the **Steller sea lion** (*Eumetopias jubatus*), feeds on many species of fish and cephalopods, and is usually observed over the continental shelf and seaward. Split into two distinct population segments (DPS), the Eastern DPS ranges from southeast Alaska to central California (NOAA 2021c). These animals breed off the coast of Humboldt County, and the Año Nuevo Island rookery in Santa Cruz County is currently the southernmost breeding site (Allen et al. 2011), with occasional observations as far south as Point Conception. Critical habitat for Steller sea lion in California has been established at Sugarloaf Island and Cape Mendocino, the Farallon Islands, and Año Nuevo Island, which includes a protected aquatic zone that extends 914 m (3,000 ft) seaward as well as an air zone 914 m (3,000 ft) above these rookeries.

Harbor seals (*Phoca vitulina*) are phocids, or earless seals. They spend a large portion of their lives at sea, but haul out to breed, thermoregulate, and molt. They consume fish, crustaceans, and shellfish, and forage in coastal habitats landward of the continental shelf break. They tend to remain relatively resident in a given area but will travel great distances to follow prey resources (NOAA Fisheries 2021c). This species breeds and hauls out in Humboldt county on isolated beaches, mudflats, and in Humboldt Bay.

Northern elephant seals (*Mirounga angustirostris*) are also phocids. They live 80 to 95% of their lives at sea (Allen et al. 2011). They pursue a variety of different foraging strategies but are most often found at the mid-water (91-213 m [300-700 ft]) mixing zone between the California Current and the Davidson Current where upwelling drives a robust food web and concentration of prey (Robinson et al. 2012). Female elephant seals may also feed along the continental shelf or near areas such as seamounts (Robinson et al. 2012). Males more often forage on the bottom along the continental margin (Allen et al. 2011). Because they can be prey to white sharks and Southern Resident killer whales, elephant seals do most of their feeding at night, which is also when their prey are closer to the surface. They tend to rest in the early morning around sunrise, after a long night of foraging (Beltran et al. 2021). Female northern elephant seals make two foraging trips every year. After the breeding season (December to March), they head out to sea for two months before returning to the rookery to molt (March to August). Then they leave on a long post-molting migration that often lasts eight months, from June to January. Juveniles will haul out from September to November (Allen et al. 2011). Observing an elephant seal at sea is rare.

Sea Otters

Although **southern sea otters** once ranged throughout California, their slow recovery from being hunted for the fur trade has resulted in a reduction of their range. Currently, the species is listed as Threatened under the U.S. Endangered Species Act. Their breeding range and distribution extends from north of Santa Cruz to the northwestern California Bight (Hatfield et al. 2019, USFWS 2021); those that are observed in the waters off Humboldt and Mendocino counties are vagrants. They tend to congregate in coastal waters and estuaries, as they forage in shallow water for prey living on kelp or the ocean floor. Because of their affinity for near-coastal environments, they are unlikely to be observed in the HWEA and its immediate vicinity.

Availability of Marine Mammal Data

Becker et al. (2020) created species distribution models using ship-based survey data that were collected between 1991 and 2018. Most of the surveys extended approximately 200 to 300 nm (370 to 556 km) offshore. The models include additional sighting data over the continental shelf and slope that were surveyed more sparsely in previous years, providing better representation of these habitat regions, and improvements were made to more accurately account for uncertainty based on methodological improvements. The figures used in this section are from Becker et al. (2020; Dataset Table 5.1).

Woodman et al. (2019) have also created an R package called eSDM that can create species distribution models from a variety of data sources, such as ship-based surveys (as described in Becker et al. 2020) and satellite tagging surveys (as described in Hazen et al. 2017). The data ensemble approach to species distribution modeling is a weighted or unweighted average (or combination) of the data to provide an established method for resolving differences between individual models. It also has options for incorporating or calculating uncertainty. This is an additional tool to assist users in identifying spatial uncertainties and making informed conservation and management decisions.

Pinniped data are often only available on limited temporal or spatial scales. The Tagging of Pacific Predators (TOPP) program has collected multiple years of location data for northern fur seals (two years), California sea lions (eight years), and northern elephant seals (~17 years). These data have been used to assess cumulative impacts of human influence on marine predators (Maxwell et al. 2013) and may have some utility in other marine resource use planning contexts. One product created using these data are Kernel Utilization Distribution (KUD) maps, which indicate the probability of an animal being found in a given location. This can provide information on the distribution and key habitat of the tagged individuals, which serve as a conservative (and possibly underestimated) proxy of habitat use. These data are available by direct request to TOPP (TOPP 2021).

Adams et al. (2019) have compiled information on programs that collect marine mammal data that may be useful in completing environmental risk assessments for offshore energy activities. The Northern California region covers the area of the HWEA. The database created from the survey information contains 60 marine mammal research and monitoring records for this area. The records were collected from colleges and universities, NGOs, and government agencies. This compilation also lists other sources of marine mammal data that did not meet the criteria to be included in the initial survey effort but represent consistent and standardized long-term programs. For marine mammals, data on abundance, distribution, and threat risk (e.g., strikes and entanglement) were determined to be of highest value to inform potential impacts of offshore energy development on those species (Adams et al. 2019). The complete database is available online (Lafferty et al. 2019).

General Status and Threats to Marine Mammals

Marine mammals are susceptible to injury or death from many anthropogenic sources including fisheries conflicts (entanglement, prey population reduction), contaminants (oil spills, pollution, plastic ingestion and entanglement, organochlorines and heavy metals, and industrial and agricultural runoff), vessel impacts (strikes, disturbance, noise), and alteration of and disturbance at haul out and breeding sites for pinnipeds. Climate change may also impact marine mammal populations, through ocean acidification, sea temperature changes, shifts in distribution and abundance of prey species, sea level rise (for pinnipeds), increased susceptibility to illness and disease, and increased occurrence and extent of harmful algal blooms (NOAA Fisheries 2021c).

Noise disturbance can affect all species of marine mammals by causing disruption to natural behaviors such as feeding or masking vocal communication among individuals. In addition, toothed whales, which use echolocation, can experience tissue trauma from energetic anthropogenic sound sources such as high-frequency sonar (Southall et al. 2019).

Humpback and gray whales are highly susceptible to entanglement in fishing gear, although there are also records of blue and sperm whales being entangled. The marine heatwaves that occurred from 2014 to 2016 resulted in a significant increase in whale entanglements, mainly humpback whales, with Dungeness crab fishing gear because they caused a narrowing of the zone where food was most available (Santora et al. 2020). Blue whale populations are impacted by fishing gear entanglements particularly from Dungeness crab and other gear types, estimated at 1.44 blue whales annually (NOAA Fisheries 2021d). Shipping channels off California overlap with baleen whale migration routes, resulting in ship strikes. Because gray whales occur primarily on or near the continental shelf and in coastal waters during much of the year, they are particularly susceptible to strikes from vessels (Silber et al. 2021). Since 2007, 12 ship strikes to blue whales have been documented, resulting in an estimated mortality of 0.4 ship strike deaths per year (NOAA Fisheries 2021d).

HT Harvey and Associates (2020) compiled a list of potential impacts to marine mammals of offshore wind development and operation in the HWEA. The document describes and assesses the existing biological conditions in the HWEA, as well as potential disturbance and environmental effects. For marine mammals, it summarizes the risks of collision, entanglement, avoidance, artificial lighting, noise and habitat alteration. Noting existing uncertainties of the interactions between marine mammals and wind energy operations and maintenance, extensive monitoring may be required, as well as flexibility in program operations.

Data gaps and Limitations

While species distribution models can be effective for generalizing over large areas, the scale may be too coarse to forecast fine-scale distribution patterns required for some dynamic management applications such as ship-strike risk (Becker et al. 2016) as well as the level of activities that could be expected during construction and operation of a wind farm. More refinement of the models can be expected as more sightings are collected over a wider range of oceanographic and atmospheric conditions. The researchers, too, could also assess whether finer scale distribution patterns and density estimates can be captured by the modeled data. One method to do this is a tool called WhaleWatch (Hazen et al. 2017) that uses satellite data from tagged blue whales to predict where they are likely to occur in near real-time. This information was then combined with other environmental data such as sea surface temperature, chlorophyll concentrations, and wind speed. The relationship between whales and these environmental data can be used to predict the likelihood of blue whale presence across the modeled areas.

As in most ocean research, deepwater and rare marine mammals are likely under-represented in the data. Environmental deoxyribonucleic acid (eDNA) is an emerging tool that uses DNA fragments from soil and water samples to monitor biodiversity. eDNA is becoming a well-established tool for monitoring biodiversity that could potentially be used to assess the presence of rare, cryptic, or vulnerable cetacean species in conjunction with acoustic and visual cues (Baker et al. 2018). There is also a need to obtain additional genetic data to identify population differences among marine mammal species because of differences in habitat preferences and other behaviors.

Acoustic monitoring is another tool that is increasingly being used to detect and quantify cetacean distribution and abundance. Recently, NOAA Fisheries and BOEM developed recommendations for the use of passive acoustic listening systems for monitoring and mitigation programs associated with offshore wind energy developments in the U.S. Northeast (Van Parijs et al. 2021).

Summary Table of Selected Marine Mammal Datasets

Dataset Table 5.1: Seasonal Cetacean Density Models

Dataset Title	Seasonal Cetacean Density Models
Species/ Resource	*Summer/Fall*: Baird's Beaked Whale; Bottlenose Dolphin; Dall's Porpoise; Long-Beaked Common Dolphin; Northern Right Whale Dolphin; Pacific White-sided Dolphin; Risso's Dolphin; Short-beaked Common Dolphin; Short beaked whale guild; Sperm Whale; Striped Dolphin. *Summer_Fall/Winter_Spring*: Blue Whale; Fin Whale; Humpback Whale
Abstract	Includes density, area, and abundance for each species and cell. Species distribution models (SDMs) are important management tools for highly mobile marine species because they provide spatially and temporally explicit information on animal distribution. Two prevalent modeling frameworks used to develop SDMs for marine species are Generalized Additive Models (GAMs) and Boosted Regression Trees (BRTs), but comparative studies have rarely been conducted; most rely on presence-only data; and few have explored how features such as species distribution characteristics affect model performance. Since the majority of marine species BRTs have been used to predict habitat suitability, we first compared BRTs to GAMs that used presence/absence as the response variable. We then compared results from these habitat suitability models to GAMs that predict species density (animals km-2) because density models built with a subset of the data used here have previously received extensive validation. We compared both the explanatory power (i.e., model goodness-of-fit) and predictive power (i.e., performance on a novel dataset) of the GAMs and BRTs for a taxonomically diverse suite of cetacean species using a robust set of systematic survey data (1991-2014) within the California Current Ecosystem. Both BRTs and GAMs were successful at describing overall distribution patterns throughout the study area for the majority of species considered, but when predicting on novel data, the density GAMs exhibited substantially greater predictive power than both the presence/absence GAMs and BRTs, likely due to both the different response variables and fitting algorithms. Our results provide an improved understanding of some of the strengths and limitations of models developed using these two methods. These results can be used by modelers developing SDMs and resource managers tasked with the spatial management of marine species to determine the best modeling technique for their question of interest.
Strength/ Weakness	These data and analyses are updated periodically as new data become available. No planned updates are scheduled, but updates are expected. Data current to 2018 covering a larger area than prior analyses. Incorporates and accounts for measures of uncertainty. The maps/data represent model-derived spatial predictions of long-term average density. They 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. Also, the maps do not provide predictions of density at a specific time; they only indicate seasonal distributions averaged across the timeframe of the survey dataset.
File Name	NOAA_2020_CetaceanSDM_Data-Becker_etal2020.gdb
DataType	vectorized rasters in geodatabase
Spatial Extent	U.S. Contiguous West Coast; 48.506100 -131 -117.097556 30; 0.1 degree cell size
Time Scale	1991-2014; published in 2020

Contact/ Source	https://cetsound.noaa.gov; Karin A. Forney; karin.forney@noaa.gov
License/Use Restrictions	Creative Commons License
Citation Info	Becker, E.A., J.V. Carretta, K.A. Forney, J. Barlow, S. Brodie, R. Hoopes, M.G. Jacox, S.M. Maxwell, J.V. Redfern, N.B. Sisson, H. Welch, E.L. Hazen. 2020. Performance evaluation of cetacean species distribution models developed using generalized additive models and boosted regression trees. Ecology and Evolution, 10, 5759-5784. For Blue_whale_winter_spring: Hazen, E. L., Palacios, D. M., Forney, K. A., Howell, E. A., Becker, E., Hoover, A. L., … Bailey, H. (2017). WhaleWatch: A dynamic management tool for predicting blue whale density in the California Current. Journal of Applied Ecology, 54(5), 1415–1428. https://doi.org/10.1111/1365-2664.12820. For Humpback_whale_winter_spring and Fin_whale_winter_spring: U.S. Department of the Navy. (2019). U.S. Navy Marine Species Density Database Phase III for the Northwest Training and Testing Study Area. NAVFAC Pacific Technical Report. Naval Facilities Engineering Command Pacific, Pearl Harbor, HI. 262 pp.
Metadata Link	https://www.fisheries.noaa.gov/inport/item/63298
Online Link	https://noaa.maps.arcgis.com/home/item.html?id=96ae05c033a540bf83e0f6c00a25cf5a

Dataset Table 5.2: Biologically Important Areas for Cetaceans within U.S. Waters

Dataset Title	Biologically Important Areas for Cetaceans within U.S. Waters
Species/ Resource	Cetaceans including fin whale, gray whale, north Pacific right whale, Bryde's whale, bottlenose dolphin, minke whale, harbor porpoise, sei whale, Blainville's beaked whale, Cuvier's beaked whale, dwarf sperm whale, blue whale, humpback whale
Abstract	Biologically important areas (BIAs) for cetaceans were defined by compiling the best available information from scientific literature (including books, peer-reviewed articles, and government or contract reports), unpublished data (sighting, acoustic, tagging, genetic, photo identification), and expert knowledge. This information was then used to create written summaries and maps highlighting areas shoreward of the U.S. Exclusive Economic Zone that are biologically important to cetacean species (or populations), either seasonally or year-round. This collection contains the data displayed by BIA type, including feeding, migratory corridors, reproduction, and small and resident populations. Feeding BIAs include areas and months within which a particular species or population selectively feeds. These may either be found consistently in space and time, or may be associated with ephemeral features that are less predictable but can be delineated and are generally located within a larger identifiable area. Migratory Corridor BIAs include areas and months within which a substantial portion of a species or population is known to migrate. Reproduction BIAs include areas and months within which a particular species or population selectively mates, gives birth, or is found with neonates or other sensitive age classes. Small and Resident Population BIAs include areas and months within which small and resident populations occupy a limited geographic extent.

Strength/ Weakness	Updates irregular; coarse spatial scale
File Name	cetsound.noaa.gov/Assets/cetsound/data/CetMap_BIA_WGS84.zip
DataType	vector
Spatial Extent	UL 72.265057 -179.726956 LR 18.59151 -66.19249
Time Scale	Published 07/2016
Contact/ Source	NOAA Data Catalog http://data.noaa.gov/
License/Use Restrictions	Use Constraints: These data are available for public use. At least one of the following citations must be included in any publication or report that uses this data. The first citation covers the entire dataset and special issue publication, other citations are specific to each regional dataset (East Coast, Gulf of Mexico, West Coast, Hawaii, Gulf of Alaska, Aleutian Islands and Bering Sea, Arctic). Van Parijs, S. M., Curtice, C., & Ferguson, M. C. (Eds.). (2015). Biologically important areas for cetaceans within U.S. waters. Aquatic Mammals (Special Issue), 41(1), 1-128. Other citations available at https://data.noaa.gov/dataset/dataset/biologically-important-areas-for-cetaceans-within-u-s-waters
Citation Info	Van Parijs, S. M., Curtice, C., & Ferguson, M. C. (Eds.). (2015). Biologically important areas for cetaceans within U.S. waters. Aquatic Mammals (Special Issue), 41(1), 1-128.
Metadata Link	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/ArcGIS/rest/services/CetMap_BIA/FeatureServer/0
Online Link	https://data.noaa.gov/dataset/dataset/biologically-important-areas-for-cetaceans-within-u-s-waters

SECTION 6. SEABIRDS

At least 80 species of seabirds occur along the California coast of which five species (sooty shearwater, western gull, common murre, California gull, and Cassin's auklet) comprise 70% of all individuals seen during surveys (Dick 2016). From these 80 species, 28 are local breeders and 52 are migratory. Distribution and abundance of seabirds vary widely depending on species and season. Their distribution is also highly variable due to prey availability, subsurface features, marine climate, and oceanographic characteristics.

Predicted seabird distribution data presented in this catalog are based on Dick (2016). These models used 15 years (1997-2012) of at-sea seabird survey data in the California Current System to create mean predicted density models for 30 seabird species along the California, Oregon, and Washington coasts. Forty-eight species represent 1.1% of individuals seen during surveys, hence they were not included in the modeling effort. This work expands on similar analyses done by Nur et al. (2011). In Dick (2016), each seabird species has predicted density data for four months (February, May, July, October), which represent the four seasons (Winter, Spring, Summer, and Fall). Only one month is chosen for mapping purposes in this document based on the season with the highest predicted density for a given species in and around the HWEA (Appendix B). However, general density ranks relative to the entire model dataset are provided for each season (Table 6.1).

Additional updated data has become available from Leirness et al. (2021), in a report produced by BOEM. This report contains seasonal density distribution models and accompanying uncertainty based on data from at-sea surveys conducted between 1980 and 2017. These models describe the density distribution of 33 individual species and 13 species groups. At the time of writing this data catalog, the Leirness et al. report was available, with the data was released during the process of finalization. The specific maps and data are not included in this document. Species mentioned in the report but not included in Dick (2016), are included in this document in species descriptions but not in graphics or maps.

Marine bird densities at sea are known to be influenced by features of the seabed and oceanographic conditions. In an analysis of survey data from regions greater than 50 km (31 mi)) from shore, Dick (2016) found that areas consisting of seamounts, ridges, and other bathymetric features, especially north of Cape Mendocino, tended to have higher seabird use than other pelagic regions. Overall, highest seabird abundance occurred nearshore, peaking during the spring and summer (May-July) inshore of the 200-m isobath and especially near river mouths (Dick 2016). Additionally, sea surface height (SSH), sea surface temperature (SST), latitude, average depth, and distance to land are believed to influence seabird presence. Dick (2016) found that species who are year-round residents and breed in the CCS would be more sensitive to changes in SST, SSH, and Chlorophyll-a than migratory species. Seabird colonies are frequently located near areas with reliably high productivity to sustain the large energetic requirements of breeding and chick provisioning. A change in timing or location of upwelling-induced productivity would reduce nesting success and alter local population distributions.

There have been multiple studies indicating potential and actual impacts of offshore wind development on seabirds. In the CCS, vulnerability of marine bird populations to collision and habitat displacement due to the presence of offshore wind infrastructure was discussed in Adams et al. (2017) and Kelsey et al. (2018). They incorporated metrics such as population size, monthly presence, survival, breeding status, threat status, and flight information such as nocturnal and diurnal flight activity, macro-avoidance of turbines, and flight height. Kelsey et al. (2018) indicated that jaegers, skuas, pelicans, terns, and gulls have high vulnerability to collision with offshore wind infrastructure, whereas loons, grebes, sea ducks, and alcids have high habitat displacement vulnerability. These metrics lack an explicit spatial component and are best utilized in concert with reliable spatial distribution or density data as part of a model incorporating vulnerability. Adams et al. (2017) also provides a useful literature review of other studies based in the Atlantic Ocean in the U.S. and Europe, including Garthe and Hüppop (2004), Desholm (2009), Furness and Wade (2012), Furness et al. (2013), and Robinson Willmott et al. (2013). A database related to Adams et al. (2017, Dataset Table 6.3) includes vulnerability scores and is updatable as new information becomes available.

Seabirds With Potential to Occur in the HWEA or Vicinity

Albatross

Three species of albatross occur on the U.S. West Coast, two of which are likely to occur in the HWEA: Laysan albatross (*Phoebastria immutabilis*) and black-footed albatross (*P. nigripes*). The third species, short-tailed albatross (*P. albartrus*), is rare and has a low potential for occurrence in the HWEA, although the area does encompass foraging habitat (see the next section for species with low potential). These species are long-distance migrants and foragers, visiting the U.S. West Coast year-round with greater abundances during spring and summer. Albatross are known for their large wingspans and ability to glide and fly for large distances over multiple days. Their methods of flight and foraging may increase their risk of collision with turbine infrastructure, and the presence of turbines may result in their displacement from foraging or transit areas.

Major threats for these species include introduced predators and sea-level rise at their colonies, ingestion of plastic and lead, and by-catch in fisheries, particularly longline fishing. The three species are listed by the IUCN, the United States, and the State of California as being at various levels of risk (Table 6.2). Per sighting data on eBird (2021), black-footed albatross observations are most common in the HWEA, followed by Laysan albatross. At-sea survey data off California indicates the ratio of Laysan to black-footed albatross sightings is 1:32 on average (Dick 2016). There are no short-tailed albatross sightings in the at-sea dataset, and eBird (2021) has no records of short-tailed albatross within the boundaries of the HWEA.

Laysan albatross nest primarily in the northwestern Hawaiian island archipelago, with small colonies on the western main Hawaiian Islands, islands off Japan, and islands west of Baja California and Baja California Sur in Mexico. The Laysan albatross population is estimated at 2.5 million birds, of which 1.6 million make up the breeding population (Birds of the World 2021). An estimated 90% of the population breeds on Midway Atoll.

In the HWEA, Dick (2016) predicts that Laysan albatross density is low to moderate depending on the season (Table 6.1). These birds tend to be pelagic, spending the majority of their time well offshore in colder, northern waters in winter and spring, moving closer to shore in northern California in the summer and fall when nearshore waters are cooler. This results in a higher density of birds in and near the HWEA relative to the surrounding waters in summer and fall. Predicted average density values from the model are highest in winter, but that value is low compared to the highest predicted density value in the CCS for that season (Figure B.1).

Black-footed albatross nest primarily in the northwestern Hawaiian island archipelago, with small colonies on the western main Hawaiian Islands, as well as islands off Japan. An effort is currently underway on Guadalupe Island off Baja California, Mexico, to reintroduce this species to their historic nesting areas there. Black-footed albatross global populations are estimated at 240,000 individuals (Birds of the World 2021). Black-footed albatross are a pelagic species but tend to forage closer to the coast than Laysan albatross.

These birds can commonly be found along the coast and offshore of northern California, Oregon, and Washington, with a more dispersed at-sea distribution in the fall and winter months. In all seasons, Black-footed albatross predicted density values in the HWEA are high compared to other areas in the California Current System, especially in spring and summer, when birds concentrate along the coast of northern California within 40 nm (74 km) of shore (Table 6.1, Figure B.2).

Alcids

There are eleven species of alcids on the U.S. West Coast, all of which are known to occur along the California coast. Seven species breed in California: common murre (*Uria aalge*), pigeon guillemot (*Cepphus columba*), Scripps's murrelet (*Synthliboramphus scrippsi*), marbled murrelet (*Brachyramphus marmoratus*), Cassin's auklet (*Ptychoramphus aleuticus*), rhinoceros auklet (*Cerorhinca monocerata*), and tufted puffin (*Fratercula cirrhata*). The others are migrants observed during at-sea surveys including Guadalupe murrelet (*S. hypoleucus*), Craveri's murrelet (*S. craveri*), ancient murrelet (*S. antiquus*), and horned puffin (*F. corniculata*). Alcids are heavy-bodied, short-winged birds that forage by diving after prey, propelled by their wings. The majority prey on small schooling fishes, with some species also foraging on cephalopods and zooplankton.

Major threats for these species include habitat loss, introduced predators for island nesting species, human attracted predators such as corvids and domestic animals, oil spills and wildfires, entanglement in fishing gear, and loss of prey base due to overfishing. Murrelet populations are all decreasing, with marbled and Guadalupe murrelets listed as endangered by the IUCN (2021), and Scripps's and Craveri's as threatened. Marbled murrelets are also listed as Threatened by the U.S. and Endangered by the State of California, with Scripps's and Guadalupe murrelets listed as Threatened by California. Cassin's auklet is listed as Near Threatened by the IUCN because of a decreasing global population trend. Tufted puffins are identified as a California Species of Special Concern during their breeding season, as that is when they are most common in the state (Table 6.2).

The **common murre** is one of the most numerous seabirds in California and is a resident species, accounting for 63% of alcid observations during at-sea surveys (Dick 2016). As of 2002, eight of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of common murres, for a total of 96,574 birds, approximately 18% of the state's population (CDFG 2010). On the U.S. West Coast, common murres breed from south of Monterey Bay to central Oregon and Washington. Common murres feed primarily over the continental shelf (H.T. Harvey & Associates 2020). They tend to congregate in large, dispersed rafts at sea, and may travel in sizable flocks. In all seasons, common murres are distributed very close to the coast and are central place foragers during the breeding season. Predicted density values in the HWEA are consistently low compared to the surrounding areas and the CCS as a whole (Table 6.1). Highest predicted densities in the call area occur in the summer (Figure B.3), but nearshore densities exceed these in the vicinity of the seabird colonies to the north and south.

Pigeon guillemots are rarely observed during at-sea surveys, representing only 1% of observations of alcids and 0.2% of all observations (Dick 2016). However, they are common breeders along the U.S. West Coast, from Point Conception in California to northern Washington. Most of the California population is presumed to migrate to British Columbia outside of the breeding season. As of 2002, 21 of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of pigeon guillemots, but they are generally small (seven have fewer than five birds), with a total of 521 birds, approximately 4% of the state's population (CDFG 2010). Leirness et al. (2021) created spring and summer predicted density models for pigeon guillemots indicating very low densities in and around the HWEA, representing no more than 1% of the maximum predicted density value. Given their propensity to remain close to shore and low population numbers in the area, densities within the HWEA are likely very low year-round.

Scripps's murrelet, **Guadalupe murrelet**, and **Craveri's murrelet** can be difficult to distinguish at sea. Until 2012, Scripps's and Guadalupe murrelets were considered a single species: Xantus's murrelet (*S. hypoleucus*). These three murrelet species represent 1.1% of the total number of individuals of alcids observed during at-sea surveys, with the majority of observations made south of Cape Mendocino (Dick 2016). Scripps's and Guadalupe murrelets overlap in their breeding range from the California Channel Islands to islands along the Pacific coast of Baja California, Mexico. The Guadalupe murrelet's breeding range continues into Baja California Sur, and overlaps with Craveri's murrelets to the southern end of the Baja Peninsula. Craveri's murrelets also breed on islands in the Gulf of California. The migration range of Scripps's and Guadalupe murrelets is similar, extending north into British Columbia, Canada, whereas Craveri's murrelets tend to remain south of Cape Mendocino in California (Birds of the World 2021)

Dick (2016) modeled available data for **Xantus's murrelets** which here will be considered representative of a combination of the **Scripps's and Guadalupe murrelets**. Leirness et al. (2021) grouped the three species and only modeled density distribution for spring due to low observation numbers during the other seasons. Because the migratory range of **Craveri's murrelets** terminates south of Cape Mendocino, it is very unlikely that they will be present in the HWEA. In winter and spring, Scripps's and Guadalupe murrelet distribution is concentrated well south of Cape Mendocino, namely around the Channel Islands and south of the Southern California Bight. The birds may be seen further north when they disperse post-breeding but tend to remain concentrated in southern California. Predicted densities are expected to be higher in the HWEA in the summer relative to the surrounding area (Dick 2016; Table 6.1, Figure B.4). All three species tend to congregate closer to shore.

Marbled murrelets nest inland in old-growth conifer trees, leading to high population sensitivity to habitat modification and loss. These birds forage for small fish and invertebrates in nearshore waters, primarily within 5 km (3 mi) of the coast. Forests adjacent to the Cape Mendocino and northern California coast are within the breeding range for this species. Surveys for marbled murrelets were not included in Dick's (2016) analysis. Those that were included in Leirness et al. (2021) were conducted in the spring and summer and were limited to the coast north of San Francisco Bay. Models produced from these data indicate that at-sea marbled murrelet densities are highest near shore, and densities in the HWEA and immediate vicinity would be very low.

Cassin's auklets are the second most numerous alcid observed in California at-sea surveys, representing 29% of all alcids observed (Dick 2016). As of 2002, one of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported a small population of Cassin's auklets, with a total of 84 birds, approximately 0.1% of the state's population (CDFG 2010). These birds are primarily planktivores and tend to feed over the shelf (H.T. Harvey & Associates 2020). Because of this foraging strategy, there is an increased likelihood of this species being found in and around the HWEA. In the winter and spring, they tend to concentrate in waters off Washington, British Columbia, and the Farallon Islands dispersing south to breed. Overall, relative densities within the HWEA are low to very low, with highest predicted densities in fall (Dick 2016), even though these densities rank low compared to the surrounding area and the CCS as a whole (Table 6.1, Figure B.5).

Rhinoceros auklets are less common in California at-sea surveys and represent 6% of all alcids observed (Dick 2016). These birds are primarily piscivores and will readily kleptoparasitize other birds such as pigeon guillemots and murres to obtain their prey. They tend to congregate in small flocks and remain close to shore. As of 2002, six of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of rhinoceros auklets, for a total of 42 birds, approximately 2% of the state's population (CDFG 2010). Relative densities of rhinoceros auklets in the HWEA are low to very low, with highest predicted densities in winter (Dick 2016; Table 6.1, Figure B.6).

Tufted puffins are resident breeders along the California coast but are not commonly observed during at-sea surveys, making up less than 1% of all alcid observations. These wing-propelled divers forage for fish and invertebrates and characteristically carry multiple fish aligned in their bills when feeding chicks. As of 2002, six of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of tufted puffins, for a total of 58 birds, approximately 18% of the state's breeding population (CDFG 2010). During the breeding season, these birds tend to forage nearshore and over the continental shelf but are found well away from shore in deep pelagic environments the remainder of the year, usually well to the north of the HWEA. According to Dick (2016), the predicted density of tufted puffins in and around the HWEA is very low year-round, but is highest in spring (Table 6.1, Figure B.7).

Cormorants

There are three species of cormorant in the California Current System, all three of which reside along the California coast: Brandt's cormorant (*Urile penicillatus*), pelagic cormorant (*U. pelagicus*), and double-crested cormorant (*Nannopterum auritum*). According to Adams et al. (2014), the three resident cormorant species can be difficult to distinguish at sea. All three species are piscivores, diving from the ocean's surface using their feet to propel themselves. Brandt's and pelagic cormorants are found exclusively in marine environments, whereas double-crested cormorants can be found in all aquatic environments. During migration, all three species can travel in large flocks, usually in straight lines or delta shapes at low altitudes to reduce wind resistance. Threats to these species include human disturbance at breeding and roosting sites, extreme climate events such as heat waves and sea temperature change, entanglement in fishing gear, and exotic/invasive species. The IUCN lists the three species as of Least Concern, but populations of Brandt's and pelagic cormorants are decreasing globally (Table 6.2).

Brandt's cormorants roost on rocky headlands and islets but will also roost on artificial structures at sea (Kelsey et al. 2018). This species feeds at sea away from its roost site, commuting as much as 10 mi (16 km) away. Along the Northern California region, breeding occurs from March to August, with egg laying from April to July (CDFG 2005). They are the most numerous cormorant species observed during at-sea surveys, making up 88% of all cormorants observed. The majority of these observations occur nearshore or around islands. As of 2002, ten of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of Brandt's cormorants, for a total of 3,100 birds, approximately 5% of the state's population

(CDFG 2010). Compared to the CCS, the predicted density of Brandt's cormorants in and around the HWEA is very low year-round, with highest values in the Humboldt area in winter (Dick 2016; Table 6.1, Figure B.8).

In spite of their name, **pelagic cormorants** are uncommon away from shore, and observations comprise only 1.5% of at-sea observations of cormorants in California (Dick 2016). The smallest of the cormorants in the CCS, this species forages on fish and other demersal prey in shallow waters over the shelf. As of 2002, 20 of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of pelagic cormorants, for a total of 1,584 birds, approximately 13% of the state's population (CDFG 2010). Leirness et al. (2021) predicted highly coastal CCS-wide densities of pelagic cormorants for spring and summer and illustrated slightly higher densities in spring in the Humboldt area. However, for both seasons, the relative densities were very low in the HWEA.

At-sea observations of **double-crested cormorants** off California make up 10% of all cormorants observed (Dick 2016). This is the most common cormorant species in the United States, with the majority of the population residing in freshwater habitats such as lakes and rivers. However, coastal populations exist along the entirety of the CCS. As of 2002, seven of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of double-crested cormorants, for a total of 1,425 birds, approximately 23% of the state's coastal breeding population (CDFG 2010). Leirness et al. (2021) predicted coastal double-crested cormorant densities during spring and summer to be very low overall, with densities in the Humboldt area to be higher in spring. However, in both seasons, predicted densities in the HWEA and vicinity were very low relative to the rest of the CCS.

Leirness et al. (2021) also created fall and winter density models for all cormorant species combined due to low counts of these species during these seasons. These models indicate similar distribution and relative densities to the individual species for spring and summer. All species combined tend to have higher densities near the coast/islands and over the continental shelf, and densities in and around the HWEA are very low for both seasons.

Shearwaters and Fulmars

Shearwaters and fulmars are members of the family Procellaridae, the tubenoses. Shearwaters are highly migratory species; those that are observed in the California Current breed in South America, Australia, New Zealand, as well as Mexico. There are six species that have been observed during at-sea surveys: sooty shearwater (*Adrenna grisea*), pink-footed shearwater (*A. creatopus*), short-tailed shearwater (*A. tenuirostris*), flesh-footed shearwater (*A. carneipes*), Buller's shearwater (*A. bulleri*), and black-vented shearwater (*Puffinus opisthomelas*). They generally forage on small fish, crustaceans, zooplankton, and squid, pursuing their prey by diving from low-level flight and using their wings to propel themselves underwater or by dipping their heads to capture prey at the surface (Birds of the World 2021). The flight pattern of shearwaters is distinct as they are adept at using surface winds and ground effect to travel great distances with minimal effort. Northern fulmars (*Fulmarus glacialis*) are a northern hemisphere species. They breed in Alaska and Canada and disperse south after breeding season. They forage where their prey--fish, squid, and zooplankton--are concentrated, typically over the continental slope and seamounts in upwelling areas. They are also known to eat carrion and other floating refuse, especially from vessels. This species feeds by picking items at or below the surface and making shallow feet- and wing-propelled dives (Birds of the World 2021).

Sooty, flesh-footed, and black-vented shearwaters are listed as Near Threatened by the IUCN (2021), pink-footed and Buller's shearwaters are Vulnerable, and short-tailed shearwaters and northern fulmars are considered to be of Least Concern (Table 6.2). Most shearwater populations are either decreasing or have unknown growth status, with only Buller's shearwaters having a stable population. Northern fulmar populations are growing globally but have experienced notable mortality events along the California coast in the last two decades. Threats to these birds include entanglement in fishing gear, alteration and loss of nesting and foraging habitat, invasive predators at their nesting colonies, plastic and contaminant ingestion, and temperature extremes.

Sooty shearwaters migrate to the California coast in spring and summer from South America, New Zealand, and Australia. Their local distribution appears to be related to food availability, and they tend to travel, forage, and rest in very large flocks, sometimes made up of thousands of birds. While mostly pelagic, these flocks can occasionally be observed from shore when prey are concentrated over the shelf. This species is by far the most numerous shearwater species observed along the California coast, representing 85% of at-sea observations of shearwaters (Dick 2016). Density models of sooty shearwaters predict the highest concentrations of this species in or near the HWEA in summer, with higher densities over the shelf than in the HWEA itself (Figure B.9). Overall, relative densities year-round of this species in and around the HWEA are low compared to the CCS as a whole (Table 6.1).

Pink-footed shearwaters migrate to the CCS from breeding grounds in Chile. Like other shearwaters, this highly pelagic species is usually found beyond the continental shelf during migration in the CCS, but can be observed in flocks with other shearwater species over the shelf and closer to shore. Nearly 7% of shearwaters observed during at-sea surveys were pink-footed (Dick 2016). Compared to the CCS as a whole, the predicted density of pink-footed shearwaters in and around the HWEA is moderately high in summer, similar to spring (Table 6.1, Figure B.10).

Several other shearwater species are observed off California during the spring and summer including **short-tailed shearwater** (from Australia), **flesh-footed shearwater** (from Australia and New Zealand), **Buller's shearwater** (from New Zealand), and **black-vented shearwater** (from northwestern Mexico). Together, these species make up the remaining 15% of at-sea observations off California, with black-vented shearwaters being the most numerous representing 6% of shearwaters observed. Most of these species are transequatorial migrants and inhabit the open ocean during their non-breeding season. Black-vented shearwaters are the exception, as they tend to remain relatively closer to shore (within 200 nm [370km]) and generally do not range north of San Francisco Bay.

Densities of the combined short-tailed/sooty/flesh-footed shearwater group, Buller's shearwater, and black-vented shearwater were modeled by Leirness et al. (2021). While Dick (2016) modeled densities of sooty shearwaters separately, Leirness grouped them with short-tailed and flesh-footed shearwaters as these species breed in similar areas and are all transpacific and transequatorial migrants. The model results are driven by the counts of sooty shearwaters and are similar to those developed by Dick (2016). During spring and summer, these species are widely distributed in coastal and pelagic waters, becoming more dispersed away from shore into fall. Densities are highest in spring and summer but are low in the HWEA compared to the entire CCS. Predicted density values for Buller's shearwater in and near the HWEA are highest in fall and are moderate compared to the CCS as a whole. This species tends to concentrate in pelagic areas north of Cape Mendocino in the spring, dispersing closer to shore and further south in summer. In contrast to the other shearwater species, black-vented shearwaters are predicted to have their highest density values in fall, but overall very low predicted densities in the HWEA and vicinity, since they tend to concentrate coastally south of Monterey.

In California, **northern fulmars** are uncommon south of Point Conception, and represent only 1.5% of the birds observed during at-sea surveys in the shearwater and fulmar group (Dick 2016). Their predicted density is highest in and around the HWEA in fall (Figure B.11) but is low year-round (Table 6.1), with higher, more dispersed concentrations predicted to the north, off Washington and British Columbia, Canada. This species is most common over the continental shelf and slope in the Humboldt area in all seasons but is likely to be more pelagic in winter.

Grebes and Loons

Grebes and loons are migratory species in the California Current System and are not commonly observed during at-sea surveys, representing 0.6% of birds observed. In spite of this rarity during surveys, these birds gather and travel in large flocks during migration, with the larger grebe species resting on the water during the day, and loons traveling in miles-long skeins when wind conditions are optimal. Species that can be observed off the California coast include western grebes (*Aechmophorus occidentalis*), Clark's grebes (*A. clarkii*), Pacific loons (*Gavia pacifica*), common loons (*G. immer*), red-throated loons (*G. stellata*), and yellow-billed loons (*G. adamsii*). Both grebe species breed in inland fresh- and brackish water wetlands. The loons breed in Arctic and sub-Arctic wetlands, and winter in coastal waters, including bays and estuaries. Both loons and grebes are foot-propelled divers, foraging for fish in marine environments, and fish, aquatic and terrestrial invertebrates, and occasionally amphibians in their freshwater breeding phase.

Population status varies by species, with western grebe and common loon populations stable, Pacific loon populations increasing, and the other three loon species decreasing. The two grebe species and three of the loon species are listed as Least Concern by the IUCN (2021); only yellow-billed loons are listed as Near Threatened (Table 6.2). Threats to these species include pollution and contaminants, fisheries conflicts, and habitat shifts or alterations due to development or climate change.

Pacific loons spend time in the Northern California region in spring and fall during their migration to nesting areas in the Arctic and Alaska, and wintering grounds in Mexico. The majority of the birds occur within a couple of miles of the coastline (Adams et al. 2014). During at-sea surveys, Pacific loons are the most common loon species observed, representing 64% of all loons observed. Dick (2016) predicted densities of Pacific loons to be highest in the HWEA during winter, but these densities are very low relative to other areas in the CCS (Table 6.1, Figure B.12). Because of the coastal tendencies for this (and other loon) species, densities are predicted to be very low to low in the HWEA year-round. However, migratory flight patterns for Pacific loons and other loons are not well documented, and this information may clarify the potential impact of development in the HWEA on this and other loon species.

Leirness et al. (2021) included density models for red-throated loons and common loons, as well as a model for the four loon species combined (including yellow-billed loons). Common and red-throated loon models are limited to spring and summer due to the availability of observation data. Predicted density for both **red-throated loons** and **common loons** in and near the HWEA is highest in spring, with red-throated loon distribution extending further away from shore toward the shelf break than common loons. Within and near the HWEA, predicted densities for both species are relatively low in spring, and very low in the summer compared to the CCS as a whole. The models indicate loon density is highest inshore of the shelf break. The combined four-species model is driven by the presence of Pacific loons because of the numerical dominance of Pacific loons during surveys. These models confirm the nearshore distribution of these species, with densities predicted to be higher in the Cape Mendocino area in winter and spring, and spring distribution to extend further from shore into the HWEA, albeit at lower densities than nearshore.

Leirness et al. (2021) also modeled predicted densities for **western grebes** and **Clark's grebes** combined, although the model is driven by the numerically dominant western grebe. These models show that densities are predicted to be highest in the CCS during the winter but dispersed slightly more offshore in the spring. Both species congregate close to shore over the shelf, and generally have low predicted densities in the HWEA. Similar to the loons, the flight and migratory patterns of grebes are not well documented and will be necessary to ascertain the impact of offshore wind development on these species.

Larids, Jaegers, and Skuas

The larids, jaegers, and skuas make up the most commonly observed species group in the CCS. A total of 26 species have been observed during at-sea surveys, seven of which breed on the California coast, the remainder of which are migrants. Larids comprise the gulls and terns, both of which are sometimes further classified based on their size (large/medium/small).

Larids

Fourteen gull species were observed during at-sea surveys, including California breeding species western gull (*L. occidentalis*), California gull (*L. californicus*); California migrant species Bonaparte's gull (*Chroicocephalus philadelphia*), herring gull (*L. argentatus*), glaucous-winged gull (*L. glaucescens*), Iceland gull (formerly Thayer's gull-2017; *L. glaucoides thayeri*), Heermann's gull (*L. heermanni*), Sabine's gull (*Xema sabini*), and black-legged kittiwake (*Rissa tridactyla*). Less common migrant species will be covered in the Rare or Data Deficient Seabirds section below: ring-billed gull (*L. delawarensis*), short-billed gull (formerly mew gull-2021; *L. brachyrhynchus*), glaucous gull (*L. hyperboreus*), Franklin's gull (*Leucophaeus pipixcan*), and kelp gull (*L. dominicanus*). Most of the medium and large gull species are opportunistic omnivores, foraging on marine food sources, kleptoparasitizing other seabirds, scavenging carrion, ship scraps, and garbage, consuming eggs and chicks of other birds, and, for inland species, consuming terrestrial invertebrates, small vertebrates, and raiding garbage dumps. Species that are more limited in dietary preferences are described below.

All gulls described here are listed by the IUCN (2021) as Least Concern with the exception of Heermann's gulls which are listed as Near Threatened, and black-legged kittiwakes which are Vulnerable due to recent steep population declines in European colonies. None of these gull species are listed by the U.S. or the State of California as being at risk (Table 6.2). While individual species may be more strongly influenced by some threats, gull species in general are impacted by the threats of oil spills and pollution, loss of nesting habitat, human disturbance, climate change resulting in sea-level rise or shifting foraging and breeding habitat, and human encroachment at inland nesting and roosting areas.

Western gulls are the second-most numerous seabird observed off California, and the most numerous resident breeding larid species, representing 11% of all seabirds observed during at-sea surveys, and 54% of all gulls observed. Although this species is common in the coastal CCS, it has a smaller overall population than other North American gulls, as its distribution is restricted to the Pacific coast from British

Columbia to Baja California Sur. High at-sea densities are seen throughout the year, and birds remain resident year-round travelling locally to follow food sources. They are not usually observed far from shore but will follow ships and fishing vessels. This large gull has adapted to coastal development and will readily establish breeding colonies within urban coastal areas. As of 2002, 23 of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of western gulls, for a total of 999 birds, approximately 3% of the state's coastal breeding population (CDFG 2010). Predicted density models indicate relative density in and near HWEA to be low year-round compared to coastal areas to the south (Dick 2016; Table 6.1). The local density value is highest in summer, increasing closer to shore (Figure B.13).

Herring gulls are large gulls that breed in Canada and Alaska but migrate and overwinter along the west coast of North America as well as inland. They represent 3.6% of gulls observed during at-sea surveys in the CCS. In the Pacific they are commonly found coastally in shallow water, near beaches, estuaries, and bays. Local density in and near the HWEA is highest in winter, but overall is very low year-round compared to the CCS as a whole (Dick 2016; Table 6.1, Figure B.14), with the majority of the distribution located off the coasts of Oregon, Washington, and British Columbia.

Iceland gulls are extremely uncommon during at-sea surveys in the CCS, representing only 0.02% of gulls observed (Dick 2016). This medium-sized gull breeds in the Arctic and migrates to northern coasts in the Pacific and Atlantic. In California, they are a coastal species, usually observed in low numbers in flocks of other gulls. Leirness et al. (2021) included this species in a mixed species predicted density model with herring gulls. Because of the predominance of herring gull data, Iceland gull data likely has minimal influence on the model. Similar to the herring gull only model, density values in and near the HWEA were low in spring through fall, and highest in winter. However, patterns varied slightly with a higher southern density distribution in summer as opposed to northerly or a wider coastal distribution for the remainder of the year.

Glaucous-winged gulls are less common during at-sea surveys, representing only 0.26% of gulls observed in the CCS. However, this species readily hybridizes with western, glaucous, and herring gulls, so a number of hybrid gulls may be difficult to identify at sea. This northern transpacific species breeds from the Kamchatka Peninsula, Russia to British Columbia, Canada. It is a strictly coastal species and overwinters off the California coast. As with other gull species, it is generally found close to shore, often in mixed species flocks. Dick (2016) predicted densities of this species to be highest off British Columbia and Washington year-round, with very low densities in and near the HWEA (Table 6.1). Density values in the HWEA were highest in the winter (Figure B.15).

California gulls are an inland breeding species, with a transcontinental range in Canada and the U.S.. Some birds winter in coastal areas, but a large number also winter inland. This medium sized gull represents 25% of gulls observed during at-sea surveys in the CCS, and 5% of seabirds overall. Coastal wintering birds concentrate in shallow waters nearshore, estuaries, beaches, and mudflats, often in large flocks with other species. Predicted density models indicate California gull densities are very low in and near the HWEA year-round, with the majority of the predicted distribution being to the south or highly associated with the coast (Dick 2016; Table 6.1). As with other non-California coastal breeding species, density values in the HWEA were highest in the winter (Figure B.16).

Heermann's gulls are medium-sized gulls that breed in the winter on islands off the Pacific and Gulf of California coasts of Mexico. In the CCS, they represent 4% of all gulls observed during at-sea surveys (Dick

2016). They are highly associated with brown pelicans, and breed, migrate, and roost in the same seasons and locations. Strictly coastal, it migrates from spring to fall from central Mexico to British Columbia, Canada. They forage by surface feeding for fish, kleptoparasitizing brown pelicans, and scavenging carrion. They are rare inland, and are usually found in shallow coastal waters, beaches, and estuaries. Predictive density models indicate very low density values in and near the HWEA year round, compared to areas south of San Francisco (Dick 2016; Table 6.1). Average predicted density values are highest in the HWEA in the fall (Figure B.17).

Bonaparte's gulls represent 7% of gulls observed during at-sea surveys in the CCS, and 1.5% of all seabirds. The population of this small gull is transcontinental, breeding in Alaska and Canada, migrating over both inland and coastal areas. The Pacific wintering population is coastal with some birds overwintering at the Salton Sea. This species has a more limited diet, foraging in the marine environment by surface feeding, kleptoparasitism, and taking terrestrial invertebrates at inland sites. Dick (2016) found that this species had a highest predicted density in and near the HWEA in fall, but that relative density in this area was very low year-round compared to areas to the south (Table 6.1, Figure B.18).

Sabine's gull is another small gull with a limited foraging strategy, taking fish and invertebrates from the water's surface, as well as foraging in shallow water and mudflats. In the CCS, observations of this species represent 2% of gull observations. It breeds in the Arctic tundra and migrates coastally and over the open ocean to overwintering sites in Central America. Predicted density values in and near the HWEA are highest in summer but are low year-round compared to the remaining coastwide distribution of this species (Dick 2016; Table 6.1, Figure B.19).

Black-legged kittiwakes represent 3% of gulls observed during at-sea surveys. This small gull is a migrant in the CCS; it breeds in coastal areas of Alaska and northern Canada. It feeds on fish and zooplankton, foraging by surface feeding or plunge diving often in large groups of other kittiwakes and gulls where food is abundant. These birds prefer to forage over the continental shelf and slope in areas where upwelling is concentrated. This species is one of the few gulls that are not well adapted to human environments and are not opportunistic foragers of trash or landfills. Because this species forages and overwinters offshore, it is likely to be found in the HWEA and vicinity. Density models of black-legged kittiwakes predict the highest concentrations of this species in or near the HWEA in winter, with higher densities over the shelf than in the HWEA itself (Dick 2016; Figure B.21). Overall, relative densities year-round of this species in and around the HWEA are very low compared to the CCS as a whole (Table 6.1), with birds tending to concentrate in coastal areas around Vancouver Island and British Columbia, Canada.

Eight tern species were observed during at-sea surveys in the CCS including California breeding species elegant tern (*Thalasseus elegans*), and Caspian tern *(Hydroprogne caspia*), and migrant species Arctic tern (*Sterna paradisaea*), royal tern (*T. maximus*), common tern (*S. hirundo*). Less common breeding species that will be included in the Rare or Data Deficient Seabirds section below: least tern (*Sternula antillarum browni*), Forster's tern (*Sterna forsteri*), and black skimmer (*Rynchops niger*). These species represent 0.8% of all seabird observations (Dick 2016).

The species described below are plunge-divers, foraging on fish and large zooplankton in surface waters, concentrating in coastal areas including nearshore, estuarine, and bay habitats. They are often seen foraging and roosting in mixed species flocks, including other terns, gulls, and pelicans. Only elegant terns are listed by the IUCN (2021) as Near Threatened, although their global population is stable. The other five species are listed as Least Concern, with variable population trends (Table 6.2). Because these species use a variety of marine and inland habitats, threats range widely from human and introduced species disturbance at nest and roost sites, climate change and inundation of nest sites, and loss of habitat.

Two species of large terns were observed during at-sea surveys in the CCS, one of which is the **Caspian tern**, representing 15% of all terns observed. Caspian terns are the largest bodied of the tern group, with an increasing global population. They breed in coastal and inland areas; in California they are mostly coastal from the San Francisco Bay area to Monterey Bay. The Pacific population migrates and overwinters along coastal California and eastern and central Mexico. Dick (2016) modeled predicted relative density in and near HWEA as being very low year-round, with highest, but still very low, local density values in spring (Table 6.1, Figure B.22).

Royal terns are another large tern and represent 8% of all terns observed and have a stable global population. They have a small breeding population in southern California as well as in Baja California, Baja California Sur, and Nayarit, Mexico. The non-breeding distribution extends as far north as Morro Bay, California. These birds are a marine species, and tend to concentrate in coastal areas, although they can forage far offshore even during breeding season. See the paragraph on elegant terns for information about a predictive density model.

Elegant terns are medium-sized terns, representing 43% of terns observed in the CCS, 0.3% of seabirds. They breed in southern California and islands off both coasts of Baja California and Baja California Sur Mexico. They migrate both north and south from their breeding range, with the northern range extending to southern Oregon. When migrating and foraging, they tend to congregate in nearshore and in upwelling areas, within 16km (10 mi) of the coast. Leirness et al. (2021) created a predicted density model for royal and elegant terns combined, which indicates very low values in and near the HWEA from spring to fall. Local densities were likely highest in fall, when the density distribution of the two species extends along the California coast to the Oregon border.

Common terns are medium-sized terns and represent 7% of terns observed during at-sea surveys in the CCS. The status of their global population is currently unknown due the extent of their breeding range but is increasing in the European population. They breed at inland sites in the north of the U.S. and Canada and migrate both inland and along the coast to sites in southern Mexico, Central America, and the Gulf Coast. Offshore of California, they tend to forage over the shelf and shelf slope. See the paragraph on arctic terns for information about a predictive density model.

Arctic terns are a small-bodied tern species which exhibit one of the greatest migratory ranges of all birds. They breed in northern Canada and Alaska and migrate over the sea transequatorially to the Southern Ocean. Their global population is decreasing; however, they represent 19% of terns observed during at-sea surveys in the CCS. Because this species migrates away from land, densities nearshore are likely to be very low. Leirness et al. (2021) created a predicted density model for common and arctic terns combined, which indicates low to very low values in and near the HWEA from spring to fall. Local densities were likely highest in fall when the density distribution of the two species extends offshore along the CCS. In spring the predicted density distribution is concentrated nearshore in northern California, whereas in summer that pattern moves offshore north of Cape Mendocino.

Jaegers

Jaegers are migrants in the CCS and represent 0.4% of seabirds observed during at-sea surveys (Dick 2016). Three species have been observed in California: pomarine jaeger (*Stercorarius pomarinus*), parasitic jaeger (*S. parasiticus*), and long-tailed jaeger (*S. longicaudus*). All three species are kleptoparasites, actively stealing prey from other seabirds, but will also forage on fish, carrion, and ship discards. They breed in the Arctic, and “winter” in the Southern Ocean. They all have stable global populations, and are listed by the IUCN (2021) as Least Concern (Table 6.2). As arctic breeders, they are subject to the impacts of climate change, sea level rise, disturbance at nesting sites, and loss of forage and breeding habitat. Their populations may also be impacted by oil spills, pollutants, and heavy metal contamination.

Pomarine jaegers represent 48% of jaegers observed during at-sea surveys in the CCS (Dick 2106). This species tends to migrate and forage over the continental shelf and slope and is not common nearshore. Predicted density models indicate low density year-round in and near the HWEA compared to the remainder of the CCS (Dick 2016; Table 6.1). Highest density values are predicted in and near the HWEA in the fall, with densities decreasing with distance from shore and from north to south (Figure B.23).

Parasitic jaegers represent 28% of jaegers observed during at-sea surveys in the CCS (Dick 2016). This species migrates and overwinters closer to shore than the other two species and may be observed from shore. Predicted density models indicate moderate density year-round in and near the HWEA compared to the remainder of the CCS (Dick 2016; Table 6.1). Highest density values are predicted in the fall, with high densities over the shelf and slope, decreasing to the west and south (Figure B.24).

Long-tailed jaegers represent 18% of jaegers observed during at-sea surveys in the CCS (Dick 2016). They are the most pelagic of the three species, migrating at or beyond the shelf slope. Predicted density models indicate low to moderate density in and near the HWEA compared to the remainder of the CCS (Dick 2016; Table 6.1). Highest density values in the HWEA are predicted in the fall, although they are higher n all seasons to the north and west of the Humboldt area (Figure B.25).

Skuas

South polar skuas breed in the Antarctic and migrate over an extremely wide range including the North Pacific in spring and fall. They are more common offshore past the shelf break and slope. Similar to the jaegers, they forage on fish during migration, but are known for kleptoparasites and scavengers. A predicted density model for fall indicates low densities in and near the HWEA, with higher densities to the west of the shelf break from San Francisco to northern Washington (Leirness et al. 2021). Data are unavailable for other seasons.

Pelicans

California brown pelicans (*Pelecanus occidentalis californicus*) are year-round species in the CCS although local population sizes vary due to seasonal migration and breeding patterns. The majority of pelicans breed on islands off Baja California, Baja California Sur, Sonora, and Nayarit, Mexico, with the remainder breeding on Anacapa and Santa Barbara Islands in California. In northern California, it is common to see pelicans from June to November, then it becomes rare to uncommon in December to February and May during which time adults and some sub-adults are concentrated at their breeding grounds (CDFG 2005). The brown pelican feeds almost entirely on fish that are caught by diving from heights of 6-12 m (20-40 ft) and occasionally from up to 20 m (66 ft) in the air (CDFG 2005). These birds can travel in large, dispersed flocks and are known to participate in dense, multi-species foraging flocks when prey species are concentrated at the surface, sometimes by co-foraging marine mammals and large predatory fish. In general, this species is coastal, foraging at or within the edge of the continental shelf.

Brown pelicans are considered a species of Least Concern by the IUCN (2021) and were removed from the U.S. Endangered Species list in 2009 after having been listed as endangered since 1970 (Table 6.2). The global population is thought to be increasing; however, recent Pacific coast breeding declines and nesting failures may have future impacts on the local population. Risks to the population include oil spills and pollution, loss of forage due to fishing and harvesting, and human disturbance at breeding and roosting sites.

Dick (2016) found that densities of this species were consistently lower in and around the HWEA than in the CCS overall (Table 6.1), as the HWEA is located past the shelf break, and this species tends to concentrate south of Cape Mendocino. However, the highest densities of pelicans in the HWEA were predicted to be in the fall (Figure B.26), as birds are gathering to return to their breeding grounds from northern foraging areas.

Phalaropes

Phalaropes are shorebirds that migrate and forage in aquatic marine environments. While they are shorebirds, they have lobed toes which allow them to swim on the surface of bodies of water. They occur commonly off the California coast as they migrate from Arctic nesting areas to their wintering areas in South and Central America. Two species are observed during at-sea surveys in the CCS: Red-necked phalaropes (*Phalaropus lobatus*) and red phalaropes (*P. fulicarius*). A third species, Wilson's phalarope (*P. tricolor*), is a resident of coastal marshes and wetlands but is almost never observed at sea. The red phalarope tends to be more concentrated over the continental slope than the red-necked phalarope, which is found relatively closer to shore. In ocean environments, these birds are surface gleaners, foraging for zooplankton and fish eggs or larvae while they float on the water's surface.

Red and red-necked phalaropes are considered species of Least Concern by the IUCN (2021), although the global population trend of red phalaropes is unknown, and of red-necked phalaropes is decreasing (Table 6.2). Populations of these birds are threatened by breeding and migration habitat alteration due to climate change, and oil exposure and pollution in the marine environment.

Red-necked phalaropes represent 56% of phalaropes and 3.6% of all birds observed during at-sea surveys (Dick 2016). Because of their propensity to concentrate over the continental shelf and closer to shore, red-necked phalaropes are predicted to be relatively less dense in the HWEA. They are also likely to be present in lower numbers than red phalaropes in the HWEA. Overall, their highest densities in the HWEA are predicted to occur in fall (Figure B.27), but they have low density in the HWEA and vicinity year-round compared to the CCS as a whole (Table 6.1).

Red phalaropes represent 44% of phalaropes and 2.8% of all birds observed during at-sea surveys (Dick 2016). This species has a strong offshore predicted density distribution in winter and spring, concentrating closer to the continental slope in the HWEA and vicinity in summer and fall. Highest densities of red phalaropes in and near the HWEA are also predicted to occur in the fall (Figure B.28), with the average density in the area considered low year-round compared to the distribution of density values in the CCS (Table 6.1).

Storm-Petrels

There are seven species of storm-petrels that have been observed during at-sea surveys, comprising 4.4% of all seabirds observed: Leach's storm-petrel (*Hydrobates leuchorhous*), fork-tailed storm-petrel (*H. furcatus*), ashy storm-petrel (*H. homochroa*), black storm-petrel (*H. melania*), least storm-petrel *(H. microsoma*), wedge-rumped storm-petrel (*H. tethys*), and Wilson's storm-petrel (*Oceanites oceanicus*). Least, wedge-rumped, and Wilson's storm-petrels are included in the section on Rare or Data Deficient Seabirds below. Storm-petrels are surface feeders, foraging on zooplankton and nekton, and occasionally small fish. They commonly forage in areas above and beyond the continental shelf where upwelling supports their prey populations. Almost all storm-petrels are nocturnal at their breeding sites, presumably to avoid predators.

The four remaining storm-petrel populations are all listed in as being potentially in decline. Ashy storm-petrels are listed by the IUCN (2021) as Endangered and are a California Species of Special Concern (breeding, 2nd priority), as their global population is small (estimated at 3,500-6,700 birds) and decreasing. Leach's storm-petrel is listed by the IUCN (2021) as Vulnerable, with a decreasing global population. Fork-tailed and black storm-petrels are both listed as Least Concern by the IUCN (2021), but are California Species of Special Concern (breeding, 3rd priority). The global populations of fork-tailed storm-petrels are increasing, whereas black storm-petrels are decreasing (Table 6.2). These species are threatened by pollution and oil spills, overfishing, habitat degradation, human disturbance and habitat modification in breeding areas, and introduced predators and disease.

Leach's storm-petrel is the most common storm-petrel observed during at-sea surveys in the CCS; they represent 86% of storm-petrels observed, and 3.8% of all seabirds (Dick 2016). This species breeds in the North Pacific and Atlantic oceans, with the North American population occupying isolated island colonies extending from Alaska to northern Mexico. As of 2002, five of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of Leach's storm-petrels, for a total of 8,487 birds, approximately 78% of the state's population (CDFG 2010). Outside of the breeding season, they tend to disperse widely into the tropics of the central and eastern Pacific, although they can be observed foraging over the continental slope west of California.

Dick (2016) predicted that densities of Leach's storm-petrels were highest in and near the HWEA in spring, but, similar to summer and fall, densities are very low compared to the CCS where densities are higher to the north (Table 6.1, Figure B.29). In the winter, relative density in the HWEA area is higher, but is still considered low as the predicted densities increase further offshore and to the north.

Fork-tailed storm-petrel is uncommon from late fall to early spring where it occurs along the open ocean of California. It obtains all its food at sea, although little is known of its diet. Observations of this species represent 3.6% of all storm-petrels counted during at-sea surveys. The majority of breeding habitat for this species is in the North Pacific but terminates in northern California. Breeding occurs on six small islets off Del Norte and Humboldt counties. As of 2002, four of the 27 seabird colonies within 30 nm (56 km) of the HWEA supported populations of fork-tailed storm-petrels, for a total of 259 birds, approximately 62% of the state's population (CDFG 2010). They can forage at great distances away from their nest sites, putting the HWEA in their foraging range while nesting. Outside of the breeding season, these birds are highly pelagic, foraging beyond the continental shelf and usually well north of California.

Predicted density models indicate fork-tailed storm petrels have low densities in and near the HWEA in the winter, and very low densities for the remainder of the year, compared to the CCS as a whole (Dick 2016; Table 6.1). Local densities are predicted to be highest in spring (Figure B.30), but similar from winter to summer. The proximity of breeding sites and presence of preferred foraging habitat indicates fork-tailed storm-petrels may utilize the HWEA and surrounding area.

Ashy storm-petrels have a relatively restricted range extending from Cape Mendocino to the northern portion of western Baja California Sur. They represent 3.3% of storm-petrels observed during at-sea surveys in the CCS (Dick 2016). The vast majority of the population breeds on the Farallon Islands and the Channel Islands, with small numbers inhabiting other offshore features. None of the seabird colonies within 30 nm (56 km) of the HWEA supported populations of ashy storm-petrels in 2002 (CDFG 2010). During the breeding season, they forage near the edge of the continental shelf near their nesting areas. In winter, they concentrate over deep waters, especially in Monterey Bay (Birds of the World 2021). This species does not exhibit the long-distance, open-ocean migration strategy of other storm-petrels and tends to remain within the southern CCS during the non-breeding season.

Leirness et al. (2021) found that predicted ashy storm-petrel density in the CCS was highest in fall. Modeled values in and near the HWEA were very low in spring and summer, when densities were predicted to be higher south of Point Arena, especially around the Farallones and the Channel Islands. In fall, slightly higher density predictions near the HWEA may be driven by bathymetric predictor variables, as the distribution is more dispersed and offshore along the California Coast.

Black storm-petrel is a warm-water species which inhabits the west coast of North, Central, and South America. It represents 5.6% of storm-petrels observed during at-sea surveys in the CCS, with the majority of these observations occurring south of San Francisco Bay. This species breeds in the Channel Islands and islands on the Pacific and Gulf of California coasts of Baja California, Mexico. It is uncommon north of Monterey Bay during the breeding season. However, in fall and winter it disperses offshore over the shelf slope, with a portion of the population traveling north to the vicinity of Point Arena. Leirness et al. (2021) modeled predicted density for this species for spring through fall, indicating very low densities in and near the HWEA from spring to fall. Similar to predictions for ashy storm-petrel, increased density predictions relative to the CCS in the fall were likely driven by the presence of bathymetric predictor variables.

Table 6.1. Local residency status and average predicted density ranks (Dick 2016) for select seabird species in and near the HWEA. Average predicted density ranks are compared to the maximum predicted density in the CCS for a given season. Ranks were calculated as follows: local average density/CCS max ≤ 0.05 = very low, >0.05 and ≤0.25 = low, >0.25 and ≤0.5 = moderate, >0.5 = high. Bold text indicates the season with the highest average predicted density value (not rank) in or near the HWEA.

Species	Local Residency Status	Average Predicted Density Rank			
		Winter	Spring	Summer	Fall
Laysan albatross	migrant	**low**	low	moderate	moderate
Black-footed albatross	migrant	high	moderate	**moderate**	moderate
Common murre	resident	very low	very low	**very low**	very low
Scripps's/Guadalupe murrelet*	migrant	low	low	**moderate**	low
Cassin's auklet	resident	low	low	very low	**very low**
Rhinoceros auklet	resident	**low**	very low	very low	very low
Tufted puffin	resident	very low	**very low**	very low	very low
Brandt's cormorant	resident	**very low**	very low	very low	very low
Sooty shearwater	migrant	low	low	**low**	low
Pink-footed shearwater	migrant	low	moderate	**moderate**	low
Northern fulmar	migrant	low	low	low	**low**
Pacific loon	migrant	**very low**	low	low	low
Long-tailed jaeger	migrant	moderate	low	moderate	**low**
Parasitic jaeger	migrant	moderate	moderate	moderate	**moderate**
Pomarine jaeger	migrant	low	low	low	**low**
Bonaparte's gull	migrant	very low	very low	very low	**very low**
Mew/short-billed gull	migrant	**very low**	very low	very low	very low
California gull	migrant	**very low**	very low	very low	very low
Herring gull	migrant	very low	very low	very low	**very low**
Glaucous-winged gull	migrant	**very low**	very low	very low	very low
Western Gull	resident	low	low	**low**	low
Heermann's gull	migrant	very low	very low	very low	**very low**
Sabine's gull	migrant	low	low	**low**	low
Black-legged kittiwake	migrant	**very low**	very low	very low	very low
Caspian tern	migrant	very low	**very low**	very low	very low
Brown pelican	migrant	low	low	low	**low**
Red phalarope	migrant	low	low	low	**low**
Red-necked phalarope	migrant	low	low	low	**low**
Fork-tailed Storm-Petrel	resident	low	**very low**	very low	very low
Leach's Storm-Petrel	resident	low	**very low**	very low	very low

Rare or Data Deficient Seabirds

Albatross

Short-tailed albatross (*P. albartrus*) breed on two isolated Japanese islands, with one known pair successfully breeding on Midway Atoll in the northwestern Hawaiian island archipelago. They are rare visitors to the West Coast and are not commonly seen during at-sea seabird surveys. The population of short-tailed albatross is estimated to be 1,734 birds (Birds of the World 2021). The IUCN lists this species as Vulnerable, and it is Endangered under the U.S. ESA (Table 6.2). This species is occasionally observed offshore in the CCS, but there are no current records in or near the HWEA (eBird 2021). Because of their low population numbers, there is no predicted density model for this species for the HWEA. However, the HWEA does encompass the shelf break and slope, which is suitable foraging habitat for short-tailed albatross.

Alcids

Ancient murrelets (*Synthliboramphus antiquus)* nest in burrows, crevices, or under rocks, and forage in shallow waters. Their North American breeding range extends from Alaska to British Columbia. Birds found offshore of California are likely migrants/wintering. This species is not covered in Dick (2016), but Leirness et al. (2021) includes a density distribution map for spring, which is driven by observations offshore of the Olympic Peninsula in Washington. Densities in the HWEA are likely to be low to very low, as this species prefers to forage near shore, and does not breed in the area.

Horned puffins (*F. 97orniculate*) are migrants and are rarely observed during at-sea surveys, representing 0.04% of alcids observed (Dick 2016). Breeding sites are found on islands and coastal areas off northern British Columbia, Canada, and Alaska. Their non-breeding distribution is similar to that of tufted puffins in that they disperse to deep pelagic environments well away from the coast outside of the breeding season.

Both ancient murrelets and horned puffins are listed as Least Concern by the IUCN (2021), but both are experiencing global population declines (Table 6.2).

Larids

Two species of large gull, the **glaucous gull** (*L. hyperboreus*) and the **kelp gull** (*L. dominicanus*) are rarely observed during at-sea surveys. Glaucous gulls breed in the Arctic and overwinter in the northern CCS, rarely traveling south of Cape Mendocino. Kelp gulls breed and winter in the southern hemisphere, and are highly vagrant in the CCS. Both are coastal species, and are opportunistic omnivores that have adapted well to human development for the purposes of foraging, similar to many other large gull species. Both species are listed as Least Concern by the IUCN, although global glaucous gull populations are decreasing, while kelp gull populations are increasing. Because of their limited distribution in the area, both species are uncommon in the HWEA or vicinity.

The **ring-billed gull** (*L. delawarensis*) is a mid-sized gull which represents 1% of gulls observed during at-sea surveys in the CCS. This species is also a migrant in the CCS where it overwinters, although the majority of the population breeds and lives year-round in inland areas across Mexico, the U.S., and Canada. When overwintering, it is highly coastal, commonly found in harbors and estuaries and is rarely observed far from shore. Like other gulls, it has adapted to human development and is omnivorous, congregating at feeding sites whether they are bays, farm fields, or garbage dumps. The global population of this species is increasing, and the IUCN lists it as Least Concern. Due to this species' affinity for nearshore and inland environments, it is uncommon in the HWEA or vicinity.

Two small gull species, the **short-billed gull** (*L. brachyrhynchus*, formerly **mew gull** until 2021) and **Franklin's gull** (*Leucophaeus pipixcan*), are also rarely observed during at-sea surveys in the CCS. Both species migrate through the CCS and breed in coastal and inland environments, short-billed gulls in Alaska and western Canada, Franklin's gulls in central Canada and the north-central U.S.. Even during migration they inhabit coastal and inland habitats, and are rarely observed away from shore. Short-billed gulls overwinter in the CCS, and their abundance decreases south of Point Conception. Franklin's gulls overwinter along the west coast of South America. As with other gulls, both species are opportunistic omnivores, but short-billed gulls are less likely to utilize anthropogenic food sources. Both species are listed by the IUCN as Least Concern, with global populations of Franklin's gull increasing, whereas the population trend of short-billed gulls is unknown (Table 6.2). Because of their affinity to nearshore and inland habitats, both species are uncommon in the HWEA and vicinity. For short-billed gull, this is supported by predicted density maps which indicate very low densities of this species in and near the HWEA in all seasons relative to the CCS as a whole (Dick 2016). Nearshore densities are predicted to be higher from spring through fall than in the HWEA itself.

The **black skimmer** (*Rynchops niger*) is a large tern with a unique appearance: the lower mandible is much longer than the upper. This facilitates the skimmer's foraging strategy, as it drags the bottom mandible through the water while flying low over the surface, snapping the bill closed when it comes in contact with a prey item. Skimmers represent 0.2% of terns observed during at-sea surveys, as they tend to concentrate in shallow water areas nearshore and in estuaries and bays. In the U.S., they are a coastal species, except for a colony at the Salton Sea, with their northernmost breeding colony in the San Francisco Bay area. The IUCN (2021) lists this species as Least Concern, although the global population is decreasing. The State of California lists it as a Species of Special Concern, 3rd priority (breeding). Because these birds are rarely observed at sea, and even more rarely north of the San Francisco Bay area, this species is uncommon in or near the HWEA.

California least tern (*Sternula antillarum browni*) represents 5.6% of terns observed at-sea in the CCS. This small tern is a colonial nester, breeding in coastal areas from San Francisco Bay area to western Mexico. It is considered a vagrant north of Cape Mendocino. West coast populations are thought to overwinter in Central America. These birds are commonly observed nearshore, although they will travel some distance from breeding sites to acquire food if resources are limited nearby. They forage in any aquatic habitat, from shallow coastal waters, bays, estuaries, and coastal lakes. Least terns in general are listed as Least Concern by the IUCN (2021) although their global population trend is decreasing. The California least tern is listed by the U.S. ESA and by the State of California as Endangered. While this population is heavily monitored, little is known of its non-breeding distribution or at-sea density.

Forster's tern (*Sterna forsteri*) represents 2.6% of terns observed during at-sea surveys in the CCS. They are listed by the IUCN (2021) as Least Concern with an increasing global population. This medium-sized tern has a transcontinental distribution, breeding in the north central U.S., central Canada, and scattered locations throughout the intermountain west. In California, they breed in the greater San Francisco Bay area. The portion of the population that winters on the Pacific coast is common south of Cape Mendocino to Mexico and Central America. Like most terns, these medium-sized birds are piscivorous plunge-divers and are highly social, foraging and roosting in large flocks. At present there are no predicted density distribution models for this species in the CCS.

Petrels

Petrels are migrants in the CCS and are not commonly observed during at-sea surveys due to the fact that they tend to utilize habitats that are greater than 100 nm (185 km) from shore. Five species were observed during surveys, with total counts representing 0.1% of the total number of birds observed (Dick 2016). Most common was **Cook's petrel** (*Pterodroma cookii*), followed by **mottled petrel** (*P. inexpectata*, one observation, multiple individuals), **Murphy's petrel** (*P. ultima*), **black petrel** (*P. parkinsoni*, one individual), and **Stejneger's Petrel** (*P. longirostris*, one individual). Murphy's and Cook's petrels are most likely to be seen far offshore of northern California during the spring, and rarely during the remainder of the year (Leirness et al. 2021). These species tend to breed on a limited number of small, isolated islands in the south or south-western Pacific. They are vulnerable to sea level rise, introduced predators, entanglement in fishing gear, and habitat loss. Only Murphy's petrels are considered by the IUCN (2021) to be of Least Concern; mottled petrels are listed as Near Threatened, and the remaining species are considered Globally Endangered with Cook's, Parkinson's, and Stejneger's petrels listed as Vulnerable (Table 6.2). Because these birds are highly pelagic and rarely occur within 100 nm of shore in northern California, they are likely uncommon in the HWEA.

Storm-petrels

Least storm-petrel, wedge-rumped storm-petrel, and **Wilson's storm-petrel** represent less than 0.08% of all species and 1.8% of storm-petrels observed off California during at-sea surveys. Least storm-petrels nest on islands off western Mexico, and range into California, and are rarely observed north of San Francisco Bay (eBird 2021). This species tends to concentrate over and beyond the continental shelf south of Point Conception. Wedge-rumped and Wilson's storm-petrels are vagrants on the Pacific coast of the U.S. as they are predominantly southern hemisphere species; wedge-rumped storm-petrels nest off the west coast of South America; Wilson's storm-petrels nest in Antarctica and Southern Ocean islands along the west coast of southern Chile. They tend to winter in the open ocean far offshore of their breeding grounds or, in the case of the Wilson's storm-petrel, also off the U.S. Atlantic coast where it is extremely common (Birds of the World 2021). Both species are very uncommon in California waters, with a smattering of observations offshore over the shelf break and beyond, mostly south of San Francisco Bay (eBird 2021). All three species are listed by the IUCN (2021) as being of Least Concern, although the population trend of wedge-rumped storm-petrels is decreasing.

Sea ducks and geese

Scoters are migratory in California and concentrate in coastal areas as they forage in sub- and inter-tidal waters. They often travel over the shallower portions of the continental shelf in long skeins of multiple birds. There are a total of two records for at-sea observations of **surf scoters** (*Melanitta perspicillata*), none for **white-winged scoters** (*M. deglandi*) off California (Dick 2016). Leirness et al. (2021) created a combined predicted density model for three species of surf scoter (including **black scoter** (*M. americana*)) and unidentified scoters. Observations of surf scoter were predominant in fall and winter, whereas white-winged scoter was the more commonly observed species in spring and summer; each species likely drove the density models for those seasons respectively. In all seasons, especially summer, scoter densities in the HWEA are likely to be very low, as this species prefers to forage near shore, and does not breed in the area. Black scoters are listed as Near Threatened by the IUCN (2021), with a decreasing population trend; both surf and white-winged scoters are listed as being of Least Concern although their populations are also decreasing (Table 6.2).

Black brant (*Branta bernicla nigricans*) is a Pacific coast subspecies of a goose that breeds in the high Arctic. Much of the population migrates and winters along the west coast of the U.S. and northern Mexico, and sometimes travels in large flocks. These birds are primarily herbivores and are therefore limited to feeding in shallow waters when on the ocean or in estuaries or bays. Because of this, they are unlikely to be found far offshore in or near the HWEA. However, they are common in nearby Humboldt Bay during fall and winter, as this area supports 35-40% of California's eelgrass, their preferred food (Audubon California 2017). While this subspecies is a California Species of Special Concern (2nd priority, wintering/staging), it is hunted in Humboldt, with a limited season in early November to mid-December (California Fish and Game Commission 2021).

*Table 6.2. Listing status for seabirds under the IUCN Red List (IUCN 2021). When applicable, status under the U.S. Endangered Species Act and the California Endangered Species Act/list of Species of Special Concern is included. IUCN population values are provided where available and indicate the number of mature individuals. * indicates species that are included in Leirness et al. 2021 only. ^ indicates species that are included in Dick 2016 only. ~ indicates species that are not included in Leirness et al. (2021) or Dick (2016).*

Common Name	**Scientific Name**	**Population Status**	**Global Population Trend**
Laysan albatross	*Phoebastria immutabilis*	IUCN: Near Threatened	Stable 1,600,000
Black-footed albatross	*Phoebastria nigripes*	IUCN: Near Threatened	Increasing 139,800
Short-tailed albatross~	*Phoebastria albartrus*	IUCN: Vulnerable U.S. ESA: Endangered CA CESA/SSC: Species of Special Concern year round	Increasing 1,734
Common murre	*Uria aalge*	IUCN: Least Concern	Increasing
Pigeon guillemot*	*Cepphus columba*	IUCN: Least Concern	Stable
Marbled murrelet*	*Brachyramphus marmoratus*	IUCN: Endangered U.S. ESA: Threatened CA CESA/SSC: Endangered	Decreasing 240,000-280,000
Scripps's murrelet	*Synthliboramphus scrippsi*	IUCN: Vulnerable CA CESA/SSC: Threatened	Decreasing 10,000-20,000
Guadalupe murrelet	*Synthliboramphus hypoleucus*	IUCN: Endangered CA CESA/SSC: Threatened	Decreasing 5,000
Craveri's murrelet*	*Synthliboramphus craveri*	IUCN: Vulnerable	Decreasing 8,000
Ancient murrelet*	*Synthliboramphus antiquus*	IUCN: Least Concern	Decreasing
Cassin's auklet	*Ptychoramphus aleuticus*	IUCN: Near Threatened CA CESA/SSC: Species of Special Concern - breeding, 3rd priority	Decreasing 3,600,000
Rhinoceros auklet	*Cerorhinca monocerata*	IUCN: Least Concern	Decreasing

Common Name	**Scientific Name**	**Population Status**	**Global Population Trend**
Tufted puffin	*Fratercula cirrhata*	IUCN: Least Concern CA CESA/SSC: Species of Special Concern - breeding, 1st priority	Stable 2,300,000
Horned puffin	*Fratercula corniculata*	IUCN: Least Concern	Decreasing 800,000
Brandt's cormorant	*Urile penicillatus*	IUCN: Least Concern	Decreasing
Pelagic cormorant*	*Urile pelagicus*	IUCN: Least Concern	Decreasing
Double-crested cormorant*	*Phalacrocorax auritus*	IUCN: Least Concern	Increasing
Sooty shearwater	*Ardenna grisea*	IUCN: Near Threatened	Decreasing 8,800,000
Pink-footed shearwater	*Ardenna creatopus*	IUCN: Vulnerable	Unknown 59,146
Short-tailed shearwater*	*Ardenna tenuirostris*	IUCN: Least Concern	Decreasing
Flesh-footed shearwater*	*Ardenna carneipes*	IUCN: Near Threatened	Decreasing 148,000
Buller's shearwater*	*Ardenna bulleri*	IUCN: Vulnerable	Stable
Black-vented shearwater*	*Puffinus opisthomelas*	IUCN: Near Threatened	Unknown 82,000
Northern fulmar	*Fulmarus glacialis*	IUCN: Least Concern	Increasing 7,000,000
Western grebe*	*Aechmophorus occidentalis*	IUCN: Least Concern	Stable 80,000-90,000
Clark's grebe*	*Aechmophorus clarkii*	IUCN: Least Concern	Decreasing 7,300-14,000
Pacific loon	*Gavia pacifica*	IUCN: Least Concern	Increasing
Common loon*	*Gavia immer*	IUCN: Least Concern	Stable
Red-throated loon*	*Gavia stellata*	IUCN: Least Concern	Decreasing
Yellow-billed loon*	*Gavia adamsii*	IUCN: Near Threatened	Decreasing 11,000-21,000
Surf scoter*	*Melanitta perspicillata*	IUCN: Least Concern	Decreasing
White-winged scoter*	*Melanitta deglandi*	IUCN: Least Concern	Decreasing
Black scoter*	*Melanitta americana*	IUCN: Near Threatened	Decreasing 350,000-560,000
Long-tailed jaeger	*Stercorarius longicaudus*	IUCN: Least Concern	Stable 250,000-750,000
Parasitic jaeger	*Stercorarius parasiticus*	IUCN: Least Concern	Stable 400,000-600,000
Pomarine jaeger	*Stercorarius pomarinus*	IUCN: Least Concern	Stable 400,000
South polar skua*	*Stercorarius maccormicki*	IUCN: Least Concern	Stable 6,000-15,000
Bonaparte's gull	*Chroicocephalus philadelphia*	IUCN: Least Concern	Increasing
Short-billed/Mew gull^	*Larus brachyrhynchus*	IUCN: Least Concern	Unknown
California gull	*Larus californicus*	IUCN: Least Concern	Decreasing
Herring gull	*Larus argentatus*	IUCN: Least Concern	Decreasing

Common Name	Scientific Name	Population Status	Global Population Trend
Iceland gull*	*Larus glaucoides*	IUCN: Least Concern	Stable
Glaucous-winged gull	*Larus glaucescens*	IUCN: Least Concern	Increasing
Western Gull	*Larus occidentalis*	IUCN: Least Concern	Increasing
Heermann's gull	*Larus heermanni*	IUCN: Near Threatened	Unknown 350,000
Sabine's gull	*Xema sabini*	IUCN: Least Concern	Stable 340,000
Black-legged kittiwake	*Rissa tridactyla*	IUCN: Vulnerable	Decreasing
Caspian tern	*Hydroprogne caspia*	IUCN: Least Concern	Increasing
Common tern*	*Sterna hirundo*	IUCN: Least Concern	Unknown
Arctic tern*	*Sterna paradisaea*	IUCN: Least Concern	Decreasing
Royal tern*	*Thalasseus maximus*	IUCN: Least Concern	Stable
Elegant tern*	*Thalasseus elegans*	IUCN: Near Threatened	Stable
Brown pelican	*Pelecanus occidentalis*	IUCN: Least Concern	Increasing
Red phalarope	*Phalaropus fulicarius*	IUCN: Least Concern	Unknown
Red-necked phalarope	*Phalaropus lobatus*	IUCN: Least Concern	Decreasing
Wilson's phalarope*	*Phalaropus tricolor*	IUCN: Least Concern	Increasing
Cook's petrel*	*Pterodroma cookii*	IUCN: Vulnerable	Increasing 670,000
Murphy's petrel*	*Pterodroma ultima*	IUCN: Least Concern	Unknown
Mottled petrel	*Pterodroma inexpectata*	IUCN: Near Threatened	Decreasing
Parkinson's/black petrel	*Pterodroma parkinsoni*	IUCN: Vulnerable	Stable 5,500
Stejneger's petrel	*Pterdroma longirostris*	IUCN: Vulnerable	Decreasing 262,000
Leach's storm-petrel	*Hydrobates leuchorhous*	IUCN: Vulnerable	Decreasing 6,700,000-8,300,000
Fork-tailed storm-petrel	*Hydrobates furcatus*	IUCN: Least Concern CA CESA/SSC: Species of Special Concern - breeding, 3rd priority	Increasing 4,000,000
Ashy storm-petrel*	*Hydrobates homochroa*	IUCN: Endangered CA CESA/SSC: Species of Special Concern - breeding, 2nd priority	Decreasing 3,500-6,700
Black storm-petrel*	*Hydrobates melania*	IUCN: Least Concern CA CESA/SSC: Species of Special Concern - breeding, 3rd priority	Decreasing 600,000

Availability of Data on Seabirds

For the California Current in general and the HWEA in particular, seabird density distribution models (spatial data) are available from Dick (2016), and those described in Leirness et al. (2021) will soon become available. There are several long-term observational datasets available from multiple sources, a number of which are utilized and cited in Dick (2016) and Leirness et al. (2021). However, observational data alone may be insufficient to determine the influence of wind energy development on local seabird populations.

Adams et al. (2019) have compiled information on programs that collect seabird (and marine mammal) data that may be useful in completing environmental risk assessments for offshore energy activities. The Northern California region covers the area of the HWEA. The database created from the survey information contains 129 seabird research and monitoring records for this area. The records were collected from colleges and universities, NGOs, and government agencies. This compilation also lists other sources of seabird data that did not meet the criteria to be included in the initial survey effort but represent consistent and standardized long-term programs. For seabirds, data on at-sea behavior and distribution were determined to be of highest value to inform potential impacts of offshore energy development on those species (Adams et al. 2019). The complete database is available online (Lafferty et al. 2019).

For seabird life history data, one of the most complete assemblage of information available is Birds of the World, https://birdsoftheworld.org, a compilation of comprehensive data for over ten thousand bird species. Access requires a subscription. Some of these data are available in summarized or limited form on related sites including All About Birds, https://allaboutbirds.org, another Cornell Lab of Ornithology product, the Audubon Field Guide, https://www.audubon.org, and eBird, https://ebird.org.

General Status and Threats to Seabirds

Fisheries bycatch directly impacts some seabird species, and human exploitation of fish prey (fisheries competition) indirectly affects some species. Pollution, including oil, chemical, and sewage spills, plastics, and contaminants affect survival and reproduction of many seabird species. Exposure to or ingestion of pollutants and plastics is increasingly common in seabird populations. Habitat alteration and human disturbance along coastlines affects seabird breeding, roosting and foraging locations, as does the introduction of exotic species. Introduced or human-attracted predators can cause partial or complete breeding failure as well as loss of members of the adult breeding population. Introduced species may also cause displacement of roosting or breeding seabirds or introduce novel diseases that can impact the population. Finally, climate related influences, such as marine heat waves, sea temperature extremes and shifts, and sea-level rise may cause shifts or loss of breeding, roosting, or migratory habitat (IUCN 2021, Birds of the World 2021).

HT Harvey and Associates (2020) compiled a list of potential impacts to seabirds of offshore wind development and operation in the HWEA. The document describes and assesses the existing biological conditions in the HWEA, as well as potential disturbance and environmental effects. For seabirds, it summarizes the risks of collision or avoidance, artificial lighting, and habitat alteration. Noting existing uncertainties of the interactions between seabirds and wind energy operations and maintenance, extensive monitoring may be required, as well as flexibility in program operations.

Data Gaps and Limitations

Spatially explicit data illustrating local species-specific migratory patterns and data flight behaviors (flight height, etc.) of seabirds is rare or highly localized. At-sea survey data may not be capturing important migratory pathways or routes that are intensively used such as during foraging to and from breeding and nesting sites. Collision risk from wind turbines is related to flying or soaring height, which is not currently captured in at-sea surveys. Data on the distribution of flying height needs to be collected by categorizing the altitude of birds that are seen in flight. For the HWEA, this is especially important for pelagic species which are not easily observed from shore such as albatrosses, loons, grebes, shearwaters, and petrels. Shearwaters in particular may experience an acute risk from offshore wind energy installations due to their flight and travel behaviors as well as their tendency to migrate in large flocks.

At-sea surveys are generally conducted on a coarse scale over a large area. To improve information about species that utilize the area in and around the HWEA, future surveys will need to be done on a finer spatial and temporal scale than they are currently. There may also be a lag time between collection and release of observation data, and additional time before the data are compiled and standardized in models which cover large areas and time scales. It is inherent in the data collection process that the data may not be available or analyzed for a few years after it is collected.

Summary Tables of Selected Seabird Datasets

Dataset Table 6.1: Seabird Distribution Models in the California Current System

Dataset Title	Seabird Distribution Models in the California Current System
Species/ Resource	Black-footed Albatross, Laysan Albatross, Cassin's Auklet, Common Murre, Rhinoceros Auklet, Tufted Puffin, Scripps's Murrelet/Guadalupe Murrelet, Brandt's Cormorant, Northern Fulmar, Pink-footed Shearwater, Sooty Shearwater, Pacific Loon, Black-legged Kittiwake, Bonaparte's Gull, California Gull, Caspian Tern, Glaucous-winged Gull, Heermann's Gull, Herring Gull, Long-tailed Jaeger, Mew Gull, Parasitic Jaeger, Pomarine Jaeger, Sabine's Gull, Western Gull, Brown Pelican, Red Phalarope, Red-necked Phalarope, Fork-tailed Storm-Petrel, Leach's Storm-Petrel
Abstract	Marine conservation measures such as marine protected areas (MPAs) rely on a robust understanding of the relationships between species and their environment. We developed species-specific, spatially explicit seabird-habitat association models to identify multispecies foraging aggregations (hotspots) in the California Current System. Using negative binomial regression, we built and validated models for 30 species using 15 years (1997-2012) of seabird survey data from multiple cruises spanning the California Current combined with predictor variables derived from bathymetric and remotely sensed oceanographic data as well as climate indices. We predicted species-specific abundances during four focal months (February, May, July, and October). Predicted abundances were averaged by month across all years and by year and standardized. Standardized predicted means for all species were averaged for each focal month, for each year, and across all months/years to create scenario-specific multispecies hotspot maps for relative abundance and species richness (number of species). Average depth and sea surface temperature (SST) were the most important explanatory variables in our models, while no distance related variables were included in any final models. Model outputs yielded similar results - where there was high relative abundance there was also high species richness. Peak values of both measures were found along most of the coast, both within and outside National Marine Sanctuaries. Results also predicted high habitat use by seabirds in

	association with offshore bathymetric features, especially north of the Mendocino Ridge where seafloor complexity increases. Our use of seabirds as indicator species combined with a multispecies approach provides an example of using at-sea seabird data combined with remotely sensed data and spatial modeling techniques to help prioritize protected area designation in the CCS. This approach can be used in other regions of the world where similar data exist, as well as explore the possible effects of climate change on seabird at-sea distribution.
Strength/ Weakness	These data are finalized and will not be updated as new data become available. The maps represent model-derived spatial predictions of long-term average density of nearshore and pelagic seabird species. They 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. Also, the maps do not provide predictions of density at a specific time; they only indicate seasonal distributions averaged across the timeframe of the survey dataset. While models were validated, these data do not include spatially explicit model performance metrics or estimated uncertainty values.
File Name	FNStudyArea.shp; AllSpp_AllMonths_PredictedMeans.csv; AllSpp_AllMonths_PredictedMeans_Standardized.csv
Data Type	Vectorized raster with related .csv tables
Spatial Extent	Northern Baja California to southern British Columbia; 52.3 -139.167, 29.75 -116.917; 1/12 degree cells (~9km)
Time Scale	Data from 1997-2012; products are seasonal (winter, spring, summer, fall); published in 2016
Contact/ Source	Dori Dick; https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/mg74qp30b
License/Use Restrictions	Permission from data owner.
Citation Info	https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/mg74qp30b
Online Link	Unavailable. Contact data owner.
Metadata Link	Unavailable. Contact data owner.

Dataset Table 6.2: Modeling at-sea density of marine birds

Dataset Title	Modeling at-sea density of marine birds to support renewable energy planning on the Pacific Outer Continental Shelf of the contiguous United States.
Species/ Resource	Surf Scoter, White-Winged Scoter, Black Scoter, Western Grebe, Clark's Grebe, Wilson's Phalarope, Red-necked Phalarope, Red Phalarope, South Polar Skua, Parasitic Jaeger, Long-tailed Jaeger, Pomarine Jaeger, Common Murre, Pigeon Guillemot, Marbled Murrelet, Scripps's Murrelet, Guadalupe Murrelet, Craveri's Murrelet, Ancient Murrelet, Cassin's Auklet, Rhinoceros Auklet, Tufted Puffin, Black-legged Kittiwake, Sabine's Gull, Bonaparte's Gull, Heermann's Gull, California Gull, Western Gull, Glaucous-winged Gull, Herring Gull, Iceland Gull, Caspian Tern, Common Tern, Arctic Tern, Royal Tern, Elegant Tern, Red-throated Loon, Arctic

	Loon, Pacific Loon, Common Loon, Yellow-billed Loon, Laysan Albatross, Black-footed Albatross, Fork-tailed Storm-Petrel, Leach's Storm-Petrel, Ashy Storm-Petrel, Black Storm-Petrel, Northern Fulmar, Murphy's Petrel, Cook's Petrel, Buller's Shearwater, Pink-footed Shearwater, Short-tailed Shearwater, Sooty Shearwater, Flesh-footed Shearwater, Black-vented Shearwater, Brandt's Cormorant, Pelagic Cormorant, Double-crested Cormorant, Brown Pelican
Abstract	This report describes the at-sea spatial distributions of marine birds in Pacific OCS waters off the contiguous U.S. to inform marine spatial planning in the region. The goal was to estimate long-term average spatial distributions for marine bird species using all available science-quality transect survey data and numerous bathymetric, oceanographic, and atmospheric predictor variables. We developed seasonal habitat-based spatial models of the at-sea distribution for 33 individual species and 13 taxonomic groups of marine birds throughout the study region. A statistical modeling framework was used to estimate numerical relationships between bird sighting data (i.e., standardized counts) and a range of temporal (e.g., Pacific Decadal Oscillation [PDO] index), spatially static (e.g., depth), and spatially dynamic (e.g., sea surface chlorophyll-a concentration) environmental variables. The estimated relationships were then used to predict spatially explicit long-term average density (individuals per km2) throughout the study area for each species/group in each of four seasons. Bird sighting data came from multiple scientific survey programs and consisted of at-sea counts of birds collected between 1980 and 2017 using boat-based and fixed-wing aerial transect survey methods. Spatial environmental variables were derived from remote sensing satellite data and an ocean dynamics model.
Strength/ Weakness	The maps represent model-derived spatial predictions of long-term average density. They 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. Also, the maps do not provide predictions of density at a specific time; they only indicate seasonal distributions averaged across the timeframe of the survey dataset. In addition to density estimate models, model performance metrics and estimated uncertainty were calculated for each species/season model. It is important to recognize that the model performance metrics mainly reflect the statistical fit of the models to the existing real-world data. They reflect only the data that were analyzed, and they do not reflect the quality of model predictions away from the original data. As with the model performance metrics, the estimated uncertainty in the model predictions is conditional on the model and the data. It does not capture all of the uncertainty associated with our model predictions. Nevertheless, the estimated uncertainty is an important indication of the precision of the model predictions, and it should be an integral consideration when using the model predictions.
File Name	Model_input_predictors.zip; model_output_predictions.zip
Data Type	Raster
Spatial Extent	Northern Baja California to Vancouver Island; UL 49 -131, LR 29.8 -117.1; 2 km cells
Time Scale	Data from 1980-2017; products are seasonal (winter, spring, summer, fall); published in 2021
Contact/Source	Jeffrey Leirness, jeffery.leirness@noaa.gov, Bureau of Ocean Energy Management Data and Information Systems
License/Use Restrictions	Public data. Cite as: Leirness, Jeffery B.; Adams, Josh; Ballance, Lisa T.; Coyne, Michael; Felis, Jonathan J.; Joyce, Trevor; Pereksta, David M.; Winship, Arliss J. (2022). NCCOS Assessment: Modeling at-sea density of marine birds to support renewable energy planning on the Pacific Outer Continental Shelf of the contiguous United States (NCEI Accession 0242882). [indicate

	subset used]. NOAA National Centers for Environmental Information. Dataset. https://www.ncei.noaa.gov/archive/accession/0242882. Accessed [date].
Citation Info	Report citation: Leirness JB, Adams J, Ballance LT, Coyne M, Felis JJ, Joyce T, Pereksta DM, Winship AJ, Jeffrey CFG, Ainley D, Croll D, Evenson J, Jahncke J, McIver W, Miller PI, Pearson S, Strong C, Sydeman W, Waddell JE, Zamon JE, Christensen J. 2021. Modeling at-sea density of marine birds to support renewable energy planning on the Pacific Outer Continental Shelf of the contiguous United States. Camarillo (CA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-014. 385 p. https://espis.boem.gov/final%20reports/BOEM_2021-014.pdf
Online Link	https://doi.org/10.25921/xqf2-r853
Metadata Link	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:0242882;view=iso

Dataset Table 6.3: Marine bird population, collision and displacement vulnerability

Dataset Title	Data for calculating population, collision and displacement vulnerability among marine birds of the California Current System associated with offshore wind energy infrastructure (ver. 2.0, June 2017)
Species/ Resource	81 seabird species known to occur in the CCS, including: sea ducks and geese, loons, grebes, albatross, fulmars, petrels, shearwaters, storm-petrels, cormorants, pelicans, phalaropes, jaegers, skuas, murrelets, guillemots, auklets, puffins, kittiwakes, gulls, terns, and skimmers.
Abstract	The U.S. Geological Survey, Western Ecological Research Center (USGS-WERC) was requested by the Bureau of Ocean Energy Management (BOEM) to create a database for marine birds of the California Current System (CCS) that would allow quantification and species ranking regarding vulnerability to offshore wind energy infrastructure (OWEI). This was needed so that resource managers could evaluate potential impacts associated with siting and construction of OWEI within the California Current System section of the Pacific Offshore Continental Shelf, including California, Oregon, and Washington. Along with its accompanying Open File Report (OFR), this comprehensive database can be used (and modified or updated) to quantify marine bird vulnerability to OWEIs in the CCS at the population level. For 81 marine bird species present in the CCS, we generated numeric scores to represent three vulnerability indices associated with potential OWEI: population vulnerability, collision vulnerability, and displacement vulnerability. The metrics used to produce these scores includes global population size, proportion of the population in the CCS, threat status, adult survival, breeding score, annual occurrence in the CCS, nocturnal and diurnal flight activity, macro-avoidance behavior, flight height, and habitat flexibility; values for these metrics can be updated and adjusted as new data become available. The scoring methodology was peer-reviewed to evaluate if the metrics identified, and the values generated were appropriate for each species considered. The numeric vulnerability scores in this database can readily be applied to areas in the CCS with known species distributions and where offshore renewable energy development is being considered. We hope that this information can be used to assist meaningful planning decisions that will impact seabird conservation.
Strength/ Weakness	This is not spatial data. For all metrics, preference was given to more recently published sources when multiple literature sources were available. If no sources were available to generate a metric score, data from a similar species was used. The scoring methodology was peer reviewed to evaluate if the metrics identified, and the values generated, were representative for the species considered. Scores given for each species are relative values

	generated for the purpose of this database, and should not be interpreted as an absolute value of vulnerability for the species. The values generated for most of the metrics in this database have inherent uncertainty. Therefore the level of uncertainty for each metric was determined to be low (10%), medium (25%), or high (50%) depending on the number of data sources, how current the data sources were, and the range of values published in those data sources. When appropriate, expert opinion also was used to determine values and uncertainty. The uncertainties given for each metric and species are relative values generated for the purpose of this database and should not be interpreted as an absolute uncertainty value of vulnerability for the species or metric. No planned updates are scheduled, but updates may occur.
File Name	Population Vulnerability: CCS_vulnerability_FINAL_VERSION_v9_PV.csv; Collision Vulnerability: CCS_vulnerability_FINAL_VERSION_v10_CV.csv; Displacement Vulnerability: CCS_vulnerability_FINAL_VERSION_v10_DV.csv;
Data Type	Tabular text (.csv) files
Spatial Extent	California Current System, northern Washington to southern Baja California Sur; no explicit spatial component to data
Time Scale	Current to 2017 with updates possible; no explicit temporal component to data.
Contact/Source	U.S. Geological Survey, Pacific Region; Josh Adams, josh_adams@usgs.gov
License/Use Restrictions	The authors of these data require that users direct any questions pertaining to appropriate use or assistance with understanding limitations and interpretation of the data to the individuals/organization listed in the Point of Contact section in the metadata.
Citation Info	Adams, J., Kelsey, E.C., Felis J.J., and Pereksta, D.M., 2017, Data for calculating population, collision and displacement vulnerability among marine birds of the California Current System associated with offshore wind energy infrastructure (ver. 2.0, June 2017): U.S. Geological Survey data release, https://doi.org/10.5066/F79C6VJ0.
Online Link	https://www.sciencebase.gov/catalog/item/58f7fadae4b0b7ea5451fc5c
Metadata Link	https://www.sciencebase.gov/catalog/file/get/58f7fadae4b0b7ea5451fc5c?f=__disk__d5%2F05%2F3b%2Fd5053b4c093be6660b8f0ab4c69ef359d577209f&transform=1&allowOpen=true

SECTION 7. SEA TURTLES

Although sea turtles live most of their lives in the ocean, adult females must come back to land to lay their eggs. Sea turtles migrate hundreds to thousands of miles every year between their feeding grounds and nesting beaches. There are four species of sea turtle found in U.S. West Coast waters, all of which are protected under the U.S. ESA. Three turtle species are more commonly found off California: green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), and olive ridley (*Lepidochelys olivacea*). Loggerheads (*Caretta caretta*) are labelled as rare in California, but juveniles may sometimes forage off Southern California during warm water years (Welch et al. 2019) and the animals are sometimes found as bycatch in the swordfish and thresher shark drift gillnet fishery off Southern California (NOAA and USFWS 2020). To reduce this bycatch, NOAA Fisheries implemented seasonal closures and additional closures during El Niño events (NOAA and USFWS 2020).

Sea Turtles With Potential to Occur in the Wind Energy Area or Vicinity

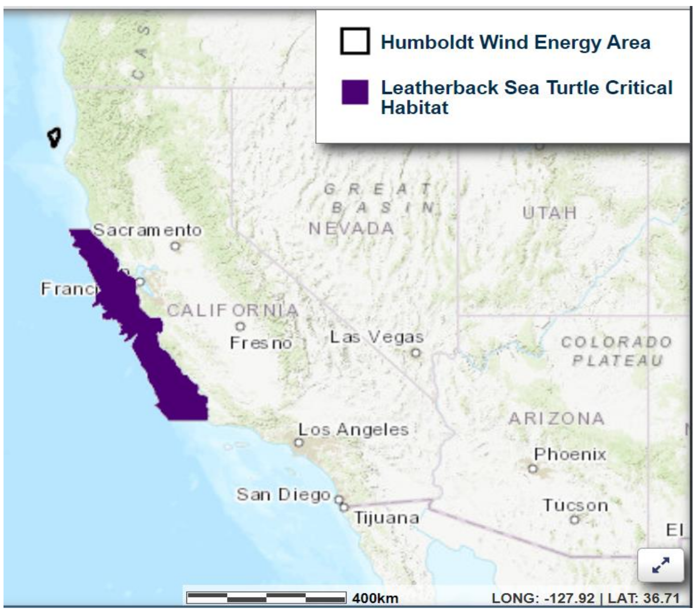

Figure 7.1. Leatherback sea turtle critical habitat in relation to the HWEA (CA Offshore Wind Energy Gateway 2021)

Leatherback sea turtles are among the most highly migratory animals on earth, traveling as many as 10,000 miles or more each year. They are the most pelagic of the four sea turtle species that may occur along the California coast. They are globally distributed but return to tropical or subtropical beaches for nesting. Leatherbacks are highly migratory, some swimming more than 10,000 km (6,213 mi) in a year between nesting and foraging grounds (NOAA Fisheries 2019b). They are also deep divers, with the deepest recorded dive at nearly 1,219 m (4,000 ft) deep (NOAA Fisheries 2021c). Leatherbacks have unique physiological and behavioral traits that enable it to inhabit cold water, unlike the other sea turtle species. These include a countercurrent circulatory system, a thick layer of insulating fat, large body size that limits heat loss, and the ability to elevate body temperature through increased metabolic activity (NOAA Fisheries 2019b). Leatherback sea turtle critical habitat has also been designated on the U.S. West Coast. This includes approximately 43,800 km^2 (16,200 mi^2) from Point Arena to Point Arguello east of the 3,000-m (9,850-ft) depth contour (Figure 7.1). A Pacific Leatherback Conservation Area (PLCA) (Benson and Dewar 2009) was also established that prohibits drift-gillnet fishing for swordfish in leatherback foraging grounds off California, Oregon, and Washington from August 15 to November 15 each year.

Leatherback turtles tagged after nesting in July in Indonesia were found in waters off California and Oregon during July-August of the following year coinciding with the development of seasonal aggregations of jellyfish (NOAA Fisheries 2019b) and when sea surface water temperature warms to 15-16 °C (59-61 °F). Their habitat preferences also suggest that they could be present around the HWEA during certain times of the year depending on the presence of certain prey. Their primary food source are cnidarians such as jellyfish and siphonophores and, to a lesser extent, tunicates such as pyrosomes and salps (NOAA Fisheries 2019b). Annual abundance of leatherback turtles in the California Current Ecosystem is affected by local oceanographic events and their arrival and departure can be predicted using upwelling indices at various latitudes with time lags. Sightings and incidental capture data indicate that this species is found as far north as Alaska but is most frequently encountered off the coast of central California. Benson et al. (2007) estimated that leatherback sea turtle abundance along the "North Coast" was 18 individuals based on aerial surveys conducted from 1990 to 2003 from Point Arena to the California/Oregon border. Given its global distribution, it is assumed that leatherback sea turtles may occur in or near the HWEA from late summer to fall depending on local conditions.

Rare or Data Deficient Sea Turtles

Olive ridley are the smallest and most abundant sea turtle species in the eastern Pacific Ocean. They have been found in the open ocean more than 3,862 km (2,400 mi) from shore, but they also inhabit coastal areas (NOAA Fisheries 2021c). Since individuals may live far offshore for the majority of their lives, their life history is generally unknown to researchers. It is believed that they exploit persistent but dynamic oceanographic features as distinct food webs (Peavey et al. 2017). The common range of this species extends to the California/Baja California border, but individuals have been sighted in Humboldt County and as far north as British Columbia in warm water years (Nafis 2020).

Green sea turtles have a slightly wider at-sea range than olive ridley sea turtles but have a similar distribution in coastal California. They have been found as far north as the Farallon Islands, but data is currently restricted to coastal areas off Santa Monica and San Diego. There are occasional sightings of green sea turtles reported along the coasts of Washington and Oregon. Because of the limited geographic scope of these data, they are likely very rare in the HWEA area (Nafis 2020).

Loggerhead sea turtles are the largest hard-shelled turtle in existence. They are rarely observed and have no known nesting sites on the west coast of North or South America, although their common range covers the tropical and temperate east coast of those continents, as well as coasts of Africa, Europe, Australia, and Asia. In California, they are sometimes observed south of Point Conception, with one observation in Humboldt County (Nafis 2020). Unlike the other three sea turtles, their nesting sites are more often found in temperate rather than tropical locations. They share their pelagic range with the other sea turtle species.

Availability of Data on Sea Turtles

Observer data are collected by NOAA Fisheries for the California deep-set pelagic longline fishery beyond the Exclusive Economic Zone since 2005 to document the incidental capture of sea turtles. In a report documenting observations from 8,956 California drift gillnet fishery sets between 1990 and 2017, one olive ridley and 25 leatherbacks were found as bycatch (Carretta et al. 2019). The Southwest Fisheries

Science Center, Marine Mammal and Turtle Division also conducts research on sea turtles in all oceans of the world, with an emphasis on the Pacific (Dataset Table 7.1).

The California Offshore Wind Energy Gateway has modeled leatherback utilization distribution data from 2003 to 2009 (Dataset Table 7.2). This is based on satellite and light-based geolocation tracking data from the TOPP project. TOPP (2021) uses electronic tagging technologies to study migration patterns of large open-ocean animals and the oceanographic factors controlling these patterns. Utilization Distribution is the probability of an animal being found in a given location. The tagging data in this project were used to model the distribution and key habitats of eight protected predator species across three taxa groups within the U.S. California Current System. In addition to leatherback sea turtles, other tagged animals included marine mammals, Laysan albatrosses, sooty shearwaters, and black-footed albatrosses. Distributions and potential risks to key species were then modeled and examined in relation to marine sanctuaries. Study findings suggest that the highest potential impact regions are on the continental shelf and in the sanctuaries. The TOPP data are not accessible online but can be requested.

The USGS has an extensive database on vertebrate species and plants as part of their Gap Analysis Project (GAP) to support national and regional assessments (Dataset Table 7.3). This information primarily covers terrestrial-based animals, but it also includes five species of sea turtles as well as sea otter, six species of seals and sea lions (fur seals, elephant seal, harbor seal, and California sea lion), and several seabird species (mainly gulls, terns, pelicans, grebes, shearwaters, jaegers, and murres). The work focuses on the spatial patterns of richness derived from species' habitat distribution models. These species level models were spatially combined to show variation in richness across the conterminous United States at a spatial resolution of 30 m (98 ft). Since these models are logically linked to mapped data layers that constitute habitat suitability, the suite of data can also provide an intuitive data system for further exploration of biodiversity and implications for change at ecosystem and landscape scales (Gergely et al. 2019).

Because of the limited geographic scope of information on green and loggerhead sea turtles along the U.S. West Coast, no datasets to be found and they were not further analyzed in relation to the HWEA planning process.

General Status and Threats to Sea Turtles

Long standing man-made threats to sea turtles include by-catch in fishing nets, gear entanglements, beach loss from coastal developments, collection of eggs, oil spills, and ship strikes. More recent threats are likely to occur due to climate change, which could be particularly problematic to sea turtles because the sex ratios in the populations are temperature-dependent, and their nesting beaches may be impacted by sea level rise (Hawkes et al. 2009).

Data Gaps and Limitations

Spatially explicit population and distribution data for sea turtle species on the U.S. west coast is rare or difficult to obtain. This may be because there are not many turtles in this area of their range, they are difficult to observe at-sea even when they might be present, and observational data is often not recorded or publicly available online. Data that do exist are limited in geographic scope or are highly generalized and may be of limited use to offshore wind planning and operation. Of the three most common species, leatherbacks are most common along the U.S. west coast, and are best represented in the datasets that are described although accessing the data is limited.

In general, data for these sea turtle species (leatherback, green, and loggerhead) do not exist for the HWEA except for a narrow coastal strip of Environmental Sensitivity Index data for leatherback sea turtles (Dataset Table 7.4). Loggerhead and green sea turtles are only represented in geographically generalized Environmental Sensitivity Index data for Southern California, outside of the range of the HWEA. The general range of green and loggerhead sea turtles on the west coast of North America extends from Mexico to Canada, but they are considered less common north of Mexico, whereas leatherback sea turtles are considered more common in this range (Nafis 2020).

Other sources of potential sea turtle data include the Welch et al. (2019) study, which used fisheries dependent and independent datasets to determine loggerhead bycatch events (n = 16 turtles) in the California Drift Gillnet Fishery. This type of information has been recorded since 1990 through the observer program managed by the NOAA Fisheries West Coast Regional Office. Independent datasets (i.e., "sighted turtles") include data from an aerial line-transect survey during September and October 2015 (n = 215 turtles, see details of survey methodology in Eguchi et al. 2018), a citizen science loggerhead sighting hotline from April 2015 to July (Briscoe et al. 2017), and a satellite telemetry study conducted by National Marine Fisheries Service's Southwest Fisheries Science Center in 2015 and 2016 (n = 3 tagged turtles). All of this information, even if it is older data, would be helpful as a start toward mapping potential distribution and habitat preferences for sea turtles off the Northern California coast.

For sea turtle data that is mapped, such as on the California Offshore Wind Energy Gateway, it is incumbent on the users to understand the underlying data, if certain assumptions are being made. For example, the map viewer for the "Leatherback Sea Turtle Distribution Model" in the California Offshore Wind Energy Gateway shows "known or probable occurrence, year-round (both winter and summer)." This appears to be a compilation of two USGS datasets for both their "range" and the habitat model data that shows clusters of leatherback sea turtle distribution, which are not around the HWEA region (Dataset Table 7.3). This suggests that while leatherback sea turtles are widely distributed along the California coast, they are potentially rare in or near the HWEA.

Summary Tables of Selected Sea Turtle Datasets

Dataset Table 7.1. Sea Turtle Aerial Survey Data

Dataset Title	Southwest Fisheries Science Center Sea Turtle Aerial Surveys
Species/Resource	Sea turtles (*Cheloniidae* and *Dermochelyidae*)
Abstract	The Southwest Fisheries Science Center, Marine Mammal and Turtle Division (MMTD) conducts research on turtles in all oceans of the world, with an emphasis on the Pacific in an effort to address management objectives in U.S. waters, or where the U.S. has a vested interest. The Marine Turtle Research Programs within the MMTD conduct aerial surveys, nesting beach surveys, and in water capture efforts to estimate marine turtle abundance, stock structure, habitat use, and movement patterns. The MMTD Research Programs also receive data from other sources, such as biological samples and bycatch data from fisheries observation programs and worldwide sample donations to our Marine Mammal and Sea

	Turtle Research Collection, which also serves as the designated NMFS National Sea Turtle Sample Repository.
Strength/Weakness	This data is not accessible online even though there are many references to it. Also, the contact person is no longer at the email or phone number provided.
File Name	Not known
Data Type	Vector polygons with species-specific abundance, seasonality, status, life history, and source information stored in relational data tables that are designed to be used in conjunction with this spatial data layer.
Spatial Extent	Not known
Time Scale	2016-2019
Contact/Source	Alan R. Jackson, NOAA Southwest Fishery Science Center, al.jackson@noaa.gov; (858) 546-7048
License/Use Restrictions	User must read and fully comprehend the metadata prior to use. Acknowledgement of NOAA SWFSC, as the source from which these data were obtained, in any publications and/or other representations of these data is requested. The user is responsible for the results of any application of these data for other than its intended purpose.
Citation Info	Not known
Online Link	Not known
Metadata Link	Not known

Dataset Table 7.2. Leatherback Sea Turtle Utilization Distribution, California Current

Dataset Title	Leatherback Sea Turtle Utilization Distribution, California Current
Species/Resource	Leatherback sea turtles
Abstract	These data have been post-processed and clipped to the Exclusive Economic Zone for the Pacific Coast. Leatherback Sea Turtle (*Dermochelys coriacea*) 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 U.S. waters of the California Current System.
Strength/Weakness	While the webpage indicates that the site September was last modified in September 2017, which is when the page might have been created, it appears that the latest tracking data was from January 2009. It is not known if there has been additional leatherback sea turtle data collected by TOPP since 2009.
File Name	file://\\MOREL\G$\CA_Offshore_Wind\Data\Sara_Maxwell_data\Layer_packs\Leatherback_Sea_Turtle_EEZ\v103\masked_sm_rasters.gdb
Data Type	Raster
Spatial Extent	West Boundary -129.163686

	East Boundary -117.163686 North Boundary 49.042098 South Boundary 30.542098
Time Scale	June 2003 to January 2009
Contact/Source	Rebecca Degagne, Geospatial Scientist, The Conservation Biology Institute (541-368-5811) or Sara Maxwell, Associate Professor, University of Washington - Bothell Campus (smmax@uw.edu)
License/Use Restrictions	Data Basin, by the Conservation Biology Institute (CBI), is a public resource of user-contributed data about conservation issues. Any content including datasets, files, logos, and documents contributed by the user and any resulting data generated by such user belongs to the user, and CBI makes no claim to this content, nor does CBI provide any warranty to this content whatsoever. The Data Basin platform itself, and all related documentation, design, and graphic elements (the website as a whole) are the proprietary property of CBI, and CBI possesses all right and title. All of these Data Basin platform rights are reserved.
Citation Info	Maxwell, S. M. et al. Cumulative human impacts on marine predators. Nat. Commun. 4:2688 doi: 10.1038/ncomms3688 (2013)
Online Link	https://caoffshorewind.databasin.org/datasets/9bdddb86c6e04c13963bf0b421cc4027/
Metadata Link	https://caoffshorewind.databasin.org/datasets/9bdddb86c6e04c13963bf0b421cc4027/layers/9919230e0a2a43c58a8472bc9b5611f8/metadata/original/

Dataset Table 7.3. Leatherback Sea Turtle Distribution Model

Dataset Title	Leatherback Sea Turtle Distribution Model
Species/Resource	Leatherback sea turtles
Abstract	GAP distribution models represent the areas where species are predicted to occur based on habitat associations. GAP distribution models are the spatial arrangement of environments suitable for occupation by a species. In other words, a species distribution is created using a deductive model to predict areas suitable for occupation within a species range. To represent these suitable environments, GAP compiled existing GAP data, where available, and compiled additional data where needed. Existing data sources were the Southwest Regional Gap Analysis Project (SWReGAP) and the Southeast Gap Analysis Project (SEGAP) as well as a data compiled by Sanborn Solutions and Mason, Bruce and Girard. Habitat associations were based on land cover data of ecological systems and--when applicable for the given taxon--on ancillary variables such as elevation, hydrologic characteristics, human avoidance characteristics, forest edge, ecotone widths, etc. Distribution models were generated using a python script that selects model variables based on literature cited information stored in a wildlife habitat relationship database (WHRdb); literature used includes primary and gray publications. Distribution models are 30-meter raster data and delimited by GAP species ranges. Distribution model data were attributed with information regarding seasonal use based on GAP regional projects (NWGAP, SWReGAP, SEGAP, AKGAP, HIGAP, PRGAP, and USVIGAP), NatureServe data, and IUCN data.
Strength/Weakness	The map viewer for this dataset in the California Offshore Wind Energy Gateway shows that leatherback sea turtles are spread widely along the California coast, which is actually the “range” depicted by USGS in their range map

	(https://www.sciencebase.gov/catalog/item/imap/59f5ec32e4b063d5d307e4f5). Another report on this data is the USGS Species Habitat Model Report for leatherback sea turtles, which shows clusters of leatherback sea turtle's distribution, which does not include the HWEA. The Habitat Model Report can be downloaded at: https://gapanalysis.usgs.gov/apps/species-data-download/. Most of the links that are listed for this dataset in the California Offshore Wind Energy Gateway are no longer valid. For example, the Gateway notes that a full report documenting the parameters used in the Leatherback Sea Turtle model can be found at: http://dingo.gapanalysisprogram.com/SpeciesViewer/ModelReport.ashx?species=rleatx, but this link is no longer accessible. The USGS provides a recommendation that the user should acquire these data directly from the USGS Gap Analysis Program server, and not indirectly through other sources, which may have modified the data in some way. USGS also strongly recommends that careful attention be paid to the contents of the metadata file associated with these data. Other recommendations on data uses can be found in the "Use Constraints" section of this dataset on the California Offshore Wind Energy Gateway.
File Name	Leatherback Sea Turtle Distribution Model
Data Type	Raster shape files. Species habitat and range maps are also available in an Open Geospatial Consortium (OGC) Web Map Service (WMS) at: http://gis1.usgs.gov/ArcGIS/rest/services/NAT_Species_Reptiles/rleatx/MapServer
Spatial Extent	U.S. West Coast
Time Scale	Not specified in the California Offshore Wind Energy Gateway, but the USGS report the state date of the data as 2008 and the end date is 2013
Contact/Source	Dr. Alexa J. McKerrow, Biologist, USGS Science Analytics and Synthesis; (571) 218-5474; amckerrow@usgs.gov
License/Use Restrictions	Data Basin, by the Conservation Biology Institute (CBI), is a public resource of user-contributed data about conservation issues. Any content including datasets, files, logos, and documents contributed by the user and any resulting data generated by such user belongs to the user, and CBI makes no claim to this content, nor does CBI provide any warranty to this content whatsoever. The Data Basin platform itself, and all related documentation, design, and graphic elements (the website as a whole) are the proprietary property of CBI, and CBI possesses all right and title. All of these Data Basin platform rights are reserved.
Citation Info	U.S. Geological Survey Gap Analysis Program (USGS-GAP). 2013. National Species Distribution Models.
Online Link	https://www.sciencebase.gov/catalog/item/58fe19e6e4b0f87f0854ad61 for the Habitat Map and https://www.sciencebase.gov/catalog/item/59f5ec32e4b063d5d307e4f5 for the Range Report
Metadata Link	https://www.usgs.gov/programs/gap-analysis-project/science/species-data-download

Dataset Table 7.4. Leatherback Sea Turtle Resource Data

Dataset Title	Sensitivity of Coastal Environments and Wildlife to Spilled Oil: Central California: REPTILES (Reptile and Amphibian Polygons)
Species/Resource	Sea turtles (Cheloniidae and Dermochelyidae)

Abstract	This data set contains sensitive biological resource data for amphibians and reptiles in Central California. Vector polygons in this data set represent sea turtle distribution and rare reptile and amphibian species occurrences. Species-specific abundance, seasonality, status, life history, and source information are stored in relational data tables (described below) designed to be used in conjunction with this spatial data layer. This data set comprises a portion of the Environmental Sensitivity Index (ESI) data for Central California. ESI data characterize the marine and coastal environments and wildlife by their sensitivity to spilled oil. The ESI data include information for three main components: shoreline habitats, sensitive biological resources, and human-use resources. See also the REPTILEL (Reptile and Amphibian Lines) data layer, part of the larger Central California ESI database, for additional amphibian and reptile information.
Strength/Weakness	Spatial extent indicates that the data extend throughout California but the abstract only references Central California. Also, based on information in the metadata file, the sea turtle data are based on personal information and unpublished sources. This is also a dataset in the California Offshore Wind Energy Gateway that is entitled, "Leatherback Sea Turtle Presence, Northern California ESI," but there is limited granularity; the map shows that leatherback sea turtles are present all months of the year along the California coast.
File Name	Not known.
Data Type	Vector (polygon) with associated tables
Spatial Extent	Northern Baja California to southern British Columbia; 38.125 -123.5 -120.375 34.217
Time Scale	Data from 1999-2006; published in 2006
Contact/Source	National Oceanic and Atmospheric Administration (2006) National Ocean Service, Office of Response and Restoration, Hazardous Materials Response Division, Seattle Washington
License/Use Restrictions	There are restrictions and legal prerequisites for using the data set after access is granted.
Citation Info	Unpublished or personal communication
Online Link	https://response.restoration.noaa.gov/sites/default/files/esimaps/gisdata/CentralCal_2006_GDB.zip
Metadata Link	https://response.restoration.noaa.gov/sites/default/files/esimaps/gisdata/CentralCal_2006_Meta.pdf (starting on page 272)

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APPENDIX A: MARINE MAMMAL MAPS (Becker et al. 2020)

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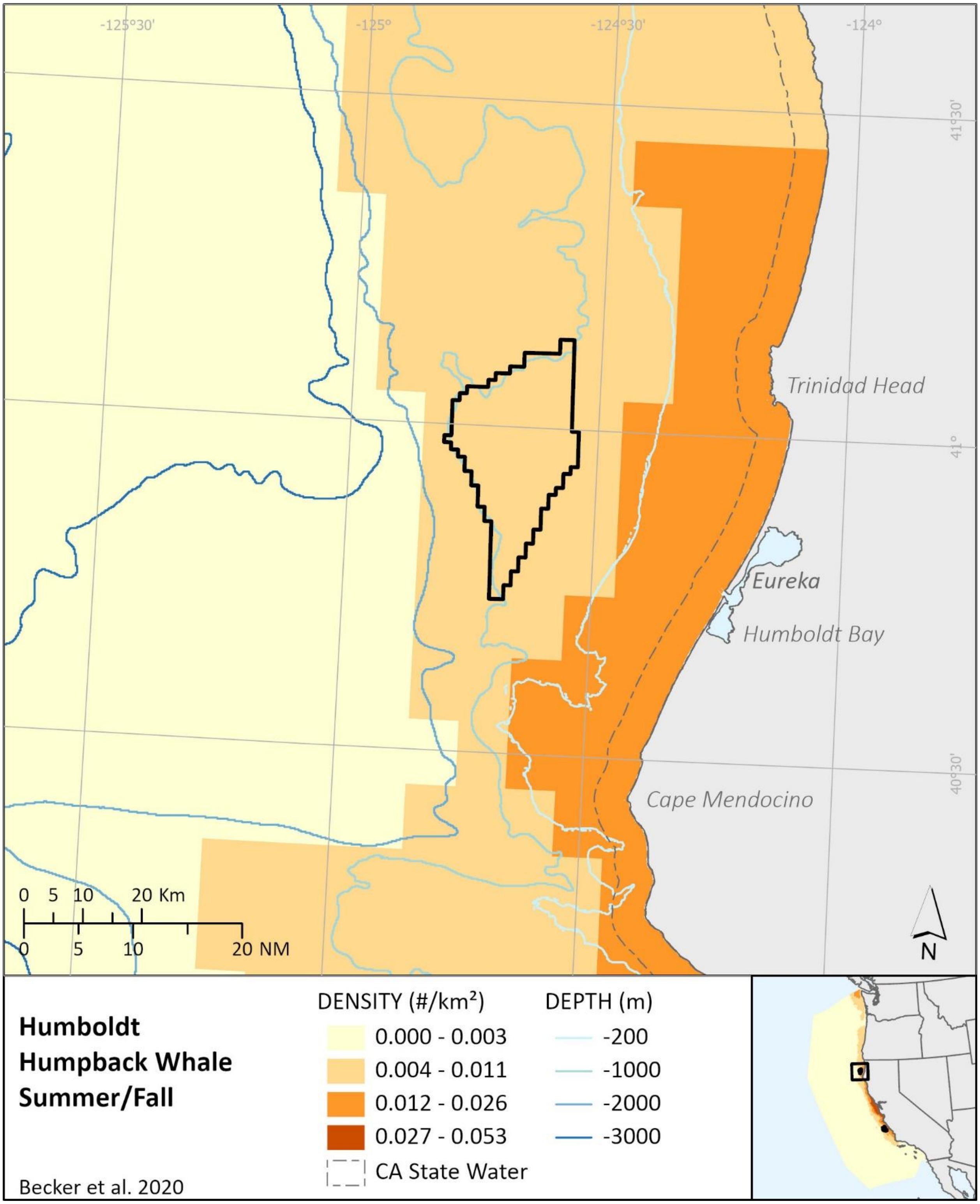

Figure A.1. Humpback whale summer/fall predicted density/distribution in/near the HWEA.

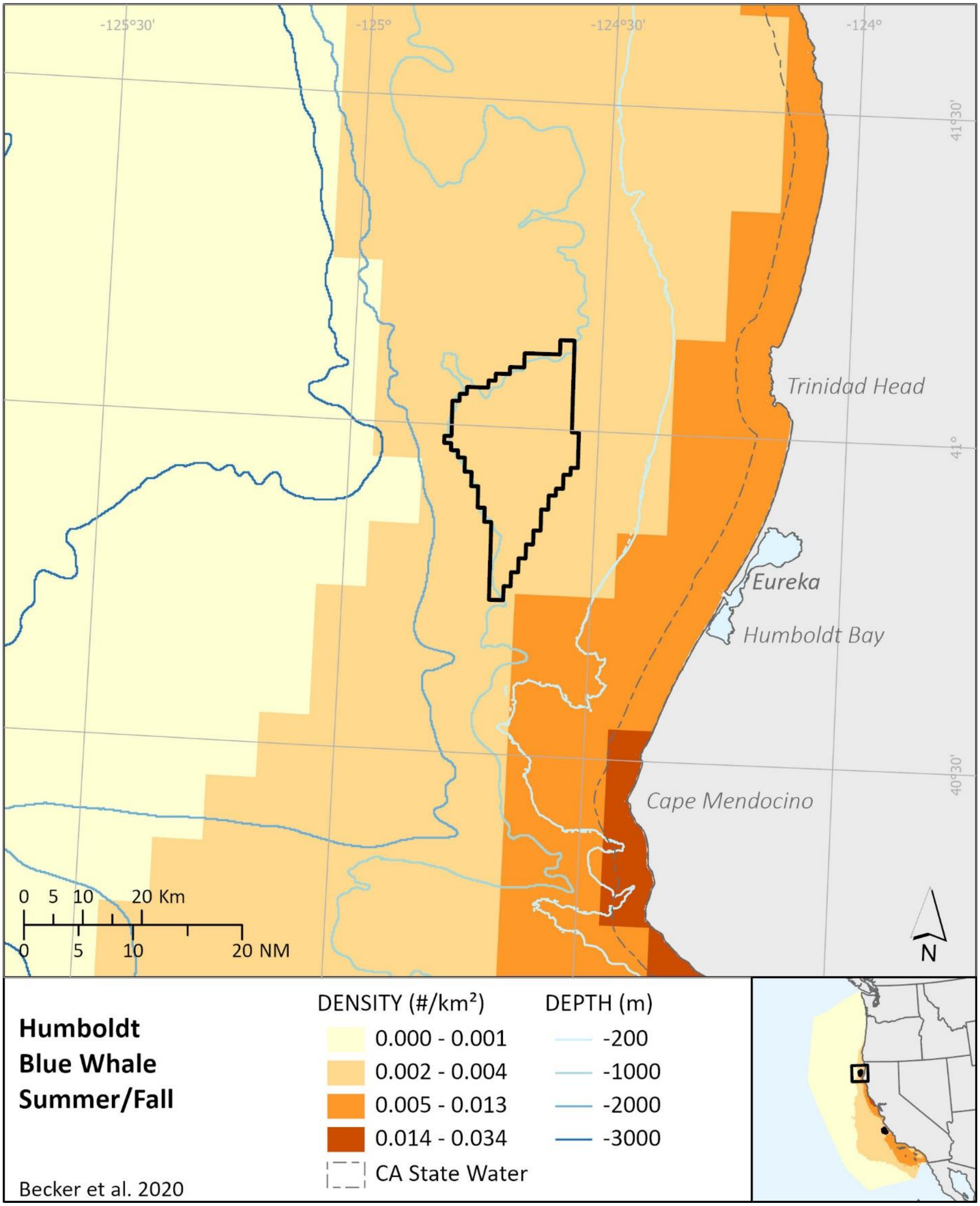

Figure A.2. Blue whale summer/fall predicted density/distribution in/near the HWEA.

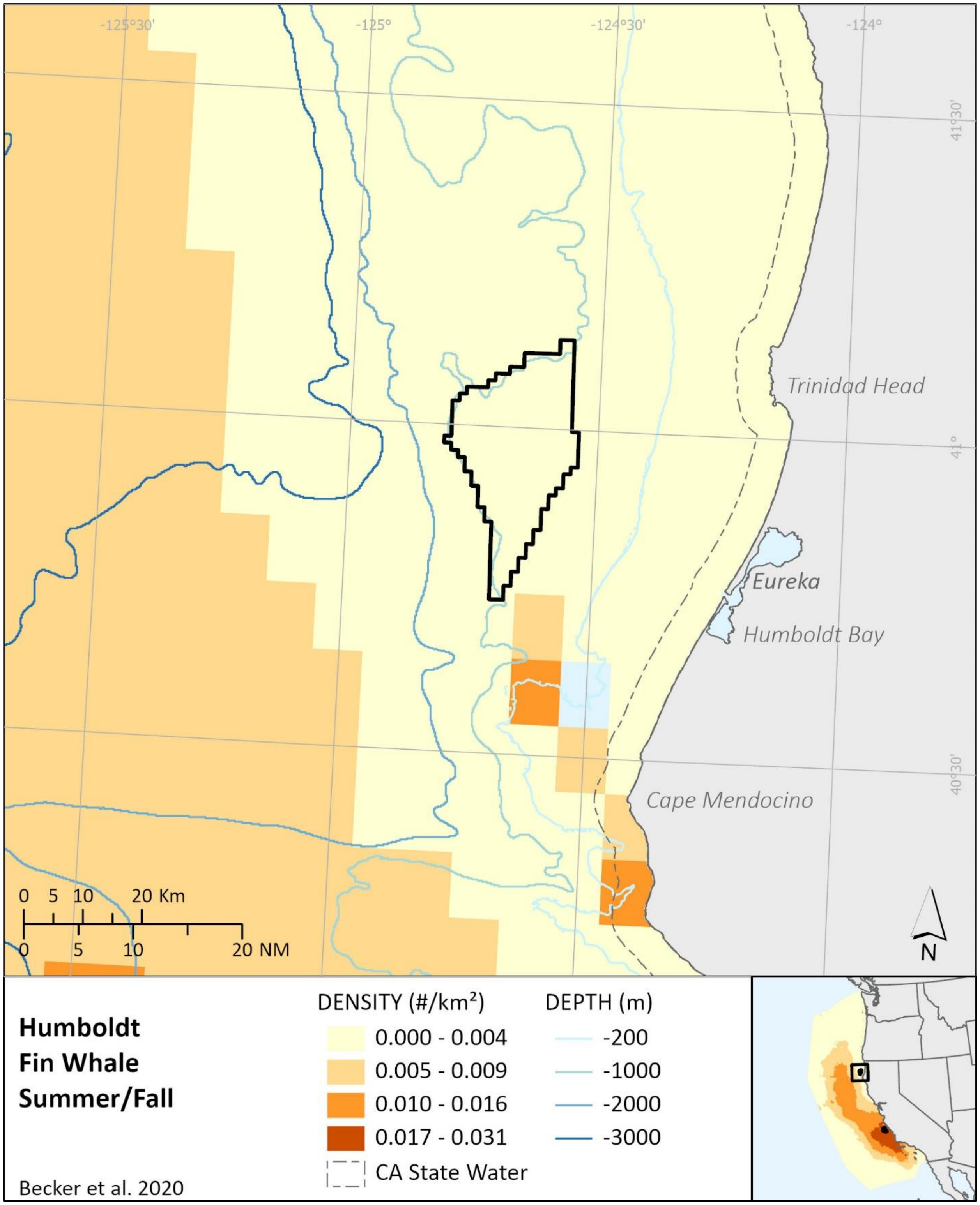

Figure A.3. Fin whale summer/fall predicted density/distribution in/near the HWEA.

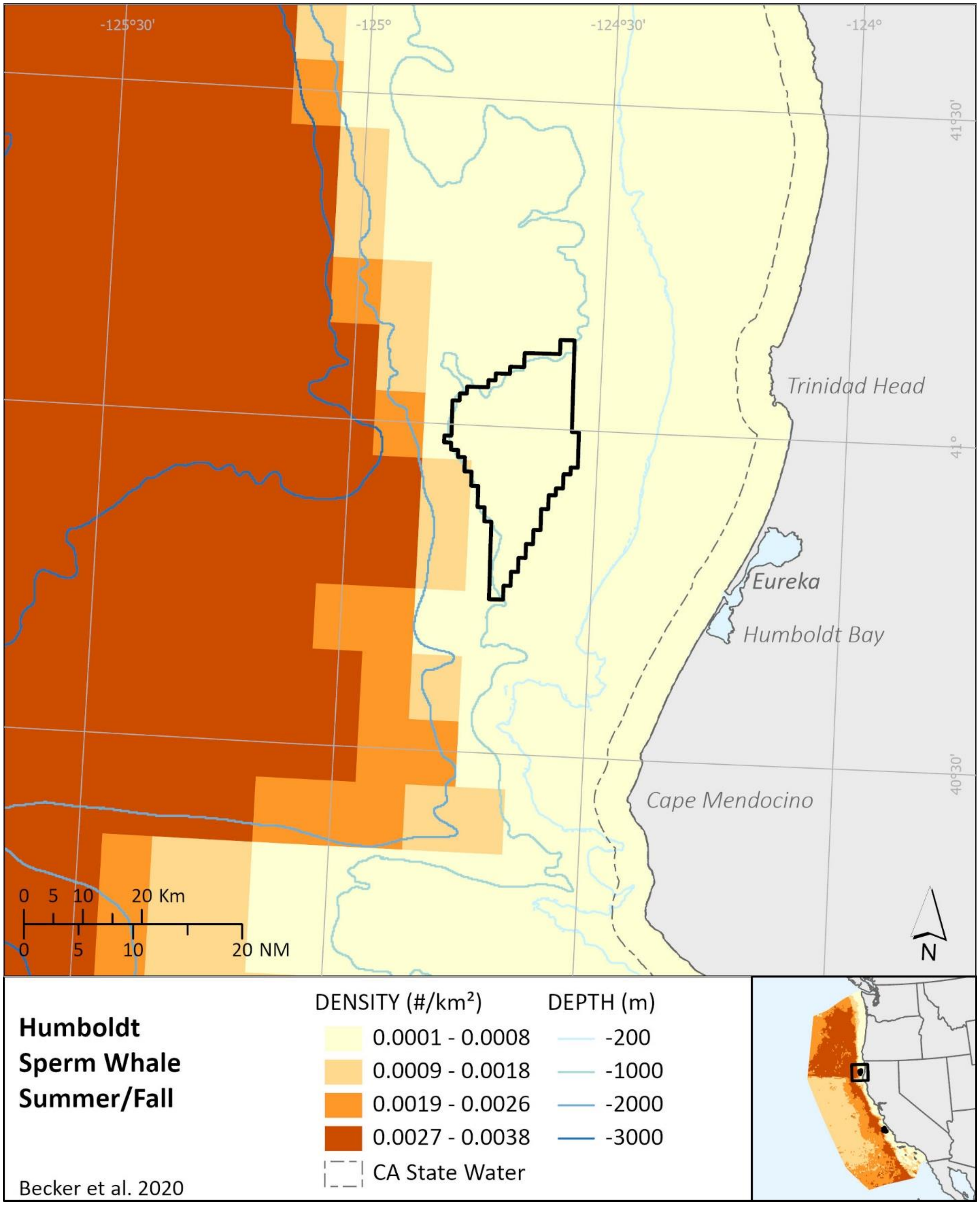

Figure A.4. Sperm whale summer/fall predicted density/distribution in/near the HWEA.

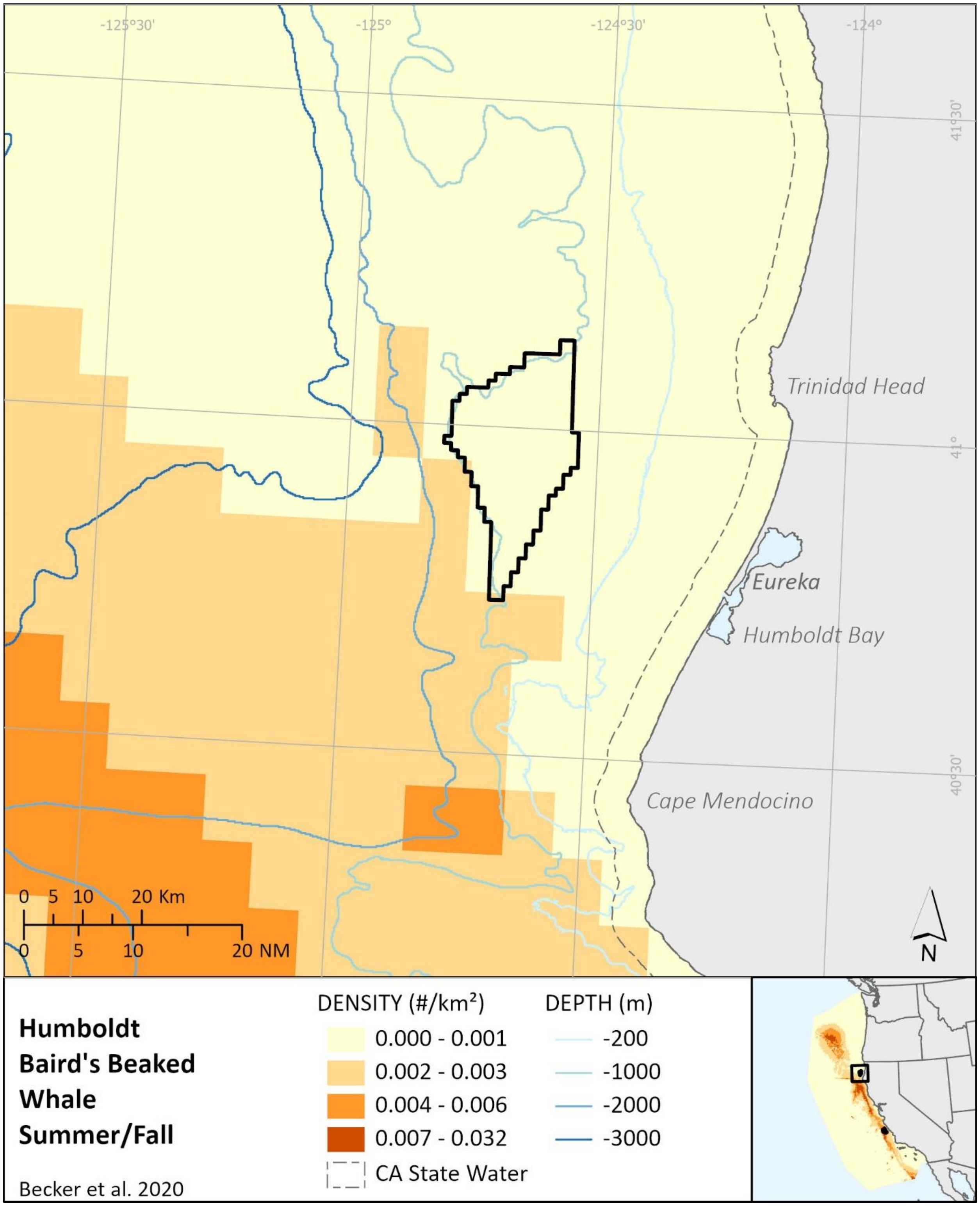

Figure A.5. Baird's beaked whale summer/fall predicted density/distribution in/near the HWEA.

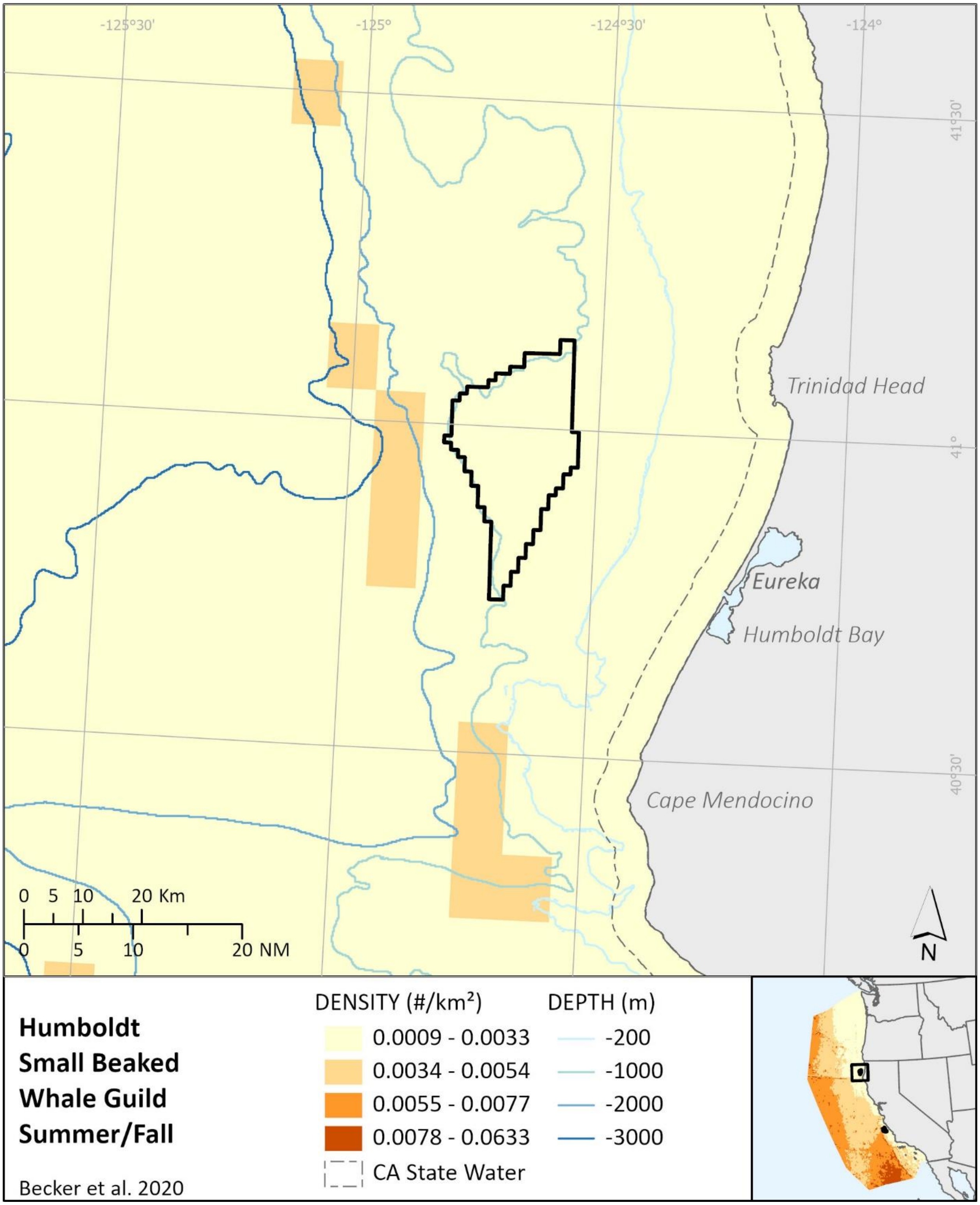

Figure A.6. Small beaked whale guild summer/fall predicted density/distribution in/near the HWEA.

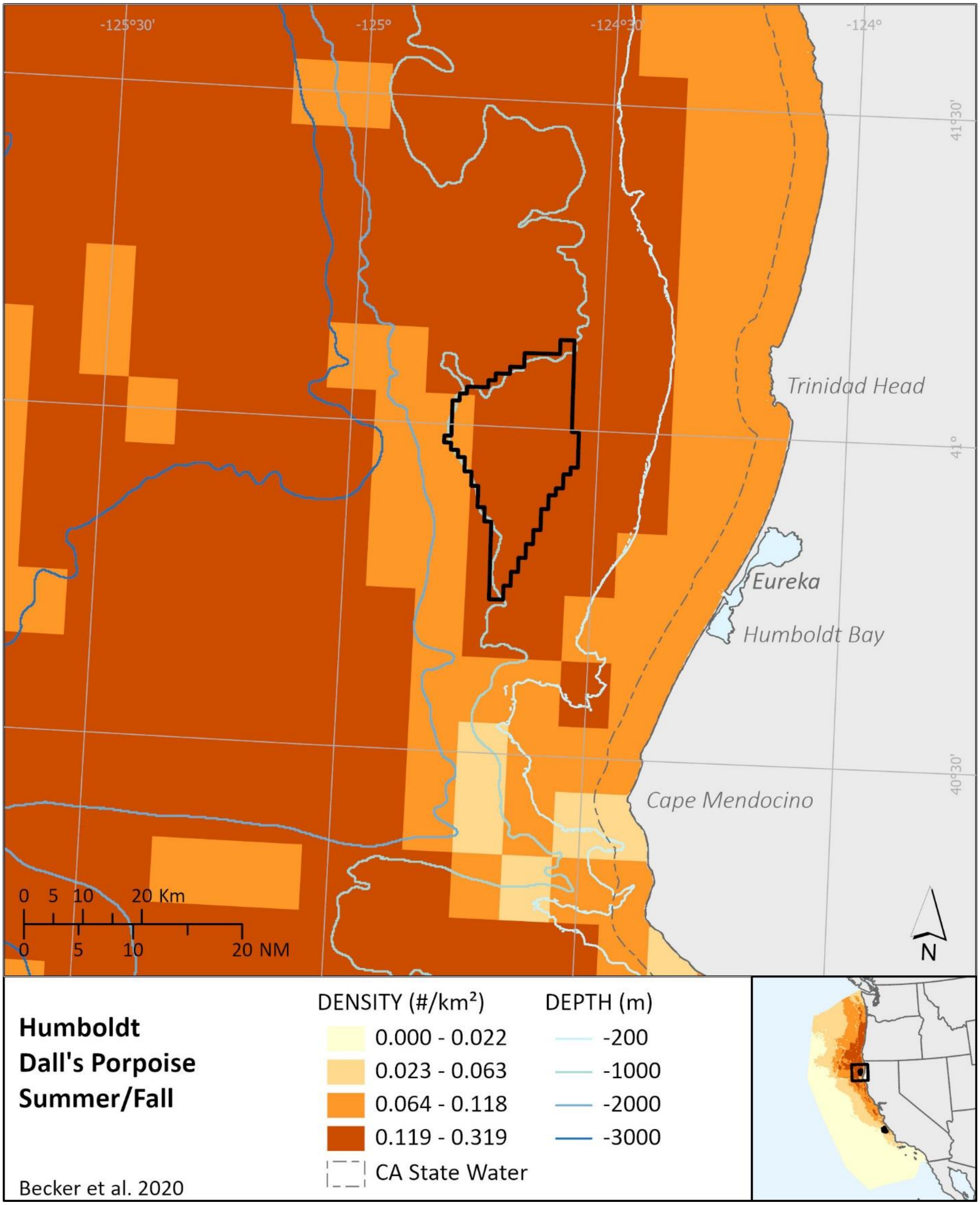

Figure A.7. Dall’s porpoise summer/fall predicted density/distribution in/near the HWEA.

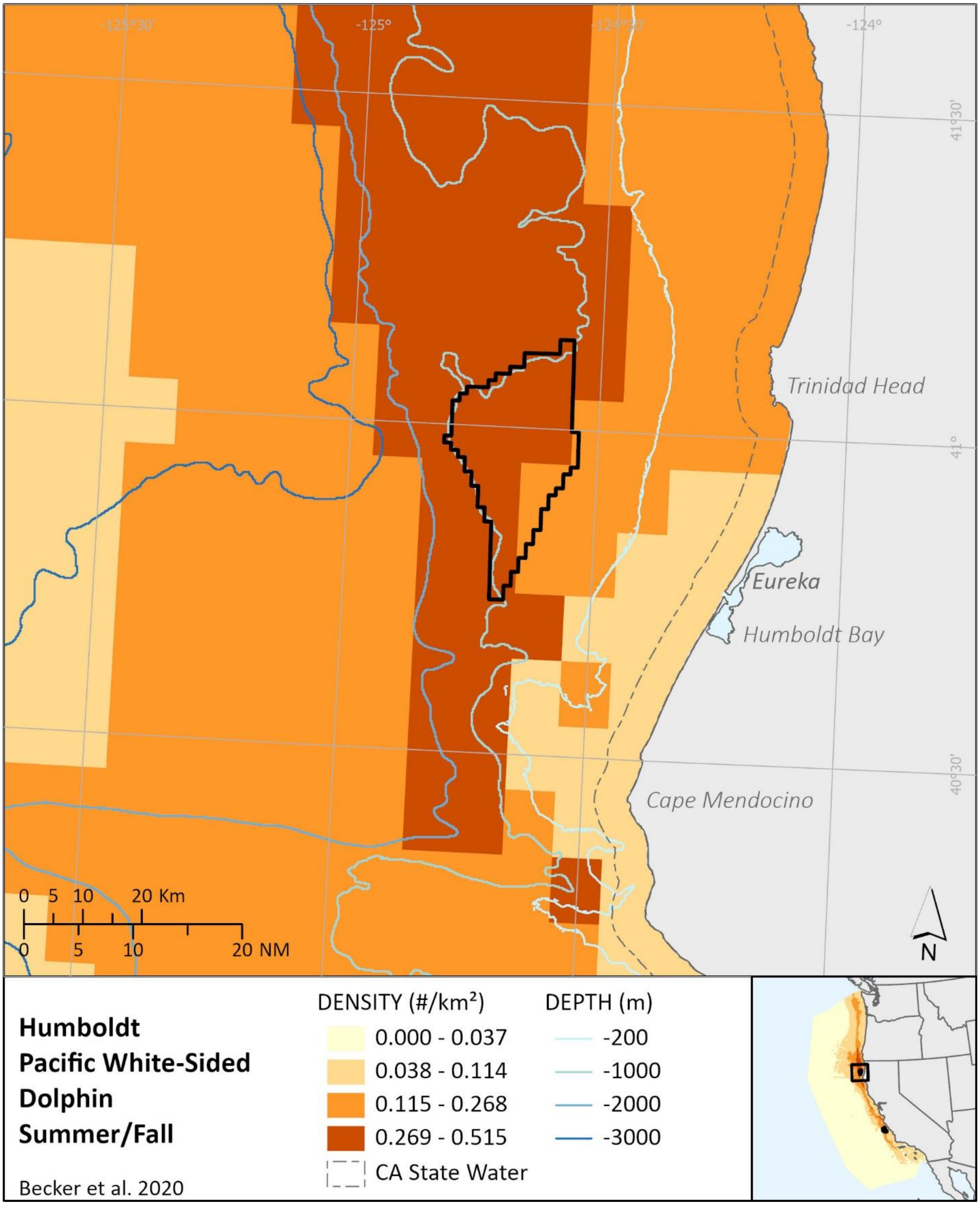

Figure A.8. Pacific white-sided dolphin summer/fall predicted density/distribution in/near the HWEA.

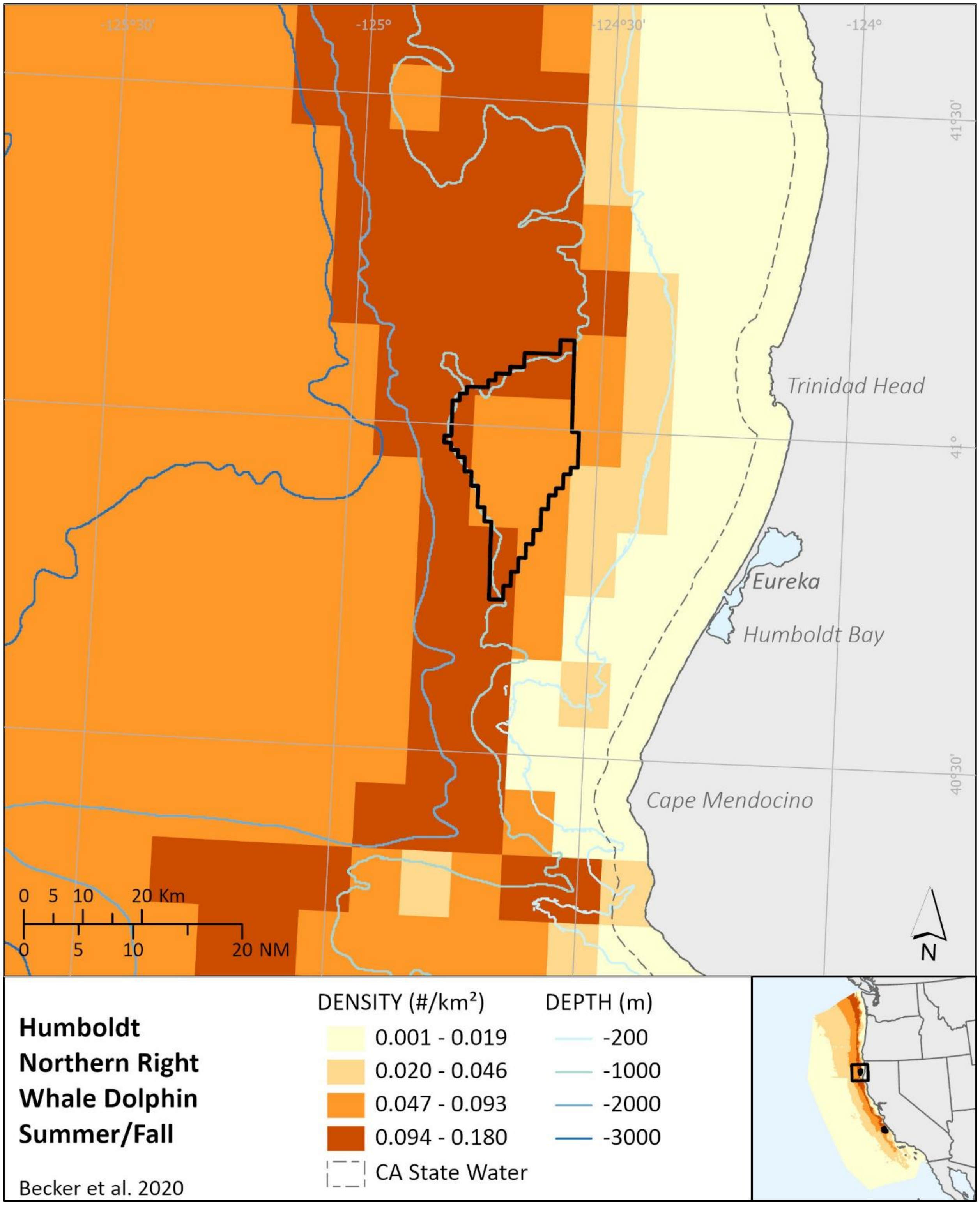

Figure A.9. Northern right whale dolphin summer/fall predicted density/distribution in/near the HWEA.

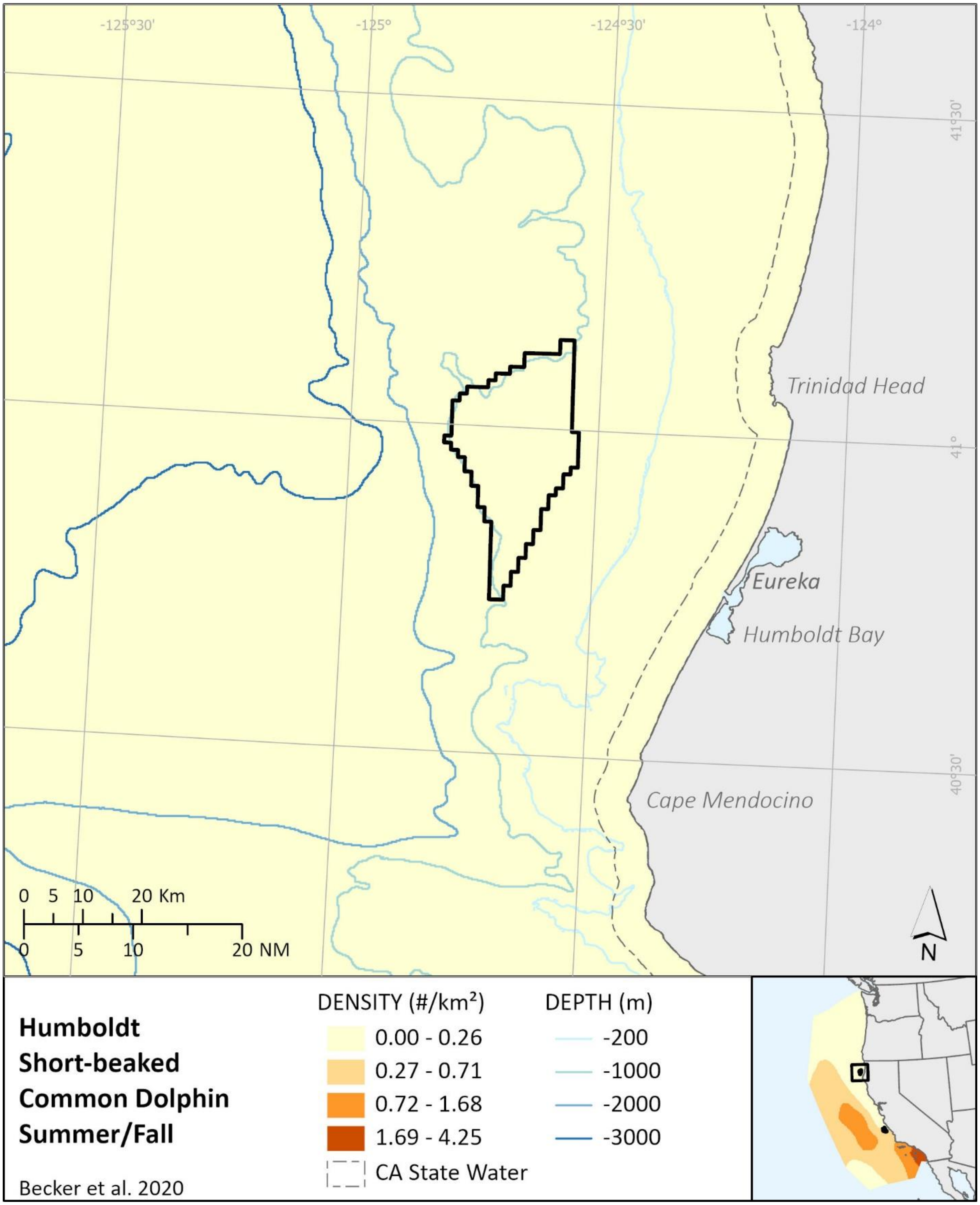

Figure A.10. Short-beaked common dolphin summer/fall predicted density/distribution in/near the HWEA.

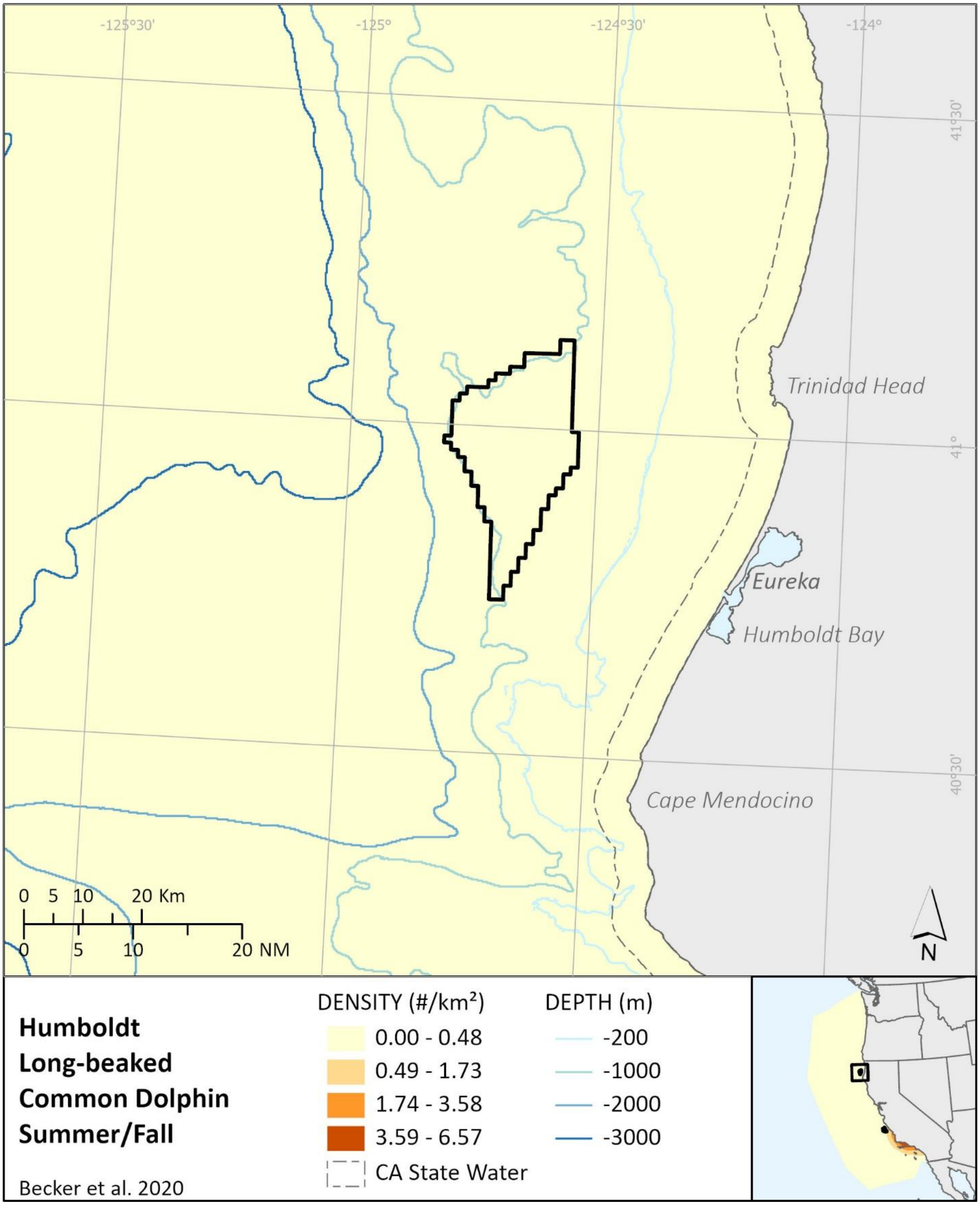

Figure A.11. Long-beaked common dolphin summer/fall predicted density/distribution in/near the HWEA.

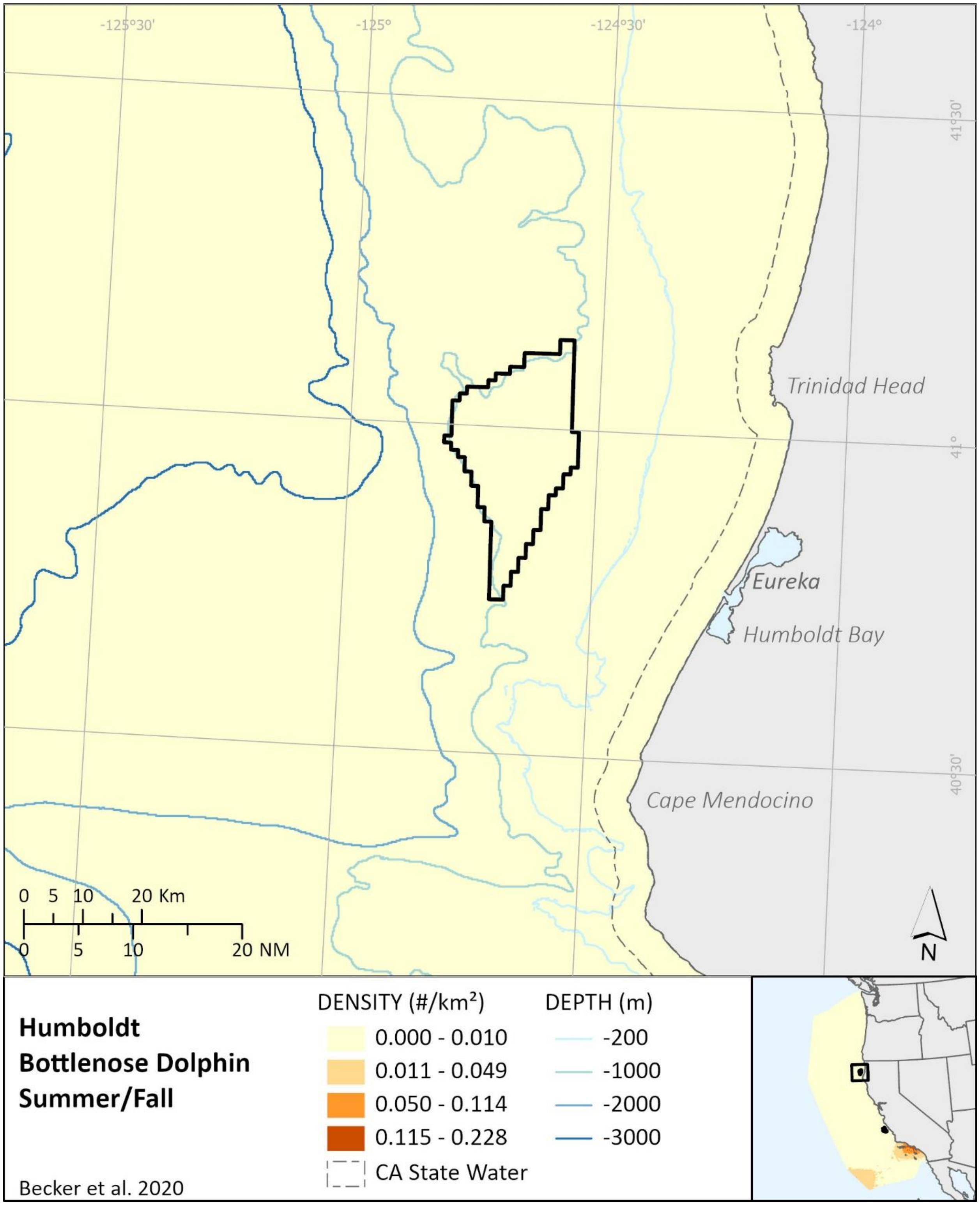

Figure A.12. Bottlenose dolphin summer/fall predicted density/distribution in/near the HWEA.

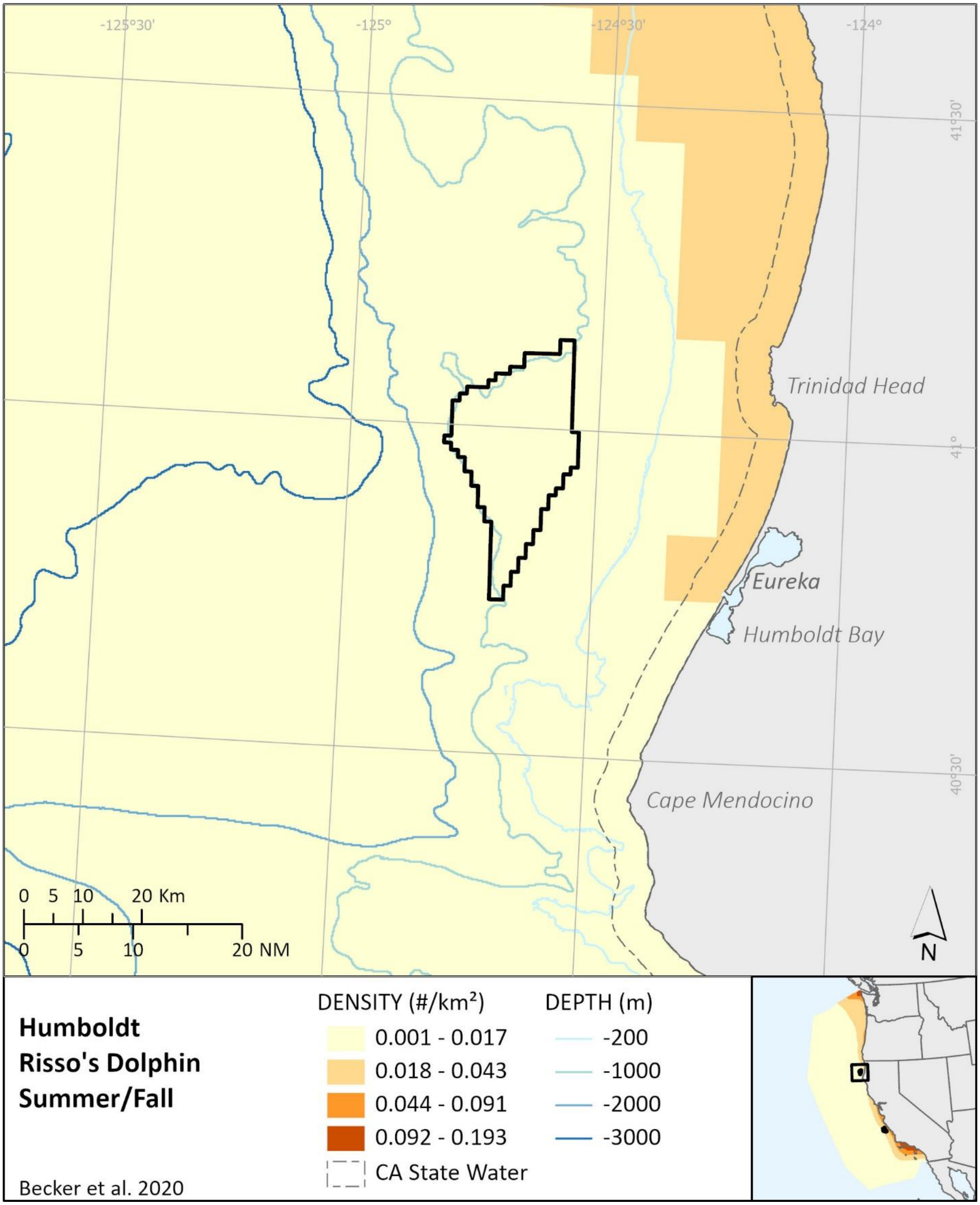

Figure A.13. Risso's dolphin summer/fall predicted density/distribution in/near the HWEA.

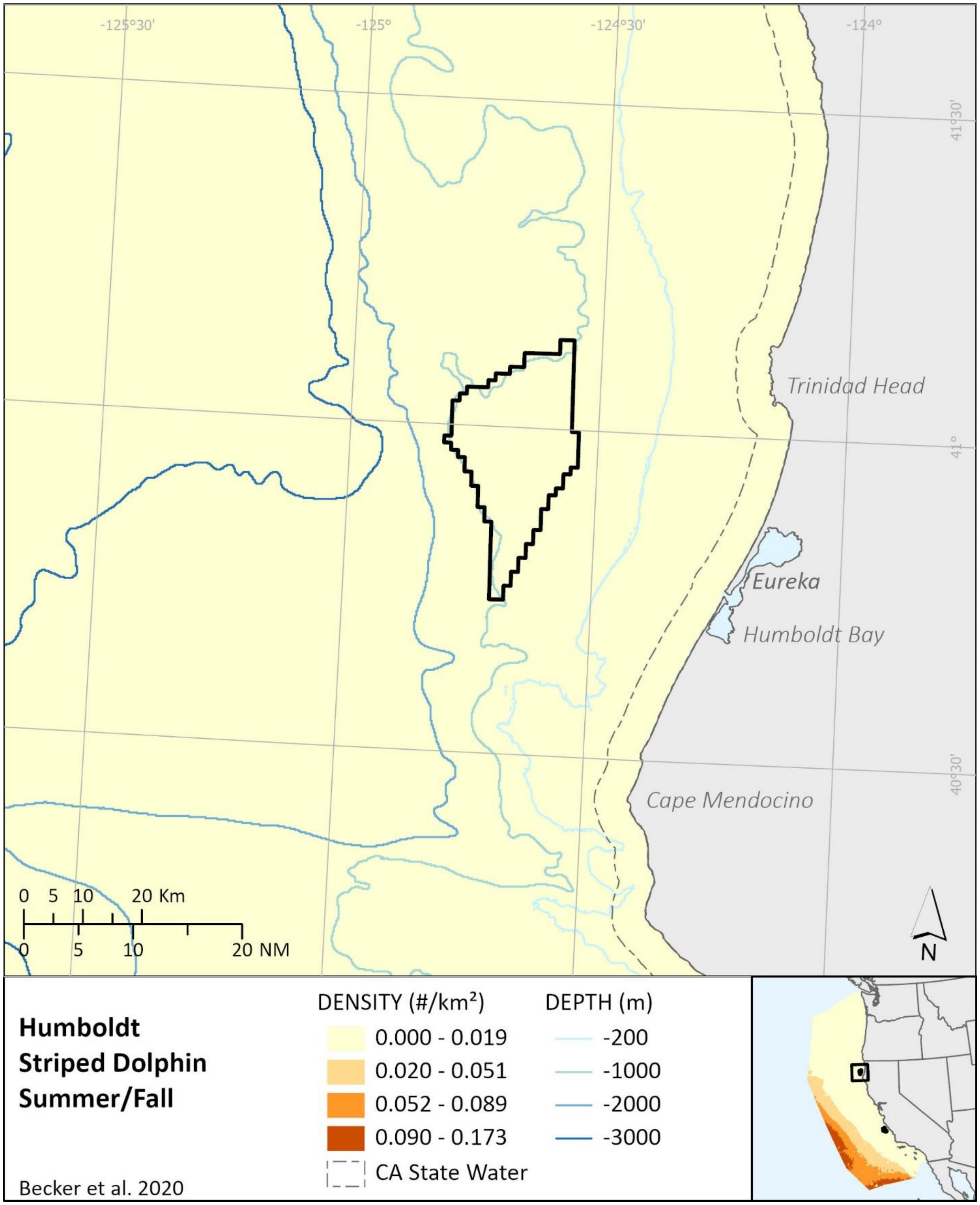

Figure A.14. Striped dolphin summer/fall predicted density/distribution in/near the HWEA.

APPENDIX B: SEABIRD MAPS (Dick 2016)

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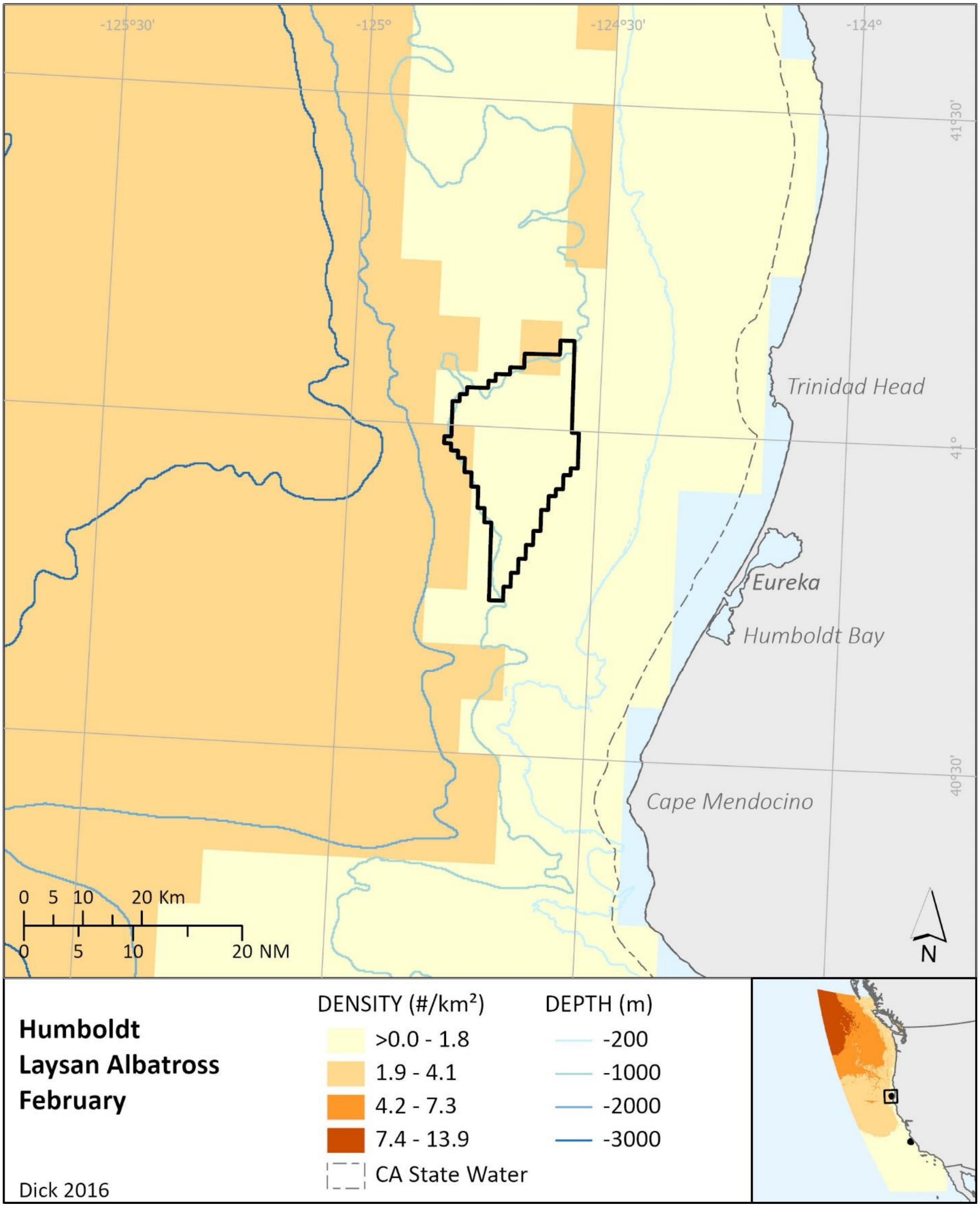

Figure B.1. Laysan albatross winter predicted density/distribution in/near the HWEA.

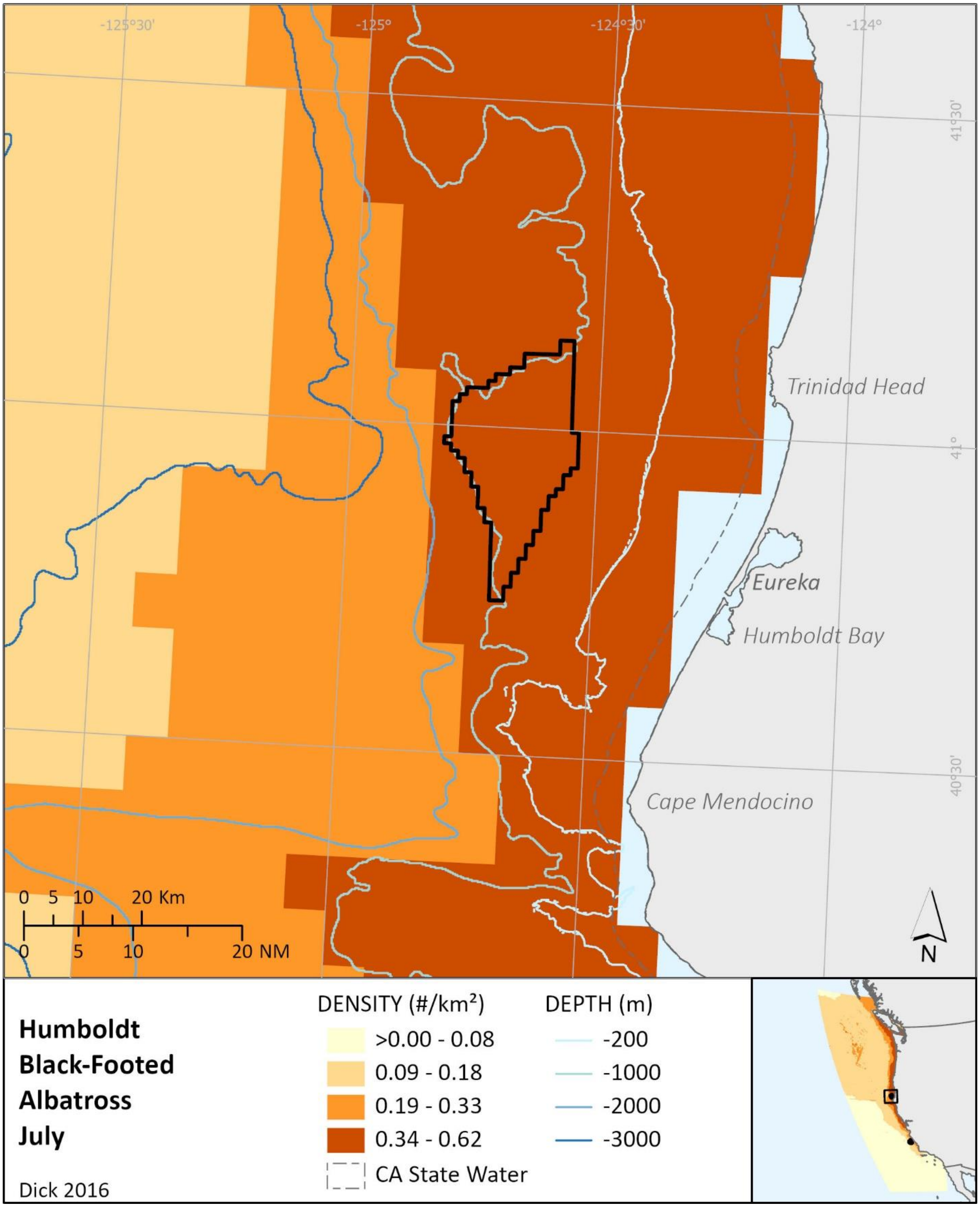

Figure B.2. Black-footed albatross summer predicted density/distribution in/near the HWEA.

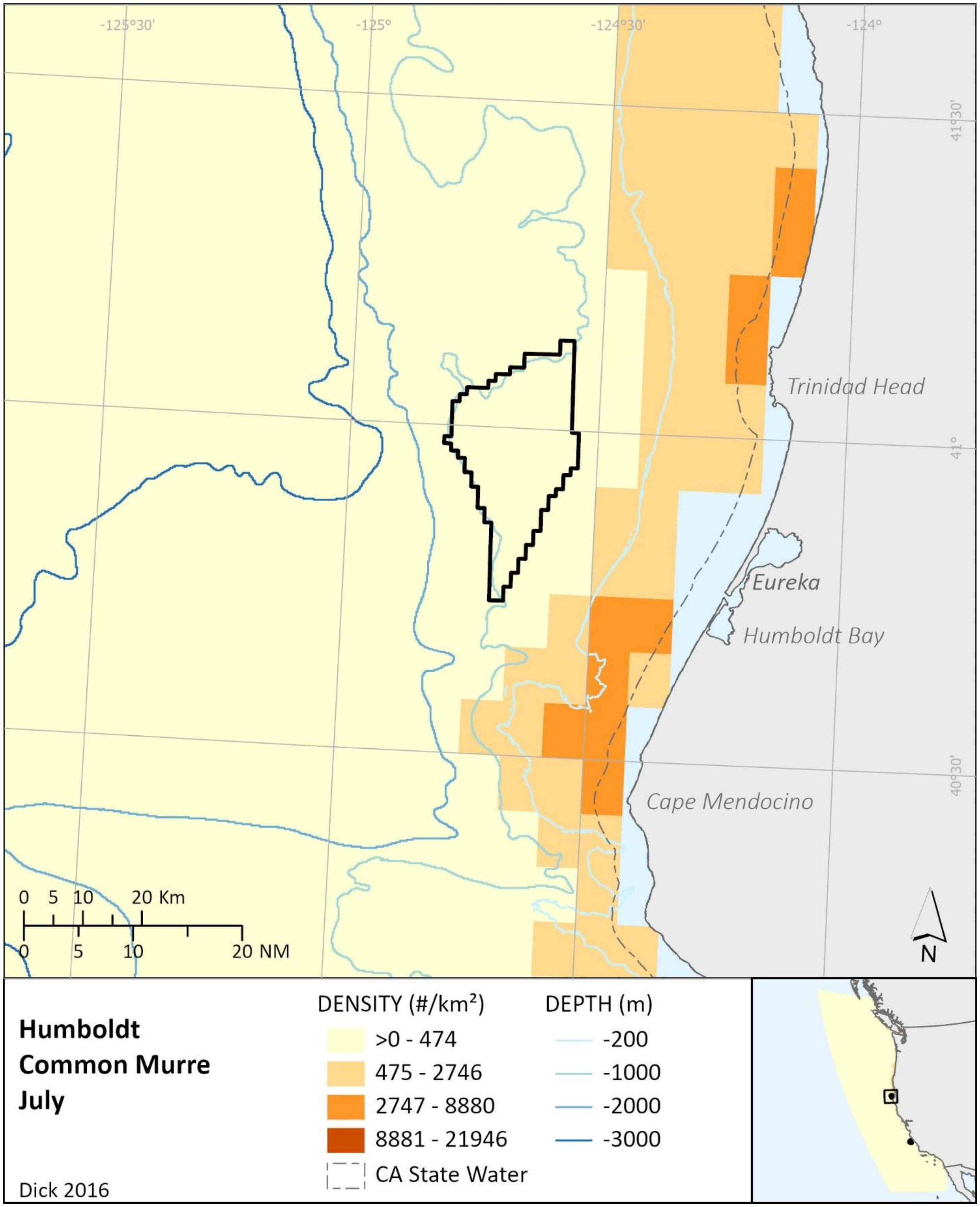

Figure B.3. Common murre summer predicted density/distribution in/near the HWEA.

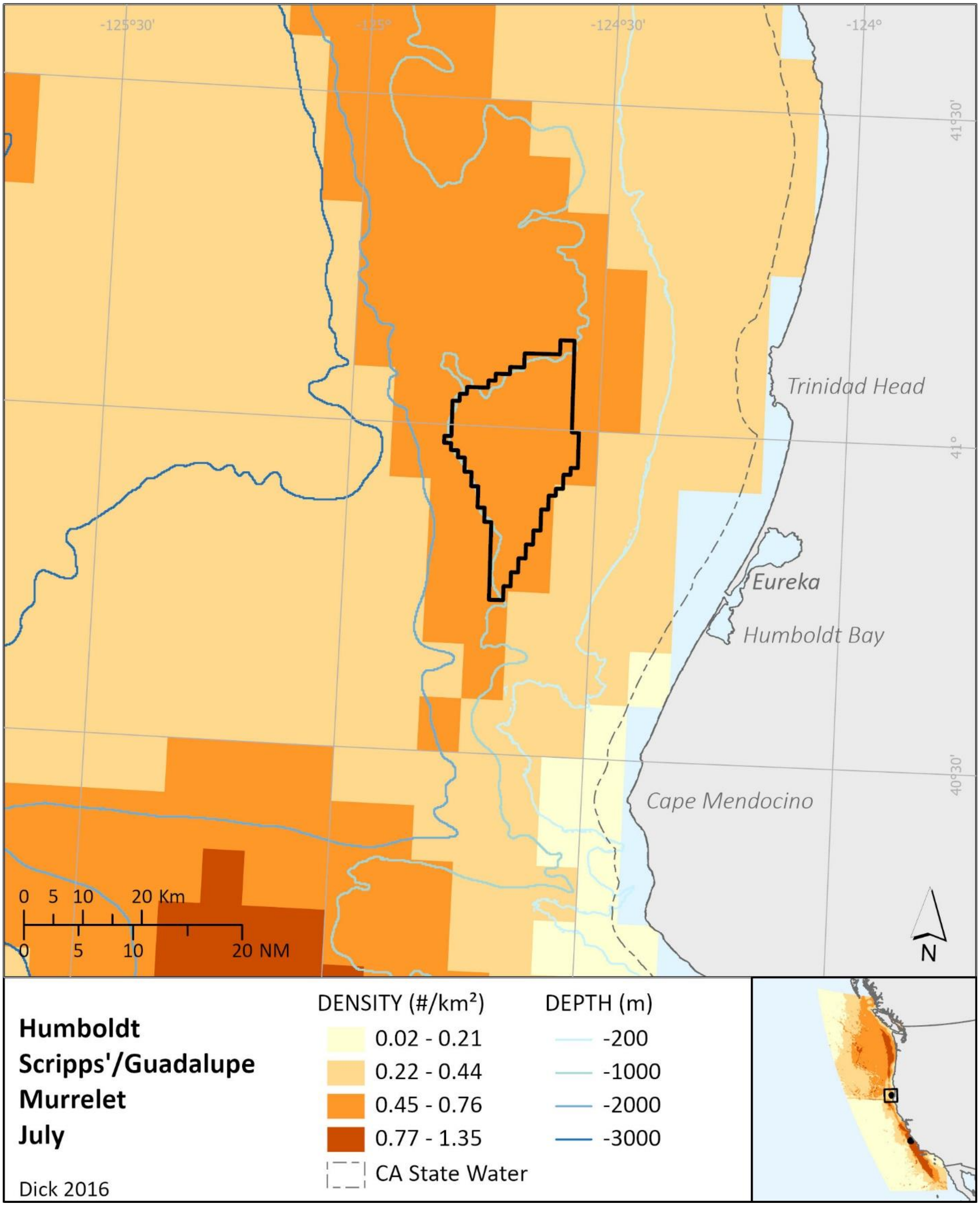

Figure B.4. Scripps's/Guadalupe murrelet (Xantus's murrelet) summer predicted density/distribution in/near the HWEA.

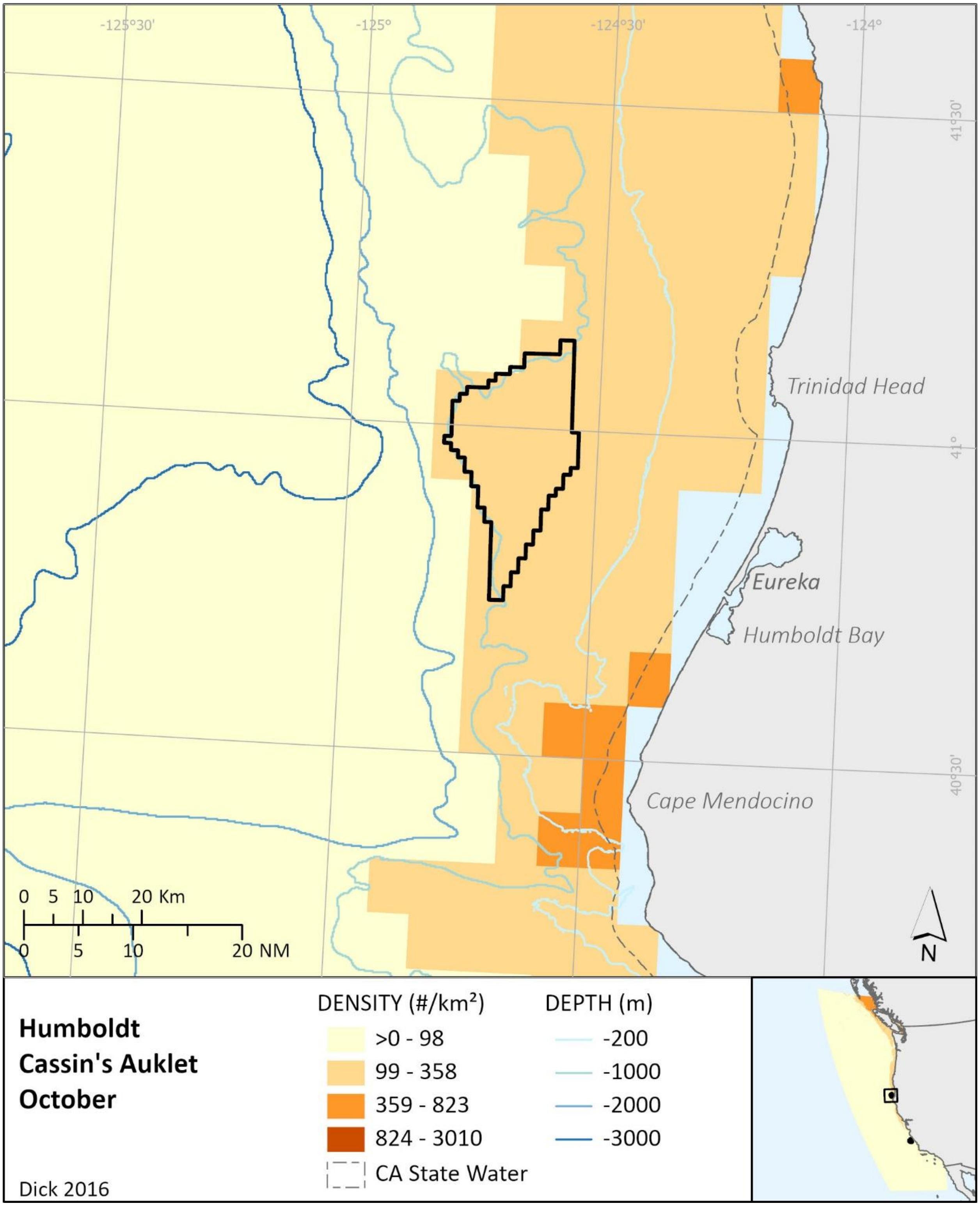

Figure B.5. Cassin's auklet fall predicted density/distribution in/near the HWEA.

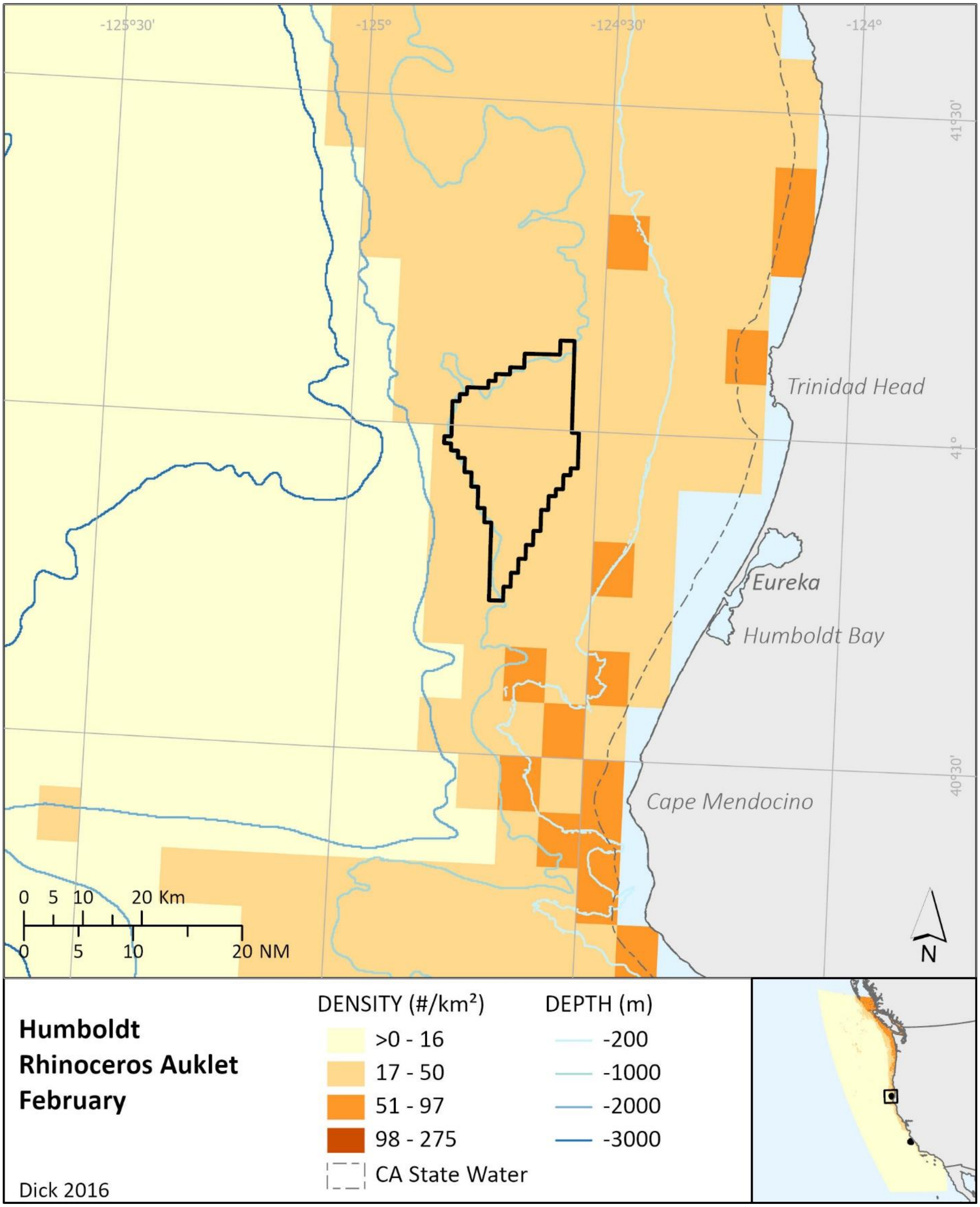

Figure B.6. Rhinoceros auklet winter predicted density/distribution in/near the HWEA.

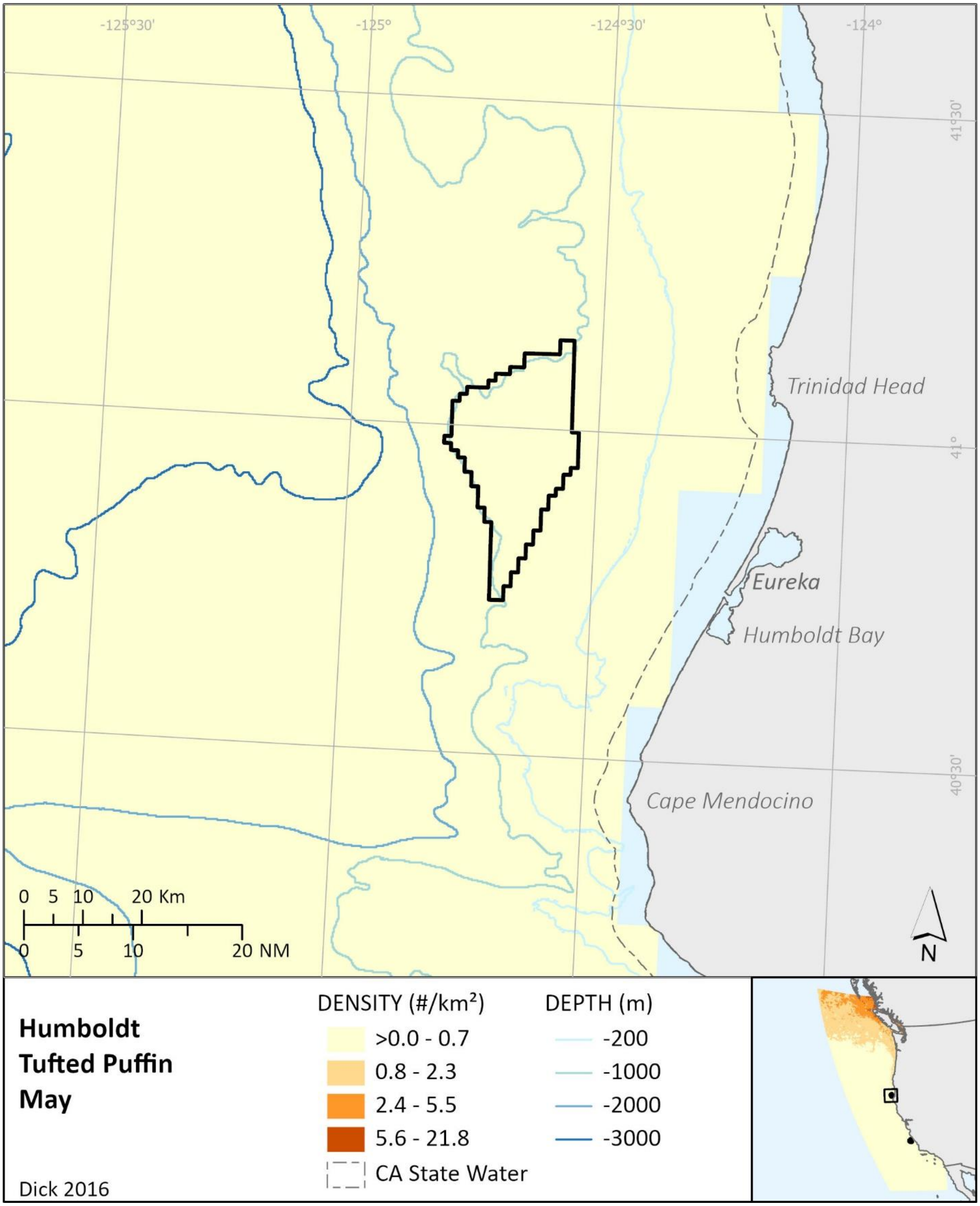

Figure B.7. Tufted puffin spring predicted density/distribution in/near the HWEA.

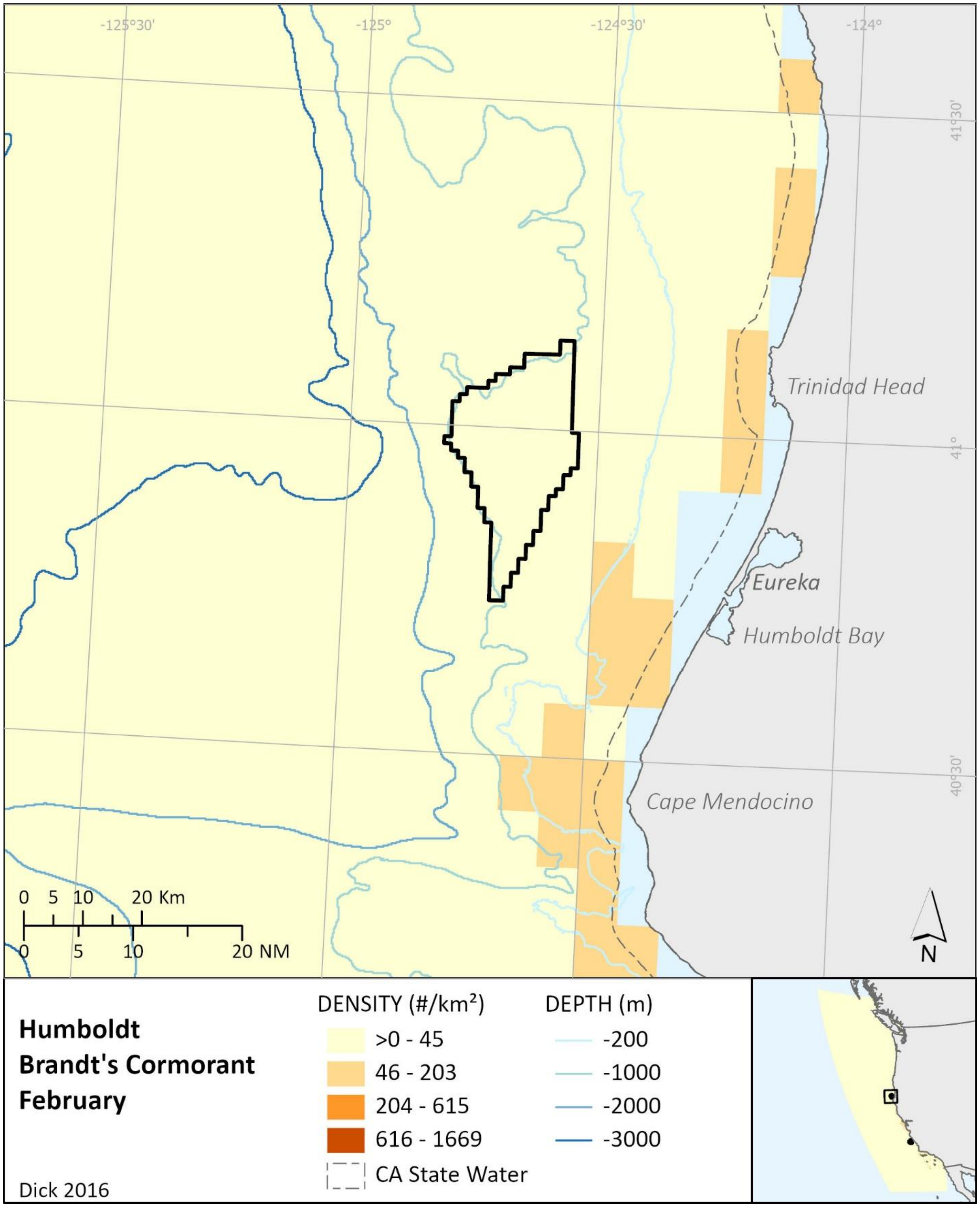

Figure B.8. Brandt's cormorant winter predicted density/distribution in/near the HWEA.

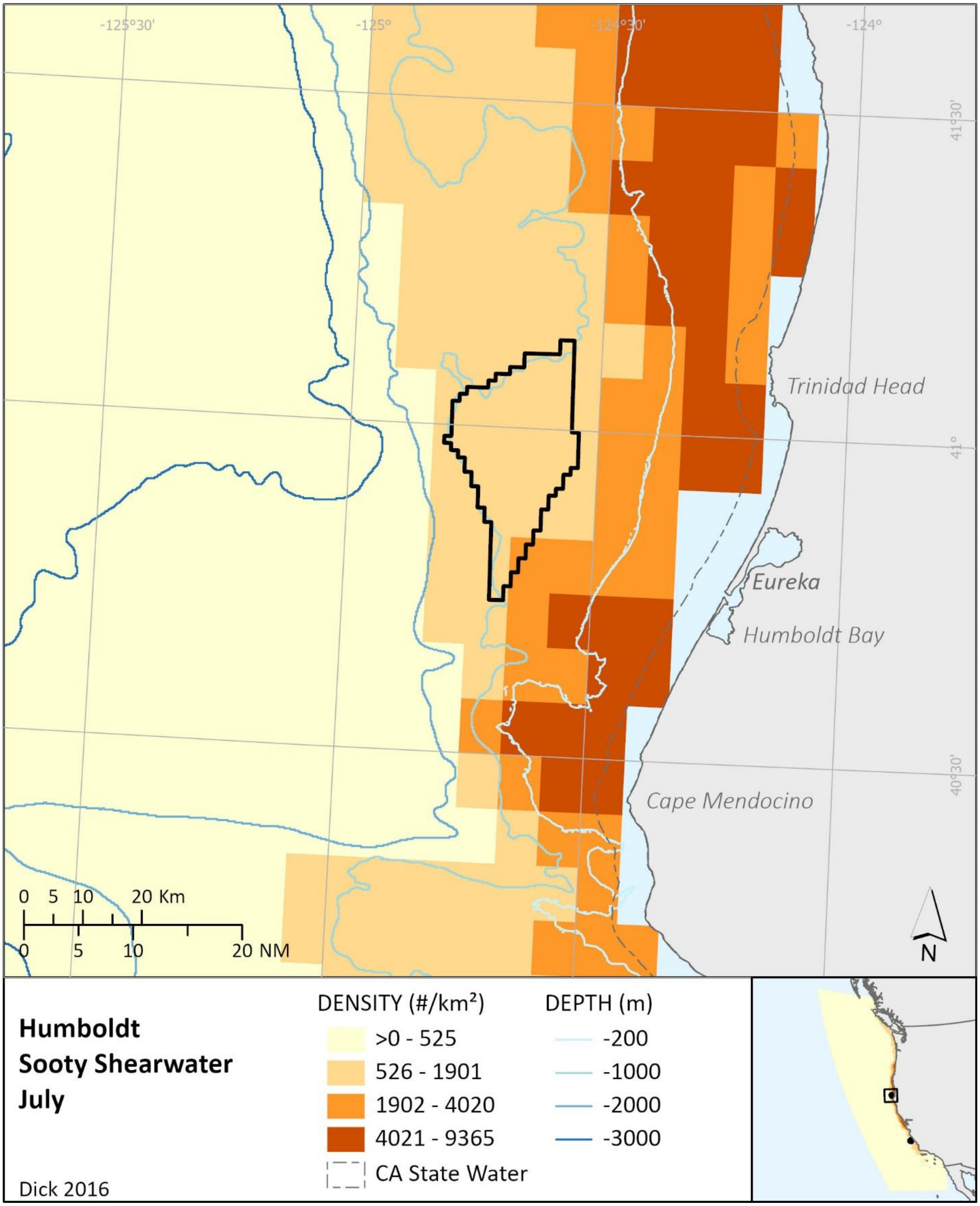

Figure B.9. Sooty shearwater summer predicted density/distribution in/near the HWEA.

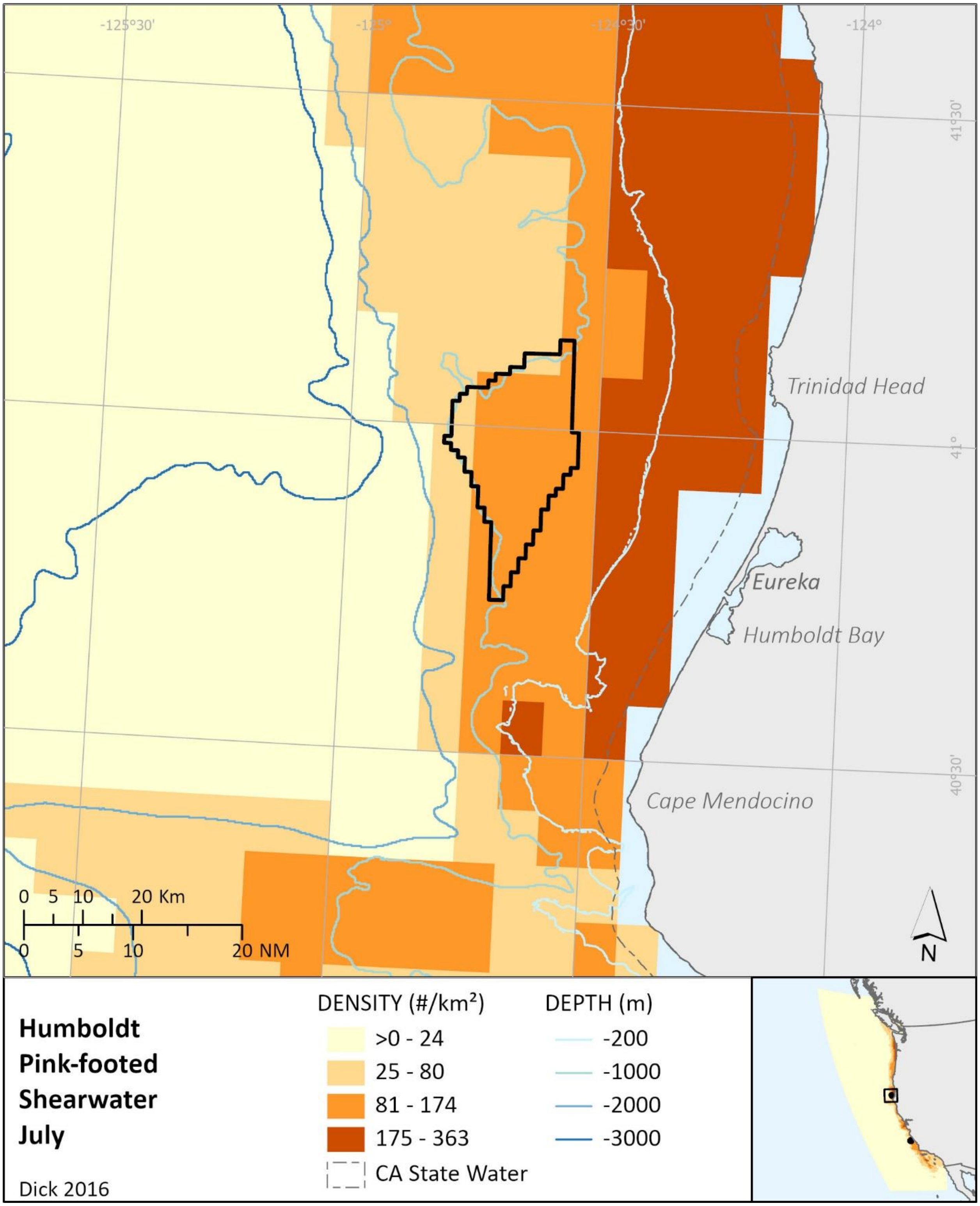

Figure B.10. Pink-footed shearwater summer predicted density/distribution in/near the HWEA.

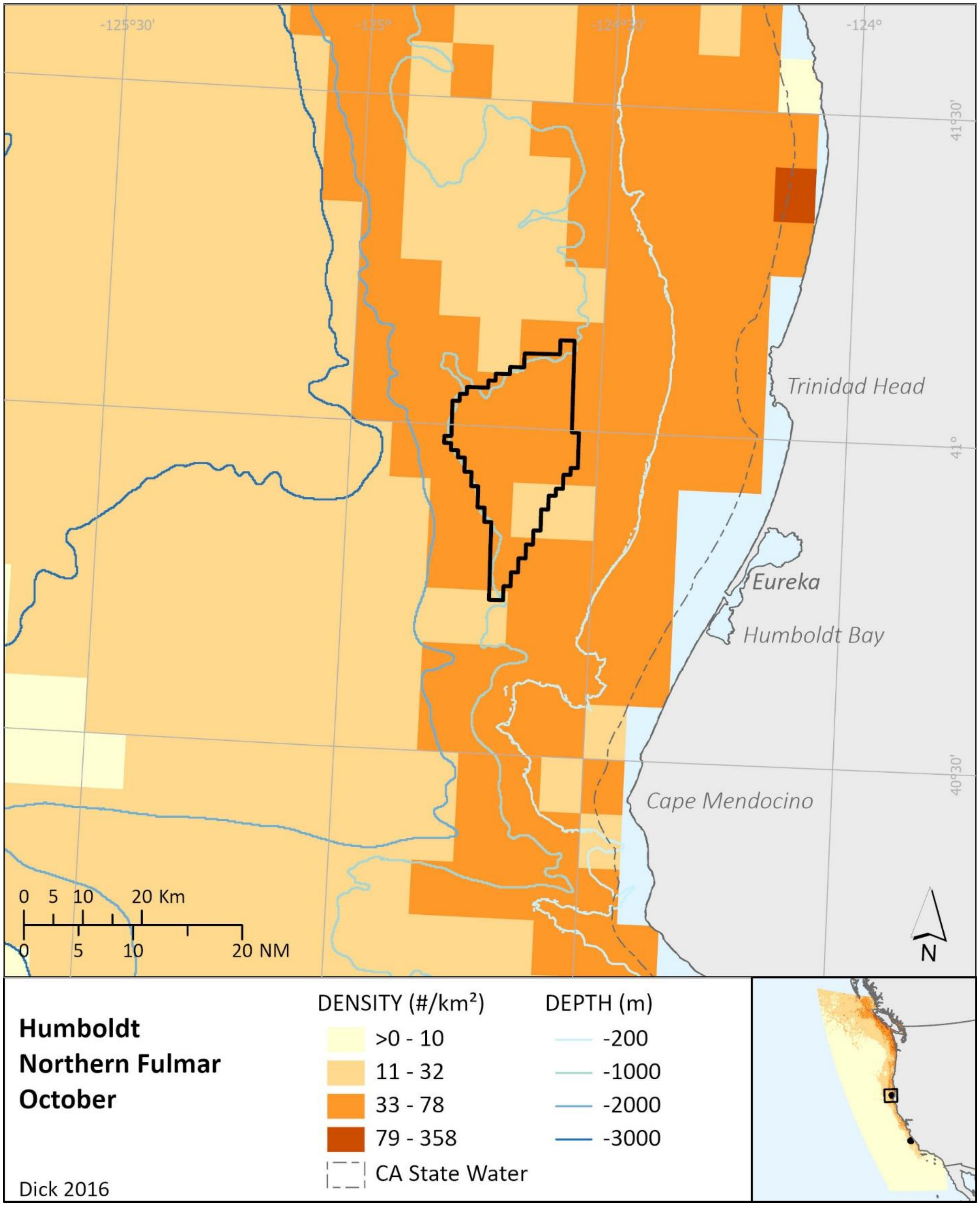

Figure B.11. Northern fulmar fall predicted density/distribution in/near the HWEA.

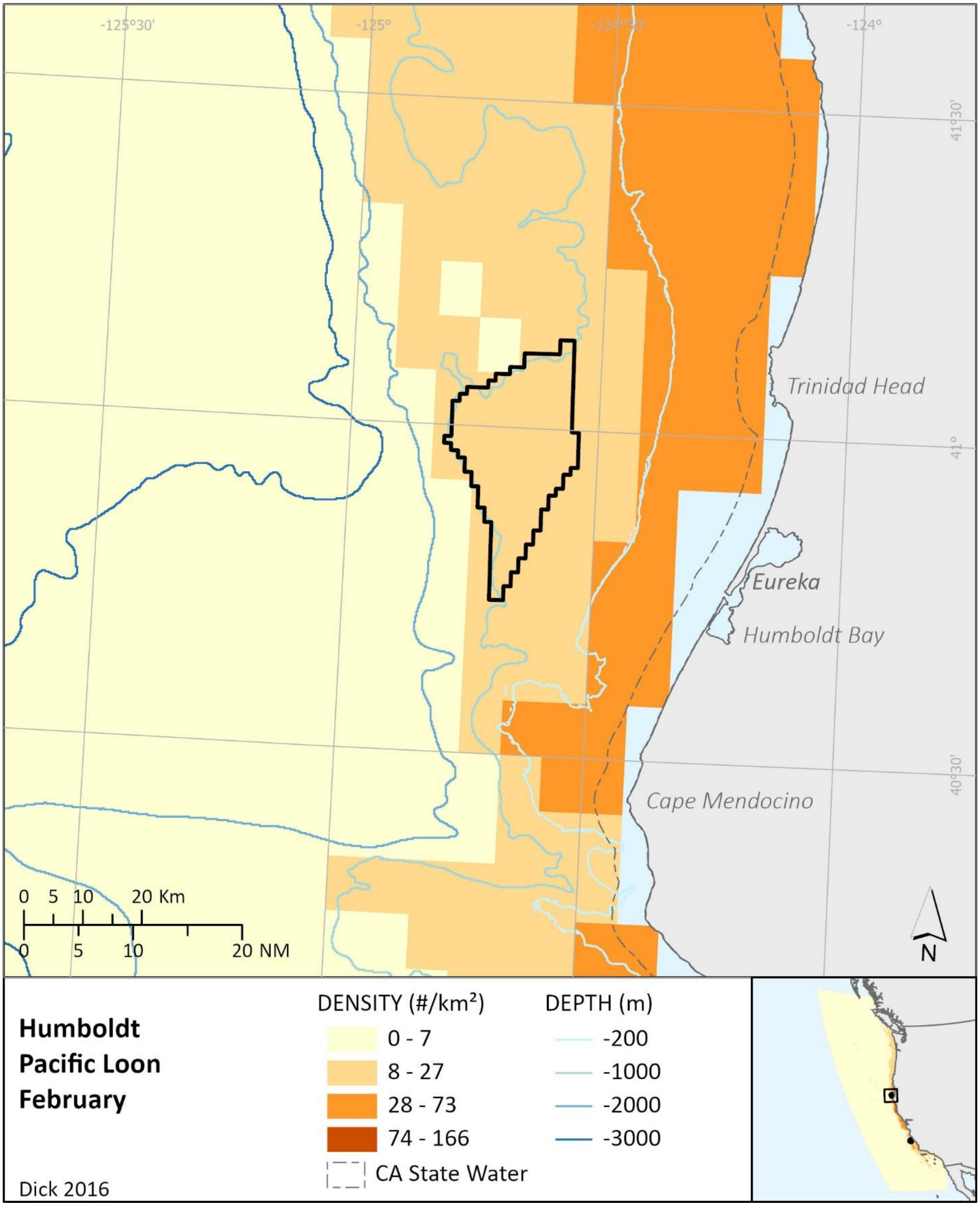

Figure B.12. Pacific loon winter predicted density/distribution in/near the HWEA.

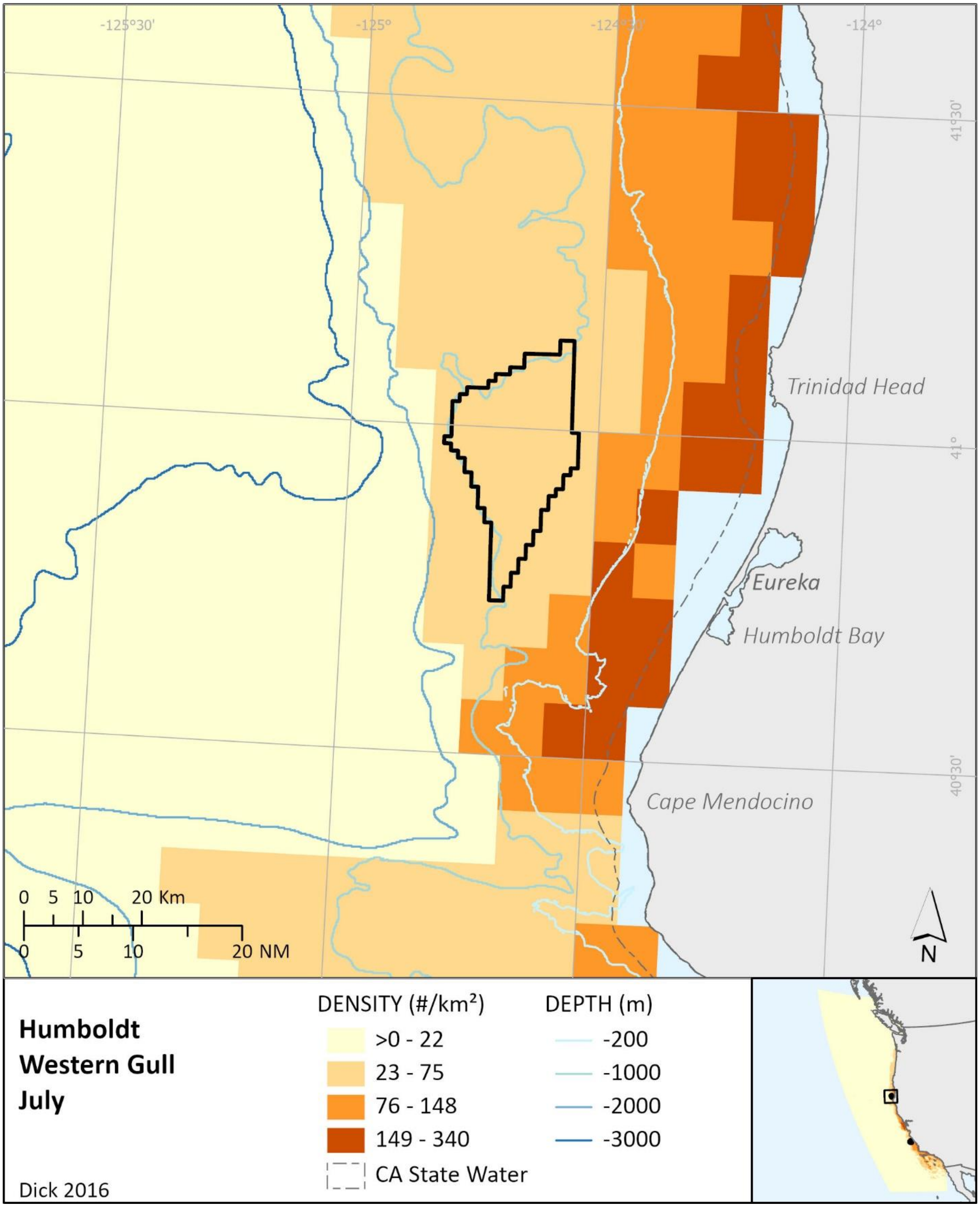

Figure B.13. Western gull summer predicted density/distribution in/near the HWEA.

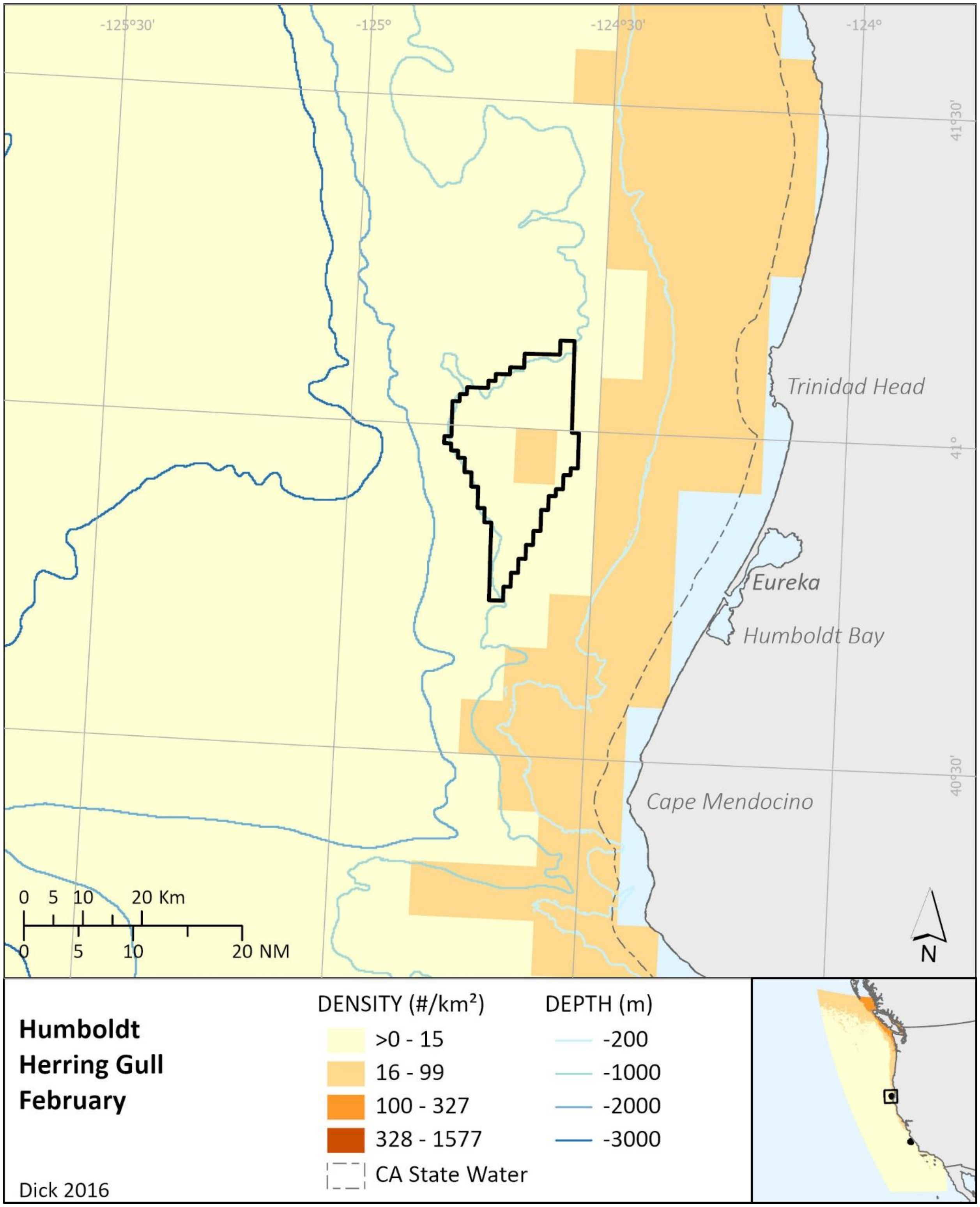

Figure B.14. Herring gull winter predicted density/distribution in/near the HWEA.

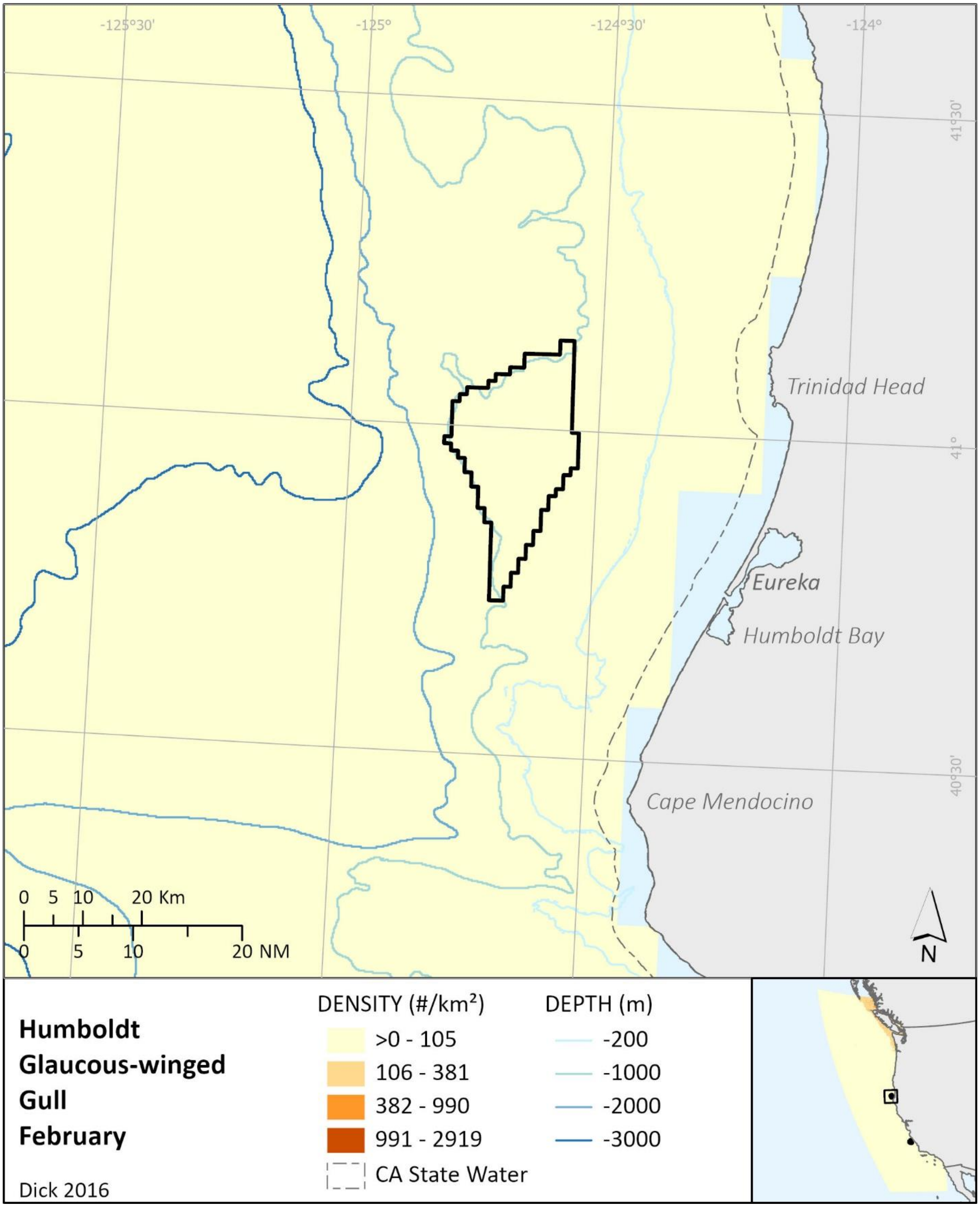

Figure B.15. Glaucous-winged gull winter predicted density/distribution in/near the HWEA.

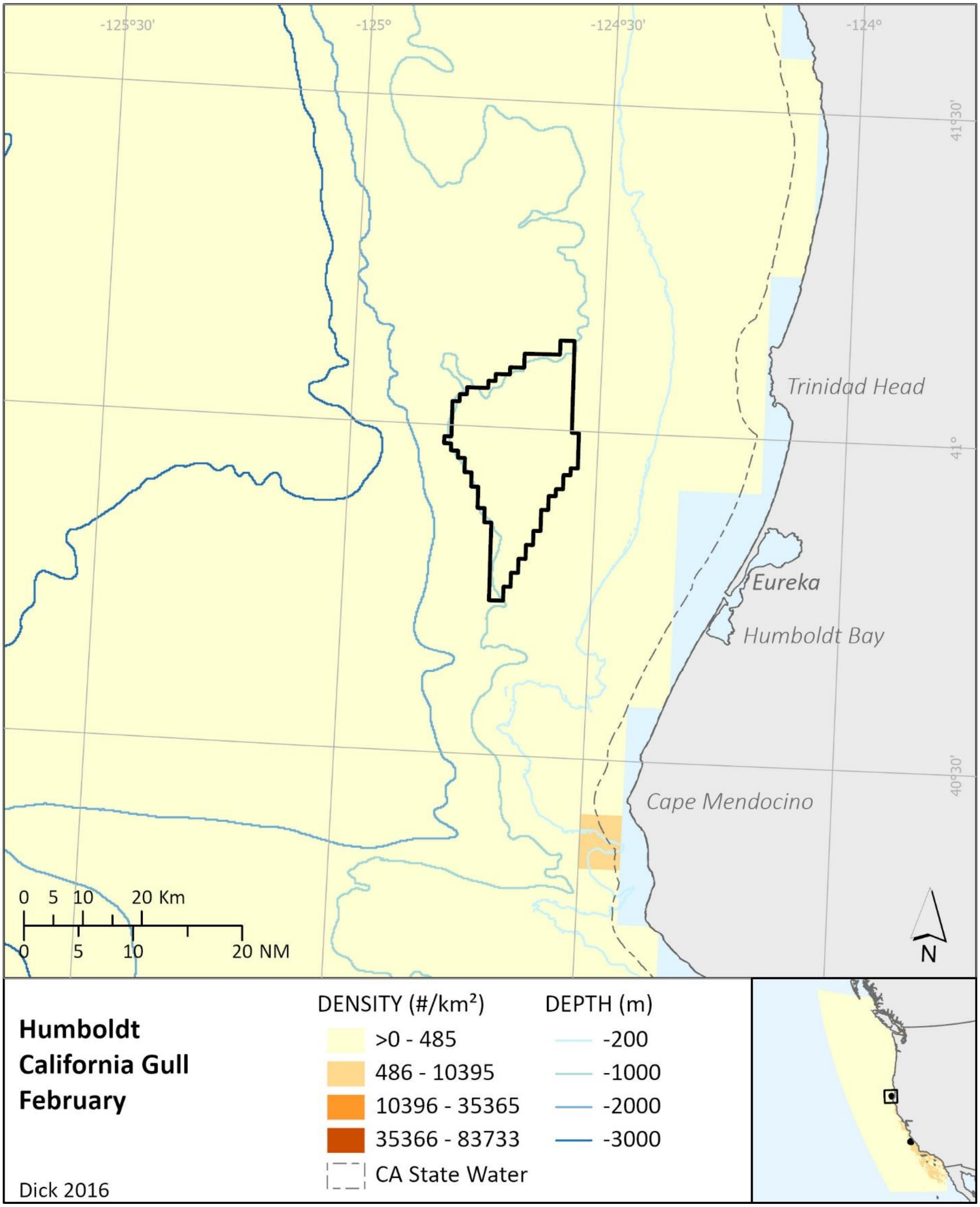

Figure B.16. California gull winter predicted density/distribution in/near the HWEA.

Figure B.17. Heermann's gull fall predicted density/distribution in/near the HWEA.

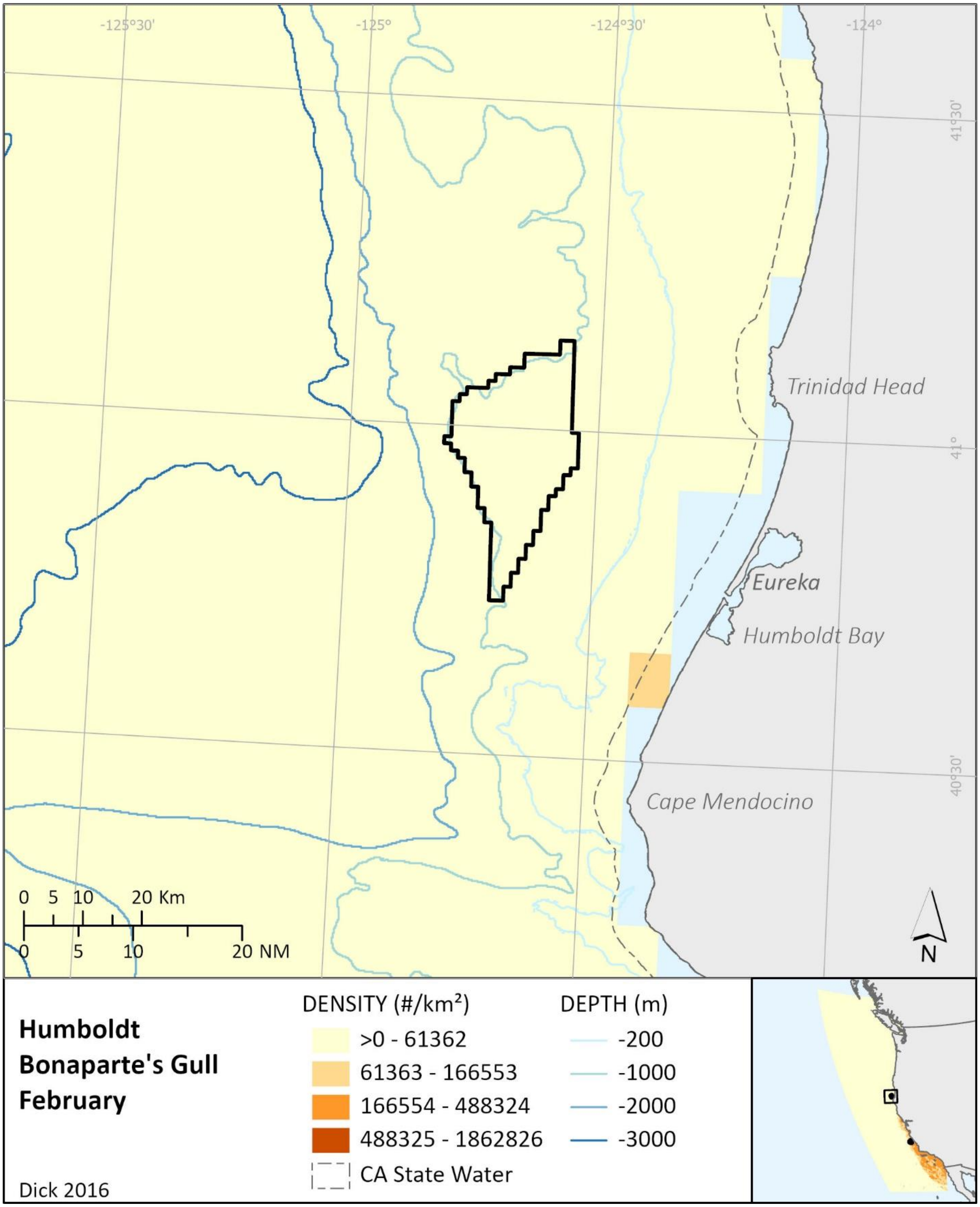

Figure B.18. Bonaparte's gull winter predicted density/distribution in/near the HWEA.

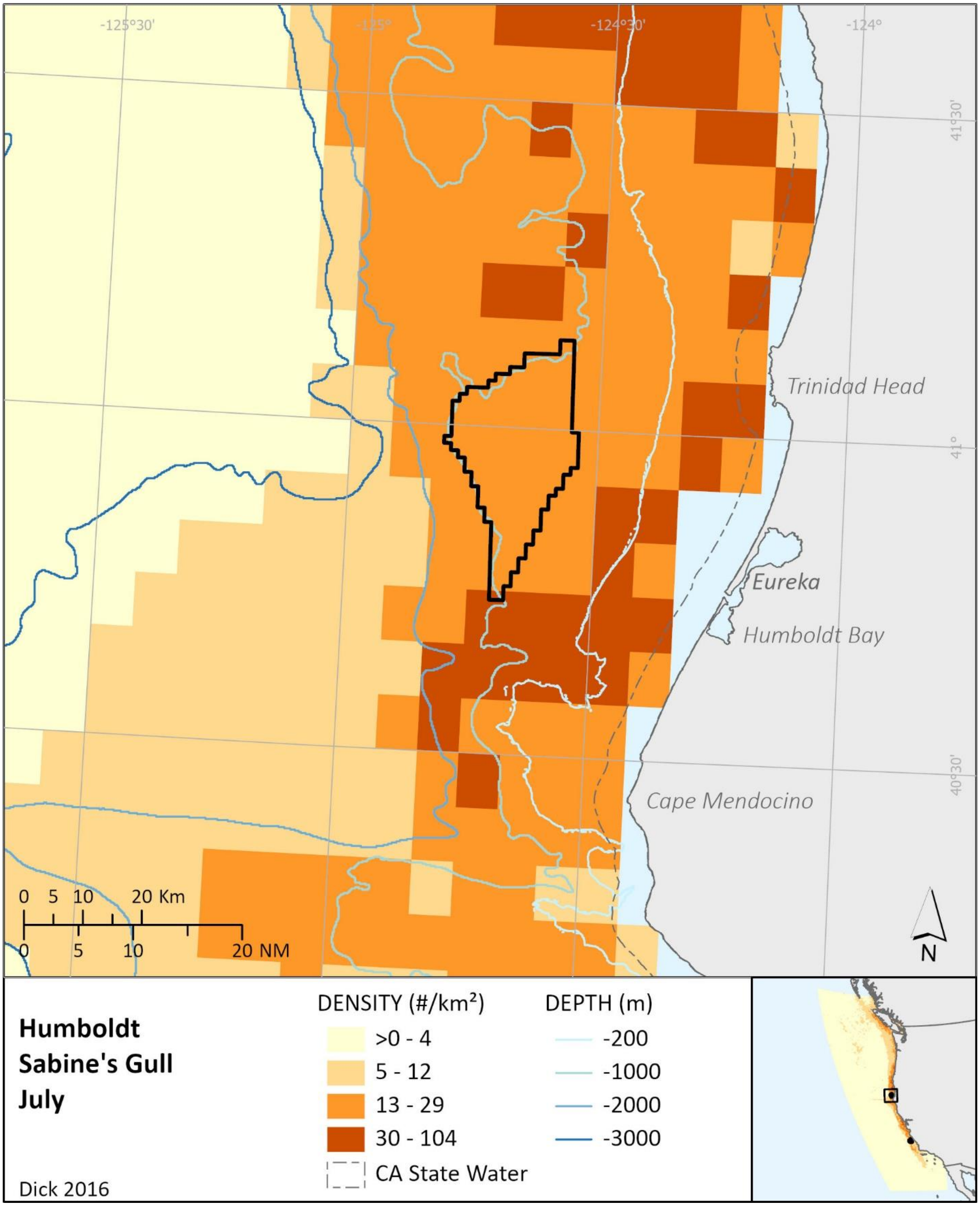

Figure B.19. Sabine’s gull summer predicted density/distribution in/near the HWEA.

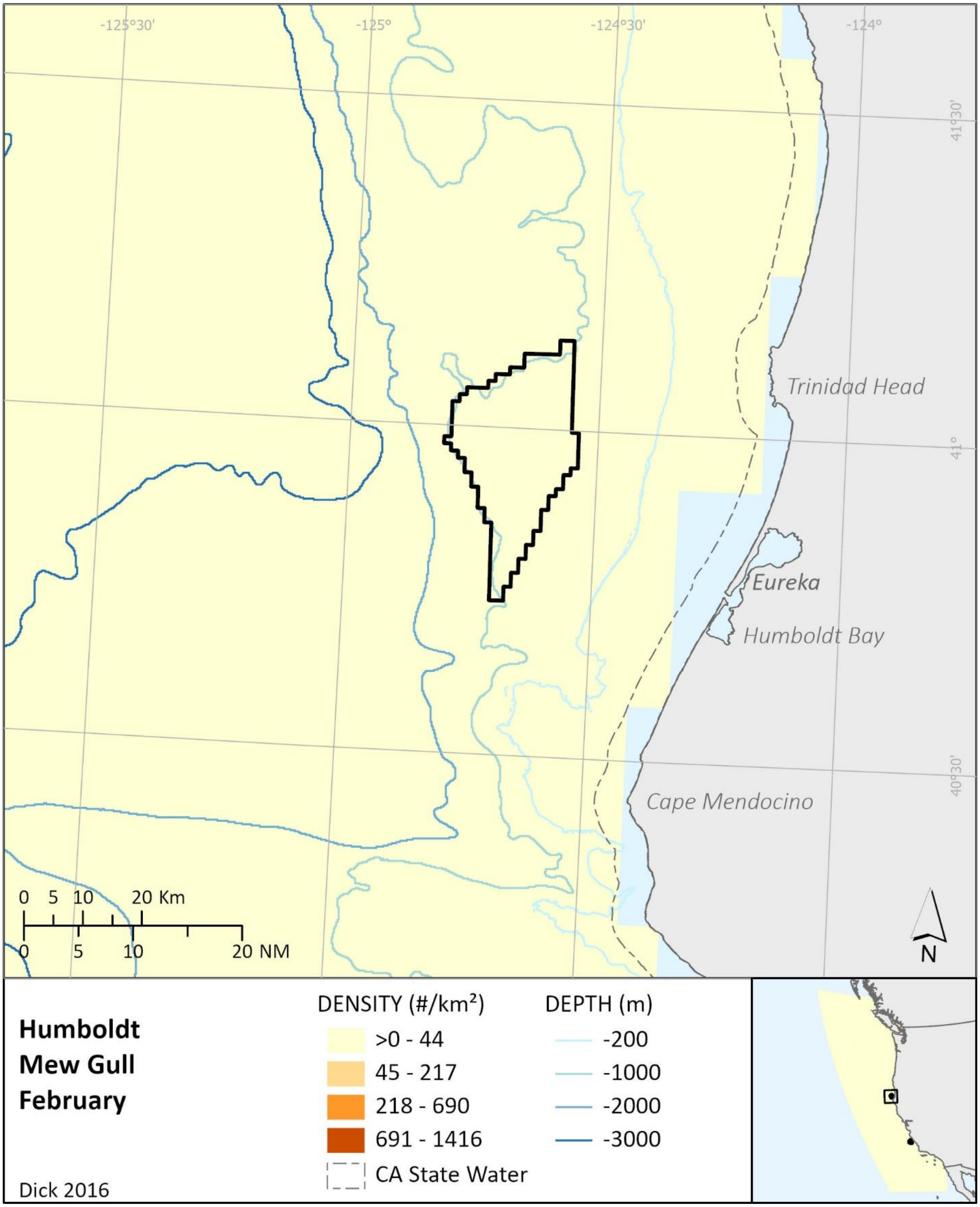

Figure B.20. Mew/short-billed gull winter predicted density/distribution in/near the HWEA.

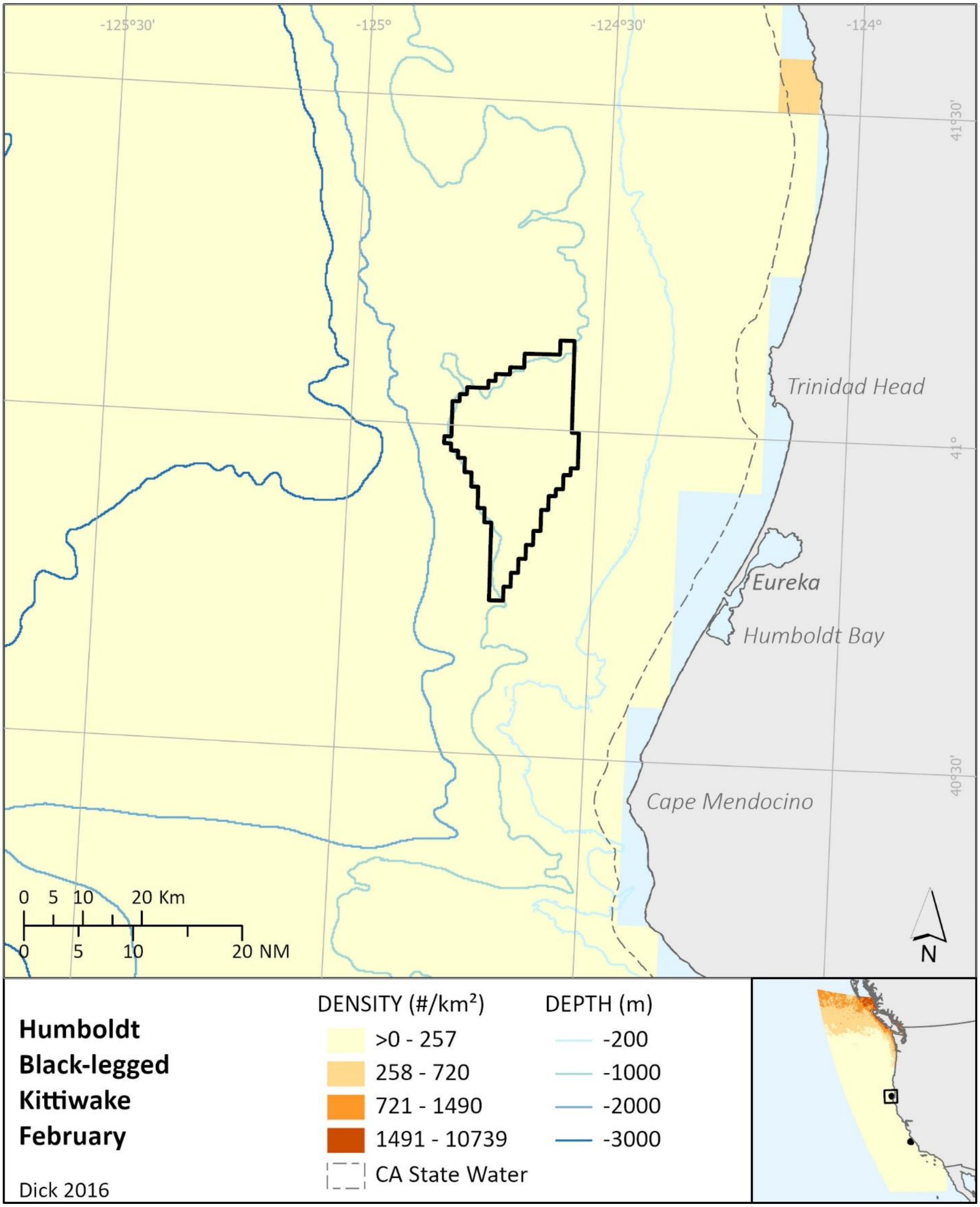

Figure B.21. Black-legged kittiwake winter predicted density/distribution in/near the HWEA.

Figure B.22. Caspian tern spring predicted density/distribution in/near the HWEA.

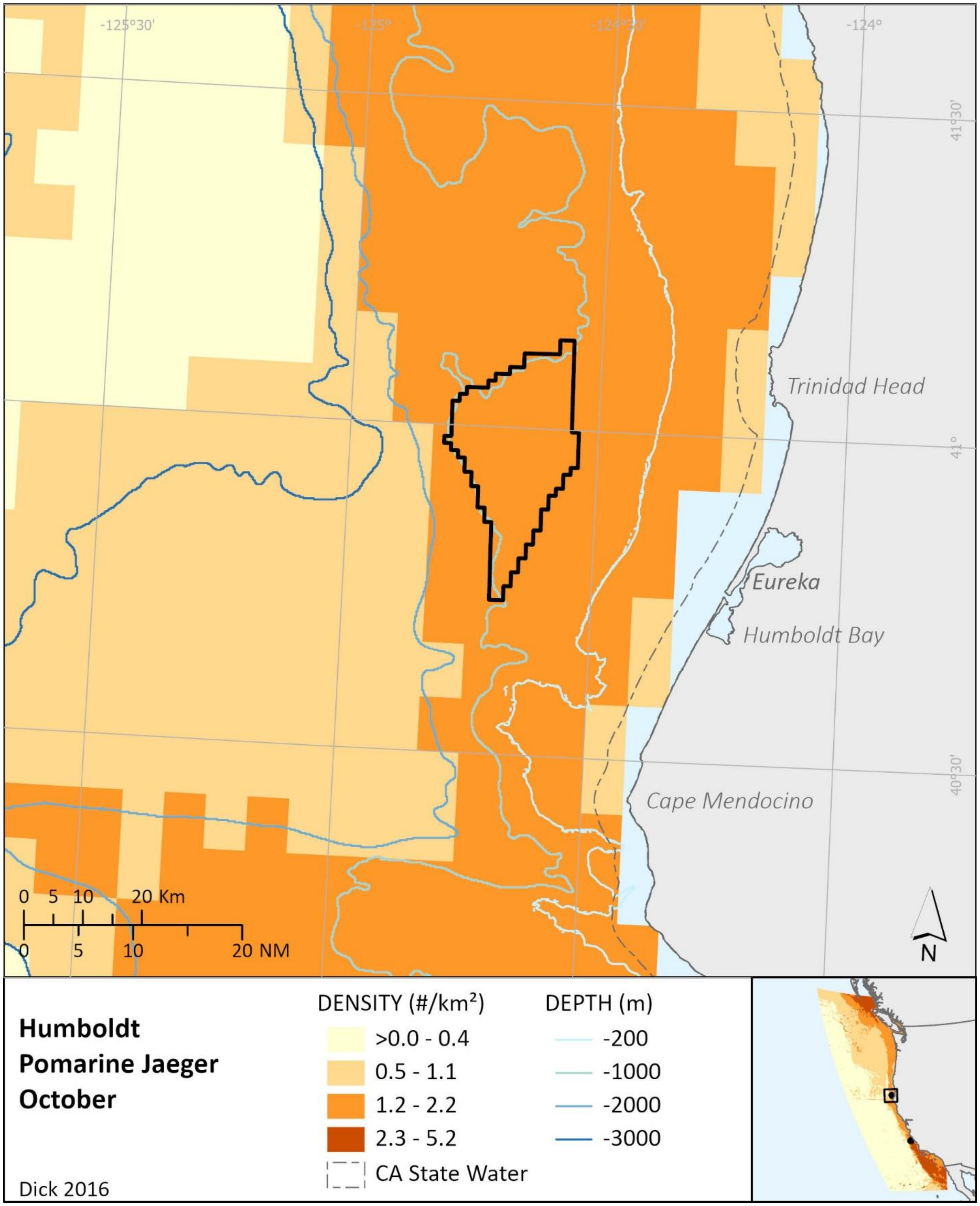

Figure B.23. Pomarine jaeger fall predicted density/distribution in/near the HWEA.

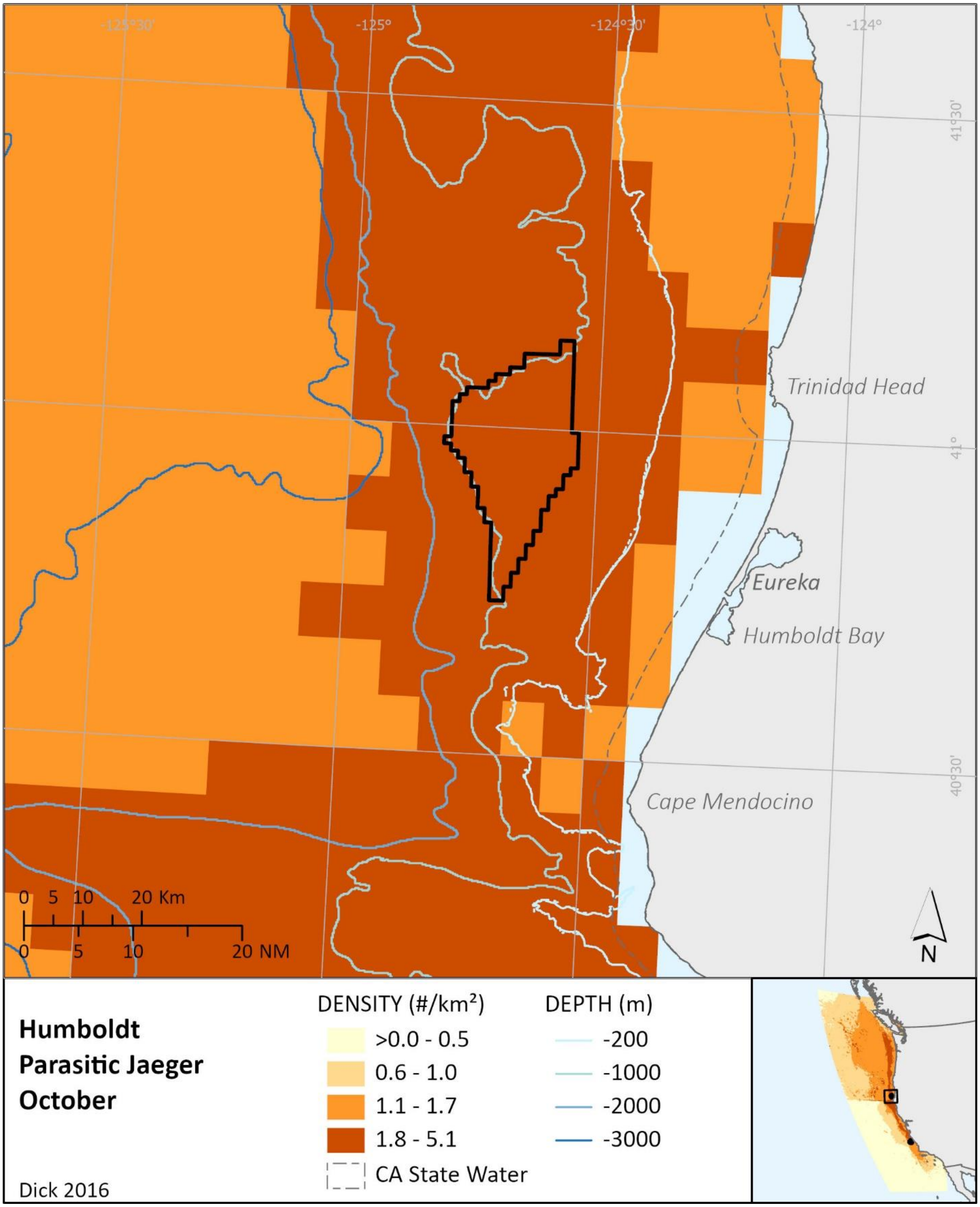

Figure B.24. Parasitic jaeger fall predicted density/distribution in/near the HWEA.

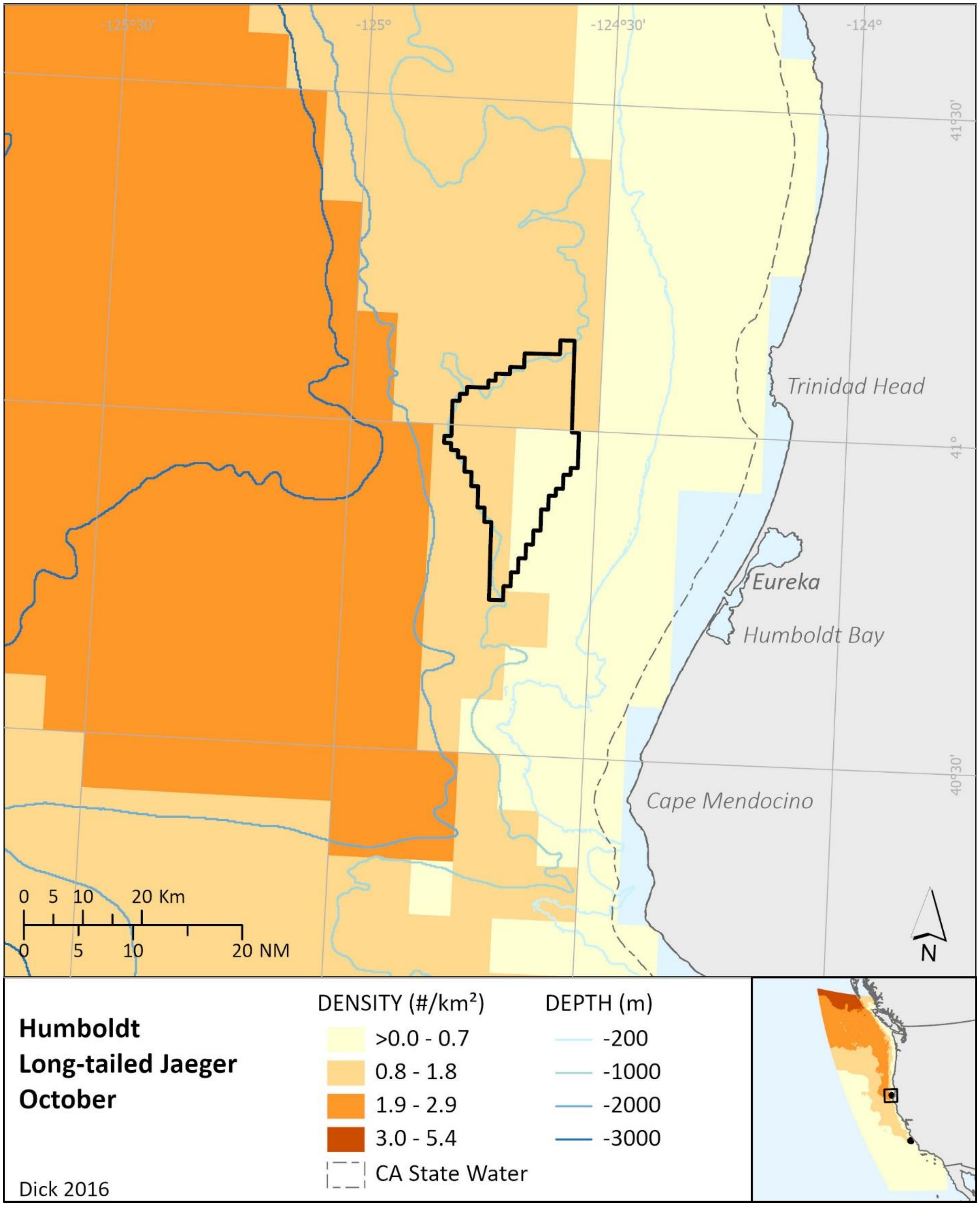

Figure B.25. Long-tailed jaeger fall predicted density/distribution in/near the HWEA.

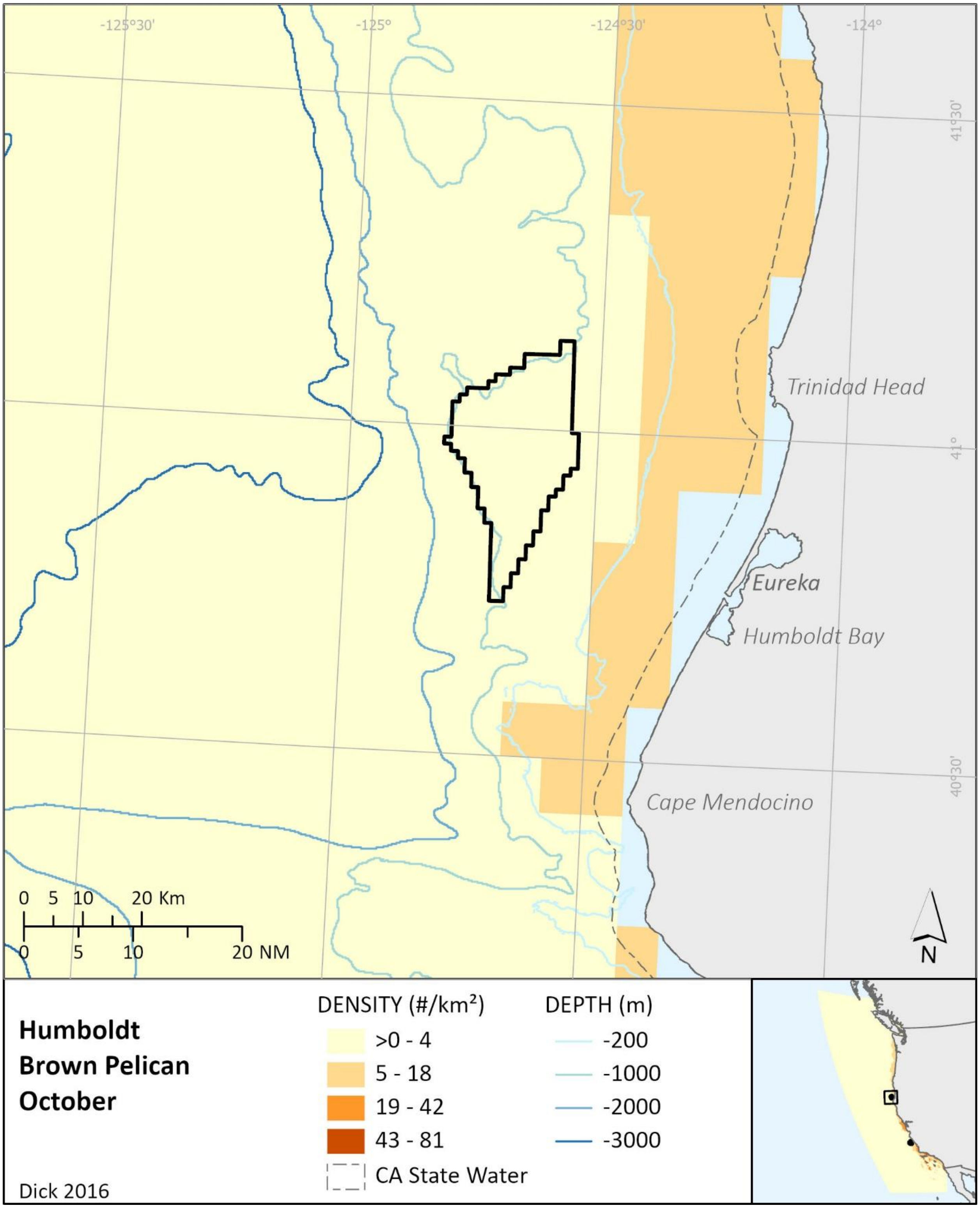

Figure B.26. Brown pelican fall predicted density/distribution in/near the HWEA.

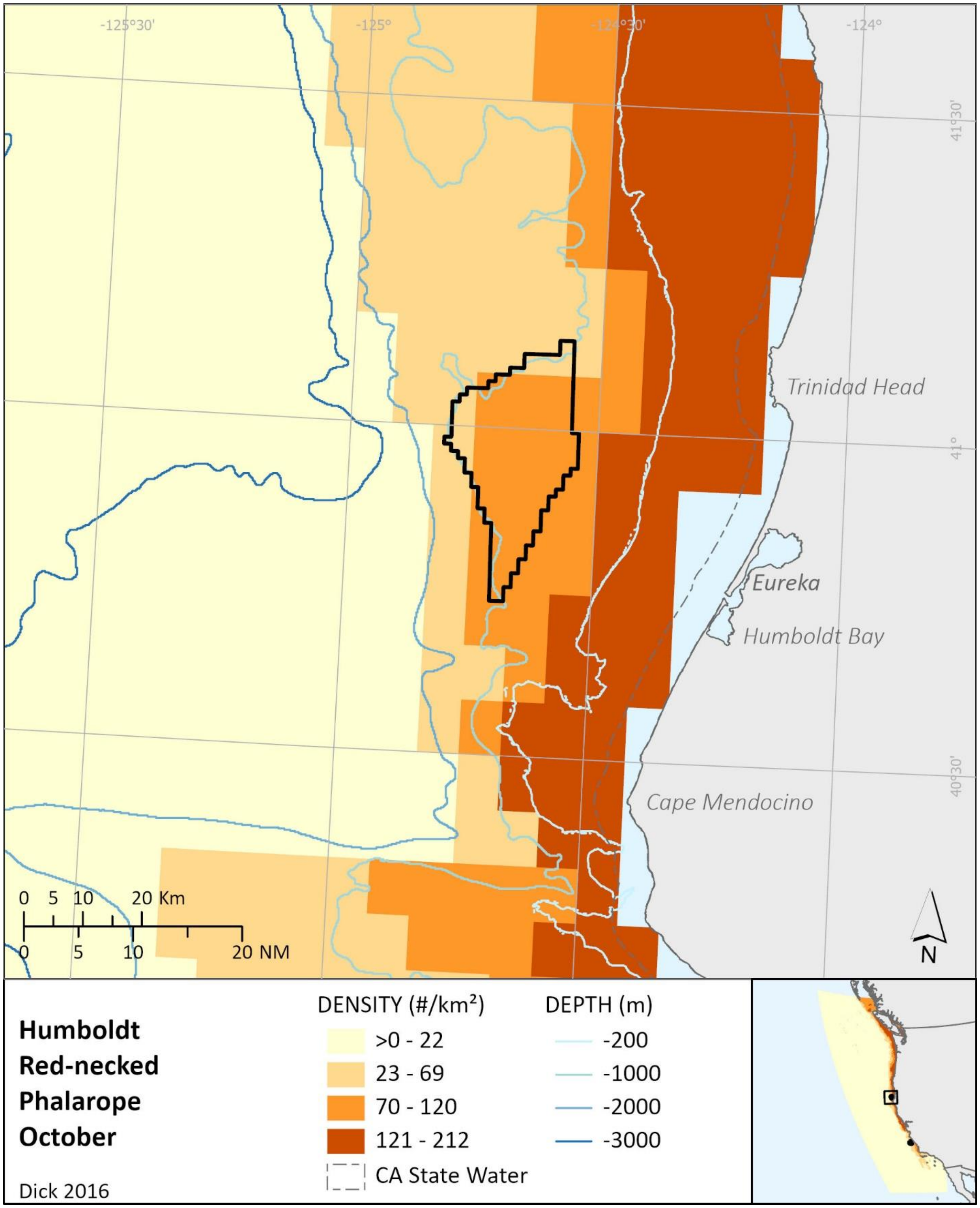

Figure B.27. Red-necked phalarope fall predicted density/distribution in/near the HWEA.

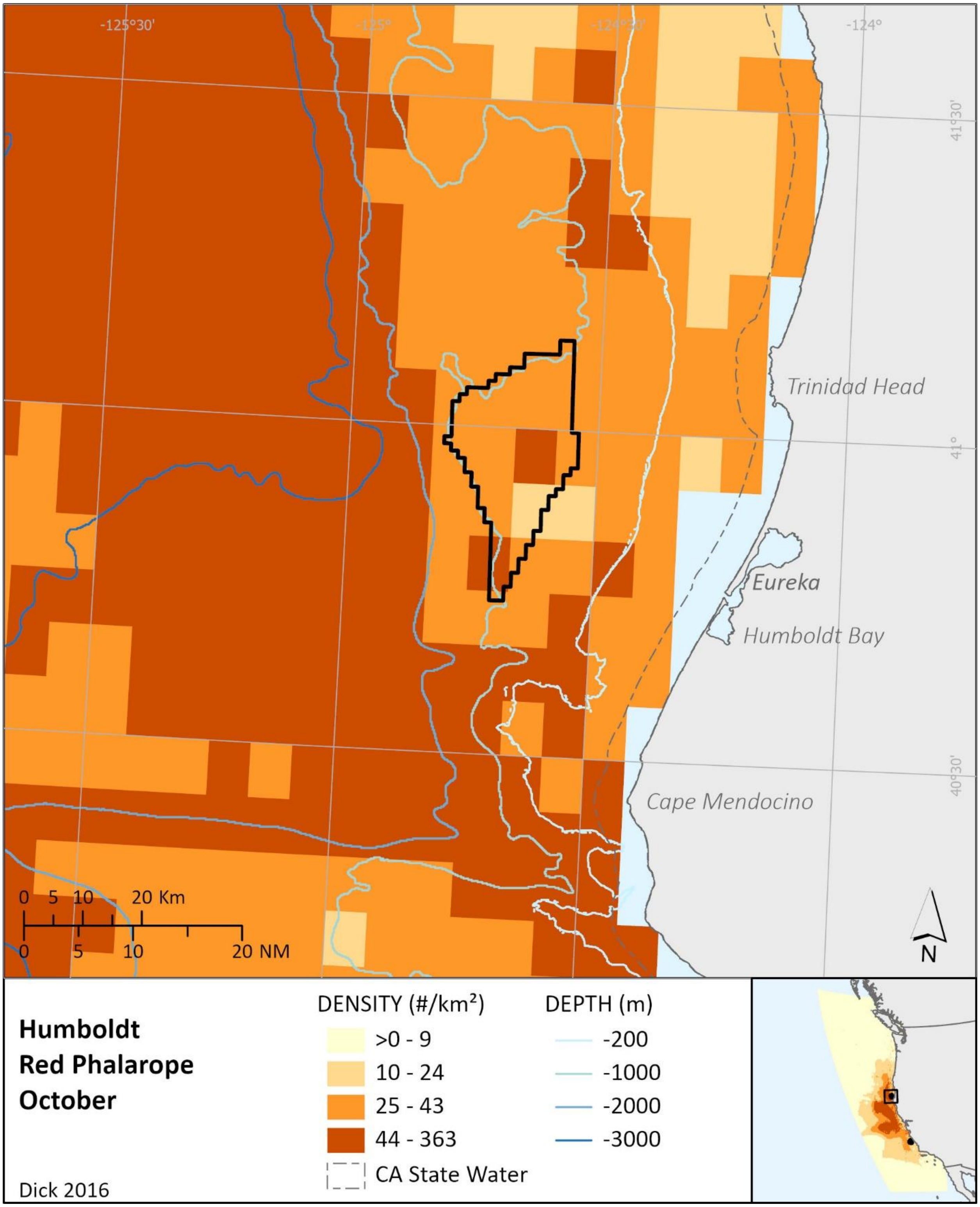

Figure B.28. Red phalarope fall predicted density/distribution in/near the HWEA.

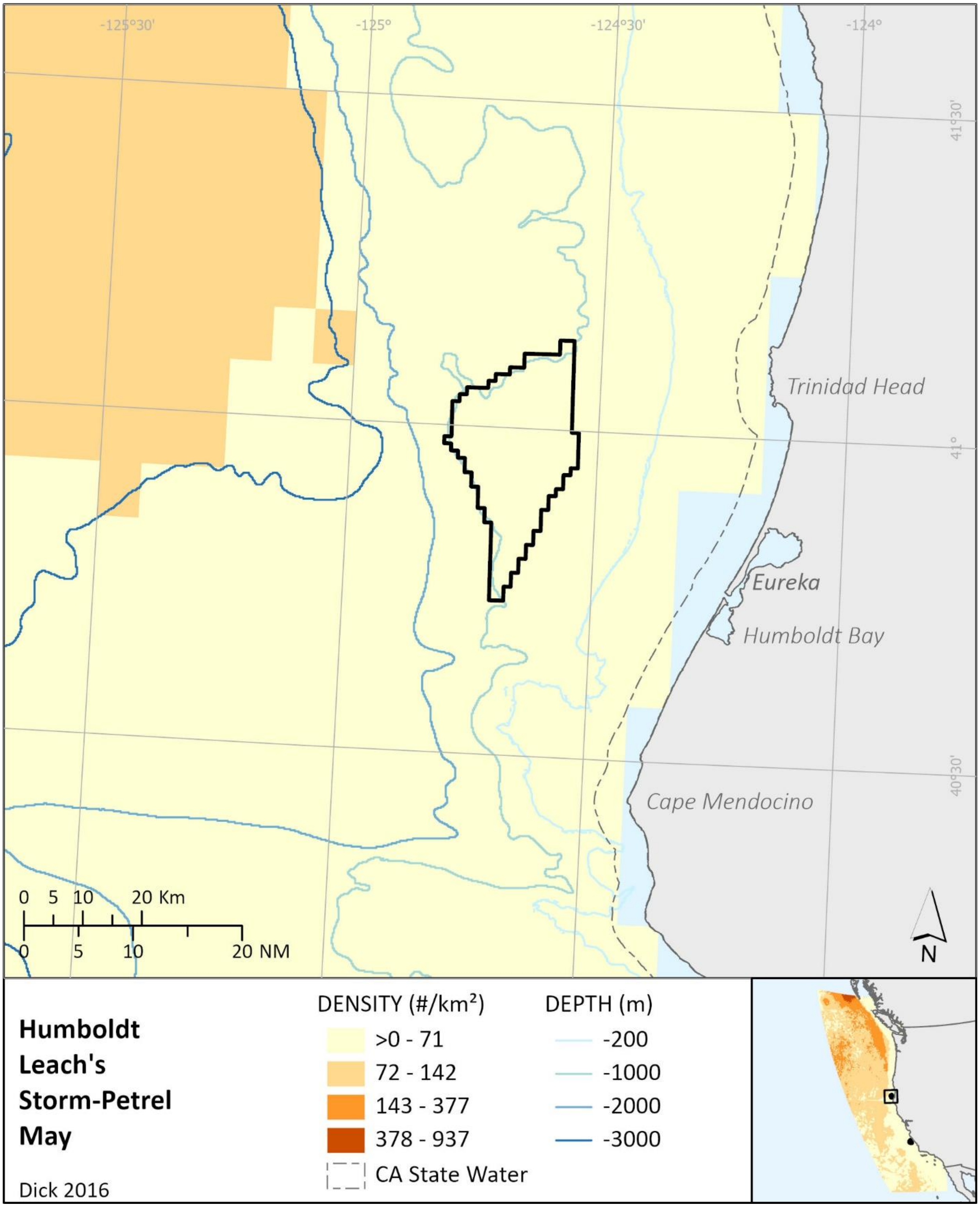

Figure B.29. Leach's storm-petrel spring predicted density/distribution in/near the HWEA.

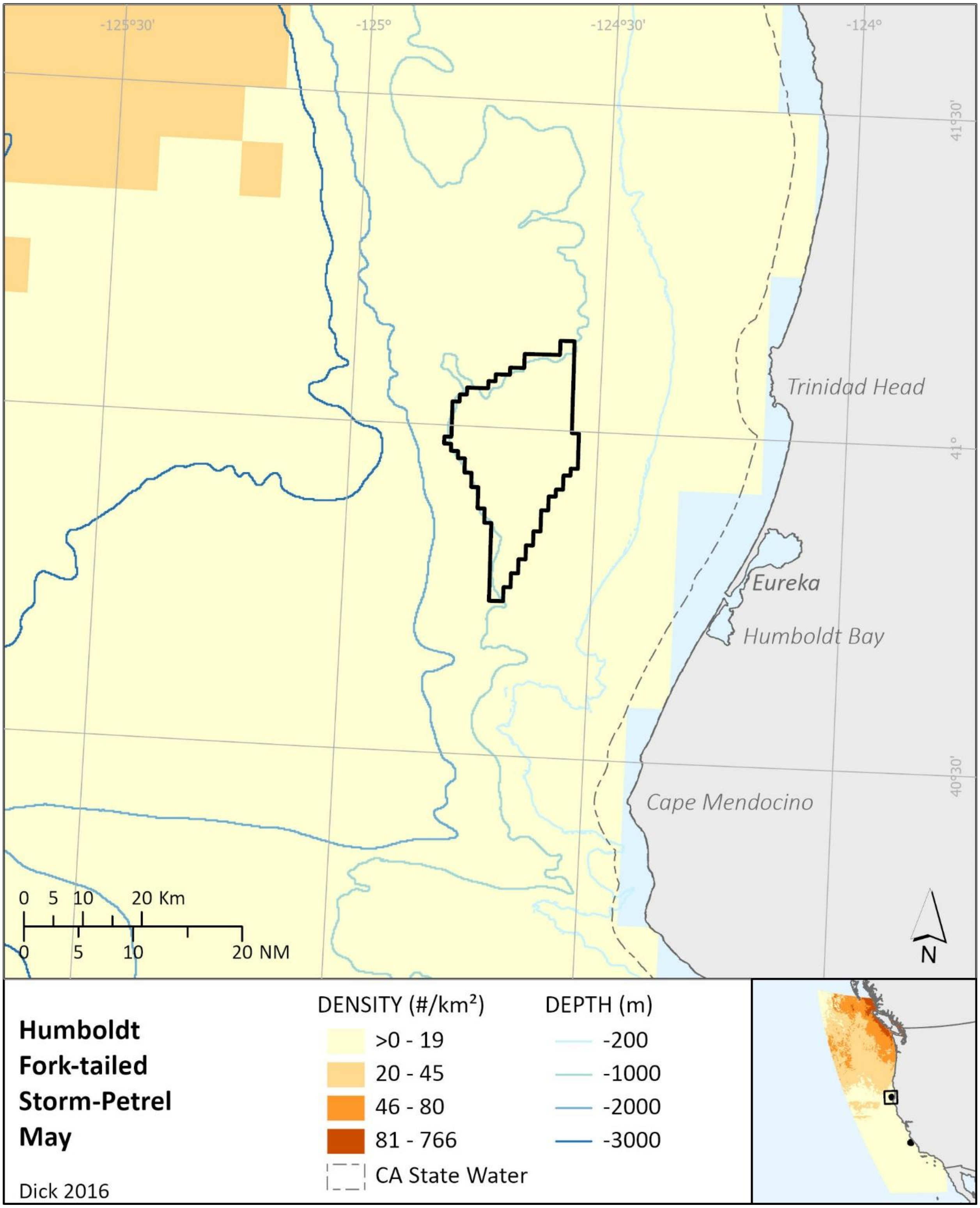

Figure B.30. Fork-tailed storm-petrel spring predicted density/distribution in/near the HWEA.