

BIRDS AND MAMMALS THAT DEPEND ON THE SALISH SEA: A COMPILATION

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ABSTRACT—Efforts are underway to restore the Salish Sea, a 16,925 km² inland sea shared by Washington State, USA, and British Columbia, Canada. A list of the birds and mammals that use this marine ecosystem is lacking. We compiled information from varied sources and identified 172 bird and 37 mammal species that depend on the Salish Sea marine ecosystem. Of these species, 72 bird and 29 mammal species are both highly dependent on intertidal or marine habitat as well as on marine derived food. One hundred bird species and 8 mammal species that use the Salish Sea marine ecosystem have varying degrees of dependence on the marine and terrestrial ecosystems to meet significant life history needs. These interactions between the marine and terrestrial ecosystems indicate the need to integrate marine and terrestrial restoration efforts to achieve long-term conservation of the suite of birds and mammals that use and depend on the marine ecosystem. This comprehensive list of avian and mammal fauna for the Salish Sea serves as a foundation for determining the occurrence of new species and the disappearance of others, enables selection of species as indicators for ecosystem health, and also provides a basis for identifying the mechanisms responsible for marine bird and mammal declines.

Key words: birds, checklist, ecosystem health, Georgia Basin, indicator species, mammals, Puget Sound, Salish Sea

The Salish Sea is a 16,925 km² inland sea extending from Olympia, Washington, USA, north to Campbell River, British Columbia, Canada, and includes Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca. It is bounded by mainland British Columbia and Washington State on the east, Vancouver Island and the Olympic Peninsula on the west, and includes 7470 km of coastline (Gaydos and others 2008). Like other coastal zones around the world (Small and Nicholls 2003), the Salish Sea has been dramatically altered by human activities including conversion of native forest and shoreline habitat to urban and residential development, increased water and sediment contamination, changes in food web dynamics, the introduction of non-native and invasive species that alter habitat structure and native species composition, and the potential overharvest of resources (Gaydos and others 2008). These ecosystem pressures will likely be exac-

erbated in the future by the effects of climate change and activities associated with a growing human population (Scavia and others 2002).

Acknowledging that residents of the Georgia Basin and Puget Sound region share a common watershed, marine waters, and a common flyway for migratory birds as well as common concerns over urban growth, unilateral and bilateral efforts by the United States and Canada have been underway since the late 1980s to improve the health of the Salish Sea marine ecosystem (Fraser and others 2006; Gaydos and others 2008). These include plans and programs of tribes and First Nations, and the governments of Washington State, British Columbia, the USA, and Canada.

As efforts increase to reverse declines in the Salish Sea ecosystem, timely information will be needed on ecosystem changes. Data on wildlife occurrence and abundance can be a useful indicator of changes in ecosystem condition or

health (Hare and Mantua 2000). Marine birds and mammals are particularly useful indicators of ecosystem change because some species and communities respond to changes in environmental conditions, are relatively easily enumerated with well-established methods, and use a variety of habitat types (Piatt and Sydeman 2007). In addition, their diet is often correlated with independent measures of prey abundance (Montevecchi and Myers 1995) and available prey size distributions (Davoren and Montevecchi 2003), and some are vulnerable to many human activities (Furness and Tasker 2000). For example, marine bird and mammal diet has been used as an indicator of fish population trends and potentially fishery recruitment (Miller and Sydeman 2004), basin-scale climate change (Hedd and others 2006), and shorter-term climatic events (Velarde and others 2004; Bertram and others 2005; Sydeman and others 2006). Marine birds and mammals are also sentinels for ecosystem contamination and emerging diseases and pathogens, some of which can affect human health (Burger and Gochfeld 2004; Mallory and others 2006; Newman and others 2007; Moore 2008).

Monitoring marine bird and mammal populations could serve as an excellent indicator for the health of the Salish Sea; however a list of bird and mammal species using the marine waters of this inland sea has never been compiled. To address this information need, we use natural history information as well as abundance estimates, stranding data, and sighting reports to assemble a list of birds and mammals that use the Salish Sea marine ecosystem, and to rank their dependence on habitat and food in this ecosystem.

METHODS

Data on species occurrence and abundance, including scientific surveys and sighting and stranding data from Washington State and British Columbia were used to identify birds and mammals that use the Salish Sea marine ecosystem. These data also were used to rank species abundance by season and to rank their dependence on the marine ecosystem. Marine, estuarine, and inter-tidal environments were considered components of the marine ecosystem. Use of the marine ecosystem included use of the marine environment to meet significant

life history needs (reproduction, migration, molt, foraging, or over-wintering habitat). We included species that occur in the Salish Sea regularly, species that are rarely observed, and species not typically associated with the marine environment but that depend on the marine ecosystem to some extent. Examples of this latter group include the Savannah Sparrow (*Passerculus sandwichensis*) that nests in salt marsh habitats (Cade and Bartholomew 1959), the Snow Bunting (*Plectrophenax nivalis*) that over winters in salt marsh and mudflat habitats (Dierschke and Bairlein 2004), and Black Bear (*Ursus americanus*) and Black-tailed Deer (*Odocoileus hemionus columbianus*) that occasionally forage in the intertidal zone (Carlton and Hodder 2003).

To establish the bird list and to rank bird abundance and dependence on the marine ecosystem, we used data from: (1) summer (1992–1999) and winter (1993–2009) bird surveys conducted by Washington Department of Fish and Wildlife's Puget Sound Ambient Monitoring Program (Nysewander and others 2005); (2) the British Columbia Coastal Waterbird Survey conducted in Canadian waters from 1999 to 2009 (Badzinski and others 2008); (3) the Northwest Forest Plan effectiveness monitoring program (Huff and others 2006; Raphael and others 2007) where data are collected on most marine bird species encountered; and (4) other available information (Butler and Campbell 1987; Speich and Wahl 1989; Vermeer and Butler 1989; Campbell and others 1990; Butler and Vermeer 1994; Wahl and others 2005; Bird Studies Canada 2009; Kenyon and others 2009). Bird taxonomy and nomenclature follow the American Ornithologists' Union (1998) and subsequent supplements. For mammals, published and unpublished abundance, stranding and sighting records were used. References were species specific and are cited in Table 2. Mammal taxonomy and nomenclature follows Wilson and Reeder (2005).

Bird species with <5 reported sightings were considered vagrants and were not included; all confirmed mammal sightings and strandings were included. Bird abundance was scored by season: "No Reports" = never reported during season; "Rare" = sighted occasionally (<100 times/season/y); "Low" = seen regularly but at low abundance 100–500/season/y; "Medi-

um" = seen regularly at medium abundance (500–5000/season/y); and "High" = seen regularly at high abundance (>5000/season/y). Mammal abundance also was scored by season, although less quantified: "No Reports" = never reported during season; "Rare" = few sightings reported; "Low" = seen regularly but at low abundance; "Medium" = seen regularly at medium abundance; and "High" = seen regularly at high abundance. Seasons used were: Winter = 1 December–28 February; Spring = 1 March–30 May; Summer = 1 June–15 August; Fall = 16 August–30 November.

We qualitatively assigned each species a ranking for dependence on marine and intertidal marine habitat when using the Salish Sea ecosystem and included habitat from the upper limit of the wave spray and splash zone through the intertidal and into the deepest depths of the marine zone. A score of "High" was assigned if they do not or very rarely venture from marine or intertidal habitat; a score of "Medium" was assigned if they move regularly between marine and terrestrial or freshwater habitats; and a score of "Low" was assigned if they only occasionally use the marine ecosystem.

Similarly, each species was qualitatively ranked for dependence on marine-derived food, including food found from the upper limit of the wave spray and splash zone through the intertidal and into the deepest depths of the marine zone: "High" = completely dependent on the marine or marine nearshore-derived food when present; "Medium" = use both marine and terrestrial or freshwater food sources; and "Low" = only occasionally use marine- or nearshore-derived food.

RESULTS

One hundred and seventy-two (172) bird species have been recorded using the Salish Sea marine ecosystem ≥ 5 times (Table 1). Of those, 73 are highly dependent, 74 are moderately dependent, and 25 have low dependence on marine or intertidal habitat when present. Similarly, 73 species are highly dependent, 62 species are moderately dependent, and 37 species have a low dependence on marine-derived food. Seventy-two (72) species are both highly dependent on intertidal or marine habitat as well as on marine-derived food.

Of the 37 species of mammals that have been documented using the Salish Sea marine ecosystem, 29 are highly dependent, 4 are moderately dependent, and 4 have a low dependence on the marine or intertidal habitat and marine-derived food when present (Table 2).

Mammal abundance patterns are fairly uniform throughout the year. Bird abundance, however, varies dramatically within and among species depending on use of the Salish Sea for breeding, migrating, and overwintering. Overall bird abundance is greatest in the fall and spring, intermediate in the winter, and lowest in the summer. This pattern indicates the particular importance of the Salish Sea to migrating and overwintering bird species.

DISCUSSION

We documented 172 bird and 37 mammal species that depend on the Salish Sea marine ecosystem for habitat or food; of these, 42% (72) of the bird and 78% (29) of the mammal species are highly dependent on the marine ecosystem. This means that 58% of the birds and 22% of the mammals using the Salish Sea marine ecosystem are co-dependent on marine and terrestrial ecosystems for significant life history needs, which highlights the importance of ensuring that marine conservation efforts in the Salish Sea do not stop at the high-tide mark. If they do, it is possible that the complete life history needs of 108 of 209, or over 50% of the bird and mammal species documented to use the marine ecosystem could not be met.

Undoubtedly our list represents the minimum number of birds and mammals that rely on the Salish Sea marine ecosystem for habitat or food and should be considered a starting point for a more comprehensive list that will evolve over time as we learn more about species distributions or as distributions change. For example, we could see a change in the use of the Salish Sea by species known to occur in the region and known to use marine resources in other portions of their range, but that have not been documented as using the Salish Sea marine ecosystem. Gray Wolves (*Canis lupus*) occur in the northern portion of the Salish Sea and they have been documented to forage on returning salmon in other parts of British Columbia (Dairmont and others 2003), but this has not yet been documented in the Salish Sea, so they

TABLE 1. Bird species recorded using the Salish Sea marine ecosystem and their relative abundance and dependence on the ecosystem. H = High; M = Medium; L = Low; R = Rare; NR = No Report.

Order/Family/Species	Common name	Abundance in marine water or nearshore				Dependence on	
		(Winter)	(Spring)	(Summer)	(Fall)	Marine and intertidal habitat (when present)	Marine-derived food (when present)
ANSERIFORMES							
Anatidae							
<i>Anas acuta</i>	Northern Pintail	H	H	R	H	M	M
<i>Anas americana</i>	American Wigeon	H	H	R	H	M	M
<i>Anas clypeata</i>	Northern Shoveler	L	L	R	L	L	L
<i>Anas crecca</i>	Green-winged Teal	H	H	R	H	M	M
<i>Anas cyanoptera</i>	Cinnamon Teal	R	R	R	R	L	L
<i>Anas discors</i>	Blue-winged Teal	NR	R	R	R	L	L
<i>Anas penelope</i>	Eurasian Wigeon	L	L	NR	L	M	M
<i>Anas platyrhynchos</i>	Mallard	H	H	H	M	M	M
<i>Anas strepera</i>	Gadwall	M	M	R	M	L	L
<i>Anser albifrons</i>	Greater White-fronted Goose	R	L	NR	L	M	L
<i>Aythya affinis</i>	Lesser Scaup	M	M	R	M	M	M
<i>Aythya americana</i>	Redhead	R	R	NR	R	L	L
<i>Aythya collaris</i>	Ring-necked Duck	L	R	NR	R	L	L
<i>Aythya fuligula</i>	Tufted Duck	R	R	NR	R	M	M
<i>Aythya marila</i>	Greater Scaup	H	H	R	H	H	H
<i>Aythya valisineria</i>	Canvasback	M	M	NR	M	L	L
<i>Branta bernicula</i>	Brant	H	H	R	H	H	H
<i>Branta canadensis</i>	Canada Goose	H	H	M	H	M	L
<i>Branta hutchinsii</i>	Cackling Goose	M	M	R	M	M	L
<i>Bucephala albeola</i>	Bufflehead	H	H	R	H	H	H
<i>Bucephala clangula</i>	Common Goldeneye	H	H	R	H	H	H
<i>Bucephala islandica</i>	Barrow's Goldeneye	H	H	R	H	H	H
<i>Chen caerulescens</i>	Snow Goose	H	H	NR	H	M	L
<i>Chen canagica</i>	Emperor Goose	R	R	NR	R	L	L
<i>Chen rossii</i>	Ross' Goose	R	R	NR	R	M	L
<i>Clangula hyemalis</i>	Long-tailed Duck	H	H	R	M	H	H
<i>Cygnus buccinator</i>	Trumpeter Swan	M	M	NR	M	M	L
<i>Cygnus columbianus</i>	Tundra Swan	R	R	NR	R	M	L
<i>Cygnus olor</i>	Mute Swan	L	L	L	L	M	M
<i>Histrionicus histrionicus</i>	Harlequin Duck	H	H	M	H	H	H
<i>Lophodytes cucullatus</i>	Hooded Merganser	M	M	R	M	M	M
<i>Melanitta fusca</i>	White-winged Scoter	H	H	H	H	H	H
<i>Melanitta nigra</i>	Black Scoter	M	M	R	M	H	H
<i>Melanitta perspicillata</i>	Surf Scoter	H	H	H	H	H	H
<i>Mergus merganser</i>	Common Merganser	M	M	R	M	M	M
<i>Mergus serrator</i>	Red-breasted Merganser	H	H	R	H	M	H
<i>Oxyura jamaicensis</i>	Ruddy Duck	M	M	R	M	M	M
<i>Somateria spectabilis</i>	King Eider	R	R	NR	R	H	H
CHARADRIIFORMES							
Alcidae							
<i>Brachyramphus marmoratus</i>	Marbled Murrelet	M	M	M	M	H	H

TABLE 1. Continued.

Order/Family/Species	Common name	Abundance in marine water or nearshore				Dependence on	
		(Winter)	(Spring)	(Summer)	(Fall)	Marine and intertidal habitat (when present)	Marine-derived food (when present)
<i>Brachyramphus perdix</i>	Long-billed Murrelet	NR	NR	R	R	H	H
<i>Cephus columba</i>	Pigeon Guillemot	H	H	H	H	H	H
<i>Cerorhinca monocerata</i>	Rhinoceros Auklet	L	H	H	H	H	H
<i>Fratercula cirrhata</i>	Tufted Puffin	R	L	L	L	H	H
<i>Fratercula corniculata</i>	Horned Puffin	R	R	R	R	H	H
<i>Ptychoramphus aleuticus</i>	Cassin's Auklet	L	M	M	L	H	H
<i>Synthliboramphus antiquus</i>	Ancient Murrelet	M	L	L	H	H	H
<i>Uria aalge</i>	Common Murre	H	H	H	H	H	H
Charadriidae							
<i>Charadrius semipalmatus</i>	Semipalmated Plover	R	M	L	M	H	H
<i>Charadrius vociferous</i>	Killdeer	H	H	H	H	M	M
<i>Pluvialis dominica</i>	American Golden Plover	NR	R	R	R	M	M
<i>Pluvialis fulva</i>	Pacific Golden Plover	NR	R	R	R	H	H
<i>Pluvialis squatarola</i>	Black-Bellied Plover	M	H	M	H	H	H
Haematopodidae							
<i>Haematopus bachmani</i>	Black Oystercatcher	L	L	M	M	H	H
Laridae							
<i>Chlidonias niger</i>	Black Tern	NR	R	NR	R	M	M
<i>Chroicocephalus philadelphia</i>	Bonaparte's Gull	M	H	M	H	H	H
<i>Chroicocephalus ridibundus</i>	Black-headed Gull	R	R	NR	R	M	M
<i>Hydrocoloeus minutus</i>	Little Gull	R	R	NR	R	H	H
<i>Larus argentatus</i>	Herring Gull	M	M	R	M	M	M
<i>Larus californicus</i>	California Gull	M	H	M	H	M	M
<i>Larus canus</i>	Mew Gull	H	H	M	H	H	H
<i>Larus delawarensis</i>	Ring-billed Gull	H	H	H	H	M	M
<i>Larus glaucescens</i>	Glaucon-winged Gull	H	H	H	H	M	M
<i>Larus heermanni</i>	Heermann's Gull	R	R	H	M	H	H
<i>Larus hyperboreus</i>	Glaucon-winged Gull	R	R	NR	R	M	M
<i>Larus glaucooides</i>	Iceland Gull	R	R	NR	R	M	M
<i>Larus schistisagus</i>	Slaty-backed Gull	R	R	NR	R	M	M
<i>Larus occidentalis</i>	Western Gull	M	L	L	M	M	M
<i>Larus thayeri</i>	Thayer's Gull	H	H	R	H	M	M
<i>Leucophaeus pipixcan</i>	Franklin's Gull	R	R	R	L	M	M
<i>Rissa tridactyla</i>	Black-Legged Kittiwake	R	L	R	L	H	H
<i>Sterna caspia</i>	Caspian Tern	R	M	M	M	H	H
<i>Sterna forsteri</i>	Forster's Tern	NR	NR	NR	R	M	M
<i>Sterna hirundo</i>	Common Tern	NR	L	L	M	H	H
<i>Sterna paradisaea</i>	Arctic Tern	NR	L	R	L	H	H
<i>Xema sabini</i>	Sabine's Gull	NR	R	R	R	H	H
Recurvirostridae							
<i>Himantopus mexicanus</i>	Black-necked Stilt	NR	R	R	NR	M	M

TABLE 1. Continued.

Order/Family/Species	Common name	Abundance in marine water or nearshore				Dependence on	
		(Winter)	(Spring)	(Summer)	(Fall)	Marine and intertidal habitat (when present)	Marine-derived food (when present)
<i>Recurvirostra americana</i>	American Avocet	NR	R	R	R	M	M
Scolopacidae							
<i>Actitis macularius</i>	Spotted Sandpiper	L	M	M	M	M	M
<i>Aphriza virgata</i>	Surfbird	M	M	L	M	H	H
<i>Arenaria interpres</i>	Ruddy Turnstone	R	L	L	L	H	H
<i>Arenaria melanocephala</i>	Black Turnstone	M	M	M	M	H	H
<i>Calidris pusilla</i>	Semipalmated Sandpiper	NR	NR	R	NR	M	M
<i>Calidris acuminata</i>	Sharp-tailed Sandpiper	NR	R	R	R	M	M
<i>Calidris alba</i>	Sanderling	M	M	L	M	H	H
<i>Calidris alpina</i>	Dunlin	H	H	M	H	M	M
<i>Calidris bairdii</i>	Baird's Sandpiper	NR	NR	L	L	M	M
<i>Calidris canutus</i>	Red Knot	NR	R	R	R	H	H
<i>Calidris himantopus</i>	Stilt Sandpiper	NR	NR	R	R	M	M
<i>Calidris mauri</i>	Western Sandpiper	L	H	H	H	H	H
<i>Calidris melanotos</i>	Pectoral Sandpiper	NR	R	R	L	M	M
<i>Calidris minutilla</i>	Least Sandpiper	L	M	M	M	M	M
<i>Calidris ptilocnemis</i>	Rock Sandpiper	R	R	R	R	H	H
<i>Gallinago delicata</i>	Wilson's Snipe	L	L	L	L	L	L
<i>Limnodromus griseus</i>	Short-billed Dowitcher	R	H	H	H	M	M
<i>Limnodromus scolopaceus</i>	Long-billed Dowitcher	M	H	H	H	M	M
<i>Limosa fedoa</i>	Marbled Godwit	R	R	R	R	H	H
<i>Limosa lapponica</i>	Bar-tailed Godwit	NR	NR	R	R	H	H
<i>Limosa haemastica</i>	Hudsonian Godwit	NR	NR	R	R	M	M
<i>Numenius americanus</i>	Long-billed Curlew	R	R	R	R	M	M
<i>Numenius phaeopus</i>	Whimbrel	L	M	L	M	H	H
<i>Phalaropus lobatus</i>	Red-necked Phalarope	R	L	L	M	H	H
<i>Phalaropus fulicaria</i>	Red Phalarope	R	R	L	M	H	H
<i>Phalaropus tricolor</i>	Wilson's Phalarope	NR	R	R	R	L	L
<i>Philomachus pugnax</i>	Ruff	NR	R	R	R	L	L
<i>Tringa flavipes</i>	Lesser YelLlegs	R	M	M	M	M	M
<i>Tringa incana</i>	Wandering Tattler	R	L	L	L	H	H
<i>Tringa melanoleuca</i>	Greater YelLlegs	M	H	M	H	M	M
<i>Tringa semipalmata</i>	Willet	L	L	R	L	H	H
<i>Tryngites subruficollis</i>	Buff-breasted Sandpiper	NR	NR	R	R	L	L
Stercorariidae							
<i>Stercorarius longicaudus</i>	Long-tailed Jaeger	NR	NR	R	R	H	H
<i>Stercorarius maccornicki</i>	South Polar Skua	NR	NR	R	R	H	H
<i>Stercorarius parasiticus</i>	Parasitic Jaeger	NR	R	R	L	H	H
<i>Stercorarius pomarinus</i>	Pomarine Jaeger	R	R	R	R	H	H
CICONIIFORMES							
Ardeidae							
<i>Ardea alba</i>	Great Egret	R	R	R	R	M	M
<i>Ardea herodias</i>	Great Blue Heron	H	H	H	H	M	M

TABLE 1. Continued.

Order/Family/Species	Common name	Abundance in marine water or nearshore				Dependence on	
		(Winter)	(Spring)	(Summer)	(Fall)	Marine and intertidal habitat (when present)	Marine-derived food (when present)
<i>Botaurus lentiginosus</i>	American Bittern	L	L	L	L	M	M
<i>Bubulcus ibis</i>	Cattle Egret	R	NR	NR	R	M	M
<i>Butorides virescens</i>	Green Heron	R	L	L	L	L	L
COLUMBIFORMES							
Columbidae							
<i>Patagioenas fasciata</i>	Band-tailed Pigeon	L	L	L	L	L	L
CORACIIFORMES							
Alcedinidae							
<i>Megasceryle alcyon</i>	Belted Kingfisher	M	M	M	M	M	M
FALCONIFORMES							
Accipitridae							
<i>Buteo jamaicensis</i>	Red-tailed Hawk	H	H	H	H	L	L
<i>Buteo lagopus</i>	Rough-legged Hawk	L	L	NR	L	L	L
<i>Circus cyaneus</i>	Northern Harrier	M	M	M	M	M	M
<i>Haliaeetus leucocephalus</i>	Bald Eagle	M	M	M	M	M	M
<i>Pandion haliaetus</i>	Osprey	L	L	L	L	M	M
Cathartidae							
<i>Cathartes aura</i>	Turkey Vulture	R	L	L	L	M	M
Falconidae							
<i>Falco columbarius</i>	Merlin	L	L	L	L	M	M
<i>Falco peregrinus</i>	Peregrine Falcon	L	L	L	L	M	M
<i>Falco rusticolus</i>	Gyrfalcon	R	R	NR	R	M	M
GAVIIFORMES							
Gaviidae							
<i>Gavia adamsii</i>	Yellow-billed Loon	R	R	R	R	H	H
<i>Gavia arctica</i>	Arctic Loon	R	NR	NR	NR	H	H
<i>Gavia immer</i>	Common Loon	M	M	L	M	H	H
<i>Gavia pacifica</i>	Pacific Loon	H	H	L	H	H	H
<i>Gavia stellata</i>	Red-throated Loon	H	H	L	H	H	H
GRUIFORMES							
Gruidae							
<i>Grus canadensis</i>	Sandhill Crane	R	R	R	L	L	L
Rallidae							
<i>Fulica americana</i>	American Coot	M	L	L	L	M	M
<i>Porzana carolina</i>	Sora	R	L	L	L	L	L
<i>Rallus limicola</i>	Virginia Rail	L	L	L	L	M	M
PASSERIFORMES							
Corvidae							
<i>Corvus brachyrhynchos</i>	Common Crow	L	L	L	L	L	L
<i>Corvus caurinus</i>	Northwestern Crow	H	H	H	H	M	M
<i>Corvus corax</i>	Common Raven	L	L	L	L	L	L
Emberizidae							
<i>Calcarius lapponicus</i>	Lapland Longspur	R	R	NR	NR	L	L
<i>Passerculus sandwichensis</i>	Savannah Sparrow	M	H	H	H	M	L
<i>Plectrophenax nivalis</i>	Snow Bunting	L	L	NR	L	M	L

TABLE 1. Continued.

Order/Family/Species	Common name	Abundance in marine water or nearshore				Dependence on	
		(Winter)	(Spring)	(Summer)	(Fall)	Marine and intertidal habitat (when present)	Marine-derived food (when present)
<i>Zonotrichia atricapilla</i>	Golden-crowned Sparrow	H	H	NR	H	L	L
<i>Zonotrichia leucophrys</i>	White-crowned Sparrow	H	H	H	H	L	L
Fringillidae <i>Spinus tristis</i>	American Goldfinch	H	H	H	H	L	L
Hirundinidae <i>Progne subis</i>	Purple Martin	NR	M	M	M	M	M
Troglodytidae <i>Cistothorus palustris</i>	Marsh Wren	H	H	H	H	H	L
PELECANIFORMES							
Pelicanidae							
<i>Pelecanus erythrorhynchus</i>	American White Pelican	R	R	R	R	M	M
<i>Pelecanus occidentalis</i>	Brown Pelican	R	R	L	L	H	H
Phalacrocoracidae							
<i>Phalacrocorax auritus</i>	Double-crested Cormorant	H	H	H	H	M	M
<i>Phalacrocorax pelagicus</i>	Pelagic Cormorant	H	H	H	H	H	H
<i>Phalacrocorax penicillatus</i>	Brandt's Cormorant	H	M	L	H	H	H
PODICIPEDIFORMES							
Podicipedidae							
<i>Aechmophorus clarkii</i>	Clark's Grebe	R	R	NR	R	H	H
<i>Aechmophorus occidentalis</i>	Western Grebe	H	M	L	H	H	H
<i>Podiceps auritus</i>	Horned Grebe	H	H	R	H	H	H
<i>Podiceps grisegena</i>	Red-necked Grebe	H	H	R	H	H	H
<i>Podiceps nigricollis</i>	Eared Grebe	L	L	NR	L	M	M
<i>Podilymbus podiceps</i>	Pied-billed Grebe	L	L	NR	L	L	L
PROCELLARIIFORMES							
Diomedidae							
<i>Phoebastria nigripes</i>	Black-footed Albatross	R	R	R	L	H	H
Hydrobatidae							
<i>Oceanodroma furcata</i>	Fork-tailed Storm-Petrel	NR	L	L	L	H	H
<i>Oceanodroma leucorhoa</i>	Leach's Storm-Petrel	NR	L	L	L	H	H
Procellariidae							
<i>Fulmarus glacialis</i>	Northern Fulmar	R	NR	NR	R	H	H
<i>Puffinus bulleri</i>	Buller's Shearwater	NR	NR	R	R	H	H
<i>Puffinus carneipes</i>	Flesh-footed Shearwater	NR	L	L	L	H	H
<i>Puffinus creatopus</i>	Pink-footed Shearwater	NR	L	L	L	H	H
<i>Puffinus griseus</i>	Sooty Shearwater	R	M	H	H	H	H
<i>Puffinus tenuirostris</i>	Short-tailed Shearwater	R	NR	NR	R	H	H

TABLE 1. Continued.

Order/Family/Species	Common name	Abundance in marine water or nearshore				Dependence on	
		(Winter)	(Spring)	(Summer)	(Fall)	Marine and intertidal habitat (when present)	Marine-derived food (when present)
STRIGIFORMES							
Strigidae							
<i>Asio flammeus</i>	Short-eared Owl	R	L	R	L	M	L
<i>Bubo scandiacus</i>	Snowy Owl	R	R	NR	R	M	M
<i>Bubo virginianus</i>	Great Horned Owl	M	M	M	M	M	L

do not appear on our list. Several species of rodents, such as Keen's Mouse (*Peromyscus keeni*; Blight and others 1999; Drever and others 2000) and Norway Rat (*Rattus norvegicus*; Drever and Harestad 1998), are known to occur in the Salish Sea region and have been documented consuming seabird eggs and even seabirds (Hobson and others 1999) in areas outside of the Salish Sea, but not within the region and so were also not included on the list. Similarly, marine invertebrates contribute substantially to the diet of non-breeding Northern Saw-whet Owls (*Aegolius acadicus*) from the Queen Charlotte Islands (Canada; Hobson and Sealy 1991), but this too has not been documented in the Salish Sea, precluding the inclusion of Saw-whet owls on the list.

As would be expected, species distribution is not uniform throughout the Salish Sea and the inclusion of a bird or mammal on our list of species does not imply that they can be found throughout the inland sea. For example, Grizzly Bears (*Ursus arctos*) are primarily observed at the northern end of the Salish Sea where they can be found feeding heavily in the summer and fall on returning salmon (*Oncorhynchus* spp.). Similarly, many of the pelagic marine birds, such as Black-footed Albatross (*Phoebastria nigripes*), Northern Fulmar (*Fulmarus glacialis*), and Shearwater species (*Puffinus* spp.) are almost exclusively restricted to the western end of the Strait of Juan de Fuca. Additionally, the Fraser River is the largest source of freshwater entering the Salish Sea and because of its size and productivity, the river's estuary is an important stopover site

for a number of shorebirds that are not normally seen in other parts of the sea, such as Baird's Sandpiper (*Calidris bairdii*), Red Knot (*Calidris canutus*), and Ruff (*Philomachus pugnax*).

Species richness (for example alpha diversity) is a fundamental measurement of diversity and can be used as a gross indicator of biodiversity (Gotelli and Colwell 2001). Documenting 172 species of birds and 37 species of mammals that rely on the Salish Sea marine ecosystem is impressive, but difficult to compare to other marine ecosystems similar in size and latitude due to the paucity of detailed species lists from well-defined marine ecosystems. In 1 list of birds and mammals of Micronesia, a tropical island ecosystem over 700 times the size of the Salish Sea, Wiles (2005) recorded 279 avian and 44 mammal species, but this list included marine, freshwater, and terrestrial species. A species list from the York River watershed including the Chesapeake Bay indicates that 230 species of birds and 50 species of mammals have been recorded in this watershed, but this list also includes species associated with non-marine environments (Brown and Erdle 2009) whereas our list is confined to species associated with marine and estuarine habitats. Moreover, unlike other lists, we identify the geographic and ecological scope, the criteria for inclusion on the list, and a qualitative metric for their dependence on the ecosystem. As scientists begin to see the value of identifying the birds and mammals using ecosystems, increased numbers of published lists for other systems should become available, permitting greater comparison.

TABLE 2. Mammal species recorded using the Salish Sea marine ecosystem and their relative abundance and dependence on the ecosystem. See Appendix for definition of corresponding numbers in the Citation column and * in Abundance and Dependence columns. H = High; M = Medium; L = Low; R = Rare; NR = No Report.

Order/Family/Species	Common Name	Abundance in marine water or nearshore				Dependence on		Citation
		(Winter)	(Spring)	(Summer)	(Fall)	marine or intertidal habitat (when present)	marine-derived food (when present)	
ARTIODACTYLA								
Cervidae								
<i>Odocoileus hemionus columbianus</i>	Black-tailed Deer	L	L	L	L	L	L	1
CARNIVORA								
Canidae								
<i>Vulpes vulpes</i>	Red Fox	R*	R*	R*	R*	R*	L*	2
Mustelidae								
<i>Enhydra lutris</i>	Sea Otter	L	L	L	L	H	H	3
<i>Lontra canadensis</i>	North American River Otter	M	M	M	M	M	M	4
<i>Neovison vison</i>	Mink	L	L	L	L	M	M	5
Otariidae								
<i>Callorhinus ursinus</i>	Northern Fur Seal	R	R	NR	NR	H	H	6
<i>Eumetopias jubatus</i>	Steller's Sea Lion	L	L	R	L	H	H	6
<i>Zalophus californianus</i>	California Sea Lion	L	L	L	L	H	H	8
Phocidae								
<i>Mirounga angustirostris</i>	Northern Elephant Seal	L	L	L	L	H	H	9
<i>Phoca vitulina</i>	Harbor Seal	H	H	H	H	H	H	10
Procyonidae								
<i>Procyon lotor</i>	Raccoon	L	L	L	L	L	L	11
Ursidae								
<i>Ursus americanus</i>	Black Bear	R	R	R	R	M	M	12
<i>Ursus arctos</i>	Grizzly Bear	NR	NR	R	R	M	M	13
CETECEA								
Balaenopteridae								
<i>Balaenoptera acutorostrata</i>	Minke Whale	R	L	L	L	H	H	14
<i>Balaenoptera edeni</i>	Bryde's Whale	R	NR	NR	NR	H	H	15
<i>Balaenoptera physalis</i>	Fin Whale	R	NR	R	R	H	H	16
<i>Megaptera novaeangliae</i>	Humpback Whale	NR	R	R	R	H	H	17
Delphinidae								
<i>Delphinus delphis</i>	Short-beaked Common Dolphin	R	R	R	R	H	H	18
<i>Delphinus capensis</i>	Long-beaked Common Dolphin	R	NR	NR	R	H	H	19
<i>Globicephala macrorhynchus</i>	Short-finned Pilot Whale	R	R	R	R	H	H	20

TABLE 2. Continued.

Order/Family/Species	Common Name	Abundance in marine water or nearshore				Dependence on		Citation
		(Winter)	(Spring)	(Summer)	(Fall)	marine or intertidal habitat (when present)	marine-derived food (when present)	
<i>Grampus griseus</i>	Risso's Dolphin	NR	R	R	R	H	H	21
<i>Lagenorhynchus obliquidens</i>	Pacific White-sided Dolphin	L	L	R	L	H	H	22
<i>Lissodelphis borealis</i>	Northern Right Whale	R*	R*	R*	R*	H	H	23
<i>Orcinus orca</i>	Killer Whale	R	L	L	L	H	H	24
<i>Pseudorca crassidens</i>	False Killer Whale	NR	R	R	NR	H	H	25
<i>Stenella coeruleoalba</i>	Striped Dolphin	NR	R	NR	NR	H	H	26
<i>Tursiops truncatus</i>	Bottlenose Dolphin	NR	R	NR	NR	H	H	27
Eschrichtiidae								
<i>Eschrichtius robustus</i>	Gray Whale	R	L	L	R	H	H	28
Kogiidae								
<i>Kogia brevirostris</i>	Pygmy Sperm Whale	R*	R*	R*	R*	H	H	29
Phocoenidae								
<i>Phocoena phocoena</i>	Harbor Porpoise	M	M	M	M	H	H	30
<i>Phocoenoides dalli</i>	Dall's Porpoise	M	M	M	M	H	H	31
Ziphiidae								
<i>Berardius bairdii</i>	Baird's Beaked Whale	R	R	R	R	H	H	32
<i>Mesoplodon carlhubbsi</i>	Hubb's beaked Whale	R*	R*	R*	R*	H	H	33
<i>Mesoplodon stejnegeri</i>	Stejneger's Beaked Whale	R*	R*	R*	R*	H	H	34
<i>Ziphius cavirostris</i>	Cuvier's Beaked Whale	R	R	R	R	H	H	34
RODENTIA								
Castoridae								
<i>Castor canadensis</i>	Beaver	L	L	L	L	H	H	35
<i>Ondatra zibethicus</i>	Muskrat	R*	R*	R*	R*	L*	L*	36

The list that we developed for the Salish Sea marine ecosystem can potentially serve many purposes including: (1) identifying potential targets for ecological restoration; (2) a foundation for evaluating the occurrence of new

species and the disappearance of others as well as for evaluating factors contributing to population changes; (3) understanding the suite of species that use this environment and a preliminary understanding of their relative abundance

in and dependence on the ecosystem that can be used as potential indicators of ecosystem health; or (4) for a comparative life history approach to identify a potential suite of mechanisms for population declines (such as pathogens or disease).

When last calculated on 1 September 2008, 22 avian and 6 mammalian species that use the Salish Sea were legally listed as species at risk or were candidates for such listing by ≥ 1 of the state, provincial, or federal governments that manage wildlife in the Salish Sea (Gaydos and Brown 2009). In addition, long-term monitoring indicates severe population declines for some species associated with the Salish Sea (Anderson and others 2009; Bower 2009). Determining common risk factors for declines in and among species requires not only knowing which risk factors are applicable to the declining species, but also on being able to determine if there are other species in the ecosystem with similar life histories that may also be declining due to shared risk factors. To do this, it is imperative that one start with a comprehensive list of species that use the ecosystem. Such a list provides a foundation for analyzing risk factors for marine bird and mammal declines in the Salish Sea ecosystem and a baseline for establishing recovery and conservation objectives.

Understanding species abundance patterns and dependence on the Salish Sea ecosystem is useful for selecting a suite of indicators as either targets for restoration or to evaluate the effectiveness of ecological restoration or management actions. The availability of relative and seasonal abundance data on all species within the ecosystem allows managers to select species that are abundant enough for determining trends, and that are present year-round and therefore whose declines are likely associated with the Salish Sea. For example, if overwintering migrant seabirds are declining but locally breeding birds are not, this may suggest that factors outside this ecosystem could be influencing their decline.

A list of birds and mammals using a discrete ecosystem also can be valuable when determining the role of disease in species declines or their potential role in recovery. Often, very little is known about a certain species in decline; however, good data are available for closely related sympatric species that could share

similar mechanisms responsible for decline (such as disease). This comparative approach was used for evaluating the impacts of infectious diseases on the endangered southern resident Killer Whale (*Orcinus orca*) population. Only 15 infectious agents had been reported world-wide in Killer Whales; however, 28 potentially important additional agents were reported in sympatric cetacean species, some of which have the ability to affect the recovery of this endangered species and need to be considered in recovery planning (Gaydos and others 2004). As recovery plans are developed for other mammals and birds in decline, having a list of sympatric species allows scientists to better identify potential threats.

Identifying the bird and mammal species that use the Salish Sea marine ecosystem serves as a foundation for evaluating the occurrence of new species and the disappearance of others. It also provides a foundation for analyzing risk factors for marine birds and mammal population trends, permits better selection of indicator species, and can assist with determining the role of disease in species declines or their potential role in recovery. While few lists currently exist for discrete ecosystems, the development of ecosystem-based lists in the future will allow comparisons of species richness and diversity between ecosystems.

ACKNOWLEDGMENTS

This manuscript was supported by in-kind contributions from the Washington Department of Fish and Wildlife and the SeaDoc Society, a program of the Wildlife Health Center, which is a center of excellence at the University of California Davis School of Veterinary Medicine. We thank S Berta, J Calambokidis, H Garrett, WG Hood, A Traxler, K Wilkinson, the Whale Museum, and the Washington Department of Fish and Wildlife for providing data. We thank P Davidson, J Evenson, S Jeffries, J Kenagy, J Watson and 3 anonymous reviewers for providing helpful comments that improved the manuscript.

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Submitted 2 February 2010, accepted 9 November 2010. Corresponding Editor: Thomas Jung.

APPENDIX: DEFINITIONS OF NUMBERS IN CITATION COLUMN OF TABLE 2

1. Gaydos personal observation; grazes intertidal kelp species; Carlton and Hodder 2003
2. Holmes 1992 in Carlton and Hodder 2003; *ranked rare for seasonal abundance and low for dependence on marine habitat and marine-derived food due to insufficient evidence to rank otherwise
3. Lance and others 2004
4. Gaydos and others 2007
5. Gaydos personal observation; observed foraging on crabs and other invertebrates intertidally and swimming in marine waters; Carlton and Hodder 2003
6. NOAA NW Regional Marine Mammal Stranding Network, unpub. data
7. Calambokidis and Baird 1994
8. Calambokidis and Baird 1994
9. Calambokidis and Baird 1994; NOAA NW Regional Marine Mammal Stranding Network, unpub. Data
10. Jeffries and others 2003
11. Gaydos personal observation; observed foraging intertidally; feces often contain large amounts of crab and clam shells; Carlton and Hodder 2003
12. Gaydos personal observation; observed turning over rocks to eat crabs, clams and

- barnacles intertidally; Carlton and Hodder 2003 report use in regions outside of the Salish Sea
13. Mowat and Heard 2006; McLellan 1998
 14. Calambokidis and Baird 1994; Norman and others 2004
 15. Personal communication J Calambokidis; 1 stranding reported January 2010 in South Puget Sound
 16. Scheffer and Slipp 1948; Norman and others 2004; Whale Museum unpublished sighting data; note: 1 live whale sighted, 3 dead whales died of ship strike believed to have occurred at the mouth of Juan de Fuca Strait and carried in by the ship that hit them
 17. Calambokidis and Steiger 1990; Orca Network Unpublished sighting data; Whale Museum unpublished sighting data
 18. Osborne and others 1988; Calambokidis and Baird 1994; Norman and others 2004
 19. Ford 2005
 20. Stacey and Baird 1993; Norman and others 2004
 21. Osborne and others 1988; Baird and Stacey 1991
 22. Stacey and Baird 1991a
 23. Osborne and others 1988; *1 sighting reported in 1977, month not reported
 24. Baird 2001; Wiles 2004
 25. Scheffer and Slipp 1948; Baird and others 1989; Scordino 1991; Stacey and Baird 1991b; Norman and others 2004
 26. Baird and others 1993
 27. Ferrero and Tsunoda 1989
 28. Calambokidis and Baird 1994; Calambokidis and others 2002; Norman and others 2004; Whale Museum unpublished sighting data
 29. Osborne and others 1988; *2 strandings reported (1977 and 1985), month not reported
 30. Calambokidis and Baird 1994
 31. Calambokidis and Baird 1994
 32. Calambokidis and Baird 1994
 33. Scheffer and Slipp 1948 report a sighting of suspect *Mesoplodon* species in Puget Sound with no date; *Osborne and others 1988 report 2 strandings however month and year were not reported; identified as *M. stejnegeri* or *M. carlhubbsi*
 34. Scheffer and Slipp 1948 report a sighting of suspect *Mesoplodon* species in Puget Sound with no date; *Osborne and others 1988 report 2 strandings however month and year were not reported; identified as *M. stejnegeri* or *M. carlhubbsi*
 35. Personal communication WG Hood; beaver create tidal dams in intertidal oligohaline marshes where they consume sedges and other intertidal vegetation
 36. Martinez and others 1986 in Carlton and Hodder 2003; *ranked rare for seasonal abundance and low for dependence on marine habitat and marine-derived food due to insufficient evidence to rank otherwise