**OCS Study**

**NSL-PC-12-01**

**Vulnerability Index for Scaling the Possible Adverse Effects of**

**Offshore Renewable Energy Projects on Seabirds of the Pacific OCS**

Assessing collision and displacement vulnerability among seabirds of the California Current Region





**U.S. Department of the Interior**

**Bureau of Ocean Energy Management**

**Office of Renewable Energy Programs**

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**Assessing collision and displacement vulnerability among seabirds of the California Current Region**

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ABOUT THE COVER

Cover photo: Pink-footed Shearwater in flight. Courtesy of Jeff Poklen.

# ABSTRACT

Offshore wind power is considered a viable alternative energy source for the United States west coast. The implementation of offshore wind-energy infrastructure will affect the marine environment, including marine bird life. Marine birds are vulnerable to collision with and displacement by offshore wind-energy infrastructure. Based on similar assessments quantifying marine bird vulnerability to offshore wind facilities in the North Sea, UK, and western Atlantic, we created a comprehensive database of marine bird vulnerability to potential offshore wind-energy infrastructure in the California Current System (CCS). Using published values on natural history and demography, flight heights and flight styles, and avoidance behavior observed at existing offshore wind power sites; we quantified collision and displacement vulnerability for 62 seabird and 17 marine water bird species that occur in the CCS. At the taxonomic level, pelicans, cormorants, and terns have the greatest collision vulnerability due to low avoidance rates and a high percentage of time flying at the height of turbine blades. Alcids, terns, and loons have the most vulnerable to displacement by offshore wind power infrastructure due to their sensitivity to disturbance and low habitat flexibility. The levels of vulnerability generated using this database can readily be applied to areas in the CCS where offshore renewable energy development is being considered and can be used to help inform planning decisions that will impact seabird conservation.

**Table of Contents**

[ABSTRACT 5](#_Toc418586418)

[1.0 INTRODUCTION 9](#_Toc418586419)

[2.0 METHODS 11](#_Toc418586420)

[2.1 Species Vulnerability Assessment Method 11](#_Toc418586421)

[2.2.1 Population Vulnerability 12](#_Toc418586422)

[2.1.2 Collision Vulnerability 16](#_Toc418586423)

[2.1.3 Displacement Vulnerability 21](#_Toc418586424)

[2.2 Species Selection 24](#_Toc418586425)

[3.0 Vulnerability results 26](#_Toc418586426)

[4.0 MARINE BIRD SPECIES ACCOUNTS 33](#_Toc418586427)

[Scoters (*Melanitta spp.*) 33](#_Toc418586428)

[Brant (*Branta bernicla*) 34](#_Toc418586429)

[Mergansers (*Mergus spp.*) 34](#_Toc418586430)

[Loons (*Gavia spp.*) 35](#_Toc418586431)

[Grebes (*Aechmophorus spp./ Podiceps spp.*) 36](#_Toc418586432)

[Albatrosses (*Phoebastria spp.*) 37](#_Toc418586433)

[Shearwaters (*Puffinus spp.*) 38](#_Toc418586434)

[Pacific Northern Fulmar (*Fulmarus glacialis rodgersii*) 40](#_Toc418586435)

Gadfly [Petrels (*Pterodroma spp.*) 40](#_Toc418586436)

[Storm-Petrels (*Hydrobates spp./Oceanites spp.*) 41](#_Toc418586437)

[Pelicans (*Pelecanus occidentalis and P. erythrorhynchos*) 42](#_Toc418586438)

[Cormorants (*Phalacrocorax penicillatus, P. auritus, and P. pelagicus*) 43](#_Toc418586439)

[Red and Red-necked Phalarope (*Phalaropus fulicarius and P. lobatus*) 44](#_Toc418586440)

[Gulls 44](#_Toc418586441)

[Terns 48](#_Toc418586442)

[Jaegers and Skua (*Stercorarius spp.*) 50](#_Toc418586443)

[Alcids 51](#_Toc418586444)

[6.0 Literature Cited 55](#_Toc418586445)

**Abbreviations and Acronyms**

Adult Survival AS

Annual Occurrence (months in CCS) AO

Bureau of Ocean Energy Management BOEM

Breeding and Feeding Time in CCS BR

California Current System CCS

Proportion of Species Population found in California Current System CCSpop

Diurnal Flight Activity DFA

U.S. Fish and Wildlife Service USFWS

Global Positioning System GPS

Habitat Flexibility HF

International Union for Conservation of Nature IUCN

Macro Avoidance of Wind Turbines MA

Nautical Miles NM

Nocturnal Flight Activity NFA

Offshore wind-energy infrastructure OWEI

Pacific Continental Shelf Environmental Assessment PaCSEA

Pacific Offshore Continental Shelf POCS

Population Collision Vulnerability PCV

Population Displacement Vulnerability PDV

Rotor Swept Zone RSZ

Percent Time in Rotor Swept Zone RSZt

Global Population Size POP

Threat Status TS

U.S. Geological Survey – Western Ecological Research Center USGS WERC

**Definitions**

Risk A species chance of exposure to injury or death due to OWEI.

Metric A standard chosen for measuring vulnerability levels of marine bird species. The metrics used in this report are: global population size, percent of species found in the CCS, annual occurrence in the CCS, breeding/feeding time in the CCS, diurnal flight activity, nocturnal flight activity, habitat flexibility, macro-avoidance, percent time spent flying the rotor sweep zone, adult survival, and threat status.

Value The quantity assigned to a species for a given metric, determined from published data.

Uncertainty Value A number quantifying the level of uncertainty around each metric value, based on the number of data sources available and the range of values assigned for the metric.

Range The value for a metric plus and minus its uncertainty values. Each metric value was given a low (10%), medium (25%), or high (50%) degree of uncertainty. This uncertainty was then multiplied by the metric value and added/subtracted to create the range.

Factor An element used to determine the value of one or more of the metrics described above (e.g. - species flight characteristics, bird morphology, habitat use, species diurnal behavior cycles, sea surface temperature and ocean upwelling).

Vulnerability The susceptibility of a species to being impacted by OWEI. Three types of vulnerability are defined in this report: Population Vulnerability, Collision Vulnerability, and Displacement Vulnerability.

Index The quantification of species vulnerability derived from metrics values. The indices derived in the report are the: Population Vulnerability Index, Collision Vulnerability Index, and Displacement Vulnerability Index.

Score The final number produced from the Population Vulnerability, Collision Vulnerability, and Displacement Vulnerability calculations

Population Collision Score The product of the Population Vulnerability Score and the Collision Vulnerability Score.

Population Displacement Score The product of the Population Vulnerability Score and the Displacement Vulnerability Score.

Best Estimate Score The final Population Collision Vulnerability, and Population Displacement Vulnerability scores without taking uncertainty into consideration.

Rank Best estimate scores were then ranked as ‘high’, ‘medium’, or ‘low’ vulnerability based on if their score was in the bottom, middle, or top third of all species’ scores.

# 1.0 INTRODUCTION

The U.S. Geological Survey, Western Ecological Research Center (USGS-WERC) was requested by the Bureau of Ocean Energy Management (BOEM) to create a vulnerability database for marine birds that would allow resource managers to evaluate potential impacts associated with siting and construction of offshore wind-energy infrastructure within the California Current System (CCS) section of the Pacific Offshore Continental Shelf (POCS), including California Oregon, and Washington. With growing climate change concerns and energy constraints, there is an increasing need for alternative energy sources within the United States and globally. To help meet this need, the United States has set a goal for 20% of the country’s overall electricity production to come from wind-power by 2030 (DOE 2008). The production capacity of wind energy facilities in the United States has already grown by an order of magnitude in the last decade (6,370 MW generated in 2003 to 61,108 MW in 2013; The Wind Power 2014). Presently, all wind-energy production in the US is from terrestrial wind energy generators. Looking forward, offshore wind-energy has the potential to produce a significant proportion of the power needed to reach the 20% wind-energy goal (Musial and Ram 2010).

Currently, there are approximately 73 offshore wind-energy production sites in Europe across 11 countries with a production capacity of 7,343 MW (Musial and Ram 2010 Corbetta 2014). Cape Wind in Cape Cod, Massachusetts is the first American offshore wind-energy production site to be approved for construction and currently is in its financing phase (Cape Wind 2014, Handwerk 2014).

Offshore wind-energy sites can capitalize open areas within state and federal waters that have consistently high winds and large energy production potential. Until recently, research on the construction of offshore wind-energy infrastructure (OWEI) in the California Current System (CCS) has been limited due to offshore topography; there are few locations in the CCS where it would be acceptable to build pile-mounted wind turbines in waters <50 m deep, which has been the global industry norm. However, with the development of technology able to support deep-water wind energy infrastructure (>60m of water depth), the possibility of wind-energy production in the CCS is now real (Musial and Ram 2010).

California, Oregon, and Washington already are among the top six leading wind energy states in the country and all three states have set goals to generate a significant portion of their states’ energy from alternative energy sources by the 2020s (AWEA 2013, The Wind Power 2014). Some of these sources include power generation infrastructure and support activities located within continental shelf waters, and potentially within deeper waters off the US Pacific coast and beyond state waters (i.e., outside three nautical miles [NM]). Currently, BOEM is considering renewable energy proposals off the coast of Oregon. Because the majority of proposed offshore wind-energy sites in the CCS would be deep-water sites greater than 60 m of water, interactions with offshore marine life will be unavoidable (Musial and Ram 2010).

Understanding the potential impacts of wind-energy infrastructure in our nation’s marine ecosystem is an integral part of offshore wind-energy research (Desholm 2009, Halpern et al. 2009, Manville 2009, Musial and Ram 2010, Wilhelmsson et al. 2010, Vaissière et al. 2014). This report presents a comprehensive database to quantify marine bird vulnerability to OWEIs in the CCS. These data were used to quantify marine bird vulnerabilities at the population level throughout the CCS. For 76 marine bird species in the CCS, we generated numeric scores to represent vulnerability of collision and displacement associated with potential OWEI. The metrics used to produce these scores are dynamic and can be updated and adjusted as new data become available. The scoring methodology was peer reviewed to evaluate if the metrics identified, and the values generated, are representative for each species considered. Hawaii is also considered part of the POCS and is considering offshore wind energy proposals. In addition, Hawaii State Legislature recently introduced House Bill 632 that would set the state’s goal for 100% renewable energy by 2045 (Hawaii State Legislature 2015). However, marine bird species native to Hawaii were not considered in this database because

Similar vulnerability databases and evaluations were created for areas in the Atlantic Ocean (northwestern Europe and the northeastern United States) where offshore wind-energy production exists or is being considered (Garthe and Hüppop 2004, Desholm 2009, Furness and Wade 2012, Furness et al. 2013, Willmott et al. 2013). These studies, described below, used preexisting data on life history, population sizes, habitat use, disturbance sensitivity, and conservation status to create similar vulnerability scores for bird species of interest.

Garthe and Hüppop (2004) used 9 metrics to rank the vulnerability of 26 marine bird species to OWEI sites in the North Sea: flight maneuverability, flight altitude, percent time flying, nocturnal flight activity, disturbance sensitivity, habitat use flexibility, biogeographical population size, adult survival rate, and threat. Each metric was given values on a scale of one to five and combined to create a comprehensive vulnerability ranking for each species. Four of their nine metrics were subjective; therefore results generated for these metrics were reviewed by ten experts. Garthe and Hüppop (2004) also analyzed the metrics on a spatial and temporal scale, indicating that species in near shore waters had greater threat levels to OWEI, based on their metrics, and that vulnerabilities changed seasonally (Garthe and Hüppop 2004). This study was published 13 years after the first offshore wind-energy site was built in Europe and provided a way to evaluate seabird vulnerability using preexisting data that could also be updated and applied to different systems.

Desholm (2009) used a different approach to create a simple index for describing seabird vulnerability at Nysted wind farm in the Baltic Sea. This vulnerability ranking used two metrics: relative species abundance and demographic sensitivity. Demographic sensitivity was defined as population elasticity to varying levels of adult survival and fecundity. Desholm (2009) found adult survival a better indicator of population sensitivity than fecundity (e.g. species with greater survival rates were more likely to be sensitive to disturbance). With just two metrics, Desholm (2009) suggested his analysis could be standardized across species where varying levels of data were available and that his method avoided combining correlated data from multiple metrics, as was potentially problematic using the approach taken by Garthe and Hüppop (2004). Desholm’s approach, however, does not take into account species-specific behavior, such as the likelihood that species vary according to the degree they could be displaced by and/or collide with wind turbines. Furthermore, although population elasticity based primarily on adult survival rates can be effective when evaluating bird species with a broad range of adult survival rates, our study focuses primarily on long-lived seabird species. Therefore, use of survival rates that are relatively invariable (generally high for marine birds) to indicate relative demographic sensitivity would not generate distinctive variability in risk among species evaluated.

Furness and Wade (2012) and Furness et al. (2013) used similar metrics as Garthe and Hüppop (2004) to evaluate seabird vulnerability but they separated ten metrics into three indices: conservation significance (European and British conservation importance, percentage of time in English waters, and adult survival), collision vulnerability (flight altitude [greatest weighting], flight maneuverability, percentage of time flying, and nocturnal flight activity), and habitat displacement (disturbance caused by windmills, ships, or helicopter traffic, and habitat specialization). This approach separated collision and displacement and also decreased combinations of correlated data, considered problematic in the assessment by Garthe and Hüppop (2004).

Willmott et al. (2013) adapted methods used in the aforementioned three European studies and applied them to the Atlantic Outer Continental Shelf (AOCS) off North America. Willmott et al. (2013) used the same metrics and indexing system as Furness and Wade (2012) and Furness et al. (2013), but incorporated breeding status into the population conservation index, macro-avoidance behavior into the collision and displacement indices, and added uncertainty measures for all metrics where discrepancies were found among published values. Similar to Desholm (2009), adult survival was based solely on survival rate (and excluding longevity, age at first reproduction, and clutch size). Similar to previous studies, data quantifying flight heights was limited.

Based on data and methods of Garthe and Hüppop (2004), Desholm (2009), Furness and Wade (2012), Furness et al. (2013), and Willmott et al. (2013), we created a database to quantify seabird vulnerability in the CCS. Specifically, we used the methods of Willmott et al. (2013) as our framework, and created three vulnerability indices: Population Vulnerability, Collision Vulnerability, and Displacement Vulnerability.

# 2.0 METHODS

Compared with previous studies (Desholm 2009, Furness and Wade 2012, Furness et al. 2013, Garthe and Hüppop 2004, Willmott et al. 2013), we modified and/or eliminated three metrics in the database: (1) *Threat Status*- was modified to incorporate regional and international indices, (2) *Flight Height*- was modified to include results from a more comprehensive analysis developed by Ainley et al. (2015), and (3) *Disturbance*- was not included because the data used for this metric (based on disturbance caused by boat and helicopter traffic) was considered not relevant to potential displacement from offshore wind-energy sites. Instead, we evaluated information regarding specific disturbance of birds at OWEI sites to generate our macro-avoidance metric.

## 2.1 Species Vulnerability Assessment Method

We considered the same three vulnerability indices (population, collision, and displacement) as Willmott et al. (2013) and used factor-values from published literature sources to quantify vulnerability among seabirds in the CCS (Table 1). For each species, Collision and Displacement Vulnerability scores were multiplied by a Population Vulnerability score to create a *Population* Collision Vulnerability score and a *Population* Displacement Vulnerability score (equations 1 and 2).

**Table 1**. Organization for metrics used calculating the three vulnerability indices.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Population Vulnerability | | Collision Vulnerability | | Displacement Vulnerability | |
| POP | Global Population Size | AO | Annual Occurrence (hrs. in CCS) | MA | Macro-Avoidance of Wind Turbines |
| CCSpop | Proportion of Pop in CCS | NFA | Nocturnal Flight Activity | HF | Habitat Flexibility |
| TR | Threat Status | DFA | Diurnal Flight Activity | AO | Annual Occurrence (hrs. in CCS) |
| AS | Adult Survival | RSZt | Percent Time in RSZ | BR | Breeding and Feeding time in CCS |
|  |  | MA | Macro-Avoidance of Wind Turbines |  |  |
|  |  | BR | Breeding & Feeding time in CCS |  |  |

[1] *Population Collision Vulnerability* = Collision Vulnerability × Population Vulnerability

[2] *Population Displacement Vulnerability* = Displacement Vulnerability × Population Vulnerability

The values generated for most of the metrics in this database have inherent uncertainty. For example, the Global Population Size (POP) for a given species is a best estimate, not an exact count of the number of individuals globally; therefore, uncertainty around the POP metric value was generated. The level of uncertainty for each metric was calculated based on the number of data sources and the range of values available for the metric. When appropriate, expert opinion also was used to determine values and uncertainty. The value for each metric was given a low (10%), medium (25%), or high (50%) degree of uncertainty. This uncertainty was then multiplied by the metric value and added/subtracted to create the range (Table 2). The range around each metric value indicates potential data limitations associated with that value. These limitations can be considered by resource managers who might use these values to evaluate potential impacts to species or to make decisions regarding alternative energy siting (Masden et al. 2014). Whereas Willmott et al. (2013) restricted the range of uncertainty to stay within their 1-5 value categories, we did not restrict the uncertainty values because we wanted the ranges to reflect all possible values.

**Table 2.** The range of values for each metric based on their given level of uncertainty.

|  |  |  |  |
| --- | --- | --- | --- |
| Metric Value | Level of Uncertainty | | |
| **Low (10%)** | **Medium (25%)** | **High (50%)** |
| 1 | 0.9 – 1.1 | 0.75 – 1.25 | 0.5 – 1.5 |
| 2 | 1.8 – 2.2 | 1.5 – 2.5 | 1 – 3 |
| 3 | 2.7 – 3.3 | 2.25 – 3.75 | 1.5 – 4.5 |
| 4 | 3.6 – 4.4 | 3 – 5 | 2 – 6 |
| 5 | 4.5 – 5.5 | 3.75 – 6.25 | 2.5 – 7.5 |

### 2.1.1 Population Vulnerability

The species evaluated in this database include wide-spread species with large populations and less numerous species with limited population ranges. Therefore, a measure of Population Vulnerability was needed to evaluate potential impact resulting from cumulative collision with, or displacement by OWEI within the CCS. Four metrics were used to determine Population Vulnerability: global population size, percent of the population present in the CCS (integrated over one year), threat status, and adult survival. Using these four metrics to determine population vulnerability follows the methods created by Willmott et al. (2013), based on Garthe and Hüppop (2004), Furness and Wade (2012), and Furness et al. (2013), and is depicted in equation 3.

[3] Population Vulnerability =

where,

POP = Global Population Size

CCSpop = Proportion of Species Population found in CCS

TR = Threat Status

AS = Adult Survival

u = uncertainty

Each metric was given equal weight in the equation. This is identical to the equation used by Willmott et al. (2013); there was no *a priori* knowledge to indicate that a different weighting scheme would be more appropriate. Each metrics is explained below.

#### 2.1.1.1 Global Population Size

American Bird Conservancy (ABC 2013) and Birdlife International (2013) compile data from numerous sources and update their lists regularly. These references, along with other primary sources, were used for population size estimates (Appendix Table A1). Estimates usually were given as a range. When multiple sources were used, all published values were included in the population range (Table 4).

We assigned global population size (POP) values from 1 to 5 (see Willmott et al. 2013 and Garthe and Hüppop 2004):

1 = >3,000,000 individuals

2 = 1,000,001 – 3,000,000 individuals

3 = 500,001 – 1,000,000 individuals

4 = 100,000 – 500,000 individuals

5 = <100,000 individuals

The level of uncertainty in the values was determined by the range of population sizes and how well they fit into the 1-5 categories:

10% = Published values fall within a single category range.

25% = Published values fall within two category ranges, but the majority of the literature supports the values of the chosen range. Or, published values falls within a single category range but literature sources are minimal.

50% = Published values varies between three or more category ranges, but the literature supports the values within the chosen range. Or, published values falls within one or two category ranges and literature sources are minimal.

#### 2.1.1.2 Proportion of Population in CCS

For most species, estimates of local population sizes were determined using at-sea surveys for California, Oregon and Washington, following Briggs et al. (1981, 1983, 1987, 1992). For some species, data on local population size from Birdlife International (2014), ABC (2013), and other primary sources also were used (Appendix Figure A2). Some accounts for species that breed within the CCS region were estimates of breeding pairs and did not account for non-breeders. In these cases, the number of non-breeders contributing to population size was estimated and added to the breeding pair estimate. For example, estimates have been given for the number of storm-petrel breeding pairs in the CCS region (Carter et al. 2008, Sowls et al. 1980, Spear and Ainley 2007). Spear and Ainley (2007) also estimated 49% of Leach’s Storm-Petrels at sea were juveniles; therefore, we multiplied the estimated numbers of breeding storm-petrels by 2 to include non-breeders. For Cassin’s auklets, Manuwal (1972) estimated a 70% floating population of nonbreeders in addition to the breeding population on Southeast Farallon Island; therefore, an additional 70% was added to the estimated number of breeding Cassin’s Auklets to represent the total population size for the CCS region.

The best-estimate local population size was divided by the average estimated global population size to yield the percentage of the population occurring in the CCS (Table 4). For some species (e.g.- Yellow-billed Loon and Laysan Albatross) no data exists to estimate local population size so an estimate was made based on the opinions of experts. The numerical values were based on the percent of the population present in the CCS (CCSpop) and were consistent with Willmott et al. (2013).

1 = <1%

2 = 1 – 33%

3 = 34 – 66%

4 = 67 – 99%

5 = >99%

Also consistent with Willmott et al. (2013), uncertainties were based on the variation among values found in different sources:

10% = Published values fall within a single category range.

25% = Published values fall within two category ranges, but the majority of the literature values fall within one category. Or, published values fall within a single category range but literature sources are minimal.

50% = Published values varies between three category ranges, but the literature supports the values within the chosen range. Or, published values falls within one or two category ranges and data is insufficient.

#### 2.1.1.3 Threat Status

The International Union for Conservation of Nature (IUCN) species threat status (IUCN 2014) and the U.S. Fish and Wildlife national threat status lists (USFWS 2014) were used to determine the threat status values for each species. Where available, threat status values from USFWS Pacific Region (USFWS 2005), California (Shuford and Gardali 2008), Oregon (Oregon Department of Fish and Wildlife), and Washington (Washington State Department of Fish and Game, 2003) also were evaluated (Appendix Figure A3).

Threat status values are as follows:

IUCN: USFWS: USFWS Pacific Region:

1 = Least Concern 1 = No Ranking 1 = No Risk

2 = Near-Threatened 2 = Petitioned 2 = Low Concern

3 = Vulnerable 3 = Candidate Species 3 = Moderate Concern

4 = Endangered 4 = Threatened 4 = High Concern

5 = Critical 5 = Endangered 5 = Highly Imperiled

CA Species of Special Concern\*: OR Sensitive, Threatened, or Endangered Species:

1 = No Ranking 1 = No Ranking

2 = Third Priority 2 = Vulnerable Sensitive Species

3 = Forth Priority 3 = Critical Sensitive Species

4 = Fifth Priority 4 = Threatened Species

5 = Endangered Species

\* Value standardized to 1-5 to fit with other threat values:

x = ((xCA)/4\*5))

Washington Species of Concern:

1 = Monitored Species

2 = Candidate Species

3 = Sensitive Species

4 = Threatened Species

5 = Endangered Species

From these six threat-status sources, the highest value was chosen for each species (Table 4, Appendix Table A3). Specifically, for species that migrate through the CCS but breed in another country, we considered threat status value from all countries where the species is found (e.g. - Canada, Mexico, Chile, New Zealand, and Japan); the greatest value was chosen to calculate population vulnerability. For example, the Pink-footed Shearwater (*Puffinus creatopus*) breed on three small islands off the coast of Chile and a proportion of the adult population winters in the orthern Pacific off Mexico, the United States, and Canada. The Pink-footed Shearwater is given the lowest threat value (1) by USFWS, California, Oregon, and Washington. It is given a value of Vulnerable (3) by the IUCN and the Canadian government, and Special Protection (2) by the Mexican government (COSEWIC 2004, IUCN 2014, Ministerio del Medio Ambiente 2012). However, in Chile, where the shearwaters breed, they are considered Endangered (4, Flores 2010). Therefore, we gave the Pink-footed Shearwaters a threat value of 4 (Endangered). This method established a threat status value based on the geographical and ecological scope relevant to the species, as opposed to one based on geopolitical boundaries (Hyrenbach et al. 2000, Nevins et al. 2009).

All species were evaluated on a case by case basis to determine the most appropriate method for evaluating threat value. For example, the Leach’s Storm-Petrel has three subspecies identified in Mexico (Flores 2010). Two of these subspecies are listed as Threatened (3) and one subspecies is Endangered (4). It is unclear to what degree these subspecies of Leach’s occur in the CCS, but their threat status in their breeding grounds is relevant to consider when ascribing their status in the CCS; therefore, we consider Leach’s Storm-Petrel at a greater threat value (threat status of 3, Threatened) than indicated by IUCN (1) and USFWS (2).

#### 2.1.1.4 Adult Survival

Adult annual survival rate is indicative of life history characteristics among birds (Gill 1989, Krements et al. 1989, Saether et al. 1996). According to species, birds with greater survival rates will be more impacted by mortality due to collisions with wind farms (Desholm 2008). We reviewed annual adult survival rates for each species (Table 4). When multiple rates were available for a given species, the most recent and/or the most locally relevant data were used (Appendix Figure A4). In the cases where no survival rate or other life history information was available for a species, survival rate data from a similar species was used. Uncertainty in adult survival values also was evaluated. Adult survival values (AS) and uncertainty ranges are consistent with Willmott et al. (2013).

1 = <0.75

2 = 0.75 – 0.80

3 = 0.81 – 0.85

4 = 0.86 – 0.90

5 = 0.91 – 1.00

Adult Survival Uncertainty (ASu):

10% = Variation of published values fall within one category range.

25% = Variation of published values fall within two categories with the majority (or the most relevant) of the data supporting the chosen category. Or, published values fall within one category but are not well supported in the literature.

50% = Variation of published values fall within three or more categories with the majority (or the most relevant) of the data supporting the chosen category. Or published values fall within one or two categories but are not well supported in the literature.

## 2.1.2 Collision Vulnerability

Wind turbine-bird collision risk modeling has been used to assess probability that birds will collide with wind turbines. These collision-risk models can be complex and incorporate flight characteristics, bird morphology, researcher and radar observations, landscape features, turbine dimensions, and other factors to determine collision risk. Some collision risk models are site-specific (e.g., Villegas-Patraca et al. 2014), while others may be applied to a variety of locations (Tucker 1996, Desholm and Kahlert 2005, Chamberlain et al. 2006, Band 2012, Cook et al. 2012, Blocker et al. 2014, Johnston et al. 2014). Some of the factors commonly used in collision risk modeling (e.g., site-specific turbine characteristics) were outside the scope of our study. Therefore, instead of modeling values of collision vulnerability, we selected metrics to use in our Collision Vulnerability Index based on the most common factors used in most collision risk modeling.

The ability of a bird to maneuver around a wind turbine (i.e., avoidance) is one of the most important factors for assessing collision vulnerability and has been major focus of post-construction studies at existing wind farm sites (Desholm and Kahlert 2005, Desholm 2005, Chamberlain et al. 2006, Blew et al. 2008, Krijgsveld 2009, Krijgsveld 2011, Peterson et al. 2011, Cook et al. 2012, Plonczkier and Simms 2012, Vanermen et al. 2013, Cook et al. 2014). Birds exhibit two types of avoidance behavior: macro-avoidance and micro-avoidance. Macro-avoidance refers to changes in flight course to avoid entering a wind farm area entirely. Micro-avoidance refers to an acute maneuver to avoid hitting a turbine blade or structure while flying through a wind farm area (Band 2012, Cook et al. 2012). The definition of micro-avoidance used here also is referred to as “with-in wind farm avoidance”, which incorporates last-minute instantaneous maneuvers performed by birds to avoid turbine blades as well as more general avoidance measures taken by birds once they are already flying through the wind farm (Cook et al. 2014).

In vulnerability analyses by Garthe and Hüppop (2004), Furness and Wade (2012), and Furness et al. (2013), a subjective value of in-flight maneuverability among bird species was used to estimate micro-avoidance rates at OWEI. Micro-avoidance at OWEI is difficult to detect by direct observation or derive using mortality estimates (Deshom 2005, Peterson et al. 2006, Cook et al. 2012, Marques et al. 2014, Peters et al. 2014). However, recent studies have increased visual observations and radar detections to better evaluate micro-avoidance among birds at constructed OWEI sites. These studies have found that greater maneuverability may not be directly correlated with greater micro-avoidance rates (Willmott et al. 2013, Marques et al. 2014). Furthermore, overall avoidance at OWEI appeared great (Deshom 2005, Peterson et al. 2006, Cook et al. 2012, Marques et al. 2014, Peters et al. 2014).

In their study observing Pink-footed Geese (*Anser brachyrhynchus*) using radar at Lynn and Inner Dowsing Wind Farms, Plonczkier and Simms (2012) found, among birds with no macro-avoidance behavior, > 90% showed micro-avoidance behavior by flying higher than the RSZ when flying within the wind farm area. Radar results from Peterson et al. (2006) indicated when birds flew into the wind farm area; they changed direction to exit as quickly as possible. Very few birds were observed flying among the wind turbines at Nysted and Horns Rev Wind Farms, and only 7% of birds seen flying in the wind farm area flew within the RSZ (Krijgsveld et al. 2011). Based on these studies, during the day and under observable conditions, micro-avoidance behavior for most species at OWEI sites was near 100%.

Recent studies also have shown that micro-avoidance is not directly correlated with maneuverability, as previously thought, and species-specific factors that contribute to micro-avoidance are complex. Although variables related to bird morphology and flight styles, specifically wing loading and aspect ratio, were positively correlated with collision rates at terrestrial wind farm sites (Bevanger 1994, de Lucas et al. 2004, Janss 2000, Herrera-Alisina et al. 2013, Marques et al. 2014), these correlations also depended on weather and topography. For example, vulture (with greater wing loading than other raptor species) are more likely to collide with wind turbines in low-wind conditions, when vultures have less updraft to keep them off the ground (Barrios and Rodrguez 2004, de Lucas et al. 2008). Herrera-Alsina et al. (2013) found passerine species with greater wing loading were more likely to fly through the RSZ; however, smaller birds with lesser wing loading were more likely to collide with turbines. Herrera-Alsina et al. (2013) concluded that the correlation between wing loading and collision rate was more related to foraging strategy than maneuverability. Other studies also found interspecific differences in micro-avoidance rates vary with flight style, morphology, habitat utilization, and time of year (Peterson et al. 2006, Band 2012, Furness and Wade 2012, Furness et al. 2013, Willmott et al. 2013, Marques et al. 2014, Villegas-Patraca 2014).

Based on the results of the studies described above, we recognize that micro-avoidance rates can very among different species, and that this variability depends on a species’ maneuverability, morphology, habitat use, and environmental factors. With the information currently available, we cannot effectively quantify species-specific micro-avoidance associated with OWEI and have not yet incorporated micro-avoidance in our estimation of collision vulnerability

Species-specific flight heights also are an important metric for determining collision vulnerability. Data on flight heights were limited in previous Collision Vulnerability models at OWEI sites (Desholm 2009, Furness and Wade 2012, Furness et al. 2013, Garthe and Hüppop 2004, Willmott et al. 2013). Recent studies have improved flight-height data collected using different survey methods (i.e. - boat surveys prior to wind farm construction, data recorded by GPS and radar, and platform observations at constructed farm sites) and new studies have contributed additional flight-height data (Cook et al. 2012, Ainley et al. 2014, Bradbury et al. 2014, Corman and Garthe 2014).

We used macro-avoidance, flight-height (defined as time spent in rotor sweep zone), annual occurrence in the CCS, diurnal and nocturnal flight activity, and breeding/feeding behavior to create our Collision Vulnerability Index. Our calculation of Collision Vulnerability (Equation 4) is based off of the calculation used by Willmott et al. (2013):

[4] *Collision Vulnerability =*

where,

AO = Annual Occurrence in the CCS

NFA = Nocturnal Flight Activity

DFA = Diurnal Flight Activity

RSZt = Percent time spent in Rotor Sweep Zone

MA = Macro-Avoidance

BR = Breeding and Feeding Time in CCS

*u* = uncertainty

All metrics are described below.

#### 2.1.2.1 Annual Occurrence in the CCS (AO)

The percentage of time a species spends in the CCS each year will influence the amount of time it would be vulnerable to colliding with OWEI in the area. Migratory seabirds and certain far-ranging seabirds from outside the CCS are only present in the CCS for part of the year (e.g., Pink-footed Shearwater, Black-footed Albatross, Pacific Loon). Other species breed in the CCS and are present year round (e.g., Western Gull, Scripps’s Murrelet).

We approximated the number of months per year (annual occurrence, AO) that each species resided within the CCS to calculate Collision Vulnerability. Annual Occurrence data were derived from Briggs surveys (1981, 1983, 1987, 1992), PaCSEA surveys (Adams et al. 2014), eBird sightings, and other sources (Appendix Table A5). For some migratory species, timing of migration is not well known and/or interannually variable; therefore, we used the most conservative estimation of annual occurrence, from when the first migrants arrive in the CCS, until the last migrants are thought to leave the CCS. Although this may give an overestimation of annual occurrence for some species, this range accounts for inter-annual variation in migratory timing.

#### 2.1.2.2 Nocturnal Flight Activity (NFA) and Diurnal Flight Activity (DFA)

The amount of time that a species spends in flight during different parts of the day has been associated with its collision vulnerability (Krijgsveld et al. 2009, Band 2012, Marques et al. 2014). In addition, OWEI avoidance behavior can differ during day and night time periods for some bird species (Desholm and Kahlert 2005, Peterson et al. 2006). We included nocturnal flight activity (NFA) and diurnal flight activity (DFA) into our estimation of collision vulnerability.

Water birds (e.g., Loons, Grebes, and Scoters) are less likely to migrate at night or during periods of inclement weather (Peterson et al. 2006). Other marine bird species migrating through the CCS will sustain flight and spend minimal, or no, time resting on the water or foraging (del Hoyo and Sargatal 1992). We used information from the Birds of North America accounts, previous OWEI vulnerability assessments (Furness and Wade 2012, Furness et al. 2013 Garthe and Hüppop 2004, Willmott et al. 2013), and other sources to estimate the percentage of time each species spends in flight during day and night periods (Appendix Table A6). Some species, such as alcids and pelicans, travel to their nest and roosting sites during crepuscular periods (del Hoyo and Sargatal 1996). Because visibility of obstacles while in flight during crepuscular periods is more comparable to nighttime visibility than to daytime visibility (Stienen et al. 2007), we categorized crepuscular periods as nighttime for the purpose of this metric.

Data on nocturnal and diurnal flight activity was sparse for most species; therefore, numerical categories represent a range of values. Similar to the other metrics, we report an uncertainty value associated with each value. The range of values used for NFA and DFA follow those established by Willmott et al. (2013) and represent equal intervals between 0 and 100%:

1 = 0 – 20%

2 = 21 – 40%

3 = 41 – 60%

4 = 61 – 80%

5 = 81 – 100%

NFA and DFA Uncertainly (NFAu and DFAu):

10% = Published values fall within one category range. Data come from multiple sources.

25% = Published values fall within two category range and/or published values are insufficient.

50% = Published values fall within more than two category ranges, published values are insufficient, or no data are available for this species so values are based on similar species values.

#### 2.1.2.3 Rotor Sweep Zone (RSZ)

The amount of time a bird spends flying at the same height as the sweeping zone of the turbine blades will influence the probably of collision. We were able to evaluate new data on flight heights among seabirds in the UK (Bradbury et al. 2014) and in the eastern Pacific (Ainley et al. 2015) to inform our estimations of the percentage of time each species spends flying at the height of the rotor sweep zone (RSZ; Appendix Table A7). We definite the RSZ as 10 – 200 m above the ocean. Previous work has set the lower limit of the RSZ at 20 m, but more recently published work (Ainley et al. 2014) set the lower RSZ limit at 10 m to accommodate their analysis which included seabirds in the CCS. We adopted a revised range to accommodate all studies from which values were collected. Even with newly published values, flight-height value categories are broad and uncertainties are large, especially for birds that spend >20% of their time in the RSZ. For example, the amount of time that a Herring Gull spends flying within the RSZ height (10-200 m above the water) varies across studies:

48% - Ainley et al. 2015

28% - Cook et al. 2012

35% - Furness et al. 2013

20% - Johnston et al. 2014

35% - Bradbury et al. 2014

13 – 50% - Willmott et al. 2013

Therefore, we binned data based on percentage of time spent in the RSZ. Our bin assignments follow Willmott et al. (2013) who defined categories for quantifying time spent in the RSZ. Because values are used in the denominator within our collision vulnerability equation, greater values correspond to lesser percentage of time in the RSZ (RSZt):

1 = >20%

3 = 5 – 20%­

5 = <5%

The RSZ categories represent a range of values; therefore, we interpreted uncertainty (RSZtu) as follows.

10% = Published values fall within one category range. Data come from multiple sources.

25% = Published values fall within two category ranges or data fall within one category range but is only represented by a few sources.

50% = Published values fall within two or more category ranges and/or data are insufficient.

#### 2.1.2.4 Macro Avoidance (MA)

Post-construction analyses of the effects of OWEI on some birds species have increased our knowledge regarding seabird avoidance rates at OWEI (Desholm 2005, Desholm and Kahlert 2005, Peterson et al. 2006, Larsen and Guillemette 2007, Blew et al. 2008, Krijgsveld et al. 2009, Krijgsveld et al. 2011, Peterson et al. 2011, Cook et al. 2012, Plonczkier and Simms 2012, Vanermen et al. 2013, Cook et al. 2014, Vandermen et al. 2014). We reviewed macro-avoidance data collected from visual and radar observations at constructed OWEI sites to determine macro-avoidance rates for ecologically equivalent or similar species in the CCS (Appendix Table A8).

In addition to avoidance, there exists concern that some species may be attracted to OWEI for roosting or foraging. Gulls, alcids, loons, pelicans, and cormorants were attracted to offshore oil and gas platforms by artificial light and presence of roosting habitat (Burke et al. 2012, Ronconi et al. 2014, Hamer et al. 2014). Within the CCS, gulls (primarily Western Gull) consisted of 90% of the species attracted to oil rig lighting in the Channel Island (Hamer et al. 2014). Post-construction observations at Nysted, Horns Rev, Thorntonbank, and Bligh Bank OWEI in the North Sea indicated small increases in the numbers of gulls, terns, and cormorants post-construction, especially among the peripheral turbines and within the wind farm area when turbines were turned off (Peterson et al. 2006, Vanermen et al. 2013, Vanermen et al. 2014). Gulls, terns, and cormorants could be attracted to OWEIs a place to roost and also as a new location for central-place foraging or to facilitate foraging resulting from artificial ‘reef effects’ created by the turbine pilings (Peterson et al. 2006, Vanermen et al. 2013, Vanermen et al. 2014). OWEI-specific features, including amount of light on a platform, distance between turbines within the site, weather conditions, and distance from land contribute to the level of attraction of birds to the wind farms (Cook et al. 2012, Marques et al. 2014, Vanermen et al. 2014). For our evaluation, not enough information on attraction to OWEI exists to include attraction to OWEI as a separate metric for all species considered; therefore, we incorporated potential attraction as a negative contribution to the macro-avoidance rate of the species.

We determined macro-avoidance as the probability of wind energy infrastructure avoidance. Greater macro-avoidance indicates lower risk of collision (consistent with Willmott et al. 2013); therefore higher avoidance rates were given a lesser value in our macro-avoidance metric (MA):

1 = >40% avoidance

2 = 30 – 40% avoidance

3 = 18 – 29% avoidance

4 = 6 – 17% avoidance

5 = 0 – 5% avoidance

For species that are thought to be attracted to OWEI, their avoidance rate value was increased by one. With increasing post-construction studies at OWEI in Europe, we reviewed and incorporated data from more studies on macro-avoidance rates than previously were available (Furness and Wade 2012, Furness et al. 2013, Garthe and Hüppop 2004); however, there still exists much uncertainty among macro-avoidance values. Uncertainty ranges (MAu) used were similar to Willmott et al (2013):

10% = Published values fall within a single category range, and data are from multiple sources.

25% = Published values are within two category ranges, or data are not well supported in the literature.

50% = Published values fall within two or more category ranges, are largely variable in published literature, or are based on data from similar species only.

#### 2.1.2.5 Breeding (BR)

Because mortality factors that affect adult breeders have disproportionate effects on intrinsic population growth, the potential impact of a collision with a wind turbine for a bird that is foraging to feed its young is exacerbated- if the collision is fatal to the adult bird it will most likely also be fatal to its young that were relying on that adult for food. Furthermore, disruption of long-term, effective pair-bonds in seabirds can have negative effects on reproductive output (Bradley et al. 1990, Mills and Ryan 2005, Sanchez-Macouzet et al. 2014). Therefore we incorporated a breeding value into the Collision Vulnerability Index. If a species forages to feed its young in the CCS, its presence counts for that of itself, and of its young (Appendix Table A9). We considered the likelihood of each species to breed and/or forage for young in the CCS and calculated breeding value following Willmott et al. (2013):

1 = Species is unlikely to be foraging to feed young in the CCS

1.5 = Some individuals of species will forage for young in the CCS

2 = Species is known to regularly forage to feed young in the CCS

#### 2.1.2.6 Population Collision Vulnerability

The Collision Vulnerability score was multiplied by the Population Vulnerability score for each species to create a Population Collision Vulnerability (PCV) score (Equation 1). This value represents a combined Collision Vulnerability score that accounts for the species’ population in the CCS. To account for the uncertainty in the PCV scores, the upper Collision Vulnerability uncertainty and the upper Population Vulnerability uncertainty scores were multiplied together, as were the lower Collision Vulnerability uncertainty scores and lower Population Vulnerability uncertainty scores.

[1] *Population Collision Vulnerability* = Collision Vulnerability × Population Vulnerability

The PCV best estimate score ranged from 3 to 1530, with uncertainty scores ranging from 1.53 to 2250. PCV best estimate scores were then ranked as ‘high’, ‘medium’, or ‘low’ vulnerability based on if they were in the bottom, middle, or top third of all scores respectively (Table 7). The scores given for each species are relative values generated for the purpose of this database, and should not be interpreted as an absolute value of vulnerability for the species.

## 2.1.3 Displacement Vulnerability

In addition to the risk of collision with wind turbines, OWEI can cause barrier effects and/or habitat loss for seabirds, by displacing individuals from important habitat (Hüppop et al. 2006, Band 2012, Bradbury et al. 2014, Cook et al. 2014). Displacement of birds from areas during the construction, operation, and maintenance of offshore energy infrastructure can have direct and indirect effects on species. Displacement vulnerability depends on how individuals of a species use the area, such as if individuals are self-foraging only, foraging also for young, traveling along a migratory pathway, or commuting between their colony and foraging areas at sea.

Species with greater habitat flexibility (i.e., ability to feed on a wide range of food sources from varying habitats) are less likely to be effected by wind energy infrastructure construction in an area than a species that forage on a specific prey type or in a specific habitat (Masden et al. 2010). Furthermore, a species that uses an OWEI site to forage to feed its young will be more greatly affected than a species that is only found in the area during the nonbreeding season. We incorporated habitat flexibility and breeding/feeding behavior into our calculation of displacement vulnerability. The other metrics that contribute to displacement vulnerability are macro-avoidance rates and annual occurrence in the CCS.

In previous vulnerability assessments, a disturbance-level metric was created based on seabird species’ short-term disturbance behavior from boat and helicopter traffic (Garthe and Hüppop 2004, Furness and Wade 2012, Furness et al. 2013, Willmott et al. 2013). Past studies have shown that the construction of OWEI sites in Europe have caused short-term disturbance to the resident bird species; for example, individuals will tend to avoid the area affected (Cook et al. 2014, Peterson et al. 2006, Vanermen et al. 2014, Willmott et al. 2013). However, more recent studies have indicated the majority of species that are disturbed from OWEI sites during construction return to the area following wind energy infrastructure installation (Cook et al. 2014, Vanermen et al. 2014). Therefore, initial disturbance levels, as inferred from helicopter and boat disturbance, are not an accurate representation of the long-term disturbance behavior displayed by species in response to OWEI construction, operation, and deconstruction. Considering new information, we determined that disturbance to boat and helicopter traffic was not necessarily a valid indicator of potential disturbance by OWEI sites. We believe that the data measuring actual avoidance or disturbance at OWEI sites should be incorporated into the macro-avoidance metric (see Macro-Avoidance Section 2.1.2.5) which we consider the most applicable indicator of disturbance by OWEI areas for marine.

Our calculation of Displacement Vulnerability was similar to Willmott et al. (2013) however we did not incorporate disturbance values (see explanation below).

[5] *Displacement Vulnerability =*

W=where,

AO = Annual Occurrence in the CCS

MA = Macro-Avoidance

BR = Breeding and Feeding Time in CCS

HF = Habitat Flexibility

All metrics are further explained below.

#### 2.1.3.1 Annual Occurrence (AO)

The more time a bird spends in the CCS (foraging, migrating, resting, breeding, etc.) the greater chance it has of being affected by the presence of OWEIs in the area. We determined the number of months per year (annual occurrence, AO) that each species spent in the CCS as a function for their Displacement Vulnerability (see Section 2.1.2.1 for full description of methods; Appendix Table A5).

#### 2.1.3.2 Macro Avoidance (MA)

Macro-avoidance is a measure to quantify the degree to which an individual of a species will avoid OWEI while in flight. The values determined for this metric were based on avoidance rates from observational and radar studies conducted post-construction at existing wind energy production sites(Appendix Table A8). In contrast with how this metric was applied to the Collision Vulnerability index (Section 2.1.2.5), for the Displacement Vulnerability Index, greater macro-avoidance indicates greater Displacement Vulnerability (here a low value equals low avoidance rate):

1 = 0 – 5% avoidance

2 = 6 – 17% avoidance

3 = 18 – 29% avoidance

4 = 30 – 40% avoidance

5 = >40% avoidance

Uncertainty measurements (MAu):

10% = Published values fall within single category range, and values are consistent across multiple studies.

25% = Published values fall within two category ranges, or sources are limited.

50% = Published values fall within two or more category ranges, is highly variable throughout the published literature, or is based on data from similar species only.

#### 2.1.3.3 Habitat Flexibility (HF)

Seabirds exhibit varying degrees of habitat flexibility. Some species depend on specific prey in specific locations. For example, Elegant Tern and Brown Pelican feed primarily on anchovy and depend on the availability and location of anchovy schools for their survival and successful reproduction (del Hoyo 1996). Species with great habitat flexibility, such as gulls, are generalists and will feed opportunistically where prey is available and abundant, but individuals can alter foraging strategies when conditions change. We used accounts of feeding behavior from the Birds of North America species accounts, del Hoyo and Sargatal (1992), del Hoyo and Sargatal (1996) and other sources to determine habitat flexibility values (Appendix Table A10). Our habitat flexibility values are similar to Furness and Wade (2012), Furness et al. (2013) and Willmott et al. (2013).

1 = Species uses a wide range of foraging habitats over a large area. Species are opportunistic foragers and have the ability to switch among prey types based on availability.

2 – 4 = Species show some grade of behavior between 1 and 5.

5 = Species have very habitat- and prey- specific requirements and do not have much flexibility in foraging behavior, habitat selection, or diet.

Uncertainty in habitat flexibility values (HFu) was based on the availability of published values on foraging habitat and behavior, and discrepancies within the published literature:

10% = Consensus among data in all published literature sources.

25% = Inconsistent or conflicting reports in published literature sources.

50% = Little to no data available for species, assumptions are made based on similar species accounts.

#### 2.1.3.4 Breeding (BR)

Breeding time in CCS was also incorporated into the Displacement Vulnerability Index. We determined the likelihood of each species to breed and/or forage for young in the CCS and calculated breeding time in CCS following Willmott et al. (2013). Specifically, if a species is foraging to feed its young in the CCS, its presence in the area counts for the presence of itself and of its young. See Section 2.1.2.7 for full methods (and Appendix Table A9).

1 = Species is unlikely to be foraging to feed young in the CCS

1.5 = Some individuals of species will forage for young in the CCS

2 = Species is known to regularly forage to feed young in the CCS

#### 2.1.3.5 Population Displacement Vulnerability

The Displacement Vulnerability score was multiplied by the Population Vulnerability score for each species to create a Population Displacement Vulnerability (PDV) score (Equation 2). This value is the Displacement Vulnerability score adjusted for the species’ population in the CCS. To account for the uncertainty in the PDV scores, the upper uncertainty Displacement Vulnerability score and the upper uncertainty Population Vulnerability score were multiplied together, as were the lower uncertainty Displacement Vulnerability score and lower uncertainty Population Vulnerability score.

[2] *Population Displacement Vulnerability* = Displacement Vulnerability × Population Vulnerability

The PDV best estimate scores ranged from 10.9 to 1350. Uncertainty scores ranged from 2.4 to 3361.5. PDV best estimate scores were then ranked as ‘high’, ‘medium’, or ‘low’ vulnerability based on if they were in the bottom, middle, or top third of all scores respectively (Table 7). The scores given for each species are relative values generated for the purpose of this database, and should not be interpreted as an absolute value of vulnerability for the species.

## 2.2 Species Selection

The species selected for this database all were marine birds that occur regularly in the CCS (Table 3). The species list was created based on historic survey records (Briggs et al. 1981, Briggs et al. 1983, Briggs et al. 1985, Briggs et al. 1991) and on more recent results from the 2011-2012 Pacific Continental Shelf Environmental Assessment (PaCSEA; Adams et al. 2014).

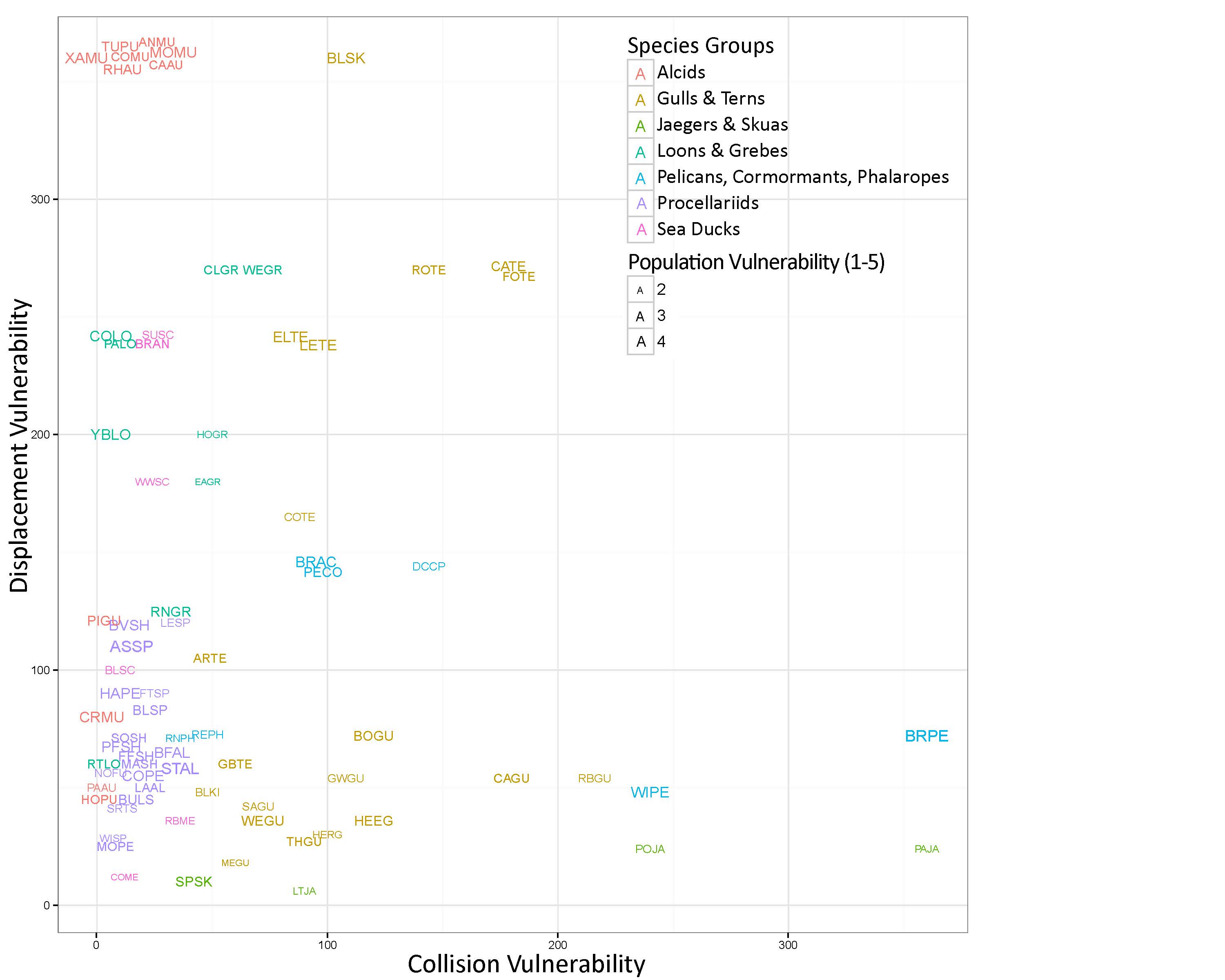
Most survey records reported Xantus’s Murrelet, which have since been recognized as two distinct species, Scripps’s and Guadalupe Murrelet (Birt et al. 2012). Survey data from Xantus’s Murrelet was applied to Scripps’s Murrelet for this database. It is unclear to what extents Guadalupe Murrelet inhabits the CCS, so they were not considered in this database. This species list also was supplemented with species that did not appear on the PaCSEA surveys but are known to exist in the CCS (e.g., Black Skimmer, Tufted Puffin, and Yellow-billed Loon; Table 3). Although several shore birds, raptors and passerines are known to occur offshore within the CCS, they were not considered in this study.

**Table 3**. Species and species groups of the CCS evaluated for their potential vulnerability to offshore wind-energy infrastructure. The species are ordered by taxonomic classification number (Clement et al. 2014).

|  |  |  |
| --- | --- | --- |
| **Taxonomy** | **Common Name** | **Scientific Name** |
| Sea Ducks | Brant | *Branta bernicla* |
| Surf Scoter | *Melanitta perspicillata* |
| White-winged Scoter | *Melanitta deglandi* |
| Black Scoter | *Melanitta americana* |
| Common Merganser | *Mergus merganser* |
| Red-breasted Merganser | *Mergus serrator* |
| Loons | Red-throated Loon | *Gavia stellata* |
| Pacific Loon | *Gavia pacifica* |
| Common Loon | *Gavia immer* |
| Yellow-billed Loon | *Gavia adamsii* |
| Grebes | Horned Grebe | *Podiceps auritus* |
| Red-necked Grebe | *Podiceps grisegena* |
| Eared Grebe | *Podiceps nigricollis* |
| Western Grebe | *Aechmophorus occidentalis* |
| Clark's Grebe | *Aechmophorus clarkii* |
| Procellariids | Laysan Albatross | *Phoebastria immutabilis* |
| Black-footed Albatross | *Phoebastria nigripes* |
| Short-tailed Albatross | *Phoebastria albatrus* |
| Pacific Northern Fulmar | *Fulmarus rodgersii* |
| Manx Shearwater | *Puffinus puffinus* |
| Mottled Petrel | *Pterodroma inexpectata* |
| Hawaiian Petrel | *Pterodroma sandwichensis* |
| Cooks Petrel | *Pterodroma cookii* |
| Pink-footed Shearwater | *Ardenna creatopus* |
| Flesh-footed Shearwater | *Ardenna carneipes* |
| Buller's Shearwater | *Ardenna bulleri* |
| Sooty Shearwater | *Ardenna griseus* |
| Short-tailed Shearwater | *Puffinus tenuirostris* |
| Black-vented Shearwater | *Puffinus opisthomelas* |
| Willson's Storm-Petrel | *Oceanites oceanicus* |
| Fork-tailed Storm-Petrel | *Oceanodroma furcata* |
| Leach's Storm-Petrel | *Oceanodroma leucorhoa* |
| Ashy Storm-Petrel | *Oceanodroma homochroa* |
| Black Storm -Petrel | *Oceanodroma melania* |
| Cormorants | Brandt's Cormorant | *Phalacrocorax penicillatus* |
| Double-crested Cormorant | *Phalacrocorax auritus* |
| Pelicans | Pelagic Cormorant | *Phalacrocorax pelagicus* |
| American White Pelican | *Pelecanus erythrorhynchos* |
| Brown Pelican | *Pelecanus occidentalis* |
| Phalaropes | Red Phalarope | *Phalaropus fulicarius* |
| Red-necked Phalarope | *Phalaropus lobatus* |
| Jaegers & Skuas | South Polar Skua | *Stercorarius maccormicki* |
| Pomarine Jaeger | *Stercorarius pomarinus* |
| Parasitic Jaeger | *Stercorarius parasiticus* |
| Long-tailed Jaeger | *Stercorarius longicaudus* |
| Alcids | Common Murre | *Uria aalge* |
| Pigeon Guillemot | *Cepphus columba* |
| Marbled Murrelet | *Brachyramphus marmoratus* |
| Scripps’s Murrelet | *Synthliboramphus scrippsi* |
| Craveris Murrelet | *Synthliboramphus craveri* |
| Ancient Murrelet | *Synthliboramphus antiquus* |
| Cassin's Auklet | *Ptychoramphus aleuticus* |
| Parakeet Auklet | *Aethia psittacula* |
| Rhinoceros Auklet | *Cerorhinca monocerata* |
| Horned Puffin | *Fratercula corniculata* |
| Tufted Puffin | *Fratercula cirrhata* |
| Gulls & Terns | Black-legged Kittiwake | *Rissa tridactyla* |
| Sabine's Gull | *Xema sabini* |
| Bonaparte's Gull | *Chroicocephalus philadelphia* |
| Heermann's Gull | *Larus heermanni* |
| Mew Gull | *Larus brachyrhynchus* |
| Ring-billed Gull | *Larus delawarensis* |
| Western Gull | *Larus occidentalis* |
| California Gull | *Larus californicus* |
| Herring Gull | *Larus smithsonianus* |
| Thayer's Gull | *Larus thayeri* |
| Glaucous-winged Gull | *Larus glaucescens* |
| Least Tern | *Sternula antillarum* |
| Gull-billed Tern | *Sterna nilotica* |
| Caspian Tern | *Hydroprogne caspia* |
| Common Tern | *Sterna hirundo* |
| Arctic Tern | *Sterna paradisaea* |
| Forster's Tern | *Sterna forsteri* |
| Royal Tern | *Thalasseus maximus* |
| Elegant Tern | *Thalasseus elegans* |
| Black Skimmer | *Rynchops niger* |

# 3.0 RESULTS

Ashy Storm-petrels had the greatest Population Vulnerability score (Table 4). Brown Pelican had the greatest Collision Vulnerability score (Table 5). Black Skimmer had the greatest Displacement Vulnerability score (Table 6). Overall, pelicans, cormorants, and terns had the greatest Population Collision Vulnerability scores (Table 7, Figure 1). Alcids, terns, and loons had the greatest Population Displacement Vulnerability scores (Table 7, Figure 1).



**Figure 1**. The relative Population, Collision, and Displacement Vulnerability of all species.

**Table 4.** Values and uncertainties for each metric in the population vulnerability calculation and final population vulnerability scores for all species. POP= global population, CCSpop = population in the California Current, TS = threat status, AS = adult survival, *u* = uncertainty value, BE = best estimate value, - = BE - *u*, + = BE + *u*.

| Species Common Name | POP  BE *u* | | CCSpop  BE *u* | | TS | AS  BE *u* | | Population Vulnerability  - BE + | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Black Scoter | 3 | 0.75 | 2 | 0.5 | 2 | 2 | 1 | **1.69** | **2.25** | **2.81** |
| Surf Scoter | 3 | 1.5 | 3 | 0.75 | 1 | 2 | 1 | **1.50** | **2.31** | **3.13** |
| White-winged Scoter | 2 | 1 | 2 | 0.5 | 1 | 2 | 1 | **1.19** | **1.81** | **2.44** |
| Brant | 3 | 0.75 | 2 | 0.5 | 1 | 3 | 0.75 | **1.81** | **2.31** | **2.81** |
| Common Merganser | 2 | 0.2 | 1 | 0.5 | 1 | 1 | 0.5 | **1.01** | **1.31** | **1.61** |
| Red-breasted Merganser | 3 | 0.3 | 1 | 0.25 | 1 | 2 | 1 | **1.43** | **1.81** | **2.20** |
| Common Loon | 3 | 0.3 | 3 | 0.75 | 3 | 5 | 1.25 | **2.93** | **3.50** | **4.08** |
| Pacific Loon | 2 | 0.5 | 3 | 0.75 | 1 | 4 | 1 | **2.00** | **2.56** | **3.13** |
| Red-throated Loon | 4 | 1 | 2 | 0.5 | 1 | 4 | 1 | **2.19** | **2.81** | **3.44** |
| Yellow-billed Loon | 5 | 0.5 | 2 | 0.5 | 3 | 5 | 1.25 | **3.19** | **3.75** | **4.31** |
| Clark's Grebe | 5 | 0.5 | 3 | 1.5 | 2 | 1 | 0.5 | **2.13** | **2.75** | **3.38** |
| Western Grebe | 4 | 0.4 | 4 | 2 | 2 | 1 | 0.5 | **2.03** | **2.75** | **3.48** |
| Eared Grebe | 1 | 0.1 | 2 | 0.5 | 1 | 1 | 0.5 | **1.04** | **1.31** | **1.59** |
| Horned Grebe | 3 | 1.5 | 1 | 0.25 | 3 | 1 | 0.5 | **1.44** | **2.00** | **2.56** |
| Red-necked Grebe | 4 | 0.4 | 2 | 0.5 | 3 | 3 | 1.5 | **2.40** | **3.00** | **3.60** |
| Black-footed Albatross | 4 | 0.4 | 3 | 1.5 | 3 | 5 | 2.5 | **2.65** | **3.75** | **4.85** |
| Laysan Albatross | 2 | 0.2 | 1 | 0.1 | 3 | 5 | 0.5 | **2.55** | **2.75** | **2.95** |
| Short-tailed Albatross | 5 | 0.5 | 2 | 0.5 | 5 | 5 | 2.5 | **3.38** | **4.25** | **5.13** |
| Buller's Shearwater | 2 | 0.2 | 2 | 1 | 3 | 5 | 2.5 | **2.08** | **3.00** | **3.93** |
| Manx Shearwater | 3 | 0.75 | 1 | 0 | 1 | 5 | 0.5 | **2.25** | **2.56** | **2.88** |
| Pink-footed Shearwater | 5 | 0.5 | 2 | 0.5 | 4 | 5 | 2.5 | **3.13** | **4.00** | **4.88** |
| Flesh-footed Shearwater | 3 | 0.3 | 1 | 0.5 | 3 | 5 | 2.5 | **2.18** | **3.00** | **3.83** |
| Short-tailed Shearwater | 1 | 0.1 | 1 | 0.25 | 1 | 5 | 2.5 | **1.35** | **2.06** | **2.78** |
| Sooty Shearwater | 1 | 0.1 | 3 | 0.75 | 2 | 5 | 2.5 | **1.91** | **2.75** | **3.59** |
| Black-vented Shearwater | 4 | 0.4 | 2 | 0.5 | 4 | 5 | 2.5 | **2.90** | **3.75** | **4.60** |
| Pacific Northern Fulmar | 1 | 0.1 | 2 | 0.5 | 1 | 5 | 0.5 | **2.04** | **2.31** | **2.59** |
| Hawaiian Petrel | 5 | 0.5 | 1 | 0.25 | 5 | 5 | 2.5 | **3.19** | **4.00** | **4.81** |
| Cooks Petrel | 3 | 0.75 | 3 | 0.75 | 4 | 5 | 2.5 | **2.75** | **3.75** | **4.75** |
| Mottled Petrel | 2 | 0.2 | 2 | 0.5 | 2 | 5 | 2.5 | **1.95** | **2.75** | **3.55** |
| Ashy Storm-petrel | 5 | 0.5 | 5 | 1.25 | 4 | 4 | 2 | **3.56** | **4.50** | **5.44** |
| Black Storm-petrel | 3 | 0.75 | 1 | 0.1 | 5 | 4 | 2 | **2.54** | **3.25** | **3.96** |
| Fork-tailed Storm-petrel | 1 | 0.25 | 1 | 0.1 | 3 | 4 | 2 | **1.54** | **2.13** | **2.71** |
| Leach's Storm-petrel | 1 | 0.1 | 2 | 0.5 | 2 | 4 | 2 | **1.60** | **2.25** | **2.90** |
| Wilson's Storm-petrel | 1 | 0.1 | 1 | 0.5 | 1 | 4 | 1 | **1.41** | **1.81** | **2.21** |
| Brown Pelican | 4 | 1 | 3 | 0.75 | 5 | 5 | 1.25 | **3.50** | **4.25** | **5.00** |
| American White Pelican | 4 | 0.4 | 3 | 1.5 | 5 | 3 | 1.5 | **2.90** | **3.75** | **4.60** |
| Brandt's Cormorant | 4 | 0.4 | 4 | 0.4 | 3 | 3 | 0.3 | **3.23** | **3.50** | **3.78** |
| Double-crested Cormorant | 2 | 0.2 | 2 | 0.2 | 1 | 4 | 1 | **1.96** | **2.31** | **2.66** |
| Pelagic Cormorant | 4 | 0.4 | 2 | 0.2 | 4 | 3 | 1.5 | **2.73** | **3.25** | **3.78** |
| Red Phalarope | 2 | 0.2 | 4 | 1 | 1 | 1 | 0.5 | **1.64** | **2.06** | **2.49** |
| Red-necked Phalarope | 1 | 0.1 | 4 | 1 | 1 | 1 | 0.5 | **1.41** | **1.81** | **2.21** |
| Black-legged Kittiwake | 1 | 0.1 | 2 | 0.2 | 1 | 4 | 2 | **1.49** | **2.06** | **2.64** |
| Bonaparte's Gull | 4 | 1 | 4 | 2 | 1 | 3 | 1.5 | **1.94** | **3.06** | **4.19** |
| Sabine's Gull | 3 | 0.3 | 2 | 0.2 | 1 | 3 | 1.5 | **1.81** | **2.31** | **2.81** |
| California Gull | 3 | 0.3 | 3 | 0.75 | 2 | 3 | 1.5 | **2.11** | **2.75** | **3.39** |
| Heermann's Gull | 3 | 0.3 | 3 | 1.5 | 3 | 3 | 1.5 | **2.18** | **3.00** | **3.83** |
| Mew Gull | 1 | 0.25 | 2 | 1 | 1 | 2 | 1 | **1.00** | **1.56** | **2.13** |
| Ring-billed Gull | 2 | 0.2 | 2 | 0.5 | 1 | 3 | 0.75 | **1.70** | **2.06** | **2.43** |
| Herring Gull | 1 | 0.25 | 2 | 0.5 | 1 | 3 | 1.5 | **1.25** | **1.81** | **2.38** |
| Thayer's Gull | 5 | 0.5 | 2 | 1 | 1 | 3 | 1.5 | **2.06** | **2.81** | **3.56** |
| Glaucous-winged Gull | 3 | 0.3 | 2 | 1 | 1 | 3 | 1.5 | **1.61** | **2.31** | **3.01** |
| Western Gull | 4 | 0.4 | 4 | 2 | 1 | 3 | 1.5 | **2.09** | **3.06** | **4.04** |
| Caspian Tern | 4 | 0.4 | 2 | 0.5 | 3 | 4 | 2 | **2.53** | **3.25** | **3.98** |
| Arctic Tern | 2 | 0.2 | 2 | 0.5 | 2 | 4 | 2 | **1.83** | **2.50** | **3.18** |
| Common Tern | 2 | 0.5 | 1 | 0.25 | 2 | 4 | 1 | **1.81** | **2.25** | **2.69** |
| Elegant Tern | 5 | 0.5 | 3 | 1.5 | 4 | 4 | 2 | **3.00** | **4.00** | **5.00** |
| Royal Tern | 4 | 0.4 | 1 | 0.25 | 2 | 4 | 2 | **2.09** | **2.75** | **3.41** |
| Forster's Tern | 4 | 0.4 | 2 | 0.2 | 1 | 4 | 2 | **2.16** | **2.81** | **3.46** |
| Least Tern | 5 | 0.5 | 2 | 0.5 | 5 | 4 | 2 | **3.25** | **4.00** | **4.75** |
| Gull-billed Tern | 4 | 1 | 1 | 0.25 | 1 | 4 | 2 | **1.75** | **2.56** | **3.38** |
| Black Skimmer | 4 | 0.4 | 2 | 0.2 | 4 | 4 | 2 | **2.85** | **3.50** | **4.15** |
| Long-tailed Jaeger | 1 | 0.5 | 1 | 0.5 | 1 | 4 | 2 | **1.06** | **1.81** | **2.56** |
| Parasitic Jaeger | 1 | 0.5 | 1 | 0.5 | 1 | 4 | 2 | **1.06** | **1.81** | **2.56** |
| Pomarine Jaeger | 2 | 1 | 2 | 0.5 | 1 | 3 | 1.5 | **1.31** | **2.06** | **2.81** |
| South Polar Skua | 5 | 0.5 | 2 | 1 | 1 | 5 | 0.5 | **2.81** | **3.31** | **3.81** |
| Ancient Murrelet | 2 | 0.2 | 3 | 1.5 | 3 | 2 | 0.5 | **1.95** | **2.50** | **3.05** |
| Marbled Murrelet | 3 | 0.75 | 2 | 0.5 | 5 | 4 | 1 | **2.94** | **3.50** | **4.06** |
| Scripps's Murrelet | 5 | 0.5 | 2 | 0.2 | 4 | 4 | 2 | **3.08** | **3.75** | **4.43** |
| Craveri’s murrelet | 5 | 0.5 | 2 | 1 | 4 | 3 | 1.5 | **2.75** | **3.50** | **4.25** |
| Common Murre | 1 | 0.1 | 2 | 0.2 | 3 | 5 | 1.25 | **2.36** | **2.75** | **3.14** |
| Pigeon Guillemot | 4 | 0.4 | 2 | 0.2 | 3 | 3 | 1.5 | **2.48** | **3.00** | **3.53** |
| Tufted Puffin | 1 | 0.25 | 2 | 0.5 | 5 | 5 | 2.5 | **2.44** | **3.25** | **4.06** |
| Horned Puffin | 2 | 0.2 | 1 | 0.5 | 2 | 5 | 2.5 | **1.70** | **2.50** | **3.30** |
| Rhinoceros Auklet | 2 | 0.2 | 2 | 0.5 | 4 | 4 | 1 | **2.58** | **3.00** | **3.43** |
| Parakeet Auklet | 2 | 0.2 | 1 | 0.5 | 1 | 4 | 2 | **1.39** | **2.06** | **2.74** |
| Cassin's Auklet | 1 | 0.25 | 2 | 0.5 | 4 | 3 | 1.5 | **1.94** | **2.50** | **3.06** |

**Table 5.** Values and uncertainties for each metric in the collision vulnerability calculation and final collision vulnerability scores for all species. AO= annual occurance, NFA = nocturnal flight activity, DFA = diurnal flight activity, RTZt = percent time spent in rotor sweep zone, MA = macro-avoidance, BR = breed/feeding time in the CCS, *u* = uncertainty value, BE = best estimate value, - = BE - *u*, + = BE + *u*.

| Species Common Name | AO | NFA  BE *u* | | DFA  BE *u* | | RSZt  BE *u* | | MA  BE *u* | | BR | Collision Vulnerability  - BE + | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Black Scoter | 5 | 3 | 1.5 | 3 | 1.5 | 3 | 0.75 | 1 | 0.25 | 1 | **5** | **10** | **15** |
| Surf Scoter | 12 | 4 | 1 | 2 | 1 | 3 | 1.5 | 1 | 0.25 | 1 | **24** | **24** | **27** |
| White-winged Scoter | 12 | 3 | 0.75 | 3 | 0.75 | 3 | 1.5 | 1 | 0.25 | 1 | **27** | **24** | **25** |
| Brant | 12 | 1 | 0.5 | 1 | 0.5 | 1 | 0.25 | 1 | 0.25 | 1 | **12** | **24** | **36** |
| Common Merganser | 2 | 1 | 0.25 | 1 | 0.25 | 1 | 0.5 | 2 | 1 | 1.5 | **9** | **12** | **15** |
| Red-breasted Merganser | 9 | 1 | 0.1 | 1 | 0.1 | 1 | 0.5 | 2 | 1 | 1 | **32** | **36** | **40** |
| Common Loon | 12 | 1 | 0.5 | 2 | 1 | 5 | 2.5 | 1 | 0.1 | 1 | **6** | **7** | **8** |
| Pacific Loon | 12 | 1 | 0.5 | 3 | 1.5 | 5 | 2.5 | 1 | 0.1 | 1 | **9** | **10** | **11** |
| Red-throated Loon | 3 | 1 | 0.25 | 2 | 0.5 | 3 | 1.5 | 1 | 0.1 | 1 | **4** | **3** | **3** |
| Yellow-billed Loon | 10 | 1 | 0.5 | 2 | 1 | 5 | 2.5 | 1 | 0.1 | 1 | **5** | **6** | **7** |
| Clark's Grebe | 12 | 2 | 1 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1.5 | **27** | **54** | **81** |
| Western Grebe | 12 | 3 | 1.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1.5 | **36** | **72** | **108** |
| Eared Grebe | 12 | 3 | 1.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | **24** | **48** | **72** |
| Horned Grebe | 10 | 3 | 1.5 | 2 | 1 | 1 | 0.5 | 1 | 0.5 | 1 | **25** | **50** | **75** |
| Red-necked Grebe | 8 | 3 | 1.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | **16** | **32** | **48** |
| Black-footed Albatross | 12 | 3 | 0.75 | 4 | 2 | 3 | 1.5 | 1 | 0.5 | 1 | **17** | **28** | **39** |
| Laysan Albatross | 10 | 3 | 0.75 | 4 | 2 | 3 | 1.5 | 1 | 0.5 | 1 | **14** | **23** | **33** |
| Short-tailed Albatross | 12 | 3 | 1.5 | 4 | 2 | 3 | 1.5 | 1 | 0.5 | 1 | **14** | **28** | **42** |
| Buller's Shearwater | 9 | 3 | 1.5 | 3 | 1.5 | 5 | 2.5 | 1 | 0.5 | 1 | **5** | **11** | **16** |
| Manx Shearwater | 12 | 3 | 0.75 | 3 | 0.75 | 5 | 2.5 | 1 | 0.25 | 1 | **16** | **14** | **15** |
| Pink-footed Shearwater | 12 | 3 | 1.5 | 3 | 1.5 | 5 | 2.5 | 1 | 0.5 | 1 | **7** | **14** | **22** |
| Flesh-footed Shearwater | 12 | 3 | 1.5 | 4 | 2 | 5 | 2.5 | 1 | 0.5 | 1 | **8** | **17** | **25** |
| Short-tailed Shearwater | 9 | 3 | 1.5 | 3 | 1.5 | 5 | 2.5 | 1 | 0.5 | 1 | **5** | **11** | **16** |
| Sooty Shearwater | 12 | 3 | 0.75 | 3 | 0.75 | 5 | 0.5 | 1 | 0.25 | 1 | **9** | **14** | **20** |
| Black-vented Shearwater | 12 | 3 | 1.5 | 3 | 1.5 | 5 | 2.5 | 1 | 0.5 | 1 | **7** | **14** | **22** |
| Northern Fulmar | 12 | 4 | 1 | 2 | 0.5 | 5 | 0.5 | 1 | 0.25 | 1 | **9** | **14** | **20** |
| Hawaiian Petrel | 6 | 3 | 1.5 | 5 | 2.5 | 5 | 2.5 | 1 | 0.5 | 1 | **5** | **10** | **14** |
| Cooks Petrel | 11 | 4 | 2 | 5 | 2.5 | 5 | 2.5 | 1 | 0.5 | 1 | **10** | **20** | **30** |
| Mottled Petrel | 5 | 3 | 1.5 | 5 | 2.5 | 5 | 2.5 | 1 | 0.5 | 1 | **4** | **8** | **12** |
| Ashy Storm-petrel | 11 | 4 | 2 | 3 | 1.5 | 5 | 2.5 | 1 | 0.5 | 1 | **8** | **15** | **23** |
| Black Storm-petrel | 11 | 4 | 2 | 3 | 1.5 | 5 | 2.5 | 1 | 0.5 | 1.5 | **12** | **23** | **35** |
| Fork-tailed Storm-petrel | 12 | 4 | 2 | 3 | 1.5 | 5 | 2.5 | 1 | 0.5 | 1.5 | **13** | **25** | **38** |
| Leach's Storm-petrel | 12 | 4 | 1 | 3 | 0.75 | 5 | 0.5 | 1 | 0.25 | 2 | **21** | **34** | **48** |
| Wilson's Storm-petrel | 5 | 4 | 1 | 3 | 0.75 | 5 | 2.5 | 1 | 0.25 | 1 | **8** | **7** | **7** |
| Brown Pelican | 12 | 1 | 0.25 | 3 | 0.75 | 1 | 0.5 | 5 | 2.5 | 1.5 | **270** | **360** | **450** |
| American White Pelican | 12 | 1 | 0.5 | 3 | 1.5 | 1 | 0.5 | 5 | 2.5 | 1 | **120** | **240** | **360** |
| Brandt's Cormorant | 12 | 1 | 0.5 | 3 | 1.5 | 3 | 0.75 | 3 | 1.5 | 2 | **32** | **96** | **173** |
| Double-crested Cormorant | 12 | 1 | 0.1 | 5 | 0.5 | 3 | 1.5 | 3 | 1.5 | 2 | **130** | **144** | **158** |
| Pelagic Cormorant | 12 | 1 | 0.5 | 3 | 1.5 | 3 | 0.75 | 3 | 1.5 | 2 | **32** | **96** | **173** |
| Red Phalarope | 12 | 3 | 1.5 | 3 | 1.5 | 5 | 2.5 | 3 | 1.5 | 1 | **22** | **43** | **65** |
| Red-necked Phalarope | 12 | 2 | 1 | 3 | 1.5 | 5 | 2.5 | 3 | 1.5 | 1 | **18** | **36** | **54** |
| Black-legged Kittiwake | 8 | 3 | 0.75 | 3 | 0.75 | 1 | 0.25 | 1 | 0.5 | 1 | **24** | **48** | **72** |
| Bonaparte's Gull | 12 | 2 | 1 | 3 | 1.5 | 1 | 0.25 | 2 | 1 | 1 | **40** | **120** | **216** |
| Sabine's Gull | 7 | 2 | 1 | 3 | 1.5 | 1 | 0.25 | 2 | 1 | 1 | **23** | **70** | **126** |
| California Gull | 12 | 2 | 1 | 3 | 1.5 | 1 | 0.25 | 2 | 1 | 1.5 | **60** | **180** | **324** |
| Heermann's Gull | 12 | 2 | 1 | 3 | 1.5 | 1 | 0.25 | 2 | 1 | 1 | **40** | **120** | **216** |
| Mew Gull | 6 | 2 | 1 | 3 | 1.5 | 1 | 0.25 | 2 | 1 | 1 | **20** | **60** | **108** |
| Ring-billed Gull | 12 | 3 | 1.5 | 3 | 1.5 | 1 | 0.25 | 2 | 1 | 1.5 | **72** | **216** | **389** |
| Herring Gull | 10 | 3 | 0.75 | 2 | 1 | 1 | 0.1 | 2 | 1 | 1 | **36** | **100** | **184** |
| Thayer's Gull | 9 | 2 | 1 | 3 | 1.5 | 1 | 0.1 | 2 | 1 | 1 | **25** | **90** | **184** |
| Glaucous-winged Gull | 12 | 3 | 1.5 | 3 | 1.5 | 1 | 0.1 | 1 | 0.5 | 1.5 | **30** | **108** | **221** |
| Western Gull | 12 | 3 | 1.5 | 3 | 1.5 | 1 | 0.1 | 1 | 0.5 | 1 | **20** | **72** | **147** |
| Caspian Tern | 12 | 5 | 0.5 | 5 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1.5 | **162** | **180** | **198** |
| Arctic Tern | 7 | 2 | 1 | 5 | 1.25 | 1 | 0.5 | 1 | 0.5 | 1 | **33** | **49** | **65** |
| Common Tern | 11 | 3 | 1.5 | 5 | 1.25 | 1 | 0.5 | 1 | 0.5 | 1 | **58** | **88** | **118** |
| Elegant Tern | 8 | 2 | 1 | 5 | 2.5 | 1 | 0.5 | 1 | 0.5 | 1.5 | **42** | **84** | **126** |
| Royal Tern | 12 | 4 | 1 | 4 | 1 | 1 | 0.5 | 1 | 0.5 | 1.5 | **108** | **144** | **180** |
| Forster's Tern | 12 | 5 | 1.25 | 5 | 1.25 | 1 | 0.5 | 1 | 0.5 | 1.5 | **135** | **180** | **225** |
| Least Tern | 8 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 1 | 0.5 | 2 | **32** | **96** | **173** |
| Gull-billed Tern | 6 | 5 | 0.5 | 5 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | **54** | **60** | **66** |
| Black Skimmer | 12 | 3 | 1.5 | 3 | 1.5 | 1 | 0.5 | 1 | 0.5 | 1.5 | **54** | **108** | **162** |
| Long-tailed Jaeger | 3 | 1 | 0.25 | 5 | 1.25 | 1 | 0.25 | 5 | 1.25 | 1 | **68** | **90** | **113** |
| Parasitic Jaeger | 12 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 5 | 1.25 | 1 | **180** | **360** | **540** |
| Pomarine Jaeger | 12 | 1 | 0.25 | 3 | 1.5 | 1 | 0.25 | 5 | 1.25 | 1 | **135** | **240** | **345** |
| South Polar Skua | 5 | 1 | 0.5 | 4 | 2 | 3 | 1.5 | 5 | 2.5 | 1 | **21** | **42** | **63** |
| Ancient Murrelet | 12 | 2 | 1 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 2 | **11** | **14** | **18** |
| Marbled Murrelet | 12 | 2 | 1 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 2 | **11** | **14** | **18** |
| Scripps's Murrelet | 12 | 2 | 1 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 1.5 | **8** | **11** | **14** |
| Craveri’s murrelet | 4 | 2 | 1 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 1 | **2** | **2** | **3** |
| Common Murre | 12 | 2 | 1 | 1 | 0.5 | 5 | 2.5 | 1 | 0.1 | 2 | **13** | **14** | **16** |
| Pigeon Guillemot | 4 | 1 | 0.5 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 2 | **2** | **3** | **4** |
| Tufted Puffin | 12 | 1 | 0.5 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 2 | **7** | **10** | **12** |
| Horned Puffin | 3 | 1 | 0.5 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 1 | **1** | **1** | **2** |
| Rhinoceros Auklet | 12 | 1 | 0.5 | 1 | 0.5 | 5 | 2.5 | 1 | 0.5 | 2 | **5** | **10** | **14** |
| Parakeet Auklet | 5 | 1 | 0.5 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 1 | **2** | **2** | **3** |
| Cassin's Auklet | 12 | 2 | 1 | 1 | 0.5 | 5 | 2.5 | 1 | 0.25 | 2 | **11** | **14** | **18** |

**Table 6.** Values and uncertainties for each metric in the displacement vulnerability calculation and final displacement vulnerability scores for all species. AO = annual occurrence, MA = macro-avoidance, HF = habitat flexibility, BR = breeding/feeding time in CCS, *u* = uncertainty value, BE = best estimate value, - = BE - *u*, + = BE + *u*.

| Species Common Name | AO | MA  BE *u* | | HF  BE *u* | | BR | Displacement  Vulnerability  - BE + | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Black Scoter | 5 | 5 | 1.25 | 4 | 2 | 1 | **38** | **100** | **188** |
| Surf Scoter | 12 | 5 | 1.25 | 4 | 2 | 1 | **90** | **240** | **450** |
| White-winged Scoter | 12 | 5 | 1.25 | 3 | 1.5 | 1 | **68** | **180** | **338** |
| Brant | 12 | 5 | 1.25 | 4 | 2 | 1 | **90** | **240** | **450** |
| Common Merganser | 2 | 4 | 2 | 1 | 0.25 | 1.5 | **5** | **12** | **23** |
| Red-breasted Merganser | 9 | 4 | 2 | 1 | 0.5 | 1 | **9** | **36** | **81** |
| Common Loon | 12 | 5 | 0.5 | 4 | 0.4 | 1 | **194** | **240** | **290** |
| Pacific Loon | 12 | 5 | 0.5 | 4 | 2 | 1 | **108** | **240** | **396** |
| Red-throated Loon | 3 | 5 | 0.5 | 4 | 0.4 | 1 | **49** | **60** | **73** |
| Yellow-billed Loon | 10 | 5 | 0.5 | 4 | 2 | 1 | **90** | **200** | **330** |
| Clark's Grebe | 12 | 5 | 2.5 | 3 | 1.5 | 1.5 | **68** | **270** | **608** |
| Western Grebe | 12 | 5 | 2.5 | 3 | 1.5 | 1.5 | **68** | **270** | **608** |
| Eared Grebe | 12 | 5 | 2.5 | 3 | 1.5 | 1 | **45** | **180** | **405** |
| Horned Grebe | 10 | 5 | 2.5 | 4 | 0.4 | 1 | **90** | **200** | **330** |
| Red-necked Grebe | 8 | 5 | 2.5 | 3 | 0.3 | 1 | **54** | **120** | **198** |
| Black-footed Albatross | 12 | 5 | 2.5 | 1 | 0.5 | 1 | **15** | **60** | **135** |
| Laysan Albatross | 10 | 5 | 2.5 | 1 | 0.5 | 1 | **13** | **50** | **113** |
| Short-tailed Albatross | 12 | 5 | 2.5 | 1 | 0.5 | 1 | **15** | **60** | **135** |
| Buller's Shearwater | 9 | 5 | 2.5 | 1 | 0.5 | 1 | **11** | **45** | **101** |
| Manx Shearwater | 12 | 5 | 1.25 | 1 | 0.1 | 1 | **41** | **60** | **83** |
| Pink-footed Shearwater | 12 | 5 | 2.5 | 1 | 0.5 | 1 | **15** | **60** | **135** |
| Flesh-footed Shearwater | 12 | 5 | 2.5 | 1 | 0.5 | 1 | **15** | **60** | **135** |
| Short-tailed Shearwater | 9 | 5 | 2.5 | 1 | 0.5 | 1 | **11** | **45** | **101** |
| Sooty Shearwater | 12 | 5 | 1.25 | 1 | 0.1 | 1 | **41** | **60** | **83** |
| Black-vented Shearwater | 12 | 5 | 2.5 | 2 | 1 | 1 | **30** | **120** | **270** |
| Northern Fulmar | 12 | 5 | 1.25 | 1 | 0.1 | 1 | **41** | **60** | **83** |
| Hawaiian Petrel | 6 | 5 | 2.5 | 3 | 1.5 | 1 | **23** | **90** | **203** |
| Cooks Petrel | 11 | 5 | 2.5 | 1 | 0.5 | 1 | **14** | **55** | **124** |
| Mottled Petrel | 5 | 5 | 2.5 | 1 | 0.5 | 1 | **6** | **25** | **56** |
| Ashy Storm-petrel | 11 | 5 | 2.5 | 2 | 1 | 2 | **55** | **220** | **495** |
| Black Storm-petrel | 11 | 5 | 2.5 | 1 | 0.5 | 1.5 | **21** | **83** | **186** |
| Fork-tailed Storm-petrel | 12 | 5 | 2.5 | 1 | 0.5 | 1.5 | **23** | **90** | **203** |
| Leach's Storm-petrel | 12 | 5 | 1.25 | 1 | 0.1 | 2 | **81** | **120** | **165** |
| Wilson's Storm-petrel | 5 | 5 | 1.25 | 1 | 0.5 | 1 | **9** | **25** | **47** |
| Brown Pelican | 12 | 1 | 0.5 | 4 | 2 | 1.5 | **18** | **72** | **162** |
| American White Pelican | 12 | 1 | 0.5 | 4 | 2 | 1 | **12** | **48** | **108** |
| Brandt's Cormorant | 12 | 3 | 1.5 | 2 | 0.2 | 2 | **65** | **144** | **238** |
| Double-crested Cormorant | 12 | 3 | 1.5 | 2 | 0.2 | 2 | **65** | **144** | **238** |
| Pelagic Cormorant | 12 | 3 | 1.5 | 2 | 0.2 | 2 | **65** | **144** | **238** |
| Red Phalarope | 12 | 3 | 1.5 | 2 | 0.5 | 1 | **27** | **72** | **135** |
| Red-necked Phalarope | 12 | 3 | 1.5 | 2 | 0.5 | 1 | **27** | **72** | **135** |
| Black-legged Kittiwake | 8 | 3 | 1.5 | 2 | 0.2 | 1 | **22** | **48** | **79** |
| Bonaparte's Gull | 12 | 3 | 1.5 | 2 | 0.5 | 1 | **27** | **72** | **135** |
| Sabine's Gull | 7 | 3 | 1.5 | 2 | 0.5 | 1 | **16** | **42** | **79** |
| California Gull | 12 | 3 | 1.5 | 1 | 0.5 | 1.5 | **14** | **54** | **122** |
| Heermann's Gull | 12 | 3 | 1.5 | 1 | 0.5 | 1 | **9** | **36** | **81** |
| Mew Gull | 6 | 3 | 1.5 | 1 | 0.5 | 1 | **5** | **18** | **41** |
| Ring-billed Gull | 12 | 3 | 1.5 | 1 | 0.5 | 1.5 | **14** | **54** | **122** |
| Herring Gull | 10 | 3 | 1.5 | 1 | 0.1 | 1 | **14** | **30** | **50** |
| Thayer's Gull | 9 | 3 | 1.5 | 1 | 0.5 | 1 | **7** | **27** | **61** |
| Glaucous-winged Gull | 12 | 3 | 1.5 | 1 | 0.25 | 1.5 | **20** | **54** | **101** |
| Western Gull | 12 | 3 | 1.5 | 1 | 0.1 | 1 | **16** | **36** | **59** |
| Caspian Tern | 12 | 5 | 2.5 | 3 | 1.5 | 1.5 | **68** | **270** | **608** |
| Arctic Tern | 7 | 5 | 2.5 | 3 | 0.3 | 1 | **47** | **105** | **173** |
| Common Tern | 11 | 5 | 2.5 | 3 | 0.3 | 1 | **74** | **165** | **272** |
| Elegant Tern | 8 | 5 | 2.5 | 4 | 2 | 1.5 | **60** | **240** | **540** |
| Royal Tern | 12 | 5 | 2.5 | 3 | 1.5 | 1.5 | **68** | **270** | **608** |
| Forster's Tern | 12 | 5 | 2.5 | 3 | 1.5 | 1.5 | **68** | **270** | **608** |
| Least Tern | 8 | 5 | 2.5 | 3 | 1.5 | 2 | **60** | **240** | **540** |
| Gull-billed Tern | 6 | 5 | 2.5 | 2 | 1 | 1 | **15** | **60** | **135** |
| Black Skimmer | 12 | 5 | 2.5 | 4 | 2 | 1.5 | **90** | **360** | **810** |
| Long-tailed Jaeger | 3 | 1 | 0.25 | 2 | 1 | 1 | **2** | **6** | **11** |
| Parasitic Jaeger | 12 | 1 | 0.25 | 2 | 0.2 | 1 | **16** | **24** | **33** |
| Pomarine Jaeger | 12 | 1 | 0.25 | 2 | 1 | 1 | **9** | **24** | **45** |
| South Polar Skua | 5 | 1 | 0.5 | 2 | 1 | 1 | **3** | **10** | **23** |
| Ancient Murrelet | 12 | 5 | 1.25 | 3 | 0.75 | 2 | **203** | **360** | **563** |
| Marbled Murrelet | 12 | 5 | 1.25 | 3 | 0.75 | 2 | **203** | **360** | **563** |
| Scripps's Murrelet | 12 | 5 | 1.25 | 4 | 1 | 1.5 | **203** | **360** | **563** |
| Craveri’s murrelet | 4 | 5 | 1.25 | 4 | 2 | 1 | **30** | **80** | **150** |
| Common Murre | 12 | 5 | 0.5 | 3 | 0.3 | 2 | **292** | **360** | **436** |
| Pigeon Guillemot | 4 | 5 | 1.25 | 3 | 0.75 | 2 | **68** | **120** | **188** |
| Tufted Puffin | 12 | 5 | 1.25 | 3 | 0.75 | 2 | **203** | **360** | **563** |
| Horned Puffin | 3 | 5 | 1.25 | 3 | 0.75 | 1 | **25** | **45** | **70** |
| Rhinoceros Auklet | 12 | 5 | 2.5 | 3 | 0.75 | 2 | **135** | **360** | **675** |
| Parakeet Auklet | 5 | 5 | 1.25 | 2 | 0.5 | 1 | **28** | **50** | **78** |
| Cassin's Auklet | 12 | 5 | 1.25 | 3 | 0.75 | 2 | **203** | **360** | **563** |

**Table 7.** Final Population Collision Vulnerability (PCV) and Population Displacement Vulnerability (PDV) scores and rankings for each species. PCV = Collision Vulnerability × Population Vulnerability, PDV = Displacement Vulnerability × Population Vulnerability, BE = best estimate value, - = BE - *u*, + = BE + *u, u* = uncertainty value.

| Species Common Name | PCV  - BE + rank | | | | PDV  - BE + rank | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Black Scoter | 8 | 23 | 42 | LOW | 63 | 225 | 527 | MEDIUM |
| Surf Scoter | 36 | 56 | 83 | MEDIUM | 135 | 555 | 1406 | HIGH |
| White-winged Scoter | 32 | 44 | 61 | MEDIUM | 80 | 326 | 823 | MEDIUM |
| Brant | 27 | 48 | 117 | MEDIUM | 203 | 480 | 1463 | HIGH |
| Common Merganser | 9 | 16 | 24 | LOW | 5 | 16 | 36 | LOW |
| Red-breasted Merganser | 46 | 65 | 87 | MEDIUM | 13 | 65 | 178 | LOW |
| Common Loon | 19 | 25 | 32 | LOW | 569 | 840 | 1183 | HIGH |
| Pacific Loon | 17 | 25 | 33 | LOW | 216 | 615 | 1238 | HIGH |
| Red-throated Loon | 9 | 8 | 9 | LOW | 106 | 169 | 250 | MEDIUM |
| Yellow-billed Loon | 17 | 23 | 28 | LOW | 287 | 750 | 1423 | HIGH |
| Clark's Grebe | 57 | 149 | 273 | HIGH | 143 | 743 | 2050 | HIGH |
| Western Grebe | 73 | 198 | 375 | HIGH | 137 | 743 | 2111 | HIGH |
| Eared Grebe | 25 | 63 | 114 | MEDIUM | 47 | 236 | 643 | MEDIUM |
| Horned Grebe | 36 | 100 | 192 | MEDIUM | 129 | 400 | 846 | MEDIUM |
| Red-necked Grebe | 38 | 96 | 173 | MEDIUM | 130 | 360 | 713 | MEDIUM |
| Black-footed Albatross | 45 | 105 | 189 | MEDIUM | 40 | 225 | 655 | MEDIUM |
| Laysan Albatross | 36 | 64 | 96 | MEDIUM | 32 | 138 | 332 | MEDIUM |
| Short-tailed Albatross | 47 | 119 | 215 | MEDIUM | 51 | 255 | 692 | MEDIUM |
| Buller's Shearwater | 11 | 32 | 64 | LOW | 23 | 135 | 397 | MEDIUM |
| Manx Shearwater | 36 | 37 | 43 | LOW | 91 | 154 | 237 | MEDIUM |
| Pink-footed Shearwater | 23 | 58 | 105 | MEDIUM | 47 | 240 | 658 | MEDIUM |
| Flesh-footed Shearwater | 18 | 50 | 96 | MEDIUM | 33 | 180 | 516 | MEDIUM |
| Short-tailed Shearwater | 7 | 22 | 45 | LOW | 15 | 93 | 281 | LOW |
| Sooty Shearwater | 17 | 40 | 73 | LOW | 77 | 165 | 296 | MEDIUM |
| Black-vented Shearwater | 21 | 54 | 99 | MEDIUM | 87 | 450 | 1242 | MEDIUM |
| Northern Fulmar | 18 | 33 | 53 | LOW | 83 | 139 | 213 | MEDIUM |
| Hawaiian Petrel | 15 | 38 | 69 | LOW | 72 | 360 | 975 | MEDIUM |
| Cooks Petrel | 27 | 74 | 141 | MEDIUM | 38 | 206 | 588 | MEDIUM |
| Mottled Petrel | 8 | 22 | 43 | LOW | 12 | 69 | 200 | LOW |
| Ashy Storm-petrel | 27 | 69 | 126 | MEDIUM | 196 | 990 | 2692 | HIGH |
| Black Storm-petrel | 29 | 75 | 137 | MEDIUM | 52 | 268 | 736 | MEDIUM |
| Fork-tailed Storm-petrel | 19 | 54 | 103 | MEDIUM | 35 | 191 | 549 | MEDIUM |
| Leach's Storm-petrel | 34 | 76 | 138 | MEDIUM | 130 | 270 | 479 | MEDIUM |
| Willson's Storm-petrel | 11 | 13 | 16 | LOW | 13 | 45 | 104 | LOW |
| Brown Pelican | 945 | 1530 | 2250 | HIGH | 63 | 306 | 810 | MEDIUM |
| American White Pelican | 348 | 900 | 1656 | HIGH | 35 | 180 | 497 | MEDIUM |
| Brandt's Cormorant | 103 | 336 | 652 | HIGH | 209 | 504 | 897 | HIGH |
| Double-crested Cormorant | 254 | 333 | 422 | HIGH | 127 | 333 | 633 | MEDIUM |
| Pelagic Cormorant | 87 | 312 | 652 | HIGH | 177 | 468 | 897 | HIGH |
| Red Phalarope | 35 | 89 | 161 | MEDIUM | 44 | 149 | 336 | MEDIUM |
| Red-necked Phalarope | 25 | 65 | 119 | MEDIUM | 38 | 131 | 299 | MEDIUM |
| Black-legged Kittiwake | 36 | 99 | 190 | MEDIUM | 32 | 99 | 209 | LOW |
| Bonaparte's Gull | 78 | 368 | 905 | HIGH | 52 | 221 | 565 | MEDIUM |
| Sabine's Gull | 42 | 162 | 354 | HIGH | 29 | 97 | 221 | LOW |
| California Gull | 127 | 495 | 1098 | HIGH | 29 | 149 | 412 | MEDIUM |
| Heermann's Gull | 87 | 360 | 826 | HIGH | 20 | 108 | 310 | LOW |
| Mew Gull | 20 | 94 | 230 | MEDIUM | 5 | 28 | 86 | LOW |
| Ring-billed Gull | 122 | 446 | 943 | HIGH | 23 | 111 | 295 | LOW |
| Herring Gull | 45 | 181 | 437 | HIGH | 17 | 54 | 118 | LOW |
| Thayer's Gull | 52 | 253 | 656 | HIGH | 14 | 76 | 216 | LOW |
| Glaucous-winged Gull | 48 | 250 | 665 | HIGH | 33 | 125 | 305 | LOW |
| Western Gull | 42 | 221 | 595 | HIGH | 34 | 110 | 240 | LOW |
| Caspian Tern | 409 | 585 | 787 | HIGH | 170 | 878 | 2415 | HIGH |
| Arctic Tern | 61 | 123 | 206 | MEDIUM | 86 | 263 | 550 | MEDIUM |
| Common Tern | 105 | 198 | 318 | HIGH | 135 | 371 | 732 | MEDIUM |
| Elegant Tern | 126 | 336 | 630 | HIGH | 180 | 960 | 2700 | HIGH |
| Royal Tern | 225 | 396 | 614 | HIGH | 141 | 743 | 2073 | HIGH |
| Forster's Tern | 292 | 506 | 779 | HIGH | 146 | 759 | 2103 | HIGH |
| Least Tern | 104 | 384 | 821 | HIGH | 195 | 960 | 2565 | HIGH |
| Gull-billed Tern | 95 | 154 | 223 | HIGH | 26 | 154 | 456 | MEDIUM |
| Black Skimmer | 154 | 378 | 672 | HIGH | 257 | 1260 | 3362 | HIGH |
| Long-tailed Jaeger | 72 | 163 | 288 | HIGH | 2 | 11 | 29 | LOW |
| Parasitic Jaeger | 191 | 653 | 1384 | HIGH | 17 | 44 | 85 | LOW |
| Pomarine Jaeger | 177 | 495 | 970 | HIGH | 12 | 50 | 127 | LOW |
| South Polar Skua | 59 | 138 | 238 | HIGH | 7 | 33 | 86 | LOW |
| Ancient Murrelet | 21 | 36 | 55 | LOW | 395 | 900 | 1716 | HIGH |
| Marbled Murrelet | 32 | 50 | 73 | MEDIUM | 595 | 1260 | 2285 | HIGH |
| Scripps's Murrelet | 25 | 41 | 60 | LOW | 623 | 1350 | 2489 | HIGH |
| Craveris murrelet | 5 | 8 | 13 | LOW | 83 | 280 | 638 | MEDIUM |
| Common Murre | 31 | 40 | 50 | LOW | 689 | 990 | 1367 | HIGH |
| Pigeon Guillemot | 6 | 10 | 14 | LOW | 167 | 360 | 661 | MEDIUM |
| Tufted Puffin | 18 | 31 | 49 | LOW | 494 | 1170 | 2285 | HIGH |
| Horned Puffin | 2 | 3 | 5 | LOW | 43 | 113 | 232 | LOW |
| Rhinoceros Auklet | 12 | 29 | 49 | LOW | 348 | 1080 | 2312 | HIGH |
| Parakeet Auklet | 2 | 4 | 7 | LOW | 39 | 103 | 214 | LOW |
| Cassin's Auklet | 21 | 36 | 55 | LOW | 392 | 900 | 1723 | HIGH |

# 4.0 MARINE BIRD SPECIES ACCOUNTS

The vulnerability score for each species are addressed in the context of species life history, highest threat status, and the metric factors that contribute significantly to their collision and displacement vulnerability score. We also discuss the final vulnerability scores and rankings for each species and how they compare with vulnerability scores from previous assessments (Garthe and Hüppop 2004, Desholm 2009, Furness and Wade 2012, Furness et al. 2013, Willmott et al. 2013). When applicable, information of species behavior at OWEI based on post-OWEI construction studies also is addressed.

## Scoters (*Melanitta spp.*)

Three species of scoter are found in the CCS: Surf Scoter (*Melanitta perspicillata*), White-winged Scoter (*Melanitta fusca*), and Black Scoter (*Melanitta americana*). Black Scoters migrate down the west coast of North America after the breeding season and winter along the coast from the Pribilof and Aleutian Islands down to Baja California (Briggs 1983, Borage and Savard 2011). This is the least-common species of scoter in the CCS and there is little reliable information on their abundance and distribution (Briggs et al. 1981). When migrating, Black Scoters fly 100 – 300 m over the water (Bordage and Savard 2011). They feed primarily on mollusks and crustaceans in both fresh and salt water (Borage and Savard 2011). The species is considered Near Threatened due to a number of threats causing population decline throughout its range (IUCN 2014). Black Scoter had a PCV best estimate score of 23, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 255, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 2).

Surf Scoters breed in scattered, isolated, freshwater ecosystems across boreal and sub-arctic Canada and Alaska and non-breeders summer along the Pacific coast. During fall-spring, breeders that winter in the Pacific are found in coastal waters from southeast Alaska through northern Baja California, Mexico, and within the northern reaches of the Gulf of California, Mexico. The fall migration tends to be separated by sex and life-stage; off Oregon, birds arrive in early September and numbers peak in October and November (Briggs et al. 1992). During spring migration, birds start leaving wintering grounds during March (Savard et al. 1998), traveling in loose flocks at altitudes from sea-level to near 100 m (J. Adams, pers. obs.). Coastal migration past a single line of latitude can reach from 100s to 1000s of birds per hour during April (Savard et al. 1998). Migratory flights overland are known to take place at night, but there is little information about migratory movements over the ocean (Savard et al. 1998). The Surf Scoter is considered a Species of Least Concern (IUCN 2014). Surf Scoter had a PCV best estimate score of 56, ranking it at ‘medium’ risk to collision, and a PDV best estimate score of 2.16, ranking it at ‘high’ risk for displacement (Table 7, Figure 2). The high displacement vulnerability is due to high macro-avoidance and low (high value) habitat flexibility (Table 6).

White-winged Scoters nest in freshwater ecosystems within the northwestern interior of North America (Brown et al. 1997). Outside of summer, White-winged Scoters often are associated with the more numerous Surf Scoters off Washington, Oregon, and California, with numbers of White-winged Scoters decreasing from north to south (Briggs et al. 1987). Details surrounding White-winged Scoter migration are not well known, but timing and flight behaviors likely are similar to Surf Scoter. Both species occur in greatest numbers within a few km of shore and generally are more abundant over sandy substrates in the lee of coastal promontories (Briggs et al. 1987). Briggs et al. (1992), however noted that scoter distribution at sea extended to the mid-shelf off Washington. White-winged Scoter is a Species of Least Concern (IUCN 2014). White-winged Scoter had a PCV best estimate score of 44, ranking it at ‘medium’ risk for collision and a PDV best estimate score of 326, ranking it at ‘medium’ risk for displacement by OWEI (Table 7, Figure 2).

Previous vulnerability indices found scoters to be vulnerable to displacement by OWEI. Garthe and Hüppop (2004) determined Velvet Scoter (*Melanitta fusca*) to be the third-most sensitive species (after 2 loon species) to OWEI in the German North and Baltic Sea. Deshom (2009) estimated that water birds (loons, swans, geese, and ducks) were the species most sensitive to OWEI disturbance at Nysted offshore wind farm in Denmark. In the Scottish waters of the North Sea, Common Scoters (*Melanitta nigra*), along with loons, were considered the most vulnerable species to displacement by OWEI (Furness and Wade 2012, Furness et al. 2013). Willmott et al. (2013) also found scoters (along with loons, terns and alcids) to have the highest displacement vulnerability on the Atlantic Outer Continental Shelf of North America. Post-construction studies at offshore wind farms in the North Sea have supported these projections of high displacement risk for scoters. At Egmond aan Zee wind farm in the North Sea, Krijgsveld et al. (2011) found scoters (along with loons, gannets and alcids) actively avoided OWEI. Desholm and Kahlert (2005) found the number of geese and duck flocks flying through Nysted offshore wind farm off the coast of Denmark decreased significantly post-construction. Patterson et al. (2006) found Common Scoters were noticeably absent from the offshore wind farm areas of Nysted and Horns Rev in the Dutch North Sea, where they had been commonly seen pre-construction.

### Brant (*Branta bernicla*)

Brant nest in Arctic regions and migrate through the CCS on their way to wintering locations off the coast of Mexico (Briggs et al. 1981). Seventy-five percent of the American population of Brant winters in Mexico although not all fly through the CCS, as some are thought to take inland routes (David and Deuel 2008). A small percent of the Brant population winter in Humboldt, Tomales, Bodega, Morro, and San Diego Bays within the CCS (Briggs et al. 1981). They eat primarily eel grass during the nonbreeding season (Lewis et al. 2013). The species is considered a species of Least Concern (IUCN 2014). Brant had a PCV best estimate score of 48, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 480, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 3). The high displacement vulnerability is due to high macro-avoidance value and low (high value) habitat flexibility (Table 6).

Similar to our results for Brant, Deshom (2009) estimated swans and geese were the species most sensitive to OWEI disturbance. High displacement among geese has been reported at offshore wind farms in the North Sea. In a 4-year radar detection study of Pink-footed Geese (Anser brachyrhynchus) at two offshore wind farms, Plonczkier and Simms (2012) found that 95% of goose flocks avoided flying through OWEI. Desholm and Kahlert (2005) found that the number of geese and duck flocks flying through Nysted offshore wind farm off the coast of Denmark decreased significantly post-construction.

### Mergansers (*Mergus spp.*)

Mergansers prefer estuaries, bays, and other inland protected areas but are not uncommon on the open coast within the CCS. Common Mergansers (*Mergus merganser*) breed throughout the world; the percentage of the world’s population found in the CCS is unclear. They are found wintering along the west coast of America but are more common on inland waters (Mallory and Metz 1999). Common Mergansers feed mostly on small fish and aquatic invertebrates (Mallory and Metz 1999). They are a species of Least Concern (IUCN 2014). Common Mergansers had a PCV best estimate score of 16, ranking it at ‘low’ risk of collision and a PDV best estimate score of 16, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 4).

Red-breasted Mergansers (*Mergus serrator*) are found along the CCS during the migration and winter seasons (Briggs et al. 1981). An estimated 6,000 use the Pacific Flyway during migration (Titman 1999). Their food consists primarily of small fish and crustaceans (Titman 1999). Peterson et al. (2006) found that Red-breasted Mergansers were attracted to offshore wind-energy infrastructure at Nysted and Horns Rev wind farms in Denmark, probably due to increased fish availability. They are a species of Least Concern (IUCN 2014). Red-breasted Mergansers had a PCV best estimate score of 65, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 65, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 4).

Although no previous OWEI vulnerability index has addressed merganser species, other duck species have been found to be vulnerable to displacement by OWEI. As previously mentioned Deshom (2009) and Willmott et al. (2013) determined that sea ducks have high displacement vulnerability. In addition, Desholm and Kahlert (2005) found that the number of geese and duck flocks flying through Nysted offshore wind farm off the coast of Denmark decreased significantly post OWEI construction.

### Loons (*Gavia spp*.)

There are four loon species present in the CCS. The Common Loon (*Gavia immer*) is the most abundant loon species in the CCS, with widespread breeding occurring throughout boreal and sub-arctic Canada (94% of the total breeding population of ca. 260,000 pairs; Evers et al. 2010). Approximately 30% of the total world population (those nesting in western Canada through British Columbia, and Southeast Alaska) disperses westward and southward during the fall post-breeding period when an estimated 220,000 individuals (including juveniles) over-winter off the Pacific Coast of North America (Evers et al. 2010). Spring and fall migration and wintering ecology are relatively poorly known. Ocean migrants employ a stepping-stone migration with movements interspersed with staging areas that are typically near-shore with relatively clear water and abundant prey (Evers et al. 2010). Peak migrations off California occur in late April to early May and during late November, and during early May and November off Oregon (Briggs et al. 1992). During the non-breeding season, Common Loons in marine ecosystems are most frequently located within a few km of shore as they pursue benthic prey available in relatively shallow waters. Individuals rarely are observed outside inner-shelf waters (less than 100-m depth; Briggs et al. 1992, Evers et al. 2010). They are a State Sensitive Species in Washington due to the decrease in available nesting habitat and increase in pollution exposure as a result of coastal human development (Washington State Department of Fish and Game 2003). Common Loon had a PCV best estimate score of 25, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 840, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 5). Their high displacement vulnerability is due to their high macro-avoidance, low (high value) habitat flexibility, and their high Population Vulnerability score (Tables 4 & 6).

Pacific Loons (*Gavia pacifica*) nest throughout the northwestern arctic and sub-arctic tundra and taiga regions of Canada and Alaska. The species undergoes a somewhat asynchronous migration along the Pacific coast during spring and fall, with a primary wintering destination among breeders occurring off the west coast of Baja California, Mexico (Russell 2002). The first southward fall migrants reach the Washington and Oregon coasts in August, with peaks generally in late October to early November (Russell 2002). Migration rates off northern California during fall have been estimated at 600 - 800 individuals h-1 (Palmer 1962). This species has been observed during the winter off California in large flocks which can influence regional density estimates at sea. Off California and Oregon, spring migration starts during late March, peaks in mid-April, and tapers off through June, with peak passage rates of 2500 – 3000 birds per hour off Oregon and Washington (Crowell and Nehls 1976). During migration, the majority of birds occur within a few km of the coastline, generally flying diurnally at altitudes <100 m and usually >10 m (Russell 2002). When flying into weak headwinds during migration, Pacific Loons can reach altitudes >100m (B. Henry, pers. com). They are a species of Least Concern (IUCN 2014). Pacific Loons had a PCV best estimate score of 25, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 615, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 5). Their high displacement vulnerability was due to their high macro-avoidance and low (high value) habitat flexibility (Table 5).

Red-throated Loons (*Gavia* *stellata)* share much of the breeding range of Pacific Loons; however, their nesting habitat is more restricted to coastal areas (Barr et al. 2000). Whereas breeders in northern Alaska are known to winter in Southeast Asia, Red-throated Loons nesting elsewhere in Alaska spend the non-breeding season off the west coast of North America, as far south as Baja California, Mexico (Schmutz et al. 2009). Red-throated Loons wintering off western North America follow a similar migration timing and pattern as Pacific Loons, although they prefer waters very near the coast (Briggs et al. 1987, Briggs et al. 1992). Although both loon species occur off the California, Oregon, and Washington coasts, Pacific Loons dominate numerically in this region (Briggs et al. 1987; Briggs et al. 1992). They are a species of Least Concern (IUCN 2014). Garthe and Hüppop (2004) found that Red-throated Loons (along with Black-throated Loons, *G. arctica*) were most sensitive to OWEI in their index for marine birds of the German North Sea. Red-throated Loons had a PCV best estimate score of 8, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 169, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 5).

Of the global Yellow-billed Loon (*Gavia adamsii*) population, an estimated 2-3% migrate to or through the CCS during the nonbreeding season (J. Schmutz, pers com). While migrating, they stay a couple hundred meters off shore and fly at altitudes <100 m (North 1994). They primarily eat fish, although they consume some invertebrates and vegetation as well (North 1994). They are considered Threatened by the US Endangered Species Act, Near Threatened by the IUCN, and of Special Concern in Canada due to high rates of subsistence harvesting of loons in some breeding grounds (COSEWIC 2004, IUCN 2014, USFWS 2014). Yellow-billed Loons had a PCV best estimate score of 23, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 750, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 5). Their high displacement vulnerability was due to their high macro-avoidance rate, low (high value) habitat flexibility, and their high Population Vulnerability (Tables 4 & 6).

Previous vulnerability indices also found some loon species to be at high risk of displacement by OWEI. Deshom (2009) estimated water birds (loons, swans, geese, and ducks) were the species most sensitive to OWEI disturbance. Furness and Wade (2012) and Furness et al. (2013) estimated loons (along with Common Scoters) would be the most vulnerable to displacement by OWEI in Scottish North Sea. Willmott et al. (2013) found that on the Atlantic Outer Continental Shelf of North America, loons (along with scoters, terns and alcids) have the highest displacement vulnerability. These predictions of high loon displacement are supported by post construction reports at offshore wind farms. At Egmond aan Zee wind farm in the North Sea, Krijgsveld et al. (2011) found loons (along with scoters, gannets and alcids) actively avoided OWEI. Patterson et al. (2006) reported that loons were not found in the offshore wind farm areas of Nysted and Horns Rev in the Danish North Sea, although they were frequently found in those areas before the OWEI construction.

### Grebes (*Aechmophorus spp./ Podiceps spp*.)

There are six grebe species that occur in the CCS including Pied-billed Grebe (*Podilymbus podiceps*) which is rarely observed and only in coastal/estuarine environs and will not be considered here. Western (*Aechmophorus occidentalis*) and Clark’s Grebe (*A. clarkii*) are very similar in appearance and behavior and often co-occur in the marine waters of the CCS; therefore, we consider their distribution together and refer collectively to these as *Aechmophorus* grebes (Clark’s Grebes represent *ca.*8 – 13% of the total population of *Aechmophorus* grebes; LaPorte et al. 2013). *Aechmophorus* grebes breed inland throughout the western United States and central-southwestern Canada. Western Grebes achieve greatest numbers within coastal waters of the NCCS during October through May within a narrow coastal band, usually <0.5 km from the coast (Briggs et al. 1987, Mason et al. 2007). During winter and spring, *Aechmophorus* Grebes are among the most numerous species observed immediately adjacent to the coast (e.g., local densities in Monterey Bay, CA: *ca*. 200 - 400 birds km-2; Henkel 2004). Migratory movements occur primarily at night, but are poorly documented (LaPorte et al. 2013). They migrate to post-breeding molt sites where many birds undergo wing molt before continuing on to wintering sites (LaPorte et al. 2013). During winter months, flocks often are found in sheltered waters (e.g., in the lee of coastal promontories) and are associated with shallow, sandy-bottom habitats (Briggs et al. 1987, LaPorte et al. 2013). *Aechmophorus* grebes are considered Near Threatened by Washington State Species of Special Concern (Washington State Department of Fish and Game 2003). Clark’s Grebe had a PCV best estimate score of 149, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 473, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 6). Western Grebe had PCV best estimate score of 198, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 473, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 6). *Aechmophorus* grebes’ high collision vulnerabilities were due to their high percent time flying in the RSZ and high Population Vulnerability (Table 4 & 5). High displacement vulnerabilities in *Aechmophorus* grebes were due to high macro-avoidance rate, low (high value) habitat flexibility, and high Population Vulnerability (Tables 4 & 6).

Eared Grebes (*Podiceps nigricollis*) breed in interior North America from the central United States up through Canada (Cullen et al. 1999). The majority of the Eared Grebes on the west coast of America winter in the Gulf of California and the Salton Sea (Cullen et al. 1999); small numbers also occur along the Oregon and Washington coast during winter (Briggs et al. 1987). They feed primarily on invertebrates and crustaceans (Cullen et al. 1999). They are a species of Least Concern (IUCN 2014). Eared Grebe had a PCV best estimate score of 63, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 236, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 6).

Western Horned Grebe (*Podiceps auritus*) breeds in central and southern Alaska down through central Canada. The species winters mostly in coastal estuaries and bays from southern Alaska to Baja California and the Gulf of California, Mexico (Stedman 2000). Horned Grebes are opportunistic feeders who feed primarily in the benthos, on fish and crustaceans during the winter (Stedman 2000). The species considered Threatened in Canada (COSEWIC 2004). Western Horned Grebe had a PCV best estimate score of 100, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 400, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 6).

Red-necked Grebe (*Podiceps grisegena*) breeding range is northern Alaska down through central Canada. The species winters along the west coast of North America from southern Alaska to central California. It is generally agreed upon as being the most bad-ass of the grebes. Largest abundances are found around Vancouver Island, Strait of Georgia, and Puget Sound (Stout and Nuechterlein 1999). They feed on fish, crustaceans and aquatic insects (Stout and Nuechterlein 1999). The species is considered Threatened in Oregon and Near Threatened in Canada due to significant declines in local population sizes (COSEWIC 2004, Oregon Department of Fish and Wildlife 2014). Red-necked Grebe had a PCV best estimate score of 96, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 360, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 6).

### Albatrosses (*Phoebastria spp*.)

The Black-footed Albatross (*Phoebastria nigripes*), Laysan Albatross (*Phoebastria immutabilis*) and Short-tailed Albatross (*Phoebastria albatrus*) are the three northern-hemisphere-breeding albatross species. Greater than 95% (*ca.* 55,000 breeding pairs in 2005) of the total world population of Black footed Albatross nests in the northwestern Hawaiian Islands, with a smaller sub-population nesting in the Bonin and Izu island groups off Japan (Awkerman et al. 2008). They are extremely far-ranging and can occur within the CCS year-round, but greatest abundances occur from summer to early fall during their non-breeding dispersal period. Black-footed Albatrosses are avid scavengers and aggregations within the CCS have been associated with fishing vessels (Briggs et al. 1992). The species is listed as Near Threatened by the IUCN and Threatened in Mexico and Canada due to fisheries bycatch and breeding habitat loss (Awkerman et al. 2008, COSEWIC 2013). Black-footed Albatrosses had a PCV best estimate score of 105, ranking it at ‘medium’ risk of collision and a PDV best estimate score of 225, ranking it at ‘medium’ risk of displacement to OWEI (Table 7, Figure 7).

Movements of Laysan Albatross within the CCS are largely unknown. However the majority of the population that breeds on Guadalupe Island, Mexico forages in the offshore waters of the CCS during the breeding season (B. Henry *personal communication*). They are seen off the west coast of North America March through May and in small numbers until they disperse more toward the north/central Pacific for the duration of the nonbreeding season (McDermond and Morgan 1993). The presence of Laysan Albatross in the near offshore waters of the CCS is thought to increase as the population nesting on Guadalupe Island increases (B. Henry *personal communication*). Their diet consists of squid, flying fish eggs, crustaceans, and other fish (Awkeman et al. 2009). Laysan Albatross is considered Near Threatened by the IUCN, a species of Least Concern in the United States, and the small population that nests in Mexico is listed at Threatened due to on-going pressures from long-line fisheries (Flores 2010, IUCN 2014, USFWS 2014). Laysan Albatross had a PCV best estimate score of 64, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 138, ranking it at ‘medium risk of displacement to OWEI (Table 7, Figure 7).

Historically, Short-tailed Albatross had at least nine breeding colonies in the East China Sea and south of Japan (Piatt et al. 2006). Currently there are two extant colonies: Torishima Island of Japan and Minami-kojima in the Senkaku Islands of Taiwan (Birdlife 2014). Little is known about the dispersal patterns of Short-tailed Albatross; an estimated 12% of the population occurs annually within the CCS, the majority of which are males and juveniles (Suryan et al. 2007). The species is listed as Threatened by the IUCN, Endangered by USFWS, Oregon State Fish and Wildlife, Japan and Canada due to their small population size and limited breeding range (USFWS 2014, IUCN 2014, Ministry of Enviro Japan 1991, Shuford and Gardali 2008). Short-tailed Albatross had a PCV best estimate score of 119, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 255, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 7).

### Shearwaters (*Puffinus spp.*)

The Sooty Shearwater (*Puffinus griseus*) is one of the world’s most abundant seabirds (>20 million birds; Heather and Robertson 1997, Newman et al. 2009). In the Pacific, it nests in the southern hemisphere on islands off Chile and New Zealand. After chick-rearing, adults perform a trans-equatorial migration and a proportion (estimated to be one-third) of the adult breeding population from New Zealand arrives to reside within the CCS during April through October (Shaffer et al. 2009, Adams et al. 2012). Off California, Sooty Shearwaters dominate the marine avian biomass in summer (Briggs and Chu 1986). Briggs et al. (1987) reported a latitudinal trend in the timing of maximum densities, with greatest densities off northern California during July through September, and slightly earlier south of Cape Mendocino, CA. The species can achieve impressive densities at sea, and single foraging flocks can extend for several kilometers and number in the hundreds of thousands of individuals (Briggs et al. 1987). Individuals tend to aggregate in the lee of coastal promontories, downstream from active upwelling cells (Briggs and Chu 1986). Recent satellite tracking studies reveal inter-annual variability in offshore extent of habitat use and important aggregation areas associated with the Columbia River Plume and the Cape Blanco to Heceta Bank region of the shelf off Oregon, within Monterey Bay, and throughout the Santa Barbara Channel off southern California (Adams et al. 2012). Sooty Shearwater is considered Near Threatened due to rapid decline in population size thought to be due to fisheries impacts and chick harvest on breeding colonies (IUCN 2014). The species had a PCV best estimate score of 40, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 165, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 8).

The Buller’s Shearwater (*Puffinus bulleri*) is a transequatorial migrant that breeds in the southwestern Pacific Ocean, primarily on two of the Poor Knights Islands (Aorangi and Tawhiti Rahi) off northern New Zealand. The global population (*ca*. 2.5 million, but probably less; BirdLife International 2013) is highly vulnerable to the introduction of mammalian predators because of its restricted breeding range (BirdLife International 2013). In their non-breeding season, Buller’s Shearwaters migrate to the north Pacific from Japan and then to North America and are present off California, Oregon, and Washington during the boreal summer and early fall. Peak numbers are typically found in July and November off Washington and Oregon (Briggs et al. 1992) and in August and September off northern California (Briggs et al. 1987). The species is considered Vulnerable due to its restricted breeding range and vulnerability to invasive species at breeding grounds (IUCN 2014). Buller’s Shearwater had a PCV best estimate score of 32, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 135, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 8).

The Pink-footed Shearwater (*Puffinus creatopus*) is a Chilean endemic breeder of which a portion of the adult breeding population (*ca*. 28,000 breeding pairs, Muñoz and Hodum, *unpubl. data*) undergoes a seasonal, trans-equatorial migration to occupy shelf and slope waters of the CCS from March through October, with maximal abundance during July through September (Briggs et al. 1987). Pink-footed Shearwaters are similarly-sized compared to the much more abundant Sooty Shearwater, and during summer months the two species often co-occur off California, Oregon, and Washington (Briggs et al. 1987, 1992). Interannual abundance off Oregon and Washington can be highly variable, presumably associated with inter-annual oceanographic conditions and forage fish abundances (Phillips et al. 2010). Owing to habitat loss and predation by introduced mammals, combined with a limited number of colonies off Chile, the species is recognized as Vulnerable by IUCN, Threatened by Canada, and Endangered by Chile (Ministerio del Medio Ambiente 2012, IUCN 2014). Pink-footed Shearwaters had a PCV best estimate score of 58, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 240, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 8).

Manx Shearwater (*Puffinus puffinus*) is native to the Atlantic Ocean. They are found infrequently in the Pacific, and it is thought that they have traveled there accidentally (Lee and Hanley 1996). They eat primarily small schooling fish, as well as cephalopods, small crustaceans, and offal (Lee and Hanley 1996). The species is considered of Least Concern (IUCN 2014). Manx Shearwater had a PCV best estimate score of 37, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 154, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 8).

Flesh-footed Shearwaters (*Puffinus carneipes*) breed in the southwest Pacific and travel north to the West Pacific, Africa and the Northern Indian Ocean during the nonbreeding season. A small percentage of the population is found in the CCS during this time (Birdlife International 2014). The species thought to be most active, flying and feeding, during the day (del Hoyo 1992). The species is considered Threatened in New Zealand due to threats at breeding grounds (Robertson et al. 2013). Flesh-footed Shearwater had a PCV best estimate score of 50, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 180, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 8).

The number of Short-tailed Shearwaters (*Puffinus tenuirostris*) found in the CCS is unclear due to the fact that they appear indistinguishable from Sooty Shearwaters during aerial surveys and therefore they cannot be counted individually. However, it is estimated that a very small percentage of the shearwaters seen in the CCS each year are Short-tailed (Briggs et al. 1987, Briggs et al. 1992). The species is considered of Least Concern (IUCN 2014). Short-tailed Shearwater had a PCV best estimate score of 22, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 93, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 8).

The Black-vented Shearwater (*Puffinus opisthomelas*) breeds in Mexico and travels north along the coast during the nonbreeding season (Birdlife International 2014); numbers off central-southern California increase in association with anomalous warm ocean conditions in the CCS. Black-vented Shearwater populations declined significantly due to breeding habitat loss and the introduction of nonnative predators to breeding grounds. These threats have decreased significantly; however, the species is still considered Near Threatened by the IUCN and Endangered in Mexico (Flores 2010, IUCN 2014). Black-vented Shearwater had a PCV best estimate score of 54, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 450, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 8).

### Pacific Northern Fulmar (*Fulmarus glacialis rogersii*)

Pacific Northern Fulmars are abundant throughout the boreal and sub-arctic north Pacific and are especially widespread during winter. Approximately 99% of the northeastern Pacific Ocean and Bering Sea breeding population (ca. 2 million individuals) nests at four colonies: Semidi Islands (Gulf of Alaska), Chagulak Island (Aleutians), Pribalof Islands (Bering Sea), and St. Matthew/ Hall Islands (Bering Sea; Mallory et al. 2012). Birds from the Semidi Islands population migrate seasonally to overwinter in the CCS (Mallory et al. 2012). First arrivals off central California occur in late September, with a peak in abundance during November (Briggs et al. 1987); breeders first arrive at northern boreal/arctic colonies in late April to May. The species exhibits dramatic plumage polymorphism ranging from solid dark grey to all white. At sea, Northern Fulmars are known to be aggressive scavengers and their distribution at local scales can be influenced by certain fishing activities, especially offal discharge from industrial trawling operations (Mallory et al. 2012). In post-construction analysis at Belgian Bligh Bank wind farm in the North Sea, fulmars were found to be negatively associated with OWEI, showing strong avoidance behavior (Vanermen et al. 2014). The species is considered of Least Concern (IUCN 2014). Pacific Northern Fulmar had a PCV best estimate score of 33, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 139, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 9).

### Gadfly Petrels (*Pterodroma spp*.)

Three species of gadfly petrel are found in the CCS: Hawaiian Petrel (*Pterodroma sandwichensis*), Cooks Petrel (*Pterodroma cookii*) and Mottled Petrel (*Pterodroma inexpectata*). All are found far offshore and none are seen in great abundance. Hawaiian Petrels breed in the main Hawaiian Islands (MHI) and are very rarely sited off the coast of California and Oregon (Briggs et al. 1987, Simons and Hodges 1998). Hawaiian and Galapagos Petrels (*P. phaeopygia*) are extremely hard to differentiate by sight alone at sea (Pyle et al. 2011). However, the long-distance ranging patterns of Hawaiian Petrel breeding throughout the MHI are influenced by winds associated with the summertime North pacific high pressure system (Adams and Flora 2010); the size and eastward extent of this feature may influence the likelihood that Hawaiian Petrels occur within the outer CCS during summer and fall months (J. Adams *unpublished data*). The species is considered Endangered due to nest habitat reduction and predation threats (USFWS 2014). Hawaiian Petrel had a PCV best estimate score of 38, ranking it at ‘low’ risk of collision and a PDV best estimate score of 380, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 10).

There are two distinct populations of Cooks Petrel, one of which breeds on Little Barrier Island, NZ. This population consists of 286,000 breeding pairs and is thought to migrate into the eastern Pacific Ocean and the CCS during the non-breeding season (Birdlife International 2014, Rayner et al. 2011). The species is considered Threatened by the USFWS Endangered Species Act due to historical population declines, the population is now increasing due to increased protection at breeding habitat (USFWS 2014). Cooks Petrel had a PCV best estimate score of 74, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 206, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 10).

The Mottled Petrel is also an endemic breeder to New Zealand (Birdlife International 2014). Over 100,000 birds are seen in the Gulf of Alaska during the summer, and it is thought that some of these birds migrate through the CCS as they travel to their their nonbreeding waters (Bartle et al. 1991, Briggs et al. 1987). The species is considered Near Threatened due to small overall population size and nonnative predators at breeding grounds (IUCN 2014). Mottled Petrel had a PCV score of 22, ranking it at ‘low’ risk of collision, and a PDV score of 69, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 10).

### Storm-Petrels (*Hydrobates spp./Oceanites spp*.)

Nearly all (98%) of Ashy Storm-Petrels (*Hydrobates homochroa*) breed in California (Carter et al. 2008). Little is known about their diet (G. McChesney *unpublished data*). Individuals off California generally occupy waters of the continental slope > 800 m depth (Adams and Takekawa 2008). The species is considered Endangered by the IUCN, USFWS Endangered Species Act, and the Mexican Especies en Riesgo due to rapid population declines resulting from multiple threats (Flores 2010, IUCN 2014, USFWS 2014). Ashy Storm-petrels had a PCV best estimate score of 69, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 990, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 11). The high displacement vulnerability was due to high Population Vulnerability and high macro-avoidance rate (Table 6).

Black Storm-Petrels (*Hydrobates melania*) breed on islands off Southern California, Baja California, and the Gulf of California. Thousands move north after the breeding season and are found off the coast of California (Ainley 2008). The species is considered Endangered by the USFWS Pacific Seabird Conservation Status due to significant population declines seen in CCS colonies (USFWS 2014). Black Storm-petrel had a PCV best estimate score of 75, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 268, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 11).

Fork-tailed Storm-Petrel (*Hydrobates furcata*) is one of the most abundant breeding seabird species throughout the Gulf of Alaska and Aleutian Islands (*ca*. 5 – 10 million individuals; Boersma and Silva 2001). Scattered, smaller Fork-tailed Storm-Petrel colonies (100s to 2000 individuals) exist on isolated offshore islets in Washington, Oregon, and northern California. Generally they are thought to range 75 to 150 km from colonies during the breeding season and are associated with the waters of the continental slope (Boersma and Silva 2001). Dispersal during winter is widespread within the north Pacific above 40° N. This small, pelagic denizen of the north Pacific is generally thought to occupy waters father offshore from the shelf-slope during winter, but stormy weather can result in near-shore occurrences (Boersma and Silva 2001). Briggs et al. (1992) noted that Fork-tailed Storm-Petrels were among several species with strong negative correlations with Sooty Shearwaters off Oregon and Washington. In the Gulf of Alaska, the individuals are attracted to fishing vessels, modifying local-scale abundance and aggregation (Gould et al. 1982). Fork-tailed Storm-Petrel is considered Vulnerable by the California Species of Special Concern due to increases in nest habitat destruction (McChesney and Carter 2008). The species had a PCV best estimate score of 58, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 191, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 11).

The Leach’s Storm-Petrel (*Hydrobates leucorhoa*) is an abundant pelagic seabird and recognized as the most widespread procellariiform breeding in the northern hemisphere. There are *ca.* 36,000 breeders of the “light-rumped” subspecies (*H. l. leucorhoa*) on isolated islets off northern Washington (Speich and Wahl 1989) and an estimated 482,000 breeders off Oregon (37% of the total Oregon breeding seabird population), making it the second-most abundant locally breeding seabird species after Common Murres (Naughton et al. 2007). During the summer breeding season, breeding Leach’s Storm-Petrels are thought to forage within 200 km of their colonies, but can range farther (Huntington et al. 1996). Winter dispersal is thought to be primarily to the central and eastern tropical Pacific, but birds are seen year-round within the CCS (Briggs et al. 1987, 1992). Three distinct “dark-rumped” subspecies of Leach’s Storm-Petrels breed off southern California and Mexico (Huntington et al. 1996). *H. l. chapmani* nests off central Baja California and Mexico (and perhaps the California Channel Islands; J. Adams *pers. com.*). Two subspecies of Leach’s Storm-Petrel (*H. l. socorroensis* and *H. l. cheimomnestes*) are threatened with extinction; however, these subspecies are not thought to occur in the central-northern CCS (Huntington et al. 1996, Spear and Ainley 2007), therefore we did not consider the conservation status of these subspecies when estimating the CCS population threat status value for the Leach’s Storm-Petrel (Flores 2010, USFWS 2005, USFWS 2014, IUCN 2014, Shuford and Gardali 2008). The species had a PCV best estimate score of 76, ranking it at ‘medium’ risk of collision and a PDV best estimate score of 270, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 11).

Three species of Wilson’s Storm-Petrel (*Oceanites oceanicus spp.*) breed in the southern hemisphere on subantarctic islands and the Antarctic mainland- where breeding populations number in the millions. Some individuals perform transequitoral migrations during the non-breeding season. The majority of the breeding population is found in the Atlantic and Indian Oceans during the summer but it is thought that small proportions of the two populations are found in the Eastern Pacific (Birdlife International, Spear and Ainley 2007). Individuals are recorded off western North America during late summer and fall (Spear and Ainley 2007). These birds often fly low over the water, especially in strong head-winds, enabling them to employ the unique sea-anchor flying behavior that sets them apart from most other types of storm-petrels (Ainley et al. 2015). Wilson’s Storm-petrel is considered a species of Least Concern (IUCN 2014). The species had a PCV best estimate score of 13, ranking it at ‘low’ risk of collision and a PDV best estimate score of 45, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 11).

### Pelicans (*Pelecanus occidentalis and P. erythrorhynchos*)

In the Pacific off North America, the Brown Pelican (*Pelecanus occidentalis*) nests from southern California through Mexico and throughout the Gulf of California, Mexico. Wintertime non-breeding range among California and Mexican populations appears to fluctuate with latitude according to an inter-annual and inter-decadal periodicity associated with changes in forage fish distribution and abundance and regional sea-surface temperature. During cold-water periods, most non-breeding Brown Pelicans tend to remain south of Oregon, but during warm-water conditions and since 1985, thousands have dispersed annually to reach waters off the coasts of Oregon and Washington (Jaques 1994, Sheilds 2002). Numbers in the central and northern CCS tend to peak during September and October, and then decrease as adults return to breeding colonies by December. Offshore extent during migration is within 10 km of the coast (Briggs et al. 1983). The species is considered Endangered in California, Oregon, and Washington due to population declines, most likely due to decreases in prey availability (Washington State Department of Fish and Game 2003, Shuford and Gardali 2008, Oregon Department of Fish and Wildlife 2014). Brown Pelicans had a PCV best estimate score of 1530, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 306, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 12). The high PCV score was due to their year-round presence in the CCS, high percent time flying in the RSZ, low macro-avoidance rate, and high Population Vulnerability (Tables 4 & 5).

The American White Pelican (*Pelecanus erythrorhynchos*) is split into two migrating groups, those that migrate down the continental divide and those that migrate down the west coast of North America (Knopf and Evans 2004). They are opportunistic, cooperative foragers, with the majority of their diet consisting of freshwater prey (Knopf and Evans 2004). American White Pelicans are rarely observed offshore in marine environments. The species is considered Endangered (State Sensitive Species) in Washington due to loss of inland nesting and foraging habitat (Washington State Department of Fish and Game 2003). American White Pelican had a PCV best estimate score of 900, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 180, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 12). The high PCV score was due to their year-round presence in the CCS, high percent time flying in the RSZ, low macro-avoidance rate, and high Population Vulnerability (Tables 4 & 5).

### Cormorants (*Phalacrocorax penicillatus, P. auritus, and P. pelagicus*)

There are three cormorant species that breed in the CCS. They generally occupy similar habitats at sea, mostly over the inner-shelf and usually within 25 km of land (Briggs et al. 1987). Cormorant distribution at sea (in all seasons) generally follows the distribution of colonies along the coast, many of which are used during the non-breeding season as roosting sites (Briggs et al. 1992). In Washington during the late 1980s, breeding Pelagic Cormorants (*P. pelagicus*) outnumbered breeding Double-crested Cormorants (*P. auritus*) and Brandt’s Cormorants (*P. penicillatus*) combined (4866, 3296, and 554 individuals, respectively; Speich and Wahl 1989). Throughout coastal Washington, the number of Double-crested Cormorant breeding pairs has declined by 50% from 1564 (during 1987-92) to 788 in 2009 (Adkins et al. 2014). Oregon supports an order of magnitude more breeders than Washington of each species with Double-crested Cormorants in greater abundance than Brandt’s Cormorants and Pelagic Cormorants (30,400, 21,200, and 10,100 individuals, respectively; Speich and Whal 1989). Double-crested Cormorants have more than doubled in number along the coast of Oregon recently from an estimated 6303 breeding pairs in 1987-92 to 14,730 breeding pairs in 2009, with population change mostly driven by annual increases at the largest colony at East Sand Island in the Columbia River Estuary (Anderson et al. 2004, Adkins et al. 2014). Off northern California in 1989, there were an estimated 15,500 breeding Brandt’s Cormorants, 3252 Double-crested Cormorants, and 8400 Pelagic Cormorants (Carter et al. 1992). The USFWS has issued a depredation permit to cull individual Brandt’s, Double-crested, and Pelagic Cormorants under the Migratory Bird Treaty Act to reduce cormorant predation of juvenile salmonids in the Columbia River Estuary starting in the summer of 2015 (USFWS 2015).

Brandt’s Cormorant is considered Vulnerable by the USFWS Pacific Seabird Conservation Plan and is a Candidate Species for the Washington Species of Concern (Washington State Department of Fish and Game 2003, USFWS 2005). The species had a PCV best estimate score of 336, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 504, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 13). Brandt’s Cormorant high collision vulnerability is due to year-round presence in the CCS, relatively high percent of time spent in the RSZ, and high percent of time spent flying when commuting to roosting and nesting grounds (Table 5). The high displacement vulnerability is due to year-round presence in the CCS and high levels of macro-avoidance (Table 6).

Double-crested Cormorant is a species of Special Concern in Canada (COSEWIC 2004). The species had a PCV best estimate score of 333, ranking it at ‘high’ risk of collision and a PDV best estimate score of 333, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 13). The high collision vulnerability of the Double-crested Cormorant is due to year-round presence in the CCS, relatively high percent of time spent in the RSZ, and the high percent of time they spend flying when commuting to roosting and nesting grounds (Table 5).

Pelagic Cormorant is considered Threatened by the USFWS Pacific Seabird Conservation Plan (USFWS 2005). The species had a PCV best estimate score of 312, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 468, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 13). Pelagic Cormorant high collision vulnerability is due to year-round presence in the CCS, relatively high percent of time spent in the RSZ, and the high percent of time spent flying when commuting to roosting and nesting grounds (Table 5). The high displacement vulnerability is due to year-round presence in the CCS and moderate levels of macro-avoidance (Table 6).

Previous vulnerability reports also predicted cormorants to be at risk of collision and displacement by OWEI. Garthe and Hüppop (2004) found that Great Cormorant (*Phalacrocorax carbo*) was the fourth most sensitive species (after loon, scoter, and tern species) to OWEI in their vulnerability index for marine birds of the German North Sea. Willmott et al. (2013) estimated that on the Atlantic Outer Continental Shelf of North America, cormorants have high collision and displacement vulnerability. Post-construction reports of cormorant behavior at offshore wind farms support these calculations (Rothery et al. 2009, Krijgsveld et al. 2011). At two large wind turbines off the northeast coast of England, the number of cormorants found in the area significantly decreased after the windmill construction, possibly because the turbines were deterring them from foraging in the area (Rothery et al. 2009). In contrast, at Egmond aan Zee wind farm in the North Sea, Krijgsveld et al. (2011) found that cormorants did not show any avoidance behavior and showed some indication of being attracted to OWEI as a place to roost. Cormorants are known to be attracted to offshore oil rigs as a roosting location and it is thought that the same behavior would be displayed at OWEI (Hamer et al. 2014). Cormorants are obligated to roost daily because they lack waterproof feathers. Peterson et al. (2006) also found that cormorants did not show avoidance behavior around Nysted and Horns Rev wind farms in the Dutch North Sea, putting them at increased risk of collision. Further increasing their collision risk; cormorants, which have very low aspect ratios, increase flapping with increase wind speed and are most likely to fly into headwinds (Spear and Ainley 2007, Ainley et al. 2015).

### Red and Red-necked Phalarope (*Phalaropus fulicarius and P. lobatus*)

These two marine “shorebird” members of the Scolopacid family nest in the arctic and winter throughout the Peru and Humboldt Currents off South America (Rubega et al. 2000, Tracy et al. 2002). Red Phalarope is considered the most marine of the three phalarope species (including Wilson’s Phalarope, *Phalaropus tricolor*, not considered herein). Using boat surveys off California, Briggs et al. (1987) noted that Red Phalaropes occurred >50 km offshore; whereas Red-necked Phalaropes occurred consistently closer to shore, but the two species often co-occurred at sea. Red Phalarope numbers peaked approximately one month later than Red-necked Phalaropes during spring and fall migrations off California (Briggs et al. 1987). Peak fall densities off northern California, Oregon, and Washington were observed between July and October, and peaks in spring migration were much less protracted and occurred during April and May (Briggs et al. 1987, 1992). Red Phalarope is considered a species of Least Concern (IUCN 2014). The species had a PCV best estimate score of 89, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 149, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 14). Red-necked Phalarope is considered a species of Least Concern (IUCN 2014). The species had a PCV best estimate score of 65, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 131, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 14).

In contrast to our results, Willmott et al. (2013) found that on the Atlantic Outer Continental Shelf of North America phalaropes (along with gulls, cormorants and jaegers) have the greatest collision vulnerability. The variation in our predictions likely is due to population sizes and frequency of occurrence.

### Gulls

The Black-legged Kittiwake (*Rissa tridactyla*) is a small, abundant, well-studied (breeding season) pelagic gull that, in the Pacific, nests throughout the Gulf of Alaska and Aleutian Archipelago; they also breed in the Bering and Chukchi Seas (Hatch et al. 2009). Black-legged Kittiwakes move into the northern CCS during November to January with greatest numbers off California in January to March; they depart by May to return to northern colonies (Briggs et al. 1987). Black-legged Kittiwake distribution during the winter off California, Oregon, and Washington shows no clear pattern or trends associated either with distance to shore or other environmental factors such as sea surface temperature and upwelling (Briggs et al. 1987, 1992, Ainley and Hyrenbach 2010). The species is considered of Least Concern (IUCN 2014). Black-legged Kittiwakes had a PCV best estimate score of 99, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 99, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 15).

Bonaparte’s Gull (*Chroicocephalus philadephia*) breeds along the west coast of Canada and Alaska and migrates through the CCS during the nonbreeding season (Briggs et al. 1992, Burger and Gochfeld 2002). A large percentage of the population over winters in Southern California; much smaller numbers are found in Northern California, Oregon, and Washington (Briggs et al. 1983, Briggs et al. 1987, Briggs et al. 1992). Bonaparte’s Gull is considered a species of Least Concern (IUCN 2014). The species had a PCV best estimate score of 368, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 221, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 15). The high collision vulnerability is due to year-round presence in the CCS and high percent of time flying in the RSZ (Table 5).

The Sabine’s Gull (*Xema sabini*) is a small, conspicuous, Holarctic nesting gull of pelagic nature that favors southern-hemisphere coastal upwelling ecosystems during its annual non-breeding season. Unknown proportions of individuals over-winter in the Humboldt Current (off Peru) and Benguela Currents (off South Africa). Fall migration abundances off the western U.S. tend to be more protracted with individuals being less-concentrated at sea (Briggs et al. 1987, Day et al. 2001), and seasonal timing likely reflects inter-annual variability in departure related to breeding success (Davis et al. 2012). Off California, spring migration numbers increase from late-April to reach a peak during mid-May (estimated at 50,000 individuals; Briggs et al. 1987); the spring migration peak occurs slightly later off Oregon and Washington (Briggs et al. 1987, 1992). In the fall, numbers off Washington and Oregon peak during August – September and slightly later (September – October) off California (Briggs et al. 1987, 1992). Limited observations of birds flying during migration revealed low-elevation of flight over the sea-surface (5 – 15 m; Day et al. 2001). Sabine’s Gull is considered a species of Least Concern (IUCN 2014). The species had a PCV best estimate score of 162, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 97, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 15). The high collision vulnerability is due to high percent of time flying in the RSZ (Table 5).

The California Gull (*Larus californicus*) is a medium-sized gull that historically nested in the semi-arid interior of northwestern North America, with the largest breeding colonies (>20,000 individuals) in California, Idaho, and Utah (Winkler 1996). However, recent establishment of breeding colonies in San Francisco Bay, CA, and, to a lesser extent, the Columbia River Estuary, have expanded the summertime range of this species to the Pacific coast (Ackerman et al. 2006). California Gulls undergo a seasonal migration between interior breeding grounds and the Pacific coast where they range from southern British Columbia, Canada, to central Mexico. Breeders from the Canadian prairies are thought to follow the Columbia River basin (Winkler 1996) and reach peak abundance in coastal waters off Oregon and Washington in September and again in March (Briggs et al. 1992). Arrival of post-breeding adults at the coasts off Oregon and Washington begins in July (Briggs et al. 1992), but non-breeders and juvenile birds may reside in coastal waters year round (Winkler 1996). Local abundances at sea, often in large flocks from fall to spring, can be greatly influenced by associations with fishing vessels (Wahl and Heinemann 1979). Coastal distributions also likely are associated with proximity to municipal landfill sites (Winkler 1996). The California Gull is considered Near Threatened by the USFWS Pacific Seabird Conservation Status due to significant disturbances to breeding colonies (USFWS 2014). The species had a PCV best estimate score of 495, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 149, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 15). The high collision vulnerability score was due to year-round presence in the CCS and high percent time flying in the RSZ (Table 5).

The medium-sized Heermann’s Gull (*Larus heermanni*) is unique among the suite of gulls that inhabit the northern CCS. It is the only all-dark gull present off North America. There are an estimated 300,000 breeders of which approximately 90% of the global population nest on Isla Raza, in the Gulf of California, Mexico (Islam 2002). It also is unique because it is the only North American gull to migrate northward along the Pacific Coast during fall and winter, reaching, in low numbers, as far as southern British Columbia, Canada (Islam 2002). Most breeding adults depart for southern colonies by mid-March; abundance peaks off northern California in late June and off Oregon in late July (Briggs et al. 1987, 1992). Heermann’s Gulls have a mixed diet during the non-breeding period and individuals often are seen intermingling with shorebirds in pursuit of decapod crustaceans in surf-washed, sandy-beach habitats along the exposed outer coast (Islam 2002). Individuals often associate also with feeding Brown Pelicans and occasionally southern sea otters (*Enhydra lutris*; J. Adams pers. obs.). Heermann’s Gull is considered Vulnerable by the USFWS Pacific Seabird Conservation Status due to its limited breeding habitat (USFWS 2014). The species had a PCV best estimate score of 360, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 108, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 15). The high collision vulnerability score was due to their year-round presence in the CCS and high percent time flying in the RSZ (Table 5).

Based on Christmas bird counts, it is estimated that 50,000 Mew Gulls (*Larus brachyrhynchus*) winter along the west coast of the United States (William and Bevier 2002). The wintering population in southern California is about 1500 (Briggs et al. 1987). Mew Gull is of Least Concern (IUCN 2014). The species had a PCV best estimate score of 94, ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 28, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 15).

Ring-billed Gulls (*Larus delawarensis*) winter along the west coast of North America, along the Great Lakes, and along the south-eastern coast of the US, the Caribbean, and southeast Mexico (Pollet et al. 2012). At least 10,000 of these gulls winter along the southern California coast (Briggs et al. 1987). The Ring-billed Gull is of Least Concern (IUCN 2014). The species had a PCV best estimate score of 446, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 111, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 15). The high collision vulnerability score was due to year-round presence in the CCS and high percent time flying in the RSZ (Table 5).

Herring Gull (*Larus argentatus*) is an abundant, well studied circumboreal/sub-arctic breeder with one recognized subspecies, *L. a. smithsonianus*, that nests on both the east and west coasts of North America (Pierotti and Good 1994). Herring Gulls hybridize with Glaucous-winged Gulls where breeding distributions overlap (Pierotti 1987). Herring Gulls generally arrive in the northern CCS during fall, with peak abundances recorded from December to February (Briggs et al. 1987). The species is of Least Concern (IUCN 2014). Herring Gull had a PCV best estimate score of 181, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 54, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 15). The high collision vulnerability was due to high percent time flying in the RSZ (Table 5).

The Thayer’s Gull (*Larus thayeri*) nests in the central-eastern Canadian Arctic, and following post-breeding dispersal, can be relatively abundant and common over shelf waters off Washington and Oregon, with offshore distribution potentially linked to fishing activities (Morgan et al. 1991, Snell 2002). Because of near complete plumage intergradation, the darkest Thayer’s Gull is virtually inseparable from a Herring Gull (Snell 2002). Details surrounding the migration of this species are lacking compared with those of Herring Gulls. The species is of Least Concern (IUCN 2014). Thayer’s Gull had a PCV best estimate score of 253, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 76, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 15). The high collision vulnerability was due to a high percent time flying in the RSZ (Table 5).

The large-bodied Glaucous-winged Gull (*Larus glaucescens*) nests from Oregon through the Gulf of Alaska and around the perimeter of the North Pacific to Japan. This species can be difficult to identify at sea because it hybridizes with Western Gulls in northern Oregon and Washington, and with Herring Gulls and Glaucous Gulls in Alaska. Glaucous-winged Gulls nest throughout coastal Washington with an estimated 36,923 breeding birds (107 colonies) statewide during the late 1980s (Speich and Wahl 1989). Fewer gulls nest within Oregon, but hybridization with Western Gulls in this region prevented accurate numerical species-specific estimation; the combined estimate for the two species (and hybrids) within Oregon was 32,300 breeding birds (Naughton et al. 2007). Post-breeding dispersal both to the north and south takes place from late August through October and birds generally leave southern wintering areas in May (Hayward and Verbeek 2008). Glaucous-winged Gulls are considered among the most widely distributed gulls throughout the north Pacific and can be seen from shore to 100s of kilometers offshore (Briggs et al. 1992). Briggs et al. (1992) found this species widely distributed off northern Washington, but much less frequently encountered south of the Columbia River. This species maintains an opportunistic diet and flocks often associate with fishing vessels and offal at sea. The species is of Least Concern (IUCN 2014). Glaucous-winged gulls had a PCV best estimate score of 250, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 125 ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 15). The high collision vulnerability score was due to year-round presence in the CCS and high percent time flying in the RSZ (Table 5).

The Western Gull (*Larus occidentalis*) is among the least abundant North American gull species with a global population estimated at about 40,000 breeding pairs (Pierotti et al. 1995). In the northern CCS region of Oregon and Washington, Western Gulls readily hybridize with Glaucous-winged Gulls, and the two species, together with the hybrids are treated as one in breeding population estimates within Washington (36,923 breeding individuals; Speich and Wahl 1989) and Oregon (32,300 breeding individuals; Naughton et al. 2007). Post-breeding dispersal is regional in this species, with some birds moving north and some south during fall and winter (Pierotti et al. 1995). Breeding birds generally occupy similar areas during winter as during the breeding season, but can be more far-ranging during the non-breeding season (Pierotti et al. 1995). Most breeding pairs begin to occupy nesting territories by March (Penniman et al. 1990). At sea off Washington, Western Gulls (together with Glaucous-winged Gulls and hybrids) tend to associate with large multi-species flocks, especially near-shore where these large gulls serve as “catalysts” or initiators of flock-foraging events (Hoffman et al. 1981). Briggs et al. (1992) found that Western Gulls were negatively associated with Sooty Shearwaters within mixed-species flocks. Briggs et al. (1987) found Western Gulls to be most evenly distributed during winter, with relatively greater numbers present within 25 km of shore between Point Arena and the Oregon border. The species is of Least Concern (IUCN 2014). Glaucous-winged Gull had a PCV best estimate score of 221, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 110 ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 15). The high collision vulnerability score was due to year-round presence in the CCS and high percent time flying in the RSZ (Table 5).

Previous vulnerability indices also found gulls to be at high risk of collision. In the Scottish waters of the North Sea, gulls (along with [*Haliaeetus albicilla*], Northern Gannets [*Morus bassanus*], and skuas) were found to be the most vulnerable to collision (Furness and Wade 2012, Furness et al. 2013). Willmott et al. (2013) found that on the Atlantic Outer Continental Shelf of North America, gulls (along with phalaropes, cormorants and jaegers) have the highest collision vulnerability. Post-construction reports from offshore wind energy sites support these predictions of high collision risk in gulls. At Egmond aan Zee wind farm in the North Sea, Krijgsveld et al. (2011) found that gulls did not show any avoidance behavior and showed some indication of being attracted to OWEI as a place to roost. Vanermen et al. (2013) found that Little Gull(*Hydrocoloeus minutus*), Lesser Black-backed Gull (*Larus fuscus*), and Herring gulls to be attracted to OWEI at Thorntonbank and Blighbank wind farms during the first phase of their construction. If this attraction continues as the rest of the wind farms are built, it could pose a significant collision risk for these species (Vanermen et al. 2013). Peterson et al. (2006) found that gulls did not show avoidance behavior at Nysted and Horns Rev wind farms in the Dutch North Sea, thus increasing their potential risk of collision. Thaxter et al. (2015) found that Lesser Black-backed gulls in the Scottish North Sea were commonly found in OWEI areas when foraging for chicks, which coincided with the time of year for heightened offshore wind energy production in the area. Furthermore, the gulls spent more time in offshore wind farm areas foraging to feed their young in years of high productivity (Thaxter et al. 2015), suggesting that collision risk is also dependent on breeding behaviors and inter-annual variations.

### Terns

Caspian Tern (*Hydroprogne caspia*) population of the Pacific coast region of North America has more than doubled (to 12,900 breeding pairs) during the period from 1981 – 2000 (Suryan et al. 2004). Coincident with this rapid population growth has been a significant shift in the distribution of breeding birds with 69% of breeders in 2000 (*vs*. 7% in the late 1970s) concentrated in Oregon, mostly within the Columbia River Estuary, where the species has capitalized on artificial nesting islands generated by river dredge spoils (Suryan et al. 2004). Breeders, together with young, depart colonies in the Pacific Northwest during late summer through early fall. Pacific coast breeders generally winter along the west coast of Mexico and into Guatemala (Cuthbert et al. 1999). The species is considered Vulnerable by the USFWS Pacific Seabird Conservation Status due to their high risk of habitat loss and degredation (USFWS 2005). Caspian Tern had a PCV best estimate score of 585, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 878, ranking it at ‘high’ risk of displacement to OWEI (Table 7, Figure 16). The high collision vulnerability score was due to year-round presence in the CCS and high percent time flying in the RSZ (Table 5). The high displacement vulnerability was due to year-round presence in the CCS and high macro-avoidance rate (Table 6).

Due to their similar morphology, habitats, and migration patterns Arctic (*Sterna paradisaea*) and Common Terns (*S. hirundo*) are often grouped together during survey counts. Gould et al. (1982) recorded 150,000 - 218,000 Arctic and Common Terns in the Gulf of Alaska during peak periods after the breeding season; 95% of these are estimated to be Artic Terns. The majority of these birds are thought to then migrate down the coast for the winter, where 200,000 have been recorded off of central California and 50,000 off of southern California (Briggs et al. 1987). Arctic Terns have been recorded taking long flights at high altitudes during the night when the winds are favorable (Hatch 2002). They are opportunistic foragers that will adapt their diet based on tidal changes, diurnal cycles, and other variations (Hatch 2002). Arctic Tern is considered a Near Threatened species by the USFWS Seabird Conservation Status due to their small breeding population (USFWS 2005). Arctic Tern had a PCV best estimate score of 123 ranking it at ‘medium’ risk of collision, and a PDV best estimate score of 263, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 16).

The majority of the Common Terns that appear in the CCS are thought to breed in Canada (Shuford and Gardali 2008). Common Terns are thought to migrate during the night, at high altitudes (Nisbet 2002). They are opportunistic feeders, their diet consists of a wide range of fish and invertebrates based on the tides, diurnal cycles and other factors (Nisbet 2002). The species is considered Near Threatened in Canada (COSEWIC 2004). Common Tern had a PCV best estimate score of 198, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 371, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 16). The high collision vulnerability is due to almost year-round presence in the CCS and the amount of time spent flying in the RSZ (Table 5).

The majority (95%) of Elegant Terns (*Thalasseus elegans*) breed on Isla Raza in the Gulf of California, Mexico, and the remainder breed on coastally in Southern California. Most Elegant Terns travel north up the California coast during the nonbreeding season (Burness et al. 1999). Elegant Terns feed primarily on Northern Anchovy (Burness et al. 1999). The species is considered Endangered by the USFWS Pacific Seabird Conservation Status due to its restricted range, sensitivity to human disturbance, and habitat loss to development (USFWS 2005). Elegant Tern had a PCV score of 336, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 960, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 16). The high collision vulnerability score is due to the percent time spent flying in the RSZ and high Population Vulnerability (Table 5). The high displacement vulnerability is due to the high macro-avoidance rate, low (high value) habitat flexibility, and high Population Vulnerability (Tables 4 & 6).

At least 10,000 pairs of Royal Terns (*Thalasseus maxiums*) breed in the Gulf of California, Mexico, and a few pairs breed along the coast of California. The majority of the population is thought to winter along the coast of central and southern California (Buckley and Buckley 2002). Royal Terns are opportunistic feeders with a variable diet of fish, crustaceans, and shrimp (Buckley and Buckley 2002). The species is considered Near Threatened by the USFWS Pacific Seabird Conservation Status due to its sensitivity to human disturbance (USFWS 2005). Royal Tern had a PCV best estimate score of 396, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 743, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 16). The high collision vulnerability score is due to year-round presence in the CCS and the percent time spent flying in the RSZ (Table 5). The high displacement vulnerability is due to the year-round presence in the CCS and high macro-avoidance rate (Table 6).

At least 8,000 Forster’s Terns (*Sterna forsteri*) breed on the Pacific Coast of North America (Mcnicholl et al. 2001). The California breeding population is estimated at 3,550 individuals (Carter et al. 1992). The species is considered of Least Concern (IUCN 2014). Forester’s Tern had a PCV best estimate score of 506, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 759, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 16). The high collision vulnerability score is due to year-round presence in the CCS and the percent time spent flying in the RSZ (Table 5). The high displacement vulnerability is due to year-round presence in the CCS and high macro-avoidance rate (Table 6).

An estimated 13,000 Least Terns (*Sternula antillarum*) breed on the west coast of the United States and roughly 300 breed in California (ABC, Carter et al. 1992). The species is considered Critically Endangered by the USFWS Endangered Species Act due to habitat loss, pollution, and sensitivity to human disturbance (USFWS 2014). Least Tern had a PCV best estimate score of 384, ranking it at ‘high’ risk of collision and a PDV best estimate score of 960, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 16). The high collision vulnerability score is due to the percent time spent flying in the RSZ and high Population Vulnerability score (Tables 4 & 5). The high displacement vulnerability is due to high macro-avoidance rate and high Population Vulnerability score (Tables 4 & 6).

One colony of 20 - 40 breeding pairs of Gull-billed Terns (*Sterna nilotica*) in San Diego, California, makes up the entire population in the CCS (Molina et al. 2014). Gull-billed Tern is an opportunistic feeder that consumes both terrestrial and marine prey (Parnell et al. 2014). The species is considered of Least Concern (IUCN 2014). Gull-billed Tern had a PCV best estimate score of 154, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 154, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 16). The high collision vulnerability score is due to the percent time spent flying in the RSZ (Table 5).

There are roughly 2100 Black Skimmers (*Rynchops niger*) that breed along the coast of southern California (Molina 2008). The species is considered Endangered by the USFWS Seabird Conservation Status due to human disturbance and habitat loss to development (USFWS 2005). Black Skimmers had a PCV best estimate score of 378, ranking it at high risk of collision and a PDV best estimate score of 1260, ranking it at high risk of displacement by OWEI (Table 7, Figure 16). The high collision vulnerability score is due to year-round presence in the CCS, the percent time spent flying in the RSZ, and high Population Vulnerability (Tables 4 & 5). The high displacement vulnerability is due to year-round presence in the CCS, high macro-avoidance rate, high (low value) habitat flexibility, and high Population Vulnerability (Tables 4 & 6).

Similar to our results, previous reports found terns to be highly vulnerable to OWEI. Garthe and Hüppop (2004) found that Sandwich Tern (*Thalasseus sandvicensis*) was the fourth most sensitive species (behind loon and scoter species) to OWEI in their index of the German North Sea. Willmott et al. (2013) listed four tern species to be among those with the greatest displacement vulnerability on the Atlantic Outer Continental Shelf of North America. Post-construction reports confirm these vulnerabilities. Peterson et al. (2006) found that terns do not show avoidance behavior in wind farm areas, thus increasing their collision risk. Similarly, Vanermen et al. (2013) found that Sandwich Tern and Common Tern were attracted to OWEI at Thorntonbank wind farm during the first phase of construction. Collision risk will be significant if this attraction behavior continues through the construction of the second part of the wind farm (Vanermen et al. 2013).

### Jaegers and Skua (*Stercorarius spp.*)

The Pomarine Jaeger (*Stercorarius pomarinus*) is the largest and most numerous of the three jaegers that frequent the CCS during the spring and fall migration when birds move between arctic breeding sites and subtropical-tropical Pacific wintering areas. Off Washington, this species occurs from mid-July through October with peak abundance off California during late September and October (Briggs et al. 1987, 1992). Sightings are rare the rest of the year, and it is thought that the spring migration of this species occurs further offshore than in the late summer and fall (Briggs et al. 1987). At sea in the CCS, Pomarine Jaegers tend to occur as scattered individuals and in small flocks associated mostly with the continental slope waters where they often co-occur with gulls, and occasionally with fishing vessels (Briggs et al. 1992). During migration, individuals may settle on the water during high winds or achieve heights of 30 - 50 m above sea level but frequently occur >10 m above sea level during mild weather (Wiley and Lee 2000). Pomarine Jaeger is considered of Least Concern (IUCN 2014). The species had a PCV best estimate score of 495, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 50, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 17). The high collision vulnerability is due to year-round presence in the CCS, high percent time flying in the RSZ and low macro-avoidance rate (Table 5).

The smaller two of the three North American jaeger species, Parasitic (*Stercorarius parasiticus*) and Long-tailed Jaegers (*Stercorarius longicaudus*) are particularly hard to distinguish at sea, especially among juveniles and during the non-breeding season when migrants from northern breeding sites occur within the CCS. Although an order of magnitude less common than Pomarine Jaegers (*S. pomarinus*), Briggs et al. (1987, 1992) did record a few Parasitic/Long-tailed jaegers over the continental shelf and slope off California, Oregon, and Washington during the fall. Parasitic Jaegers nest throughout the arctic in North America and along the west coast of Alaska into the Gulf of Alaska; the species winters in the temperate southern Pacific (Wiley and Lee 1999). Parasitic Jaegers reach greatest abundances in the CCS during fall and spring, when they occasionally are observed close to the coastline chasing gulls and terns while engaged in bouts of kleptoparasitism (Briggs et al. 1987, Briggs et al. 1992, Wiley and Lee 1999). The species is considered of Least Concern (IUCN 2014). Parasitic Jaegers had a PCV best estimate score of 365, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 44, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 17). The high collision vulnerability is due to year-round presence in the CCS, high percent time flying in the RSZ and low macro-avoidance rate (Table 5).

Long-tailed Jaegers nest in the Arctic and also winter in the southern temperate Pacific. Their migratory movements generally occur far from shore over and beyond the continental shelf domain southward during July – October and northward during April – June (Wiley and Lee 1998). During migration, this species can fly up to 250 m above sea-level in calm conditions, but flies much nearer the surface during headwinds; it may bank and soar in high-wind conditions (Wiley and Lee 1998). Long-tailed Jaeger is considered a species of Least Concern (IUCN 2014). The species had a PCV best estimate score of163, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 11, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 17). The high collision vulnerability is due to high percent time flying in the RSZ and low macro-avoidance rate (Table 5).

A small number of South Polar Skua (*Stercorarius maccormicki*) pass through the CCS when undergoing their trans-equatorial migration from their antarctic breeding grounds to the norhtern hemisphere for the nonbreeding season (Briggs et al. 1983). They likely fly > 10 meters above the water, and are unlikely to change flight height with changing wind speed or direction (Ainley et al. 2014). South Polar Skua is considered a species of Least Concern (IUCN 2014). The species had a PCV best estimate score of138, ranking it at ‘high’ risk of collision, and a PDV best estimate score of 33, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 17). The high collision vulnerability is due to high percent time flying in the RSZ and low macro-avoidance rate (Table 5).

Previous indices also determined that jaegers and skuas would have high collision vulnerability at OWEI. In the Scottish waters of the North Sea, skuas (along with White-tailed Eagles, Northern Gannets, and gulls) were found to be the most vulnerable to collision by Furness and Wade (2012) and Furness et al. (2013). Willmott et al. (2013) found that on the Atlantic Outer Continental Shelf of North America, jaegers (along with phalaropes, gulls and cormorants) have the highest collision vulnerability. These predictions of high collision vulnerability are supported by radar observations at Egmond aan Zee wind farm. Here Krijgsveld et al. (2011) found that skuas commonly flew at the height of the RSZ, but were rarely seen within the OWEI. However the infrequency of skua sightings at Egmond aan Zee could be due in part to the fact that skuas were traveling at night and during periods of high winds when observers were not collecting data (Krijgsveld et al. 2011).

### Alcids

The Ancient Murrelet (*Synthliboramphus antiquus*) is a small (*ca.* 200 g), diving alcid that nests in scattered colonies throughout the boreal Alaska Current from British Columbia, Canada, westward throughout the Alaska Peninsula and Aleutian Archipelago, and extending southward through Russia, Japan, and into the Yellow Sea off China. Approximately a quarter to half of the world’s population (*ca*. 500,000 birds) breeds in the Haida Gwaii Archipelago, British Columbia, Canada (Gaston and Shoji 2010). Post-breeding dispersal and wintering ecology at sea in the CCS are poorly known, but southward movements from British Columbia and extending to the central California Current occur during August – October (Gaston and Shoji 2010). Previous survey efforts at sea described very infrequent sightings (a total of 11 individuals) of Ancient Murrelet off northern Washington and Oregon during winter and spring (Briggs et al. 1992) and occasional sightings beyond the shelf-break off northern California during February – April, south of Point Arena (Briggs et al. 1987). The species is considered Threatened by the USFWS Seabird Conservation Status and Environment Canada due to historically dramatic population reduction caused by introduced mammalian predators on breeding islands (USFWS 2005, COSEWIC 2013). Ancient Murrelet had a PCV best estimate score of 36, ranking it at ‘low’ risk of collision and a PDV best estimate score of 900, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 18). The high displacement vulnerability is due to year-round presence in the CCS and high macro-avoidance rate (Table 6).

The Marbled Murrelet (*Brachyramphus marmoratus*) is a small alcid found in the Pacific coastal waters from Alaska to northern California. In Washington, Oregon, and northern California the species is associated with old-growth forests where it nests inland on the large limbs of coniferous trees. Marbled Murrelet has a restricted near-shore distribution; individuals are rarely encountered at sea >5-km from shore and very often are found in shallow waters 0.1 – 2-km from shore. The most recent 5-year Status Review reported an estimated 12,940 Marbled Murrelets off outer Washington through northern California (Cape Flattery through Cape Mendocino), with about half of these off Oregon north of Cape Blanco (USFWS 2009). The species is listed federally as Endangered and is considered Critically Endangered by the USFWS Seabird Conservation Status due to loss of breeding habitat to logging, oil spills, and bycatch in gill net fisheries (USFWS 2005, USFWS 2014). Marbled Murrelet had a PCV best estimate score of 10, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 360, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 18).

Xantus’s Murrelet (*Synthliboramphus hypolecus*) recently was split into two distinct species: Guadalupe Murrelet (*Synthliboramphus hypoleucus*) and Scripps’s Murrelet (*S. scrippsi*, Birt et al. 2012). To date there is limited information on population sizes, habitat ranges, behavior, and threat value differences between Guadalupe and Scripps’s Murrelet, however Scripps’s Murrelet is known to occur in the CCS in greater frequency. Therefore only the Scripps’s Murrelet is considered herein (although the majority of the metric values used are comparable for Guadalupe Murrelet; Birdlife’s Globally Threatened Bird Forums 2014). Their diet is poorly known but is thought to consist primarily of larval to early life-stage anchovies; years of poor anchovy production are correlated with late breeding and poor reproductive effort in this species (Drost and Lewis 1995). Scripps’s Murrelet is considered Endangered by the USFWS Pacific Seabird Conservation Status and in Mexico due to oil and light pollution as well as fisheries bycatch, which is exacerbated by their limited breeding range (USFWS 2005, Flores 2010). The species had a PCV best estimate score of 41, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 1350, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 18). The high displacement vulnerability is due to year-round presence in the CCS, low (high value) habitat flexibility, high macro-avoidance rate, and high Population Vulnerability (Table 6).

Craveri’s Murrelet (*Synthliboramphus craveri*) breeds in the Gulf of California, Mexico. During the nonbreeding season they are found off Southern California, the Gulf of California, Mexico, and possibly south to Guatemala (Birdlife International 2014). At-sea densities and overall numbers are low off California, but individuals have been recorded consistently in Southern California (Briggs et al. 1983, Briggs et al. 1987). Craveri’s Murrelet is considered Threatened in Mexico and by the USFWS Pacific Seabird Conservation Status listing due to its restricted breeding range and low population size (USFWS 2005, Flores 2010). The species had a PCV best estimate score of 8, ranking it at ‘low’ risk of collision and a PDV best estimate score of 280, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 18).

With the exception of the Sooty Shearwater during summer, the Common Murre (*Uria aalge*) dominates year-round in both number and biomass within the marine avian community from northern California through Washington. Carter et al. (2001) summarized recent knowledge of the population trends throughout the west coast of North America, excluding Alaska. Off northern California in 1989, 11 colonies supported 261,400 breeding birds (24% of the *U. a. californica* population). The largest single colony complex in California is located on Castle Rock, 20 km south of the California – Oregon border (142,400 birds in 1982); the majority of the sub-species’ population resides off the coast of Oregon, where by 1988, approximately 711,900 breeding birds occurred at 66 colonies (66% of the total population). Colonies off Oregon are distributed according to available steep rocky cliffs and offshore rocky habitat which occurs predominantly in the north and south of the state (Naughton et al. 2007). Numbers of breeding Common Murre off Washington are less, on the order of 5900 – 9600 individuals in 1994 and 1995, respectively (Carter et al. 2001). At sea off Oregon, Briggs et al. (1992) reported greatest densities over mid-shelf waters. Local densities during the nesting season can exceed 100 birds km-2 as rafts of birds aggregate near breeding colonies; there appeared to be a trend for Common Murre to be more aggregated farther offshore during the winter when densities increased in association with the shelf-break (Briggs et al. 1992). Common Murre undergo a flightless molt period at sea in late summer/fall (Carter et al. 2001). The species is considered Vulnerable by the USFWS Pacific Seabird Conservation Status due to its sensitivity to human disturbance, pollution, and gill nets (USFWS 2005). Common Murre had a PCV best estimate score of 40, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 990, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 18). The high displacement vulnerability is due to year-round presence in the CCS and high macro-avoidance rate (Table 6).

Pigeon Guillemot (*Cepphus Columba*) breeds in small scattered colonies all along the coast of the CCS. In Washington, there are an estimated 700 - 4270 breeding Pigeon Guillemots (Briggs et al. 1983, Beich and Wahl 1989). 2100 guillemots breed in Oregon and 12,500 - 15,500 breed in California (Briggs et al. 1983, Carter et al. 1992, Sowls et al. 1980). The Pigeon Guillemots diet can vary considerably between colony locations and years (Ewins 1993). Birds in Alaska are known to switch to alternative prey when preferred, lipid-rich prey (such as capelin, cods, and sculpin) are not readily available; but, lack of sufficient lipid-rich prey can cause poor reproductive output (Litzo et al. 2002). Pigeon Guillemot is considered Vulnerable by the USFWS Pacific Seabird Conservation Status due to its sensitivity to human disturbance, pollution, and gill nets (USFWS 2005). The species had a PCV best estimate score of 10, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 360, ranking it at ‘medium’ risk of displacement by OWEI (Table 7, Figure 18).

Tufted Puffins are found throughout the North Pacific, breeding on rocky coasts and islands from California through Alaska and Japan. They are opportunistic feeders (Piatt and Kitaysky 2002). Tufted Puffins used to nest from the Channel Islands in California north through Oregon and Washington (Briggs et al. 1981). Breeding populations in the CCS have declined by 85 to 90 percent since the 1980s and a petition to list the California, Oregon, and Washington Tufted Puffin breeding populations as federally endangered was submitted in February 2014 (NRDC 2014). The species had a PCV best estimate score of 31, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 1170, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 18). The high displacement vulnerability is due to year-round presence in the CCS and high macro-avoidance rate (Table 6).

Horned Puffins (*Fratercula corniculata*) are rarely seen in the coastal CCS, although they do occasionally wash up in wrecks along the California, Oregon, and Washington coast. The majority of the population (85%) breeds in Alaska but only 2% of them spend the nonbreeding season there. Therefore it is suspected that they travel south during the winter (Piatt and Kitaysky 2002). Horned Puffins feed on whatever forage fishes are abundant, but are not as attracted to upwelling areas as other alcids (Piatt and Kitaysky 2002). The species is considered a Near Threatened in Oregon (Oregon Department of Fish and Wildlife 2014). Horned Puffins had a PCV best estimate score of 3, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 113, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 18).

The Rhinoceros Auklet is a medium-sized alcid of the puffin tribe (Fraterculini). In the northeastern Pacific, the species’ breeding range extends from the Gulf of Alaska to southern California (Gaston and Deshesne 1996). In 1988, there were an estimated 60,814 breeders nesting in Washington, mostly at Protection Island (34,216) and Destruction Island (23,600) to the north of our study area (Gaston and Deshesne 1996). Off Oregon, approximately 475 breeding birds (94% of state’s breeding population) occur along the southern coastline (Naughton et al. 2007). In 1988, Carter et al. (1992) estimated 1032 breeding birds nested at Castle Rock National Wildlife Refuge off northern California. Rhinoceros Auklets are much more numerous in British Columbia, Canada (*ca*. 333,000 breeders; Rodway 1991), and are unique among the puffins in the northeastern Pacific in that they are strictly nocturnal at their colonies. Post-breeding dispersal from large colonies in Washington is southward with an influx of birds occurring off Oregon and California during fall and winter (Gaston and Dechesne 1996). Briggs et al. (1987) noted increased abundances off northern California by late October, and a decline here as birds moved south to waters off central and southern California during winter. Rhinoceros Auklet is considered Endangered by the USFWS Pacific Seabird Conservation Status due to oil contamination, risk of fisheries bycatch, and habitat degradation (USFWS 2014). The species had a PCV best estimate score of 29, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 1080, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 18). The high displacement risk is due to year-round presence in the CCS and high macro-avoidance rate (Table 6)

Approximately one million Parakeet Auklets (*Aethia psillacula*) breed in Alaska (Jones 2001). After the breeding season they can be found in small numbers throughout the CCS (Briggs et al. 1983). The species is considered of Least Concern (IUCN 2014). Parakeet Auklet had a PCV best estimate score of 4, ranking it at ‘low’ risk of collision, and a PDV best estimate score of 103, ranking it at ‘low’ risk of displacement by OWEI (Table 7, Figure 18).

The Cassin’s Auklet (*Ptychoramphus aleuticus*) is a small (*ca*. 160 g), diving alcid that breeds in colonies from Mexico through Alaska. The geographical delineations for the two distinct subspecies recently was determined; *P. a. aleuticus* breeding colonies are distributed north of Point Conception in Southern California, *P. a. austral* included breeders in the California Channel Islands and Mexico (Wallace et al. 2015). The center of the breeding distribution for the northern subspecies (*P. a. aleuticus*)occurs in the Scott Island group, British Columbia, Canada, where *ca*. 2 million individuals resided in the 1980s (Ainley et al. 2011). Off central to northern Washington, seven colonies accounted for *ca*. 88,000 birds during the 1980s (Speich and Wahl 1989). A small portion of the estimated total breeding population nests within the CCS with small colonies located in Oregon (*ca*. 400 breeding birds; e.g. Haystack Rock [hundreds], and off Cape Blanco [hundreds]; Naughton et al. 2007) and at Castle Rock National Wildlife Refuge, California (705 breeding pairs in 2007; Cunha 2011). During the spring-summer nesting season, breeding adults forage within approximately 30 km of their colonies (Adams et al. 2004). Post-breeding dispersal from British Columbia is thought to be southward extending into California (Briggs et al. 1987), with some indication that southern breeders may move northward into the northern CCS during the post-breeding period (late summer and fall; Adams et al. 2004). Cassin’s Auklet is considered Endangered by the USFWS Pacific Seabird Conservation Status due to interactions with gill net fisheries, oil spills, and sensitivity to prey stocks (USFWS 2005). The species had a PCV best estimate score of 36, ranking it at ‘low’ risk of collision and a PDV best estimate score of 900, ranking it at ‘high’ risk of displacement by OWEI (Table 7, Figure 18). The high displacement vulnerability is due to year-round presence in the CCS and high macro-avoidance rate (Table 6).

Similar to our reports on alcid vulnerability, Willmott et al. (2013) found that on the Atlantic Outer Continental Shelf of North America, Atlantic Puffin (*Fratercula arctica*), Razorbill (*Alca torda*), and Common Murre (along with scoters, loons and tern species) have the highest displacement vulnerability. These predictions are supported by post-construction reports from offshore wind energy sites. At Egmond aan Zee wind farm in the North Sea, Krijgsveld et al. (2011) found murres and other alcid species (along with scoters, loons, and gannets) actively avoided OWEI. Three years after the construction of Blighbank wind farm in the North Sea, Vanermen et al. (2013) found that Common Murres and Razorbill (along with Northern Gannets) showed significant avoidance of OWEI areas.

# 5.0 CONCLUSIONS

Pelicans, cormorants, and terns have the greatest collision vulnerability due to low avoidance rates and a high percentage of time flying at the height of turbine blades (Table 5, Figure 1). Alcids, terns, and loons have the greatest vulnerability of displacement by offshore wind power infrastructure due to their high disturbance sensitivity and low habitat flexibility (Table 6, Figure 1). The final Population Collision Vulnerability and Population Displacement Vulnerability scores provided for each species provides a significance level to the potential impacts of OWEI on marine birds within the CCS. Bailey et al. (2014) identified the need to understand impacts of OWEI on marine populations as one of the four primary lessons learned for OWEI construction in Europe to date. This study sets the framework to fulfill this need for environmental impacts within the CCS.

Studies have shown that spatial and temporal variation can play a significant role in the exposure of seabirds to wind energy sites (Braham et al. 2015, Thaxter et al. 2015). The levels of vulnerability generated in this database can readily be applied to areas in the CCS where offshore renewable energy development is being considered and can be used to help inform decisions that will impact seabird conservation. Vulnerability assessment results can be combined with recent marine bird at-sea distribution and abundance data to evaluate seabird vulnerability to offshore renewable energy site locations in the CCS. For example, in their index of seabird vulnerability to OWEI in the North Sea, Garthe and Hüppop (2004) created seabird vulnerability maps for each season (spring, summer, fall, winter) based on the vulnerability scores of each species and species distributions recorded in boat-based surveys throughout the year. Combining the vulnerability values presented in this report with data collected during the PaCSEA project (Adams et al. 2014), as well as data compiled for site-specific analyses of seabird distributions at proposed OWEI construction sites (e.g., Suryan et al. 2012), will provide useful seasonal vulnerability maps for species in the CCS. For some of the species in this vulnerability assessment, available tracking data quantifying utilization of areas in the CCS may provide continuous spatial information at a greater resolution. These distributions can be integrated with information on wind patterns (Mateos and Arroyo 2011), to create a density distribution analysis of locations in the CCS where the impacts of OWEI on marine birds would be greatest (Christel et al. 2013, Maxwell et al. 2013).

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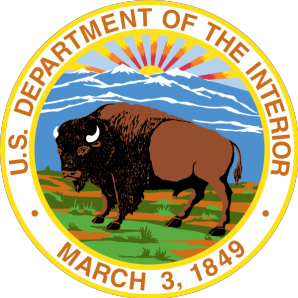
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**The Department of the Interior Mission**

As the Nation’s principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

**The Bureau of Ocean Energy Management**

As a bureau of the Department of the Interior, the Bureau of Ocean Energy Management (BOEM) primary responsibilities are to manage the mineral resources located on the Nation’s Outer Continental Shelf (OCS) in an environmentally sound and safe manner.

**The BOEM Environmental Studies Program**

The mission of the Environmental Studies Program (ESP) is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments.