APPENDIX E

Brief Overview of the Ecology, Morphology, and Flight Behavior of Seabirds Included in the Study

Pacific Ocean seabirds can be separated into 29 flight-style groupings (FG) (Spear & Ainley, 1997; Ainley et al., 2015). Among these, 18 occur in the California Current System (CCS) in sufficient numbers to devise reliable density estimates using the existing 1980-2016 assembly of at-sea surveys (see Results). A few of the 29 (i.e., large gadfly petrels, small gadfly petrels, boobies, tropicbirds, and frigatebirds) occur but not commonly enough in the CCS to have amassed a sufficient sample size for our analysis (Table A3). Nevertheless, a few of these less-represented FGs contain special-status species and will need to be addressed going forward. In other cases, e.g., small albatross FG, they include special status species but otherwise are common enough to have provided adequate sample sizes for modeling that group. Thus, the vulnerability to collision with offshore wind (OSW) turbines for uncommon, special-status species can be generally assessed for the FG based on flight behavior characterizing its group.

The information provided herein provides information on seabird flight-style as it relates to their collision vulnerability and can be used to contextualize the results provided by the project. First, we provide an overview of four seabird flight modes. Then, we provide background information on each of the FGs covered in the 3D Framework. Note, there is mention of species not modeled by the 3D Framework.

In the data set used in 3D Framework, analysis was conducted on 18 FGs, each composed of species (or taxa) that have similar morphology. Note, this is why the species within FGs are consistent with taxonomy (Ainley et al., 2015; Table E1). The species within each FG fall into four overall modes of seabird flight, sequenced by the amount of flapping flight: flappers, flap-gliders, glide-flappers, and gliders (Table E2). These represent the modes of seabirds traveling point-to-point, which is not necessarily typical of them foraging nor maneuvering to land-at/take-off from colonies or roosts.

Seabirds that travel using fapping flight almost never glide when flying over the open ocean, and usually travel close to the ocean surface, as it offers some aerodynamic advantage (i.e., higher air density provides more lift; Pennycuick, 1989) (Table E2). However, when experiencing updrafts along bluffs and cliffs near nesting colonies or roosting sites they glide, i.e., travel without flapping (known as ‘slope soaring’; Pennycuick, 1987).

Flappers have short and wide wings, with an aspect ratio <10 in most cases (Table E1) and are very maneuverable. The opposite is true for gliders, which almost never flap when traveling over the open ocean, unless taking off from the sea surface to gain speed (Table E2). They have long, narrow wings, like an airplane glider, with aspect ratio generally above 10 (Table E1). They need moving air (wind) to take off, or very large waves that allow down-slope launching. Once aloft, flappers become dynamic soarers. The latter (DS) swoop in a circular pattern between the sea surface and height of their swoop. They flap only for a quick coarse alteration, usually at the bottom of the swoop. Otherwise, dynamic soarers use gravity to gain speed in the downward portion of their swoop, and the higher their swoop, the more speed they can gain in forward flight. As wind increases, their swooping height and speed increases. In contrast to flappers, dynamic soarers flap upon approaching or leaving nest or roost sites, needing the flapping for close maneuvering.

Intermediate between flappers and gliders are the other two styles of flight (Table E2). Glide-flappers more or less exhibit dynamic soaring interspersed with segments of flapping at the bottom of their 'swoop,' near the sea surface, in order to maintain speed for the upward swoop. Glide-flappers have long, narrow wings, and increase their flight height and reduce the amount of flapping with higher winds. Flap-gliders are the opposite and mostly flap interspersed with segments of gliding. They, too, generally remain close to the ocean surface, and the gliding segments may be to conserve energy expended by flapping or to maintain the speed needed for the glide phase. Flappers and flap-gliders often fly in line or V-formation, i.e., "slip streaming" another means to conserve energy (unless a bird is the leader).

The following taxonomic and flight-style groups (Table E1) can contain both species that nest along the coast of the study area, but mostly species that are seasonal residents or passage migrants. In general, all the species most vulnerable to encountering the turbine RSZ and at risk of collision are not considered CA resident species. Most would have little direct interaction with an OSW turbine, if the wind facility is not situated on the CA continental shelf, especially near to shore (i.e., CA state waters).

TABLE E1

Morphology and Flight-Style of Each Seabird Flight-Style Group[a]

Flight Group	Species	Body Mass (g)	Wing Span (mm)	Wing Area (cm^2)	Wing Load (newtons per m^2)	Wing Aspect Ratio	Flight-Style[b]
Small Albatross	6	3449	2170	3456	98	13.6	DS
Fulmar	7	1362	1174	1389	77	10.5	FG
Large Gadfly Petrel	9	360	972	856	42	11.1	DS
Small Gadfly Petrel	7	136	722	524	25	9.9	FG
Surface Feeding Shearwater	2	391	1019	1044	37	10.0	FG
Large Diving Shearwater	2	651	978	828	77	11.6	GF
Small Diving Shearwater	2	632	913	760	68	11.0	GF
Storm-Petrel	2	33	432	244	13	7.7	FL
Pelicans	1	4120	2224	4920	82	10.1	GF
Booby	5	1746	1590	2202	76	11.5	GF
Cormorant	4	1766	1052	1681	127	6.6	FL
Phalarope	2	38	388	212	18	7.1	FL
Skua	6	887	1392	1671	48	9.2	FL
Large Gull	5	1154	1489	2428	47	9.2	FL
Medium Gull	4	522	1188	1420	37	10.1	FL
Small Gull	1	255	1015	945	26	10.9	FL
Tern	5	147	790	617	22	10.2	FL
Large Alcid	2	1042	729	560	183	9.5	FL
Medium Alcid	6	585	612	440	129	8.6	FL
Small Alcid	8	208	434	238	85	8.1	FL
Loon, Grebe, Duck	7	612	591	413	133	8.7	FL

[a] Morphological characteristics of seabirds portioned by flight group are summarized from Spear & Ainley (1997; also Ainley et al., 2015).

[b] DS = dynamic soarers; FG = flap-gliders; GF = glide-flappers; FL = flappers

TABLE E2

Proportion of Individuals that Flap Versus Glide for Each of Four Basic Seabird Flight-Styles[a]

Flight-Style	Proportion Flapping	Proportion Gliding
Flapper	0.71 – 0.92	0.01 – 0.10
Glide-flapper	0.14 – 0.44	0.02 – 0.15
Flap-glider	0.03 – 0.12	0.21 – 0.53
Gliders/dynamic soarer	0.00 – 0.09	0.73 – 1.00

[a] Data derived from 117 cruises in all portions of the Pacific Ocean, 1976-2006 (*n* >152,000 sightings; Ainley et al., 2015).

Small Albatross

Visitors to the CCS and, despite being called "small," among the largest seabirds. Their heavy bodies and wing shape requires that they exist in regions where the wind is persistent and strong, because otherwise their ability to remain airborne and engage in dynamic soaring would not be possible. Black-footed Albatross *Phoebastria nigripes* are present in the CCS during the spring and summer (Upwelling season). Laysan Albatross *Phoebastria immutabilis* nest among the Hawaiian Islands and is present in the CCS during the winter. However, with recent colonization of some islands off Mexico, the presence of Laysan Albatross in the CCS has recently extended to be year-round. Both these species are listed as near threatened by IUCN and in Annex I of the Agreement on the Conservation of Albatrosses and Petrels (ACAP). The Short-tailed Albatross *Phoebastria albatrus* is also a visitor and is listed as endangered under the federal Endangered Species Act (ESA; and so listed by IUCN and ACAP). Short-tailed Albatross mainly occur during the Upwelling season. They are very rare, but numbers, and sightings have been increasing in response to recovery of breeding colonies and restrictions of long-line fishing in the Gulf of Alaska. Small albatrosses, owing to their dynamic soaring, are potentially more vulnerable to turbine blade collision than many CCS species.

Fulmar

While several fulmar species (sometimes called fulmarine petrels) are abundant in the Southern Hemisphere, only the Northern Fulmar *Fulmarus glacialis* is present in the CCS. Northern Fulmars nest in the Bering Sea region and typically remain in waters of the Gulf of Alaska but may fly as far south as the CCS in appreciable numbers during the Davidson Current season.

Large Gadfly Petrels

Large gadfly petrels are abundant in the Southern Hemisphere, but also in the eastern and western tropical Pacific. The Hawaiian Petrel *Pterodroma sandwichensis* nests among the main islands of Hawaii, and forages widely across the Pacific Ocean basin reaching into the edge of the CCS. They are listed as endangered under the federal ESA but populations have been increasing due to ongoing conservation measures. The species has been observed more routinely in the outer CCS although still too infrequently to devise meaningful density estimates. Like the small albatross, the propensity for this species in this FG is to engage in dynamic soaring. This method of flying makes it especially likely to be present at heights overlapping RSZs, and thus they are likely to be vulnerable to collision with turbine blades. A few other species in this FG have been detected in the CCS but at very low frequencies.

Small Gadfly Petrels

Small gadfly petrels are another group abundant in the Southern Hemisphere, and in the subtropical Pacific (leeward Hawaiian Islands). Numbers of species in the CCS were too sparse to generate density estimates, though one species in particular, Cook's Petrel *Pt. cooki*, has been increasingly detected and has been responding well to conservation measures at nesting colonies in the southwest Pacific.

Surface-Feeding Shearwaters

The Pink-footed Shearwater *Ardenna creatopus* and Buller's Shearwater *A. bulleri* nest in Chile and New Zealand, respectively. The Pink-footed Shearwater is listed as Vulnerable by IUCN, endangered in the waters of Chile and Canada, and under Annex I of ACAP. Appreciable numbers visit the CCS, present during the Oceanic season, and mainly offshore at the edge of subtropical waters in association with tuna. When Flap-gliding, they mostly occur close to the sea surface. The same patterns are evident in Buller's Shearwater.

Large Diving Shearwaters

The Sooty Shearwater *A. grisea* and Short-tailed shearwaters *A. tenuirostris* nest in New Zealand, Patagonia and Australia, respectively. Their populations number in the millions, although they are decreasing mainly from resource competition with commercial fisheries and entanglement

as bycatch. Large numbers of Sooty Shearwaters spend their non-breeding period in the CCS and occur at greatest concentrations during the Upwelling season. Short-tailed Shearwaters occur more in the Oceanic season. Both, owing to their relatively large body size, switch from a flap-gliding flight style to a dynamic soaring flight style in high winds (above 15 m/s) to reach appreciable heights above the sea surface.

Small Diving Shearwaters

Black-vented Shearwaters *Puffinus opisthomelas* nest in colonies off Mexico and Central America, only visiting the CCS in small numbers during Oceanic and Davidson Current seasons. They remain close to the sea surface as they transit using a glide-flapping style of flight. These are the 'Manx style shearwaters' in Ainley et al. (2015).

Storm-Petrels

Leach's, Ashy, and Fork-tailed Storm-petrels (*Hydrobates leuchorus, H. homochroa, H. furcatus*) are abundant in the CCS, especially along the shelf break and in offshore waters. All three species nest in colonies on various CA islands, the Ashy (and Black Storm-petrel *H. Melania*) more in the south and the other two in the north. Ashy and Fork-tailed storm-petrels occur year-round, while Leach's migrate south from Gulf of Alaska in autumn and back in spring. A portion of the Leach's Storm-petrels are passage migrants that nest in great abundance from British Columbia to the Aleutian Islands but also travel to eastern tropical Pacific waters for the non-breeding period. A few other storm-petrel species visit CCS waters, especially the Black Storm-petrel (which nests in the southern CA Channel Islands, though mostly in islands of Baja CA). Numbers of Black Storm-petrels disperse north to central CA waters in the Oceanic period after the breeding season. Storm-petrels fly by Flapping close to the sea surface (or at times using "sea-anchor soaring," pushing off the water with their feet to then glide and flap; Spear & Ainley, 1997). Ashy, Fork-tailed and Black storm-petrels are listed by the state of CA as Species of Special Concern.

Pelicans

The Brown Pelican *Pelecanus occidentalis* is a very large, heavy bird with broad wings. It flies by flapping or glide-flapping, often in follow-the-leader flocks. Otherwise, it is very maneuverable. They fly higher than 10 m especially when searching for food, principally in waters over the

continental shelf and closer to shore. The species once was listed as Endangered under federal and CA ESA but has been delisted. It mostly nests on islands of Baja CA, though appreciable colonies exist in the CA Channel Islands as well. Within our study area, it is a seasonal resident mainly during the late Upwelling and Oceanic seasons. However, presence can be variable, depending on whether ocean climate (El Niño – La Niña) favors nesting: Brown pelicans may be more abundant, for longer parts of the year during El Niño. Generally, they don't nest during El Niño because of insufficient food, and during these periods they can be present in the study area year-round.

Boobies

Prehistorically abundant in the CCS, a few species of booby have recently returned in low numbers to nest in the CA Channel Islands. Numbers are increasing but are not yet common enough in our study area during the survey periods to be included in the 3D Framework. Like pelicans, they fly by glide-flapping and reach appreciable heights generally only when foraging.

Phalaropes

The Red and Red-necked phalaropes (*Phalaropus fulicarius, P. lobatus*) represent one of the grouped taxa in the 3D Framework because of difficulty in differentiating them quickly, especially in aerial surveys. Both are migrants present in the study area, mainly in the vicinity of the shelf break, as they pass through the CCS to/from Arctic breeding grounds and the Humboldt Current off of South America. They probably pass by in the millions, heading southward during the Oceanic season and northward during Upwelling. During the latter, they wait for the periodic lulls in the otherwise persistent, strong upwelling headwinds. They fly by flapping and remain very close to the sea surface.

Skuas

Skuas include four members of the genus *Stercorarius*, one of which, South Polar Skua *S. maccormicki* is a seasonal resident from the polar south, and three that are seasonal residents or passage migrants from the Arctic. South Polar Skuas are present during Oceanic season. All skuas fly by flapping and are highly maneuverable, using that attribute to harass other species, especially terns, to drop their prey. They do at times fly relatively high, perhaps expanding their ability to locate multi-species feeding flocks.

Large Gulls

This group is dominated by Western and Glaucous-winged gulls (and hybrids; *Larus occidentalis, L. glaucescens*). Both are year-round residents, with Western Gulls being more in the southern portion and Glaucous-winged Gulls more in the northern portion of the study area. They are most densely concentrated near to the coast, especially during the non-breeding period (Davidson Current season) and nest on islands, islets, warehouses etc. along the coast. Herring and Iceland gulls (*L. argentatus*, *L. glaucoides*) are seasonal residents, mainly during the Davidson Current season. They visit from subarctic and Arctic breeding sites. Large gulls typically remain close to the water as they travel by flapping flight, and are highly maneuverable.

Medium Gulls

This is one of the most species-rich FGs in the study area, with appreciable contributions from Heermann's, California, and Ring-billed gulls (*L. heermanni*, *L. californicus*, *L. delawarensis*), and Black-legged Kittiwakes *Rissa tridactyla*. California Gulls nest in CA at fresh water or brackish water sites and are year-round residents. The remaining species are seasonal residents. Medium gulls are most abundant in CCS waters during the Davidson Current season, their non-breeding season. Heermann's Gull nests mostly on islands of Baja CA, while the remainder are subarctic nesters. Hermann's Gull presence can be somewhat eruptive depending on ocean climate in the Gulf of CA (no breeding during El Niño), the species principally being in part a kleptoparasite of Brown Pelicans.

Small Gulls

Sabine's and Bonaparte's gulls (*Xema sabini*, *Chroicocephalus philadephia*) are mainly migrants that pass through the CCS study area, rather than reside and during such migrations they primarily occur at or beyond the outer continental shelf. Their southward migration occurs during the Oceanic season, and northward migration during the Upwelling season with most of their progress being made during lulls in headwinds. They travel by flapping flight fairly close to the sea surface. Short-billed Gulls breed in Alaska and Canada, and winter primarily in nearshore habitats. They are most common in outer shelf and shelf break waters.

Terns

There are several genera in this group. The smallest is the California Least Tern *Sternula antillarum*, which is listed as Endangered by the federal ESA. A small colony exists on the coast of the southern portion of the study area, generally foraging in continental shelf waters. It is present mostly during the Upwelling period (wintering perhaps off South America). Then there are the slightly larger *Sterna* spp., including the Arctic and Common terns (*Sterna paradisaea, St. hirundo*). Arctic and Common terns in the study area are passage migrants, moving between Arctic nesting areas and Southern Hemisphere waters for non-breeding; southward during the Oceanic season and northward during Upwelling, and mainly along the shelf break and waters to the west. Lastly, there are the larger *Hydroprogne and Thalasseus* spp. These include the Caspian and Elegant terns (*Hy. caspia, T. elegans*) and a few Royal Terns *T. maximus*. Elegant Terns nest largely on islands in the Gulf of CA, while Caspian Terns nest at inland river bars and lake islands. They are seasonal residents in the study area during their non-breeding period (Oceanic and Davidson Current seasons). They mainly frequent waters overlying the continental shelf, flying by flapping at relatively high altitudes at times to search for fish schools. All terns are among the most highly maneuverable flyers, being flappers, and mostly would fly below RSZs.

Cormorants

Brandt's, Pelagic and Double-crested cormorants (*Urile penicillatus, U. pelagicus, Nannopterum auritum*), all nest on CA islands, coastal islets or headlands. They frequent waters of the continental shelf and are capable of diving to reach prey on the ocean bottom. All are heavy flappers and often travel in follow-the-leader flocks, staying close to the sea surface.

Large Alcids

In the CCS study area this FG is represented by one species, the Common Murre *Uria aalge*, the subspecies *U. a. californica* endemic to the CCS. One of the two most abundant species in the seabird observation data set, it is a year-round resident, nesting on islands and headlands from the Channel Islands (just a few) north into central Oregon; it concentrates largely in continental shelf waters from central to northern CA. Recovering from former negative human influence, the overall population of the Common Murre has been steadily increasing during recent decades. They have short, stubby wings, with high body mass and wing loading, requiring very rapid

flapping flight. They use their wings for under-water “flight” as well. Unless approaching or leaving nesting colonies that are elevated, they generally fly close to the sea surface. They are flightless during molt, which occurs during the Oceanic season.

Medium Alcids

Included in this group are Pigeon Guillemot *Cepphus columba*, Tufted Puffins fratercula cirrhata and Rhinoceros Auklet *Cerorhinca monocerata* (actually a puffin). Of these medium alcids, the Rhinoceros Auklet is the only year-round resident, frequenting the shelf break waters when not associated with nesting islands (central CA to the Pacific Northwest). The other two species are only residents in the study area during the breeding season. Otherwise, they reside in waters of British Columbia and Gulf of Alaska during the remainder of the year. All have short, stubby wings used for diving and must stay aloft by flapping flight, high wing-beat frequency, and remain very close to the sea surface except when approaching and leaving elevated nesting sites.

Small Alcids

Small alcids are another specious FG in the study area and include the taxon composed of the three closely related *Synthliboramphus* murrelets (Scripps’s, Guadalupe, and Craveri’s (*Sy. scrippsi, Sy. hypoleucas, Sy. craveri*) formerly lumped as one species, the Xantus’s Murrelet, plus Marbled Murrelet *Brachyramphus marmoratus*, Ancient Murrelet *Sy. antiquum*, and Cassin’s Auklet *Ptychoramphus aleuticus*. Ancient Murrelet is a visitor to the CCS from the Pacific Northwest during the Oceanic and Davidson seasons. The others are year-round residents off CA, though the *Synthliboramphus* ‘Xantus’s’ group nests to the south of the study area. The latter disperse northward during the post-breeding season, mostly swimming north, remaining in shelf break and more westerly waters. Marbled Murrelets rarely stray farther than a few kilometers (km) from shore, while the Cassin’s Auklet frequents the outer shelf and shelf break waters. The Marbled Murrelet is listed as Threatened under the federal ESA and as endangered under CA ESA, and the Scripps’s and Guadalupe murrelets are listed as Threatened under CA ESA. All members of this group have short, stubby wings, used in diving, and generally remain very close to the sea surface when flying.

Loons, Grebes, Ducks

There are four loons (Common, Red-throated, Pacific and Arctic (*Gavia immer, G. stellata, G. pacifica, G. arctica*) included in this FG. These species are flappers and all nest in the subarctic/arctic. They frequent CCS coastal waters largely during the Davidson Current season but can also be passage migrants (those wintering in coastal Mexican waters). Clark's and Western grebes (*Aechmophorus clarkii, A. occidentalis*) require a very close look to identify in the field, so these two species were treated as one taxon for purposes of this study. These grebes nest in marshes of the CA interior, coming to the coast during Oceanic and Davidson Current season, when they remain close to shore. Finally, for the ducks or, more accurately, sea ducks, there are Surf Scoters *Melanitta perspicillata* and Black Brant *Branta bernicla* that range between passage migrants and seasonal residents during the Davidson Current season. All the species in this FG generally travel in large, single-species flocks, sometimes in V-formation, at low to medium heights above the sea surface. Unlike the alcids, they propel themselves underwater using their feet, rather than their wings, and thus are more rapid, agile fliers than the alcids.

Appendix E References

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