Prepared in cooperation with Bureau of Ocean Energy Management
(OCS Study, BOEM 2016-043)

Collision and Displacement Vulnerability among Marine Birds of the California Current System Associated with Offshore Wind Energy Infrastructure

Open–File Report 2016–1154
Version 1.1, July 2017

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photograph showing Ashy Storm-Petrel (*Oceanodroma homochroa*). Photograph courtesy of David M. Pereksta. Used with permission.

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SALLY JEWELL, Secretary

U.S. Geological Survey
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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in)	2.54	centimeter (cm)
inch (in)	25.40	millimeter (mm)
foot (ft)	0.31	meter (m)
mile (mi)	1.61	kilometer (km)
mile, nautical (nmi)	1.85	kilometer (km)
yard (yd)	0.91	meter (m)

International System of Units to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.5400	mile, nautical (nmi)
kilometer (km)	0.6214	mile (mi)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as °F = (1.8 × °C) + 32.

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as °C = (°F – 32) / 1.8.

Abbreviations and Acronyms

Annual Occurrence (months in CCS)	AO
Adult Survival	AS
Atlantic Outer Continental Shelf	AOCS
Bird of Conservation Concern (USFWS)	BCC
Bureau of Ocean Energy Management	BOEM
Breeding Status in CCS	BR
Bird Species of Special Concern (CDFW)	BSSC
California Current System	CCS
California Department of Fish and Wildlife (Game)	CDFW(G)
California Endangered Species Act	CESA
Proportion of Species Population found in California Current System	CCSpop
Diurnal Flight Activity	DFA
Exclusive Economic Zone	EEZ
Global Positioning System	GPS
Habitat Flexibility	HF
International Union for Conservation of Nature	IUCN
Macro-Avoidance of Wind Turbines	MA
Nocturnal Flight Activity	NFA
Oregon Department of Fish and Wildlife	ODFW
Oregon Endangered Species Act	OESA
Offshore wind-energy infrastructure	OWEI
Pacific Continental Shelf Environmental Assessment	PaCSEA
Population Collision Vulnerability	PCV
Population Displacement Vulnerability	PDV
Global Population Size	POP
Pacific Offshore Continental Shelf	POCS
Rotor Sweep Zone	RSZ
Percent Time in Rotor Sweep Zone	RSZt
Threat Status	TS
U.S. Fish and Wildlife Service	USFWS
U.S. Geological Survey-Western Ecological Research Center	USGS-WERC
Washington Department of Fish and Wildlife	WDFW
Washington Endangered Species Act	WESA

Collision and Displacement Vulnerability among Marine Birds of the California Current Region Associated with Offshore Wind Energy Infrastructure

By Josh Adams[1], Emily C. Kelsey[1], Jonathan J. Felis[1], and David M. Pereksta[2]

Abstract

With growing climate change concerns and energy constraints, there is an increasing need for renewable energy sources within the United States and globally. Looking forward, offshore wind-energy infrastructure (OWEI) has the potential to produce a significant proportion of the power needed to reach our Nation's renewable energy goal. Offshore wind-energy sites can capitalize open areas within Federal waters that have persistent, high winds with large energy production potential. Although there are few locations in the California Current System (CCS) where it would be acceptable to build pile-mounted wind turbines in waters less than 50 m deep, the development of technology able to support deep-water OWEI (>200 m depth) could enable wind-energy production in the CCS. As with all human-use of the marine environment, understanding the potential impacts of wind-energy infrastructure on the marine ecosystem is an integral part of offshore wind-energy research and planning. Herein, we present a comprehensive database to quantify marine bird vulnerability to potential OWEI in the CCS (see https://doi.org/10.5066/F79C6VJ0). These data were used to quantify marine bird vulnerabilities at the population level. For 81 marine bird species present in the CCS, we created three vulnerability indices: Population Vulnerability, Collision Vulnerability, and Displacement Vulnerability. Population Vulnerability was used as a scaling factor to generate two comprehensive indicies: *Population Collision Vulnerability* (PCV) and *Population Displacement Vulnerability* (PDV). Within the CCS, pelicans, terns (Forster's [*Sterna forsteri*], Caspian [*Hydroprogne caspia*], Elegant [*Thalasseus elegans*], and Least Tern [*Sternula antillarum*]), gulls (Western [*Larus occidentalis*] and Bonaparte's Gull [*Chroicocephalus philadelphia*]), South Polar Skua (*Stercorarius maccormicki*), and Brandt's Cormorant (*Phalacrocorax penicillatus*) had the greatest PCV scores. Brown Pelican (*Pelicanus occidentalis*) had the greatest overall PCV score. Some alcids (Scripps's Murrelet [*Synthliboramphus scrippsi*], Marbled Murrelet [*Brachyramphus marmoratus*], and Tufted Puffin [*Fratercula cirrhata*]), terns (Elegant and Least Lern), and loons (Yellow-billed [*Gavia adamsii*] and Common Loon [*G. immer*]) had the greatest PDV scores. Ashy Storm-Petrel (*Oceanodroma homochroa*) had the greatest overall PDV score. To help inform decisions that will impact seabird conservation, vulnerability assessment results can now be combined with recent marine bird at-sea distribution and abundance data for the CCS to evaluate vulnerability areas where OWEI development is being considered. Lastly, it is important to note that as new information about seabird behavior and populations in the CCS becomes available, this database can be easily updated and modified.

[1]U.S. Geological Survey.
[2]Bureau of Ocean Energy Management.

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 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 (fig. 1). With growing climate change concerns and energy constraints, there is an increasing need for renewable energy sources within the United States and globally. To help meet this need, the United States has set a goal for 20 percent of the country's overall electricity production to come from wind-power by 2030 (U.S. Department of Energy, 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). In 2015, all wind-energy production in the United States was 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 percent wind-energy goal (Musial and Ram, 2010).

By 2014, there were 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, and Block Island Wind Farm off the coast of Rhode Island were the first American offshore wind-energy production sites to be approved for construction. Cape Wind is currently in its financing phase (Cape Wind, 2014; Handwerk, 2014). Block Island is currently under construction and will be the first offshore wind farm in U.S. waters (Cardwell, 2015).

Offshore wind-energy sites can capitalize open areas within State and Federal waters that have persistent, high winds with large energy production potential. Until recently, research on the construction of offshore wind-energy infrastructure (OWEI) in the 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 less than 50 m deep, which has been the global industry norm (fig. 1). However, with the development of technology able to support deep-water wind energy infrastructure (>60 m 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 renewable energy sources by the 2020s (American Wind Energy Association, 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 U.S. Pacific coast and beyond State waters (that is, outside three nautical miles [nmi]). Since 2014, BOEM has received several renewable energy proposals off the coast of Oregon, California, and Hawaii (see http://www.boem.gov/Renewable-Energy/). As OWEI becomes a reality for the CCS, interactions with offshore marine life at proposed offshore wind-energy sites in the CCS will be unavoidable (Musial and Ram, 2010).

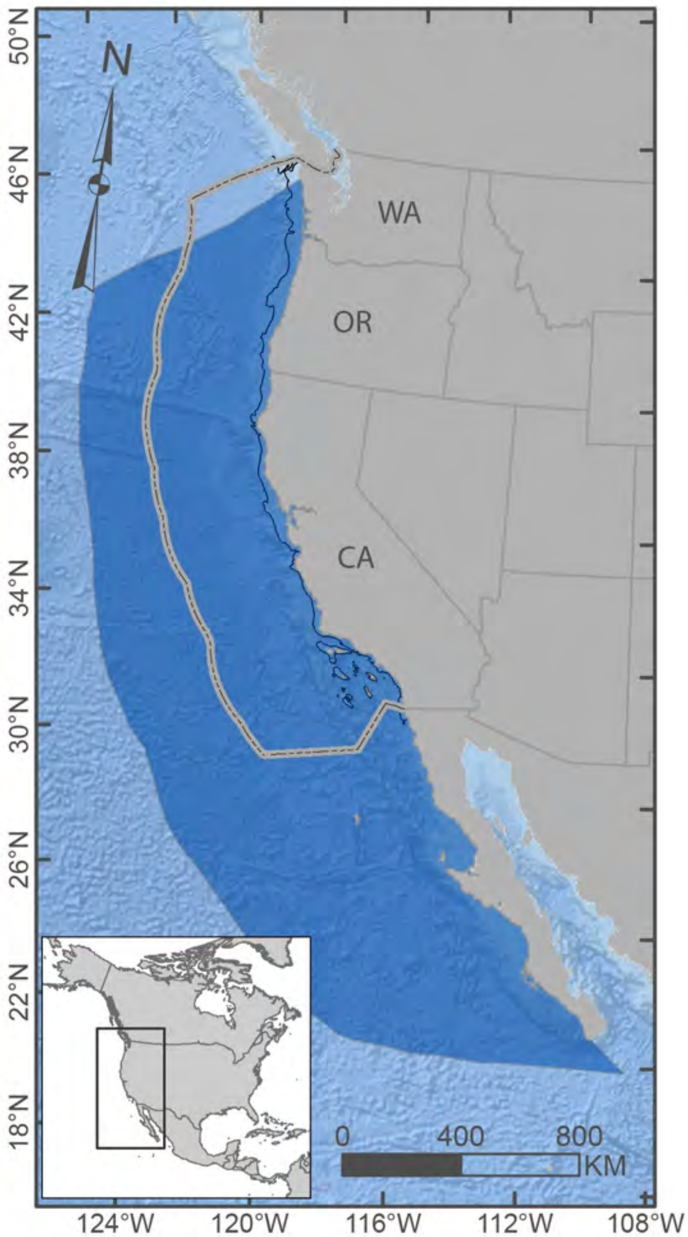

Figure 1. Map of the west coast of North America showing California (CA), Oregon (OR), Washington (WA), and the extent of the U.S. Exclusive Economic Zone (US EEZ, tan and black line outline) in relation to the California Current Large Marine Ecosystem (dark blue shading; NOAA IEA: http://www.noaa.gov/iea/regions/california-current-region/index.html). Black line indicates the continental shelf break (200 m water depth).

As with all human-use of the marine environment, understanding the potential impacts of wind-energy infrastructure on the marine ecosystem is an integral part of offshore wind-energy research (Desholm, 2009; Halpern and others, 2009; Vaissière and others, 2014). This report presents a comprehensive database to quantify marine bird vulnerability to OWEI in the CCS. These data were used to quantify marine bird vulnerabilities at the population level. For 81 marine bird species present in the CCS (table 1), we generated numerical 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 by experts with experience quantifying seabird vulnerability to OWEI in Europe to evaluate if the metrics identified, methods, and values generated, were appropriate for the suite of species considered. Hawaii also is considered part of the POCS and BOEM presently is considering offshore wind energy proposals in offshore Hawaiian waters. Hawaii recently introduced House Bill 632 that would set the State's goal for 100 percent renewable energy by 2045 (Hawaii State Legislature, 2015). Except for species that also occur in the CCS (for example, Laysan Albatross [*Phoebastria immutabilis*], Black-footed Albatross [*Phoebastria nigripes*], and Hawaiian Petrel [*Pterodroma sandwichensis*]), the marine bird species of Hawaii were not considered in this database because there are not sufficient data on species abundance and distribution within the Hawaiian Islands to generate accurate Population Vulnerability scores.

Similar vulnerability databases and evaluations have been created for areas in the Atlantic Ocean (northwestern Europe and the northeastern United States) where OWEI exists or is being considered (Garthe and Hüppop, 2004; Desholm, 2009; Furness and Wade, 2012; Furness and others, 2013; Robinson Willmott and others, 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. Because Garthe and Hüppop (2004) created their vulnerability rankings before metrics could be informed by existing data on OWEI and seabird interactions, the results generated for four of their 9 metrics were reviewed by 10 experts. They also analyzed the metrics on a spatial and temporal scale, and results indicated that species in nearshore 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 also could 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 in response to varying levels of adult survival and fecundity. Desholm (2009) found that adult survival was a better indicator of population sensitivity than fecundity (that is, species with greater survival rates were more sensitive to disturbance). With just two metrics, Desholm (2009) suggested his analysis could be standardized across species where varying amounts of data were available and that his method avoided combining correlated data from multiple metrics, a potential concern regarding the approach taken by Garthe and Hüppop (2004). Desholm's approach, however, did not take into account species-specific behavior, such as the likelihood that species differ in 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, survival rates that are similar (that is, generally high for marine birds) and then used to indicate relative demographic sensitivity, would not contribute substantial variability in risk among species evaluated.

Furness and Wade (2012) and Furness and others (2013) used similar metrics as Garthe and Hüppop (2004) to evaluate seabird vulnerability, but they separated 10 metrics into 3 indices: conservation significance (European and British conservation importance, percentage of time in British waters, and adult survival), collision vulnerability (flight height [greatest weighting], flight maneuverability, percentage of time flying, and nocturnal flight activity), and habitat displacement (habitat specialization and disturbance caused by wind turbines, ships, or helicopter traffic). This approach separated collision and displacement and also decreased combinations of correlated data, considered problematic in the previous assessment by Garthe and Hüppop (2004).

Robinson Willmott and others (2013) adapted methods used in the aforementioned three European studies and applied them to the Atlantic Outer Continental Shelf (AOCS) off North America. Robinson Willmott and others (2013) used the same metrics and indexing system as Furness and Wade (2012) and Furness and others (2013), but they incorporated breeding status and macro-avoidance behavior into the collision and displacement indices. In addition, they 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 excluded longevity, age at first reproduction, and clutch size). Similar to previous studies, data quantifying flight heights were limited.

Based on data and methods similar to Garthe and Hüppop (2004), Desholm (2009), Furness and Wade (2012), Furness and others (2013), and Robinson Willmott and others (2013), we created a database to quantify seabird vulnerability in the CCS (Adams and others, 2017; https://doi.org/10.5066/F79C6VJ0). Specifically, we created three vulnerability indices for marine birds in the CCS: Population Vulnerability, Collision Vulnerability, and Displacement Vulnerability; Population Vulnerability was combined with Collision and Displacement Vulnerabilities to create two comprehensive indicies specific to the marine bird community in the CCS: *Population Collision Vulnerability* and *Population Displacement Vulnerability*.

Methods

Species Selection

The species selected for this database include all marine birds that occur regularly in the CCS (table 1). The species list was created based on historical survey records (Briggs and others, 1981, 1983; 1992) and recent results from the 2011 to 2012 Pacific Continental Shelf Environmental Assessment (PaCSEA; Adams and others, 2014).

Most historical survey records reported Xantus's Murrelet (*Synthliborrampus hypoleucus*), which have since been recognized as two distinct species: Scripps's (*S. scrippsi*) and Guadalupe Murrelet (*S. hypolucus*) (Birt and others, 2012; Chesser and others, 2012). Survey data that refer to Xantus's Murrelet were applied to Scripps's Murrelet (fig. 2) for this database. It is unclear to what extent Guadalupe Murrelet inhabits the CCS, so it was not considered specifically in this database. Our species list also was supplemented with species that did not appear on the PaCSEA surveys but are known to exist in the CCS (for example, Black Skimmer [*Rynchops niger*], Tufted Puffin [*Fratercula cirrhata*], and Yellow-billed Loon [*Gavia adamsii*]; table 1). Although shorebirds, raptors, and passerines are known to occur offshore within the CCS, lack of similar data comparable with marine birds precluded us from considering these taxa in this study.

Figure 2. Scripps's Murrelet (*Synthliboramphus scrippsi*). Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

Table 1. Species and species groups of the CCS evaluated for their potential vulnerability to offshore wind-energy infrastructure.

[Species are ordered by taxonomic classification number (Clements and others, 2015)]

Taxa	Common name	Scientific name	Alpha code
Sea Ducks and Geese	Brant	*Branta bernicla*	BRAN
	Common Merganser	*Mergus merganser*	COME
	Red-breasted Merganser	*Mergus serrator*	RBME
	Harlequin Duck	*Histrionicus histrionicus*	HADU
	Surf Scoter	*Melanitta perspicillata*	SUSC
	White-winged Scoter	*Melanitta deglandi*	WWSC
	Black Scoter	*Melanitta americana*	BLSC
	Long-tailed Duck	*Clangula hyemalis*	LTDU
Loons	Red-throated Loon	*Gavia stellata*	RTLO
	Pacific Loon	*Gavia pacifica*	PALO
	Common Loon	*Gavia immer*	COLO
	Yellow-billed Loon	*Gavia adamsii*	YBLO
Grebes	Horned Grebe	*Podiceps auritus*	HOGR
	Red-necked Grebe	*Podiceps grisegena*	RNGR
	Eared Grebe	*Podiceps nigricollis*	EAGR
	Western Grebe	*Aechmophorus occidentalis*	WEGR
	Clark’s Grebe	*Aechmophorus clarkii*	CLGR
Procellariids	Laysan Albatross	*Phoebastria immutabilis*	LAAL
	Black-footed Albatross	*Phoebastria nigripes*	BFAL
	Short-tailed Albatross	*Phoebastria albatrus*	STAL
	Northern Fulmar	*Fulmarus glacialis rodgersii*	NOFU
	Murphy’s Petrel	*Pterodroma ultina*	MUPE
	Mottled Petrel	*Pterodroma inexpectata*	MOPE
	Hawaiian Petrel	*Pterodroma sandwichensis*	HAPE
	Cook’s Petrel	*Pterodroma cookii*	COPE
	Pink-footed Shearwater	*Puffinus creatopus*	PFSH
	Flesh-footed Shearwater	*Puffinus carneipes*	FFSH
	Buller’s Shearwater	*Puffinus bulleri*	BULS
	Sooty Shearwater	*Puffinus griseus*	SOSH
	Short-tailed Shearwater	*Puffinus tenuirostris*	SRTS
	Manx Shearwater	*Puffinus puffinus*	MASH
	Black-vented Shearwater	*Puffinus opisthomelas*	BVSH
	Wilson’s Storm-Petrel	*Oceanites oceanicus*	WISP
	Fork-tailed Storm-Petrel	*Oceanodroma furcatus*	FTSP
	Leach’s Storm-Petrel	*Oceanodroma leucorhoa*	LESP
	Ashy Storm-Petrel	*Oceanodroma homochroa*	ASSP
	Black Storm-Petrel	*Oceanodroma melania*	BLSP
	Least Storm-Petrel	*Oceanodroma microsoma*	LSTP

Taxa	Common name	Scientific name	Alpha code
Cormorants	Brandt's Cormorant	*Phalacrocorax penicillatus*	BRAC
	Double-crested Cormorant	*Phalacrocorax auritus*	DCCO
	Pelagic Cormorant	*Phalacrocorax pelagicus*	PECO
Pelicans	American White Pelican	*Pelecanus erythrorhynchos*	AWPE
	Brown Pelican	*Pelecanus occidentalis*	BRPE
Phalaropes	Red-necked Phalarope	*Phalaropus lobatus*	RNPH
	Red Phalarope	*Phalaropus fulicarius*	REPH
Jaegers & Skuas	South Polar Skua	*Stercorarius maccormicki*	SPSK
	Pomarine Jaeger	*Stercorarius pomarinus*	POJA
	Parasitic Jaeger	*Stercorarius parasiticus*	PAJA
	Long-tailed Jaeger	*Stercorarius longicaudus*	LTJA
Alcids	Common Murre	*Uria aalge*	COMU
	Pigeon Guillemot	*Cepphus columba*	PIGU
	Marbled Murrelet	*Brachyramphus marmoratus*	MAMU
	Scripps's Murrelet	*Synthliboramphus scrippsi*	SCMU
	Craveri's Murrelet	*Synthliboramphus craveri*	CRMU
	Ancient Murrelet	*Synthliboramphus antiquus*	ANMU
	Cassin's Auklet	*Ptychoramphus aleuticus*	CAAU
	Parakeet Auklet	*Aethia psittacula*	PAAU
	Rhinoceros Auklet	*Cerorhinca monocerata*	RHAU
	Horned Puffin	*Fratercula corniculata*	HOPU
	Tufted Puffin	*Fratercula cirrhata*	TUPU
Gulls & Terns	Black-legged Kittiwake	*Rissa tridactyla*	BLKI
	Sabine's Gull	*Xema sabini*	SAGU
	Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU
	Heermann's Gull	*Larus heermanni*	HEEG
	Mew Gull	*Larus brachyrhynchus*	MEGU
	Ring-billed Gull	*Larus delawarensis*	RBGU
	Western Gull	*Larus occidentalis*	WEGU
	California Gull	*Larus californicus*	CAGU
	Herring Gull	*Larus smithsonianus*	HERG
	Thayer's Gull	*Larus thayeri*	THGU
	Glaucous-winged Gull	*Larus glaucescens*	GWGU
	Least Tern	*Sternula antillarum*	LETE
	Gull-billed Tern	*Sterna nilotica*	GBTE
	Caspian Tern	*Hydroprogne caspia*	CATE
	Black Tern	*Chlidonias niger*	BLTE
	Common Tern	*Sterna hirundo*	COTE
	Arctic Tern	*Sterna paradisaea*	ARTE
	Forster's Tern	*Sterna forsteri*	FOTE
	Royal Tern	*Thalasseus maximus*	ROYT
	Elegant Tern	*Thalasseus elegans*	ELTE
	Black Skimmer	*Rynchops niger*	BLSK

Species Vulnerability Assessment Methods

Compared with previous studies (Garthe and Hüppop, 2004; Desholm, 2009; Furness and Wade, 2012; Furness and others, 2013; Robinson Willmott and others, 2013), we modified and (or) eliminated three metrics in our database: (1) *Threat Status* was modified to incorporate regional and international indices, (2) *Flight Height* was modified to include results from a comprehensive analysis developed by Ainley and others (2015), and (3) *Disturbance* was not included because data used to assess disturbance in previous studies (based on disturbance caused by boat and helicopter traffic), were reviewed and used to inform our Macro-Avoidance metric.

We considered the same three vulnerability indices (population, collision, and displacement) as Robinson Willmott and others (2013) and used values generated from available sources to quantify vulnerability among seabirds in the CCS (table 2). Population Vulnerability was used to scale Collision Vulnerability and Displacement Vulnerability; for each species, Collision Vulnerability and Displacement Vulnerability scores each were multiplied by a Population Vulnerability score to create a *Population Collision Vulnerability* score and a *Population Displacement Vulnerability* score (eqs. 1 and 2).

Table 2. Organization for metrics used calculating the three vulnerability indices.

[CCS, California Current System; RSZ, Rotor Swept Zone]

Population Vulnerability		Collision Vulnerability		Displacement Vulnerability	
POP	Global Population Size	NFA	Nocturnal Flight Activity	MA	Macro-Avoidance of wind turbines
CCSpop	Proportion of POP in CCS	DFA	Diurnal Flight Activity	HF	Habitat Flexibility
AO	Annual Occurrence (number of months in CCS)	MA	Macro-Avoidance of wind turbines		
AS	Adult Survival	RSZt	Percent Time in RSZ		
BR	Breeding Score for the CCS				
TS	Threat Status				

$$\textit{Population Collision Vulnerability} = \text{Collision Vulnerability} \times \text{Population Vulnerability} \quad (1)$$

$$\textit{Population Displacement Vulnerability} = \text{Displacement Vulnerability} \times \text{Population Vulnerability} \quad (2)$$

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 alive globally. Therefore, uncertainty around the POP metric value was included. The level of uncertainty for each metric was determined to be low (10 percent), medium (25 percent), or high (50 percent) depending on the number of data sources, how current the data sources were, and the range of values published in those data sources. When appropriate, expert opinion also was used to determine values and uncertainty. The uncertainty percentage was multiplied by 4 (that is, the difference between the greatest and least possible values [5 - 1 = 4]) to provide the following three uncertainty ranges:

50 percent = $0.50 \times 4 = 2.0$
25 percent = $0.25 \times 4 = 1.0$
10 percent = $0.10 \times 4 = 0.4$

These values were applied to metric values to create a range of possible values considering the level of uncertainty (table 3). The range of values for each metric indicates potential data limitations associated with that metric value—a greater range of values (that is, greater uncertainty) indicates greater potential limitations in the application of that metric. This uncertainty can be considered by resource managers who seek to fill information gaps, plan to use these values to evaluate potential impacts to species, or to make decisions regarding renewable energy siting (Masden and others, 2014). The uncertainty values were capped to stay within the 1–5 value categories. The uncertainties given for each metric and species are relative values generated for the purpose of this database and should not be interpreted as an absolute uncertainty value of vulnerability for the species or metric.

Table 3. Range of values for each metric based on their given level of uncertainty.

Metric value	Level of uncertainty Low (10 percent)	Medium (25 percent)	High (50 percent)
1	1.0–1.4	1–2	1–3
2	1.6–2.4	1–3	1–4
3	2.6–3.4	2–4	1–5
4	3.6–4.4	3–5	2–5
5	4.4–5.0	4–5	3–5

Population Vulnerability

The species evaluated in this database include widespread 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 collision with, or displacement by OWEI within the CCS. Six metrics were used to determine Population Vulnerability: global population size, annual occurrence in the CCS, proportion of the population present in the CCS, threat status, breeding score in the CCS, and annual adult survival. Using these six metrics to determine Population Vulnerability is similar to methods used by Garthe and Hüppop (2004), Furness and Wade (2012), and Furness and others (2013), Robinson Willmott and others (2013), and is depicted in equation 3:

$$\text{Population Vulnerability} = (POP \pm POPu) + (AO \times (CCSpop \pm CCSpopu)) + TS + (BR \times (AS \pm ASu)), \quad (3)$$

where,

POP = Global Population Size
CCSpop = Proportion of Species' Population in CCS
AO = Annual Occurrence in the CCS
TS = Threat Status
BR = Breeding Score
AS = Adult Survival
u = uncertainty (Global Population Size uncertainty, Proportion of Species Population in CCS uncertainty, and Adult Survival uncertainty).

POP, CCSpop, TS, and AS were each valued on a scale of 1–5. AS, and BR were valued on a scale of 1–2 and considered weighting factors for CCSpop and AS, respectively. If a species spends more time in the CCS annually (AO = 2), its CCSpop score was weighted more than a species that only spent a few months annually in the CCS (AO = 1). Similarly, if a species breeds within the CCS (BR = 2), its AS contribution to Population Vulnerability was weighted more than a species that does not breed in the CCS (BR = 1). We have scaled BR with AS recognizing that although long-term studies of seabirds reveal age-related changes in survival and reproduction, there remains the need for more information about individuals (like breeders) who contribute disproportionately to population growth (Wooller and others 1992). This method is based on the equation used by Robinson Willmott and others (2013) and was modified after peer review suggestions were considered. Each metric is explained below.

Global Population Size (POP)

American Bird Conservancy (2012) and Birdlife International (2014a) compile data from numerous sources and update their lists regularly. These references, along with other available sources, were used for population size estimates (appendix table A1). Estimates usually were given as a range. When multiple sources were used, all available values were included in the population range (table 4).

We assigned global population size (POP) values from 1 to 5 (Garthe and Hüppop, 2004; Robinson Willmott and others, 2013):

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.

Table 4. Values and uncertainties for each metric in the Population Vulnerability calculation and Population Vulnerability scores for all species.

[POP, Global Population; AO, Annual Occurrence; CCSpop, California Current Population; TS, Threat Status; BR, Breeding Score; AS, Adult Survival; BE, best-estimate value; *u*, uncertainty value (±)]

Common name	POP		AO	CCSpop		TS	BR	AS		Population Vulnerability		
	BE	*u*		BE	*u*			BE	*u*	Lower	Best	Upper
Brant	3.0	1.0	2.0	2.0	1.0	3.0	1.0	3.0	1.0	9.0	13.0	17.0
Common Merganser	2.0	0.4	1.5	1.0	2.0	1.0	1.5	1.0	2.0	5.6	6.0	12.4
Red-breasted Merganser	3.0	0.4	2.0	1.0	1.0	1.0	1.0	2.0	2.0	6.6	8.0	12.4
Harlequin Duck	4.0	0.4	1.5	2.0	2.0	3.0	1.0	4.0	2.0	10.1	14.0	18.4
Surf Scoter	3.0	2.0	2.0	3.0	1.0	1.0	1.0	2.0	2.0	7.0	12.0	18.0
White-winged Scoter	2.0	2.0	1.5	2.0	1.0	1.0	1.0	2.0	2.0	4.5	8.0	13.5
Black Scoter	3.0	1.0	1.5	2.0	1.0	2.0	1.0	2.0	2.0	6.5	10.0	14.5
Long-tailed Duck	1.0	0.4	1.5	1.0	2.0	3.0	1.0	1.0	1.0	6.5	6.5	10.9
Red-throated Loon	4.0	1.0	1.5	2.0	1.0	2.0	1.0	4.0	1.0	9.5	13.0	16.5
Pacific Loon	2.0	1.0	1.5	3.0	1.0	1.0	1.0	4.0	1.0	8.0	11.5	15.0
Common Loon	3.0	0.4	1.5	3.0	1.0	3.0	1.0	5.0	1.0	12.6	15.5	17.4
Yellow-billed Loon	5.0	0.4	2.0	2.0	1.0	2.0	1.0	5.0	1.0	12.6	16.0	18.0
Horned Grebe	3.0	2.0	2.0	1.0	1.0	3.0	1.0	1.0	2.0	7.0	9.0	15.0
Red-necked Grebe	4.0	0.4	1.5	2.0	1.0	2.0	1.0	1.0	2.0	8.1	10.0	13.9
Eared Grebe	1.0	0.4	2.0	2.0	1.0	1.0	1.0	1.0	2.0	5.0	7.0	11.4
Western Grebe	4.0	0.4	2.0	4.0	2.0	3.0	1.5	1.0	2.0	12.1	16.5	21.9
Clark’s Grebe	5.0	0.4	2.0	3.0	2.0	3.0	1.5	1.0	2.0	11.1	15.5	22.5
Laysan Albatross	2.0	0.4	2.0	1.0	0.4	3.0	1.0	5.0	0.4	11.2	12.0	13.2
Black-footed Albatross	4.0	0.4	1.5	3.0	2.0	3.0	1.0	5.0	2.0	11.1	16.5	19.9
Short-tailed Albatross	5.0	0.4	2.0	2.0	1.0	5.0	1.0	5.0	2.0	14.6	19.0	21.0
Northern Fulmar	1.0	0.4	2.0	2.0	1.0	1.0	1.0	5.0	0.4	8.6	11.0	13.4
Murphy’s Petrel	4.0	2.0	1.0	2.0	2.0	2.0	1.0	5.0	2.0	8.0	13.0	16.0
Mottled Petrel	2.0	0.4	1.5	2.0	1.0	2.0	1.0	5.0	2.0	8.1	12.0	13.9
Hawaiian Petrel	5.0	0.4	1.5	1.0	1.0	5.0	1.0	5.0	2.0	14.1	16.5	18.0
Cook’s Petrel	3.0	1.0	1.5	3.0	1.0	3.0	1.0	5.0	2.0	11.0	15.5	18.0
Pink-footed Shearwater	5.0	0.4	1.5	4.0	1.0	4.0	1.0	5.0	2.0	16.1	20.0	21.5
Flesh-footed Shearwater	3.0	0.4	1.5	1.0	2.0	3.0	1.0	5.0	2.0	10.1	12.5	15.9
Buller’s Shearwater	2.0	0.4	1.0	2.0	2.0	3.0	1.0	5.0	2.0	8.6	12.0	14.4
Sooty Shearwater	1.0	0.4	2.0	3.0	1.0	2.0	1.0	5.0	2.0	10.0	14.0	16.4
Short-tailed Shearwater	1.0	0.4	1.5	1.0	1.0	1.0	1.0	5.0	2.0	6.5	8.5	10.4
Manx Shearwater	3.0	1.0	2.0	1.0	2.0	1.0	1.0	5.0	0.4	9.6	11.0	16.0
Black-vented Shearwater	4.0	0.4	2.0	2.0	1.0	4.0	1.0	5.0	2.0	12.6	17.0	19.4
Wilson’s Storm-Petrel	1.0	0.4	1.5	1.0	2.0	1.0	1.0	4.0	1.0	6.5	7.5	11.9
Fork-tailed Storm-Petrel	1.0	1.0	1.0	1.0	0.4	3.0	1.5	4.0	2.0	8.0	11.0	13.9
Leach’s Storm-Petrel	1.0	0.4	1.0	2.0	1.0	1.0	2.0	4.0	2.0	7.0	12.0	15.4
Ashy Storm-Petrel	5.0	0.4	2.0	5.0	1.0	4.0	2.0	4.0	2.0	20.6	27.0	29.0
Black Storm-Petrel	3.0	1.0	1.5	1.0	0.4	3.0	1.5	4.0	2.0	9.5	13.5	16.6
Least Storm-Petrel	3.0	2.0	1.5	1.0	2.0	2.0	1.5	4.0	2.0	7.5	12.5	19.0

Common name	POP		AO	CCSpop		TS	BR	AS		Population Vulnerability		
	BE	*u*		BE	*u*			BE	*u*	Lower	Best	Upper
Brandt’s Cormorant	4.0	0.4	2.0	4.0	0.4	3.0	2.0	3.0	0.4	19.0	21.0	23.0
Double-crested Cormorant	2.0	0.4	2.0	2.0	0.4	1.0	2.0	4.0	1.0	11.8	15.0	18.2
Pelagic Cormorant	4.0	0.4	2.0	2.0	0.4	1.0	2.0	3.0	2.0	9.8	15.0	20.2
American White Pelican	4.0	0.4	2.0	3.0	2.0	5.0	1.0	3.0	2.0	11.6	18.0	24.4
Brown Pelican	4.0	1.0	2.0	3.0	1.0	5.0	1.5	5.0	1.0	18.0	22.5	25.5
Red-necked Phalarope	1.0	0.4	1.5	4.0	1.0	1.0	1.0	1.0	2.0	7.5	9.0	12.9
Red Phalarope	2.0	0.4	2.0	4.0	1.0	1.0	1.0	1.0	2.0	9.6	12.0	16.4
South Polar Skua	5.0	0.4	1.5	2.0	2.0	1.0	1.0	5.0	0.4	11.7	14.0	17.0
Pomarine Jaeger	2.0	2.0	1.5	2.0	1.0	1.0	1.0	3.0	2.0	4.5	9.0	14.5
Parasitic Jaeger	1.0	2.0	1.5	1.0	2.0	1.0	1.0	4.0	2.0	5.5	7.5	13.5
Long-tailed Jaeger	1.0	2.0	1.5	1.0	2.0	1.0	1.0	4.0	2.0	5.5	7.5	13.5
Common Murre	1.0	0.4	2.0	2.0	0.4	3.0	2.0	4.0	1.0	13.2	16.0	19.2
Pigeon Guillemot	4.0	0.4	2.0	2.0	0.4	1.0	2.0	4.0	2.0	11.8	17.0	20.2
Marbled Murrelet	3.0	1.0	2.0	2.0	1.0	5.0	2.0	4.0	1.0	15.0	20.0	25.0
Scripps’s Murrelet	5.0	0.4	2.0	2.0	0.4	4.0	1.5	4.0	2.0	14.8	19.0	21.3
Craveri’s Murrelet	5.0	0.4	1.0	2.0	2.0	4.0	1.0	4.0	2.0	11.6	15.0	18.0
Ancient Murrelet	2.0	0.4	1.0	3.0	2.0	1.0	2.0	2.0	1.0	5.6	10.0	14.4
Cassin’s Auklet	1.0	1.0	2.0	2.0	1.0	3.0	2.0	3.0	2.0	8.0	14.0	21.0
Parakeet Auklet	2.0	0.4	1.5	1.0	2.0	1.0	1.0	4.0	2.0	6.1	8.5	12.9
Rhinoceros Auklet	2.0	0.4	2.0	2.0	1.0	3.0	2.0	4.0	1.0	12.6	17.0	21.4
Horned Puffin	2.0	0.4	1.5	1.0	2.0	2.0	1.0	5.0	2.0	8.1	10.5	13.9
Tufted Puffin	1.0	1.0	1.5	2.0	1.0	5.0	2.0	5.0	2.0	13.5	19.0	21.5
Black-legged Kittiwake	1.0	0.4	1.5	2.0	0.4	1.0	1.0	4.0	2.0	6.4	9.0	11.0
Sabine’s Gull	3.0	0.4	1.5	2.0	0.4	1.0	1.0	3.0	2.0	7.0	10.0	13.0
Bonaparte’s Gull	4.0	1.0	2.0	4.0	2.0	1.0	1.0	3.0	2.0	9.0	16.0	21.0
Heermann’s Gull	3.0	0.4	2.0	3.0	2.0	2.0	1.0	3.0	2.0	7.6	14.0	20.4
Mew Gull	1.0	1.0	1.5	2.0	2.0	1.0	1.0	2.0	2.0	4.5	7.0	13.0
Ring-billed Gull	2.0	0.4	2.0	2.0	1.0	1.0	1.5	3.0	1.0	7.6	11.5	15.4
Western Gull	4.0	0.4	2.0	4.0	2.0	1.0	2.0	3.0	2.0	10.6	19.0	25.4
California Gull	3.0	0.4	2.0	3.0	1.0	1.0	1.5	3.0	2.0	9.1	14.5	19.9
Herring Gull	1.0	1.0	2.0	2.0	1.0	1.0	1.0	3.0	2.0	5.0	9.0	14.0
Thayer’s Gull	5.0	0.4	2.0	2.0	2.0	1.0	1.0	3.0	2.0	8.6	13.0	19.0
Glaucous-winged Gull	3.0	0.4	2.0	2.0	2.0	1.0	1.5	3.0	2.0	7.1	12.5	19.9
Least Tern	5.0	0.4	1.5	2.0	1.0	5.0	2.0	4.0	2.0	15.1	21.0	24.5
Gull-billed Tern	4.0	1.0	1.5	1.0	1.0	3.0	1.0	4.0	2.0	9.5	12.5	16.0
Caspian Tern	4.0	0.4	2.0	2.0	1.0	2.0	1.5	4.0	2.0	10.6	16.0	19.9
Black Tern	2.0	2.0	1.0	1.0	2.0	3.0	1.0	3.0	2.0	6.0	9.0	15.0
Common Tern	2.0	1.0	1.5	1.0	1.0	2.0	1.0	4.0	1.0	7.5	9.5	13.0
Arctic Tern	2.0	0.4	1.5	2.0	1.0	1.0	1.0	4.0	2.0	6.1	10.0	12.9
Forster’s Tern	4.0	0.4	2.0	2.0	0.4	1.0	1.5	4.0	2.0	10.8	15.0	17.7
Royal Tern	4.0	0.4	2.0	1.0	1.0	1.0	1.5	4.0	2.0	9.6	13.0	16.9
Elegant Tern	5.0	0.4	1.5	3.0	2.0	2.0	1.5	4.0	2.0	11.1	17.5	22.0
Black Skimmer	4.0	0.4	2.0	2.0	0.4	3.0	1.5	4.0	2.0	12.8	17.0	19.7

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 percent = Published values fall within a single category range.
25 percent = Published values fall within two category ranges, but the most current and (or) most literature supports the values of the chosen range. Or, published values fall within a single category range but literature sources are limited (less than three sources).
50 percent = Published values varies between three or more category ranges, but the most current and (or) most literature supports the values within the chosen range. Or, published values fall within one or two category ranges and literature sources are limited (less than three sources).

Proportion of Population in CCS (CCSpop)

For most species, estimates of local population sizes were determined using at-sea surveys for California, Oregon, and Washington following Briggs and others (1981, 1983, 1987, 1992). For some species, data on local population size from American Bird Conservancy (2012), Birdlife International (2014a), and other sources also were used (appendix table A3). Preference was given to more recently published sources, assuming that they provided the most current estimates for CCS population sizes. Some accounts for species that breed within the CCS region were estimates of breeding pairs and did not account for non-breeders or ‘floaters’. 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 (Sowls and others, 1980; Spear and Ainley, 2007; Carter and others, 2008). Spear and Ainley (2007) also estimated 49 percent of Leach’s Storm-Petrels (*Oceanodroma leucorhoa*) at sea were juveniles; therefore, we multiplied the estimated numbers of breeding storm-petrels by 2 to include non-breeders. For Cassin’s auklets (*Ptychoramphus aleuticus*), Manuwal (1972) estimated a 70 percent floating population of non-breeders in addition to the breeding population on Southeast Farallon Island; therefore, an additional 70 percent 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. For some species (for example, Yellow-billed Loon and Laysan Albatross) no data exist to estimate local population size so an estimate was made based on the opinions of experts. The numerical values (1–5) were consistent with numerical values also used by Robinson Willmott and others (2013) and herein were based on the percent of the population present in the CCS (CCSpop):

1 = <1 percent
2 = 1–33 percent
3 = 34–66 percent
4 = 67–99 percent
5 = >99 percent

Also consistent with the methods of Robinson Willmott and others (2013), we based uncertainties on the variation among values found in different sources:

10 percent = Published values fall within a single category range.
25 percent = Published values fall within two category ranges, but the most current and (or) the most literature values fall within one category. Or, published values fall within a single category range but literature sources are minimal (less than three sources).
50 percent = Published values varies between three category ranges, but the most current and (or) the most literature supports the values within the chosen range. Or, published values fall within one or two category ranges and data are insufficient (less than three sources).

Annual Occurrence (AO) in the CCS

The total percentage of time a species spends in the CCS (foraging, migrating, resting, breeding, etc.) each year will influence the amount of time individuals would be vulnerable to colliding with OWEI in the area. Migratory seabirds and certain far-ranging marine birds from outside the CCS only are present in the CCS for part of the year (for example, Pink-footed Shearwater [*Puffinus creatopus*], Black-footed Albatross [*P. nigripes*], Pacific Loon [*Gavia pacifica*]). Other species breed in the CCS and are present year round (for example, Ashy Storm-Petrel [*Oceanodroma homochroa*], Western Gull [*Larus occidentalis],* and Scripps's Murrelet [*Synthliboramphus scrippsi*]). This variation in annual occurrence contributes to the proportion of time a species is in the CCS (just as CCSpop reflects the proportion of individuals found in the CCS).

We estimated the number of months per year (Annual Occurrence, AO) that each species resided within the CCS to calculate Population Vulnerability. Annual Occurrence data were derived from Briggs' aerial seabird surveys (Briggs and others, 1981, 1983, 1987, 1992), USGS aerial surveys off southern California (Mason and others 2007), recent USGS PaCSEA surveys off northern California, Oregon, and southern Washington (Adams and others, 2014), eBird sightings, and other sources (appendix table A2). For some migratory species, timing of migration is not well known and (or) varies interannually; therefore, we used a conservative estimate for AO, from when the first migrants arrive in the CCS, until the last migrants are reported to leave the CCS. Although this may give an overestimation of AO for some species, this range accounts for inter-annual variation in migratory timing. When using eBird sightings, we did not count anomalous sightings during times of year when the species is not typically found in the CCS, with exceptions made for species that are always rare in the CCS (for example, Short-tailed Albatross [*P. albatrus*] and Manx Shearwater [*P. puffinus*]); for these species, all sightings were counted. To account for these uncertainties and interannual variation, we binned the AO into three values:

1.0 = 1–4 months in the CCS each year
1.5 = 5–8 months in the CCS each year
2.0 = 9–12 months in the CCS each year.

We considered AO to be a weighting factor (multiplied with CCSpop) in our calculation of Population Vulnerability.

Threat Status (TS)

The International Union for Conservation of Nature (IUCN) species threat status (International Union for Conservation of Nature, 2014) and the U.S. Fish and Wildlife national threat status lists (U.S. Fish and Wildlife, 2008, 2014) were used to determine the Threat Status (TS) values for each species. Where available, threat status values from USFWS Birds of Conservation Concern (U.S. Fish and Wildlife, 2012), California Endangered Species Act (California Department of Fish and Wildlife, 2015), California Department of Fish and Wildlife Bird Species of Special Concern list (BSSC; Shuford and Gardali, 2008), Oregon Department of Fish and Wildlife (2014), and Washington Department of Fish and Wildlife State Sensitive Species and State Candidate Species (2015) also were evaluated (appendix table A4).

Threat Status values are as follows:

International Union for Conservation of Nature (International Union for Conservation of Nature, 2014):

1 = Least Concern
2 = Near-Threatened
3 = Vulnerable
4 = Endangered
5 = Critical

U.S. Fish and Wildlife Service national threat status list (U.S. Fish and Wildlife Service, 2014) and Birds of Conservation Concern (U.S. Fish and Wildlife Service, 2008):

1 = No Ranking
2 = Petitioned/Pacific Region (Bird of Conservation Concern [BCC], U.S. Fish and Wildlife Service, 2005)
3 = Candidate Species
4 = Threatened
5 = Endangered

California Endangered Species Act (California Department of Fish and Wildlife, 2015) and Bird Species of Special Concern (BSSC, Shuford and Gardali, 2008):

1 = No Ranking
2 = Bird Species of Special Concern (BSSC), "*Taxa to Watch*"
3 = Bird Species of Special Concern (BSSC)
4 = Threatened Species
5 = Endangered Species

Oregon Department of Fish and Wildlife Sensitive, Threatened, or Endangered Species (Oregon Department of Fish and Wildlife, 2014):

1 = No Ranking
2 = Vulnerable Sensitive Species
3 = Critical Sensitive Species
4 = Threatened Species
5 = Endangered Species

Washington Department of Fish and Wildlife (2015) State Sensitive Species and State Candidate Species):

1 = Monitored Species
2 = Sensitive Species
3 = Candidate Species
4 = Threatened Species
5 = Endangered Species

From these five sources, the greatest TS value was chosen for each species (appendix table A4). Specifically, for species that migrate through the CCS but breed in another country, we considered TS values from all countries where the species' threat status was assessed (for example, Canada, Mexico, Chile, New Zealand, and Japan); the greatest value was chosen to calculate Population Vulnerability. For example, the Pink-footed Shearwater breeds on three small islands off the coast of Chile and a proportion of the adult population winters in the northern Pacific off Mexico, the United States, and Canada. The Pink-footed Shearwater is given the lowest threat status value (TS = 1) by USFWS, California, Oregon, and Washington. It is listed as Vulnerable by the IUCN and the Canadian government (TS = 3), and as Special Protection by the Mexican government (TS = 2) (Committee on the Status of Endangered Wildlife in Canada, 2004; Ministerio del Medio Ambiente, 2012; International Union for Conservation of Nature, 2014). However, in Chile, where the shearwaters breed, they are considered Endangered (TS = 4, Flores, 2010). Therefore, we gave the Pink-footed Shearwaters a TS value of 4 (Endangered). This method established a TS value based on the geographical and ecological scope considered relevant to the species, as opposed to one based on a status constrained by geopolitical boundaries (Hyrenbach and others, 2000; Nevins and others, 2009).

All species were evaluated on a case-by-case basis to determine the most appropriate method for assigning a TS value. For example, the Leach's Storm-Petrel has three subspecies identified in Mexico (Flores, 2010). Two of these subspecies are listed as Threatened (TS = 3) and one subspecies is Endangered (TS = 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 TS in the CCS; therefore, we consider Leach's Storm-Petrel at a greater threat status value (TS = 3, Threatened) than indicated by IUCN (TS = 1) and USFWS (TS = 2).

Breeding Score (BR)

Because mortality factors that affect adult breeders have disproportionate effects on intrinsic population growth, the potential population vulnerability for a bird that is foraging to feed its young is exacerbated for multiple reasons. First, if a collision is fatal to the adult incubating or chick-rearing bird, it will likely also be fatal to its eggs or young. Second, disruption of long-term, effective pair-bonds in adult breeding seabirds can have negative effects on reproductive output (Bradley and others, 1990; Mills and Ryan; 2005; Sanchez-Macouzet and others, 2014). Lastly, during chick rearing, breeding birds can conduct multiple foraging trips per day, which would increase their potential vulnerability to collision and displacement. Therefore, we incorporated Breeding Score (BR) into Population Vulnerability as a weighting factor for the Adult Survival (AS) metric. If a species forages to feed its young in the CCS, its BR counts for twice as much as a nonbreeding bird (appendix table A5). We considered the likelihood that each species breeds and forages to raise young in the CCS and ascribed a Breeding Score following Robinson Willmott and others (2013):

1.0 = 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
2.0 = Species is known to regularly forage to feed young in the CCS.

Adult Survival (AS)

Adult annual survival rate is indicative of life history characteristics among birds (Saether and others, 1996). Species with greater survival rates will be more impacted by mortality due to collisions with wind farms (Desholm, 2009). We reviewed annual adult survival rates for each species. When multiple rates were available for a given species, the most recent and (or) the most locally relevant data were used (appendix table A6). In the cases where no survival rate or other life history information were available for a species, survival rate data from a similar species was used. Uncertainty in adult survival values also was evaluated. Our classifications of Adult Survival (AS) values and uncertainty ranges are consistent with Robinson Willmott and others (2013):

1 = <0.75
2 = 0.75–0.80
3 = 0.81–0.85
4 = 0.86–0.90
5 = >0.90

The level of uncertainty in the Adult Survival values was determined by the range of reported values and how well they fit into the 1–5 categories:

10 percent = Variation of published values fall within one category range.
25 percent = Variation of published values fall within two categories with the most current and (or) most data supporting the chosen category. Or, published values fall within one category but are not well supported in the literature (less than three sources).
50 percent = Variation of published values fall within three or more categories with the most current and (or) the most data supporting the chosen category, published values fall within one or two categories but are not well supported in the literature (less than three sources), or values are based on data from similar species.

Collision Vulnerability

Wind turbine/bird-collision-risk modeling has been used to assess the probability that birds will collide with wind turbines. These collision-risk models can be complex and incorporate detailed flight characteristics, bird morphology, visual and radar observations, landscape features, turbine dimensions, and other factors. Some collision risk models are site-specific (for example, Villegas-Patraca and others, 2014), whereas others may be applied to a variety of locations (Tucker, 1996; Desholm and Kahlert, 2005; Band, 2012; Cook and others, 2012; Johnston and others, 2014). Some factors commonly used in collision-risk modeling (for example, site-specific turbine characteristics) were outside the scope of inclusion in our study; therefore, we selected metrics to calculate Collision Vulnerability that were based on the most common ecological factors used in collision-risk modeling.

The ability of a bird to maneuver around a wind turbine (that is, 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; Blew and others, 2008; Desholm, 2009; Krijgsveld and others, 2009; Krijgsveld and others, 2011; Cook and others, 2012; Plonczkier and Simms, 2012; Vanermen and others, 2013; Cook and others, 2014). There have been two recognized types of avoidance behavior by birds: macro-avoidance and micro-avoidance. Macro-avoidance refers to a bird’s ability to change its flight course to entirely avoid entering a wind farm area. Micro-avoidance refers to acute maneuvering required to avoid collision while flying through a wind energy area (Band, 2012; Cook and others, 2012). Micro-avoidance could also be described as “within wind farm avoidance,” which incorporates last-minute instantaneous maneuvers performed by birds to avoid turbine blades (also termed micro-avoidance by Cook and others, 2014) and more general avoidance measures taken by birds once they are already flying through the wind energy area (termed meso-avoidance by Cook and others, 2014).

Unlike similar vulnerability analyses by Garthe and Hüppop (2004), Furness and Wade (2012), and Furness and others (2013), we did not use micro-avoidance as a separate metric to calculate Collision Vulnerability. The reasons for this decision are explained below.

Garthe and Hüppop (2004), Furness and Wade (2012), and Furness and others (2013) used a subjective value of in-flight maneuverability to estimate micro-avoidance at OWEI. However, recent studies have shown that maneuverability is not directly correlated with micro-avoidance 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; Janss, 2000; de Lucas and others, 2004; Herrera-Alsina and others, 2013; Marques and others, 2014), these correlations also depended on weather and topography. For example, vultures (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 Rodríguez, 2004; de Lucas and others, 2008). Herrera-Alsina and others (2013) found that although passerine species with greater wing loading were more likely to fly through the rotor sweep zone (RSZ), smaller birds with lesser wing loading were more likely to collide with turbines. Herrera-Alsina and others (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 varied with flight style, morphology, habitat utilization, and time of year (Peterson and others, 2006; Band, 2012; Furness and Wade, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Marques and others, 2014; Villegas-Patraca and others, 2014).

In their study observing Pink-footed Geese (*Anser brachyrhynchus*) using radar at Lynn and Inner Dowsing Wind Farms, Plonczkier and Simms (2012) found that greater than 90 percent of geese that flew through the OWEI area showed micro-avoidance behavior by flying higher than the RSZ. Radar results from Peterson and others (2006) indicated when birds flew into the wind farm area, they changed direction to exit as quickly as possible. Similarly, very few birds were observed flying among the wind turbines at Nysted and Horns Rev Wind Farms, and only 7 percent of birds seen flying in the wind farm area flew within the RSZ (Krijgsveld and others, 2011). Based on these studies, during the day and with observable conditions, micro-avoidance behavior for most species at OWEI sites was near 100 percent.

Based on the results of the studies described above, we recognize that micro-avoidance can vary among 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 therefore not yet incorporated micro-avoidance in our estimation of Collision Vulnerability.

Species-specific flight heights also are important for estimating Collision Vulnerability. Data on flight heights were limited in previous collision vulnerability assessments at OWEI sites (Garthe and Hüppop, 2004; Desholm, 2009; Furness and Wade, 2012; Furness and others, 2013; Robinson Willmott and others, 2013). Recent studies using different survey methods (for example, boat surveys prior to wind farm construction, data recorded by GPS and radar, and platform observations at completed OWEI sites) have improved our understanding of flight-height (Cook and others, 2012; Bradbury and others, 2014; Corman and Garthe, 2014; Ainley and others, 2015).

We used diurnal and nocturnal flight activity, flight height (defined as time spent in rotor sweep zone), and macro-avoidance to calculate Collision Vulnerability. Collision Vulnerability (eq. 4) is modified from the equations used by Furness and Wade (2012), Furness and others (2013), Garthe and Hüppop (2004), and Robinson Willmott and others (2013):

$$\text{Collision Vulnerability} = \frac{(2 \times NFA \pm NFAu) + (DFA \pm DFAu)}{3} + (RSZt \pm RSZtu) + (MA \pm MAu), \quad (4)$$

where,

NFA = Nocturnal Flight Activity
DFA = Diurnal Flight Activity
RSZt = Percent time spent in Rotor Sweep Zone
MA = Macro-Avoidance
u = uncertainty (Nocturnal and Diurnal Flight Activity uncertainty, Percent time spent in Rotor Sweep Zone uncertainty, and Macro-avoidance uncertainty).

All Collision Vulnerability metrics are described below.

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 and others, 2009; Band, 2012; Marques and others, 2014). In addition, OWEI avoidance behavior can differ during day and night time periods for some bird species (Desholm and Kahlert, 2005; Peterson and others, 2006). We included Nocturnal Flight Activity (NFA) and Diurnal Flight Activity (DFA) into our estimation of Collision Vulnerability. To quantify flight activity, we calculated the weighted average of NFA and DFA, such that NFA carried twice the weight as DFA because we assumed birds face greater collision risk when flying at night (Marques and others, 2014; Hüppop and others, 2016).

Certain marine birds (for example, loons, grebes, and scoters) are less likely to migrate through the CCS at night or during periods of inclement weather (Peterson and others, 2006). Other marine bird species will sustain flight during migration and spend minimal, or no, time resting on the water or foraging (del Hoyo and others, 1992). We used information from the Birds of North America accounts, previous OWEI vulnerability assessments (Garthe and Hüppop, 2004; Furness and Wade, 2012; Furness and others, 2013; Robinson Willmott and others, 2013), and additional sources to estimate the percentage of time each species spends in flight during day and night periods (appendix table A7). Some species (for example, some alcids and pelicans) return to their nest and roosting sites during crepuscular periods (del Hoyo and others, 1996). Because visibility of obstacles while in flight during crepuscular periods is more comparable to nighttime visibility than to daytime visibility (Stienen and others, 2007), we included crepuscular periods as nighttime for the purpose of this metric.

Data on nocturnal and diurnal flight activity were 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 Robinson Willmott and others (2013) and represent equal intervals between 0 and 100 percent time spent flying at day or night:

1 = 0–20 percent
2 = 21–40 percent
3 = 41–60 percent
4 = 61–80 percent
5 = 81–100 percent

The NFA and DFA categories represent a range of values; therefore, we interpreted uncertainty (NFA*u* and DFA*u*) as follows:

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

25 percent = Published values fall within two category range with the most current and (or) the most values within one category and (or) published values are insufficient (less than three sources).

50 percent = Published values fall within more than two category ranges with the most current and (or) the most values within one category, published values are insufficient (less than three sources), or no data are available for this species so values are based on similar species values.

Percentage of Time in Rotor Sweep Zone (RSZt)

The amount of time a bird spends flying at the same height as the sweeping zone of the turbine blades will influence its probability of collision. We evaluated new data on flight heights among seabirds in the UK (Bradbury and others, 2014) and in the eastern Pacific (Ainley and others, 2015) to inform our estimations of the percentage of time each species spends flying at the height of the rotor sweep zone (RSZt; appendix table A8). Previous work has set the lower limit of the RSZ at 20 m, but more recently published work (Ainley and others, 2015) set the lower RSZ limit at 10 m for their analysis which included seabirds in the CCS. We defined the RSZ as 10–200 m above the ocean to accommodate information from all studies. Even with recently published values, we found much variation in reported flight-height values, especially for birds that spend more than 20 percent of their time in the RSZ. For example, presented below are published values for the amount of time that Herring Gulls (*L. smithsonianus*) spend flying within the RSZ height (10–200 m above the water):

48 percent	- Ainley and others, 2015
28 percent	- Cook and others, 2012
35 percent	- Furness and others, 2013
20 percent	- Johnston and others, 2014
35 percent	- Bradbury and others, 2014
13–50 percent	- Robinson Willmott and others, 2013

To best accommodate the large variability in estimates of percentage of time spent in the RSZ, we binned RSZt values into three categories (instead of 5). To keep the range of metric values between 1 and 5, the bin values were set at 1, 3, and 5 (similar to Robinson Willmott and others, 2013):

5 = >20 percent
3 = 5–20 percent
1 = <5 percent

The RSZt categories represent a range of values; therefore, we interpreted uncertainty (RSZt*u*) as follows:

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

25 percent = Published values fall within two category ranges with the most current and (or) the most values within one category range and (or) data fall within one category range but are only represented by a few sources (less than three sources).

50 percent = Published values fall within two or more category ranges with the most current and (or) the most values within one category range, data are insufficient (less than three sources), or are based on data from similar species.

Macro-Avoidance (MA)

Post-construction analyses of the effects of OWEI on some bird species have increased our knowledge regarding seabird avoidance (Desholm and Kahlert, 2005; Peterson and others, 2006; Larsen and Guillemette, 2007; Blew and others, 2008; Desholm, 2009; Krijgsveld and others, 2009; Krijgsveld and others, 2011; Cook and others, 2012; Plonczkier and Simms, 2012; Vanermen and others, 2013; Cook and others, 2014). We reviewed macro-avoidance data collected from visual and radar observations at existing OWEI sites to determine Macro-Avoidance (MA) for target species, or where data were not available, for ecologically equivalent or similar species in the CCS (appendix table A9).

In addition to avoidance, there exists concern that some species may be attracted to OWEI for roosting or foraging. Shearwaters, fulmars, and storm-petrels have been found to be attracted to increased prey availability associated with oil rigs (Baird, 1990; Burke and others, 2012). Gulls, cormorants, loons, and pelicans have been observed using roosting habitat provided by oil and gas rigs (Ronconi and others, 2014). Studies also indicate that alcids, shearwaters, storm-petrels, and seaducks can be attracted to oil and gas platform lighting at night (Wiese and others, 2001; Burke and others, 2012; Ronconi and others, 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 OWEI when turbines were turned off (Peterson and others, 2006; Vanermen and others, 2013, 2014). Gulls, terns, and cormorants could be attracted to OWEI for roosting, to engage in central-place foraging, or to facilitate foraging associated with 'artificial reef' effects created by turbine pilings or other underwater infrastructure (Peterson and others, 2006; Vanermen and others, 2013, 2014). Within the CCS, gulls (primarily Western Gull) comprised 90 percent of the species attracted to oil rig lighting in the Santa Barbara Channel off southern California (Hamer and others, 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 OWEI (Cook and others, 2012; Marques and others, 2014; Vanermen and others, 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 Macro-Avoidance.

We estimated MA as a percentage and assigned a range of scores (1–5) corresponding to OWEI avoidance. Greater MA indicates lower risk of collision (consistent with Robinson Willmott and others, 2013); therefore, for calculating Collision Vulnerability, greater avoidance was given a lesser value:

1 = >40 percent avoidance
2 = 30–40 percent avoidance
3 = 18–29 percent avoidance
4 = 6–17 percent avoidance
5 = 0–5 percent avoidance

For species considered with potential to be attracted to OWEI, their MA scores were increased by one. With increasing post-construction studies at OWEI in Europe, we reviewed and incorporated data from more studies on macro-avoidance than previously were available (Garthe and Hüppop, 2004; Furness and Wade, 2012; Furness and others, 2013); however, there still exists much uncertainty when estimating macro-avoidance. Macro-Avoidance uncertainty ranges (MA*u*) were similar to Robinson Willmott and others (2013):

10 percent = Published values fall within a single category range, and data are from multiple sources.
25 percent = Published values are within two category ranges with the most current and (or) the most values within one category range and (or) data are not well supported in the literature (less than three sources).
50 percent = Published values fall within two or more category ranges with the most current and (or) the most values within one category range, are largely variable in published literature only (less than three sources), or are based on data from similar species.

Population Collision Vulnerability (PCV)

To create a *Population Collision Vulnerability* (PCV, eq. 1) score, we multiplied Collision Vulnerability (eq. 4, table 5) by Population Vulnerability (eq. 3, table 4) for each species. *Population Collision Vulnerability* represents a combined Collision Vulnerability score that accounts for the species' Population Vulnerability 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.

Table 5. Values and uncertainties for each metric in the Collision Vulnerability calculation and Collision Vulnerability scores for all species.

[NFA, Nocturnal Flight Activity; DFA, Diurnal Flight Activity; Weighed Flight Activity, weighted average of NFA and DFA; RSZt, percent time spent in Rotor Sweep Zone; MA, Macro-Avoidance; *u*, uncertainty value (±)]

Common name	NFA		DFA		Weighted Flight Activity			RSZt		MA		Collision Vulnerability		
	BE	*u*	BE	*u*	Lower	Best	Upper	BE	*u*	BE	*u*	Lower	Best	Upper
Brant	1.0	2.0	1.0	2.0	1.0	1.0	3.0	5.0	1.0	1.0	1.0	6.0	7.0	10.0
Common Merganser	1.0	1.0	1.0	1.0	1.0	1.0	2.0	5.0	2.0	2.0	2.0	5.0	8.0	11.0
Red-breasted Merganser	1.0	0.4	1.0	0.4	1.0	1.0	1.4	5.0	2.0	2.0	2.0	5.0	8.0	10.4
Harlequin Duck	5.0	2.0	5.0	2.0	3.0	5.0	5.0	1.0	2.0	1.0	1.0	5.0	7.0	10.0
Surf Scoter	3.0	1.0	3.0	2.0	1.7	3.0	4.3	3.0	2.0	1.0	1.0	3.7	7.0	11.3
White-winged Scoter	3.0	1.0	3.0	1.0	2.0	3.0	4.0	3.0	2.0	1.0	1.0	4.0	7.0	11.0
Black Scoter	3.0	2.0	3.0	2.0	1.0	3.0	5.0	3.0	1.0	1.0	1.0	4.0	7.0	11.0
Long-tailed Duck	4.0	2.0	3.0	1.0	2.0	3.7	4.7	1.0	1.0	1.0	1.0	4.0	5.7	8.7
Red-throated Loon	1.0	1.0	2.0	1.0	1.0	1.3	2.3	3.0	2.0	1.0	0.4	3.0	5.3	8.7
Pacific Loon	1.0	2.0	3.0	2.0	1.0	1.7	3.7	1.0	2.0	1.0	0.4	3.0	3.7	8.1
Common Loon	1.0	2.0	2.0	2.0	1.0	1.3	3.3	1.0	2.0	1.0	0.4	3.0	3.3	7.7
Yellow-billed Loon	1.0	2.0	2.0	2.0	1.0	1.3	3.3	1.0	2.0	1.0	0.4	3.0	3.3	7.7
Horned Grebe	3.0	2.0	2.0	2.0	1.0	2.7	4.7	3.0	2.0	1.0	2.0	3.0	6.7	12.7
Red-necked Grebe	3.0	2.0	1.0	2.0	1.0	2.3	4.3	3.0	2.0	1.0	2.0	3.0	6.3	12.3
Eared Grebe	3.0	2.0	1.0	2.0	1.0	2.3	4.3	3.0	2.0	1.0	2.0	3.0	6.3	12.3
Western Grebe	3.0	2.0	1.0	2.0	1.0	2.3	4.3	3.0	2.0	1.0	2.0	3.0	6.3	12.3
Clark's Grebe	3.0	2.0	1.0	2.0	1.0	2.3	4.3	3.0	2.0	1.0	2.0	3.0	6.3	12.3
Laysan Albatross	4.0	1.0	4.0	2.0	2.7	4.0	5.0	3.0	2.0	1.0	2.0	4.7	8.0	13.0
Black-footed Albatross	4.0	1.0	4.0	2.0	2.7	4.0	5.0	3.0	2.0	1.0	2.0	4.7	8.0	13.0
Short-tailed Albatross	3.0	2.0	4.0	2.0	1.3	3.3	5.0	3.0	2.0	1.0	2.0	3.3	7.3	13.0

Common name	NFA		DFA		Weighted Flight Activity			RSZt		MA		Collision Vulnerability		
	BE	*u*	BE	*u*	Lower	Best	Upper	BE	*u*	BE	*u*	Lower	Best	Upper
Northern Fulmar	4.0	1.0	2.0	1.0	2.3	3.3	4.3	1.0	0.4	1.0	1.0	4.3	5.3	7.7
Murphy’s Petrel	5.0	2.0	5.0	2.0	3.0	5.0	5.0	1.0	2.0	1.0	1.0	5.0	7.0	10.0
Mottled Petrel	3.0	2.0	5.0	2.0	1.7	3.7	5.0	1.0	2.0	1.0	2.0	3.7	5.7	11.0
Hawaiian Petrel	3.0	2.0	5.0	2.0	1.7	3.7	5.0	1.0	2.0	1.0	2.0	3.7	5.7	11.0
Cook’s Petrel	4.0	2.0	5.0	2.0	2.3	4.3	5.0	1.0	2.0	1.0	2.0	4.3	6.3	11.0
Pink-footed Shearwater	3.0	2.0	3.0	2.0	1.0	3.0	5.0	1.0	2.0	1.0	2.0	3.0	5.0	11.0
Flesh-footed Shearwater	3.0	2.0	4.0	2.0	1.3	3.3	5.0	1.0	2.0	1.0	2.0	3.3	5.3	11.0
Buller’s Shearwater	3.0	2.0	3.0	2.0	1.0	3.0	5.0	1.0	2.0	1.0	2.0	3.0	5.0	11.0
Sooty Shearwater	3.0	1.0	3.0	1.0	2.0	3.0	4.0	1.0	0.4	1.0	1.0	4.0	5.0	7.4
Short-tailed Shearwater	3.0	2.0	3.0	2.0	1.0	3.0	5.0	1.0	2.0	1.0	2.0	3.0	5.0	11.0
Manx Shearwater	3.0	1.0	3.0	1.0	2.0	3.0	4.0	1.0	2.0	1.0	1.0	4.0	5.0	9.0
Black-vented Shearwater	3.0	2.0	3.0	2.0	1.0	3.0	5.0	1.0	2.0	1.0	2.0	3.0	5.0	11.0
Wilson’s Storm-Petrel	4.0	1.0	3.0	1.0	2.7	3.7	4.7	1.0	2.0	1.0	1.0	4.7	5.7	9.7
Fork-tailed Storm-Petrel	4.0	2.0	3.0	2.0	1.7	3.7	5.0	1.0	2.0	1.0	2.0	3.7	5.7	11.0
Leach’s Storm-Petrel	4.0	1.0	3.0	1.0	2.7	3.7	4.7	1.0	0.4	1.0	1.0	4.7	5.7	8.1
Ashy Storm-Petrel	4.0	2.0	3.0	2.0	1.7	3.7	5.0	1.0	2.0	1.0	2.0	3.7	5.7	11.0
Black Storm-Petrel	4.0	2.0	3.0	2.0	1.7	3.7	5.0	1.0	2.0	1.0	2.0	3.7	5.7	11.0
Least Storm-Petrel	4.0	1.0	3.0	1.0	2.7	3.7	4.7	1.0	2.0	1.0	2.0	4.7	5.7	10.7
Brandt’s Cormorant	1.0	2.0	3.0	2.0	1.0	1.7	3.7	3.0	1.0	3.0	2.0	4.0	7.7	12.7
Double-crested Cormorant	1.0	0.4	5.0	0.4	2.2	2.3	2.6	3.0	2.0	3.0	2.0	4.2	8.3	12.6
Pelagic Cormorant	1.0	2.0	3.0	2.0	1.0	1.7	3.7	3.0	1.0	3.0	2.0	4.0	7.7	12.7
American White Pelican	1.0	2.0	3.0	2.0	1.0	1.7	3.7	5.0	2.0	5.0	2.0	7.0	11.7	13.7
Brown Pelican	1.0	1.0	3.0	1.0	1.3	1.7	2.7	5.0	2.0	5.0	2.0	7.3	11.7	12.7
Red-necked Phalarope	2.0	2.0	3.0	2.0	1.0	2.3	4.3	1.0	2.0	3.0	2.0	3.0	6.3	12.3
Red Phalarope	3.0	2.0	3.0	2.0	1.0	3.0	5.0	1.0	2.0	3.0	2.0	3.0	7.0	13.0
South Polar Skua	1.0	2.0	4.0	2.0	1.3	2.0	3.7	5.0	2.0	5.0	2.0	7.3	12.0	13.7
Pomarine Jaeger	1.0	1.0	3.0	2.0	1.0	1.7	3.0	5.0	1.0	5.0	1.0	9.0	11.7	13.0
Parasitic Jaeger	1.0	2.0	5.0	2.0	1.7	2.3	3.7	5.0	1.0	5.0	1.0	9.7	12.3	13.7
Long-tailed Jaeger	1.0	1.0	5.0	1.0	2.0	2.3	3.0	5.0	1.0	5.0	1.0	10.0	12.3	13.0
Common Murre	2.0	2.0	1.0	2.0	1.0	1.7	3.7	1.0	2.0	1.0	0.4	3.0	3.7	8.1
Pigeon Guillemot	1.0	2.0	1.0	2.0	1.0	1.0	3.0	1.0	2.0	1.0	1.0	3.0	3.0	8.0
Marbled Murrelet	2.0	2.0	1.0	2.0	1.0	1.7	3.7	1.0	2.0	1.0	1.0	3.0	3.7	8.7
Scripps’s Murrelet	2.0	2.0	1.0	2.0	1.0	1.7	3.7	1.0	2.0	1.0	1.0	3.0	3.7	8.7
Craveris murrelet	2.0	2.0	1.0	2.0	1.0	1.7	3.7	1.0	2.0	1.0	1.0	3.0	3.7	8.7
Ancient Murrelet	2.0	2.0	1.0	2.0	1.0	1.7	3.7	1.0	2.0	1.0	1.0	3.0	3.7	8.7
Cassin’s Auklet	2.0	2.0	1.0	2.0	1.0	1.7	3.7	1.0	2.0	1.0	1.0	3.0	3.7	8.7
Parakeet Auklet	1.0	2.0	1.0	2.0	1.0	1.0	3.0	1.0	2.0	1.0	1.0	3.0	3.0	8.0
Rhinoceros Auklet	2.0	2.0	1.0	2.0	1.0	1.7	3.7	1.0	2.0	1.0	2.0	3.0	3.7	9.7
Horned Puffin	1.0	2.0	1.0	2.0	1.0	1.0	3.0	1.0	2.0	1.0	1.0	3.0	3.0	8.0
Tufted Puffin	1.0	2.0	1.0	2.0	1.0	1.0	3.0	1.0	2.0	1.0	1.0	3.0	3.0	8.0
Black-legged Kittiwake	3.0	1.0	3.0	1.0	2.0	3.0	4.0	5.0	1.0	1.0	2.0	7.0	9.0	12.0
Sabine’s Gull	2.0	2.0	3.0	2.0	1.0	2.3	4.3	5.0	1.0	2.0	2.0	6.0	9.3	13.3
Bonaparte’s Gull	2.0	2.0	3.0	2.0	1.0	2.3	4.3	5.0	1.0	2.0	2.0	6.0	9.3	13.3

Common name	NFA		DFA		Weighted Flight Activity			RSZt		MA		Collision Vulnerability		
	BE	*u*	BE	*u*	Lower	Best	Upper	BE	*u*	BE	*u*	Lower	Best	Upper
Heermann's Gull	2.0	2.0	3.0	2.0	1.0	2.3	4.3	5.0	1.0	2.0	2.0	6.0	9.3	13.3
Mew Gull	2.0	2.0	3.0	2.0	1.0	2.3	4.3	5.0	1.0	2.0	2.0	6.0	9.3	13.3
Ring-billed Gull	3.0	2.0	3.0	2.0	1.0	3.0	5.0	5.0	1.0	2.0	2.0	6.0	10.0	14.0
Western Gull	3.0	2.0	3.0	2.0	1.0	3.0	5.0	5.0	0.4	1.0	2.0	6.6	9.0	13.0
California Gull	2.0	2.0	3.0	2.0	1.0	2.3	4.3	5.0	1.0	2.0	2.0	6.0	9.3	13.3
Herring Gull	3.0	1.0	2.0	2.0	1.7	2.7	4.0	5.0	0.4	2.0	2.0	7.3	9.7	13.0
Thayer's Gull	2.0	2.0	3.0	2.0	1.0	2.3	4.3	5.0	0.4	2.0	2.0	6.6	9.3	13.3
Glaucous-winged Gull	3.0	2.0	3.0	2.0	1.0	3.0	5.0	5.0	0.4	1.0	2.0	6.6	9.0	13.0
Least Tern	1.0	2.0	5.0	2.0	1.7	2.3	3.7	5.0	1.0	1.0	2.0	6.7	8.3	11.7
Gull-billed Tern	5.0	0.4	5.0	0.4	4.6	5.0	5.0	5.0	2.0	1.0	2.0	8.6	11.0	13.0
Caspian Tern	5.0	0.4	5.0	0.4	4.6	5.0	5.0	5.0	2.0	1.0	2.0	8.6	11.0	13.0
Black Tern	1.0	1.0	5.0	1.0	2.0	2.3	3.0	5.0	2.0	1.0	2.0	6.0	8.3	11.0
Common Tern	5.0	2.0	5.0	1.0	3.3	5.0	5.0	5.0	2.0	1.0	2.0	7.3	11.0	13.0
Arctic Tern	5.0	2.0	5.0	1.0	3.3	5.0	5.0	5.0	2.0	1.0	2.0	7.3	11.0	13.0
Forster's Tern	5.0	1.0	5.0	1.0	4.0	5.0	5.0	5.0	2.0	1.0	2.0	8.0	11.0	13.0
Royal Tern	4.0	1.0	4.0	1.0	3.0	4.0	5.0	5.0	2.0	1.0	2.0	7.0	10.0	13.0
Elegant Tern	4.0	2.0	5.0	2.0	2.3	4.3	5.0	5.0	2.0	1.0	2.0	6.3	10.3	13.0
Black Skimmer	3.0	2.0	3.0	2.0	1.0	3.0	5.0	5.0	2.0	1.0	2.0	5.0	9.0	13.0

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 and others, 2006; Band, 2012; Bradbury and others, 2014; Cook and others, 2014). Displacement of birds from areas during the construction, operation, and maintenance of OWEI can have direct and indirect effects on species. Displacement vulnerability depends on how individuals of a species use the area. For example, are individuals self-foraging, foraging also for young, traveling along a migratory pathway, or commuting between their colonies and foraging areas?

Species with greater habitat flexibility (that is, ability to forage on diverse prey resources or occupy several habitats) are less likely to be affected by OWEI than species that forage on a specific prey type or in a specific habitat (Masden and others, 2010). Therefore, we incorporated Habitat Flexibility (HF) into our calculation of displacement vulnerability. The other metric that contributed to displacement vulnerability was Macro-Avoidance.

In previous vulnerability assessments, a disturbance metric was created based on seabird species' short-term disturbance behavior that resulted from boat and/or helicopter traffic (Garthe and Hüppop, 2004; Furness and Wade, 2012; Furness and others, 2013; Robinson Willmott and others, 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 (Peterson and others, 2006; Robinson Willmott and others, 2013; Cook and others, 2014; Vanermen and others, 2014). However, more recent studies have indicated that most species that are disturbed from OWEI sites during construction return to the area following wind energy infrastructure installation (Cook and others, 2014; Vanermen and others, 2014). Therefore, initial disturbance levels, as inferred from helicopter and boat disturbance, may not be an accurate representation of the long-term disturbance behavior displayed by species in response to OWEI construction, operation, and deconstruction. We believe data measuring actual avoidance or disturbance at OWEI sites should be incorporated into the assessment of macro-avoidance (see section, Macro-Avoidance), which we consider the most applicable indicator of short-term and long-term disturbance by OWEI areas for marine birds.

Our calculation of Displacement Vulnerability (eq. 5) was similar to Robinson Willmott and others (2013), however, '*Disturbance*' (which was used as a discrete metric by Robinson Willmott and others [2013]), was considered when we estimated Macro-Avoidance:

$$\text{Displacement Vulnerability} = (MA \pm MAu) + (HF \pm HFu) \quad (5)$$

where,

MA = Macro-Avoidance
HF = Habitat Flexibility
u = Uncertainty (Macro-Avoidance uncertainty and Habitat Flexibility uncertainty).

All metrics are explained below.

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 A9). In contrast with how this metric was used to calculate Collision Vulnerability (see section, Macro-Avoidance under Collision Vulnerability), for the Displacement Vulnerability, greater Macro-Avoidance indicates greater Displacement Vulnerability:

1 = 0–5 percent avoidance
2 = 6–17 percent avoidance
3 = 18–29 percent avoidance
4 = 30–40 percent avoidance
5 = >40 percent avoidance

Uncertainty in Macro-Avoidance values (MA*u*) was based on the availability of published values on foraging habitat and behavior, and discrepancies within the published literature:

10 percent = Published values fall within single category range, and values are consistent across multiple studies.
25 percent = Published values fall within two category ranges with the most current and (or) the most values within one category range and (or) sources are limited (less than three sources).
50 percent = Published values fall within two or more category ranges with the most current and (or) the most values within one category range, are highly variable throughout the literature, or are based on data from similar species only.

Habitat Flexibility (HF)

Seabirds exhibit varying degrees of habitat flexibility. Some species depend on specific prey in specific locations. For example, Elegant Tern (*Thalasseus elegans*) and Brown Pelican (*Pelecanus occidentalis*) feed primarily on northern anchovy (*Engraulis mordax*) and depend on the availability and location of anchovy schools for their survival and successful reproduction. Species with great habitat flexibility, such as some gulls, are generalists and will feed opportunistically where prey is available and abundant, but individuals can alter foraging strategies when conditions change (del Hoyo and others, 1996). We used accounts of feeding behavior from the Birds of North America species accounts, del Hoyo and others (1992; 1996) and other sources to determine Habitat Flexibility (HF) values (appendix table A10). Our HF values were based on similarly-scaled descriptions used by Furness and Wade (2012), Furness and others (2013), and Robinson Willmott and others (2013):

1 = Species uses a wide range of foraging habitats over a large area. Species is an opportunistic forager and has the ability to switch among prey types based on availability.
2–4 = Species shows some grade of behavior between 1 and 5.
5 = Species has very habitat- and prey-specific requirements and little flexibility in foraging range, foraging behavior, habitat selection, or diet.

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

10 percent = Consensus among data in all published literature sources.
25 percent = Inconsistent or conflicting reports in published literature sources (less than three sources).
50 percent = Little to no data available for species, assumptions are made based on similar species accounts.

Population Displacement Vulnerability (PDV)

To calculate *Population Displacement Vulnerability* (PDV) (eq. 2), we multiplied Displacement Vulnerability (eq. 5, table 6) by Population Vulnerability (eq. 3, table 4) for each species. *Population Displacement Vulnerability* is the Displacement Vulnerability adjusted for the species' Population Vulnerability in the CCS. To account for the uncertainty in the PDV scores, the upper Displacement Vulnerability uncertainty score and the upper Population Vulnerability uncertainty score were multiplied together, as were the lower Displacement Vulnerability uncertainty score and lower Population Vulnerability uncertainty score:

Population Displacement Vulnerability = Displacement Vulnerability × Population Vulnerability. [6]

Table 6. Values and uncertainties for each metric in the Displacement Vulnerability calculation and Displacement Vulnerability scores for all species.

[AO, Annual Occurrence; MA, Macro-Avoidance; HF, Habitat Flexibility; BR, Breeding Score; BE, best-estimate value; *u*, uncertainty value (±)]

Common name	MA		HF		Displacement Vulnerability		
	BE	*u*	BE	*u*	Lower	Best	Upper
Brant	5.0	1.0	4.0	2.0	6.0	9.0	10.0
Common Merganser	4.0	2.0	1.0	1.0	3.0	5.0	7.0
Red-breasted Merganser	4.0	2.0	1.0	2.0	3.0	5.0	8.0
Harlequin Duck	5.0	1.0	4.0	0.4	7.6	9.0	9.4
Surf Scoter	5.0	1.0	4.0	2.0	6.0	9.0	10.0
White-winged Scoter	5.0	1.0	3.0	2.0	5.0	8.0	10.0
Black Scoter	5.0	1.0	4.0	2.0	6.0	9.0	10.0
Long-tailed Duck	5.0	1.0	4.0	0.4	7.6	9.0	9.4
Red-throated Loon	5.0	0.4	4.0	0.4	8.2	9.0	9.4
Pacific Loon	5.0	0.4	4.0	2.0	6.6	9.0	10.0
Common Loon	5.0	0.4	4.0	0.4	8.2	9.0	9.4
Yellow-billed Loon	5.0	0.4	4.0	2.0	6.6	9.0	10.0
Horned Grebe	5.0	2.0	4.0	0.4	6.6	9.0	9.4
Red-necked Grebe	5.0	2.0	3.0	0.4	5.6	8.0	8.4
Eared Grebe	5.0	2.0	3.0	2.0	4.0	8.0	10.0
Western Grebe	5.0	2.0	3.0	2.0	4.0	8.0	10.0
Clark’s Grebe	5.0	2.0	3.0	2.0	4.0	8.0	10.0
Laysan Albatross	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Black-footed Albatross	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Short-tailed Albatross	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Northern Fulmar	5.0	1.0	1.0	0.4	5.0	6.0	6.4
Murphy’s Petrel	5.0	1.0	1.0	2.0	5.0	6.0	8.0
Mottled Petrel	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Hawaiian Petrel	5.0	2.0	3.0	2.0	4.0	8.0	10.0
Cook’s Petrel	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Pink-footed Shearwater	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Flesh-footed Shearwater	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Buller’s Shearwater	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Sooty Shearwater	5.0	1.0	1.0	0.4	5.0	6.0	6.4
Short-tailed Shearwater	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Manx Shearwater	5.0	1.0	1.0	0.4	5.0	6.0	6.4
Black-vented Shearwater	5.0	2.0	2.0	2.0	4.0	7.0	9.0
Wilson’s Storm-Petrel	5.0	1.0	1.0	2.0	5.0	6.0	8.0
Fork-tailed Storm-Petrel	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Leach’sStorm-Petrel	5.0	1.0	1.0	0.4	5.0	6.0	6.4
Ashy Storm-Petrel	5.0	2.0	2.0	2.0	4.0	7.0	9.0
Black Storm-Petrel	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Least Storm-Petrel	5.0	2.0	1.0	2.0	4.0	6.0	8.0
Brandt’s Cormorant	3.0	2.0	2.0	0.4	2.6	5.0	7.4

Common name	MA		HF		Displacement Vulnerability		
	BE	*u*	BE	*u*	Lower	Best	Upper
Double-crested Cormorant	3.0	2.0	2.0	0.4	2.6	5.0	7.4
Pelagic Cormorant	3.0	2.0	2.0	0.4	2.6	5.0	7.4
American White Pelican	1.0	2.0	4.0	2.0	3.0	5.0	8.0
Brown Pelican	1.0	2.0	4.0	2.0	3.0	5.0	8.0
Red-necked Phalarope	3.0	2.0	2.0	1.0	2.0	5.0	8.0
Red Phalarope	3.0	2.0	2.0	1.0	2.0	5.0	8.0
South Polar Skua	1.0	2.0	2.0	2.0	2.0	3.0	7.0
Pomarine Jaeger	1.0	1.0	2.0	2.0	2.0	3.0	6.0
Parasitic Jaeger	1.0	1.0	2.0	0.4	2.6	3.0	4.4
Long-tailed Jaeger	1.0	1.0	2.0	2.0	2.0	3.0	6.0
Common Murre	5.0	0.4	3.0	0.4	7.2	8.0	8.4
Pigeon Guillemot	5.0	1.0	3.0	1.0	6.0	8.0	9.0
Marbled Murrelet	5.0	1.0	3.0	1.0	6.0	8.0	9.0
Scripps’s Murrelet	5.0	1.0	4.0	1.0	7.0	9.0	10.0
Craveris murrelet	5.0	1.0	4.0	2.0	6.0	9.0	10.0
Ancient Murrelet	5.0	1.0	3.0	1.0	6.0	8.0	9.0
Cassin’s Auklet	5.0	1.0	3.0	1.0	6.0	8.0	9.0
Parakeet Auklet	5.0	1.0	2.0	1.0	5.0	7.0	8.0
Rhinoceros Auklet	5.0	2.0	3.0	1.0	5.0	8.0	9.0
Horned Puffin	5.0	1.0	3.0	1.0	6.0	8.0	9.0
Tufted Puffin	5.0	1.0	3.0	1.0	6.0	8.0	9.0
Black-legged Kittiwake	3.0	2.0	2.0	0.4	2.6	5.0	7.4
Sabine’s Gull	3.0	2.0	2.0	1.0	2.0	5.0	8.0
Bonaparte’s Gull	3.0	2.0	2.0	1.0	2.0	5.0	8.0
Heermann’s Gull	3.0	2.0	1.0	2.0	2.0	4.0	8.0
Mew Gull	3.0	2.0	1.0	2.0	2.0	4.0	8.0
Ring-billed Gull	3.0	2.0	1.0	2.0	2.0	4.0	8.0
Western Gull	3.0	2.0	1.0	0.4	2.0	4.0	6.4
California Gull	3.0	2.0	1.0	2.0	2.0	4.0	8.0
Herring Gull	3.0	2.0	1.0	0.4	2.0	4.0	6.4
Thayer’s Gull	3.0	2.0	1.0	2.0	2.0	4.0	8.0
Glaucous-winged Gull	3.0	2.0	1.0	1.0	2.0	4.0	7.0
Least Tern	5.0	2.0	3.0	2.0	4.0	8.0	10.0
Gull-billed Tern	5.0	2.0	2.0	2.0	4.0	7.0	9.0
Caspian Tern	5.0	2.0	3.0	2.0	4.0	8.0	10.0
Black Tern	5.0	2.0	3.0	1.0	5.0	8.0	9.0
Common Tern	5.0	2.0	3.0	0.4	5.6	8.0	8.4
Arctic Tern	5.0	2.0	3.0	0.4	5.6	8.0	8.4
Forster’s Tern	5.0	2.0	3.0	2.0	4.0	8.0	10.0
Royal Tern	5.0	2.0	3.0	2.0	4.0	8.0	10.0
Elegant Tern	5.0	2.0	4.0	2.0	5.0	9.0	10.0
Black Skimmer	5.0	2.0	4.0	2.0	5.0	9.0	10.0

Results

Overall, pelicans, terns, gulls, and cormorants had the greatest PCV scores (table 7, fig. 3). Brown Pelican had the greatest PCV score. PCV best-estimate scores were then ranked as ‘high’, ‘medium’, or ‘low’ vulnerability based on if they were in the bottom, middle, or top one-third of all scores, respectively (table 7). The scores and rankings 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 a given species.

For the Population Vulnerability, Collision Vulnerability, and Displacement Vulnerability values for each species, we identified ranges of uncertainty (the difference between the best value and the lower/upper uncertainty levels, without the value caps) and ranked them as ‘high’, ‘medium’, or ‘low’ based on if they were in the bottom, middle, or top third of all uncertainty scores respectively (table 8). Uncertainty ranges ranked as ‘high’ identify data gaps and help direct future research and necessary monitoring for species. The scores and rankings given for each species are relative values generated for the purpose of this database, and should be interpreted critically.

Overall, alcids, terns, and loons had the greatest PDV scores (table 7, fig. 3). Ashy Storm-Petrel had the greatest PDV score, mostly resulting from the multiplicative effect of its relatively high Population Vulnerability score, which incorporated its small global population size, Threat Status, and CCS endemism (table 4). PDV best-estimate scores were ranked as ‘high’, ‘medium’, or ‘low’ according to bottom, middle, or top third of all best-estimate scores (table 7). The scores and rankings given for each species are relative values generated for the purpose of this database, and should be interpreted critically.

Table 8 highlights the differences in uncertainty levels for Population, Collision, and Displacement Vulnerabilities. The species with ‘high’ uncertainty ranks for all vulnerability metrics (for example, Western Grebe [*Aechmophorus occidentalis*] and Clarks Grebe [*A. clarkii*]) highlight knowledge gaps that can be filled with future research and monitoring of these species. The species with ‘low’ uncertainty rankings for all vulnerability metrics (for example, Red-throated Loon [*Gavia stellata*] and Pacific Northern Fulmar [*Fulmarus glacialis rodgersii*]) highlight robust datasets and greater knowledge available for evaluating species-specific risk associated with OWEI.

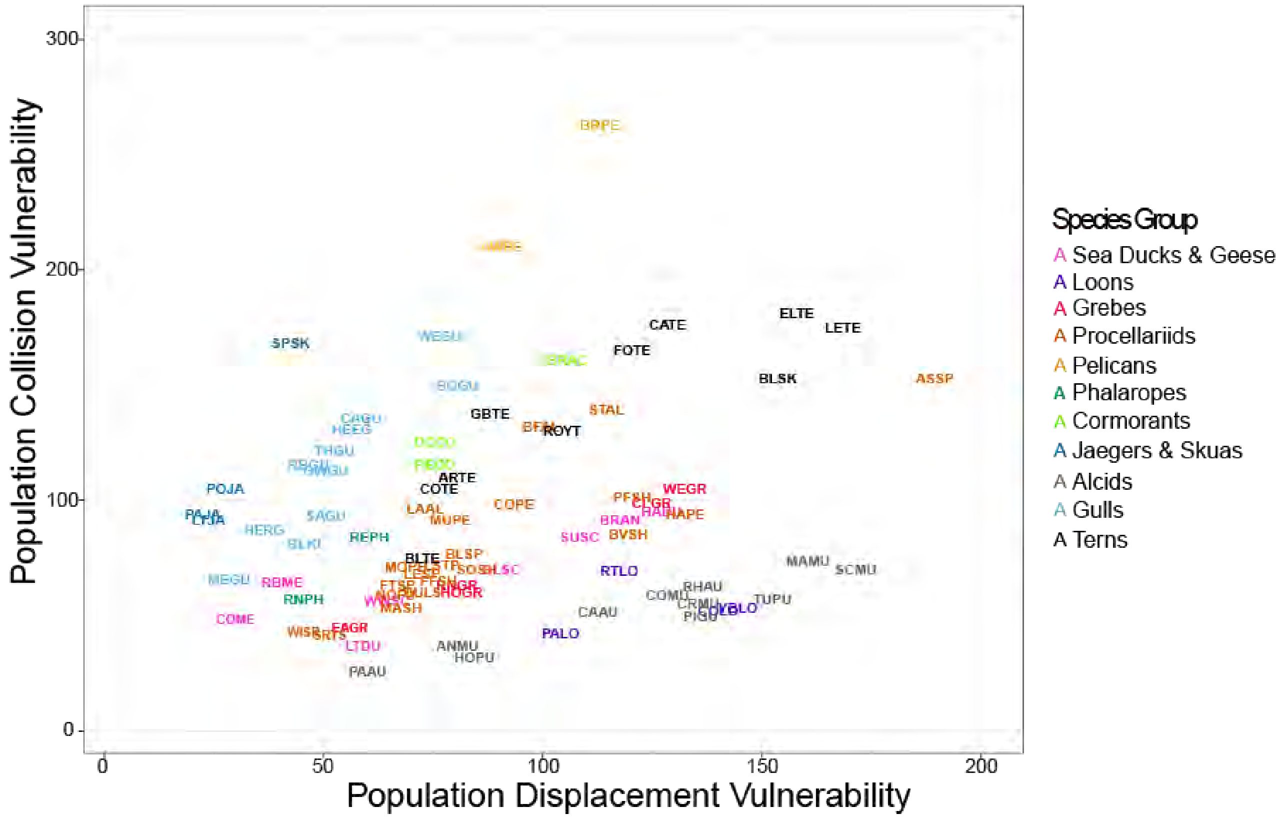

Figure 3. Population Collision Vulnerability (PCV) and Population Displacement Vulnerability (PDV) for all species. PCV and PDV values for each species are shown in table 7.

Table 7. 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; Lower = BE – *u***;** Upper = BE + *u* (*u* = uncertainty value). Species rankings: 'low' (bottom third in percent rank); 'medium' (middle third in percent rank); 'high' (top third in percent rank)]

Common name	PCV				PDV			
	Lower	BE	Upper	Rank	Lower	BE	Upper	Rank
Brant	54	91	170	MEDIUM	54	117	170	HIGH
Common Merganser	28	48	136	LOW	17	30	87	LOW
Red-breasted Merganser	33	64	129	LOW	20	40	99	LOW
Harlequin Duck	51	98	184	MEDIUM	77	126	173	HIGH
Surf Scoter	26	84	204	MEDIUM	42	108	180	HIGH
White-winged Scoter	18	56	149	LOW	23	64	135	LOW
Black Scoter	26	70	160	MEDIUM	39	90	145	MEDIUM
Long-tailed Duck	26	37	94	LOW	49	59	102	LOW
Red-throated Loon	29	69	144	MEDIUM	78	117	155	HIGH
Pacific Loon	24	42	121	LOW	53	104	150	MEDIUM
Common Loon	38	52	135	LOW	103	140	164	HIGH
Yellow-billed Loon	38	53	139	LOW	83	144	180	HIGH
Horned Grebe	21	60	190	LOW	46	81	141	MEDIUM
Red-necked Grebe	24	63	171	LOW	45	80	117	MEDIUM
Eared Grebe	15	44	141	LOW	20	56	114	LOW
Western Grebe	36	105	270	HIGH	48	132	219	HIGH
Clark's Grebe	33	98	278	MEDIUM	44	124	225	HIGH
Laysan Albatross	52	96	172	MEDIUM	45	72	106	LOW
Black-footed Albatross	52	132	259	HIGH	44	99	159	MEDIUM
Short-tailed Albatross	49	139	273	HIGH	58	114	168	HIGH
Northern Fulmar	37	59	104	LOW	43	66	86	LOW
Murphy's Petrel	40	91	160	MEDIUM	40	78	128	MEDIUM
Mottled Petrel	30	68	153	MEDIUM	32	72	111	LOW
Hawaiian Petrel	52	94	198	MEDIUM	56	132	180	HIGH
Cook's Petrel	48	98	198	MEDIUM	44	93	144	MEDIUM
Pink-footed Shearwater	48	100	237	MEDIUM	64	120	172	HIGH
Flesh-footed Shearwater	34	67	175	MEDIUM	40	75	127	MEDIUM
Buller's Shearwater	26	60	158	LOW	34	72	115	LOW
Sooty Shearwater	40	70	121	MEDIUM	50	84	105	MEDIUM
Short-tailed Shearwater	20	43	114	LOW	26	51	83	LOW
Manx Shearwater	38	55	144	LOW	48	66	102	LOW
Black-vented Shearwater	38	85	213	MEDIUM	50	119	175	HIGH
Wilson's Storm-Petrel	30	43	115	LOW	33	45	95	LOW
Fork-tailed Storm-Petrel	29	62	153	LOW	32	66	111	LOW
Leach's Storm-Petrel	33	68	124	MEDIUM	35	72	99	LOW
Ashy Storm-Petrel	76	153	319	HIGH	82	189	261	HIGH
Black Storm-Petrel	35	77	183	MEDIUM	38	81	133	MEDIUM
Least Storm-Petrel	35	71	203	MEDIUM	30	75	152	MEDIUM

Common name	PCV				PDV			
	Lower	BE	Upper	Rank	Lower	BE	Upper	Rank
Brandt’s Cormorant	76	161	291	HIGH	49	105	170	MEDIUM
Double-crested Cormorant	50	125	229	HIGH	31	75	135	MEDIUM
Pelagic Cormorant	39	115	256	HIGH	25	75	149	MEDIUM
American White Pelican	81	210	333	HIGH	35	90	195	MEDIUM
Brown Pelican	132	263	323	HIGH	54	113	204	HIGH
Red-necked Phalarope	23	57	159	LOW	15	45	103	LOW
Red Phalarope	29	84	213	MEDIUM	19	60	131	LOW
South Polar Skua	86	168	232	HIGH	23	42	119	LOW
Pomarine Jaeger	41	105	189	HIGH	9	27	87	LOW
Parasitic Jaeger	53	93	185	MEDIUM	14	23	59	LOW
Long-tailed Jaeger	55	93	176	MEDIUM	11	23	81	LOW
Common Murre	40	59	155	LOW	95	128	161	HIGH
Pigeon Guillemot	35	51	162	LOW	71	136	182	HIGH
Marbled Murrelet	45	73	217	MEDIUM	90	160	225	HIGH
Scripps’s Murrelet	44	70	185	MEDIUM	104	171	213	HIGH
Craveri’s murrelet	35	55	156	LOW	70	135	180	HIGH
Ancient Murrelet	17	37	125	LOW	34	80	130	MEDIUM
Cassin’s Auklet	24	51	182	LOW	48	112	189	HIGH
Parakeet Auklet	18	26	103	LOW	31	60	103	LOW
Rhinoceros Auklet	38	62	207	LOW	63	136	193	HIGH
Horned Puffin	24	32	111	LOW	49	84	125	MEDIUM
Tufted Puffin	41	57	172	LOW	81	152	194	HIGH
Black-legged Kittiwake	45	81	132	MEDIUM	17	45	81	LOW
Sabine’s Gull	42	93	173	MEDIUM	14	50	104	LOW
Bonaparte’s Gull	54	149	280	HIGH	18	80	168	MEDIUM
Heermann’s Gull	46	131	272	HIGH	15	56	163	LOW
Mew Gull	27	65	173	LOW	9	28	104	LOW
Ring-billed Gull	46	115	216	HIGH	15	46	123	LOW
Western Gull	70	171	330	HIGH	21	76	163	MEDIUM
California Gull	55	135	265	HIGH	18	58	159	LOW
Herring Gull	36	87	182	MEDIUM	10	36	90	LOW
Thayer’s Gull	57	121	253	HIGH	17	52	152	LOW
Glaucous-winged Gull	47	113	259	HIGH	14	50	139	LOW
Least Tern	101	175	286	HIGH	60	168	245	HIGH
Gull-billed Tern	82	138	208	HIGH	38	88	144	MEDIUM
Caspian Tern	91	176	259	HIGH	42	128	199	HIGH
Black Tern	36	75	165	MEDIUM	30	72	135	LOW
Common Tern	55	105	169	HIGH	42	76	109	MEDIUM
Arctic Tern	45	110	168	HIGH	34	80	108	MEDIUM
Forster’s Tern	86	165	230	HIGH	43	120	177	HIGH
Royal Tern	67	130	220	HIGH	38	104	169	MEDIUM
Elegant Tern	70	181	286	HIGH	56	158	220	HIGH
Black Skimmer	64	153	256	HIGH	64	153	197	HIGH

Table 8. Percent rank of cumulative vulnerability uncertainty ranges for each species.

[LOW = bottom third percent rank in uncertainty range for the vulnerability score; MEDIUM = middle third percent rank in uncertainty range for the vulnerability score; HIGH = top third percent rank in uncertainty range for the vulnerability score]

Common name	Population Vulnerability Uncertainty Rank	Collision Vulnerability Uncertainty Rank	Displacement Vulnerability Uncertainty Rank
Brant	MEDIUM	LOW	MEDIUM
Common Merganser	HIGH	LOW	LOW
Red-breasted Merganser	MEDIUM	LOW	MEDIUM
Harlequin Duck	MEDIUM	LOW	LOW
Surf Scoter	HIGH	MEDIUM	MEDIUM
White-winged Scoter	HIGH	MEDIUM	MEDIUM
Black Scoter	MEDIUM	MEDIUM	MEDIUM
Long-tailed Duck	MEDIUM	LOW	LOW
Red-throated Loon	LOW	LOW	LOW
Pacific Loon	LOW	MEDIUM	MEDIUM
Common Loon	LOW	MEDIUM	LOW
Yellow-billed Loon	LOW	MEDIUM	MEDIUM
Horned Grebe	HIGH	HIGH	MEDIUM
Red-necked Grebe	LOW	HIGH	MEDIUM
Eared Grebe	MEDIUM	HIGH	HIGH
Western Grebe	HIGH	HIGH	HIGH
Clark’s Grebe	HIGH	HIGH	HIGH
Laysan Albatross	LOW	HIGH	LOW
Black-footed Albatross	HIGH	HIGH	LOW
Short-tailed Albatross	MEDIUM	HIGH	LOW
Northern Fulmar	LOW	LOW	LOW
Murphy’s Petrel	MEDIUM	LOW	LOW
Mottled Petrel	LOW	HIGH	LOW
Hawaiian Petrel	LOW	HIGH	HIGH
Cook’s Petrel	MEDIUM	MEDIUM	LOW
Pink-footed Shearwater	LOW	HIGH	LOW
Flesh-footed Shearwater	LOW	HIGH	LOW
Buller’s Shearwater	LOW	HIGH	LOW
Sooty Shearwater	MEDIUM	LOW	LOW
Short-tailed Shearwater	LOW	HIGH	LOW
Manx Shearwater	MEDIUM	MEDIUM	LOW
Black-vented Shearwater	MEDIUM	HIGH	MEDIUM
Wilson’s Storm-Petrel	MEDIUM	MEDIUM	LOW
Fork-tailed Storm-Petrel	LOW	HIGH	LOW
Leach’s Storm-Petrel	MEDIUM	LOW	LOW
Ashy Storm-Petrel	HIGH	HIGH	MEDIUM
Black Storm-Petrel	MEDIUM	HIGH	LOW
Least Storm-Petrel	HIGH	HIGH	LOW
Brandt’s Cormorant	LOW	MEDIUM	MEDIUM
Double-crested Cormorant	LOW	MEDIUM	MEDIUM

Common name	Population Vulnerability Uncertainty Rank	Collision Vulnerability Uncertainty Rank	Displacement Vulnerability Uncertainty Rank
Pelagic Cormorant	MEDIUM	MEDIUM	MEDIUM
American White Pelican	HIGH	MEDIUM	MEDIUM
Brown Pelican	MEDIUM	MEDIUM	MEDIUM
Red-necked Phalarope	LOW	HIGH	MEDIUM
Red Phalarope	MEDIUM	HIGH	MEDIUM
South Polar Skua	LOW	MEDIUM	HIGH
Pomarine Jaeger	HIGH	LOW	MEDIUM
Parasitic Jaeger	HIGH	LOW	LOW
Long-tailed Jaeger	HIGH	LOW	MEDIUM
Common Murre	LOW	MEDIUM	LOW
Pigeon Guillemot	MEDIUM	HIGH	LOW
Marbled Murrelet	MEDIUM	MEDIUM	LOW
Scripps’s Murrelet	MEDIUM	MEDIUM	LOW
Craveri’s murrelet	LOW	MEDIUM	MEDIUM
Ancient Murrelet	MEDIUM	MEDIUM	LOW
Cassin’s Auklet	HIGH	MEDIUM	LOW
Parakeet Auklet	MEDIUM	HIGH	LOW
Rhinoceros Auklet	MEDIUM	HIGH	MEDIUM
Horned Puffin	LOW	HIGH	LOW
Tufted Puffin	HIGH	HIGH	LOW
Black-legged Kittiwake	LOW	LOW	MEDIUM
Sabine’s Gull	LOW	LOW	MEDIUM
Bonaparte’s Gull	HIGH	LOW	MEDIUM
Heermann’s Gull	HIGH	LOW	HIGH
Mew Gull	HIGH	LOW	HIGH
Ring-billed Gull	LOW	MEDIUM	HIGH
Western Gull	HIGH	MEDIUM	MEDIUM
California Gull	HIGH	LOW	HIGH
Herring Gull	MEDIUM	LOW	MEDIUM
Thayer’s Gull	HIGH	LOW	HIGH
Glaucous-winged Gull	HIGH	MEDIUM	MEDIUM
Least Tern	HIGH	LOW	HIGH
Gull-billed Tern	LOW	LOW	MEDIUM
Caspian Tern	HIGH	LOW	HIGH
Black Tern	HIGH	LOW	MEDIUM
Common Tern	LOW	LOW	MEDIUM
Arctic Tern	LOW	LOW	MEDIUM
Forster’s Tern	MEDIUM	LOW	HIGH
Royal Tern	LOW	LOW	HIGH
Elegant Tern	HIGH	LOW	HIGH
Black Skimmer	MEDIUM	MEDIUM	HIGH

Marine Bird Species and Taxa Accounts

The vulnerability scores for each species were generated after comprehensive review of species' life histories, multiple threat-status assessments, and careful consideration of the metric values that contribute to Collision and Displacement Vulnerability scores. Here, we discuss *Population Collision Vulnerability* and *Population Displacement Vulnerability* scores and rankings for each species and how these compare with similar vulnerability scores estimated in previous assessments from the Atlantic (Garthe and Hüppop, 2004; Desholm, 2009; Furness and Wade, 2012; Furness and others, 2013; Robinson Willmott and others, 2013). When relevant, we discuss specific information about species behavior observed at existing OWEI.

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 and others, 1981). Seventy-five percent of the American population of Brant winters in Mexico, although not all fly through the CCS; some are thought to take inland routes (Davis and Deuel, 2008). A small percentage of the Brant population winter in Humboldt, Tomales, Bodega, Morro, and San Diego Bays and other small inlets within the CCS (Briggs and others, 1981). They eat primarily eel grass during the nonbreeding season (Lewis and others, 2013). The species is considered a species of Least Concern by the IUCN and a California Species of Special Concern (Davis and Deuel, 2008; International Union for Conservation of Nature, 2014). Brant had a PCV best-estimate score of 91, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 117, ranking it 'high' among the suite of species (table 7, fig. 3). High PDV was due to high Macro-Avoidance and low (high value) Habitat Flexibility (table 6).

Similar to our results for Brant, Desholm (2009) estimated swans and geese were the species most sensitive to OWEI disturbance. High displacement among migratory geese has been reported at offshore wind farms in the North Sea. In a 4-year radar detection study of Pink-footed Goose (*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 most frequently use 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 not well known, but it is thought to be low. 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 (International Union for Conservation of Nature, 2014). Common Merganser had a PCV best-estimate score of 48, ranking it 'low' among the suite of species and a PDV best-estimate score of 30, ranking it 'low' among the suite of species (table 7, fig. 3).

Red-breasted Mergansers (*Mergus serrator*) are found along the CCS during the migration and winter seasons (Briggs and others, 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 and others (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 (International Union for Conservation of Nature, 2014). Red-breasted Merganser had a PCV best-estimate score of 64, ranking it 'low' among the suite of species, and a PDV best-estimate score of 40, ranking it 'low' among the suite of species (table 7, fig. 3).

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, Desholm (2009) and Robinson Willmott and others (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.

Ducks and Scoters

Harlequin Duck (*Histrionicus histrionicus*) is found on the east and west coasts of North America; the west coast population is thought to be larger in size (Robertson and Goudie, 1999). In the western United States, Harlequin ducks breed in interior Washington, Oregon, Idaho, Wyoming, and California. In the winter, they migrate to the coast where they are usually found in nearshore waters (Beedy, 2008). Harlequin Duck is a California Bird of Conservation Concern (Beedy, 2008). Harlequin Duck had a PCV best-estimate score of 98, ranking it 'medium' among the suite of species and a PDV best-estimate score of 126, ranking it 'high' among the suite of species (table 7, fig. 3). High PDV was due to high Macro-Avoidance and low (high value) Habitat Flexibility (table 6).

Three species of scoter are found in the CCS: Surf Scoter (*Melanitta perspicillata*; fig. 4), White-winged Scoter (*Melanitta fusca*), and Black Scoter (*Melanitta americana*). 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. During the fall migration, birds arrive off Oregon in early September and numbers peak in October and November (Briggs and others, 1992). During spring migration, birds start leaving wintering grounds during March (Anderson and others, 2015), traveling in loose flocks at altitudes from sea-level to near 100 m (J. Adams, U.S. Geological Survey, oral commun., May 5, 2016). Coastal migration past a single line of latitude can reach from 100s to 1,000s of birds per hour during April (Anderson and others, 2015). Migratory flights overland are known to take place at night, but there is little information about migratory movements over the ocean (Anderson and others, 2015). The Surf Scoter is considered a species of Least Concern (International Union for Conservation of Nature, 2014). Surf Scoter had a PCV best-estimate score of 84, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 108, ranking it 'high' among the suite of species (table 7, fig. 3). High PDV was due to high Macro-Avoidance and low (high value) Habitat Flexibility (table 6).

Figure 4. Surf Scoter (*Melanitta perspicillata*). Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

White-winged Scoters nest in freshwater ecosystems within the northwestern interior of North America (Brown and Fredrickson, 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 and others, 1987). White-winged Scoter migration is not well described, but timing and flight behaviors likely are similar to Surf Scoter. Both species occur in greatest numbers within a few kilometers of shore and generally are more abundant over sandy substrates in the lee of coastal promontories (Briggs and others, 1987). Briggs and others (1992), however, noted that scoter distribution at sea extended to the mid-shelf off Washington. White-winged Scoter is a species of Least Concern (International Union for Conservation of Nature, 2014). White-winged Scoter had a PCV best-estimate score of 56, ranking it ‘low’ among the suite of species and a PDV best-estimate score of 64, ranking it ‘low’ among the suite of species (table 7, fig. 3).

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, Alaska down to Baja California, Mexico (Briggs 1983; Bordage 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 and others, 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 (Bordage and Savard, 2011). The species is considered Near Threatened due to a number of threats causing population decline throughout its range (International Union for Conservation of Nature, 2014). Black Scoter had a PCV best-estimate score of 70, ranking it ‘medium’ among the suite of species, and a PDV best-estimate score of 90, ranking it ‘medium’ among the suite of species (table 7, fig. 3).

Long-tailed Duck (*Clangula hyemalis*) breeds in arctic regions and migrates to temperate regions around the globe during the winter. A portion of the population spends the winter in the northern part of the CCS (Robertson and Savard, 2002; Long-tailed Ducks can dive up to 60 m when foraging, allowing them to spend time farther offshore compared with most other duck species (Robertson and Savard, 2002). Long-tailed Duck is considered Vulnerable (International Union for Conservation of Nature, 2014). Long-tailed Duck had a PCV best-estimate score of 37, ranking it 'low' among the suite of species, and a PDV best-estimate score of 59, ranking it 'low' among the suite of species (table 7, fig. 3).

Previous vulnerability indices found scoters and ducks to be vulnerable to displacement by OWEI. Garthe and Hüppop (2004) determined Velvet Scoter (*Melanitta fusca*) to be the third-most sensitive species (after two loon species) to OWEI in the German North Sea and Baltic Sea. Desholm (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 southern North Sea, Common Scoters (*Melanitta nigra*), along with loons, were considered the most vulnerable species to displacement by OWEI (Furness and Wade, 2012; Furness and others, 2013). Robinson Willmott and others (2013) also reported scoters (along with loons, terns, and alcids) to have the highest displacement vulnerability on the east coast of the United States. Most post-construction studies at offshore wind farms in the North Sea support these predictions of high displacement risk for scoters and ducks. Petersen and others (2013) found a decrease in the number of Long-tailed ducks found in and around OWEI, with no sign of long-term habituation to the OWEI area. At Egmond aan Zee wind farm in the North Sea, Krijgsveld and others (2011) found active scoters and ducks avoided OWEI. Desholm and Kahlert (2005) reported the number of geese and duck flocks flying through Nysted offshore wind farm off the coast of Denmark decreased significantly post-construction. However, after initial avoidance of OWEI at Horns Rev 1, Common Scoters were found in equal densities inside and outside of the OWEI after 5 years, indicating that habituation to OWEI may occur over time (Petersenn and Fox, 2007).

Loons (*Gavia* spp.)

There are four loon species present in the CCS. Red-throated Loons (*Gavia stellate*; fig. 5) share much of the breeding range of Pacific Loons (*Gavia pacifica*); however, their nesting habitat is more restricted to coastal areas (Barr and others, 2000). Whereas breeders in northern Alaska are known to winter in southeast Asia, Red-throated Loons nesting elsewhere in Alaska spend the nonbreeding season off the west coast of North America, as far south as Baja California, Mexico (Schmutz and others, 2009). Red-throated Loons wintering off western North America follow a similar migration timing and pattern as Pacific Loons; although, compared with Pacific Loons, they utilize waters very near the coast (Briggs and others, 1987, 1992). Red-throated Loon is a species of Least Concern (International Union for Conservation of Nature, 2014), but recent population declines among breeders in Alaska have caused USFWS to elevate their threat status (U.S. Fish and Wildlife Service, 2008). 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. In our database, Red-throated Loon had a PCV best-estimate score of 69, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 117, ranking it 'high' among the suite of species (table 7, fig. 3). High PDV was due to high Macro-Avoidance, low (high value) Habitat Flexibility (table 6), and elevated Population Vulnerability.

Figure 5. Red-throated Loon (*Gavia stellate*) in non-breeding plumage. Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission

Pacific Loons 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). Although little information exists, migration has been observed to be strictly diurnal (R.A. Rowlett, pers. commun. in Russel, 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 per hour. Although very similar in appearance and wintering distribution to Red-throated Loon (both loon species occur off the California, Oregon, and Washington coasts), Pacific Loons dominate numerically in this region (Briggs and others, 1987; 1992). 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 2,500–3,000 birds per hour off Oregon and Washington (Crowell and Nehls, 1976). During migration, the majority of birds occur within a few kilometers of the coastline, generally flying diurnally at altitudes less than 100 m and usually less than 10 m (Russell, 2002); however, when flying into weak headwinds during migration, Pacific Loons can reach altitudes greater than 100 m (B. Henry, U.S. Geological Survey, oral commun., May 5, 2016). Pacific Loon is a species of Least Concern (International Union for Conservation of Nature, 2014). Pacific Loon had a PCV best-estimate score of 42, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 104, ranking it ‘medium’ among the suite of species (table 7, fig. 3).

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 percent of the total breeding population of ca. 260,000 pairs; Evers and others, 2010). Approximately 30 percent 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) overwinter off the Pacific coast of North America (Evers and others, 2010). Spring and fall migration and wintering ecology are relatively poorly known. Ocean migrants employ a stepping-stone migration with diurnal movements interspersed with staging areas that are typically nearshore with relatively clear water and abundant prey (Evers and others, 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 and others, 1992). During the nonbreeding season, Common Loons in marine ecosystems are most frequently located within a few kilometers of shore where they pursue benthic prey available in relatively shallow waters. Individuals rarely are observed outside inner-shelf waters (less than 100-m depth; Briggs and others, 1992; Evers and others, 2010). Common Loon is 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 Department of Fish and Game, 2003). Common Loon had a PCV best-estimate score of 52, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 140, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PDV was due to high Macro-Avoidance (table 6), low (high value) Habitat Flexibility (table 6), and high Population Vulnerability (table 4).

Of the global Yellow-billed Loon (*Gavia adamsii*) population, an estimated 2–3 percent migrate to or through the CCS during the nonbreeding season (J. Schmutz, U.S. Geological Survey, oral commun., July 31, 2014). While migrating, they stay a couple hundred meters offshore and fly at altitudes less than 100 m (North, 1994). They primarily eat fish, but they also consume some invertebrates and vegetation (North, 1994). They are considered Near Threatened (International Union for Conservation of Nature, 2014). Yellow-billed Loon had a PCV best-estimate score of 53, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 144, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PDV was due to high Macro-Avoidance (table 6), low (high value) Habitat Flexibility (table 6), and high Population Vulnerability (table 4).

Previous vulnerability indices also found some loon species to be at high risk of displacement by OWEI. Desholm (2009) estimated water birds (loons, swans, geese, and ducks) were the species most sensitive to OWEI disturbance. Furness and Wade (2012) and Furness and others (2013) estimated loons (along with Common Scoter) would be the most vulnerable to displacement by OWEI in Scottish North Sea. Robinson Willmott and others (2013) reported loons (along with scoters, terns, and alcids) would have the highest displacement vulnerabilities. These predictions of high displacement among loons are supported by post-construction reports at offshore wind farms. At Egmond aan Zee wind farm in the North Sea, Krijgsveld and others (2011) reported that loons actively avoided OWEI. Although loons were frequently found in those areas of Nysted and Horns Rev in the Danish North Sea before the OWEI construction, they were not found within the OWEI area, even more than five years after OWEI construction (Peterson and others, 2006; Petersen and Fox, 2007).

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. 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 that feed primarily in the benthos, on fish and crustaceans during the winter (Stedman, 2000). Although the species is considered of Least Concern by the IUCN, and U.S. State and Federal rankings, it is considered Threatened in Canada (Committee on the Status of Endangered Wildlife in Canada, 2004). Horned Grebe had a PCV best-estimate score of 60, ranking it 'low' among the suite of species, and a PDV best-estimate score of 81, ranking it 'medium' among the suite of species (table 7, fig. 3).

Red-necked Grebe (*Podiceps grisegena*) breeds from northern Alaska southward through central Canada. The species winters along the west coast of North America from southern Alaska to central California. 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 due to significant declines in local, inland breeding population sizes (Oregon Department of Fish and Wildlife, 2014). Red-necked Grebe had a PCV best-estimate score of 63, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 80, ranking it 'medium' among the suite of species (table 7, fig. 3).

Eared Grebe (*Podiceps nigricollis*) breeds in interior North America from the central United States north through Canada (Cullen and others, 1999). Most Eared Grebes on the west coast of North America winter in the Gulf of California, Mexico and the Salton Sea, California (Cullen and others, 1999); small numbers also occur along the California, Oregon, and Washington coasts during winter (Briggs and others, 1987). They feed primarily on invertebrates and crustaceans (Cullen and others, 1999). It is a species of Least Concern (International Union for Conservation of Nature, 2014). Eared Grebe had a PCV best-estimate score of 44, ranking it 'low' among the suite of species, and a PDV best-estimate score of 56, ranking it 'low' among the suite of species (table 7, fig. 3).

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, in marine survey datasets they often are grouped together and refered collectively as *Aechmophorus* grebes (Clark's Grebes are much less numerous and represent *ca.*8–13 percent of the total population of *Aechmophorus* grebes; LaPorte and others, 2013). *Aechmophorus* grebes breed inland throughout the western United States and central-southwestern Canada. Western Grebes achieve greatest numbers within coastal waters of the northern CCS during October through May within a narrow coastal band, usually less than 0.5 km from the coast (Briggs and others, 1987; Mason and others, 2007). During winter and spring, *Aechmophorus* Grebes are among the most numerous species observed immediately adjacent to the coast (for example, local densities in Monterey Bay, CA: *ca*. 200–400 birds km^{-2}; Henkel, 2004). Migratory movements occur primarily at night often in flocks, but migration is poorly documented (LaPorte and others, 2013). They migrate to post-breeding molting areas where many birds undergo wing molt before continuing on to wintering areas (LaPorte and others, 2013). During winter months, flocks often are found in sheltered waters (for example, in the lee of coastal promontories) and are associated with shallow, sandy-bottom habitats (Briggs and others, 1987; LaPorte and others, 2013). *Aechmophorus* grebes (Western and Clark's) are considered candidates for 'Endangered' listing by the

Washington Department of Fish and Wildlife (2015). Clark's Grebe had a PCV best-estimate score of 98, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 124, ranking it 'high' among the suite of species (table 7, fig. 3). Western Grebe had PCV best-estimate score of 105, ranking it high' among the suite of species, and a PDV best-estimate score of 132, ranking it 'high' among the suite of species (table 7, fig. 3). High PDVs in *Aechmophorus* grebes were due to high Macro-Avoidance (table 6), low (high value) Habitat Flexibility (table 6), and high Population Vulnerability (table 4). High PCVs in *Aechmophorus* grebes were due to a large percentage of time flying at night, large percentage of time flying in the RSZ (table 5), and high Population Vulnerability (table 4).

Albatrosses (*Phoebastria* spp.)

The three Northern-Hemisphere-breeding albatross species include: Black-footed Albatross (*Phoebastria nigripes*), Laysan Albatross (*Phoebastria immutabilis*, fig. 6), and Short-tailed Albatross (*Phoebastria albatrus*). Information about movements of Laysan Albatross within the CCS are not yet available, but recent tracking from Guadalupe Island, Mexico indicates broad use of the offshore waters of the CCS during the breeding season (B. Henry, U.S. Geological Survey, oral commun., May 5, 2016). Some individuals from the Hawaiian population are seen off the west coast of North America November 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 shelf waters of the CCS is thought to be increasing as the small population (143 nesting pairs in 2013) nesting on Guadalupe Island increases (Hernández-Montoya and others 2014). Their diet consists of squid, flying fish eggs, crustaceans, and fish (Awkeman and others, 2009). Laysan Albatross is considered Near Threatened by the IUCN, and a Bird of Conservation Concern (BCC) by the USFWS (International Union for Conservation of Nature, 2014; U.S. Fish and Wildlife Service, 2014). Laysan Albatross had a PCV best-estimate score of 96, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 72, ranking it 'low' among the suite of species (table 7, fig. 3).

Greater than 95 percent (*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 subpopulation nesting in the Bonin and Izu island groups off Japan (Awkerman and others, 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 nonbreeding dispersal period. Black-footed Albatrosses are avid scavengers and aggregations within the CCS have been associated with fishing vessels (Briggs and others, 1992). Conners and others (2015) showed that during the breeding season both Laysan and Black-footed Albatross spent time flying at night, the latter tend to spend slightly more time flying at night. The species is listed as Near Threatened by the IUCN, and a Bird of Conservation Concern by the USFWS (U.S. Fish and Wildlife Services, 2014). Black-footed Albatrosses had a PCV best-estimate score of 132, ranking it 'high' among the suite of species, and a PDV best-estimate score of 99, ranking it 'medium' among the suite of species (table 7, fig. 3). High PCV was due to the large amount of time spent flying, nocturnal flight activity, moderate time in the RSZ (table 5), and elevated Population Vulnerability (table 4).

Figure 6. Laysan Albatross (*Phoebastria immutabilis*). Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

Historically, Short-tailed Albatross had at least nine breeding colonies in the East China Sea and south of Japan (Piatt and others, 2006). Currently there are two extant colonies: Torishima Island, Japan and Minami-kojima in the Senkaku Islands off Taiwan (Birdlife International, 2014a). Little is known about the dispersal patterns of Short-tailed Albatross; an estimated 12 percent of the population occurs annually within the CCS, the majority of which are males and juveniles (Suryan and others, 2007). The species is listed as Threatened by the IUCN, and listed as Endangered by USFWS, Oregon Department of Fish and Wildlife, Japan, and Canada due to their small population size and limited breeding range (Ministry of Environment Japan, 1991; Shuford and Gardali, 2008; International Union for Conservation of Nature, 2014; U.S. Fish and Wildlife Service, 2014). Short-tailed Albatross had a PCV best-estimate score of 139, ranking it 'high' among the suite of species, and a PDV best-estimate score of 114, ranking it 'high' among the suite of species (table 7, fig. 3). High PCV is due to a large amount of time spent flying, moderate time in the RSZ (table 5), and high Population Vulnerability (table 4). High PDV resulted from high Macro Avoidance, and high Population Vulnerability.

Pacific Northern Fulmar (*Fulmarus glacialis rogersii*)

Pacific Northern Fulmars are abundant throughout the boreal and subarctic north Pacific and are especially widespread during winter. Approximately 99 percent 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), Pribilof Islands (Bering Sea), and St. Matthew/Hall Islands (Bering Sea; Mallory and others, 2012). Birds from the Semidi Islands population migrate seasonally to overwinter in the CCS (Mallory and others, 2012). First arrivals off central California occur in late September, with a peak in abundance during November (Briggs and others, 1987); breeders first arrive at northern boreal/arctic colonies in late April to May. The species exhibits dramatic plumage polymorphism ranging from solid dark gray 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 and others, 2012). In post-construction analysis at Belgian Bligh Bank wind farm in the North Sea, fulmars were negatively associated with OWEI, showing strong avoidance behavior (Vanermen and others, 2014). The species is considered of Least Concern (International Union for Conservation of Nature, 2014). Pacific Northern Fulmar had a PCV best-estimate score of 59, ranking it 'low' among the suite of species, and a PDV best-estimate score of 66, ranking it 'low' among the suite of species (table 7, fig. 3).

Gadfly Petrels (*Pterodroma* spp.)

Four species of gadfly petrels found in the CCS include: Murphy's Petrel (*Pterodroma ultina*), Hawaiian Petrel (*Pterodroma sandwichensis*), Cook's Petrel (*Pterodroma cookii*), and Mottled Petrel (*Pterodroma inexpectata*). All are found far offshore and none are seen frequently or in great abundance, although Mottled Petrel may occur locally abundant, at least occasionally off California.

Murphy's Petrel breeds in the southern Pacific Ocean. Their nonbreeding dispersal is not well known but some individuals are seen wintering in the CCS (Birdlife International, 2014a). Murphy's Petrel had a PCV score of 91, ranking it 'medium' among the suite of species, and a PDV score of 78, ranking it 'medium' among the suite of species (table 7, fig. 3).

The Mottled Petrel is endemic to New Zealand (Birdlife International, 2014a). More than 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 nonbreeding waters (Briggs and others, 1987; Bartle and others, 1993). The species is considered Near Threatened due to small overall population size and non-native predators at breeding grounds (International Union for Conservation of Nature, 2014). Mottled Petrel had a PCV score of 68, ranking it 'medium' among the suite of species, and a PDV score of 72, ranking it 'medium' among the suite of species (table 7, fig. 3).

Hawaiian Petrels breed in the main Hawaiian Islands (MHI) and are rarely seen off the coast of California and Oregon (Briggs and others, 1987; Simons and Hodges, 1998). Hawaiian and Galapagos Petrels (*P. phaeopygia*) are extremely hard to differentiate by sight alone at sea (Pyle and others, 2011), but tracking data from Hawaii and the Galapagos support the idea that birds seen in the CCS are *P. sandwichensis* (J. Adams, U.S. Geological Survey, unpub. data, May 5, 2016). The long-distance ranging patterns of Hawaiian Petrel from colonies located 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 annual feature may influence the likelihood that Hawaiian Petrels occur within the outer CCS during summer and fall months (J. Adams, U.S. Geological Survey, unpub. data, May 5, 2016). The species is considered Endangered by the USFWS due to nesting habitat reduction and predation threats (U.S. Fish and Wildlife Services, 2014). Hawaiian Petrel had a PCV best-estimate score of 94, ranking it ‘medium’ among the suite of species, and a PDV best-estimate score of 132, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PDV is due to high Macro-Avoidance (table 6) and high Population Vulnerability (table 4).

There are two distinct populations of Cook’s 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 nonbreeding season (Birdlife International, 2014a; Rayner and others, 2011). The species is considered Vulnerable (International Union for Conservation of Nature, 2014). Cook’s Petrel had a PCV best-estimate score of 98, ranking it ‘medium’ risk among the suite of species, and a PDV best-estimate score of 93, ranking it ‘medium’ among the suite of species (table 7, fig. 3).

Shearwaters (*Puffinus* spp.)

The Pink-footed Shearwater (*Puffinus creatopus*; fig. 7) is a Chilean endemic breeder of which a portion of the adult breeding population (*ca*. 28,000 breeding pairs, Muñoz, Corporación Nacional Forestal, Chile and P. Hodum, Oikonos, unpub. data, May 5, 2016) undergoes a seasonal, transequatorial migration to occupy shelf and slope waters of the CCS from March through October, with maximal abundance during July through September (Briggs and others, 1987). Pink-footed Shearwaters are similarly sized compared with the much more abundant Sooty Shearwater, and during summer the two species often co-occur off California, Oregon, and Washington (Briggs and others, 1987, 1992). Interannual abundance off Oregon and Washington can be highly variable, presumably associated with interannual oceanographic conditions and forage fish abundances (Phillips and others, 2010). Owing to habitat loss, threats at sea, 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; International Union for Conservation of Nature, 2014). Pink-footed Shearwaters had a PCV best-estimate score of 100, ranking it ‘medium’ among the suite of species, and a PDV best-estimate score of 120, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PDVis due to high Population Vulnerability (table 4) and high Macro-Avoidance and low Habitat Flexibility (table 6).

Flesh-footed Shearwaters (*Puffinus carneipes*) breed in the southwest Pacific and travel north to the western Pacific, Africa, and the northern Indian Ocean during the nonbreeding season. A small percentage of the population is found in the CCS during boreal summer–early fall (Birdlife International, 2014a). The species is thought to be most active, flying and feeding, during the day (del Hoyo and others, 1992). The species is considered Threatened in New Zealand due to threats at breeding colonies (Robertson and others, 2013). Flesh-footed Shearwater had a PCV best-estimate score of 67, ranking it ‘medium’ among the suite of species, and a PDV best-estimate score of 75, ranking it ‘medium’ among the suite of species (table 7, fig. 3).

Figure 7. Pink-Footed Shearwater (*Puffinus creatopus*). Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

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. During their nonbreeding 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. Maximum numbers typically are found in July and November off Washington and Oregon (Briggs and others, 1992) and in August and September off northern California (Briggs and others, 1987). The global population (*ca*. 2.5 million, but probably fewer) is considered Vulnerable due to its restricted breeding range and vulnerability to invasive species at breeding grounds (International Union for Conservation of Nature, 2014; Birdlife International, 2014a). Buller's Shearwater had a PCV best-estimate score of 60, ranking it 'low' among the suite of species, and a PDV best-estimate score of 72, ranking it 'low' among the suite of species (table 7, fig. 3).

Sooty Shearwater (*Puffinus griseus*) is one of the world's most abundant seabird species (>20 million birds; Heather and Robertson, 1997; Newman and others, 2009). In the Pacific, it nests in the Southern Hemisphere on islands off Chile and New Zealand. After chick-rearing, adults perform a transequatorial 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 (Adams and others, 2012). Off California, Sooty Shearwaters dominate the marine avian biomass in summer (Briggs and Chu, 1986). Briggs and others (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 and others, 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 interannual 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 and others, 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 (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 70, ranking it ‘medium’ among the suite of species, and a PDV best-estimate score of 84, ranking it ‘medium’ among the suite of species (table 7, fig. 3).

Short-tailed Shearwater (*Puffinus tenuirostris*) is very abundant and breeds in Australia. The majority of individuals overwinter (boreal summer) in the Bering Sea and in the vicinity of island passes throughout the Aleutian Archipelago separating the Bering Sea from the northern Gulf of Alaska. The number of Short-tailed Shearwaters found in the CCS during fall and winter aerial surveys is unclear because they appear indistinguishable from Sooty Shearwaters and therefore they cannot be counted individually. However, it is estimated that a very small percentage of the shearwaters seen in the CCS from October to March are Short-tailed (Briggs and others, 1987; 1992). The species is considered of Least Concern (International Union for Conservation of Nature, 2014). Short-tailed Shearwater had a PCV best-estimate score of 43, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 51, ranking it ‘low’ among the suite of species (table 7, fig. 3).

Manx Shearwater (*Puffinus puffinus*) is native to the Atlantic Ocean. Individuals are found infrequently in the Pacific; however, some small number of individuals might breed in the north Pacific (Lee and Haney, 1996). They eat primarily small schooling fish, as well as cephalopods, small crustaceans, and offal (Lee and Haney, 1996). The species is considered of Least Concern (International Union for Conservation of Nature, 2014). Manx Shearwater had a PCV best-estimate score of 55, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 66, ranking it ‘low’ among the suite of species (table 7, fig. 3).

Black-vented Shearwater (*Puffinus opisthomelas*) breeds in Mexico and travels north along the coast during the nonbreeding season (Birdlife International, 2014a); numbers off central-southern California increase in association with anomalous warm ocean conditions in the CCS. Black-vented Shearwaters declined significantly due to breeding habitat loss and the introduction of nonnative predators to breeding grounds. Although these threats have decreased significantly, the species is still considered Near Threatened by the IUCN and Endangered in Mexico (Flores, 2010; International Union for Conservation of Nature, 2014). Black-vented Shearwater had a PCV best-estimate score of 85, ranking it ‘medium’ among the suite of species, and a PDV best-estimate score of 119, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PDV resulted from high relative Macro-Avoidance (table 6) and relatively high Population Vulnerability (table 4).

Storm-Petrels (*Oceanodroma* spp. / *Oceanites* spp.)

Three subspecies 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 transequatorial migrations during the nonbreeding 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 occur in the eastern Pacific (Spear and Ainley, 2007; Birdlife International, 2014a). 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 headwinds, enabling them to employ the unique sea-anchor flying behavior that sets them apart from most other types of storm-petrels (Ainley and others, 2015). Wilson's Storm-Petrel is considered a species of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 43, ranking it 'low' among the suite of species, and a PDV best-estimate score of 45, ranking it 'low' among the suite of species (table 7, fig. 3).

Fork-tailed Storm-Petrel (*Oceanodroma 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 2,000 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 generally is thought to occupy waters father offshore from the shelf-slope during winter, but stormy weather can result in nearshore occurrences (Boersma and Silva, 2001). Briggs and others (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 and others, 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 62, ranking it 'low' among the suite of species, and a PDV best-estimate score of 66, ranking it 'low' among the suite of species (table 7, fig. 3).

Leach's Storm-Petrel (*Oceanodroma 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 (*O. l. leucorhoa*) on isolated islets off northern Washington (Speich and Wahl, 1989) and an estimated 482,000 breeders off Oregon (37 percent of the total Oregon breeding seabird population), making it the second-most abundant locally-breeding seabird species after Common Murre (Naughton and others, 2007a). 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 and others, 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 and others, 1987; 1992). Three distinct subspecies of Leach's Storm-Petrels breed off southern California and Mexico (Huntington and others, 1996). *O. l. chapmani* nests off central Baja California and Mexico (and perhaps the California Channel Islands; Carter, Dvorak, and others, 2016). Two subspecies of Leach's Storm-Petrel (*O. l. socorroensis* and *O. l. cheimomnestes*) are threatened with extinction; these subspecies are endemic to Guadalupe Island off of Baja California, Mexico and not thought to occur in the central-northern CCS (Huntington and others, 1996; Spear and Ainley, 2007); therefore, we did not consider the conservation status of these subspecies individually when estimating the CCS population Threat Status to apply to Leach's Storm-Petrel (Flores, 2010; International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 68, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 72, ranking it 'low' among the suite of species (table 7, fig. 3).

Nearly all (98 percent) Ashy Storm-Petrels (*Oceanodroma homochroa*) breed in California (Carter and others, 2008; Carter, Ainley, and others, 2016). Little is known about their diet (G. McChesney, U.S. Fish and Wildlife Service, unpub. data, May 5, 2016). Individuals off California generally occupy waters of the continental slope greater than 800-m depth (Adams and Takekawa, 2008). The species is considered Endangered by the IUCN and the Mexican Especies en Riesgo due to rapid population declines resulting from multiple threats (Flores, 2010; International Union for Conservation of Nature, 2014). Ashy Storm-Petrel had a PCV best-estimate score of 153, ranking it 'high' among the suite of species, and a PDV best-estimate score of 189, ranking it 'high' among the suite of species (table 7, fig. 3). Despite having the lowest score for percentage time flying in the RSZ (RSZt = 1), high PCV was due to several factors that contribut to its unique high Population Vulnerability (table 4): CCS endemism, year-round AO in the CCS, small population size, and high Threat Status coupled with a relatively large percentage of time spent flying at night (table 5). High PDV was due to high Population Vulnerability (table 4) and high Macro-Avoidance (table 6).

Black Storm-Petrel (*Oceanodroma melania*) breeds on islands off southern California, Baja California, Mexico, and islands in the Gulf of California, Mexico. Thousands move north after the breeding season and are found off the coast of California (Ainley, 2008). It is considered a Species of Special Concern in California (Ainley, 2008). Black Storm-Petrel had a PCV best-estimate score of 77, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 81, ranking it 'medium' among the suite of species (table 7, fig. 3).

Least Storm-Petrel (*Oceanodroma microsoma*) is found in the eastern Pacific from central California to Peru. Individuals primarily breed on islands in Baja California, Mexico, but a small portion of the population breeds in islands off southern California (Spear and Ainley, 2007). They are considered a Bird of Conservation Concern by the USFWS (U.S. Fish and Wildlife Services, 2014). Least Storm-Petrel had a PCV best-estimate score of 71, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 75, ranking it 'medium' among the suite of species (table 7, fig. 3).

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

There are three cormorant species that breed in the CCS and all generally occupy similar habitats at sea, mostly over the inner-shelf and usually within 25 km of land (Briggs and others, 1987). Cormorant distribution at sea (in all seasons) generally follows the distribution of colonies along the coast, many of which are used during the nonbreeding season as roosting sites (Briggs and others, 1992).

Brandt's Cormorant (*Phalacrocorax penicillatus*) is a State Sensitive Species in Washington (Washington Department of Fish and Game, 2003; U.S. Fish and Wildlife Services, 2005). The species had a PCV best-estimate score of 161, ranking it 'high' among the suite of species, and a PDV best-estimate score of 105, ranking it 'medium' among the suite of species (table 7, fig. 3). High PCV is due to year-round presence in the CCS (table 4), relatively large percentage of time spent in the RSZ (table 5), and large percentage of time spent flying when commuting to roosting and nesting grounds (table 4).

Double-crested Cormorant (*P. auritus*; fig. 8) is considered a Species of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 125, ranking it 'high' among the suite of species, and a PDV best-estimate score of 75, ranking it 'medium' among the suite of species (table 7, fig. 3). High PCV is due to year-round presence in the CCS, relatively large percentage of time spent in the RSZ (table 5), and the large percentage of time they spend flying when commuting to roosting and nesting grounds (table 4).

Figure 8. Double-crested Cormorant (*Phalacrocorax auritus*). Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

Pelagic Cormorant (*P. pelagicus*) is considered a species of least concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 115, ranking it at ‘high’ among the suite of species, and a PDV best-estimate score of 75, ranking it ‘medium’ among the suite of species (table 7, fig. 3). High PCV is due to year-round presence in the CCS, relatively large percentage of time spent in the RSZ (table 5), and the large percentage of time spent flying when commuting to roosting and nesting grounds (table 4).

Previous vulnerability indices also predicted cormorants to be at relatively greater vulnerability to collision and displacement by OWEI. Garthe and Hüppop (2004) found that Great Shag (*Phalacrocorax carbo*) was the fourth-most vulnerable species (after loon, scoter, and tern species) to OWEI. Robinson Willmott and others (2013) determined that cormorants have high collision and displacement vulnerability. Post-construction reports of cormorant behavior at offshore wind farms support these calculations indicating high displacement and high collision vulnerability. 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 and others, 2009). In contrast, at Egmond aan Zee wind farm in the North Sea, Krijgsveld and others (2011) found that cormorants did not show any avoidance behavior and showed some indication of being attracted to OWEI for roosting. Peterson and others (2006) also found that cormorants did not show avoidance behavior around Nysted and Horns Rev wind farms in the Dutch North Sea, thus increasing their risk of collision. Furthermore, at Egmond aan Zee and North Hoyle offshore wind farms, Eurpoean shags (*Phalacrocorax aristotelis*) were found to be attracted to OWEI areas, where they were not found in large numbers before, and at North Hoyle Wind Farm, shags were observed foraging near turbines (NWP Offshore Ltd, 2008; Leopold and others, 2011). Cormorants are known to be attracted to offshore oil rigs (Hamer and others, 2014) that provide roosting habitat and it is likely that the same behavior would be displayed at OWEI in the CCS. Further increasing their collision vulnerability, cormorants, which have very low aspect ratios, increase flapping with increased wind speed and are most likely to fly into headwinds (Spear and Ainley, 2007; Ainley and others, 2015).

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

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 rarely are 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 Department of Fish and Game, 2003). American White Pelican had a PCV best-estimate score of 210, ranking it ‘high’ among the suite of species, and a PDV best-estimate score of 90, ranking it ‘medium’ among the suite of species (table 7, fig. 3). High PCV was due to low Macro-Avoidance, high percent time flying in the RSZ (table 5), and high Population Vulnerability (tables 4).

In the Pacific off North America, the Brown Pelican (*Pelecanus occidentalis*; fig. 9) nests from southern California through Mexico and throughout the Gulf of California, Mexico. Wintertime nonbreeding range among California and Mexican populations appears to fluctuate with latitude according to an interannual and interdecadal periodicity associated with changes in forage fish distribution and abundance and regional sea surface temperature. During cold-water periods, most nonbreeding 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 and others, 1994). 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 mostly is within 10 km of the coast (Briggs and others, 1983). The species is considered Endangered in Oregon and Washington due to population declines, most likely resulting from decreases in prey availability (Washington Department of Fish and Game, 2003; Oregon Department of Fish and Wildlife, 2014). Brown Pelican was de-listed in California by USFWS, but de-listing status currently is being reviewed (U.S. Fish and Wildlife Service, 2014). Brown Pelican had a PCV best-estimate score of 263, ranking it ‘high’ among the suite of species, and a PDV best-estimate score of 113, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PCV was due to year-round presence in the CCS (table 4), large percentage of time flying in the RSZ (table 5), low Macro-Avoidance (high score, table 5), and high Population Vulnerability (tables 4). High PDV was due to low Habitat Flexibility (table 6), and high Population Vulnerability (table 4).

Figure 9. Brown Pelican (*Pelecanus occidentalis*) adult in breeding plumage. Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

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

These two marine “shorebird” members of the Family Scolopacidae nest in the arctic and winter throughout the Peru and Humboldt Currents off South America (Rubega and others, 2000; Tracy and others, 2002). Red Phalarope (*Phalaropus fulicarius*) is considered the most marine of the three phalarope species (including Wilson’s Phalarope, *Phalaropus tricolor*, not considered herein). Using aerial and boat surveys off California, Briggs and others (1987) noted that Red Phalaropes occurred more than 50 km offshore; whereas Red-necked Phalaropes (*P. lobatus*) occurred consistently closer to shore, but the two species often co-occurred at sea. Red Phalarope numbers reached a maximum approximately one month later than Red-necked Phalaropes during spring and fall migrations off California (Briggs and others, 1987). Maximum 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 and others, 1987, 1992). Red Phalarope is considered a species of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 84, ranking it ‘medium’ among the suite of species, and a PDV best-estimate score of 60, ranking it ‘low’ among the suite of species (table 7, fig. 3). Red-necked Phalarope is considered a species of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 57, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 45, ranking it ‘low’ among the suite of species (table 7, fig. 3).

In contrast with our results, Robinson Willmott and others (2013) found that on the Atlantic Outer Continental Shelf of North America, phalaropes (along with gulls, cormorants and jaegers) have the greatest collision vulnerability. Lesser vulnerability in our estimates likely is due to differences in percent of the population found in the CCS and differences in equations used to calculate vulnerability.

Jaegers and Skua (*Stercorarius* spp.)

A small number of South Polar Skua (*Stercorarius maccormicki*) pass through the CCS during their transequatorial migration from Antarctic breeding grounds to the Northern Hemisphere for the nonbreeding season (Briggs and others, 1983). They likely fly more than 10 m above the water, and are unlikely to change flight height with changing wind speed or direction (Ainley and others, 2015). South Polar Skua is considered a species of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 168, ranking it 'high' among the suite of species, and a PDV best-estimate score of 42, ranking it 'low' among the suite of species (table 7, fig. 3). High PCV is due to large percentage of time flying in the RSZ (table 5) and low Macro-Avoidance (high value, table 5).

The Pomarine Jaeger (*Stercorarius pomarinus*; fig. 10) 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 maximum abundance off California during late September and October (Briggs and others, 1987; 1992). Sightings are rare during the rest of the year, and it is thought that the spring migration for this species occurs farther offshore than during the late summer and fall (Briggs and others, 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 and others, 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 more than 10 m above sea level during mild weather (Wiley and Lee, 2000). Pomarine Jaeger is considered of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 105, ranking it 'high' among the suite of species, and a PDV best-estimate score of 27, ranking it 'low' among the suite of species (table 7, fig. 3). High PCV is due to year-round presence in the CCS (table 4), large percentage of time flying in the RSZ (table 5), and low Macro-Avoidance (high value, table 5).

The smaller two of the three North American jaeger species, Parasitic (*Stercorarius parasiticus*) and Long-tailed Jaegers (*Stercorarius longicaudus*) are difficult to distinguish at sea, especially among juveniles and during the nonbreeding season when migrants from northern breeding sites occur within the CCS. Although an order of magnitude less common than Pomarine Jaegers, Briggs and others (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 and others, 1987, 1992; Wiley and Lee 1999). The species is considered of Least Concern (International Union for Conservation of Nature, 2014). Parasitic Jaeger had a PCV best-estimate score of 93, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 23, ranking it 'low' among the suite of species (table 7, fig. 3).

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 closer to 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 (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 93, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 23 ranking it 'low' among the suite of species (table 7, fig. 3).

Previous indices also determined that jaegers and skuas would have high collision vulnerability at OWEI. In the southern North Sea, skuas (along with White-tailed Eagles, Northern Gannets, and gulls) were reported as the most vulnerable to collision (Furness and Wade, 2012; Furness and others, 2013). Robinson Willmott and others (2013) predicted that, along the U.S. East Coast, jaegers (along with phalaropes, gulls and cormorants) would have the highest collision vulnerability. These predictions of high collision vulnerability are supported by radar observations at Egmond aan Zee wind farm. Peterson and others (2006) observed skuas flying between turbines and at turbine height. Vanermen and others (2013) saw an increase in the number of Great skua (*Stercorarius skua*) at OWEI during construction and operation.

Figure 10. Pomarine Jaeger (*Stercorarius pomarinus*). Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

Alcids

With the exception of the Sooty Shearwater during summer, the Common Murre (*Uria aalge*; fig. 11) dominates year-round in both number and biomass within the marine avian community of the CCS from northern California through Washington. Carter and others (2001) summarized population trends throughout the west coast of North America, excluding Alaska. Off northern California in 1989, 11 colonies supported 261,400 breeding birds (24 percent 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 subspecies' population resides off the coast of Oregon, where in 1988, approximately 711,900 breeding birds occurred at 66 colonies (66 percent 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 and others, 2007a). Numbers of breeding Common Murre off Washington are less, on the order of 5,900–9,600 individuals in 1994 and 1995; respectively (Carter and others, 2001). At sea off Oregon, Briggs and others (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 and others, 1992). Common Murre undergo a flightless molt period at sea in late summer/fall (Carter and others, 2001). The species is considered a State Sensitive Species in Washington (Washington Department of Fish and Wildlife, 2015). Common Murre had a PCV best-estimate score of 59, ranking it 'low' among the suite of species, and a PDV best-estimate score of 128, ranking it 'high' among the suite of species (table 7, fig. 3). High PDV is due to year-round presence in the CCS (table 4) and high Macro-Avoidance (table 6).

Figure 11. Common Murre (*Uria aalge*) in winter plumage. Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

Pigeon Guillemot (*Cepphus Columba*) breeds in small scattered colonies throughout the coastline bordering the CCS. In Washington, there are an estimated 700–4,270 breeding Pigeon Guillemots (Briggs and others, 1983; Speich and Wahl, 1989). Approximately 2,100 guillemots breed in Oregon and 12,500–15,500 breed in California (Sowls and others, 1980; Briggs and others, 1983; Carter and others, 1992). The Pigeon Guillemot's 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, *Mallotus villosus*) are not readily available; lack of sufficient lipid-rich prey can cause poor reproductive output (Ewins, 1993). Pigeon Guillemot is considered Vulnerable by the USFWS Pacific Seabird Conservation Status due to its sensitivity to human disturbance, pollution, and gill nets (U.S. Fish and Wildlife Services, 2005). The species had a PCV best-estimate score of 51, ranking it 'low' among the suite of species, and a PDV best-estimate score of 136, ranking it 'high' among the suite of species (table 7, fig. 3). High PDV is due to year-round presence in the CCS (table 4) and high Macro-Avoidance (table 6).

Marbled Murrelet (*Brachyramphus marmoratus*) is a small alcid found in the Pacific coastal waters from Alaska through central California, and occasionally off southern California during winter. 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 nearshore distribution; individuals are rarely encountered at sea greater than 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 one-half of these off Oregon north of Cape Blanco (U.S. Fish and Wildlife Service, 2009b). The species is listed federally as Endangered and is considered Critically Endangered according to the USFWS Seabird Conservation Status listing due to loss of breeding habitat from logging, oil spills, and bycatch in gill net fisheries (U.S. Fish and Wildlife Services, 2005; 2014). Marbled Murrelet had a PCV best-estimate score of 73, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 160, ranking it 'high' among the suite of species (table 7, fig. 3). High PDV is due to year-round presence in the CCS (table 4), low (high value) Habitat Flexibility (table 6), high Macro-Avoidance (table 6), and high Population Vulnerability (table 4).

Xantus's Murrelet (*Synthliboramphus hypolecus*) recently was split into two distinct species: Guadalupe Murrelet (*Synthliboramphus hypoleucus*) and Scripps's Murrelet (*S. scrippsi*, Birt and others, 2012; Chesser and others, 2012; figs. 2 and 12). 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 International, 2014b). Their diet is poorly known but is thought to consist primarily of larval to early life-stage northern anchovies; years of poor northern anchovy production are correlated with late breeding and poor reproductive effort in this species (Drost and Lewis, 1995). Scripps's Murrelet is considered Threatened by the USFWS and Threatened in California (Shuford and Gardali, 2008; U.S. Fish and Wildlife Service, 2014). The species had a PCV best-estimate score of 70, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 171, ranking it 'high' among the suite of species (table 7, fig. 3). High PDV is due to year-round presence in the CCS (table 4), low (high value) Habitat Flexibility (table 6), high Macro-Avoidance, and high Population Vulnerability (table 5).

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, 2014a). At-sea densities and overall numbers are low off California, but individuals have been recorded consistently off southern California, being most abundant when sea temperatures are high (Briggs and others, 1983, 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 (U.S. Fish and Wildlife Service, 2005; Flores, 2010). The species had a PCV best-estimate score of 55, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 135, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PDV was due to year-round presence in the CCS (table 4), low (high value) Habitat Flexibility (table 6), high Macro-Avoidance (table 6), and high Population Vulnerability (table 4).

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 one-quarter to one-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 and others, 1992) and occasional sightings

Figure 12. Scripps’s Murrelets (*Synthliboramphus scrippsi*). Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

beyond the shelf-break off northern California during February–April, south of Point Arena (Briggs and others, 1987). More recent aerial surveys, recorded greater abundances (a total of 223 individuals) during winter and fall; the species was most abundant during January 2011, when aggregations of up to 15 individuals were observed off southern Washington and northern Oregon, mostly affiliated with offshore waters over the continental slope (Adams and others, 2014). The species is considered Threatened under USFWS Seabird Conservation Status (U.S. Fish and Wildlife Service, 2005). Ancient Murrelet had a PCV best-estimate score of 37, ranking it 'low' among the suite of species, and a PDV best-estimate score of 80, ranking it 'medium' among the suite of species (table 7, fig. 3).

Cassin's Auklet (*Ptychoramphus aleuticus*) is a small (*ca*. 160 g), diving alcid that breeds in colonies from Mexico through Alaska. Geographic and genetic delineation for two distinct subspecies recently was determined; *P. a. aleuticus* breeding colonies are distributed north of Point Conception in southern California, *P. a. australis* included breeders in the California Channel Islands and Mexico (Wallace and others, 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 and others, 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; for example, Haystack Rock [hundreds], and off Cape Blanco [hundreds]; Naughton and others, 2007a) 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 and others, 2004). Post-breeding dispersal from British Columbia is thought to be southward extending into California (Briggs and others, 1987), with some indication that southern breeders may move northward into the northern CCS during the post-breeding period (late summer and fall; Adams and others, 2004). Cassin's Auklet is considered a Species of Conservation Concern in California, Threatened in Oregon, and a State Sensitive Species in Washington due to interactions with gill net fisheries, oil spills, and sensitivity to prey stocks (Adams, 2008; Oregon Department of Fish and Wildlife, 2014; Washington Department of Fish and Wildlife, 2015). The species had a PCV best-estimate score of 51, ranking it 'low' among the suite of species, and a PDV best-estimate score of 112, ranking it 'high' among the suite of species (table 7, fig. 3). High PDV is due to year-round presence in the CCS (table 4) and high Macro-Avoidance (table 6).

Approximately 1 million Parakeet Auklets (*Aethia psillacula*) breed in Alaska (Jones and others, 2001). After the summer breeding season, they can be found in small numbers throughout the CCS (Briggs and others, 1983). The species is considered of Least Concern (International Union for Conservation of Nature, 2014). Parakeet Auklet had a PCV best-estimate score of 26, ranking it 'low' among the suite of species, and a PDV best-estimate score of 60, ranking it 'low' among the suite of species (table 7, fig. 3).

Rhinoceros Auklet (*Cerorhinca monocerata*) 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 Dechesne, 1996). In 1988, there were an estimated 60,814 breeders nesting in Washington, mostly at Protection Island (34,216) and Destruction Island (23,600) (Gaston and Dechesne, 1996). Off Oregon, approximately 475 breeding birds (94 percent of State's breeding population) occur along the southern coastline (Naughton and others, 2007a). In 1988, Carter and others (1992) estimated 1,032 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 and others (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 a Candidate Species for the USFWS Endangered Species List (U.S. Fish and Wildlife Service, 2014). The species had a PCV best-estimate score of 62, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 136, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PDV is due to year-round presence in the CCS (table 4) and high Macro-Avoidance (table 6).

Horned Puffins (*Fratercula corniculata*) rarely are seen in the coastal CCS; however, they do occasionally wash up in wrecks along the California, Oregon, and Washington coasts. The majority of the population (85 percent) breeds in Alaska but only 2 percent spend the nonbreeding season there, and it is suspected that they travel south during the winter (Piatt and Kitaysky, 2002a). Horned Puffins feed on various abundant forage fishes, but are not as affiliated with coastal upwelling areas as other alcids (Piatt and Kitaysky, 2002a). The species is considered Near Threatened in Oregon (Oregon Department of Fish and Wildlife, 2014). Horned Puffin had a PCV best-estimate score of 32, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 84, ranking it ‘medium’ among the suite of species (table 7, fig. 3).

Tufted Puffins (*Fratercula cirrhata*) 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, 2002b). Tufted Puffins previously nested from the California Channel Islands north through Oregon and Washington (Briggs and others, 1981), however, breeding populations in the CCS have declined by 85 to 90 percent since the 1980s and the species was recently declared Endangered in Washington (Washington Department of Fish and Wildlife, 2015). The species had a PCV best-estimate score of 57, ranking it ‘low’ among the suite of species, and a PDV best-estimate score of 152, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PDV is due to year-round presence in the CCS, high Threat Status (table 4), and high Macro-Avoidance (table 6).

Similar to our values quantifying alcid vulnerability, Robinson Willmott and others (2013) reported that on the U.S. Atlantic Outer Continental Shelf, Atlantic Puffin (*Fratercula arctica*), Razorbill (*Alca torda*), and Common Murre (along with scoters, loons and tern species) have the greatest displacement vulnerabilities. These predictions are supported by post-construction reports from offshore wind energy sites. At Egmond aan Zee wind farm and Alpha Ventus test site in the North Sea, Common Murres and Razorbills have been found to avoid OWEI areas during construction and during the initial stages of operation (Krijgsveld and others, 2011; Mendel and others, 2014). Some increases in abundances of Common Murres and Razorbills were seen during operation of OWEI and thought to result from enhanced foraging opportunities associated with reef effects (Walls and others, 2013; Vanermen and others, 2013).

Gulls

Black-legged Kittiwake (*Rissa tridactyla*) is a small, abundant, well-studied (especially during its breeding season) gull that, in the Pacific, nests throughout the Gulf of Alaska, Aleutian Archipelago, and the Bering and Chukchi Seas (Hatch and others, 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 and others, 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 and others, 1987; 1992; Ainley and Hyrenbach, 2010). The species is considered of Least Concern (International Union for Conservation of Nature, 2014). Black-legged Kittiwakes had a PCV best-estimate score of 81, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 45, ranking it 'low' among the suite of species (table 7, fig. 3).

Sabine's Gull (*Xema sabini*; fig. 13) is a small, conspicuous, Holarctic-nesting gull of pelagic nature that favors southern-hemisphere coastal upwelling ecosystems during its annual nonbreeding season. Unknown proportions of individuals overwinter in the Humboldt Current (off Peru) and Benguela Current (off South Africa). Abundance during fall migration off the western U.S. tends to be protracted with individuals being less-concentrated at sea (Briggs and others, 1987; Day and others, 2001); seasonal timing of migration likely reflects interannual variability in departure related to breeding success (Davis and others, 2012). Off California, numbers of individuals during spring migration increase from late-April to reach a peak during mid-May (estimated at 50,000 individuals; Briggs and others, 1987); the spring migration peak occurs slightly later off Oregon and Washington (Briggs and others, 1987, 1992). In the fall, numbers off Washington and Oregon peak during August–September and slightly later (September–October) off California (Briggs and others, 1987; 1992). Sabine's Gull is considered a species of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 93, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 50, ranking it 'low' among the suite of species (table 7, fig. 3).

Figure 13. Sabine's Gull (*Xema sabini*) in juvenile plumage. Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

Bonaparte's Gull (*Chroicocephalus philadephia*) breeds along the west coast of Canada and Alaska and migrates through the CCS during the nonbreeding season (Briggs and others, 1992; Burger and Gochfeld, 2002). A large percentage of the population overwinters off southern California; much smaller numbers are found off northern California, Oregon, and Washington (Briggs and others, 1983; 1987; 1992). Bonaparte's Gull is considered a Species of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 149, ranking it 'high' among the suite of species, and a PDV best-estimate score of 80, ranking it 'medium' among the suite of species (table 7, fig. 3). High PCV is due to year-round presence and large percentage of population present in the CCS (table 4) and moderate percentage of 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 percent 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 the CCS for southern colonies by mid-March; abundance peaks off northern California in late June and off Oregon in late July (Briggs and others, 1987; 1992). Heermann's Gulls have a mixed diet during the nonbreeding 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*). Heermann's Gull is considered Near Threatened (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 131, ranking it 'high' among the suite of species, and a PDV best-estimate score of 56, ranking it 'low' among the suite of species (table 7, fig. 3). High PCV was due to year-round presence in the CCS (table 4) and moderate percentage of 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 (Moskoff and Bevier, 2002). The wintering population in southern California numbers about 1,500 (Briggs and others, 1987). Mew Gull is of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 65, ranking it 'low' among the suite of species, and a PDV best-estimate score of 28, ranking it 'low' among the suite of species (table 7, fig. 3). Mew Gulls have a lower PCV than most other gull species due to their low Annual Occurrence.

Ring-billed Gulls (*Larus delawarensis*) winter along the west coast of North America, along the Great Lakes, and along the southeastern coast of the United States, the Caribbean, and southeast Mexico (Pollet and others, 2012). At least 10,000 of these gulls winter along the southern California coast (Briggs and others, 1987; eBird, 2014). The Ring-billed Gull is of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 115, ranking it 'high' among the suite of species, and a PDV best-estimate score of 46, ranking it 'low' among the suite of species (table 7, fig. 3). High PCV was due to year-round presence in the CCS (table 4) and large percentage of time flying in the RSZ (table 5).

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 and Annett, 1995). In the northern CCS region of Oregon and Washington, Western Gulls readily hybridize with Glaucous-winged Gulls (*Larus glaucescens*), and the two species, together with the hybrids, are treated as one taxon in breeding population estimates within Washington (36,923 breeding individuals; Speich and Wahl, 1989) and Oregon (32,300 breeding individuals; Naughton and others, 2007a). Post-breeding dispersal is regional in this species, with some birds moving north and some south during fall and winter (Pierotti and Annett, 1995). Breeding birds generally occupy similar areas during winter as during the breeding season, but can be more far-ranging during the nonbreeding season (Pierotti and Annett, 1995). Most breeding pairs begin to occupy nesting territories by March (Penniman and others, 1990). At sea off Washington, Western Gulls (together with Glaucous-winged Gulls and hybrids) tend to associate with large multi-species flocks, especially nearshore where these large gulls serve as "catalysts" or initiators of flock-foraging events (Hoffman and others, 1981). Briggs and others (1992) found that Western Gulls were negatively associated with Sooty Shearwaters within mixed-species flocks. Briggs and others (1987) also found Western Gulls to be most evenly distributed during winter, with relatively greater numbers present within 25 km of shore between Point Arena, California and the California–Oregon border. Western Gull is of Least Concern (International Union for Conservation of Nature, 2014). Western Gull had a PCV best-estimate score of 171, ranking it 'high' among the suite of species, and a PDV best-estimate score of 76 ranking it 'medium' among the suite of species (table 7, fig. 3). High PCV was due to year-round presence in the CCS (table 4) and large percentage of time flying in the RSZ (table 5).

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 and others, 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 and others, 1992). Arrival of post-breeding adults at the coasts of Oregon and Washington begins in July (Briggs and others, 1992), but non-breeders and juvenile birds may reside in coastal waters year round (Winkler, 1996). Local abundances at sea, often aggregated in large flocks from fall to spring, can be greatly influenced by associations with fishing vessels. Coastal distributions also likely are associated with proximity to municipal landfill sites (Winkler, 1996). The California Gull is considered of Least Concern (International Union for Conservation of Nature, 2014). The species had a PCV best-estimate score of 135, ranking it 'high' among the suite of species, and a PDV best-estimate score of 58, ranking it 'low' among the suite of species (table 7, fig. 3). The high PCV was due to year-round presence in the CCS (table 4) and large percentage of time flying in the RSZ (table 5).

Herring Gull (*Larus argentatus*) is an abundant, well-studied circumboreal/subarctic 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 and others, 1987). The species is of Least Concern (International Union for Conservation of Nature, 2014). Herring Gull had a PCV best-estimate score of 87, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 36, ranking it 'low' among the suite of species (table 7, fig. 3).

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 (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 (International Union for Conservation of Nature, 2014). Thayer's Gull had a PCV best-estimate score of 121, ranking it 'high' among the suite of species, and a PDV best-estimate score of 52, ranking it 'low' among the suite of species (table 7, fig. 3). High PCV was due to a large percentage of 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 and others, 2007a). 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 hundreds of kilometers offshore (Briggs and others, 1992). Briggs and others (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 (International Union for Conservation of Nature, 2014). Glaucous-winged Gull had a PCV best-estimate score of 113, ranking it 'high' among the suite of species, and a PDV best-estimate score of 50 ranking it at 'low' risk of displacement by OWEI (table 7, fig. 3). High PCV was due to year-round presence in the CCS (table 4) and large percentage of time flying in the RSZ (table 5).

Previous vulnerability assessments also found gulls to be at high risk of collision. In the Scottish waters of the North Sea, gulls (along with White-tailed Eagle [*Haliaeetus albicilla*], Northern Gannets [*Morus bassanus*], and skuas) were estimated to be among the most vulnerable to collision (Furness and Wade, 2012; Furness and others, 2013). Robinson Willmott and others (2013) reported gulls (along with phalaropes, cormorants, and jaegers) had the greatest collision vulnerability. Post-construction reports from offshore wind energy sites suggested that gull response to OWEI might vary depending on location and species. At Egmond and Zee wind farm in the North Sea, gulls did not show any avoidance behavior and showed some indication of being attracted to OWEI that provided roosting habitat (Krijgsveld and others, 2011; Leopold and others, 2011). Peterson and others (2006) found that gulls at Nysted and Horns Rev wind farms in the Dutch North Sea also did not show avoidance behavior, thus increasing their potential risk of collision. Conversely, Mendel and others (2014) found that Lesser Black-backed gulls (*Larus fuscus*) were found in significantly lower concentrations inside Alpha Ventus OWEI than outside. During the first phase of construction at Thorntonbank and Blighbank wind farms, Vanermen and others, (2013) found that Lesser Black-backed Gulls showed both avoidance and attraction behavior, but Little Gull (*Hydrocoloeus minutus*), Greater Black-backed Gulls (*Larus marinus*), Common Gulls (*Larus canus*), and Herring Gulls all showed attraction to OWEI.

Terns

An estimated 10,000 Least Terns (*Sternula antillarum*) breed in California (Frost, 2015). The species is considered Endangered by the USFWS, California, and Oregon due to habitat loss, pollution, and sensitivity to human disturbance (U.S. Fish and Wildlife Service, 2014). Least Tern had a PCV best-estimate score of 175, ranking it 'high' among the suite of species, and a PDV best-estimate score of 168, ranking it 'high' among the suite of species (table 7, fig. 3). High PCV was due to large percentage of time flying in the RSZ (table 5) and high Population Vulnerability score (table 4). High PDV was due to high Macro-Avoidance (table 6) and high Population Vulnerability (table 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. Gull-billed Tern is an opportunistic feeder that consumes both terrestrial and marine prey (Molina and others, 2014). The species is considered a Bird of Conservation Concern by the USFWS and a California Species of Special Concern (Molina, 2008a; U.S. Fish and Wildlife Service, 2014). Gull-billed Tern had a PCV best-estimate score of 138, ranking it 'high' among the suite of species, and a PDV best-estimate score of 88, ranking it 'medium' among the suite of species (table 7, fig. 3). High PCV was due to large percentage of time flying in the RSZ (table 5), nocturnal flight activity, and high Population Vulnerability.

From 1981 to 2000, the Caspian Tern (*Hydroprogne caspia*) population in the Pacific coast region of North America has more than doubled (to 12,900 breeding pairs; Suryan and others, 2004). Coincident with this rapid population growth, has been a significant shift in the distribution of breeding birds with 69 percent of breeders in 2000 (*versus* 7 percent 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 and others, 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 and nocturnal migration is not uncommon (Cuthbert and Wires, 1999). The species is considered Vulnerable by the USFWS Pacific Seabird Conservation Status due to their high risk of habitat loss and degradation (U.S. Fish and Wildlife Service, 2005). Caspian Tern had a PCV best-estimate score of 176, ranking it 'high' among the suite of species, and a PDV best-estimate score of 128, ranking it 'high' among the suite of species (table 7, fig. 3). High PCV was due to nocturnal flight activity, year-round presence in the CCS and large percentage of time flying in the RSZ (table 5). High PDV was due to year-round presence in the CCS (table 4) and high Macro-Avoidance (table 6).

Black Terns (*Chlidonias niger*) breed on interior bodies of water in southern Canada and the northern United States. The species winters in marine and coastal environments in North and Central America (Shuford, 2008). They can be seen in small numbers off the coast of southern California. Black Tern is considered a Species of Special Concern in California (Shuford, 2008). Black Tern had a PCV best-estimate score of 75, ranking it 'medium' among the suite of species, and a PDV best-estimate score of 72, ranking it 'low' risk among the suite of species (table 7, fig. 3).

Due to their similar morphology, habitats, and migration patterns Arctic (*Sterna paradisaea*) and Common Terns (*S. hirundo*; fig. 14) often are grouped together during survey counts. Gould and others (1982) recorded 150,000–218,000 Arctic/Common Terns in the Gulf of Alaska during peak periods after the breeding season; 95 percent of these were estimated to be Arctic Terns. The majority of these birds are thought to migrate down the west coast of North America for the winter, where 200,000 were estimated off central California and 50,000 off southern California (Briggs and others, 1987). The majority of the Common Terns that appear in the CCS are thought to breed in Canada. 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 of Least Concern (International Union for Conservation of Nature, 2014). Common Tern had a PCV best-estimate score of 105, ranking it ‘high’ among the suite of species, and a PDV best-estimate score of 76, ranking it ‘medium’ among the suite of species (table 7, fig. 3). High PCV is due to large percentage of time spent flying in the RSZ, and nocturnal flight activity (table 5).

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 of Least Concern (International Union for Conservation of Nature, 2014). Arctic Tern had a PCV best-estimate score of 110 ranking it ‘high’ among the suite of species, and a PDV best-estimate score of 80, ranking it ‘medium’ among the suite of species (table 7, fig. 3). High PCV is due to large percentage of time spent flying in the RSZ, and nocturnal flight activity (table 5).

At least 8,000 Forster’s Terns (*Sterna forsteri*) breed on the Pacific coast of North America (McNicholl and others, 2001). The California breeding population was estimated at 3,550 individuals (Carter and others, 1992). The species is considered of Least Concern (International Union for Conservation of Nature, 2014). Forster’s Tern had a PCV best-estimate score of 165, ranking it ‘high’ among the suite of species, and a PDV best-estimate score of 120, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PCV is due to year-round presence in the CCS (table 4) and large percentage of time spent flying in the RSZ, and nocturnal flight activity (table 5). High PDV is due to year-round presence in the CCS and high Macro-Avoidance (table 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 of Least Concern (International Union for Conservation of Nature, 2014). Royal Tern had a PCV best-estimate score of 130, ranking it ‘high’ among the suite of species, and a PDV best-estimate score of 104, ranking it ‘medium’ among the suite of species (table 7, fig. 3). High PCV is due to year-round presence in the CCS (table 4) and the percentage of time spent flying in the RSZ (table 5).

The majority (95 percent) of Elegant Terns (*Thalasseus elegans*) breed on Isla Raza in the Gulf of California, Mexico, and the remainder breed at costal sites in southern California. Most Elegant Terns travel north up the California coast during the nonbreeding season (Burness and others, 1999). Elegant Terns feed primarily on northern anchovy (Burness and others, 1999). The species is considered Near Threatened (International Union for Conservation of Nature, 2014). Elegant Tern had a PCV score of 181, ranking it ‘high’ among the suite of species, and a PDV best-estimate score of 158, ranking it ‘high’ among the suite of species (table 7, fig. 3). High PCV is due to the percentage of time spent flying in the RSZ (table 5) and high Population Vulnerability (tables 4). High PDV is due to high Macro-Avoidance, low (high value) Habitat Flexibility (table 6), and high Population Vulnerability (table 4).

Figure 14. Common Tern (*Sterna hirundo*) in juvenile plumage. Photograph courtesy of David M. Pereksta, Bureau of Ocean Energy Management. Used with permission.

There are approximately 2,100 Black Skimmers (*Rynchops niger*) that breed along the coast of southern California (Molina, 2008b). The species is considered a California Species of Special Concern (Molina, 2008b). Black Skimmer had a PCV best-estimate score of 153, ranking it 'high' among the suite of species, and a PDV best-estimate score of 153, ranking it 'high' among the suite of species (table 7, fig. 3). High PCV is due to year-round presence in the CCS, the high percentage of time spent flying in the RSZ (table 5), and high Population Vulnerability (table 4). High PDV is due to year-round presence in the CCS, high Macro-Avoidance, high (low value) Habitat Flexibility (table 6), and high Population Vulnerability (table 4).

Consistent with our results, previous reports found terns to be vulnerable to both collision and displacement by OWEI. Garthe and Hüppop (2004) reported that Sandwich Tern (*Thalasseus sandvicensis*) was the fourth-most vulnerable species (after loons and scoters) to OWEI in their index of the German North Sea. Robinson Willmott and others (2013) listed four tern species to be among the species with greatest displacement vulnerability. Post-construction reports indicated that tern vulnerability varied among sites and species. Peterson and others (2006) found that terns do not show avoidance behavior in wind farm areas, thus increasing their collision risk. Vanermen and others (2013) found that Sandwich Tern and Common Tern were attracted to OWEI at Thorntonbank wind farm during the first phase of construction. Conversely, Gill and others (2008) observed fewer Sandwich and Common Terns flying through OWEI than pre-construction. Similarly, Perrow and others (2011) found that Little Terns (*Sternula albifrons*) were displaced during OWEI construction and Leopold and others (2011) observed that Sandwich Terns were more commonly seen flying around Egmond aan Zee wind farm than through it.

Conclusions

Bailey and others (2014) identified the need to understand impacts of OWEI on marine populations as one of the four primary lessons learned regarding OWEI construction in Europe to date. This study addresses this need by providing the first quantitative evaluation of vulnerability of OWEI to marine bird populations in the CCS. The final *Population Collision Vulnerability* and *Population Displacement Vulnerability* scores provided for each species offer reference values to evaluate the potential impacts of OWEI on marine birds within the CCS (table 7). The differences in uncertainty levels for each species highlighted in table 8 identify knowledge gaps in species vulnerability that could be filled by future research and monitoring of these species.

In the CCS, pelicans, cormorants, gulls, jaegers, and terns have the greatest *Population Collision Vulnerability* due to low avoidance rates and a high percentage of time flying at the height of turbine blades (table 5, fig. 3). Some species (Common Tern, Arctic Tern) also are thought to migrate during the night thus placing them at greater potential risk for collision. Alcids, terns, grebes, loons and Ashy Storm-Petrel have the greatest *Population Displacement Vulnerability* associated with offshore wind power infrastructure due to their high Macro-Aviodance and low Habitat Flexibility (table 6, fig. 3).

Our results found terns and gulls to be vulnerable to both displacement from, and collision with OWEI. Based on post-construction reports, tern and gull species can be vulnerable to both collision and displacement, and their vulnerabilities are species- and site-specific (Peterson and others, 2006; Krijgsveld and others, 2011; Leopold and others, 2011; Vanermen and others, 2013). Furthermore, Mendel and others (2014) found that, although concentrations of Lesser Black-backed Gulls were lower in OWEI area than outside, gulls in the OWEI area spent significantly more time actively feeding, thus increasing their collision risk. Thaxter and others (2015) found that Lesser Black-backed Gulls in the southern 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. These results indicate that gulls and terns in and around OWEI could compound their risk of collision and displacement. Species-specific and site-specific behavior should continue to be investigated to better understand the comprehensive effects of OWEI on gulls, terns, and other species.

Spatial and temporal variation in marine bird distribution can play a significant role in determining potential exposure of these birds to wind energy sites (Braham and others, 2015; Thaxter and others, 2015). The estimates 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 decisions that could impact seabird conservation. Vulnerability assessment results can be combined with recent marine bird at-sea distribution and abundance data to evaluate bird vulnerability to offshore renewable energy site locations in the CCS. We plan to combine the vulnerability values for birds in the CCS presented in this report with data collected during two recent large-scale, multi-season aerial marine bird surveys: the northern CCS PaCSEA study (Adams and others, 2014) and the southern CCS surveys conducted by Mason and others, 2007). In addition, tracking data that quantify habitat utilization in the CCS are available for some of the species and can provide continuous spatial information. 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 and others, 2013; Maxwell and others, 2013). Based on recent methodology, tracking data may also be used to generate improved flight height estimations (Cleasby and others, 2015). These improved flight height data could be used to reduce uncertainty surrounding time spent in the RSZ. As these and other new studies increase our understanding of the potential effects of OWEI on marine birds in the CCS, it will be important to revise the parameter values and vulnerability indices using new information as this becomes available.

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Glossary

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, percentage 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, percentage of 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 for 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 percent), medium (25 percent), or high (50 percent) degree of uncertainty. This uncertainty was then multiplied by the metric value and added/subtracted to create the range.
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 metric 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 Vulnerability Score The product of the Population Vulnerability Score and the Collision Vulnerability Score.
Population Displacement Vulnerability 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; presented with upper and lower scores based on uncertainty.
Rank Best-estimate score ranked as ‘high’, ‘medium’, or ‘low’ vulnerability based on 3 quantiles: bottom, middle, or top third of all species’ scores.

Appendix A

Table A1. Global Population Size (POP) score for each species and corresponding references.

[**Global Population References:** ABC, American Bird Conservancy]

Common name	POP	POP references
Brant	3	Davis and Deuel, 2008; ABC, 2012; Lewis and others, 2013; Robinson Willmott and others, 2013
Common Merganser	2	ABC, 2012
Red-breasted Merganser	3	ABC, 2012
Harlequin Duck	4	ABC, 2012
Surf Scoter	3	ABC, 2012
White-winged Scoter	2	Watts, 2010; ABC, 2012
Black Scoter	3	Bordage and Savard, 2011; Birdlife International, 2014a
Long-tailed Duck	1	ABC, 2012
Red-throated Loon	4	Barr and others, 2000; ABC, 2012
Pacific Loon	2	Russell, 2002; ABC, 2012
Common Loon	3	ABC, 2012
Yellow-billed Loon	5	ABC, 2012; Birdlife International, 2014a
Horned Grebe	3	ABC, 2012; Birdlife International, 2014a
Red-necked Grebe	4	ABC 2012; Birdlife International, 2014a
Eared Grebe	1	ABC, 2012
Western Grebe	4	ABC, 2012; LaPorte and others, 2013
Clark’s Grebe	5	Storer and Nuechterlein, 1992; ABC, 2012
Laysan Albatross	2	ABC, 2012
Black-footed Albatross	4	ABC, 2012
Short-tailed Albatross	5	Birdlife International, 2014a
Northern Fulmar	1	Mallory and others, 2012
Murphy’s Petrel	4	Birdlife International, 2014a
Mottled Petrel	2	ABC, 2012
Hawaiian Petrel	5	Birdlife International, 2014a
Cook’s Petrel	3	ABC, 2012; Birdlife International, 2014a
Pink-footed Shearwater	5	ABC, 2012; Adams and others, 2014
Flesh-footed Shearwater	3	ABC, 2012
Buller’s Shearwater	2	ABC, 2012
Sooty Shearwater	1	ABC, 2012
Short-tailed Shearwater	1	ABC, 2012
Manx Shearwater	3	ABC, 2012; Robinson Willmott and others, 2013
Black-vented Shearwater	4	ABC, 2012; Birdlife International, 2014a
Wilson’s Storm-Petrel	1	Watts, 2010; Birdlife International, 2014a
Fork-tailed Storm-Petrel	1	ABC, 2012
Leach’s Storm-Petrel	1	Watts, 2010; ABC, 2012
Ashy Storm-Petrel	5	Ainley, 1995; Spear and Ainley, 2007; ABC, 2012
Black Storm-Petrel	3	Spear and Ainley, 2007

Common name	POP	POP references
Least Storm-Petrel	3	Spear and Ainley, 2007; ABC, 2012; Birdlife International, 2014a
Brandt's Cormorant	4	Boekelheide and others, 1990
Double-crested Cormorant	2	ABC, 2012
Pelagic Cormorant	4	ABC, 2012
American White Pelican	4	ABC, 2012
Brown Pelican	4	ABC, 2012
Red-necked Phalarope	1	ABC, 2012
Red Phalarope	2	ABC, 2012
South Polar Skua	5	ABC, 2012
Pomarine Jaeger	2	ABC, 2012; Robinson Willmott and others, 2013
Parasitic Jaeger	1	ABC, 2012; Robinson Willmott and others, 2013
Long-tailed Jaeger	1	ABC, 2012
Common Murre	1	ABC, 2012
Pigeon Guillemot	4	ABC, 2012
Marbled Murrelet	3	ABC, 2012
Scripps's Murrelet	5	ABC, 2012
Craveri's Murrelet	5	ABC, 2012; Birdlife International, 2014a
Ancient Murrelet	2	ABC, 2012
Cassin's Auklet	1	Adams, 2008; ABC, 2012
Parakeet Auklet	2	ABC, 2012; Birdlife International, 2014a
Rhinoceros Auklet	2	ABC, 2012
Horned Puffin	2	ABC, 2012
Tufted Puffin	1	Piatt and Kitaysky, 2002b; ABC, 2012
Black-legged Kittiwake	1	ABC, 2012
Sabine's Gull	3	Day and others, 2001; ABC, 2012
Bonaparte's Gull	4	Burger and Gochfeld, 2002; Watts, 2010; ABC, 2012
Heermann's Gull	3	Islam, 2002; ABC, 2012; Adams and others, 2014
Mew Gull	1	ABC, 2012
Ring-billed Gull	2	ABC, 2012
Western Gull	4	ABC, 2012
California Gull	3	ABC, 2012
Herring Gull	1	Watts, 2010; Robinson Willmott and others, 2013
Thayer's Gull	5	ABC, 2012
Glaucous-winged Gull	3	ABC, 2012
Least Tern	5	ABC, 2012
Gull-billed Tern	4	Watts, 2010; ABC, 2012; Birdlife International, 2014a
Caspian Tern	4	ABC, 2012
Black Tern	2	ABC, 2012
Common Tern	2	ABC, 2012; Robinson Willmott and others, 2013
Arctic Tern	2	ABC, 2012
Forster's Tern	4	ABC, 2012
Royal Tern	4	ABC, 2012
Elegant Tern	5	ABC, 2012
Black Skimmer	4	ABC, 2012; Robinson Willmott and others, 2013

Table A2. Annual Occurrence in the CCS (AO) score for each species and corresponding references.

Common name	AO	AO references
Brant	2	Briggs and others, 1981; eBird, 2014
Common Merganser	1.5	Adams and others, 2014
Red-breasted Merganser	2	Briggs and others, 1981
Harlequin Duck	1.5	Robertson and Goudie, 1999; Shuford and Gardali, 2008; eBird, 2014
Surf Scoter	2	Briggs and others, 1981, 1983, 1992; Adams and others, 2014; eBird, 2014
White-winged Scoter	1.5	Briggs and others, 1981, 1983, 1992; Adams and others, 2014; eBird, 2014
Black Scoter	1.5	Briggs and others, 1981; eBird, 2014
Long-tailed Duck	1.5	Robertson and Savard, 2002; eBird, 2014
Red-throated Loon	1.5	Briggs and others, 1981, 1992
Pacific Loon	1.5	Briggs and others, 1981, 1983, 1992; Adams and others, 2014; eBird, 2014
Common Loon	1.5	Briggs and others, 1981, 1992; eBird, 2014
Yellow-billed Loon	2	Briggs and others, 1981; eBird, 2014
Horned Grebe	2	Briggs and others, 1981; Stedman, 2000; Henkel, 2004; eBird, 2014
Red-necked Grebe	1.5	Briggs and others, 1981; Stout and Nuechterlein, 1999; eBird, 2014
Eared Grebe	2	Briggs and others, 1981; eBird, 2014
Western Grebe	2	Briggs and others, 1981, 1983, 1992; Henkel, 2004; Adams and others, 2014; eBird, 2014
Clark's Grebe	2	Briggs and others, 1981, 1983, 1992; Henkel, 2004; Adams and others, 2014; eBird, 2014
Laysan Albatross	2	Briggs and others, 1981, 1992; McDermond and Morgan, 1993
Black-footed Albatross	1.5	Briggs and others, 1981, 1992; McDermond and Morgan, 1993; Adams and others, 2014
Short-tailed Albatross	2	Briggs and others, 1981; McDermond and Morgan 1993; Birdlife International, 2014a; eBird, 2014
Northern Fulmar	2	Briggs and others, 1981, 1983, 1992; eBird, 2014
Murphy's Petrel	1	eBird, 2014
Mottled Petrel	1.5	Briggs and others, 1981; Bartle and others, 1993; eBird, 2014
Hawaiian Petrel	1.5	Briggs and others, 1981; eBird, 2014
Cook's Petrel	1.5	Briggs and others, 1981; Bartle and others, 1993; eBird, 2014
Pink-footed Shearwater	1.5	Briggs and others, 1981, 1992; eBird, 2014
Flesh-footed Shearwater	1.5	Briggs and others, 1981; eBird, 2014
Buller's Shearwater	1	Briggs and others, 1981, 1992; Adams and others, 2014; eBird, 2014
Sooty Shearwater	2	Briggs and others, 1981, 1983
Short-tailed Shearwater	1.5	Briggs and others, 1981, 1992; eBird, 2014
Manx Shearwater	2	Briggs and others, 1981; eBird, 2014
Black-vented Shearwater	2	Briggs and others, 1981; eBird, 2014
Wilson's Storm-Petrel	1.5	Briggs and others, 1981; eBird, 2014
Fork-tailed Storm-Petrel	1	Briggs and others, 1981, 1992; Adams and others, 2014; eBird, 2014
Leach's Storm-Petrel	1	Briggs and others, 1981, 1983, 1992; eBird, 2014
Ashy Storm-Petrel	2	Briggs and others, 1981; eBird, 2014
Black Storm-Petrel	1.5	Briggs and others, 1981; eBird, 2014
Least Storm-Petrel	1.5	eBird, 2014
Brandt's Cormorant	2	Briggs and others, 1981, 1983, 1992; Adams and others, 2014
Double-crested Cormorant	2	Briggs and others, 1981, 1992; Adams and others, 2014

Common name	AO	AO references
Pelagic Cormorant	2	Briggs and others, 1981, 1992; Adams and others, 2014
American White Pelican	2	Briggs and others, 1981; eBird, 2014
Brown Pelican	2	Briggs and others, 1981, 1983, 1992; Adams and others, 2014
Red-necked Phalarope	1.5	Briggs and others, 1981, 1983, 1992; eBird, 2014
Red Phalarope	2	Briggs and others, 1981, 1983, 1992; eBird, 2014
South Polar Skua	1.5	Briggs and others, 1981, 1992; Adams and others, 2014; eBird, 2014
Pomarine Jaeger	1.5	Briggs and others, 1981, 1992; Adams and others, 2014; eBird, 2014
Parasitic Jaeger	1.5	Briggs and others, 1981, 1992; Adams and others, 2014; eBird, 2014
Long-tailed Jaeger	1.5	Briggs and others, 1992; Adams and others, 2014; eBird, 2014
Common Murre	2	Briggs and others, 1981, 1983, 1992; Adams and others, 2014
Pigeon Guillemot	2	Briggs and others, 1981
Marbled Murrelet	2	Briggs and others, 1992; Adams and others, 2014; eBird, 2014
Scripps’s Murrelet	2	Briggs and others, 1981; eBird, 2014
Craveri’s Murrelet	1	Briggs and others, 1981; eBird, 2014
Ancient Murrelet	1	Briggs and others, 1981, 1992; eBird, 2014
Cassin’s Auklet	2	Briggs and others, 1981, 1983, 1992; Adams and others, 2014
Parakeet Auklet	1.5	eBird, 2014
Rhinoceros Auklet	2	Briggs and others, 1981, 1983, 1992; Adams and others, 2014
Horned Puffin	1.5	Briggs and others, 1981
Tufted Puffin	1.5	Briggs and others, 1981, 1992
Black-legged Kittiwake	1.5	Briggs and others, 1981, 1983, 1992; Adams and others, 2014; eBird, 2014
Sabine’s Gull	1.5	Briggs and others, 1981, 1992; Adams and others, 2014; eBird, 2014
Bonaparte’s Gull	2	Briggs and others, 1981, 1992; eBird, 2014
Heermann’s Gull	2	Briggs and others, 1981, 1992; Adams and others, 2014; eBird, 2014
Mew Gull	1.5	Briggs and others, 1981; Henkel, 2004, eBird, 2014
Ring-billed Gull	2	Briggs and others, 1981
Western Gull	2	Briggs and others, 1981, 1983, 1992; Adams and others, 2014
California Gull	2	Briggs and others, 1981, 1983, 1992
Herring Gull	2	Briggs and others, 1981, 1992; eBird, 2014
Thayer’s Gull	2	Briggs and others, 1981, 1992; Adams and others, 2014; eBird, 2014
Glaucous-winged Gull	2	Briggs and others, 1992; Adams and others, 2014; eBird, 2014
Least Tern	1.5	Briggs and others, 1981
Gull-billed Tern	1.5	eBird, 2014
Caspian Tern	2	Briggs and others, 1981; eBird, 2014
Black Tern	1	Shuford and Gardali, 2008; eBird, 2014
Common Tern	1.5	Briggs and others, 1981, 1983, 1992; eBird, 2014
Arctic Tern	1.5	Briggs and others, 1981, 1983, 1992; eBird, 2014
Forster’s Tern	2	Briggs and others, 1981; eBird, 2014
Royal Tern	2	Briggs and others, 1981; eBird, 2014
Elegant Tern	1.5	Briggs and others, 1981; Henkel, 2004; eBird, 2014
Black Skimmer	2	eBird, 2014

Table A3. Percentage of global population in the California Current System (CCSpop) score for each species and corresponding references.

[**CCSpop references:** ABC, American Bird Conservancy; USFWS, U.S. Fish and Wildlife Service]

Common name	CCSpop	CCSpop references
Brant	2	Pacific Flyway Council, 2002; Davis and Deuel, 2008
Common Merganser	1	Mallory and Metz, 1999; Birdlife International, 2014a
Red-breasted Merganser	1	Briggs and others, 1983; Titman, 1999
Harlequin Duck	2	Robertson and Goudie, 1999; Shuford and Gardali, 2008
Surf Scoter	3	Briggs and others, 1992; Sauer and others, 1998
White-winged Scoter	2	Briggs and others, 1983, 1992; Sauer and others, 1998
Black Scoter	2	Briggs and others, 1983; Stehn and others, 2006; Bordage and Savard, 2011; Adams and others, 2014; Birdlife International, 2014a
Long-tailed Duck	1	Robertson and Savard, 2002; Birdlife International, 2014a
Red-throated Loon	2	Briggs and others, 1992; Barr and others, 2000; Adams and others, 2014
Pacific Loon	3	Russell, 2002
Common Loon	3	Evers and others, 2010; Adams and others, 2014
Yellow-billed Loon	2	J. Schmutz, U.S. Geological Survey, oral commun., July 31, 2014
Horned Grebe	1	Briggs and others, 1987; Stedman, 2000
Red-necked Grebe	2	Briggs and others, 1987, 1992; Stout and Nuechterlein, 1999
Eared Grebe	2	Briggs and others, 1987; Cullen and others, 1999
Western Grebe	4	Briggs and others, 1987; Henkel, 2004; LaPorte and others, 2013
Clark's Grebe	3	Briggs and others, 1987; Storer and Nuechterlein, 1992; Henkel, 2004
Laysan Albatross	1	Hernández-Montoya and others, 2014
Black-footed Albatross	3	Briggs and others, 1987, 1992; Naughton and others, 2007b; Awkerman and others, 2008
Short-tailed Albatross	2	McDermond and Morgan, 1993; Suryan and others, 2007; Birdlife International, 2014a
Northern Fulmar	2	Briggs and others, 1987, 1992; Mallory and others, 2012; Adams and others, 2014
Murphy's Petrel	2	Birdlife International, 2014a; eBird, 2014
Mottled Petrel	2	Briggs and others, 1987; Bartle and others, 1993; Birdlife International, 2014a
Hawaiian Petrel	1	Briggs and others, 1987; Bartle and others, 1993; Simons and Hodges, 1998
Cook's Petrel	3	Briggs and others, 1987; Bartle and others, 1993; Rayner and others, 2011
Pink-footed Shearwater	4	J. Adams, U.S. Geological Survey, oral commun., May 9, 2016
Flesh-footed Shearwater	1	Briggs and others, 1987; Birdlife International, 2014a
Buller's Shearwater	2	Briggs and others, 1987, 1992; Adams and others, 2014; Birdlife International, 2014a
Sooty Shearwater	3	Briggs and others, 1983, 1987, 1992; Adams and others, 2012
Short-tailed Shearwater	1	Briggs and others, 1987, 1992; Birdlife International, 2014a
Manx Shearwater	1	Lee and Haney, 1996; Birdlife International, 2014a
Black-vented Shearwater	2	Briggs and others, 1987; Keitt and others, 2000; Birdlife International, 2014a
Wilson's Storm-Petrel	1	Spear and Ainley, 2007; Birdlife International, 2014a
Fork-tailed Storm-Petrel	1	Sowls and others, 1980; Briggs and others, 1983; Speich and Wahl, 1989; Spear and Ainley, 2007; McChesney and Carter, 2008
Leach's Storm-Petrel	2	Sowls and others, 1980; Speich and Wahl, 1989; Huntington and others, 1996; Naughton and others, 2007a; Spear and Ainley, 2007; Adams and others, 2014
Ashy Storm-Petrel	5	Sowls and others, 1980; Ainley, 1995; Carter and others, 2008; Adams and others, 2014

Common name	CCSpop	CCSpop references
Black Storm-Petrel	1	Sowls and others, 1980; Spear and Ainley, 2007; Ainley, 2008; Adams and others, 2014
Least Storm-Petrel	1	Sowls and others, 1980; Spear and Ainley, 2008
Brandt's Cormorant	4	Siegel-Cousey and Litvinenko, 1993; Ainley and others, 1994; Wallace and Wallace, 1998; Adams and others, 2014; Capitolo and others, 2014
Double-crested Cormorant	2	Sowls and others, 1980; Briggs and others, 1983; Siegel-Cousey and Litvinenko, 1993; Hatch and Weseloh, 1999; Adams and others, 2014
Pelagic Cormorant	2	Sowls and others, 1980; Carter and others, 1992; Siegel-Cousey and Litvinenko, 1993; Adams and others, 2014
American White Pelican	3	Knof and Evans, 2004
Brown Pelican	3	Anderson and others, 2007; USFWS, 2009a
Red-necked Phalarope	4	Briggs and others, 1983, 1987, 1992; Rubega and others, 2000
Red Phalarope	4	Briggs and others, 1983, 1987, 1992; Tracy and others, 2002
South Polar Skua	2	Briggs and others, 1987, 1992; Adams and others, 2014
Pomarine Jaeger	2	Briggs and others, 1987, 1992; Adams and others, 2014
Parasitic Jaeger	1	Briggs and others, 1987, 1992; Adams and others, 2014
Long-tailed Jaeger	1	Briggs and others, 1987, 1992; Adams and others, 2014
Common Murre	2	Sowls and others, 1980; Speich and Wahl, 1989; Carter and others, 1992; Manuwal and others, 2001; Adams and others, 2014
Pigeon Guillemot	2	Sowls and others, 1980; Briggs and others, 1983; Speich and Wahl, 1989; Carter and others, 1992
Marbled Murrelet	2	Speich and Wahl, 1989; USFWS, 2009b; Adams and others, 2014
Scripps's Murrelet	2	Sowls and others, 1980; Briggs and others, 1983; Carter and others, 1992
Craveri's Murrelet	2	Briggs and others, 1987; Birdlife International, 2014a
Ancient Murrelet	3	Briggs and others, 1987, 1992; Gaston and Shoji, 2010; Adams and others, 2014
Cassin's Auklet	2	Speich and Wahl, 1989; Ainley and others, 1990b; Adams, 2008
Parakeet Auklet	1	Briggs and others, 1983; Jones and others, 2001
Rhinoceros Auklet	2	Sowls and others, 1980
Horned Puffin	1	Briggs and others, 1987; Piatt and Kitaysky, 2002a; Birdlife International, 2014a
Tufted Puffin	2	Carter and others, 1992; Piatt and Kitaysky, 2002b
Black-legged Kittiwake	2	Briggs and others, 1983; Hatch and others, 2009
Sabine's Gull	2	Briggs and others, 1983, 1987, 1992; Day and others, 2001; Adams and others, 2014
Bonaparte's Gull	4	Briggs and others, 1987, 1992; Burger and Gochfeld, 2002
Heermann's Gull	3	Briggs and others, 1987, 1992; Adams and others, 2014; Birdlife International, 2014a
Mew Gull	2	Briggs and others, 1983, 1987, Moskoff and Bevier, 2002
Ring-billed Gull	2	Briggs and others, 1983, 1987; Pollet and others, 2012
Western Gull	4	Sowls and others, 1980; Briggs and others, 1983, 1987, 1992; Carter and others, 1992; T. Good, National Oceanic and Atmospheric Administration, oral commun., September 9, 2014
California Gull	3	Carter and others, 1992; Winkler, 1996; Adams and others, 2014
Herring Gull	2	Briggs and others, 1983, 1987; Pierotti and Good, 1994
Thayer's Gull	2	Briggs and others, 1983, 1987, 1992; Snell, 2002; Adams and others, 2014
Glaucous-winged Gull	2	Briggs and others, 1983, 1987; Speich and Wahl, 1989; Naughton and others, 2007a; Adams and others, 2014; T. Good, National Oceanic and Atmospheric Administration, oral commun., September 9, 2014
Least Tern	2	Carter and others, 1992; ABC, 2012
Gull-billed Tern	1	Molina, 2008a; Molina and others, 2014
Caspian Tern	2	Speich and Wahl, 1989; Carter and others, 1992; Suryan and others, 2004; Adams and

Common name	CCSpop	CCSpop references
		others, 2014
Black Tern	1	Heath and others, 2009
Common Tern	1	Gould and others, 1982; Briggs and others, 1983, 1992
Arctic Tern	2	Gould and others, 1982; Briggs and others, 1983, 1992
Forster’s Tern	2	Briggs and others, 1987; Carter and others, 1992
Royal Tern	1	Briggs and others, 1987; Buckley and Buckley, 2002
Elegant Tern	3	Briggs and others, 1987; Burness and others, 1999; Birdlife International, 2014a
Black Skimmer	2	Molina, 2008b; Heath and others, 2009

Table A4. Species Threat Status (TS) score and corresponding references.

[**TS reference:** COSEWIC, Committee on the Status of Endangered Wildlife in Canada; IUCN, International Union for Conservation of Nature and Natural Resources; ODFW, Oregon Department of Fish and Wildlife; USFWS, U.S. Fish and Wildlife Service; WDFW, Washington Department of Fish and Game]

Common name	TS	TS references
Brant	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Common Merganser	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali 2008; IUCN, 2014; ODFW, 2014
Red-breasted Merganser	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali 2008; IUCN, 2014; ODFW, 2014
Harlequin Duck	3	Shuford and Gardali, 2008; USFWS, 2014; IUCN, 2014; ODFW, 2014; WDFW, 2015
Surf Scoter	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
White-winged Scoter	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Black Scoter	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Long-tailed Duck	3	Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014; USFWS, 2014; WDFW, 2015
Red-throated Loon	2	WDFW, 2003; USFWS, 2005, 2008, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Pacific Loon	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Common Loon	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Yellow-billed Loon	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Horned Grebe	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Red-necked Grebe	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Eared Grebe	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Western Grebe	3	USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014; WDFW, 2015
Clark's Grebe	3	USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014; WDFW, 2015
Laysan Albatross	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; IUCN, 2014; ODFW, 2014
Black-footed Albatross	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Short-tailed Albatross	5	Ministry of Environment Japan, 1991; WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Northern Fulmar	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Murphy's Petrel	2	Shuford and Gardali, 2008; USFWS, 2014; IUCN, 2014; ODFW, 2014; WDFW, 2015
Mottled Petrel	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Hawaiian Petrel	5	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Cook's Petrel	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; Robertson and others, 2013; IUCN, 2014; ODFW, 2014
Pink-footed Shearwater	4	WDFW, 2003; COSEWIC, 2004, USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; Ministerio del Medio Ambiente, 2012; IUCN, 2014; ODFW, 2014
Flesh-footed Shearwater	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Robertson and others, 2013; IUCN, 2014; ODFW, 2014
Buller's Shearwater	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Robertson and others, 2013; IUCN, 2014; ODFW, 2014

Common name	TS	TS references
Sooty Shearwater	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Robertson and others, 2013; IUCN, 2014; ODFW, 2014
Short-tailed Shearwater	1	WDFW, 2003; USFWS, 2005, 2 014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Manx Shearwater	1	WDFW, 2003; USFWS, 2005, Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Black-vented Shearwater	4	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; IUCN, 2014; ODFW, 2014
Wilson's Storm-Petrel	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Fork-tailed Storm-Petrel	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Leach's Storm-Petrel	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; IUCN, 2014; ODFW, 2014
Ashy Storm-Petrel	4	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; IUCN, 2014; ODFW, 2014
Black Storm-Petrel	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; IUCN, 2014; ODFW, 2014
Least Storm-Petrel	2	Shuford and Gardali, 2008; USFWS, 2014; IUCN, 2014; ODFW, 2014; WDFW, 2015
Brandt's Cormorant	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Double-crested Cormorant	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Pelagic Cormorant	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
American White Pelican	5	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Brown Pelican	5	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Red-necked Phalarope	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Red Phalarope	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
South Polar Skua	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Pomarine Jaeger	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Parasitic Jaeger	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Long-tailed Jaeger	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Common Murre	3	Ministry of Environment Japan 1991, WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Pigeon Guillemot	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Marbled Murrelet	5	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Scripps's Murrelet	4	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; IUCN, 2014; ODFW, 2014
Craveri's Murrelet	4	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; IUCN, 2014; ODFW, 2014
Ancient Murrelet	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Cassin's Auklet	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; IUCN, 2014; ODFW, 2014
Parakeet Auklet	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Rhinoceros Auklet	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Horned Puffin	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014

Common name	TS	TS references
Tufted Puffin	5	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Black-legged Kittiwake	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Sabine's Gull	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Bonaparte's Gull	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Heermann's Gull	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; IUCN, 2014; ODFW, 2014
Mew Gull	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Ring-billed Gull	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Western Gull	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
California Gull	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Herring Gull	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Thayer's Gull	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Glaucous-winged Gull	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Least Tern	5	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Gull-billed Tern	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Caspian Tern	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Black Tern	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Common Tern	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; Flores, 2010; COSEWIC, 2013; IUCN, 2014; ODFW, 2014
Arctic Tern	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Forster's Tern	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Royal Tern	1	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Elegant Tern	2	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014
Black Skimmer	3	WDFW, 2003; USFWS, 2005, 2014; Shuford and Gardali, 2008; IUCN, 2014; ODFW, 2014

Table A5. Breeding Score (BR). If the species raises young in the CCS (BR = 2), sometimes raises young in the CCS (BR = 1.5), or doesn't raise young in the CCS (BR = 1) and corresponding references.

Common name	BR	BR reference
Brant	1	Lewis and others, 2013
Common Merganser	1.5	Mallory and Metz, 1999
Red-breasted Merganser	1	Titman, 1999
Harlequin Duck	1	Robertson and Goudie, 1999
Surf Scoter	1	Sauer and others, 1998
White-winged Scoter	1	Brown and Fredrickson, 1997
Black Scoter	1	Bordage and Savard, 2011
Long-tailed Duck	1	Robertson and Savard, 2002
Red-throated Loon	1	Barr and others, 2000
Pacific Loon	1	Russell, 2002
Common Loon	1	Evers and others, 2010
Yellow-billed Loon	1	North, 1994
Horned Grebe	1	Stedman, 2000
Red-necked Grebe	1	Stout and Nuechterlein, 1999
Eared Grebe	1	Cullen and others, 1999
Western Grebe	1.5	LaPorte and others, 2013
Clark's Grebe	1.5	LaPorte and others, 2013; Henkel, 2004
Laysan Albatross	1	McDermond and Morgan, 1993
Black-footed Albatross	1	McDermond and Morgan, 1993
Short-tailed Albatross	1	McDermond and Morgan, 1993
Northern Fulmar	1	Hatch and others, 1993
Murphy's Petrel	1	Birdlife International, 2014a
Mottled Petrel	1	Bartle and others, 1993
Hawaiian Petrel	1	Bartle and others, 1993
Cook's Petrel	1	Bartle and others, 1993
Pink-footed Shearwater	1	Birdlife International, 2014a; Evertt and Pitman, 1993
Flesh-footed Shearwater	1	Birdlife International, 2014a; Evertt and Pitman, 1993
Buller's Shearwater	1	Birdlife International, 2014a; Evertt and Pitman, 1993
Sooty Shearwater	1	Birdlife International, 2014a; Evertt and Pitman, 1993
Short-tailed Shearwater	1	Birdlife International, 2014a; Evertt and Pitman, 1993
Manx Shearwater	1	Birdlife International, 2014a; Evertt and Pitman, 1993
Black-vented Shearwater	1	Birdlife International, 2014a; Evertt and Pitman, 1993
Wilson's Storm-Petrel	1	Spear and Ainley, 2007
Fork-tailed Storm-Petrel	1.5	Boersma and Silva, 2004
Leach's Storm-Petrel	2	Huntington and others, 1996; Spear and Ainley, 2007
Ashy Storm-Petrel	2	Ainley, 1995; Spear and Ainley, 2007
Black Storm-Petrel	1.5	Ainley and Everett, 2001; Spear and Ainley, 2007
Least Storm-Petrel	1.5	Spear and Ainley, 2007
Brandt's Cormorant	2	Siegel-Causey and Litvinenko, 1993
Double-crested Cormorant	2	Siegel-Causey and Litvinenko, 1993

Common name	BR	BR reference
Pelagic Cormorant	2	Siegel-Causey and Litvinenko, 1993
American White Pelican	1	Knopf and Evans, 2004
Brown Pelican	1.5	Shields, 2014
Red-necked Phalarope	1	Rubega and others, 2000
Red Phalarope	1	Tracy and others, 2002
South Polar Skua	1	Birdlife International, 2014a
Pomarine Jaeger	1	Wiley and Lee, 2000
Parasitic Jaeger	1	Wiley and Lee, 1999
Long-tailed Jaeger	1	Wiley and Lee, 1998
Common Murre	2	Ainley and others, 2002
Pigeon Guillemot	2	Ewins and others, 1993
Marbled Murrelet	2	Ewins and others, 1993
Scripps's Murrelet	1.5	Drost and Lewis, 1995
Craveri's Murrelet	1	Springer and others, 1993
Ancient Murrelet	2	Springer and others, 1993
Cassin's Auklet	2	Springer and others, 1993
Parakeet Auklet	1	Springer and others, 1993
Rhinoceros Auklet	2	Gaston and Dechesne, 1996
Horned Puffin	1	Piatt and Kitaysky, 2002a
Tufted Puffin	2	Piatt and Kitaysky, 2002b
Black-legged Kittiwake	1	Hatch and others, 1993
Sabine's Gull	1	Day and others, 2001
Bonaparte's Gull	1	Burger and Gochfeld, 2002
Heermann's Gull	1	Islam, 2002
Mew Gull	1	Moskoff and Bevier, 2002
Ring-billed Gull	1.5	Pollet and others, 2012
Western Gull	2	Pierotti and Annett, 1995
California Gull	1.5	Winkler, 1996
Herring Gull	1	Pierotti and Good, 1994
Thayer's Gull	1	Snell, 2002
Glaucous-winged Gull	1.5	Hayward and Verbeek, 2008
Least Tern	2	Thompson and others, 1997
Gull-billed Tern	1	Molina and others, 2014
Caspian Tern	1.5	Cuthbert and Wires, 1999
Black Tern	1	Heath and others, 2009
Common Tern	1	Nisbet, 2002
Arctic Tern	1	Hatch, 2002
Forster's Tern	1.5	Mcnicholl and others, 2001
Royal Tern	1.5	Buckley and Buckley, 2002
Elegant Tern	1.5	Burness and others, 1999
Black Skimmer	1.5	Gochfeld and Burger, 1994

Table A6. Species Adult Survival (AS) score and corresponding references.

Common name	AS	AS references
Brant	3	Krementz and others, 1997; Ward and others, 1997; Lewis and others, 2013; Lindberg and others, 2013; Robinson Willmott and others, 2013
Common Merganser	1	Mallory and Metz, 1999; Pearce and others, 2015; Robinson Willmott and others, 2013
Red-breasted Merganser	2	Dugger and others 1999; Titman, 1999; Robinson Willmott and others, 2013
Harlequin Duck	4	Robertson and Goudie, 1999; Robinson Wilmott and others, 2013
Surf Scoter	2	Fox and others, 2006; Sauer and others, 1998; De La Cruz and others, 2013
White-winged Scoter	2	Brown and Fredrickson, 1997; Kehoe and others, 1989; Fox and others, 2006; Wayland and others, 2008; Robinson Willmott and others, 2013
Black Scoter	2	Fox and others, 2006; Bordage and Savard, 2011; Robinson Willmott and others, 2013
Long-tailed Duck	1	Robertson and Savard, 2002; Robinson Wilmott and others, 2013
Red-throated Loon	4	Furness and Wade, 2012; Robinson Willmott and others, 2013; Schmutz, 2014
Pacific Loon	4	del Hoyo and others, 1992; Russell, 2002
Common Loon	5	Evers and others, 2010; Mitro and others, 2008; Robinson Willmott and others, 2013
Yellow-billed Loon	5	J. Schmutz, U.S. Geological Survey, oral commun., July 31, 2014
Horned Grebe	1	Stedman, 2000; Abt and Konter, 2009; Furness and Wade, 2012; Robinson Willmott and others, 2013
Red-necked Grebe	1	Stout and Nuechterlein, 1999; Garthe and Hüppop, 2004; Abt and Konter, 2009; Furness and Wade, 2012; Robinson Willmott and others, 2013
Eared Grebe	1	Abt and Konter, 2009; Furness and Wade, 2012
Western Grebe	1	Abt and Konter, 2009; Furness and Wade, 2012; LaPorte and others, 2013
Clark’s Grebe	1	Storer and Nuechterlein, 1992; Abt and Konter, 2009
Laysan Albatross	5	Botkin and Miller, 1974; del Hoyo and others, 1992; Awkerman and others, 2009
Black-footed Albatross	5	Botkin and Miller, 1974; Gerber and Heppell, 2004; Awkerman and others, 2008
Short-tailed Albatross	5	Botkin and Miller, 1974; del Hoyo and others, 1992; Lee and Haney, 1996; Furness and Wade, 2012
Northern Fulmar	5	Botkin and Miller 1974; del Hoyo and others, 1992; Furness and Wade, 2012; Mallory and others, 2012
Murphy’s Petrel	5	Robinson Wilmott and others, 2013
Mottled Petrel	5	del Hoyo and others, 1992; Simon and Hodges, 1998; Furness and Wade, 2012
Hawaiian Petrel	5	Simons and Hodges, 1998
Cook’s Petrel	5	del Hoyo and others, 1992; Simon and Hodges, 1998; Furness and Wade, 2012
Pink-footed Shearwater	5	del Hoyo and others, 1992; Lee and Haney, 1996; Furness and Wade, 2012
Flesh-footed Shearwater	5	del Hoyo and others, 1992; Lee and Haney, 1996; Furness and Wade, 2012
Buller’s Shearwater	5	del Hoyo and others, 1992; Lee and Haney, 1996; Furness and Wade, 2012
Sooty Shearwater	5	Botkin and Miller, 1974; Furness and Wade, 2012
Short-tailed Shearwater	5	del Hoyo and others, 1992; Lee and Haney, 1996; Furness and Wade, 2012
Manx Shearwater	5	del Hoyo and others, 1992; Lee and Haney, 1996; Furness and Wade, 2012
Black-vented Shearwater	5	Botkin and Mileler, 1974; del Hoyo and others, 1992; Hatch, 1993; Lee and Haney, 1996; Furness and Wade, 2012
Wilson’s Storm-Petrel	4	del Hoyo and others, 1992; Robinson Willmott and others, 2013
Fork-tailed Storm-Petrel	4	del Hoyo and others, 1992; Boersma and Silva, 2001; Furness and Wade, 2012
Leach’s Storm-Petrel	4	del Hoyo and others, 1992; Huntington and others, 1996; Furness and Wade, 2012
Ashy Storm-Petrel	4	del Hoyo and others, 1992; Furness and Wade, 2012

Common name	AS	AS references
Black Storm-Petrel	4	del Hoyo and others, 1992; Furness and Wade, 2012
Least Storm-Petrel	4	Furness and Wade, 2012; Robinson Wilmott and others, 2013
Brandt’s Cormorant	3	Wallace and Wallace, 1998; Furness and Wade, 2012
Double-crested Cormorant	4	Hatch and Weseloh, 1999; Furness and Wade, 2012; Seamans and others, 2012; Robinson Willmott and others, 2013
Pelagic Cormorant	3	Furness and Wade, 2012; Hobson, 2013
American White Pelican	3	Schreiber and Mock, 1988; Anderson and others, 1996; Knopf and Evans, 2004; Robinson Willmott and others, 2013; Shields, 2014
Brown Pelican	5	Schreiber and Mock, 1988; Anderson and others, 1996; Robinson Willmott and others, 2013; Shields, 2014
Red-necked Phalarope	1	Tracy and others, 2002; Robinson Willmott and others, 2013
Red Phalarope	1	Schamel and Tracy, 1991; Sandercock, 1997; Rubega and others, 2000; Robinson Willmott and others, 2013
South Polar Skua	5	Clapp and others, 1982; del Hoyo and others, 1992; Furness and Wade, 2012
Pomarine Jaeger	3	Wiley and Lee, 2000; Desholm, 2009; Robinson Willmott and others, 2013
Parasitic Jaeger	4	Wiley and Lee, 1999; Furness and Wade, 2012; Robinson Willmott and others, 2013
Long-tailed Jaeger	4	Clapp and others, 1982; Wiley and Lee, 1998; Robinson Willmott and others, 2013
Common Murre	4	Sydeman 1993; Harris and Wanless 1995; Ralph and others, 1995; Gaston and Jones, 1998; Ainley and others, 2002; Furness and Wade, 2012
Pigeon Guillemot	4	Ewins, 1993; Ralph and others, 1995; del Hoyo and others, 1996
Marbled Murrelet	4	Ralph and others, 1995; Nelson, 1997; Gaston and Jones, 1998; Peery and others, 2006
Scripps’s Murrelet	4	del Hoyo and others, 1996; Gaston and Jones, 1998; Furness and Wade, 2012
Craveri’s Murrelet	4	Ralph and others, 1995; Gaston and Jones, 1998; Furness and Wade, 2012
Ancient Murrelet	2	Ralph and others, 1995; Gaston and Jones, 1998; Gaston and Shoji, 2010
Cassin’s Auklet	3	Gaston, 1992; Ralph and others, 1995; Gaston and Jones, 1998; Gaston and Shoji, 2010; Morrison and others, 2011
Parakeet Auklet	4	Ralph and others, 1995; del Hoyo and others, 1996; Gaston and Jones, 1998; Jones and others, 2001; Jones and others, 2003; Ainley and others, 2011; Furness and Wade, 2012
Rhinoceros Auklet	4	Ralph and others, 1995; Thayer-Mascarenhas, 1995; del Hoyo and others, 1996; Gaston and Dechesne, 1996; Gaston and Jones, 1998; Morrison and others 2011; Furness and Wade, 2012
Horned Puffin	5	del Hoyo and others, 1996; Piatt and Kitaysky, 2002a; Furness and Wade, 2012
Tufted Puffin	5	del Hoyo and others, 1996; Piatt and Kitaysky, 2002b; Morrison and others 2011; Furness and Wade, 2012
Black-legged Kittiwake	4	del Hoyo and others, 1996; Garthe and Hüppop, 2004; Hatch and others, 2009; Furness and Wade, 2012
Sabine’s Gull	3	Day and others, 2001; Furness and Wade, 2012
Bonaparte’s Gull	3	Burger and Gochfeld, 2002; Furness and Wade, 2012
Heermann’s Gull	3	Islam, 2002; Furness and Wade, 2012
Mew Gull	2	Moskoff and Bevier, 2002; Garthe and Hüppop, 2004; Furness and Wade, 2012
Ring-billed Gull	3	Furness and Wade, 2012; Pollet and others, 2012
Western Gull	3	Pierotti and Annett, 1995; Furness and Wade, 2012
California Gull	3	Winkler, 1996; Furness and Wade, 2012
Herring Gull	3	Botkin and Miller, 1974; Pierotti and Good, 1994; del Hoyo and others, 1996; Garthe and Hüppop, 2004; Furness and Wade, 2012; Robinson Willmott and others, 2013
Thayer’s Gull	3	Pierotti and Annett, 1995; Hayward and Verbeek, 2008; Furness and Wade, 2012
Glaucous-winged Gull	3	Hayward and Verbeek, 2008; Furness and Wade, 2012
Least Tern	4	del Hoyo and others, 1996; Thompson and others, 1997

Common name	AS	AS references
Gull-billed Tern	4	del Hoyo and others, 1996; Cuthbert and Wires, 1999; Furness and Wade, 2012; Molina and others, 2014
Caspian Tern	4	del Hoyo and others, 1996; Cuthbert and Wires, 1999; Suryan and others, 2004
Black Tern	3	Heath and others, 2009; Robinson Wilmott and others, 2013
Common Tern	4	del Hoyo and others, 1996; Nisbet, 2002; Furness and Wade, 2012
Arctic Tern	4	del Hoyo and others, 1996; Hatch, 2002; Garthe and Hüppop, 2004; Robinson Willmott and others, 2013
Forster's Tern	4	Mcnicholl and others, 2001; Furness and Wade, 2012
Royal Tern	4	Buckley and Buckley, 2002; Furness and Wade, 2012
Elegant Tern	4	Burness and others, 1999; Furness and Wade, 2012
Black Skimmer	4	Gochfeld and Burger, 1994; del Hoyo and others, 1996; Robinson Willmott and others, 2013

Table A7. Nocturnal Flight Activity (NFA) score, Diurnal Flight Activity (DFA) score, and corresponding references for each species.

Common name	NFA	NFA references	DFA	DFA references
Brant	1	Robinson Willmott and others, 2013	1	Robinson Willmott and others, 2013
Common Merganser	1	Cooper and Richie, 1995; Robinson Willmott and others, 2013	1	Cooper and Richie, 1995; Robinson Willmott and others, 2013
Red-breasted Merganser	1	Cooper and Richie, 1995; Robinson Willmott and others, 2013	1	Cooper and Richie, 1995; Robinson Willmott and others, 2013
Harlequin Duck	5	Robinson Willmott and others, 2013	5	Robinson Willmott and others, 2013
Surf Scoter	3	Sauer and others, 1998; Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
White-winged Scoter	3	Brown and Fredrickson, 1997; Robinson Willmott and others, 2013	3	Brown and Fredrickson 1997; Robinson Willmott and others, 2013
Black Scoter	3	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Long-tailed Duck	4	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Red-throated Loon	1	Robinson Willmott and others, 2013	2	Robinson Willmott and others, 2013
Pacific Loon	1	Russell, 2002	3	Russell, 2002
Common Loon	1	Robinson Willmott and others, 2013	2	Evers and others, 2010; Robinson Willmott and others, 2013
Yellow-billed Loon	1	similar spp, North, 1994	2	similar spp, North, 1994
Horned Grebe	3	Stedman, 2000; Robinson Willmott and others, 2013	2	Stedman, 2000; Robinson Willmott and others, 2013
Red-necked Grebe	3	Stout and Nuechterlein, 1999; Robinson Willmott and others, 2013	1	Stout and Nuechterlein, 1999; Robinson Willmott and others, 2013
Eared Grebe	3	Cullen and others, 1999	1	Cullen and others, 1999
Western Grebe	3	LaPorte and others, 2013	1	LaPorte and others, 2013
Clark’s Grebe	3	similar spp, North, 1994	1	similar spp, North, 1994
Laysan Albatross	4	del Hoyo and others, 1992; Weimerskirch and Guionnet, 2002; Conners and others, 2015	4	del Hoyo and others, 1992; Weimerskirch and Guionnet, 2002; Conners and others, 2015
Black-footed Albatross	4	del Hoyo and others, 1992; Weimerskirch and Guionnet, 2002	4	del Hoyo and others, 1992; Weimerskirch and Guionnet, 2002
Short-tailed Albatross	3	del Hoyo and others, 1992; Suryan and others, 2007; Weimerskirch and Guionnet, 2002	4	del Hoyo and others, 1992; Suryan and others, 2007; Weimerskirch and Guionnet, 2002
Northern Fulmar	4	Hatch, 1993; Robinson Willmott and others, 2013	2	Hatch, 1993; Robinson Willmott and others, 2013
Murphy’s Petrel	5	Robinson Willmott and others, 2013	5	Robinson Willmott and others, 2013
Mottled Petrel	3	similar spp.- del Hoyo and others, 1992	5	similar spp.- del Hoyo and others, 1992
Hawaiian Petrel	3	J. Adams, U.S. Geological Survey, oral commun., May 9, 2016	5	similar spp.- del Hoyo and others, 1992
Cook’s Petrel	4	similar spp.- del Hoyo and others, 1992	5	similar spp.- del Hoyo and others, 1992
Pink-footed Shearwater	3	similar spp.- Dias and others, 2012; Hedd and others, 2012; Robinson Willmott and others, 2013	3	similar spp.- Dias and others, 2012; Hedd and others, 2012; Robinson Willmott and others, 2013
Flesh-footed Shearwater	3	similar spp.- Dias and others, 2012; Hedd and others, 2012; Robinson Willmott and others, 2013	4	similar spp.- del Hoyo and others, 1992
Buller’s Shearwater	3	Dias and others, 2012; del Hoyo and others, 1992; Hedd and others, 2012; Robinson Willmott and others, 2013	3	similar spp.- Dias and others, 2012; Hedd and others, 2012; Robinson Willmott and others, 2013
Sooty Shearwater	3	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013

Common name	NFA	NFA references	DFA	DFA references
Short-tailed Shearwater	3	similar spp.- Dias and others, 2012; Hedd and others, 2012; Robinson Willmott and others, 2013	3	similar spp.- Dias and others, 2012; Hedd and others, 2012; Robinson Willmott and others, 2013
Manx Shearwater	3	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Black-vented Shearwater	3	Keitt and others, 2000	3	Keitt and others, 2000
Wilson's Storm-Petrel	4	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Fork-tailed Storm-Petrel	4	similar spp- Ainley, 1995; Ainley and Everett, 2001; Robinson Willmott and others, 2013	3	similar spp- Ainley, 1995; Ainley and Everett, 2001; Robinson Willmott and others, 2013
Leach's Storm-Petrel	4	del Hoyo and others, 1992; Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Ashy Storm-Petrel	4	Ainley, 1995	3	Ainley, 1995
Black Storm-Petrel	4	similar spp- Ainley, 1995; Ainley and Everett, 2001; Robinson Willmott and others, 2013	3	similar spp- Ainley, 1995; Ainley and Everett, 2001; Robinson Willmott and others, 2013
Least Storm-Petrel	4	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Brandt's Cormorant	1	del Hoyo and others, 1996; Wallace and Wallace, 1998	3	del Hoyo and others, 1996; Wallace and Wallace, 1998
Double-crested Cormorant	1	del Hoyo and others, 1996; Hatch and Weseloh, 1999; Robinson Willmott and others, 2013	5	Hatch and Weseloh, 1999; Robinson Willmott and others, 2013
Pelagic Cormorant	1	del Hoyo and others, 1996; Hobson, 2013	3	del Hoyo and others, 1996; Hobson, 2013
American White Pelican	1	del Hoyo and others, 1996; Knopf and Evans, 2004	3	Knopf and Evans, 2004
Brown Pelican	1	del Hoyo and others, 1996; Shields, 2014; Robinson Willmott and others, 2013	3	Shields, 2014; Robinson Willmott and others, 2013
Red-necked Phalarope	2	Rubega and others, 2000; Robinson Willmott and others, 2013	3	Rubega and others, 2000; Robinson Willmott and others, 2013
Red Phalarope	3	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
South Polar Skua	1	Robinson Willmott and others, 2013	4	Robinson Willmott and others, 2013
Pomarine Jaeger	1	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Parasitic Jaeger	1	Robinson Willmott and others, 2013	5	Robinson Willmott and others, 2013
Long-tailed Jaeger	1	Robinson Willmott and others, 2013	5	Robinson Willmott and others, 2013
Common Murre	2	Robinson Willmott and others, 2013	1	Robinson Willmott and others, 2013
Pigeon Guillemot	1	similar spp.- Robinson Willmott and others, 2013	1	similar spp.- Robinson Willmott and others, 2013
Marbled Murrelet	2	similar spp.- del Hoyo and others, 1992	1	similar spp.- Robinson Willmott and others, 2013
Scripps's Murrelet	2	similar spp.- Robinson Willmott and others, 2013	1	similar spp.- Robinson Willmott and others, 2013
Craveri's Murrelet	2	similar spp.- Robinson Willmott and others, 2013	1	similar spp.- Robinson Willmott and others, 2013
Ancient Murrelet	2	del Hoyo and others, 1996; Gaston and Shoji, 2010	1	Gaston and Shoji, 2010
Cassin's Auklet	2	del Hoyo and others, 1996; Ainley and others, 2011;	1	Ainley and others, 2011
Parakeet Auklet	1	similar spp.- Robinson Willmott and others, 2013	1	similar spp.- Robinson Willmott and others, 2013
Rhinoceros Auklet	2	similar spp.- Robinson Willmott and others, 2013	1	similar spp.- Robinson Willmott and others, 2013
Horned Puffin	1	similar spp.- Robinson Willmott and others, 2013	1	similar spp.- Robinson Willmott and others, 2013
Tufted Puffin	1	similar spp.- Robinson Willmott and others, 2013	1	similar spp.- Robinson Willmott and others, 2013

Common name	NFA	NFA references	DFA	DFA references
Black-legged Kittiwake	3	Hatch and others, 1993; Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Sabine's Gull	2	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Bonaparte's Gull	2	Burger and Gochfeld, 2002; Robinson Willmott and others, 2013	3	Burger and Gochfeld, 2002; Robinson Willmott and others, 2013
Heermann's Gull	2	similar spp.- Robinson Willmott and others, 2013	3	similar spp.- Robinson Willmott and others, 2013
Mew Gull	2	similar spp.- Robinson Willmott and others, 2013	3	similar spp.- Robinson Willmott and others, 2013
Ring-billed Gull	3	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013
Western Gull	3	S. Shaffer, San Jose State University, unpub. data, February 12, 2015, similar spp.	3	S. Shaffer, San Jose State University, unpub. data, February 12, 2015, similar spp.
California Gull	2	Winkler, 1996; simliar spp.	3	Winkler, 1996; similar spp.
Herring Gull	3	Robinson Willmott and others, 2013	2	Robinson Willmott and others, 2013
Thayer's Gull	2	similar spp.- Robinson Willmott and others, 2013	3	similar spp.- Robinson Willmott and others, 2013
Glaucous-winged Gull	3	Hayward and Verbeek, 2008	3	Hayward and Verbeek, 2008
Least Tern	1	Robinson Willmott and others, 2013	5	Robinson Willmott and others, 2013
Gull-billed Tern	5	Robinson Willmott and others, 2013	5	Robinson Willmott and others, 2013
Caspian Tern	5	Cuthbert and Wires, 1999; Robinson Willmott and others, 2013	5	Cuthbert and Wires, 1999; Robinson Willmott and others, 2013
Black Tern	1	Robinson Willmott and others, 2013	5	Robinson Willmott and others, 2013
Common Tern	5	Nisbet, 2002; Robinson Willmott and others, 2013	5	Nisbet, 2002; Robinson Willmott and others, 2013
Arctic Tern	5	Hatch, 2002; Robinson Willmott and others, 2013	5	Hatch, 2002; Robinson Willmott and others, 2013
Forster's Tern	5	Robinson Willmott and others, 2013	5	Robinson Willmott and others, 2013
Royal Tern	4	Robinson Willmott and others, 2013	4	Robinson Willmott and others, 2013
Elegant Tern	4	Blokpoel and others, 1989; similar spp.	5	Robinson Willmott and others, 2013; similar spp.
Black Skimmer	3	Robinson Willmott and others, 2013	3	Robinson Willmott and others, 2013

Table A8. Percent time spent in the Rotor Sweep Zone (RTZt) score and corresponding references for each species.

Common name	RSZt	RSZt references
Brant	5	Cooper and Ritchie, 1995; Robinson Willmott and others, 2013
Common Merganser	5	Cooper and Ritchie, 1995; Robinson Willmott and others, 2013
Red-breasted Merganser	5	Cooper and Ritchie, 1995; Robinson Willmott and others, 2013
Harlequin Duck	1	Robertson and Goudie, 2002; Cook and others, 2012; Bradbury and others, 2014
Surf Scoter	3	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014
White-winged Scoter	3	Furness and others, 2013; Robinson Willmott and others, 2013; Johnston and others, 2014
Black Scoter	3	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014
Long-tailed Duck	1	Cook and others, 2012; Bradbury and others, 2014
Red-throated Loon	3	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Ainley and others, 2015
Pacific Loon	1	Ainley and others, 2015
Common Loon	1	Ainley and others, 2015
Yellow-billed Loon	1	North, 1994; Ainley and others, 2015
Horned Grebe	3	Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014
Red-necked Grebe	3	Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014
Eared Grebe	3	Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014
Western Grebe	3	Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014
Clark’s Grebe	3	Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014
Laysan Albatross	3	Ainley and others, 2015
Black-footed Albatross	3	Ainley and others, 2015
Short-tailed Albatross	3	Suryan and others, 2008; Ainley and others, 2015
Northern Fulmar	1	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Murphy’s Petrel	1	Cook and others, 2012; Wilmott and others, 2013; Bradbury and others, 2014
Mottled Petrel	1	Robinson Willmott and others, 2013; Ainley and others, 2015
Hawaiian Petrel	1	Robinson Willmott and others, 2013; Ainley and others, 2015
Cook’s Petrel	1	Robinson Willmott and others, 2013; Ainley and others, 2015
Pink-footed Shearwater	1	Robinson Willmott and others, 2013; Bradbury and others, 2014; Ainley and others, 2015
Flesh-footed Shearwater	1	Robinson Willmott and others, 2013; Bradbury and others, 2014; Ainley and others, 2015
Buller’s Shearwater	1	Robinson Willmott and others, 2013; Ainley and others, 2015
Sooty Shearwater	1	Robinson Willmott and others, 2013; Bradbury and others, 2014; Ainley and others, 2015
Short-tailed Shearwater	1	Robinson Willmott and others, 2013; Bradbury and others, 2014; Ainley and others, 2015
Manx Shearwater	1	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Black-vented Shearwater	1	Robinson Willmott and others, 2013; Bradbury and others, 2014; Ainley and others, 2015
Wilson’s Storm-Petrel	1	Robinson Willmott and others, 2013; Bradbury and others, 2014; Ainley and others, 2015
Fork-tailed Storm-Petrel	1	Robinson Willmott and others, 2013; Ainley and others, 2015
Leach’s Storm-Petrel	1	Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Ainley and others, 2015
Ashy Storm-Petrel	1	Robinson Willmott and others, 2013; Ainley and others, 2015

Common name	RSZt	RSZt references
Black Storm-Petrel	1	Robinson Willmott and others, 2013; Ainley and others, 2015
Least Storm-Petrel	1	Cook and others, 2012; Robinson Wilmott and others, 2013; Bradbury and others, 2014
Brandt's Cormorant	3	Cook and others, 2012; Fijn and others, 2012; Furness and others, 2013; Ainley and others, 2015
Double-crested Cormorant	3	Cook and others, 2012; Fijn and others, 2012; Furness and others, 2013; Ainley and others, 2015
Pelagic Cormorant	3	Cook and others, 2012; Fijn and others, 2012; Furness and others, 2013; Ainley and others, 2015
American White Pelican	5	Ainley and others, 2015
Brown Pelican	5	Ainley and others, 2015
Red-necked Phalarope	1	Robinson Willmott and others, 2013; Ainley and others, 2015
Red Phalarope	1	Robinson Willmott and others, 2013; Ainley and others, 2015
South Polar Skua	5	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Pomarine Jaeger	5	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Parasitic Jaeger	5	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Long-tailed Jaeger	5	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Common Murre	1	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Pigeon Guillemot	1	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Marbled Murrelet	1	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Scripps's Murrelet	1	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Craveri's Murrelet	1	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Ancient Murrelet	1	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Cassin's Auklet	1	Cook and others, 2012; Fijn and others, 2012; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Parakeet Auklet	1	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Rhinoceros Auklet	1	Cook and others, 2012; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Horned Puffin	1	Cook and others, 2012; Bradbury and others, 2014; Ainley and others, 2015
Tufted Puffin	1	Cook and others, 2012; Bradbury and others, 2014; Ainley and others, 2015
Black-legged Kittiwake	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Sabine's Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Johnston and others, 2014; Bradbury and others, 2014; Ainley and others, 2015
Bonaparte's Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Heermann's Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Mew Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Ring-billed Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Western Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
California Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Herring Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015

Common name	RSZt	RSZt references
Thayer's Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Glaucous-winged Gull	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Least Tern	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Gull-billed Tern	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Johnston and others, 2014; Bradbury and others, 2014; Ainley and others, 2015
Caspian Tern	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Johnston and others, 2014; Ainley and others, 2015
Black Tern	5	Cook and others, 2012; Wilmott and others, 2013; Bradbury and others, 2014
Common Tern	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Arctic Tern	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Forster's Tern	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Royal Tern	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Elegant Tern	5	Cook and others, 2012; Furness and others, 2013; Robinson Willmott and others, 2013; Bradbury and others, 2014; Johnston and others, 2014; Ainley and others, 2015
Black Skimmer	5	Robinson Willmott and others, 2013; Ainley and others, 2015

Table A9. Macro-Avoidance (MA) score for each species and corresponding references.

[For Collision Vulnerability (CV & PCV), high macro-avoidance = low collision risk = low score. For Displacement Vulnerability (DV & PDV), high macro-avoidance = high displacement risk = high score]

Common name	MA PCV	MA PDV	MA references
Brant	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013; Bradbury and others, 2014
Common Merganser	2	4	Robinson Willmott and others, 2013
Red-breasted Merganser	2	4	Peterson and others, 2006; Robinson Willmott and others, 2013; Bradbury and others, 2014
Harlequin Duck	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013; Bradbury and others, 2014
Surf Scoter	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013; Bradbury and others, 2014
White-winged Scoter	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013; Bradbury and others, 2014
Black Scoter	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013; Bradbury and others, 2014
Long-tailed Duck	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013; Bradbury and others, 2014
Red-throated Loon	1	5	Peterson and others, 2006; Robinson Willmott and others, 2013; Bradbury and others, 2014
Pacific Loon	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Common Loon	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Yellow-billed Loon	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Horned Grebe	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Red-necked Grebe	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Eared Grebe	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Western Grebe	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Clark’s Grebe	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Laysan Albatross	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Black-footed Albatross	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Short-tailed Albatross	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Northern Fulmar	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Murphy’s Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2014
Mottled Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Hawaiian Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Cook’s Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Pink-footed Shearwater	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Flesh-footed Shearwater	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Buller’s Shearwater	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Sooty Shearwater	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Short-tailed Shearwater	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Manx Shearwater	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Black-vented Shearwater	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Wilson’s Storm-Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2013; Bradbury and others, 2014
Fork-tailed Storm-Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2013

Common name	MA PCV	MA PDV	MA references
Leach's Storm-Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2013; Bradbury and others, 2014
Ashy Storm-Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Black Storm-Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Least Storm-Petrel	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Brandt's Cormorant	3	3	Cook and others, 2012; Robinson Willmott and others, 2013
Double-crested Cormorant	3	3	Cook and others, 2012; Robinson Willmott and others, 2013
Pelagic Cormorant	3	3	Cook and others, 2012; Robinson Willmott and others, 2013
American White Pelican	5	1	similar spp.- Robinson Willmott and others, 2013
Brown Pelican	5	1	Robinson Willmott and others, 2013
Red-necked Phalarope	3	3	Robinson Willmott and others, 2013
Red Phalarope	3	3	Robinson Willmott and others, 2013
South Polar Skua	5	1	Cook and others, 2012; Robinson Willmott and others, 2013
Pomarine Jaeger	5	1	Cook and others, 2012; Robinson Willmott and others, 2013
Parasitic Jaeger	5	1	Cook and others, 2012; Robinson Willmott and others, 2013
Long-tailed Jaeger	5	1	Cook and others, 2012; Robinson Willmott and others, 2013
Common Murre	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Pigeon Guillemot	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Marbled Murrelet	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Scripps's Murrelet	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Craveri's Murrelet	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Ancient Murrelet	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Cassin's Auklet	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Parakeet Auklet	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Rhinoceros Auklet	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Horned Puffin	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Tufted Puffin	1	5	Cook and others, 2012; Robinson Willmott and others, 2013
Black-legged Kittiwake	1	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Sabine's Gull	2	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Bonaparte's Gull	2	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Heermann's Gull	2	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Mew Gull	2	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Ring-billed Gull	2	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Western Gull	1	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
California Gull	2	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Herring Gull	2	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Thayer's Gull	2	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013

Common name	MA PCV	MA PDV	MA references
Glaucous-winged Gull	1	3	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Least Tern	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Gull-billed Tern	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Caspian Tern	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Black Tern	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Common Tern	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Arctic Tern	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Forster's Tern	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Royal Tern	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Elegant Tern	1	5	Peterson and others, 2006; Cook and others, 2012; Robinson Willmott and others, 2013
Black Skimmer	1	5	Cook and others, 2012; Robinson Willmott and others, 2013

Table A10. Habitat Flexibility (HF) score for each species and corresponding references.

Common name	HF	HF references
Brant	4	Lewis and others, 2013; Robinson Willmott and others, 2013
Common Merganser	1	Mallory and Metz, 1999; Robinson Willmott and others, 2013
Red-breasted Merganser	1	Titman, 1999; Robinson Willmott and others, 2013
Harlequin Duck	4	Robertson and Goudie, 1999; Robinson Wilmott and others, 2013
Surf Scoter	4	Sauer and others, 1998; Robinson Willmott and others, 2013
White-winged Scoter	3	Brown and Fredrickson, 1997; Robinson Willmott and others, 2013
Black Scoter	4	Bordage and Savard, 2011; Robinson Willmott and others, 2013
Long-tailed Duck	4	Robertson and Savard, 2002; Robinson Wilmott and others, 2013
Red-throated Loon	4	del Hoyo and others, 1992; Barr and others, 2000; Garthe and Hüppop, 2004; Furness and Wade, 2012; Furness and others, 2013; Robinson Willmott and others, 2013
Pacific Loon	4	del Hoyo and others, 1992; Russell, 2002
Common Loon	4	del Hoyo and others, 1992; Evers and others, 2010; Furness and others, 2013; Robinson Willmott and others, 2013
Yellow-billed Loon	4	del Hoyo and others, 1992; North, 1994
Horned Grebe	4	Stedman, 2000; Furness and others, 2013; Robinson Willmott and others, 2013
Red-necked Grebe	3	Stout and Muechterlein, 1999; Garthe and Hüppop, 2004; Robinson Willmott and others, 2013
Eared Grebe	3	Cullen and others, 1999
Western Grebe	3	LaPorte and others, 2013
Clark’s Grebe	3	LaPorte and others, 2013
Laysan Albatross	1	del Hoyo and others, 1992; Ackerman and others, 2006
Black-footed Albatross	1	del Hoyo and others, 1992; Ackerman and others, 2006
Short-tailed Albatross	1	del Hoyo and others, 1992; similar spp.
Northern Fulmar	1	del Hoyo and and others, 1992; Hatch, 1993; Garthe and Hüppop, 2004; Furness and others, 2013; Robinson Willmott and others, 2013
Murphy’s Petrel	1	Robinson Wilmott and others, 2013
Mottled Petrel	1	del Hoyo and others, 1992; similar spp.
Hawaiian Petrel	3	Simons and Hodges, 1998
Cook’s Petrel	1	del Hoyo and others, 1992; similar spp.
Pink-footed Shearwater	1	del Hoyo and others, 1992; similar spp.
Flesh-footed Shearwater	1	del Hoyo and others, 1992; similar spp.
Buller’s Shearwater	1	del Hoyo and others, 1992; similar spp.
Sooty Shearwater	1	del Hoyo and others, 1992; Furness and others, 2013; Robinson Willmott and others, 2013
Short-tailed Shearwater	1	del Hoyo and others 1992; similar spp.
Manx Shearwater	1	Lee and Haney, 1996; Furness and others, 2013; Robinson Willmott and others, 2013
Black-vented Shearwater	2	del Hoyo and others, 1992; Keitt and others, 2000
Wilson’s Storm-Petrel	1	del Hoyo and others, 1992; similar spp.
Fork-tailed Storm-Petrel	1	del Hoyo and others, 1992; Boersma and Silva, 2001
Leach’s Storm-Petrel	1	del Hoyo and others, 1992; Huntington and others, 1996; Furness and others, 2013; Robinson Willmott and others, 2013
Ashy Storm-Petrel	2	del Hoyo and others, 1992; Ainley, 1995
Black Storm-Petrel	1	del Hoyo and others, 1992; Ainley and Everett, 2001
Least Storm-Petrel	1	Robinson Wilmott and others, 2013

Common name	HF	HF references
Brandt’s Cormorant	2	Ainley and others, 1990a; del Hoyo and others, 1996
Double-crested Cormorant	2	Ainley and others, 1990a; Siegel-Cousey and Litvinenko, 1993; del Hoyo and others, 1996; Robinson Willmott and others, 2013
Pelagic Cormorant	2	Ainley and others, 1990a; Siegel-Cousey and Litvinenko, 1993; del Hoyo and others, 1996
American White Pelican	4	del Hoyo and others, 1996; Knopf and Evans, 2004
Brown Pelican	4	del Hoyo and others, 1996; Robinson Willmott and others, 2013; Shields, 2014
Red-necked Phalarope	2	Rubega and others, 2000; Robinson Willmott and others, 2013
Red Phalarope	2	Tracy and others, 2002; Robinson Willmott and others, 2013
South Polar Skua	2	del Hoyo and others, 1996; similar spp.
Pomarine Jaeger	2	Wiley and Lee, 2000; Robinson Willmott and others, 2013
Parasitic Jaeger	2	Wiley and Lee, 1999; Furness and others, 2013; Robinson Willmott and others, 2013
Long-tailed Jaeger	2	Wiley and Lee, 1998; Robinson Willmott and others, 2013
Common Murre	3	Ainley and others, 1990a, 2002; Garthe and Hüppop, 2004; Furness and others, 2013; Robinson Willmott and others, 2013
Pigeon Guillemot	3	Ainley and others, 1990a; Ewins, 1993; del Hoyo and others, 1996
Marbled Murrelet	3	Ewins and others, 1993; del Hoyo and others, 1996; Nelson, 1997
Scripps’s Murrelet	4	Springer and others, 1993; Drost and Lewis, 1995
Craveri’s Murrelet	4	Springer and others, 1993; Drost and Lewis, 1995
Ancient Murrelet	3	Springer and others, 1993; Gaston and Shoji, 2010
Cassin’s Auklet	3	Springer and others, 1993; Ainley and others, 2011
Parakeet Auklet	2	Springer and others, 1993; Jones and others, 2001
Rhinoceros Auklet	3	Gaston and Dechesne, 1996
Horned Puffin	3	Piatt and Kitaysky, 2002a
Tufted Puffin	3	Ainley and others, 1990a; Piatt and Kitayksy, 2002b
Black-legged Kittiwake	2	Hatch and others, 1993; Robinson Willmott and others, 2013
Sabine’s Gull	2	Day and others, 2001; Robinson Willmott and others, 2013
Bonaparte’s Gull	2	Burger and Gochfeld, 2002; Robinson Willmott and others, 2013
Heermann’s Gull	1	del Hoyo and others, 1996; Islam, 2002
Mew Gull	1	del Hoyo and others, 1996; Moskoff and Bevier, 2002
Ring-billed Gull	1	del Hoyo and others, 1996; Pollet and others, 2012
Western Gull	1	Ainley and others, 1990a
California Gull	1	del Hoyo and others, 1996; Winkler, 1996
Herring Gull	1	Pierotti and Good, 1994; Garthe and Hüppop, 2004; Furness and others, 2013; Robinson Willmott and others, 2013
Thayer’s Gull	1	del Hoyo and others, 1996; Snell, 2002
Glaucous-winged Gull	1	Hayward and Verbeek, 2008
Least Tern	3	Thompson and others, 1997
Gull-billed Tern	2	del Hoyo and others, 1996; Molina and others, 2014
Caspian Tern	3	del Hoyo and others, 1996; Cuthbert and Wires, 1999
Black Tern	3	Robinson Wilmott and others, 2013
Common Tern	3	Nisbet, 2002; Furness and others, 2013; Robinson Willmott and others, 2013
Arctic Tern	3	Hatch, 2002; Garthe and Hüppop, 2004; Furness and others, 2013; Robinson Willmott and others, 2013
Forster’s Tern	3	Mcnicholl and others, 2001

Common name	HF	HF references
Royal Tern	3	del Hoyo and others, 1996; Buckley and Buckley, 2002
Elegant Tern	4	del Hoyo and others, 1996; Burness and others, 1999
Black Skimmer	4	Gochfeld and Burger, 1994; del Hoyo and others, 1996

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