Status and distribution of marine birds in southern Howe Sound 2014–15 and the outer Fraser River estuary, British Columbia, 2016–2017

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Abstract: We recorded 35,248 birds along a boat-based transect through southern Howe Sound between 9 June 2014 and 14 May 2015, and 3260 birds on a survey along the inbound and outbound shipping lanes in the outer Fraser River estuary between 10 November 2016 and 23 October 2017. Of 44 annually occurring marine bird species seen in Howe Sound, 13 were federally designated as Endangered, Threatened, or Special Concern, or provincially Red- or Blue-listed by the government of British Columbia. The bird list includes Marbled Murrelet, Double-crested Cormorant, Brandt's Cormorant, Western Grebe, Horned Grebe, Common Murre, Surf Scoter, Long-tailed Duck, California Gull, Peregrine Falcon, and Great Blue Heron.

In the entire Fraser River estuary, we estimated that as many as 32,000 birds could have been present in January when birds were most numerous, and 1950 in June when birds were least numerous. Of 27 annually occurring birds in the outer estuary, 14 were designated as Endangered, Threatened, or Special Concern by either the federal or provincial government designations including the following birds: Brant, Surf Scoter, Double-crested Cormorant, Brandt's Cormorant, Pelagic Cormorant, Western Grebe, California Gull, Parasitic Jaeger, Caspian Tern, Common Murre, Marbled Murrelet, Ancient Murrelet.

Barfleur Passage, Christie Islet and Pam Rocks, and Collingwood Channel were areas of special importance to birds in southern Howe Sound. The waters off Point Grey, and the North and Main Arm were of special importance in the outer Fraser River estuary. The large number of Marbled Murrelets present in winter suggests that southern Howe Sound and the outer Fraser River estuary are important locations for the imperiled population, B.C.'s south coast murrelets.

Key words: Howe Sound, Fraser River estuary, Species at Risk, birds.

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Introduction

Southern Howe Sound and the outer Fraser River estuary are part of a body of water known as the Salish Sea that straddles the Canada-USA border on the Pacific. Southern Howe Sound is part of an Important Bird Area (<www.ibacanada.com>) designation shared with English Bay, Burrard Inlet and Indian Arm and has long been a draw for birdwatchers in search of west coast waterbird specialities. The Fraser River Delta south of Vancouver holds the greatest number of many waterbirds in the Salish Sea and is considered one of Canada's most important natural resources (Butler and Campbell 1987). The importance of the intertidal beaches and uplands of the Fraser River Delta has been recognized with many conservation designations, including an Important Bird Area. Together, the Fraser River Delta, English Bay, Burrard Inlet, Indian Arm and Howe Sound are among Canada's most important

and treasured bird habitats. The outer estuary from 1.8–7.4 km (1–4 nautical miles) beyond the low tide of the Fraser River Delta overlaps the busiest shipping lane on Canada's Pacific Coast and lies outside the conservation designations.

Several authors have reported significant changes in bird species in the Salish Sea (Bower 2009, Anderson *et al*. 2009, Crewe *et al*. 2012). Vilchis *et al*. (2015) found long term declines among largely fish-eating species that they posited were in response to large ecological changes to the food web, notably small fish prey. Numbers of some species of birds of prey and waterfowl were stable or had increased (Crewe *et al*. 2012). Gaydos and Brown's (2011) review of the potential threats to wildlife in the Salish Sea included human disturbance, underwater acoustics and oil spills from increased shipping to and from ports in Vancouver and Washington, and a variety of ecological changes.

Howe Sound was industrialized in the early to late 20th century with concomitant environmental degradation (Levings *et al*. 1979) followed by restoration efforts, continuing to the present day (Mulder 2013). In the Fraser River estuary, shipping has increased with heightened public attention in recent years over the potential for increased spills from ships, most notably a higher number of oil tankers, in the Salish Sea including the Fraser River estuary.

Our knowledge of birds in Howe Sound and the Fraser River Delta arises from the unwritten centuries-old record left by indigenous people in the archeological record (Hobson and Driver 1989, Reimer 2012). Both early Spanish and English explorers crossed the Fraser River estuary two centuries ago but did not refer to bird life there (Vancouver 1798). The first written record was penned by Captain George Vancouver during one of these voyages upon entering Howe Sound in mid-June 1792 when he remarked that "not a bird nor living creature was to be seen" (Vancouver 1798). Despite Vancouver's glum assessment, Archibald Menzies, accompanying naturalist on Vancouver's voyage, wrote about shooting sea pies (oystercatchers) at the entrance to Howe Sound (Newcombe 1923). Breault and Watts (1996) reported on birds in Howe Sound between September and June and Vermeer (1981) provided an early estimate of the number of waterfowl in Howe Sound. Lacroix (2001) counted birds in southern Howe Sound between October and May 1998–1999 and September to May 1999–2000.

Information on bird abundance on the Fraser River Delta is voluminous (*e.g.* Benson 1961, Campbell *et al*. 1972, Vermeer and Levings 1977, Butler and Campbell 1987, Butler and Cannings 1989, Badzinski *et al*. 2008). There is also a large body of research into distributions and habitat associations of the major waterbird species along the shore (*e.g*. Butler 1994, Ydenberg *et al.* 2004, Shepard and Lank 2004, Pomeroy 2006, Evans Ogden *et al*. 2008, Drever *et al*. 2014, Jimenez *et al*. 2014). However, and in contrast to the Fraser River Delta shoreline, information on birds in the outer estuary is scant. Robertson (1977) conducted a year-round survey from ships and ferries of seabirds utilizing the pelagic waters of the Strait of Georgia and east of the Fraser River estuary. The paucity of birds led Robertson (1977) to conclude that the density of seabirds using the pelagic waters was minimal and their ecological role was insignificant. The birds using the estuary waters between the intertidal portions of the delta and the pelagic waters of the Strait of Georgia surveyed by Robertson (1977) have not been surveyed to our knowledge.

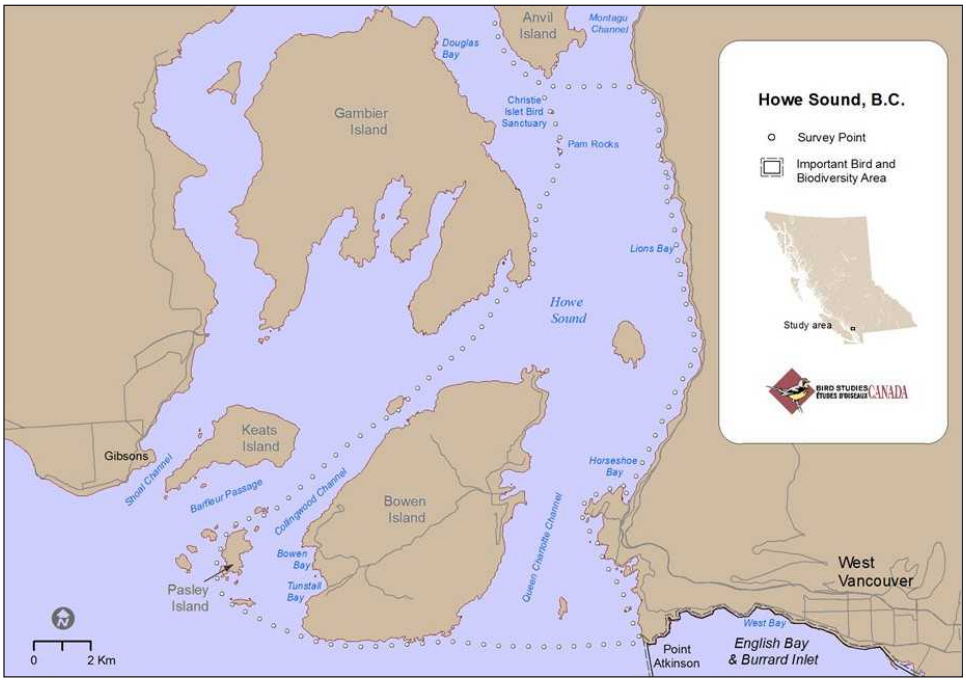

Figure 1. Southern Howe Sound study area and survey route.

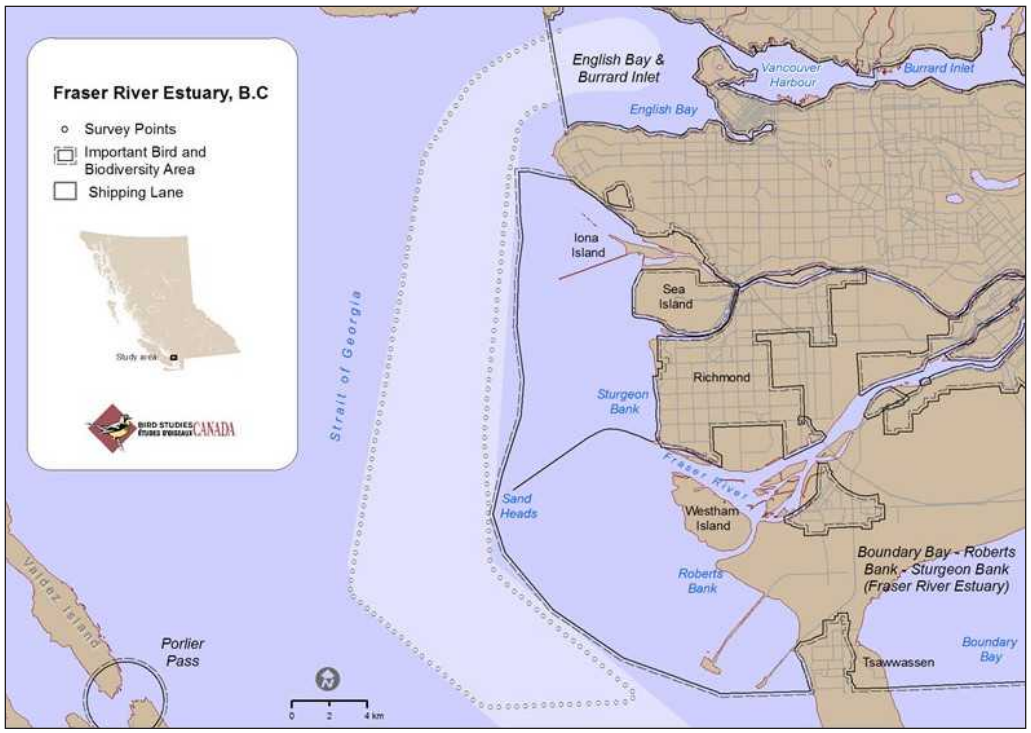

Figure 2. The Fraser River estuary study area shown in pale blue included the waters in English Bay to the Canada-U.S.A. border.

Birds in Howe Sound and the Fraser River estuary were surveyed by Butler *et al*. (2015, 2018). Maps, species accounts and technical details for the outer Fraser River estuary and southern Howe Sound surveys can be found in those respective reports (Butler *et al*. 2015, 2018). The purpose of this paper is to summarize these results with particular attention to species that are listed either by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), the Federal Species at Risk Act (SARA) or Provincially listed (Red- or Blue-listed), and provide recommendations.

Methods

Study Areas

The southern Howe Sound study area included the tidal waters of southern Howe Sound from Point Atkinson to Anvil Island (Fig. 1). Steep walls and a deep seabed about 200 m deep carved by receding glaciers at the northern end of Howe Sound is more similar to a fjord than a sound. A moraine north of Anvil Island and southeast of the Defence Islands near the northern end of the study area creates a sill that rises to within 30 m of the sea surface south from where the seabed plunges once more to a depth of 150–200 m. South of the sill and where we conducted our surveys, the shore margins become further apart, creating a true sound.

Howe Sound is rimmed with residential and industrial development interspersed with unpopulated forested areas. Houses line much of the waterfront in West Vancouver, Gibsons, Langdale and Lions Bay, as well as on Bowen and Keats islands. The rest of the shoreline is uninhabited or sparsely inhabited, and comprised of First Nations, private and public lands. Christie Islet off the south end of Anvil Island is a federal Migratory Bird Sanctuary.

The outer Fraser River estuary study area includes the waters approximately 1.8 to 7.4 km from shore extending from the Point Grey bell buoy off Point Grey south along the inside (eastern edge) of the inbound shipping lane to the USA-Canada International border, west along the International border and north along the outside (western edge) of the outbound shipping lane, to Point Atkinson (Fig. 2).

Transect Routes and Field Protocol

The aim of our Howe Sound survey was to derive an estimate of the total number of birds present and to record their distribution in mostly narrow waterways, which required us to widen the transect. We surveyed southern Howe Sound approximately once each month from June 2014 to May 2015 except September 2014. One survey in September 2015 was added to provide a full complement of survey months. Counts of birds were made from either a 5.2 m long rigid hull boat or a 7 m long aluminum boat moving at 22 km/hr (12 knots) within a 750 m wide transect either side of the boat paralleling the shoreline.

Survey methods designed to estimate population size and distribution of seabirds in large open waters such as the outer Fraser River estuary use a sampling method based on a fixed transect width (Tasker *et al*. 1984). We surveyed a fixed transect route on the eastern and western

boundaries of the shipping lane (Fig. 2). The eastern boundary was closer to shore and near the drop off of the delta, while the western boundary was closer to the middle of the Strait of Georgia. We surveyed approximately once each month from November 2016 to October 2017. Like the Howe Sound survey, counts of birds were made from a 7 m long aluminum boat moving at 22 km/hr (12 knots). However, unlike Howe Sound where all birds seen were tallied, in the outer Fraser River estuary we tallied birds within a 200 m (100 m on either side) wide transect parallel to the shoreline to estimate abundance and generate maps. We also tallied the number of birds seen beyond 100 m of the boat; they were archived in the data set but not included in the mapping and abundance estimates we present here.

In southern Howe Sound and on the outer Fraser River estuary, two observers scanned for birds on either side of the boat. We limited our surveys to periods of calm or low wind and waves < 12–19 km/hr (Beaufort Scale ≤ 3). One observer called out waypoints approximately every 500 m while the other observer recorded the data. Binoculars were used to assist in counting and identifying distant birds. In most situations, birds were counted individually. Flocks of more than about 1000 individual birds were estimated by summing the number by groups of 10s or 100s of individuals. Previously, we compared our field estimates against the number counted from a photograph of the same flock and found our precision (± 15%) to be similar to other studies (Prater 1979). Rappolt *et al*. (1985) concluded that over and underestimates canceled each other out.

Kernel and Cluster Mapping Techniques

Kernel analysis is used to estimate population density and is also used to visualize distribution patterns. Kernel applications are widely used in wildlife research. Kernel analysis creates a smooth surface in which the estimated surface value is highest at the location of the known data points and diminishes with increasing distance from the point, reaching zero at the predefined search radius distance from this point (ArcGIS 9.3; ESRI 2009).

We applied a kernel estimator to determine the spatial distribution pattern of each species of interest using effort-corrected counts. A cell size of 50 m (resolution) and a search radius of 1,500 m were used to define the kernel settings. Next, we normalized each raster layer into groups using a “natural breaks” classification method. This method creates classes by identifying naturally occurring breaks in the distribution of data values. It attempts to reduce variance within groups and maximize the variance among groups. To allow comparison among species, we labeled highest values as primary area, the second highest values as secondary area, and the third highest as tertiary area. One further tier of (lowest) values was excluded from visual representation on the species maps to minimize distraction from areas of higher importance.

In order to determine the distribution of groups of interest (*e.g.* SARA-COSEWIC species), the respective species rasters needed to be combined. In order to make the rasters comparable, it was important to use a common measurement scale and weights that allow us to make calculations of standardized criteria among several kernel rasters. To do this, we assigned numerical weights to the categories described above. Primary areas, secondary areas, and tertiary areas were assigned weights of 10, 6 and 2 respectively. After scaling the kernel raster datasets, the selected species were overlapped and summed together. The resulting rasters were displayed using "equal interval" classification which divides a dataset into groups at regular intervals containing equal ranges of values. In this way, a clustering degree was identified where primary, secondary and tertiary areas represent the species abundance and spatial distribution (and the lowest tier of values was excluded as before).

The southern Howe Sound and outer Fraser River estuary maps show the results of applying kernel analysis within 1,500 m and 200 m, respectively, of the waypoints along the survey transect route only; the analysis does not extrapolate beyond 1,500 m (in the Sound) and 200 m (in the estuary) either side of the transect line. There are shortcomings of applying this technique to waypoints along a transect line, including not accounting for spatial autocorrelation.

We included observations of birds counted within about 1 km of the boat while transiting English Bay between First Narrows and the Point Grey bell buoy.

Scientific names of birds mentioned in the text and tables follow the American Ornithological Society’s the 60th supplement (American Ornithological Society 2019).

Results

Howe Sound

We recorded a total of 35,248 birds of 44 marine bird species in Howe Sound (Table 1). Nearly 60% of the birds were Surf Scoters, followed by Barrow’s Goldeneyes and Glaucous-winged Gulls (~15% each). Birds were most numerous in November (8653 birds, mostly sea ducks) and least numerous in June (368 birds). We tallied 13 regularly occurring species of conservation concern (Table 2). Marbled Murrelet and Great Blue Heron were the most abundant and most frequently-sighted federally-listed Species at Risk.

English Bay

We tallied 941 birds of 15 species in English Bay (Table 3). The Marbled Murrelet and Western Grebe are federally listed Species at Risk.

Table 1. Number of marine birds counted during 12 line-transect surveys (within 750 meters either side of survey vessel) in Howe Sound, British Columbia, 2014–2015. (September survey was completed in 2015 but shown here in 2014 to complete a year).

Species	2014							2015					Total
	Jun (129)	Jul (129)	Aug (129)	Sep (129)	Oct (129)	Nov (129)	Dec (129)	Jan (129)	Feb (129)	Mar (129)	Apr (129)	May (129)	
Canada Goose	69	19	0	0	0	3	0	8	3	42	10	3	**157**
Trumpeter Swan	0	0	0	0	0	0	0	0	0	38	0	0	**38**
Mallard	0	0	0	0	0	0	0	0	0	0	0	4	**4**
Northern Pintail	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Harlequin Duck	5	3	8	10	71	5	2	14	8	14	20	27	**187**
Surf Scoter	40	40	120	207	5340	6753	3060	31	348	528	3023	1532	**21022**
White-winged Scoter	0	0	0	0	3	2	0	0	0	3	0	0	**8**
Long-tailed Duck	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Bufflehead	0	0	0	0	0	6	3	7	7	2	2	0	**27**
Common Goldeneye	0	0	0	0	0	1	6	21	3	11	0	0	**42**
Barrow's Goldeneye	1	0	0	0	0	1320	812	1465	1359	469	10	0	**5436**
Hooded Merganser	0	0	0	0	0	0	4	0	0	0	0	0	**4**
Common Merganser	10	5	8	59	2	2	4	4	15	14	64	12	**199**
Red-throated Loon	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Common Loon	0	0	0	0	1	5	3	3	0	0	1	1	**14**
Horned Grebe	0	0	0	0	1	0	2	2	7	4	0	0	**16**
Red-necked Grebe	0	0	0	0	0	0	1	0	0	0	0	1	**2**
Western Grebe	0	0	0	0	1	0	0	0	0	0	25	0	**26**
Brandt's Cormorant	0	0	0	0	1	1	0	3	2	1	0	0	**8**
Double-crested Cormorant	0	1	4	45	132	15	16	36	62	76	6	0	**393**
Pelagic Cormorant	25	20	68	37	69	28	12	28	19	28	57	35	**426**
Great Blue Heron	1	2	7	1	0	3	2	0	0	0	0	3	**19**
Turkey Vulture	1	2	1	0	0	0	0	0	0	0	0	0	**4**
Osprey	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Golden Eagle	0	0	0	0	0	0	0	0	0	1	0	0	**1**
Bald Eagle	11	4	9	0	4	4	209	12	36	20	7	7	**323**
Red-tailed Hawk	0	0	0	0	1	0	1	0	0	0	0	1	**3**
Peregrine Falcon	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Black Oystercatcher	9	10	7	29	59	2	1	23	3	9	16	6	**174**
Spotted Sandpiper	0	0	2	0	0	0	0	0	0	0	0	0	**2**
Least Sandpiper	0	0	1	0	0	0	0	0	0	0	0	0	**1**
Black Turnstone	0	3	19	23	0	21	0	21	13	2	7	0	**109**
Surfbird	0	0	0	0	0	320	70	23	6	0	0	0	**419**
Mew Gull	0	0	3	18	30	9	20	41	160	9	27	0	**317**

►

◀ Table 1

Species	2014							2015					Total
	Jun (129)	Jul (129)	Aug (129)	Sep (129)	Oct (129)	Nov (129)	Dec (129)	Jan (129)	Feb (129)	Mar (129)	Apr (129)	May (129)	
California Gull	0	4	10	5	1	6	0	0	0	0	0	0	**26**
Iceland Gull (Thayer's)	0	0	1	0	2	0	1	1	0	0	0	0	**5**
Glaucous-winged Gull	177	386	490	459	1318	115	133	80	126	416	1010	568	**5278**
Unidentified Gull	0	0	0	0	0	0	0	0	0	12	0	0	**12**
Common Murre	0	0	0	0	0	0	3	1	0	0	0	0	**4**
Pigeon Guillemot	15	22	34	0	1	0	0	0	19	4	4	53	**152**
Marbled Murrelet	4	0	4	2	2	29	248	30	16	12	5	2	**354**
Rhinoceros Auklet	0	0	0	1	0	2	0	0	0	0	0	0	**3**
Belted Kingfisher	0	1	0	4	0	0	0	0	0	0	0	0	**5**
Common Raven	0	0	0	0	0	0	0	0	0	2	0	0	**2**
Total	**368**	**522**	**796**	**923**	**7039**	**8653**	**4613**	**1854**	**2212**	**1717**	**4294**	**2257**	**35248**

Table 2. Regularly-occurring marine bird species of conservation priority in Howe Sound and Fraser River estuary.

Common Name	COSEWIC[1]	BC CDC[2]	SARA[3]	Location[4]
Brant	N	Blue	N	F
Surf Scoter	N	Blue	N	H, F
Horned Grebe	SC	Yellow	N	H
Western Grebe	SC	Red	SC	H, F
Double-crested Cormorant	N	Blue	N	H, F
Brandt's Cormorant	N	Red	N	H, F
Pelagic Cormorant	N	Red	N	H, F
Great Blue Heron – *fannini* subspecies	SC	Blue	SC	H
Long - tailed Duck	N	Blue	N	H
Surf Scoter	N	Blue	N	H
Peregrine Falcon – *pealei* subspecies	SC	Blue	SC	H
California Gull	N	Blue		H, F
Caspian Tern	N	Blue	N	F
Parasitic Jaeger	N	Red	N	F
Common Murre	N	Red	N	H, F
Ancient Murrelet	T	Blue	T	F
Marbled Murrelet	T	Blue	T	H, F

[1] Committee on Species of Endangered Wildlife in Canada listing (www.cosewic.gc.ca): E =Endangered; T = Threatened; SC = Special Concern; N = not assessed

[2] BC Conservation Data Centre (2015) listing (www.env.gov.bc.ca/cdc/): Red is the provincial equivalent of the federal Endangered and Threatened categories; Blue is equivalent to Special Concern; Yellow indicates not at risk.

[3] Species at Risk Act assessment (http://www.registrelep - sararegistry.gc.ca/species/schedules_e.cfm?id=1)

[4] F=Fraser River Estuary, H=Howe Sound

Table 3. Number of birds seen each month in English Bay between First Narrows and Point Grey bell buoy. Dates correspond with transect survey dates.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Surf Scoter	0	0	0	0	0	0	0	5	0	2	4	0	**11**
White-winged Scoter	0	0	0	0	0	105	0	0	0	0	12	0	**117**
Red-throated Loon	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Brandt's Cormorant	2	6	0	0	0	0	0	0	0	13	17	1	**39**
Double-crested Cormorant	1	0	3	0	0	35	1	0	0	0	2	12	**54**
Pelagic Cormorant	1	2	4	0	3	2	0	1	0	1	0	0	**14**
Western Grebe	0	0	0	0	0	0	0	0	0	0	7	0	**7**
Bonaparte's Gull	12	40	0	3	0	0	0	0	0	334	107	0	**496**
Mew Gull	11	54	23	0	0	0	0	0	0	3	0	0	**91**
California Gull	0	0	0	0	0	0	1	2	0	8	0	0	**11**
Glaucous-winged Gull	4	0	2	0	3	9	7	3	27	3	2	11	**71**
Caspian Tern	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Parasitic Jaeger	0	0	0	0	0	0	0	0	0	0	4	0	**4**
Common Murre	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Marbled Murrelet	0	0	2	0	0	0	0	0	0	3	3	2	**10**
Total	**31**	**102**	**34**	**5**	**6**	**151**	**9**	**11**	**27**	**367**	**171**	**27**	**941**

Fraser River estuary

We recorded a total of 3260 birds of 29 species in the outer Fraser River estuary (Table 4). The most abundant species were Mew Gull, Common Murre, Glaucous-winged Gull, Bonaparte's Gull, California Gull and Marbled Murrelet. We saw 237 Marbled Murrelets in January, a species designated as Threatened under Species at Risk legislation. Species designated as Special Concern were the Western Grebe and Ancient Murrelet. B.C. Red-listed species were Western Grebe, Pelagic Cormorant, Brandt's Cormorant, Parasitic Jaeger, and Common Murre, and B.C. Blue-listed species were Brant, Long-tailed Duck, Surf Scoter, Double-crested Cormorant, Caspian Tern, Marbled Murrelet, and Ancient Murrelet (Table 2).

Our study area was 1.8–7.4 km beyond the lowest tide on the Fraser River Delta and therefore 5.4 km wide. Our survey transect was 200 m wide. Therefore, the area within the 5200 m (5400 m–200 m) was not surveyed. The unsurveyed area was 26 times greater than the surveyed area (5200m/200m). By assuming the same density of birds in unsurveyed and surveyed areas, there could have been 32,136 birds (1236 birds x 26) present in the Fraser River estuary in January when birds were most numerous and 1950 birds in June when birds were least numerous. The most numerous species were Marbled Murrelet, Common Murre and Mew Gull. June was also the quietest month in Howe Sound but the greatest number of birds occurred in November when 8,653 birds were present during the arrival of fall migrant Surf Scoters and Barrow's Goldeneye (Table 4).

Historical Comparisons in abundance and distribution

Benson (1961), in his description of birds from Howe Sound to White Rock, stated that Howe Sound was not important for ducks and geese. Presumably he missed the large flocks of sea ducks which use the Sound. He mentioned that Marbled Murrelets were present in small numbers and especially numerous in August and September. In contrast, our survey showed that murrelets were most numerous in winter and very small numbers were present at other times (Table 1).

Vermeer (1981) counted 5,342 Surf Scoters and 2,934 Barrow's Goldeneyes during a boat-based survey of Howe Sound in November 1977. An average of 6,173 gulls, 3,453 Surf Scoters and 1,030 Barrow's Goldeneyes were tallied during 27 surveys in southern Howe Sound in 1998-2000 (Appendix 2 in LaCroix 2001). Vermeer (1981) and LaCroix (2001) used different methods and slightly different routes from our survey but all three studies support the conclusion that Howe Sound is annually used by large numbers of sea ducks.

A few species showing increasing trends in the region include Canada Goose, Trumpeter Swan, Bald Eagle, and Pigeon Guillemot (Crewe *et al*. 2012). Trumpeter Swan likely increased following a ban on hunting and provision of foraging habitat in local agricultural areas. The widespread resident Canada Geese are offspring from flocks intentionally introduced to the Salish Sea about 40 years ago that have taken to local fields and estuaries (Dawe and Stewart 2010). Bald Eagles are recovering regionally fol-

Table 4. Number of marine birds counted during 12–200 m wide line transect surveys (i.e. within 100 meters either side of survey vessel) in the outer Fraser River estuary, British Columbia, 2016–2017. Numbers in parentheses indicate total number of waypoints surveyed.

Species	Jan (174)	Feb (121)	Mar (174)	Apr (174)	May (174)	Jun (174)	Jul (115)	Aug (174)	Sep (174)	Oct (174)	Nov (174)	Dec (174)	Total
Brant	7	0	0	0	0	0	0	0	0	0	0	0	**7**
Canada Goose	0	0	0	0	0	0	1	0	0	0	0	0	**1**
Northern Pintail	0	0	0	0	0	0	0	5	0	0	0	0	**5**
Surf Scoter	1	0	0	28	0	0	0	0	8	1	0	0	**38**
White-winged Scoter	0	0	0	0	0	0	0	0	0	1	0	0	**1**
Red-breasted Merganser	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Ducks	0	0	0	0	0	0	0	2	0	0	0	0	**2**
Fork-tailed Storm-petrel	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Red-throated Loon	1	2	3	15	0	0	0	0	0	0	1	5	**27**
Pacific Loon	4	0	0	2	0	0	0	0	0	0	0	0	**6**
Western Grebe	37	0	0	26	0	0	0	0	0	75	0	14	**152**
Brandt's Cormorant	42	2	20	5	0	0	0	0	5	0	10	17	**101**
Double-crested Cormorant	2	3	0	0	0	2	0	0	0	0	0	4	**11**
Pelagic Cormorant	0	0	0	0	1	0	0	0	0	1	0	0	**2**
Cormorant sp.	3	0	0	0	0	0	0	0	0	0	0	0	**3**
Bald Eagle	0	2	0	1	0	0	0	0	0	0	0	0	**3**
Dunlin	0	0	0	0	0	0	0	0	0	24	0	0	**24**
Bonaparte's Gull	1	0	0	39	0	0	0	0	161	93	22	0	**316**
Mew Gull	247	76	167	38	4	0	0	0	3	46	9	141	**731**
California Gull	0	0	0	5	47	50	26	45	17	24	25	0	**239**
Herring Gull	0	0	33	0	0	0	0	0	0	0	0	0	**33**
Iceland Gull	17	0	0	0	0	0	0	0	0	0	0	1	**18**
Glaucous-winged Gull	136	33	24	11	45	10	9	65	85	24	32	28	**502**
Gulls	103	0	0	1	0	0	76	0	0	0	0	0	**180**
Caspian Tern	0	0	0	0	0	5	1	1	0	0	0	0	**7**
Pomarine Jaeger	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Parasitic Jaeger	0	0	0	1	0	0	0	0	1	0	0	0	**2**
Common Murre	303	4	1	2	0	0	0	0	0	3	15	264	**592**
Pigeon Guillemot	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Marbled Murrelet	237	2	0	0	0	0	0	0	0	0	0	3	**242**
Ancient Murrelet	0	0	0	0	0	0	0	0	0	0	0	2	**2**
Rhinoceros Auklet	0	0	0	0	1	0	0	0	0	0	1	5	**7**
Alcid	2	0	0	0	0	0	0	0	0	0	0	0	**2**
Total	**1144**	**124**	**248**	**175**	**99**	**67**	**113**	**118**	**281**	**292**	**115**	**484**	**3260**

lowing a ban on industrial contaminants and persecution (Bednarz *et al*. 1990). It is not known why Pigeon Guillemots are increasing. A strong upward trend and large flocks have been seen in surveys in the southern Gulf Islands (Crewe *et al*. 2012, Davidson *et al*. 2010).

Referring to English Bay, Fannin (1891) noted "great numbers of ducks in Howe Sound and Burrard Inlet" although he did not identify them to species. Benson (1961) wrote that scoters were plentiful off Point Grey and Greater Scaups assembled near sewage outfalls. Birds were scant along much of West Vancouver although small numbers of Marbled Murrelets were commonly seen. However, the greatest number of birds was flocks up to 3000 Western Grebes off Point Grey.

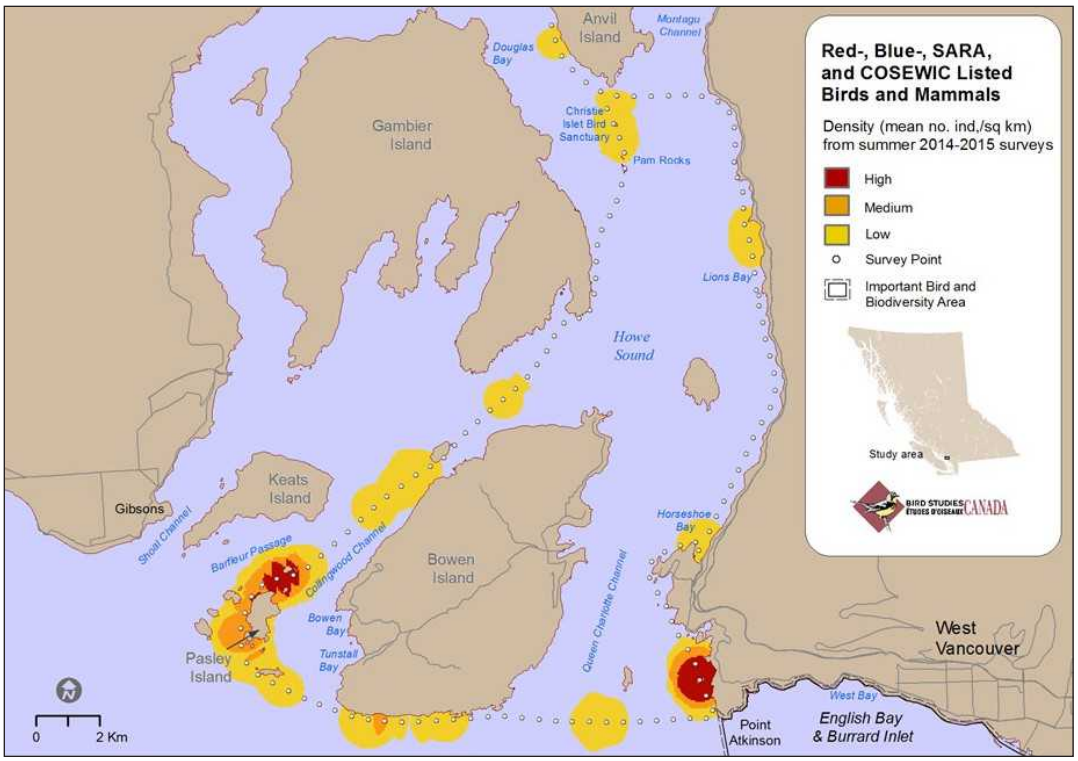

Figure 3. Primary, secondary and tertiary areas for all federal and provincial marine bird and mammal Species at Risk along the transect route in Howe Sound, based on spatial clustering analysis of all survey records of SARA-COSEWIC and B.C. Ministry of Environment Red- and Blue-listed marine bird and mammal species.

Species of conservation concern

Thirteen species listed either by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), the Federal Species at Risk Act (SARA) or Provincially (Red- or Blue-listed) were observed in Howe Sound (Fig. 3). The causes of decline are not always known and warrant specific studies to develop appropriate targeted conservation actions. Among the 13 listed species, the Marbled Murrelet was most numerous and most frequently sighted on our surveys despite declines in adjacent Burrard Inlet (Butler *et al*. 2015). Terrestrial critical habitat for the species has been identified in the Burrard Inlet watershed (Environment Canada 2014). Great Blue Heron was frequently sighted, often as single or a few birds. The heron is designated as Species of Special Concern and identified in the Important Bird and Biodiversity Area designation for adjacent Burrard Inlet. Up to 14 herons have nested on Bowen Island in Snug Cove, Galbraith Bay and Tunstall Bay since at least (by) 1998 (Gowans 2016). Surf Scoters were the most abundant and frequently sighted provincially blue-listed marine bird. The region is an important wintering and staging area for that species. Potential threats to the listed species in Howe Sound include oil spills, loss of forage fish populations, human disturbance at nesting, roosting and foraging areas, predation by raptors, underwater noise and shipping disturbance.

In the Fraser River estuary, 14 species were listed either by COSEWIC, the Federal Species at Risk Act or Provincially (Red- or Blue-listed) including Surf Scoter, Brant, Pelagic, Double-crested and Brandt's Cormorants, Parasitic Jaeger, California Gull, Common Murre, Caspian Tern, Ancient Murrelet, Marbled Murrelet and Western Grebe (Table 2). The distributions of the listed birds are shown in Figure 4. While all listed species are assumed to have declining populations, the causes are diverse and not well known and warrant specific studies to develop appropriate targeted conservation actions.

Discussion

Precision of Estimates

We assumed a high ability to detect and count most birds present on the water during our surveys. We also assumed that a single survey each month would represent the abundance of waterbirds. This latter assumption is likely valid for the majority of species that remain for the winter but less so for passage migrants like the Bonaparte's Gull and California Gull that move through in a short period of time. Our assumption that a monthly snapshot would represent the distribution of birds likely under represented the overall distribution and abundance.

There were several species of birds likely present but not seen by us in both study areas. For example, in southern Howe Sound between 16 and 300 Pacific Loons were present in Collingwood Channel in May 2016 (Patricia Beaty), and Eared Grebe and Western Gull were present in

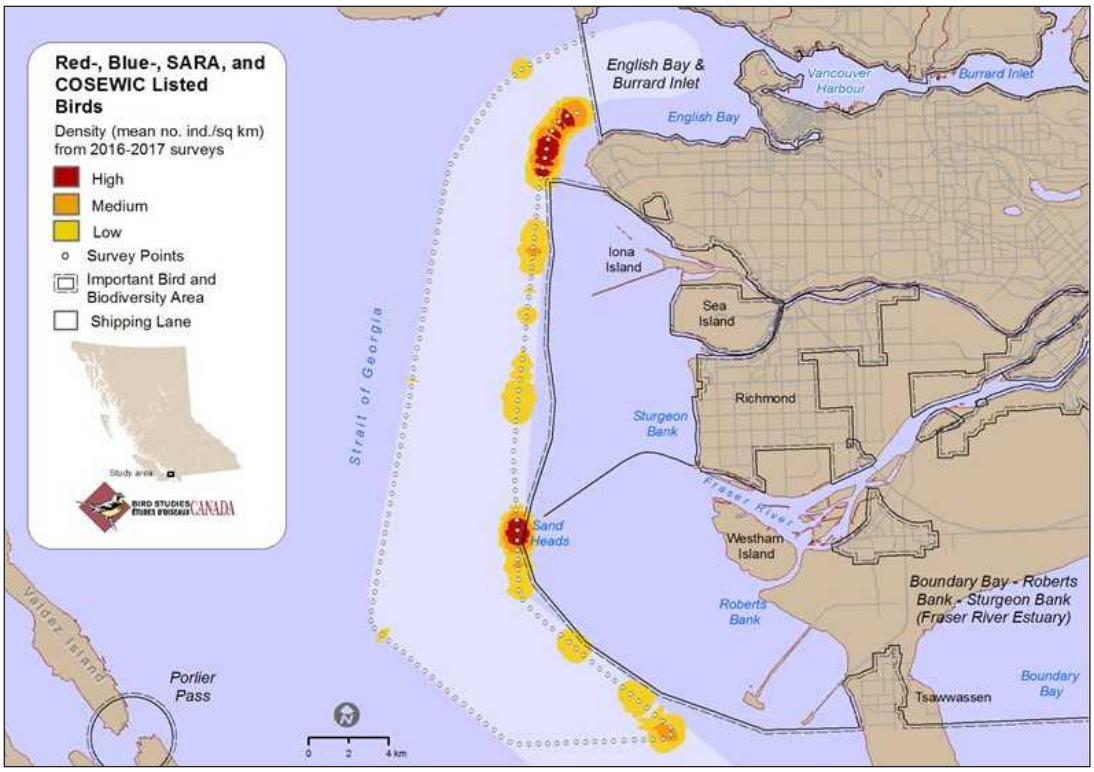

Figure. 4. Primary, secondary and tertiary areas for all federal and provincial marine bird Species at Risk along the transect route in the outer Fraser River estuary, based on spatial clustering analysis of all survey records of SARA-COSEWIC and B.C. Ministry of Environment Red- and Blue-listed marine bird species.

Bowen Bay (eBird <https://ebird.org/>). Rock Sandpipers were not seen on our surveys despite them being present on 7 December 2014 on the Grebe Islets (Pers. comm., M. Klotz and R. Lyske). eBird records show that one or a few birds use Point Atkinson, Whytecliffe Park and nearby locations. Similarly, we saw no Wandering Tattlers although one was present on Pam Rocks on 18 August 2015 (Pers. comm., L. Crowe-Hutchinson). A Snow Goose was photographed on the beach in Horseshoe Bay on 21 October 2014 was an unusual sighting (Pers. comm., E. Sewell). Sea Safari guide Julian Heavyside at Sewell's Marina reported Surfbird and Western Sandpiper on Pam Rocks on 26 July 2016. On 3 August, he saw an Ancient Murrelet off Lions Bay and a Wandering Tattler on Pam Rocks. All but the Ancient Murrelet record are expected to occur in the Sound. The murrelet seen off Lions Bay was unusual and questionable in that it was seen deep in the Sound, in summer and 500 m from the observer. The many eBird records of Ancient Murrelets in Howe Sound cluster at its entrance and fall mostly in winter.

The outer Fraser River estuary has few access points and hence few bird observations. The Duke Point-Nanaimo ferry route penetrates the southern end of the study area. The tips of jetties at Iona Island, Steveston and Roberts Bank are the closest land-based viewpoints but are still far from the eastern edge of the study area. A few species reported in eBird during the study from these vantage points and missed by us were a single Sabine's Gull on 17 September 2016 and 10 Common Terns seen 6 May 2017 seen from the ferry, and one Brown Pelican off Steveston on 28 October 2017.

This compilation of rare and threatened species allows identification of priority areas for the ongoing maintenance of species in southern Howe Sound and the outer Fraser River estuary, especially those areas used by the Marbled Murrelet. The large numbers of murrelets in Howe Sound and the outer Fraser River estuary during winter was a pleasant surprise and indicative of important non-breeding habitat for this species. The mobile nature of the thousands of scoters and goldeneyes using southern Howe Sound make these flocks vulnerable to encountering oil spills with subsequent long-term consequences for the viability of their populations (Day *et al*.1997, Peterson *et al.* 2003). Both areas deserve to be recognized for their contribution to regional conservation.

Restoring and sustaining habitats while minimizing pollution and disturbance are key actions. Important food sources for many species of birds in southern Howe Sound and the outer Fraser River estuary are small schooling and inshore fish and marine invertebrates. Maintenance of eelgrass beds, estuaries, salt marshes, mudflats, and salmon-bearing streams is an important component for all species of birds. Sometimes flocks of large numbers of birds assemble to forage in a location where an oil spill could result in large scale damage to the total population of these birds. For example, flocks of 2,000–3,000 Surf Scoters seen off Cowans Point, Bowen Island, in April 2015 was not an unusual event in southern Howe Sound between

November and April. Similarly, a herring spawn event on 25 March 2017 on Point Roberts attracted several thousand birds. Ilya Povalyaev reported to eBird that 2000 Brant, 1100 Greater Scaup, 1600 Surf Scoters, 50 White-winged Scoters, 27 Black Scoters, 125 Double-crested Cormorants, 200 Sanderlings, 400 Mew Gulls, 30 California Gulls, 30 Western x Glaucous-winged Gull hybrids and 50 Glaucous-winged Gulls were present.

Christie Islet Migratory Bird Sanctuary is a 1.23 hectare uninhabited and treeless islet south of Anvil Island. It is the only site in southern Howe Sound that supports substantial numbers of nesting seabirds. Seabirds have nested in the Sanctuary for decades. The earliest records are Glaucous-winged Gull (about 1914), Double-crested Cormorant (1941), Pigeon Guillemot (1943), and Pelagic Cormorant (1946) (Drent and Guiguet 1961). Chatwin and Burger (2013) recommend a setback of 50 m when viewing nesting seabirds in the Salish Sea to minimize disturbance. They also point out that nesting birds habituate to boats near their nests so that closer viewing is possible that does not disturb the birds. The key responsibility is for boaters to avoid approaching too close to raise alarm among the birds.

Southern Howe Sound has a few small islands with no formal legislated protection that support nesting, migrating or wintering birds. Whereas Christie Islet Migratory Bird Sanctuary supports the largest number of nesting gulls and cormorants in the Sound, nearby Pam Rocks, with no formal protection, supports shorebirds, sea ducks and seals.

The Grebe Islets near the entrance to Howe Sound are a cluster of two large islets and outlying rocks with no formal protection. The islets are used by four north Pacific shorebirds—Black Oystercatcher, Black Turnstone, Surfbird and Rock Sandpiper—and by Harlequin Ducks and cormorants. Oystercatchers have nested there for at least two centuries (Newcombe 1923).

Habitat Recommendations

Our study has established a baseline against which change, including recovery, can be measured. We also identified species of conservation priority that will require specific management actions. At a broader level, the maintenance of the most abundant species will require sustaining their habitats. Specifically, mussel beds and barnacle encrusted shores that support the suite of rocky shores specialists in southern Howe Sound need to be mapped, and spawning locations for forage fish such as herring (*Clupea harengus*), sandlance (*Ammodytes hexapeterus*), surf smelt (*Hypomesus pretiosus*) and northern anchovy (*Engraulis mordax*) need to be located and protected in both study areas. Opportunities to consider are the enhancement of habitats for forage fish such as marshes, seagrass meadows, removal or wrapping of creosote pilings, restoration of riparian edges, and enhancement of hard surfaces for mussels and barnacle attachment. A better understanding of the ecological functions that support the diversity and abundance of birds of the Fraser River estuary would greatly assist us in sustaining them.

Once the distributions of birds, mussels, barnacles and forage fish are known, subsequent monitoring of the contaminant loads in the trophic level would provide information which could guide policy of ecosystem management. The proximity of industry and urban development as sources of contaminants is real to mussels, barnacles and the birds that eat them in Howe Sound.

Conservation Priority Species

In the outer Fraser River estuary, the majority of federal and provincial species of conservation concern are clustered along the drop off of the Fraser River estuary and near the eastern edge of the incoming shipping lane. Whether the presence of ships impacts any of these species was outside the purview of this study. Nevertheless, our snapshot surveys suggest that the outer Fraser River estuary is an important extension of the Fraser River Delta that should be incorporated into the Boundary Bay-Roberts Bank-Sturgeon Bank (Fraser River estuary BC017) Important Bird and Biodiversity Area. Moreover, we recommend that more work be done on interactions between rare species and ships with a goal of ensuring the safety, persistence and recovery of these species. These interactions might include direct disruption of feeding flocks of birds by the presence of vessels, or indirect effects of the vessels on the distribution of the fish prey of birds. Also, continued care to prevent discharge and to expedite cleanup of deleterious substances from ocean-going vessels, commercial shipping vessels, fishing vessels, ferries and recreational boaters in the estuary should be a priority.

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Literature Cited

Anderson, E.M., J.L. Bower, D.R. Nysewander, J.R. Evenson and J.R. Lovvorn. 2009. Changes in avifaunal abundance in a heavily used wintering and migration site in Puget Sound, Washington, during 1966 - 2007. *Marine Ornithology* 37:19–27.

American Ornithological Society. 2019. *AOS Checklist of North and Middle American Birds*. <http://checklist.aou.org/taxa/> .

Badzinski, S.S, R. J. Cannings, T. E. Armenta, J. Komaromi and P. J.A. Davidson. 2008. Monitoring coastal bird populations in BC: the first five years of the Coastal Waterbird Survey (1999–2004). *British Columbia Birds* 17:1–35.

B.C. Conservation Data Centre. 2015. *BC Species and Ecosystems Explorer*. B.C. Ministry of Environment, Victoria, B.C. < http://a100.gov.bc.ca/pub/eswp/ > .

Bednarz, J.C., D. Klem, Jr., L. J. Goodrich and S. E. Senner. 1990. Migration counts of raptors at Hawk Mountain, Pennsylvania, as indicators of population trends, 1934-1986. *The Auk* 107: 96–109.

Benson, W.A. 1961. *An inventory of recreation of the Pacific Coast with special emphasis on waterfowl.* Unpublished report, Canadian Wildlife Service, Delta, B.C. 49 p.

Bower, J. L. 2009. Changes in marine bird abundance in the Salish Sea: 1975–2007. *Marine Ornithology* 37: 9–17.

Breault, A. and P. Watts. 1996. *Bird survey project: seasonal and spatial trends in distribution and abundance of waterbirds in Burrard Inlet, November 1996*. Burrard Inlet Environmental Action Program, North Vancouver, B.C. 156 p.

Butler, R.W. 1994. Distribution and abundance of Western Sandpipers, Dunlins, and Black-bellied Plovers in the Fraser River estuary. P. 18-23 *In* Butler, R.W. and K. Vermeer (eds). *The abundance and distribution of estuarine birds in the Strait of Georgia, British Columbia*. Canadian Wildlife Service Occasional Paper Number 83, Ottawa, Ont.

Butler, R.W. and R.W. Campbell. 1987. *The birds of the Fraser River Delta: populations, ecology and international significance.* Canadian Wildlife Service Occasional Paper No. 65, Ottawa, Ont.

Butler, R.W. and R. J. Cannings. 1989. *Distribution of birds in the intertidal portion of the Fraser River Delta*. Canadian Wildlife Service Technical Report No. 93, Delta, B.C. 58 p.

Butler, R.W., A.C. Couturier and E. Dickson. 2015. *Status and distribution of birds and mammals in Burrard Inlet and Indian Arm, British Columbia 2011-2013*. Pacific Wildlife Foundation & Bird Studies Canada. Technical Report. <http://www.pwlf.org/mbbi.pdf>.

Butler, R.W., R. MacVicar, P. Beaty, A. Couturier, S. Richmond, E. Dickson, H.A Middleton and P. Beaty. 2018. *Status and distribution of birds and mammals in southern Howe Sound, British Columbia 2014-2015*. Pacific Wildlife Foundation & Bird Studies Canada, Technical Report. <http://www.pwlf.org/howesoundreport.pdf>.

Campbell, R.W., M. G. Shepard and R. H. Drent. 1972. Status of birds in the Vancouver area in 1970. *Syesis* 5: 138–167.

Chatwin, T. and A E. Burger. 2013. Set-back distances to protect nesting and roosting seabirds off Vancouver Island from boat disturbance. *Waterbirds* 36:43–52.

Crewe, T., K. Barry, P. Davidson and D. Lepage. 2012. Coastal waterbird population trends in the Strait of Georgia 1999 – 2011: Results from the first 12 years of the British Columbia Coastal Waterbird Survey. *British Columbia Birds* 22:8–35.

Davidson, P., R.W. Butler, A. Couturier, S. Marquez and D. Lepage. 2010. *Status and distribution of birds and mammals in the southern Gulf Islands, British Columbia*. Bird Studies Canada & Pacific Wildlife Foundation unpublished report to Parks Canada. <http://www.pwlf.org/Davidson2010SGI.pdf>.

Dawe, N.K. and A.C. Stewart. 2010. The Canada Goose (*Branta canadensis*) on Vancouver Island, British Columbia. *British Columbia Birds* 20:24–40.

Day, R.H., S.M. Murphy, J.A. Wiens, G.D. Hayward, E.J. Harner and L.N. Smith 1997. Effects of the Exxon Valdez oil spill on habitat use by birds in Prince William Sound, Alaska. *Ecological Applications* 7:593–613.<http://dx.doi.org10.1890/10510761(1997)007[0593:EOTEVO]2.0.CO;2>.

Drent, R.H. and C.J. Guiguet. 1961. *A catalogue of British Columbia sea-bird colonies*. British Columbia Provincial Museum Occasional Paper No. 12, Victoria, B.C.

Drever, M. C., M. J. F Lemon, R. W. Butler and R. L. Millikin. 2014. Monitoring populations of Western Sandpipers and pacific Dunlins during northward migration on the Fraser River Delta, British Columbia, 1991–2013. *Journal of Field Ornithology* 85: 10-22.

Environment Canada. 2014. *Recovery strategy for the Marbled Murrelet (Brachyramphus marmoratus) in Canada.* Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa, Ont. 49 pp.

ESRI. 2009. ArcGIS 9.3: *How Kernel density works*. <http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=How%20Kernel%20Density %20works>.

Evans Ogden, L. J., S. Bittman, D.B. Lank and F. C. Stevenson. 2008. Factors influencing farmland habitat use by shorebirds wintering in the Fraser River Delta, Canada. *Agriculture, Ecosystems and Environment* 124: 252–258.

Fannin, J. 1891. *Check list of British Columbia birds*. Richard Woolfenden, Queen's Printer. Victoria, B.C.

Gaydos, J. and N. A. Brown. 2011. *Species of concern within the Georgia Basin Puget Sound Marine Ecosystem: changes from 2002 to 2011*. p.1-12 *In* Proceedings of the 2011 Georgia Basin Puget Sound Research Conference, Vancouver, B.C. <http://www.seadocsociety.org/files/pdfs/Salish%20Sea%20Species%20of%20Concern%202011%20Final.pdf>.

Gowans, B. 2016. *Pacific Great Blue Heron (Ardea herodias fannini) nesting activities (1998-2015) Bowen Island, BC.* Bowen Nature Club & Bowen Island

Conservancy. <http://www.sccp.ca/sites/default/files/species-habitat/documents/Bowen%20Island%20GB%20Heron%20Nesting%20Activity%20%281998-2015%29%20Jul2016–4.pdf>.

Hobson, K. and J. Driver. 1989. Archaeological evidence for use of the Strait of Georgia by marine birds. p. 168-173 *in* K. Vermeer and R.W. Butler (eds). *The ecology and status of marine and shoreline birds in the Strait of Georgia, British Columbia*. Canadian Wildlife Service Special Publication, Ottawa, Ont.

Jimenez, A., R.W. Elner, C. Favaro, K. Rickards and R.C. Ydenberg. 2014. Intertidal biofilm distribution underpins differential tide-following behavior of two sandpiper species (*Calidris mauri* and *Calidris alpina*) during northward migration. *Estuarine, Coastal and Shelf Science* 155:8–16.

Lacroix, D. 2001. *Foraging impacts and patterns of wintering Surf Scoters feeding on bay mussels in coastal Strait of Georgia, B.C*. M.Sc. thesis, Simon Fraser University, Burnaby, B.C. 126 pp.

Levings, C.D., R.B. Turner and B. Ricketts (eds). 1979. *Proceedings of Howe Sound science workshop*. Canadian Technical Report, Fisheries and Aquatic Science, West Vancouver, B.C.

Mulder, R. 2013. Howe Sound; rebirth or regress? *Discovery* 42: 30–33.

Newcombe, C. F. 1923. *Menzies' journal of Vancouver's voyage, April to October 1792*. W. Cullin, Victoria, B.C.

Peterson, C.H., S.D. Rice, J.W. Short, D. Esler, J. L.Bodkin, B. E. Ballachey and D. B. Irons. 2003. Long-term ecosystem response to the Exxon Valdez Oil Spill. *Science* 302: 2082–2086.

Pomeroy, A.C., 2006. Tradeoffs between food abundance and predation danger in spatial usage of a stopover site by Western Sandpipers, *Calidris mauri*. *Oikos* 112: 629–637.

Prater, A.J. 1979. Trends in accuracy of counting birds. *Bird Study* 26: 198 – 200.

Rappoldt, C., Kersten, M. and Smit, C. 1985. Errors in large-scale shorebird counts. *Ardea* 73:13–24.

Reimer, R. 2012. *The mountains and rocks are forever: lithics and landscapes of Skwxwú7mesh Uxwumixw*. Ph.D. thesis, McMaster University, Hamilton, Ont.

Robertson, I. 1977. Low seabird densities in the pelagic waters of the strait of Georgia, British Columbia. *Pacific Science* 31:279–283.

Shepherd, P. and D.B. Lank. 2004. Marine and agricultural habitat preferences of Dunlin wintering in British Columbia. *Journal of Wildlife Management* 68: 61–73.

Tasker, M. L., P. Jones, T. Dixon and B.F. Blake. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. *The Auk* 101:567–577.

Vancouver, G. 1798. *A voyage of discovery to the North Pacific Ocean, and round the world.* G.G. & J. Robinson, and J. Edwards, London.

Vermeer, K. 1981. Food and populations of Surf Scoter in British Columbia. *Wildfowl* 32:107–116.

Vermeer, K. and C.D. Levings. 1977. Populations, biomass and food habits of ducks on the Fraser Delta intertidal area, British Columbia. *Wildfowl* 28: 49–60.

Vilchis, L. I., C. K. Johnson, J. R. Evenson, S. F. Pearson, K. L. Barry, P. Davidson, M.G. Raphael and J. K. Gaydos. 2015. Assessing ecological correlate s of marine bird declines to inform marine conservation. *Conservation Biology* 29:154–163.

Ydenberg, R.C., R.W. Butler and D. B. Lank. 2004. Western Sandpipers have altered migration tactics as Peregrine Falcon populations have recovered. *Proceedings of the Royal Society (B)* 271:1263–1269.