Data Documentation
Dataset Information
Dataset Title:

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

Description:

This dataset provides seasonal spatial rasters of predicted long-term (1980-2017) density of 33 individual species and 13 taxonomic groups of marine birds throughout the Pacific Outer Continental Shelf (OCS) and adjacent waters off the contiguous United States at 2-km spatial resolution. Two indications of the uncertainty associated with the model predictions are also provided: 1) seasonal spatial layers indicating areas with no survey effort and 2) seasonal spatial rasters of the precision of predicted density of each species/group characterized as its coefficient of variation (CV). Predicted density should always be considered in conjunction with these two indications of uncertainty. This dataset also includes spatial rasters of environmental predictor variables that were used in the predictive modeling.

Purpose:

Marine birds have the potential to be affected by human activities in the ocean environment such as offshore wind energy development. This project was a partnership between the Bureau of Ocean Energy Management (BOEM), the US Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA) National Centers for Coastal Ocean Science (NCCOS) through Inter-Agency Agreement Numbers M15PG00009 and M15PG00010 to develop maps of the spatial distributions of marine bird species on the Pacific OCS of the contiguous United States that can be used to inform marine spatial planning in the region and guide future data collection efforts. The analysis relied on 21 unique marine bird sighting datasets provided by the various state and federal agencies, academic institutions, and private organizations. This project was conducted to inform BOEM's renewable energy policy decisions in the Pacific OCS region. Having the most up-to-date and comprehensive biogeographic information is an important part of BOEM's process to identify and fill critical data gaps, and to assess the potential direct and indirect impacts of offshore renewable energy development on marine birds. Products from this assessment may also support coastal and ocean management efforts by other local, state and federal agencies working in the Pacific OCS region.

Methods:

This analysis relied mainly on two types of data: counts of marine birds at sea from sighting surveys and information about the environment in the Pacific OCS region. Sighting datasets were provided by various state and federal agencies, academic institutions, and private organizations. Available spatial information describing the environment in the Pacific OCS region was compiled and synthesized by NCCOS. Environmental data came from a range of sources including remote sensing datasets and an ocean model dataset. Spatial environmental variables were characterized as spatial rasters, with dynamic variables represented by seasonal long-term climatologies.

Spatial predictive modeling was applied to the sighting data to account for spatial and temporal heterogeneity in survey effort, platform, and protocol. An ensemble machine-learning technique, component-wise boosting of hierarchical zero-inflated count models, was used to relate the counts of each species or taxonomic group to the environmental predictor variables while accounting for survey heterogeneity and the aggregated nature of sightings. The modeling technique allowed for complex non-linear relationships between response and predictor variables and interacting effects among predictors. Bootstrapping was used to derive estimates of the uncertainty in model predictions.

For a complete description of the methods see Leirness et al. (2021).

Cited Publications:
- 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 the at-sea density of marine birds to support renewable energy planning on the Pacific Outer Continental Shelf of the contiguous United States. Camarillo (CA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-014.

Data Sources:
- Adams J, Felis JJ, Mason JW, Takekawa JY. 2016. Pacific Continental Shelf Environmental Assessment (PaCSEA) GIS resource database: aerial seabird and marine mammal surveys off northern California, Oregon, and Washington, 2011-2012. US Geological Survey data release.
- Archiving, Validation and Interpretation of Satellite Oceanographic data (AVISO): global 'DT all sat' data of daily sea surface altimetry, https://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/madt-h-uv.html
- Computer Database Analysis System (CDAS) 3.1. 2009. Marine birds and mammals at sea. Washington, Oregon, California 1975-2008. Prepared for California Department of Fish and Game Office of Spill Prevention and Response. Data CD and Display Software.
- Copernicus Marine Environment Monitoring Service (CMEMS): datasets SEALEVEL_GLO_PHY_L4_REP_OBSERVATIONS_008_047, SST_GLO_SST_L4_REP_OBSERVATIONS_010_024, https://marine.copernicus.eu/
- General Bathymetric Chart of the Oceans (GEBCO): https://www.gebco.net/
- Global Seafloor Geomorphology: 'Canyons' data, http://www.bluehabitats.org
  - Harris P, Macmillan-Lawler M, Rupp J, Baker E. 2014. Geomorphology of the oceans. Marine Geology. 352:4-24.
- Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG): full resolution coastline data version 2.3.6, https://www.ngdc.noaa.gov/mgg/shorelines/
  - Wessel P, Smith WHF. 1996. A global, self-consistent, hierarchical, high-resolution shoreline database. Journal of Geophysical Research. 101(B4):8741-8743.
- Hybrid Coordinate Ocean Model (HYCOM): Global Reanalysis GLBu0.08, https://www.hycom.org/dataserver/gofs-3pt0/reanalysis
- National Aeronautics and Space Administration (NASA) OceanColor: Aqua and Terra MODIS and VIIRS, https://oceancolor.gsfc.nasa.gov/
- NOAA CoastWatch: datasets erdMEchla1day, erdMEssta1day, and erdQSstress1day, https://coastwatch.pfeg.noaa.gov/erddap/index.html
- Takekawa JY, Perry WM, Adams J, Felis JJ, Williams LL, Yee JL, Orthmeyer DL, Mason JW, McChesney GJ, McIver WR, et al. 2017. At-sea distribution and abundance of seabirds and

marine mammals off southern California GIS resource database: aerial seabird and marine mammal surveys off southern California, 1999-2002. US Geological Survey data release.

Associated Datasets:
- Modeling and mapping marine bird distributions on the U.S. Atlantic Outer Continental Shelf to support offshore renewable energy planning https://coastalscience.noaa.gov/project/statistical-modeling-marine-bird-distributions/

People & Projects

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- William Sydeman, Farallon Institute for Advanced Ecosystem Research
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- Jeannette E. Zamon, US DOC; NOAA; National Marine Fisheries Service; Northwest Fisheries Science Center

Funding:
- US DOC; NOAA; NOS; National Centers for Coastal Ocean Science (NCCOS)
- US DOI; Bureau of Ocean Energy Management (BOEM)

Associated Online Resources:
- NCCOS Project, Marine Bird Spatial Distributions on the Pacific Outer Continental Shelf: Data Synthesis and Modeling, https://coastalscience.noaa.gov/project/ marine-bird-distributions-pacific-outer-continental-shelf/

Extents
Start Date: 1980-01-01
End Date: 2017-12-31

Northern Boundary: 49.0
Southern Boundary: 29.8
Western Boundary: -131.0
Eastern Boundary: -117.1

Keywords
Sea Areas, Water Bodies, Marine Protected Areas:
- Channel Islands National Marine Sanctuary
- Cordell Bank National Marine Sanctuary
- Eastern North Pacific Ocean
- Greater Farallones National Marine Sanctuary
- Monterey Bay National Marine Sanctuary
- Olympic Coast National Marine Sanctuary
- Pacific Outer Continental Shelf
- Southern California Bight

NOAA Ships, Other Ships, Platforms:
- Aircraft
    - Commander AC-500 fixed-wing
    - Partenavia P-68/P-68-Observer fixed-wing
- Fishing vessels
    - *Chellissa*
    - *Frosti*
    - *Miss Sue*
    - *Pacific Fury*
    - *Piky*
- NOAA ships
    - *Bell M. Shimada*
    - *David Starr Jordan*
    - *Discoverer*
    - *McArthur*

- o *McArthur II*
- o *Researcher*
- o *Reuben Lasker*
- Research vessels
  - o *Almar*
  - o *Fulmar* (NOAA)
  - o *John H. Martin* (Moss Landing Marine Laboratories)
  - o *New Horizon* (Scripps Institution of Oceanography)
  - o *Ocean Starr*
  - o *Robert Gordon Sproul* (Scripps Institution of Oceanography)
  - o *Roger Revelle* (Scripps Institution of Oceanography)
  - o *Sally Ride* (Scripps Institution of Oceanography)
  - o *Tatoosh* (NOAA)

NCCOS Keywords: *(see [Appendix](#) for NCCOS Keywords)*
- NCCOS Research Priority > Marine Spatial Ecology
- NCCOS Research Topic > Ecological and Biogeographic Assessments
- NCCOS Research Location > Region > Pacific Ocean
- NCCOS Research Location > U.S. States and Territories > California
- NCCOS Research Location > U.S. States and Territories > Oregon
- NCCOS Research Location > U.S. States and Territories > Washington
- NCCOS Research Data Type > Geospatial
- NCCOS Research Data Type > Derived Data Product
- NCCOS Research Data Type > Model

File Information

Total File Size: 614 MB total, 400 files in 2 folders (unzipped), 561 MB (zipped)

Data File Format(s):
- Comma-separated value (.CSV)
- GeoTiff .TIF
- ShapeFile .SHP (and ancillary files .DBF, .PRJ, .SHX)

Data File Compression: N/A
Data File Resolution: 2 km
GIS Projection: WGS 1984 Hotine Oblique Mercator Azimuth Center

Data Files:
- model_input_predictors/
  - o climate_indices.CSV
  - o [predictor].TIF
    - ▪ chlorophyll_a_[season]
    - ▪ chlorophyll_a_front_strength_[season]
    - ▪ depth
    - ▪ distance_to_canyon
    - ▪ distance_to_land
    - ▪ eddy_frequency_anticyclonic_[season]
    - ▪ eddy_frequency_cyclonic_[season]

- mixed_layer_depth_[season]
- mixed_layer_depth_standard_deviation_[season]
- planform_curvature_10km
- planform_curvature_20km
- profile_curvature_10km
- profile_curvature_20km
- projected_latitude
- projected_longitude
- salinity_[season]
- salinity_standard_deviation_[season]
- sea_surface_height_[season]
- sea_surface_height_standard_deviation_[season]
- sea_surface_temperature_[season]
- sea_surface_temperature_anomaly_frequency_[season]
- sea_surface_temperature_front_strength_[season]
- sea_surface_temperature_standard_deviation_[season]
- slope_10km
- slope_20km
- slope_of_slope_10km
- slope_of_slope_20km
- surface_current_divergence_[season]
- surface_current_speed_[season]
- surface_current_velocity_eastwest_[season]
- surface_current_velocity_northsouth_[season]
- surface_current_vorticity_[season]
- turbidity_[season]
- turbidity_standard_deviation_[season]
- upwelling_[season]
- wind_divergence_[season]
- wind_stress_eastwest_[season]
- wind_stress_northsouth_[season]
- model_output_predictions/
  - [species]_[season]_[prediction].TIF
    - predicted_density
    - predicted_density_CV
  - survey_effort_mask_[season].SHP (and ancillary files .DBF, .PRJ, .SHX)

Documentation Files:
- Pacific_marine_bird_mapping_browse_graphic_PFSH_summer.JPG
- Pacific_marine_bird_mapping_preview_graphic_PFSH_summer.JPG
- Pacific_marine_bird_mapping_preview_graphic_PFSH_summer_CV.JPG
- DataDocumentation.PDF

Table 1: Climate Indices Data Dictionary

Column	Variable	Definition	Units	Range
1	year	year of corresponding climate index value	none	[1980, 2017]
2	month	calendar month of corresponding climate index value (1 = Jan, 2 = Feb, 3 = Mar, etc.)	none	[1, 12]

Column	Variable	Definition	Units	Range
3	mei	multivariate El Niño-Southern Oscillation index	none	[-1.89, 3.01]
4	mei_lag12	multivariate El Niño-Southern Oscillation index from 1 year (12 months) prior	none	[-1.89, 3.01]
5	npgo	North Pacific Gyre Oscillation index	none	[-2.47, 2.74]
6	npgo_lag12	North Pacific Gyre Oscillation index from 1 year (12 months) prior	none	[-2.47, 2.74]
7	pdo	Pacific Decadal Oscillation index	none	[-1.98, 2.63]
8	pdo_lag12	Pacific Decadal Oscillation index from 1 year (12 months) prior	none	[-1.98, 2.63]

Table 2: Model Input Spatial Predictors Data Dictionary

Predictor Variable Code: Definition	Units	Source
chlorophyll_a: seasonal mean climatologies of sea surface chlorophyll-a concentration	mg / m^3	NASA OceanColor Aqua and Terra MODIS and VIIRS (1997-2017); Leirness et al. (2021)
chlorophyll_a_front_strength: seasonal mean climatologies of gradient magnitude of fronts derived from sea surface chlorophyll-a concentration	log(mg / m^3) / km	NOAA CoastWatch (2002-13); Leirness et al. (2021)
depth: seafloor depth	m	multibeam bathymetry data; NOAA Okeanos Explorer; Monterey Bay Aquarium Research Institute; NOAA Olympic Coast NMS; USGS; University of Washington; Oregon State University; NOAA CRM; GEBCO; Leirness et al. (2021)
distance_to_canyon: distance to nearest seafloor canyon	m	Global Seafloor Geomorphology; Leirness et al. (2021)
distance_to_land: distance to nearest land	m	GSHHG; Leirness et al. (2021)
eddy_frequency_anticyclonic, eddy_frequency_cyclonic: seasonal climatologies of proportion of days with anticyclonic and cyclonic eddy rings	none	AVISO (1994-2015); Leirness et al. (2021)
mixed_layer_depth, mixed_layer_depth_standard_deviation: seasonal mean and standard deviation climatologies of depth at which temperature differed from the surface by ≥0.5 ºC	m	HYCOM (1992-2012); Leirness et al. (2021)
planform_curvature_10km, planform_curvature_20km: curvature of the seafloor along the line of intersection between the depth surface and the horizontal plane at 10 km and 20 km scales; indicates whether seafloor is convex (>0), concave (<0), or flat (0)	radians / 100 m	Leirness et al. (2021)

Predictor Variable Code: Definition	Units	Source
profile_curvature_10km, profile_curvature_20km: curvature of the seafloor along the line of intersection between the depth surface and the plane formed by the direction of slope and the z-axis at 10 km and 20 km scales; indicates whether the seafloor is convex (<0), concave (>0), or flat (0)	radians / 100 m	Leirness et al. (2021)
projected_latitude: latitude in projected coordinate system	m	Leirness et al. (2021)
projected_longitude: longitude in projected coordinate system	m	Leirness et al. (2021)
salinity, salinity_standard_deviation: seasonal mean and standard deviation climatologies of sea surface salinity	psu	HYCOM (1992-2012); Leirness et al. (2021)
sea_surface_height, sea_surface_height_standard_deviation: seasonal mean and standard deviation climatologies of sea surface height	m	CMEMS; Leirness et al. (2021)
sea_surface_temperature, sea_surface_temperature_standard_deviation: seasonal mean and standard deviation of sea surface temperature	ºC	CMEMS; Leirness et al. (2021)
sea_surface_temperature_anomaly_frequency: seasonal climatologies of proportion of days where daily sea surface temperature was more than 1ºC greater than the monthly mean ocean surface temperature	none	CMEMS; Leirness et al. (2021)
sea_surface_temperature_front_strength: seasonal mean climatologies of gradient magnitude of fronts derived from water temperature at the ocean surface	ºC / km	NOAA CoastWatch (2003-12); Leirness et al. (2021)
slope_10km, slope_20km: steepness of the seafloor at 10 km and 20 km scales	degrees	Leirness et al. (2021)
slope_of_slope_10km, slope_of_slope_20km: rate of change in slope of the seafloor at 10 km and 20 km scales	degrees of degrees	Leirness et al. (2021)
surface_current_divergence: seasonal mean climatologies of sea surface current divergence	none	HYCOM (1992-2012); Leirness et al. (2021)
surface_current_speed: seasonal mean climatologies of sea surface current speed	m / s	HYCOM (1992-2012); Leirness et al. (2021)
surface_current_velocity_eastwest, surface_current_velocity_northsouth: seasonal mean climatologies of sea surface current velocity in east-west and north-south directions	m / s	HYCOM (1992-2012); Leirness et al. (2021)
surface_current_vorticity: seasonal mean climatologies of sea surface current vorticity	none	HYCOM (1992-2012); Leirness et al. (2021)
turbidity, turbidity_standard_deviation: seasonal mean and standard deviation climatologies of sea surface turbidity (reflectance at 447 nm)	1 / sr	NASA OceanColor Aqua and Terra MODIS (2000-17); Leirness et al. (2021)
upwelling: seasonal mean climatologies of Ekman upwelling	m /s	NOAA CoastWatch (1999-2009); Leirness et al. (2021)
wind_divergence: seasonal mean climatologies of sea surface wind shear stress divergence	1 / s	NOAA CoastWatch (1999-2009); Leirness et al. (2021)

Predictor Variable Code: Definition	Units	Source
wind_stress_eastwest, wind_stress_northsouth: seasonal mean climatologies of sea surface wind shear stress in east-west and north-south directions	Pa	NOAA CoastWatch (1999-2009); Leirness et al. (2021)

Table 3: Model Output Predictions Data Dictionary

Prediction Variable Code	Definition	Units
predicted_density	model-predicted density of each species/group and season, 2-km resolution	none (proportional to number of birds / km^2)
predicted_density_CV	coefficient of variation of model-predicted density of each species/group and season, 2-km resolution	none
Survey effort masks	seasonal shapefiles with polygons indicating areas without survey effort	

Table 4: Species and Modeled Seasons Data Dictionary

Species Code	Common Name	Scientific Name	Spring	Summer	Fall	Winter
ANMU	Ancient Murrelet	*Synthliboramphus antiquus*	X			
ASSP	Ashy Storm-Petrel	*Hydrobates homochroa*	X	X	X	
BFAL	Black-footed Albatross	*Phoebastria nigripes*	X	X	X	X
BLKI	Black-legged Kittiwake	*Rissa tridactyla*	X		X	X
BLSP	Black Storm-Petrel	*Hydrobates melania*	X	X	X	
BOGU	Bonaparte's Gull	*Chroicocephalus philadelphia*	X		X	X
BRAC	Brandt's Cormorant	*Phalacrocorax penicillatus*	X	X		
BRPE	Brown Pelican	*Pelecanus occidentalis*	X	X	X	X
BULS	Buller's Shearwater	*Ardenna bulleri*		X	X	
BVSH	Black-vented Shearwater	*Puffinus opisthomelas*	X		X	X
CAAU	Cassin's Auklet	*Ptychoramphus aleuticus*	X	X	X	X
CAGU	California Gull	*Larus californicus*	X	X	X	X
CATE	Caspian Tern	*Hydroprogne caspia*	X	X		
COLO	Common Loon	*Gavia immer*	X	X		
COMU	Common Murre	*Uria aalge*	X	X	X	X
COPE	Cook's Petrel	*Pterodroma cookii*	X	X	X	
CORM	Cormorant spp.	*Phalacrocorax* spp.			X	X
COTE-ARTE	Common/Arctic Tern	*Sterna hirundo/paradisaea*	X	X	X	
DCCO	Double-crested Cormorant	*Phalacrocorax auritus*	X	X		
FTSP	Fork-tailed Storm-Petrel	*Hydrobates furcatus*	X	X	X	X
HEEG	Heermann's Gull	*Larus heermanni*		X	X	X
HERG-ICGU	Herring/Iceland Gull	*Larus argentatus/glaucoides*	X	X	X	X

Species Code	Common Name	Scientific Name	Spring	Summer	Fall	Winter
JAEG	Jaeger spp.	*Stercorarius pomarinus/parasiticus/ longicaudus*	X	X	X	X
LAAL	Laysan Albatross	*Phoebastria immutabilis*	X			X
LESP	Leach's Storm-Petrel	*Hydrobates leucorhous*	X	X	X	X
LOON	Loon spp.	*Gavia* spp.	X	X	X	X
MAMU	Marbled Murrelet	*Brachyramphus marmoratus*	X	X		
MUPE	Murphy's Petrel	*Pterodroma ultima*	X			
NOFU	Northern Fulmar	*Fulmarus glacialis*	X	X	X	X
PAJA-LTJA	Parasitic/Long-tailed Jaeger	*Stercorarius parasiticus/longicaudus*	X	X	X	
PECO	Pelagic Cormorant	*Phalacrocorax pelagicus*	X	X		
PFSH	Pink-footed Shearwater	*Ardenna creatopus*	X	X	X	
PHAL	Phalarope spp.	*Phalaropus* spp.	X	X	X	X
PIGU	Pigeon Guillemot	*Cepphus columba*	X	X		
POJA	Pomarine Jaeger	*Stercorarius pomarinus*	X	X	X	X
RHAU	Rhinoceros Auklet	*Cerorhinca monocerata*	X	X	X	X
ROYT-ELTE	Royal/Elegant Tern	*Thalasseus maximus/elegans*	X	X	X	
RTLO	Red-throated Loon	*Gavia stellata*	X	X		
SAGU	Sabine's Gull	*Xema sabini*	X	X	X	
SCMU-GUMU-CRMU	Scripps's/Guadalupe/Craveri's Murrelet	*Synthliboramphus scrippsi/hypoleucus/craveri*	X			
SCOT	Scoter spp.	*Melanitta* spp.	X	X	X	X
SPSK	South Polar Skua	*Stercorarius maccormicki*			X	
STTS-SOSH-FFSH	Short-tailed/Sooty/Flesh-footed Shearwater	*Ardenna tenuirostris/grisea/carneipes*	X	X	X	X
TUPU	Tufted Puffin	*Fratercula cirrhata*	X	X		
WEGR-CLGR	Western/Clark's Grebe	*Aechmophorus occidentalis/clarkii*	X		X	X
WEGU-WGWH-GWGU	Western/Glaucous-winged Gull	*Larus occidentalis/glaucescens*	X	X	X	X

Parameter Information

List of major parameters included in this accession:

- Predicted density

Parameter Description:

Parameters: predicted density

Property Type: calculated
Units: none
Observation Category: model output
Sampling Instrument: Models/Analyses > Data Analysis > Environmental Modeling
Sampling and Analyzing Method:

> Predicted density (proportional to number of individuals / km^2) of 33 individual marine bird species and 13 taxonomic groups (Table 4) in up to four seasons (spring: Mar-May; summer: Jun-Aug; fall: Sep-Nov; and winter: Dec-Feb) was modeled using habitat-based spatial predictive modeling. See Leirness et al. (2021) for more details.

Data Quality Method:

> A data re-sampling technique (non-parametric bootstrapping) was used to estimate the precision of predicted density. Median (50th percentile) bootstrapped predictions were chosen as the best estimate of predicted density. Precision was characterized by the coefficient of variation of bootstrapped predictions ('CV'). Seasonal spatial layers indicating areas with no survey effort are provided as an additional indication of uncertainty in model predictions. All maps of predicted density and CV were reviewed by experts with experience and knowledge of marine birds in the study area. Experts were from a range of organizations including federal and state government agencies, academic institutions, non-profits, and consultants. Comments and feedback received from the review were incorporated into the project report. See Leirness et al. (2021) for more details.

Document Information

Date: 2021-11-01
Resource Provider: NCCOS Data Manager, nccos.data@noaa.gov, US DOC; NOAA; NOS; National Centers for Coastal Ocean Science (NCCOS)
Comment: This data documentation describes data files archived as a NOAA NCEI data accession, and is intended to provide dataset-level metadata for the purposes of discovery, use, and understanding.
Use Limitation: NOAA makes no warranty, expressed or implied, regarding these data, nor does the fact of distribution constitute such a warranty. NOAA cannot assume liability for any damages caused by any errors or omissions in these data.