# **Data for the revised marine bird Collision and Displacement Vulnerability Index for Pacific Outer Continental Shelf offshore wind energy development**

Add to Metadata Wizard, for ScienceBase

## Abstract

To better inform continued offshore wind energy development in the region, U.S. Geological Survey, Western Ecological Research Center has updated the database of marine bird vulnerabilities to offshore wind energy infrastructure (OWEI) in the Pacific Outer Continental Shelf Region (POCS; waters within the Exclusive Economic Zone off California, Oregon, and Washington). The installation of OWEI at sea may affect marine birds by increasing the risk of mortality from collision with OWEI (Collision Vulnerability) and disturbance and displacement from suitable habitats (Displacement Vulnerability). For the marine bird species present in the POCS, USGS-WERC updated relative scores of Collision Vulnerability (CV) and Displacement Vulnerability (DV) to OWEI based upon new research and data, additional species present in the POCS, and an evolved understanding of the application and utility of the index. The metrics used to produce the CV and DV scores in Vulnerability Index Version 2 are flight activity, percent time spent flying at rotor swept zone height, macro-avoidance rate, and habitat specificity. Metric values were generated from over 150 published literature sources. The methods of generating metric values and calculating CV and DV from those values are described in the accompanying Data Report. This Vulnerability Index Version 2 database can be used by the Bureau of Ocean Energy Management and other resource managers to evaluate potential impacts associated with siting and construction of OWEI within the POCS. For example, the relative vulnerability scores in this database can be compiled with species distribution and density information areas in the POCS where offshore renewable energy development is being considered to potential marine bird impacts.

These data support the following publication:

## Purpose

The primary purpose of this project was to update the comprehensive database quantifying marine bird vulnerability to OWEI in the POCS. The relative Collision Vulnerability and Displacement Vulnerability scores generated in Version 2 of the database are easy to update and can readily be applied to offshore renewable energy development assessments and inform future studies of marine bird interactions with OWEI in the POCS.

## Dataset Credit(s)

This study was developed, supported and funded in part by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington D.C., through Intra-Agency Agreement Number M20PG00028 with the USGS. Thank you to Dr. Ruth Dunn, Dr. Rueda-Uribe, and Deborah Jaques for providing additional flight activity information beyond what they had published, when requested. We would also like to acknowledge Darrin Thome and Tom Kimball of the U.S. Geological Survey for their feedback and Erika Sanchez-Chopitea of the U.S. Geological Survey for data publication guidance.

## Supplemental Information

Version 1 of our vulnerability index (Adams et al. 2017, Kelsey et al. 2018) was based off similar indices created in the North Sea and U.S. Atlantic Coast: Garthe and Hüppop 2004, Desholm 2009, Furness and Wade 2012, Furness et al. 2013, Robinson Willmott et al. 2013. In the years since Version 1 was completed, abundant new research and data have been published that increase our understanding of marine bird vulnerability to OWEI. In addition, species range shifts have brought new species into the POCS. Lastly, we have learned from the uses and applications of vulnerability indices of marine birds to OEWI in the POCS, as well as from developing thoughts on how vulnerability indices should be applied. Thus, to better inform continued offshore wind energy development in the POCS, we have updated the marine bird vulnerability index based upon new research and data (over 80 new data sources were added), additional species present in the POCS (8 new species were added, for a total of 89), and an evolved understanding of the application and utility of the index. Our increased understanding of vulnerability index applications led us to make methodological changes consistent with Shavykin and Karnatov (2022), moving away from ordinal scaling and using continuous, data derived, metric values. We also did not update the Population Vulnerability portion of the index, as we found it to have little applicational utility in Version 1. Herein, we present Version 2 of our vulnerability index which provides a current, transparent, and representative quantification of marine bird vulnerability to OWEI to better inform research of and planning for offshore wind energy development in the POCS.

Citations include:

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.

Desholm, M. 2009. Avian sensitivity to mortality: prioritizing migratory bird species for assessment at proposed wind farms. Journal of Environmental Management 90(8): 2672-1679. doi:10.1016/j.jenvman.2009.02.05

Furness, B., Wade, H. 2012. Vulnerability of Scottish seabirds to offshore wind turbines. MacArthur Green Ltd Glasgow, Scotland. Available online: http://www.gov.scot/resource/0038/00389902.pdf [Accessed 8 January 2016].

Furness, B., H. Wade, E. A. Masden. 2013. Assessing vulnerability of marine bird populations to offshore wind farms. Journal of Environmental Management 119: 56-66.

Garthe, S., and Hüppop, O. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41(4): 724-734. doi:10.1111/j.021-8901.2004.0918.x

Robinson Willmott, J. C., G. Forcey, and A. Kent. 2013. The Relative Vulnerability of Migratory Bird Species to Offshore Wind Energy Projects on the Atlantic Outer Continental Shelf: An Assessment Method and Database. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2013-207. 275 pp.

Shavykin, A., and Karnatov, A., 2022, The issue of using ordinal quantities to estimate the vulnerability of seabirds to wind farms, Journal of Marine Science and Engineering, v. 10, no. 1584, https://doi.org/10.3390/jmse10111584

## Attribute Accuracy Report

The updated Collision Vulnerability and Displacement Vulnerability scores presented here in Version 2 are transparently generated and representative of relative vulnerability for POCS marine bird species. The specific updates to the index equations and metrics are described in detail in the Data Report. We adopted the following approaches when translating published data from the literature into metric values. If a data source provided multiple values or a range of values relevant a species in the POCS, the midpoint of those values was used in the database. When we obtained values from multiple sources, we took the median of all as the final metric value. When data on a metric value wasn’t available for a given species, we used data for similar species. We grouped similar species (e.g., large gull, medium gull, and small gull), to be more specific in assigning values in the absence of species-specific data. These groupings included POCS species, and their most similar counterparts globally. Thus, if data didn’t exist for a given POCS species, we could be consistent in which additional species we looked to for comparable values.

There are three potential sources for uncertainty associated with metric values for each species:

1. How many literature sources provided species values for that metric.
2. The range of values from the data in those literature sources.
3. Whether metric values were available for the species in question, or whether values were drawn from a similar species or estimated when no species-specific values were available.

We quantified these three potential uncertainty sources on a 0-1 scale for each species and metric values, see the Data Report for details. We then multiplied the metric uncertainties across the metrics in CV and DV respectively to generate a final CV uncertainty value and DV uncertainty value for each species.

## Purpose Steps

*Describe the methods performed to collect or generate the data, provide as much detail as possible*

*Step 1*

## Child Items

### Data for the revised marine bird Collision Vulnerability Index for Pacific Outer Continental Shelf offshore wind energy development

#### Abstract

To better inform continued offshore wind energy development in the region, U.S. Geological Survey, Western Ecological Research Center has updated the database of marine bird vulnerabilities to offshore wind energy infrastructure (OWEI) in the Pacific Outer Continental Shelf Region (POCS; waters within the Exclusive Economic Zone off California, Oregon, and Washington). The installation of offshore wind energy infrastructure (OWEI) at sea may affect marine birds by increasing the risk of mortality from collision with OWEI (Collision Vulnerability) and disturbance and displacement from suitable habitats (Displacement Vulnerability). We define Collision Vulnerability (CV) as the percent of time a bird of a given species is vulnerable to collision with OWEI. This data set consists of the updated CV index (Version 2), updated from Version 1 (Adams et al. 2017), include relative CV scores for the 89 marine bird species in the POCS. The Version 2 CV updates are based upon new research and data, additional species present in the POCS, and an evolved understanding of the application and utility of the index. CV values are not analogous to a collision risk model outputs or probabilities of collision. We use three metrics to determine Collision Vulnerability: Flight Activity (the proportion of time a bird spends in fight; FA), flight-height (the proportion of time in flight spent in rotor sweep zone, 20 to 200m; RSZt), and macro-avoidance rate (the proportion of birds displaced from OWEI that would have been expected to be there otherwise; MA). FA, RSZt, and MA metric values were estimated from published literature sources and combined in a multiplicative framework to generate a final CV score for each species. Possible CV scores ranged from 0 to 1.

These data support the following publication:

#### Purpose

The installation of offshore wind energy infrastructure (OWEI) at sea may affect marine birds by increasing the risk of mortality from collision with OWEI (collision vulnerability) and disturbance and displacement from suitable habitats (displacement vulnerability). This data set (Collision Vulnerability) is one of two datasets in our updated Version 2 Vulnerability Index of marine birds to OWEI in the POCS and includes updated relative CV scores based upon new research and data, additional species present in the POCS, and an evolved understanding of the application and utility of the index. The CV values, and input metrics, are easy to update and can readily be applied to offshore renewable energy development assessments and inform future studies of marine bird interactions with OWEI in the POCS.

#### Dataset Credit(s)

This study was developed, supported and funded in part by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington D.C., through Intra-Agency Agreement Number M20PG00028 with the USGS. Thank you to Dr. Ruth Dunn, Dr. Rueda-Uribe, and Deborah Jaques for providing additional flight activity information beyond what they had published, when requested. We would also like to acknowledge Darrin Thome and Tom Kimball of the U.S. Geological Survey for their feedback and Erika Sanchez-Chopitea of the U.S. Geological Survey for data publication guidance.

#### Supplemental Information

Version 1 of our vulnerability index (Adams et al. 2017) was based off similar indices created in the North Sea and U.S. Atlantic Coast: Garthe and Hüppop (2004), Desholm (2009), Furness and Wade (2012), Furness et al. (2013), Robinson Willmott et al. (2013). In Version 2, we have updated the marine bird vulnerability index based upon new research and data (over 80 new data sources were added), additional species present in the POCS (8 new species were added, for a total of 89), and an evolved understanding of the application and utility of the index. Our increased understanding of vulnerability index applications led us to make methodological changes consistent with Shavykin and Karnatov (2022), moving away from ordinal scaling and using continuous, data derived, metric values.

Citations include:

Adams, J., Felis, J.J., Mason, J.W., and Takekawa, J.Y., 2016, Pacific Continental Shelf Environmental Assessment (PaCSEA): aerial seabird and marine mammal surveys off northern California, Oregon, and Washington, 2011-2012. GIS Resource Database: U.S. Geological Survey data release. [Available at: http://dx.doi.org/10.5066/F7668B7V]

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.

Billerman, S.M., Keeney, B.K., Rodewald, P.G., and Schulenberg, T.S. (Editors), 2022, Birds of the World. Cornell Laboratory of Ornithology, Ithaca, NY, USA. <https://birdsoftheworld.org/bow/home>

Bonnet-Lebrun A-S, Dias MP, Phillips RA, Granadeiro JP, Brooke MdL, Chastel O, Clay TA, Fayet AL, Gilg O, González-Solís J, Guilford T, Hanssen SA, Hedd A, Jaeger A, Krietsch J, Lang J, Le Corre M, Militão T, Moe B, Montevecchi WA, Peter H-U, Pinet P, Rayner MJ, Reid T, Reyes-González JM, Ryan PG, Sagar PM, Schmidt NM, Thompson DR, van Bemmelen R, Watanuki Y, Weimerskirch H, Yamamoto T, Catry P (2021) Seabird Migration Strategies: Flight Budgets, Diel Activity Patterns, and Lunar Influence. Frontiers in Marine Science. 8:683071. doi: 10.3389/fmars.2021.683071

Clements, J. F., P. C. Rasmussen, T. S. Schulenberg, M. J. Iliff, T. A. Fredericks, J. A. Gerbracht, D. Lepage, A. Spencer, S. M. Billerman, B. L. Sullivan, and C. L. Wood. 2023. The eBird/Clements checklist of Birds of the World: v2023b. Downloaded from <https://www.birds.cornell.edu/clementschecklist/download/>

Desholm, M. 2009. Avian sensitivity to mortality: prioritizing migratory bird species for assessment at proposed wind farms. Journal of Environmental Management 90(8): 2672-1679. doi:10.1016/j.jenvman.2009.02.05

Drew, G.S., Schoen, S.K., Hood, M.D., Arimitsu, M.L., and Piatt, J.F., 2005, North Pacific Pelagic Seabird Database (NPPSD) (ver. 4.1, May 2023): U.S. Geological Survey data release, https://doi.org/10.5066/F7WQ01T3

eBird. 2021. eBird: An online database of bird distribution and abundance [web application]. eBird, Cornell Lab of Ornithology, Ithaca, New York. Available: http://www.ebird.org. (Accessed: May 19, 2023).

Furness, B., Wade, H. 2012. Vulnerability of Scottish seabirds to offshore wind turbines. MacArthur Green Ltd Glasgow, Scotland. Available online: http://www.gov.scot/resource/0038/00389902.pdf [Accessed 8 January 2016].

Furness, B., H. Wade, E. A. Masden. 2013. Assessing vulnerability of marine bird populations to offshore wind farms. Journal of Environmental Management 119: 56-66.

Garthe, S., and Hüppop, O. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41(4): 724-734. doi:10.1111/j.021-8901.2004.0918.x

Kelsey, E.C., J.J. Felis, M. Czapanskiy, D.M. Pereksta, and J. Adams (2018). Collision and displacement vulnerability to offshore wind energy infrastructure among marine birds of the Pacific Outer Continental Shelf. Journal of Environmental Management. v. 227, p. 229 – 247. doi.10.1016/j.jenvman.2018.08.051

Medrano, F., T. Militão, I. Gomes, M. Sardà-Serra, M. de la Fuente, H.A. Dinis, J. Gonza´ lez-Solı´s (2022). Phenological divergence, population connectivity and ecological differentiation in two allochronic seabird populations. Frontiers in Marine Science. doi.org/10.3389/fmars.2022.975716

Medrano et al. (in prep). Contrasting migratory ecology of two endangered and allochronic storm petrels breeding in the North Pacific.

Militao, T., A. Sanz-Aguilar, A. Rotger, R. Ramos (2022). Non-breeding distribution and at-sea activity patterns of the smallest European seabird, the European Storm Petrel (Hydrobates pelagicus). Ibis, 164: 1160 – 1179. doi.org/10.1111/ibi.13068

Robinson Willmott, J. C., G. Forcey, and A. Kent. 2013. The Relative Vulnerability of Migratory Bird Species to Offshore Wind Energy Projects on the Atlantic Outer Continental Shelf: An Assessment Method and Database. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2013-207. 275 pp.

Shavykin, A., and Karnatov, A., 2022, The issue of using ordinal quantities to estimate the vulnerability of seabirds to wind farms, Journal of Marine Science and Engineering, v. 10, no. 1584, <https://doi.org/10.3390/jmse10111584>

Takekawa, J.Y., Perry, W.M., Adams, J., Felis, J.J., Williams, L.L, Yee, J.L., Orthmeyer, D.L., Mason, J.W., McChesney, G.J., McIver, W.R., Carter, H.R., and Golightly, R.T., 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, GIS Resource Database: U.S. Geological Survey data release, doi.org/10.5066/F7PK0D9P

#### Attribute Accuracy Report

The updated Collision Vulnerability scores and associated metric values presented here in Version 2 are transparently generated and representative of relative vulnerability for POCS marine bird species. The specific updates to the index equation and metrics are described in detail in the associated Data Report. We adopted the following approaches when translating published data from the literature into metric values. If a data source provided multiple values or a range of values relevant a species in the POCS, the midpoint of those values was used in the database. When we obtained values from multiple sources, we took the median of all as the final metric value. When data on a metric value wasn’t available for a given species, we used data for similar species. We grouped similar species (e.g., large gull, medium gull, and small gull), to be more specific in assigning values in the absence of species-specific data. These groupings included POCS species, and their most similar counterparts globally. Thus, if data didn’t exist for a given POCS species, we could be consistent in which additional species we looked to for comparable values.

There are three potential sources for uncertainty associated with metric values for each species:

1. How many literature sources provided species values for that metric.
2. The range of values from the data in those literature sources.
3. Whether metric values were available for the species in question, or whether values were drawn from a similar species or estimated when no species-specific values were available.

We quantified these three potential uncertainty sources on a 0 to 1 scale for each species and metric values, see the Data Report for details. We then multiplied the metric uncertainties across the Version 2 CV metrics to generate a final CV uncertainty value for each species.

#### Purpose Steps

*Describe the methods performed to collect or generate the data, provide as much detail as possible*

##### Step 1

Collision Vulnerability calculation

We define Collision Vulnerability (CV) as the proportion of time a bird of a given species is vulnerable to collision with OWEI. CV values are not analogous to collision risk model outputs or probabilities of collision. Below is our Version 2 Collision Vulnerability equation. All metrics are defined in the following steps. In the context of collision, we are interested in birds that don’t show macro-avoidance (MA) behavior. Thus, we use the inverse (1–MA) for the CV equation.

##### Step 2

**Flight Activity**

A bird is at risk of collision with OWEI while in flight, and the amount of time a bird spends in flight can vary greatly among species. We quantified overall percent time flying (e.g., flight activity; FA) for the 89 species in the POCS. We used information from the Birds of The World accounts (Billerman et al. 2022), Version 1 of our vulnerability index, at-sea survey data (Drew et al., 2005; Adams et al., 2016; Takekawa et al., 2017), and additional sources found during literature searches. In literature searches, we searched by species group (e.g., “loons”), in association with each of the following phrases as standardized search terms to find all relevant sources:

* Daily activity patterns
* GLS
* Nocturnal flight behavior
* Diurnal flight behavior
* Percent time in flight
* Migratory behavior
* Movement behavior
* Activity budget
* Foraging behavior

We used at-sea survey databases of boat-based and aerial seabird observations within the POCS (Adams et al., 2016; Takekawa et al., 2017) and the North Pacific more broadly (Drew et al., 2005) to quantify DFA (since surveys were performed during the day). We combined the two POCS aerial survey datasets to increase sample sizes and have a dataset that spatially represents the entire POCS (Takekawa et al. (2017) off southern California and Adams et al. (2016) off northern California, Oregon, and Washington). In all at-sea datasets, birds were recorded as either flying or on the water. For each species (or species group) with >100 sightings in the database, we calculated the ratio of flying individuals to all individuals recorded to estimate DFA. We did not use these data for species known to spend a significant percent of their time on land (e.g., cormorants and terns), because the ratio of birds flying vs. on the water is biased by the number of uncounted birds that are on land at the time of the survey. Where available, we did record Nocturnal Flight Activity (NFA) and Diurnal Flight Activity (DFA) values separately, before averaging them for a final FA value (FA\_N&D). We preserved NFA and DFA values separately to allow for future calculations to treat collision risk according to diel period.

Our method for determining the final FA value considering FA\_N&D and FA24 values necessitated an approach that varied among species and was dependent on which data inputs were available for a given species. As an example, we determined FA values for the storm-petrel species in the POCS below.

*Species specific FA values were available for two POCS storm-petrel species:*

Leach’s Storm-Petrel: 24-hour flight activity during migration and non-breeding periods was published in Bonnet-Lebrun et al. (2021):

0.5 (non-breeding season), 0.62 (outward migration), 0.61 (return migration)

Thus,

FA24 = median(0.5, 0.62, 0.71) = 0.62

Because we found no other data for Leach’s Storm-Petrel,

FA = 0.62

Townsend’s Storm-Petrel: Nocturnal and diurnal flight activity values during the nonbreeding season were provided by F. Medrano (Medrano et al., in prep):

NFA = 0.727

DFA = 0.313

Thus,

FA\_N&D = (0.727+0.313)/2 = 0.52

Because we found no other data for Townsend’s Storm-Petrel,

FA = 0.52

*For all other storm-petrel species in the POCS, we used the above values for Leach’s and Townsends Storm-petrels, as well as the following values from similar species:*

Cape Verde Storm-Petrel: 24FA = 0.60 (Medrano et al., 2022)

Ainley’s Storm-Petrel: NFA = 0.52, DFA = 0.329 (Medrano et al., in prep)

European Storm-Petrel: NFA = 0.82, DFA = 0.55 (Militao et al., 2022)

Flying storm-petrels : all storm-petrels ratio on aerial surveys: DFA = 0.98 (Adams et al., 2016; Takekawa et al., 2017)

Flying storm-petrels : all storm-petrels ratio on NPPSD surveys: DFA = 0.68 (Drew et al., 2005)

NFA = median(0.52, 0.727, 0.8) = 0.73

DFA = median(0.313, 0.329, 0.55, 0.98, 0.68) = 0.55

Thus,

FA\_N&D = (0.73+0.55)/2 = 0.64

And

24FA = median(0.50, 0.60, 0.62, 0.71) = 0.61

We used FA24 and FA\_N&D values, when available, to generate FA for all other storm-petrel species:

FA = mean(FA\_N&D, 24FA) = mean(0.64, 0.61) = 0.62

The proportion of daylight, and thus the proportion of time spent flying during day and night, can vary with season and latitude for a given species. We prioritized flight activity estimates that were most representative of the latitudes of the POCS and the seasons that a given species spends within the region. In some cases when information on NFA and DFA was limited, we assumed equal periods (12 hr) of day (light) and night (dark) for a 24-hr day when determining NFA and DFA values.

Entities associated with Flight Activity:

* NFA\_new
* NFA\_min
* NFA\_max
* NFA\_Score
* NFA\_Uncertainty\_pct
* DFA\_new
* DFA\_min
* DFA\_max
* DFA\_Score
* DFA\_Uncertainty\_pct
* FA\_N&D
* FA24
* FA24\_min
* FA24\_max
* FA
* FA\_litSourceNo
* FA\_litSourceNo\_rescaled
* FA\_valueRangeDif
* FA\_actVSsimSpp
* uFA
* uFA\_old
* FA\_Reference

##### Step 3

**Time spent in the Rotor Swept Zone**

Birds are vulnerable to collision with OWEI turbine blades when flying within the rotor sweep zone. We collated estimates of the proportion of time a bird spends flying in the rotor swept zone (RSZt) for all species, or from similar species where species-specific estimates were lacking, and identified the median RSZt estimation for each species. We define the rotor swept zone as 20–200 m above the ocean to accommodate the most accurate information on RSZt. We collated RSZt data collected via observation, GPS tracking, range finders, and coupling radar and camera data.

Entities associated with time spent in the rotor swept zone:

* flightHeight(m)
* RSZt\_new
* RSZt\_min
* RSZt\_max
* RSZt\_litSourceNo
* RSZt\_litSourceNo\_rescaled
* RSZt\_valueRangeDif
* RSZt\_actVSsimSpp
* uRSZt
* RSZt\_Score
* RSZt\_Uncertainty\_pct
* RSZt\_Reference

##### Step 4

**Macro Avoidance**

A bird’s likelihood to avoid OWEI influences their potential collision vulnerability (higher likelihood of avoidance leads to lower collisions vulnerability) and displacement vulnerability (higher likelihood of avoidance leads to higher displacement vulnerability). We define Macro-Avoidance (MA) as the proportion of birds displaced from OWEI areas that would have been expected to be there otherwise (e.g., MA = 0.10 represents a decrease of 10% in comparison to baseline abundance numbers, Cook et al., 2014). We incorporated existing MA data (Adams et al., 2017; Kelsey et al., 2018) and MA data published since Version 1. Macro-avoidance has been a major focus of post-construction studies at existing OWEI sites, thus there was much new data available to incorporate. However, data are still deficient for many POCS species (e.g., jaegers, skuas, and pelicans). When data were not available for POCS species, we estimated MA based on MA rates measured at OWEI for similar species, and to a lesser extent, on known avoidance behavior to ships and airplane traffic. Herein, with continuous MA values (0–1) derived from the literature, we quantify MA the same way for both CV and DV (low value is low MA and high value is high MA). For CV, the focus is the birds that are not macro-avoiding OWEI, and thus we used the inverse (1–MA) in the CV equation.

Entities associated with Macro-avoidance:

* MA\_new
* MA\_min
* MA\_max
* MA\_litSourceNo
* MA\_litSourceNo\_rescaled
* MA\_valueRangeDif
* MA\_actVSsimSpp
* uMA
* MA\_Collision\_Score
* MA\_Uncertainty\_pct
* MA\_Reference

##### Step 5

**Uncertainty**

We assessed three potential sources for uncertainty associated with metric values for each species:

1. How many literature sources provided species values for a given metric.
2. The range of values from the data in those literature sources.
3. Whether metric values were available for the species in question, or whether values were drawn from a similar species or estimated when no species-specific values were available.

We quantified these three potential uncertainty sources on a 0–1 scale for each species and metric value. We took the geometric mean of these three values to generate an uncertainty for each species metric value. We then multiplied the metric uncertainties (uFA, uRSZt, uMA) to generate a final CV uncertainty value for each species:

uCV =

*u = uncertainty associated with a given metric or vulnerability score*

###### Number of literature sources

We assume that there is greater uncertainty associated with metric values derived from only one literature source, as opposed to metric values for which data from multiple literature sources were available. We quantified the number of sources used to determine each species metric value. We found that most metric values we derived from five or fewer sources. Thus, we determined that any metric value with six or more sources to be a high number of sources and, when quantifying the number of sources used, we “capped” the number of sources at six (e.g., any metric value with more than six sources used was given source value of six). We then rescaled this value from 0–1 by dividing the sources value by six.

Associated Entities:

[metric abbreviation]\_litSourceNo

[metric abbreviation]\_litSourceNo\_rescaled

###### Range of published values

When multiple metric values were presented in the literature for a given species, we took the median of those values as our final metric values. We assume that there is greater uncertainty associated with values derived from a wider range of values from the published literature, as opposed to metrics where all published values are similar. To quantify this uncertainty, we took the difference in the range of values from the published literature for each species’ metric value (difference between the maximum and minimum values found). Multiple value ranges were used in FA (value ranges for NFA, DFA, and FA24). In this case, we used the difference in values from the largest value range.

Associated Entities:

[metric abbreviation]\_valueRangeDif

###### Values from the actual vs. similar species

We assume there is greater uncertainty associated with metric values derived from similar species when no values were available for the species in consideration. To quantify the uncertainty associated with the difference between data from actual or similar species being used, we assigned uncertainty values between 0–1. Given that we used values from the most closely associated species when species-specific values weren’t available, the uncertainty values were:

0.25 = values used were from the species in question

0.5 = values used were from a similar species within the same taxonomic family

0.75 = values used were from a species from a different taxonomic family OR values used were estimates with no values available that could be associated with the species in question.

Associated Entities:

[metric abbreviation]\_actVSsimSpp

### Entity and Atribute (CV)

Overview description: *The entity and attribute information provided here describes the tabular data associated with the data set. Please review the detailed descriptions that are provided (the individual attribute descriptions) for information on the values that appear as fields/table entries of the data set*.

Citation: *The entity and attribute information was generated by the individual and/or agency identified as the originator of the data set. Please review the rest of the metadata record for additional details and information.*

**Detailed tab**

TaxNumCl\_2023: Species Taxonomy Number, based on taxonomic order (Clements et al. 2023).

Taxonomy: Species Taxonomic Group

Common\_Name: Species common English name

AlphaCode: Species 4-letter alphanumeric code

Scientific\_Name: Species Scientific Name

NFA\_new: The median of all Nocturnal Flight Activity (NFA) values found in the literature. NFA is the percent time the species is estimated to spend in flight during the night. If we found no data on NFA was found for a given species, the field = NA.

NFA\_min: The minimum NFA value found in the literature. If we found only one NFA value, it is presented in NFA\_min.

NFA\_max: The maximum NFA value found in the literature. If we found only one NFA value, it is presented in NFA\_min and this field = NA.

NFA\_Score: The ordinal NFA value used in Version 1 (Adams et al. 2017). In Version 1, we assigned an integer from 1 to 5 for each species NFA depending on the nocturnal percent time spent in flight: 1 = 0 to 20%, 2 = 21 to 40%, 3 = 41 to 60%, 4 = 61 to 80%, 5 = 81 to 100%

NFA\_Uncertainty\_pct: The percent uncertainty associated with NFA\_Score based on the number of literature sources and quality of data used in Version 1 (Adams et al. 2017).

DFA\_new: The median of all Diurnal Flight Activity (DFA) values found in the literature. DFA is the percent time the species is estimated to spend in flight during the night. If we found no data on DFA was found for a given species, the field = NA.

DFA\_min: The minimum DFA value found in the literature. If we found only one DFA value, it is presented in DFA\_min.

DFA\_max: The maximum DFA value found in the literature. If we found only one DFA value, it is presented in DFA\_min and this field = NA.

DFA\_Score: The ordinal DFA value used in Version 1 (Adams et al. 2017). In Version 1, we assigned an integer from 1 to 5 for each species DFA depending on the nocturnal percent time spent in flight: 1 = 0 to 20%, 2 = 21 to 40%, 3 = 41 to 60%, 4 = 61 to 80%, 5 = 81 to 100%

DFA\_Uncertainty\_pct: The percent uncertainty associated with NFA\_Score based on the number of literature sources and quality of data used in Version 1 (Adams et al. 2017).

FA\_N&D: Estimation of Flight Activity (FA) based on data published on NFA and DFA: the geometric mean of NFA\_new and DFA\_new values. Calculation: (NFA\_new+DFA\_new)/2

FA24: The median of all 24-hour flight activity values we found in the literature (represented in 24-hr flight activity as opposed to broken into nocturnal and diurnal periods). If no data on 24-hr flight activity was found for a species, the field = NA.

FA24\_min: The amount of time a species spends in flight over a 24-hour period. The range represents the range of values found in the literature. If we found only one FA24 value, it is presented in FA24\_min.

FA24\_max: The amount of time a species spends in flight over a 24-hour period. The range represents the range of values found in the literature. If we found only one FA24 value, it is presented in FA24\_min and this field = NA.

FA: Flight Activity, defined as the percent time a bird of a given species is estimated to spend in flight (as opposed to on land or on the water). If FA\_N&D and FA24 values were available for a given species, FA was the average of these values. If only FA\_N&D or FA24 was available, the available value was used for FA. Calculation: =IF([FA24] = "", [FA\_N&D], MEDIAN([FA\_N&D], [FA24]))

FA\_litSourceNo: The number of literature sources used to determine FA for a given species.

FA\_litSourceNo\_rescaled: The number of literature sources used to determine FA for a given species, rescaled from 0-1. We determined that any metric value with six or more sources to be a high number of sources. As such, when quantifying the number of sources used, we capped the number of sources at six (e.g., any metric value with more than six sources used was given source value of six) and divided the resulting value by six. This value was used as one of three components to quantify FA uncertainty. Calculation: =1 - IF([FA\_litSourceNo] > 6, 1, ([FA\_litSourceNo]/6))

FA\_valueRangeDif: The difference betwen NFA\_min and NFA\_max, DFA\_min and DFA\_max, or FA24\_min and FA24\_max. Because multiple value ranges were used in FA (value ranges for NFA, DFA, and/or FA24), we used the difference in values from the largest value range to quantify this uncertainty. This value was used as one of three components to quantify FA uncertainty.

FA\_actVSsimSpp: We assigned values between 0-1 to quantify the uncertainty associated with using FA\_N&D and FA24 data from a similar species when data for a given species was not available. Given that we used values from the most closely associated species when species-specific values weren’t available, the uncertainty values were:

0.25 = values used were from the species in question

0.5 = values used were from a similar species within the same taxonomic family

0.75 = values used were from a species from a different taxonomic family OR values used were estimates with no values available that could be associated with the species in question.

This value was used as one of three components to quantify FA uncertainty.

uFA: FA uncertainty. This value is the geometric mean of the three uncertainty sources we identified:

1. How many literature sources provided species data for that metric (FA\_litSourceNo\_rescaled)
2. The range of values from the data in those literature sources (FA\_valueRangeDif)
3. Whether published values were available for the species in question, or whether values were drawn from a similar species or estimated when no species-specific values were available (FA\_actVSsimSpp)

uFA\_old: The geometric mean of NFA\_Uncertainty\_pct and DFA\_Uncertainty\_pct from Version 1 (Adams et al. 2017). We generated this value to be comparable to uFA in Version 2.

FA\_Reference: Literature sources used to determine FA\_N&D and FA24 (similar spp before a reference indicates that the cited reference provided a value for a similar species, in the absence of a relevant value for the species in question).

flightHeight(m): Published flight height for the species, if available.

RSZt\_new: The percentage of time a bird of a given species spends flying at the same height as the rotor sweep zone (RSZt; 20-200 m above the water). This value represents the median of all RSZt values found in the literature.

RSZt\_min: The minimum RSZt value found in the literature. This value was used along with RSZt\_max to determine the range of RSZt values (RSZt\_valueRangeDif). If we only found one value, it is presented in RSZt\_min.

RSZt\_max: The maximum RSZt value found in the literature. This value was used along with RSZt\_min to determine the range of RSZt values (RSZt\_valueRangeDif). If we only found one value, it is presented in RSZt\_min and this field = NA.

RSZt\_litSourceNo: The number of literature sources used to determine RSZt\_new for a given species.

RSZt\_litSourceNo\_rescaled: The number of literature sources used to determine RSZt\_new for a given species, rescaled from 0-1. We determined that any metric value with six or more sources to be a high number of sources. As such, when quantifying the number of sources used, we capped the number of sources at six (e.g., any metric value with more than six sources used was given source value of six) and divided the resulting value by six. This value was used as one of three components to quantify RSZt uncertainty. Calculation: = 1 - IF([RSZt\_litSourceNo] > 6, 1, ([RSZt\_litSourceNo]/6))

RSZt\_valueRangeDif: The range of input values for RSZt\_new, the difference of RSZt\_min and RSZt\_max. This value was used as one of three components to quantify RSZt uncertainty.

RSZt\_actVSsimSpp: We assigned uncertainty values between 0-1 to quantify the uncertainty associated with using RSZt data from a similar species as opposed to the species in question. Given that we used values from the most closely associated species when species-specific values weren’t available, the uncertainty values were:

0.25 = values used were from the species in question

0.5 = values used were from a similar species within the same taxonomic family

0.75 = values used were from a species from a different taxonomic family OR values used were estimates with no values available that could be associated with the species in question.

This value was used as one of three components to quantify RSZt uncertainty.

uRSZt: RSZt uncertainty. This value is the geometric mean of the three uncertainty sources we identified:

1. How many literature sources provided species data for that metric (RSZt\_litSourceNo\_rescaled)
2. The range of values from the data in those literature sources (RSZt\_valueRangeDif)
3. Whether published values were available for the species in question, or whether values were drawn from a similar species or estimated when no species-specific values were available (RSZt\_actVSsimSpp)

RSZt\_Score: The ordinal RSZt score from Version 1 of the vulnerability index (Adams et al. 2017). Because RSZt percentage ranges tended to be large (due to uncertainty), only the values 1, 3, and 5 were used. 5 = greater than 20%, 3 = 5–20%,1 = less than 5%. The most frequent and/or relevant percent found in sources was given the most weight when assigning each score.

RSZt\_Uncertainty\_pct: The percent uncertainty associated with RSZt\_Score based on the number of literature sources and quality of data used in Version 1 (Adams et al. 2017).

RSZt\_Reference: Literature sources used to determine RSZt\_new (similar spp before a reference indicates that the cited reference provided a value for a similar species, in the absence of a relevant value for the species in question).

MA\_new: Macro-Avoidance (MA) defined as the proportion of birds displaced from OWEI that would have been expected to be there otherwise. This value is the range of all MA values found in the literature.

MA\_min: The minimum MA value found in the literature. This value was used along with MA\_max to determine the range of MA values (MA\_valueRangeDif). If we found only one value, it is presented in MA\_min.

MA\_max: The maximum MA value found in the literature. This value was used along with MA\_min to determine the range of MA values (MA\_valueRangeDif). If we found only one value, it is presented in MA\_min and this field = NA.

MA\_litSourceNo: The number of literature sources used to determine MA\_new for a given species.

MA\_litSourceNo\_rescaled: The number of literature sources used to determine MA\_new for a given species, rescaled from 0-1. We determined that any metric value with six or more sources to be a high number of sources. As such, when quantifying the number of sources used, we capped the number of sources at six (e.g., any metric value with more than six sources used was given source value of six) and divided the resulting value by six. This value was used as one of three components to quantify MA uncertainty. Calculation: = 1 - IF([RSZt\_litSourceNo] > 6, 1, ([RSZt\_litSourceNo]/6))

MA\_valueRangeDif: The range of input values for MA\_new, the difference of MA\_min and MA\_max. This value was used as one of three components to quantify MA uncertainty.

MA\_actVSsimSpp: We assigned uncertainty values between 0-1 to quantify the uncertainty associated with using MA data from a similar species as opposed to the species in question. Given that we used values from the most closely associated species when species-specific values weren’t available, the uncertainty values were:

0.25 = values used were from the species in question

0.5 = values used were from a similar species within the same taxonomic family

0.75 = values used were from a species from a different taxonomic family OR values used were estimates with no values available that could be associated with the species in question.

This value was used as one of three components to quantify RSZt uncertainty.

uMA: MA uncertainty. This value is the geometric mean of the three uncertainty sources we identified:

1. How many literature sources provided species data for that metric (MA \_litSourceNo\_rescaled)
2. The range of values from the data in those literature sources (MA\_valueRangeDif)
3. Whether published values were available for the species in question, or whether values were drawn from a similar species or estimated when no species-specific values were available (MA\_actVSsimSpp)

MA\_Collision\_Score: The ordinal MA value from Version 1 of the vulnerability index (Adams et al. 2017). We assigned ordinal 1 to 5 MA values such that high avoidance is associated with low collision risk and low avoidance rate is associated with high collision risk. 1= greater than 40% avoidance, 2 = 30 to 40% avoidance, 3 = 18 to 29% avoidance, 4 = 6 to 17% avoidance, 5 = 0 to 5% avoidance

MA\_Uncertainty\_pct: The percent uncertainty associated with MA\_Collision\_Score based on the number of literature sources and quality of data in Version 1 (Adams et al. 2017).

MA\_Reference: Literature sources used to determine MA (similar spp before a reference indicates that the cited reference provided a value for a similar species, in the absence of a relevant value for the species in question).

CV\_new: CV score from this Version 2. Calculated as the product of FA, RSZt\_new, and MA\_new. Calculation =FA\*RSZt\_new\*(1-MA\_new)

uCV: CV uncertainty. Calculated as the product of uFA, uRSZt, uMA.

CV\_Best\_Estimate\_old: CV score from Version 1 of the vulnerability index (Adams et al. 2017). Calculated as ((NFA\_Score plus DFA\_Score) divided by 2) plus RSZt\_Score plus MA\_Collision\_Score

uCV\_old: Calculated as the product of uFA\_old, RSZt\_Uncertainty\_pct, MA\_Uncertainty\_pct. We generated this summary of the percent uncertainties used in Version 1 of the vulnerability index to compare with uCV in Version 2.

### Data for the revised marine bird Displacement Vulnerability Index for Pacific Outer Continental Shelf offshore wind energy development

#### Abstract

To better inform continued offshore wind energy development in the region, U.S. Geological Survey, Western Ecological Research Center has updated the database of marine bird vulnerabilities to offshore wind energy infrastructure (OWEI) in the Pacific Outer Continental Shelf Region (POCS; waters within the Exclusive Economic Zone off California, Oregon, and Washington). The installation of offshore wind energy infrastructure (OWEI) at sea may affect marine birds by increasing the risk of mortality from collision with OWEI (Collision Vulnerability) and disturbance and displacement from suitable habitats (Displacement Vulnerability). We define Displacement Vulnerability (DV) as the as the likelihood that a bird of a given species will be displaced from important habitat by the presence of OWEI. This data set consists of DV Version 2, updated from Version 1 (Adams et al. 2017) to include relative displacement vulnerability scores for the 89 marine bird species in the POCS. The Version 2 DV updates are based upon new research and data, additional species present in the POCS, and an evolved understanding of the application and utility of the index. We use two metrics to determine DV: Macro-Avoidance rate (the proportion of birds displaced from OWEI that would have been expected to be there otherwise; MA) and Habitat Specificity (the likelihood that, if displaced, a bird can fulfill its habitat needs elsewhere). MA and HS metric values were estimated from published literature sources and combined in a multiplicative framework to generate a final DV score for each species. Possible DV scores ranged from 0 to 1.

These data support the following publication:

#### Purpose

The installation of offshore wind energy infrastructure (OWEI) at sea may affect marine birds by increasing the risk of mortality from collision with OWEI (collision vulnerability) and disturbance and displacement from suitable habitats (displacement vulnerability). This data set (Displacement Vulnerability; DV) is one of two datasets in our updated Version 2 Vulnerability Index of marine birds to OWEI in the POCS and includes updated relative DV scores based upon new research and data, additional species present in the POCS, and an evolved understanding of the application and utility of the index. The DV values, and input metrics, are easy to update and can readily be applied to offshore renewable energy development assessments and inform future studies of marine bird interactions with OWEI in the POCS.

#### Dataset Credit(s)

This study was developed, supported and funded in part by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington D.C., through Intra-Agency Agreement Number M20PG00028 with the USGS. Thank you to Dr. Ruth Dunn, Dr. Rueda-Uribe, and Deborah Jaques for providing additional flight activity information beyond what they had published, when requested. We would also like to acknowledge Darrin Thome and Tom Kimball of the U.S. Geological Survey for their feedback and Erika Sanchez-Chopitea of the U.S. Geological Survey for data publication guidance.

#### Supplemental Information

Version 1 of our vulnerability index (Adams et al. 2017) was based off similar indices created in the North Sea and U.S. Atlantic Coast: Garthe and Hüppop (2004), Desholm (2009), Furness and Wade (2012), Furness et al. (2013), Robinson Willmott et al. (2013). In Version 2, we have updated the marine bird vulnerability index based upon new research and data (over 80 new data sources were added), additional species present in the POCS (8 new species were added, for a total of 89), and an evolved understanding of the application and utility of the index. Our increased understanding of vulnerability index applications led us to make methodological changes consistent with Shavykin and Karnatov (2022), moving away from ordinal scaling and using continuous, data derived, metric values.

Citations include:

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.

Clements, J. F., P. C. Rasmussen, T. S. Schulenberg, M. J. Iliff, T. A. Fredericks, J. A. Gerbracht, D. Lepage, A. Spencer, S. M. Billerman, B. L. Sullivan, and C. L. Wood. 2023. The eBird/Clements checklist of Birds of the World: v2023b. Downloaded from <https://www.birds.cornell.edu/clementschecklist/download/>

Desholm, M. 2009. Avian sensitivity to mortality: prioritizing migratory bird species for assessment at proposed wind farms. Journal of Environmental Management 90(8): 2672-1679. doi:10.1016/j.jenvman.2009.02.05

eBird. 2021. eBird: An online database of bird distribution and abundance [web application]. eBird, Cornell Lab of Ornithology, Ithaca, New York. Available: http://www.ebird.org. (Accessed: May 19, 2023).

Furness, B., Wade, H. 2012. Vulnerability of Scottish seabirds to offshore wind turbines. MacArthur Green Ltd Glasgow, Scotland. Available online: http://www.gov.scot/resource/0038/00389902.pdf [Accessed 8 January 2016].

Furness, B., H. Wade, E. A. Masden. 2013. Assessing vulnerability of marine bird populations to offshore wind farms. Journal of Environmental Management 119: 56-66.

Garthe, S., and Hüppop, O. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41(4): 724-734. doi:10.1111/j.021-8901.2004.0918.x

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): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-014. 385 p.

Robinson Willmott, J. C., G. Forcey, and A. Kent. 2013. The Relative Vulnerability of Migratory Bird Species to Offshore Wind Energy Projects on the Atlantic Outer Continental Shelf: An Assessment Method and Database. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2013-207. 275 pp.

Shavykin, A., and Karnatov, A., 2022, The issue of using ordinal quantities to estimate the vulnerability of seabirds to wind farms, Journal of Marine Science and Engineering, v. 10, no. 1584, https://doi.org/10.3390/jmse10111584

#### Attribute Accuracy Report

The updated Displacement Vulnerability scores and associated metric values presented here in Version 2 are transparently generated and representative of relative vulnerability for POCS marine bird species. The specific updates to the index equation and metrics are described in detail in the Data Report. We adopted the following approaches when translating published data from the literature into metric values. If a data source provided multiple values or a range of values relevant a species in the POCS, the midpoint of those values was used in the database. When we obtained values from multiple sources, we took the median of all as the final metric value. When data on a metric value wasn’t available for a given species, we used data for similar species. We grouped similar species (e.g., large gull, medium gull, and small gull), to be more specific in assigning values in the absence of species-specific data. These groupings included POCS species, and their most similar counterparts globally. Thus, if data didn’t exist for a given POCS species, we could be consistent in which additional species we looked to for comparable values.

There are three potential sources for uncertainty associated with metric values for each species:

1. How many literature sources provided species values for that metric.
2. The range of values from the data in those literature sources.
3. Whether metric values were available for the species in question, or whether values were drawn from a similar species or estimated when no species-specific values were available.

We quantified these three potential uncertainty sources on a 0-1 scale for each species and metric values, see the Data Report for details. We then multiplied the metric uncertainties across the Version 2 DV metrics to generate a final DV uncertainty value for each species.

#### Purpose Steps

*Describe the methods performed to collect or generate the data, provide as much detail as possible*

##### Step 1

Displacement Vulnerability equation

We define Displacement Vulnerability (DV) as the likelihood that a bird of a given species will be displaced from important habitat by the presence of OWEI. In Version 2, DV is the species’ probability of avoiding OWEI (MA), times the inability of that species to fulfill their habitat needs elsewhere (Habitat Specificity, HS).

##### Step 2

Macro Avoidance

A bird’s likelihood to avoid OWEI influences their potential collision vulnerability (higher likelihood of avoidance leads to lower collisions vulnerability) and displacement vulnerability (higher likelihood of avoidance leads to higher displacement vulnerability). We recognize three broad types of avoidance behavior: macro-avoidance (change in flight course to avoid entering a wind farm area), meso-avoidance (change in flight direction within a wind farm area to avoid wind turbines) and micro-avoidance (last-minute flight movements to avoid a specific turbine; Cook et al., 2014). In our vulnerability index, we focus solely on macro-avoidance for two reasons. First, most birds display macro-avoidance behavior, as opposed to making within-wind farm avoidance decisions, thus decreasing the relevance of meso- and micro-avoidance in most cases. Second, macro-avoidance influences both collision and displacement vulnerability directly (albeit with the opposite effect).

We define Macro-Avoidance (MA) as the proportion of birds displaced from OWEI areas that would have been expected to be there otherwise (e.g., MA = 0.10 represents a decrease of 10% in comparison to baseline abundance numbers, Cook et al., 2014). We incorporated existing MA data (Adams et al., 2017; Kelsey et al., 2018) and MA data published since Version 1. Macro-avoidance has been a major focus of post-construction studies at existing OWEI sites, thus there was much new data available to incorporate. However, data are still deficient for many POCS species (e.g., jaegers, skuas, and pelicans). When data were not available for POCS species, we estimated MA based on MA rates measured at OWEI for similar species, and to a lesser extent, on known avoidance behavior to ships and airplane traffic.

Entities associated with Macro-avoidance:

* MA\_new
* MA\_min
* MA\_max
* MA\_litSourceNo
* MA\_litSourceNo\_rescaled
* MA\_valueRangeDif
* MA\_actVSsimSpp
* uMA
* MA\_Collision\_Score
* MA\_Uncertainty\_pct
* MA\_Reference

##### Step 3

Habitat Specificity

Habitat Specificity is a function of how diverse the species’ needs are (Foraging Specificity) and the likelihood that unaffected available habitat may be found elsewhere (Spatial Specificity).

We quantified Spatial Specificity (SS) using species distribution models developed by Leirness et al. (2021) for the POCS. Specifically, we quantified the skewness of the distribution of species-specific predicted density values across the POCS as a measure of how broad and dispersed (low skew of distribution of density values) or isolated and aggregated (high skew of distribution of density values). Figure 2 provides an example of skewness for two species; Pink-footed Shearwater is dispersed throughout the POCS, and thus has a low skew value. In contrast, Double-crested Cormorant has a more aggregated distribution, only found in a few coastal locations along the POCS (Figure 2). The final species distribution models developed by Leirness et al. (2021) were season-specific. Therefore, to generate a singular SS value, we took the weighted average of all seasonal layers for a given species. We used the sum of predicted density values for each season and gave more weight to seasons when more birds were predicted/present. We quantified the skewness of this combined weighted layer for each species. Skewness values were then natural-log-transformed and re-scaled (0–1) by dividing by the maximum species-specific SS value. Fifty-six of the 89 species in this vulnerability index had enough spatial data to be modeled by Leirness et al. (2021). For the remaining 33 species without skewness values, we generated best estimate values based on expert opinion and by referencing eBird data (eBird 2021).

Foraging Specificity (FS) provides a measure of how specific (or diverse) a species’ foraging mode and diet are. We determined FS to be a function of a species’ foraging mode (e.g., deep diving, surface dipping, plunge diving, etc.) and the size/trophic level of their prey (Table 3). To generate the FS value for each species, we assigned one point for each unique Foraging Modes used (FM) and Prey Size/Trophic Levels (ST) in their diet (Table 1). FM and ST points were summed separately (a sum for FM and a sum for ST) and rescaled so that values were equally weighted across FM and ST, respectively. We averaged FM and ST and subtracted the average from one to get the final FS value for each species. We subtracted from one so that a high value would reflect high specificity, and a low value would reflect low specificity. For each species, final SS and FS values were averaged to get a final HF value between 0 and 1.

Table 1. Options of foraging modes (FM) and prey size/trophic levels (ST) used by POCS marine bird species. To determine each species’ Foraging Specificity; FM and ST were enumerated, rescaled across all species FM and ST respectively, and averaged.

| Foraging Mode (FM) | Prey size/trophic level (ST) |
| --- | --- |
| Deep Diving | 1 prey size and/or trophic level |
|
| Shallow diving |
| 2 prey sizes and/or trophic levels |
| Surface dipping, surface seizing, or aerial pursuit |
|
| Plunge diving | 3 prey sizes and/or trophic levels |
|
| Kleptoparasitism |
| More than 3 prey sizes and/or trophic levels |
| Scavenging |
|

Entities associated with Habitat Specificity:

* FS
* SS
* HS
* uHS
* HF\_Score
* HF\_Uncertainty\_pct
* HS\_Reference

##### Step 4

**Uncertainty**

We assessed three potential sources for uncertainty associated with metric values for each species:

1. How many literature sources provided species values for a given metric.
2. The range of values from the data in those literature sources.
3. Whether metric values were available for the species in question, or whether values were drawn from a similar species or estimated when no species-specific values were available.

We quantified these three potential uncertainty sources on a 0–1 scale for each species and metric value. We took the geometric mean of these three values to generate an uncertainty for each species metric value. We then multiplied the metric uncertainties (uFA, uRSZt, uMA) to generate a final CV uncertainty value for each species:

uCV =

*u = uncertainty associated with a given metric or vulnerability score*

###### Number of literature sources

We assume that there is greater uncertainty associated with metric values derived from only one literature source, as opposed to metric values for which data from multiple literature sources were available. We quantified the number of sources used to determine each species metric value. We found that most metric values we derived from five or fewer sources. Thus, we determined that any metric value with six or more sources to be a high number of sources and, when quantifying the number of sources used, we “capped” the number of sources at six (e.g., any metric value with more than six sources used was given source value of six). We then rescaled this value from 0–1 by dividing the sources value by six.

Associated Entities:

[metric abbreviation]\_litSourceNo

[metric abbreviation]\_litSourceNo\_rescaled

###### Range of published values

When multiple metric values were presented in the literature for a given species, we took the median of those values as our final metric values. We assume that there is greater uncertainty associated with values derived from a wider range of values from the published literature, as opposed to metrics where all published values are similar. To quantify this uncertainty, we took the difference in the range of values from the published literature for each species’ metric value (difference between the maximum and minimum values found). Multiple value ranges were used in FA (value ranges for NFA, DFA, and FA24). In this case, we used the difference in values from the largest value range.

Associated Entities:

[metric abbreviation]\_valueRangeDif

###### Values from the actual vs. similar species

We assume there is greater uncertainty associated with metric values derived from similar species when no values were available for the species in consideration. To quantify the uncertainty associated with the difference between data from actual or similar species being used, we assigned uncertainty values between 0–1. Given that we used values from the most closely associated species when species-specific values weren’t available, the uncertainty values were:

0.25 = values used were from the species in question

0.5 = values used were from a similar species within the same taxonomic family

0.75 = values used were from a species from a different taxonomic family OR values used were estimates with no values available that could be associated with the species in question.

Associated Entities:

[metric abbreviation]\_actVSsimSpp

### Entity and Atribute (DV)

TaxNumCl\_2023: Species Taxonomy Number, based on taxonomic order (Clements et al. 2023).

Taxonomy: Species Taxonomic Group

Common\_Name: Species common English name

AlphaCode: Species 4-letter alphanumeric code

Scientific\_Name: Species Scientific Name

MA\_new: Macro-Avoidance (MA) defined as the proportion of birds displaced from OWEI that would have been expected to be there otherwise. This value is the range of all MA values found in the literature.

MA\_min: The minimum MA value found in the literature. This value was used along with MA\_max to determine the range of MA values (MA\_valueRangeDif). If we found only one value, it is presented in MA\_min.

MA\_max: The maximum MA value found in the literature. This value was used along with MA\_min to determine the range of MA values (MA\_valueRangeDif). If we found only one value, it is presented in MA\_min and this field = NA.

MA\_litSourceNo: The number of literature sources used to determine MA\_new for a given species.

MA\_litSourceNo\_rescaled: The number of literature sources used to determine MA\_new for a given species, rescaled from 0-1. We determined that any metric value with six or more sources to be a high number of sources. As such, when quantifying the number of sources used, we capped the number of sources at six (e.g., any metric value with more than six sources used was given source value of six) and divided the resulting value by six. This value was used as one of three components to quantify MA uncertainty. Calculation: = 1 - IF([MA\_litSourceNo] > 6, 1, ([MA\_litSourceNo]/6))

MA\_valueRangeDif: The range of input values for MA\_new, the difference of MA\_min and MA\_max. This value was used as one of three components to quantify MA uncertainty.

MA\_actVSsimSpp: We assigned uncertainty values between 0-1 to quantify the uncertainty associated with using MA data from a similar species as opposed to the species in question. Given that we used values from the most closely associated species when species-specific values weren’t available, the uncertainty values were:

0.25 = values used were from the species in question

0.5 = values used were from a similar species within the same taxonomic family

0.75 = values used were from a species from a different taxonomic family OR values used were estimates with no values available that could be associated with the species in question.

This value was used as one of three components to quantify RSZt uncertainty.

uMA: MA uncertainty. This value is the geometric mean of the three uncertainty sources we identified:

1. How many literature sources provided species data for that metric (MA \_litSourceNo\_rescaled)
2. The range of values from the data in those literature sources (MA\_valueRangeDif)
3. Whether published values were available for the species in question, or whether values were drawn from a similar species or estimated when no species-specific values were available (MA\_actVSsimSpp)

MA\_Displacement\_Score: The ordinal MA value from Version 1 of the vulnerability index (Adams et al. 2017). The percentage ranges for macro-avoidance (MA) were determined and assigned integers from 1 to 5, high avoidance rate is associated with high displacement risk and low avoidance rate is associated with low collision risk. 1=0 to 5% avoidance, 2=6 to 17% avoidance, 3=18 to 29% avoidance, 4=30–40% avoidance, 5= greater than 40% avoidance

MA\_Uncertainty\_pct: The percent uncertainty associated with MA\_Collision\_Score based on the number of literature sources and quality of data in Version 1 (Adams et al. 2017).

MA\_Reference: Literature sources used to determine MA (similar spp before a reference indicates that the cited reference provided a value for a similar species, in the absence of a relevant value for the species in question).

FS: Foraging Specificity (FS) is a measure of how specific (or diverse) a species’ foraging mode and diet is as a function of their foraging mode (e.g., deep diving, surface dipping, plunge diving, etc.) and the size/trophic level of their prey. To generate FS, we gave each species a point for each Foraging Mode used (FM; deep diving, shallow diving, surface dipping/surface seizing/aerial pursuit, plunge diving, kleptoparasitism, scavenging) and Prey Size/Trophic Level (ST; 1 prey size and/or trophic level, 2 prey sizes and/or trophic levels, 3 prey sizes and/or trophic levels, more than 3 prey sizes and/or trophic levels) in their diet. FM and ST points were separately summed for each species, rescaled so that scores were equally weighted across FM and ST respectively. FM and ST were then averaged and subtracted from one to get the final FS score for each species. We subtracted from 1 so that a high value would reflect high specificity, and a low value would reflect low specificity.

SS: Spatial Specificity (SS) is the skewness of species-specific predicted density surfaces as a measure of how broad and dispersed (low skew of distribution of density values) or isolated and aggregated (high skew of distribution of density values) a species is in space (Lierness et al., 2021). For the 56 of the 89 species in this vulnerability index had enough spatial data to be modeled by Leirness et al. (2021), we took the sum of predicted density values for each season for all seasonal species distribution layers for a given species. We then quantified the skewness of this final layer for each species. Skewness values were then natural-log-transformed and re-scaled on a 0–1 scale by dividing by the maximum species-specific SS value. For the remaining 33 species for which there weren’t skewness values, we generated best estimate values based on expert opinion and eBird data (eBird 2021).

HS: Habitat Specificity (HS) is a function of how diverse the species’ needs are (FS) and the likelihood that unaffected available habitat may be found elsewhere (SS). HS the geometric mean of FS and SS. Calculation: = (FS+SS)/2

uHS: We assigned uncertainty values between 0-1 to quantify the uncertainty associated with using HS data from a similar species as opposed to the species in question. Given that we used values from the most closely associated species when species-specific values weren’t available, the uncertainty values were:

0.25 = values used were from the species in question

0.5 = values used were from a similar species within the same taxonomic family

0.75 = values used were from a species from a different taxonomic family OR values used were estimates with no values available that could be associated with the species in question.

This was the one metric of uncertainty associated with HS.

HF\_Score: The ordinal Habitat Flexibility (HF) score used in Version 1 of the vulnerability index (Adams et al. 2017). Considering available knowledge, an ordinal score from 1 to 5 was assigned for each species depending on their habitat flexibility.

1: Species are opportunistic foragers, have a wide range of prey available to them, and/or use a wide range of foraging habitats over a large area.

2 to 4: Species show some grade of behavior between 1 and 5,

5: Species have very habitat- and prey- specific requirements and do not show flexibility in foraging behavior, habitat selection, or prey species choices.

HF\_Uncertainty\_pct: The percent uncertainty associated with HF\_Score based on the number of literature sources and quality of data used in Version 1 (Adams et al. 2017).

HS\_Reference: Literature sources used to determine HS (similar spp before a reference indicates that the cited reference provided a value for a similar species, in the absence of a relevant value for the species in question).

DV\_new: DV score. The product of MA\_new and HS. Calculation = MA\_new\*HS

uDV: DV uncertainty. The product of uMA and HS\_actVSsimSpp.

DV\_Best\_Estimate\_old: DV score from Version 1 of the vulnerability index (Adams et al. 2017). The sum of MA\_ Displacement\_Score and HF\_Score.

uDV\_old: The product of MA\_Uncertainty\_pct and HF\_Uncertainty\_pct. We generated this summary of the percent uncertainties used in Version 1 of the vulnerability index to compare with uDV (Adams et al. 2017).