MARINE BIRD SURVEYS IN QUEEN CHARLOTTE STRAIT AND ADJACENT CHANNELS, AUGUST-SEPTEMBER 2020

December 2020

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INTRODUCTION

Queen Charlotte Strait, a funnel-shaped passage extending ESE from the open waters of Queen Charlotte Sound, separates northern Vancouver Island from the mainland of British Columbia. It is connected, via Johnstone Strait, Discovery Passage and associated channels, with the more or less enclosed waters of the Salish Sea (Figure 1). Anecdotal information from eBird lists suggests that this area supports a high diversity of marine birds in winter and during the periods of northward and southward migration (https://ebird.org/canada/ accessed 7 November 2020; hereafter "eBird"). In addition, this area is important for marine mammals, being used regularly by the Northern Resident Orca stock, and by Humpback and Minke Whales, Dall's and Harbour Porpoises and Pacific White-sided Dolphins, and supporting several permanent haul-outs of Steller's Sea Lions (Ford 2014).

Figure 1. Northern Vancouver Island and adjacent mainland showing straits and inlets referred to in the text

The waters of Queen Charlotte Strait (QC Strait) are mainly <200m deep, with no major canyons. The west end of the strait is dotted with numerous islands, some of which support major colonies of seabirds, especially Pine Island (90,000 breeding pairs of Rhinoceros Auklets *Cerorhinca monocerata*), Tree Islets (>50,000 breeding pairs of Storm-Petrels) and Storm Islands (about a quarter million pairs of Storm-Petrels and 72,000 pairs of Rhinoceros Auklets). However, no breeding Rhinoceros Auklets or Storm-Petrels are known to breed east of Numas Island, midway down the Strait (Rodway and Lemon 1991). At the eastern end of the strait there are several large islands densely inhabited by people (Figure 2), as well as an anastomosing system of sounds and inlets embracing the largely uninhabited Broughton Archipelago. The narrow channel of Johnstone Strait leads eastwards from the southeastern corner of Queen Charlotte Strait and is considerably deeper, reaching >400 m. It connects to QC Strait via Blackfish Sound to the north and east of Hanson Island, and via Weynton Passage to the west of that island. It also extends westwards via Cormorant Channel, a shallow strait to the south of Malcolm Island. The bathymetry of Weynton Passage, in particular, is very variable with numerous reefs and sills, creating strong currents and extreme turbulence at certain states of tide. This is true, to a lesser extent, of all the eastern end of Queen Charlotte Strait.

Several surveys of marine bird abundance in BC waters have been published previously, some dealing with small areas over limited time periods (e.g. Guzman and Myres 1983, Hay 1992, Burger et al. 2002, 2008) and some with most, or all of the Canadian Exclusive Economic Zone in the Pacific (e.g. Morgan et al. 1991, Kenyon et al. 2009, Fox et al. 2017). To date, no systematic surveys of marine birds in Queen Charlotte Strait have been published. The surveys of Morgan et al. (1991) did not cover the area, while Kenyon et al. (2009) covered the area only in 'spring' (15 March – 15 June). Fox et al. (2017) included transect counts within Queen Charlotte Strait in spring (April-June) and fall (October and November), but coverage was sparse. We present here the results of more intensive surveys carried out over four 5-day periods between 16 August and 1 October 2020. Our surveys were designed to determine: (a) the timing of arrival of winter visitors and the dates of major passage for transient migrants; (b) the approximate numbers of birds using the study area at peak presence.

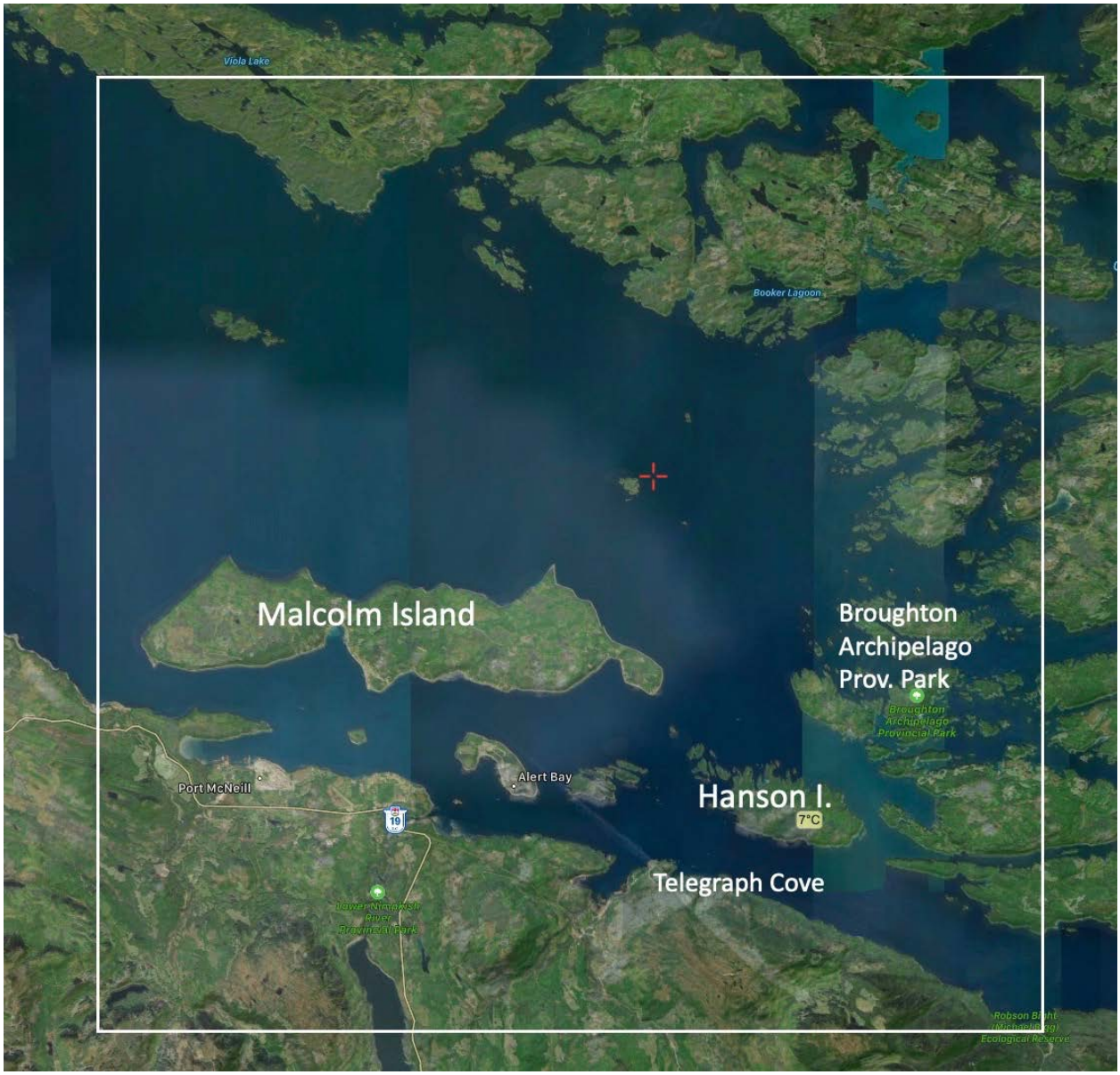

Figure 2. Boundaries of the Queen Charlotte Strait marine study area (white square)

METHODS

Field methods

Surveys were carried out during four periods spaced at approximately two-week intervals, between 16 August and 1 October: (1) 16-19 August, (2) 31 August – 3 September, (3) 14-17 September, (4) 29 September – 1 October. They comprised a series of parallel transects, running N-S across the major channels from the western end of Malcolm Island to just west of the Robson Bight Ecological Reserve in Johnstone Strait (Figure 3). N-S transects are referred to as "open water". We allowed five days for each survey, assuming that some days would be unsuitable for surveying, either because of fog, rain or sea conditions. In between the ends of transects we followed the shoreline approximately 0.5 km from the water's edge but cut across small bays and inlets. Observations on these inter-transect journeys were identical to those on linear transects and were used to create a sample of birds using 'coastal' habitat.

In the open waters of QC Strait transects were 5-7 km apart, being adjusted to avoid close approach to islands and with the most westerly transect being 1 km further from the adjacent transect to better incorporate the central reach of Queen Charlotte Strait. In Cormorant Channel, south of Malcolm Island, transects were 3 km apart and within the area east of Malcolm Island, including Weynton Passage, Blackfish Sound and the western end of Johnstone Strait, 2.5 km apart (Figure 3). In addition, a few non-shoreline transects connected the ends of parallel transects and these were run in order to make most efficient use of time and fuel. Open water transects began and ended approximately 200 m offshore, except for two which terminated in the mouth of large bays. Individual surveys included 170-189 km of open-water transects and 33-41 km of shoreline transects, with combined transect lengths ranging from 210-230 km for individual surveys (Table 1). With travel time to and from start and end points (usually at a higher speed), total boat time for each survey was 15-20 h spread over two or three days.

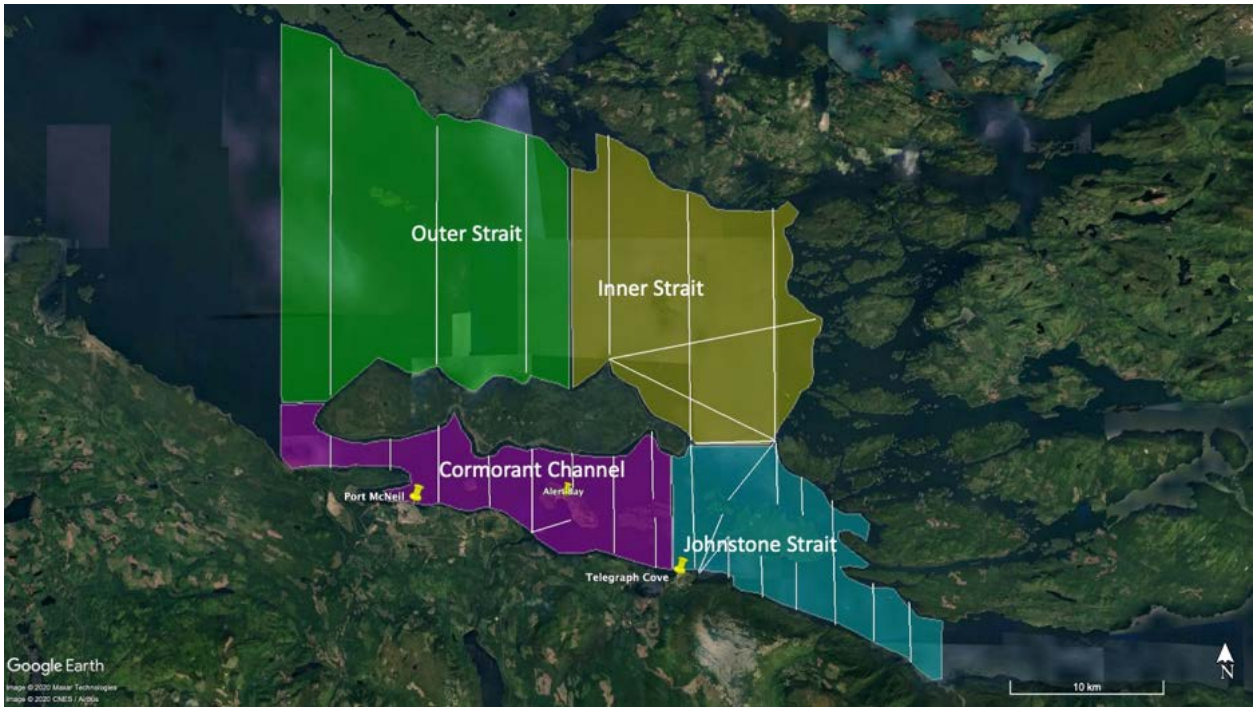

Figure 3. Open-water transect lines and the position of the zonal boundaries

Table 1. Transect distances (km)

Zone		Survey 1	Survey 2	Survey 3	Survey 4
Outer Strait		51.3	51.3	51.3	51.3
Inner Strait		50.2	50.3	45.0	45.0
Cormorant Ch.	Open water	37.8	33.5	39.9	32.4
	Shoreline	21.3	20.6	20.6	22.1
Johnstone Str.	Open water	44.7	34.6	52.8	45.4
	Shoreline	11.6	19.8	20.8	19.2
Totals		216.9	210.1	230.4	215.4
Open water		184.0	169.7	189.0	174.1
Shoreline		32.9	40.4	41.4	41.3

Surveys were conducted from an open 21 ft rigid-hull inflatable boat powered by a 150 hp outboard motor. Survey speed was determined by the minimum planing speed for the vessel, about 14.5 knots (range 13.5-16; 25-30 km/h). However, when high densities of birds or difficult identifications were encountered, the boat was slowed to about half speed or stopped briefly. We also went off transect on occasion to investigate feeding or roosting flocks, restarting the transect at the point where we broke off. The flocks so investigated were not included in transect results but were reported separately to eBird. Navigation was performed with the aid of a GPS chartplotter in which all transect start/end points had been previously entered, and via which our course was maintained.

Observations were made simultaneously by two observers seated in the centre of the boat facing ahead, each with an unobstructed view both forward and in an arc of about 120 deg to each side. Observations were made continuously throughout the transects, along a 100 m strip on either side of the course. When seated, their heads were about 1.5 m above water level. Observers used 8x or 10x binoculars or the naked eye to identify birds. The boat driver, standing behind the two primary observers also contributed observations in cases where they saw birds missed by the primary observers. Primary observers called out their observations to a recording assistant who did not observe. Where no transit time was necessary between transects, a brief break of five or more minutes was taken every 1-2 hours to avoid observer fatigue. All observers were experienced ornithologists with ample prior exposure to seabird identification at sea in BC waters. Given the unobstructed view ahead of the boat and the fact that observers faced forward, we believe that few diving birds were missed due to submerging when disturbed by the boat, as

most were detected well before the boat reached them. Primary observers were: Survey 1, K Wright and G Sorenson; 2, K Wright and G Sorenson; 3, K Wright and S Pastran; 4, S Pastran and I Lewylle. The secondary observer and boat driver was M Maftei; recorders AJ Gaston and S Pastran (survey 2).

Data recorded at the start of each transect was sea state (Beaufort scale), wind speed (estimated), precipitation (light, heavy) and estimated visibility (in km). Any change during a transect was noted. Transects were terminated when heavy rain or fog reduced visibility below about 150 m or when sea state was estimated to be greater than 2 (light breeze, small wavelets, crests do not break). Transects were not always run in the same direction, or in the same order on each survey. Each day's surveying was designed in the light of the current weather and sea conditions, with a view to optimizing conditions for observations, maximising the transect time and minimising non-transect travel. Because the order of transects varied, the stretches of shoreline surveyed between open-water transects varied among surveys.

Observers reported the species and numbers of all birds seen, whether they were within or outside the transect width and whether they were flying or on the water. Birds that could not be identified to species were recorded to genus, or in some cases merely as "duck", "gull", etc.. All marine mammals seen were also recorded. Each transect was started at the beginning of a 1-minute period and each observation was assigned by the recorder to a 1 minute interval, during which the boat covered approximately 460 m. We did not attempt to make use of the "snapshot" count to determine the densities of flying birds (Tasker et al. 1984; Gaston et al. 1987), because we deemed that, with the densities we expected to encounter and at the boat speeds we were employing, this procedure would be too taxing on observers and recorder. Likewise, with observers relatively low down, it was not considered feasible to use distance sampling, that would have required the estimation of several distance zones (e.g. Ronconi and Burger 2009).

Analysis

For analysis, all non-shoreline transects were lumped into four zones, as shown in Figure 3: Outer Strait, Inner Strait, Cormorant Channel and Johnstone Strait. For the Cormorant Channel and Johnstone Strait zones we analysed open-water and shoreline transects separately, treating them as representative samples of the given zone. In estimating bird densities away from shorelines in all zones we omitted the first and last 1-minute periods of each transect. As the boat travelled about 450 m in 1 minute, this meant that the transects included areas >650 m from the shore. Offshore transect densities were extrapolated to the zonal areas > 500 m from shore. Shoreline transect densities were extrapolated to a strip up to 500 m from shore. They were only estimated for the Cormorant Channel and Johnstone Strait zones because not all connecting transects between N-S transects in the two QC Strait zones fell within 0.5 km of the shore.

For comparisons among surveys to determine migration timing all birds seen on transect were summed, including those on the water and in flight. The relationship between numbers of birds counted in flight and actual densities in the area sampled is a complex function of flight speed and direction relative to boat speed (Gaston et al. 1987), but we have assumed that flight speeds and directions were comparable among surveys and that boat speed was constant. However, for estimates of total numbers of birds present in our four zones we used only birds seen on the water (birds seen on the water when first detected that later took off were treated as "on the water"). However, we included flying birds in the case of Storm-Petrels (*Hydrobates* spp.), using the rationale of Fox et al. (2017) that they often fly slowly and feed in flight. Fox et al. also applied this rationale to gulls (*Larus* spp.), but many of these were clearly on migration during our surveys so including birds in flight seemed problematic.

To estimate total numbers of birds present in each zone we extrapolated estimated densities, based on transect length (measured with the "ruler" or "path" tools of Google Earth Pro 7.3.3.7786) * width (200 m) to zone areas (measured with the "Add polygon" tool of Google Earth Pro).

$$D_{x.z} = \sum_{t=1}^{i} C \,/\, \sum_{t=1}^{i} 0.2L$$

Where $D_{x.z}$ = density of species x (birds/km2) in the zone, t = transect 1-i, C = total count of species x on transect i and L = length of transect i (km). The total number of species x in each zone is estimated by:

$D_{x.z}$ * the area of the zone (km^2)

Although conditions were very favourable for observation during most of the transects and although all observers were very experienced with this type of survey, detectability is imperfect and we assume that a proportion of birds were not detected. To adjust observed densities for detectability we used correction factors for 200 m strip transects taken from Ronconi and Burger (2009) who gave correction factors for very similar surveys, using almost identical methods and involving some of the same species that we encountered. For species where Ronconi and Burger did not give a correction factor we used the factor applicable to the species most similar in size and plumage colour. Correction factor assignments, based on the global models of Ronconi and Burger (2009, Table 3, P_a) are given in Table 2.

Table 2. Correction factors used to correct for detectability (from Ronconi and Burger 2009, Table 3).

Species	P_a	
	Mean	95% CI
Surf Scoter (SUSC)	0.564	0.345-0.921
American Wigeon (AMWI)	0.564	0.345-0.921
Red-necked Phalarope (RNPH)	0.529	0.519-0.540
Common Murre (COMU)	0.537	0.478-0.604*
Pigeon Guillemot (PIGU)	0.602	0.541-0.671*
Ancient Murrelet (ANMU)	0.537	0.478-0.604
Rhinoceros Auklet (RHAU)	0.516	0.401-0.665*
Marbled Murrelet (MAMU)	0.529	0.519-0.540*
California Gull (CAGU)	0.564	0.345-0.921*
Glaucous-winged Gull (GWGU)	0.564	0.345-0.921*
Iceland (Thayer's) Gull (THGU)	0.564	0.345-0.921
Mew Gull (MEGU)	0.564	0.345-0.921
Black-legged Kittiwake (BLKI)	0.564	0.345-0.921
Common Loon (COLO)	0.537	0.478-0.604
Pacific Loon (PALO)	0.537	0.478-0.604
Red-necked Grebe (RNGR)	0.537	0.478-0.604
Fork-tailed Storm Petrel (FTSP)	0.529	0.519-0.540

* Original estimates from Ronconi and Burger (2009). Others are assigned

RESULTS

Distribution by zones

Densities of birds on the water, averaged over the four surveys, were highest in Cormorant Channel (75.0 birds/km^2) and Johnstone Strait (75.5 birds/km^2), with numbers dominated by Common Murres in Cormorant Channel and by Sooty Shearwaters and California Gulls in Johnstone Strait (Figure 4). Densities of birds were lowest in the western portion of the open strait ('outer offshore'; 13.0 birds/km^2). Common Murres occurred at high densities in all zones except Johnstone Strait and California Gulls were abundant in all zones except the outer offshore. Fork-tailed Storm-Petrel was the only species found to have its highest density in the outer offshore zone, while Ancient Murrelet, Marbled Murrelet and Pacific Loon were densest in the inner offshore (Table 3). Surf Scoter, Pigeon Guillemot, California Gull and Glaucous-winged Gull were densest in the coastal strip of Cormorant Channel and Thayer's Gull was densest in the coastal strip of Johnstone Strait. Red-necked Phalarope, Rhinoceros Auklet, Black-legged Kittiwake and Sooty Shearwater were densest in the open waters of Johnstone Strait and Common Murre, Mew Gull, Common Loon and Red-necked Grebe in the open waters of Cormorant Channel.

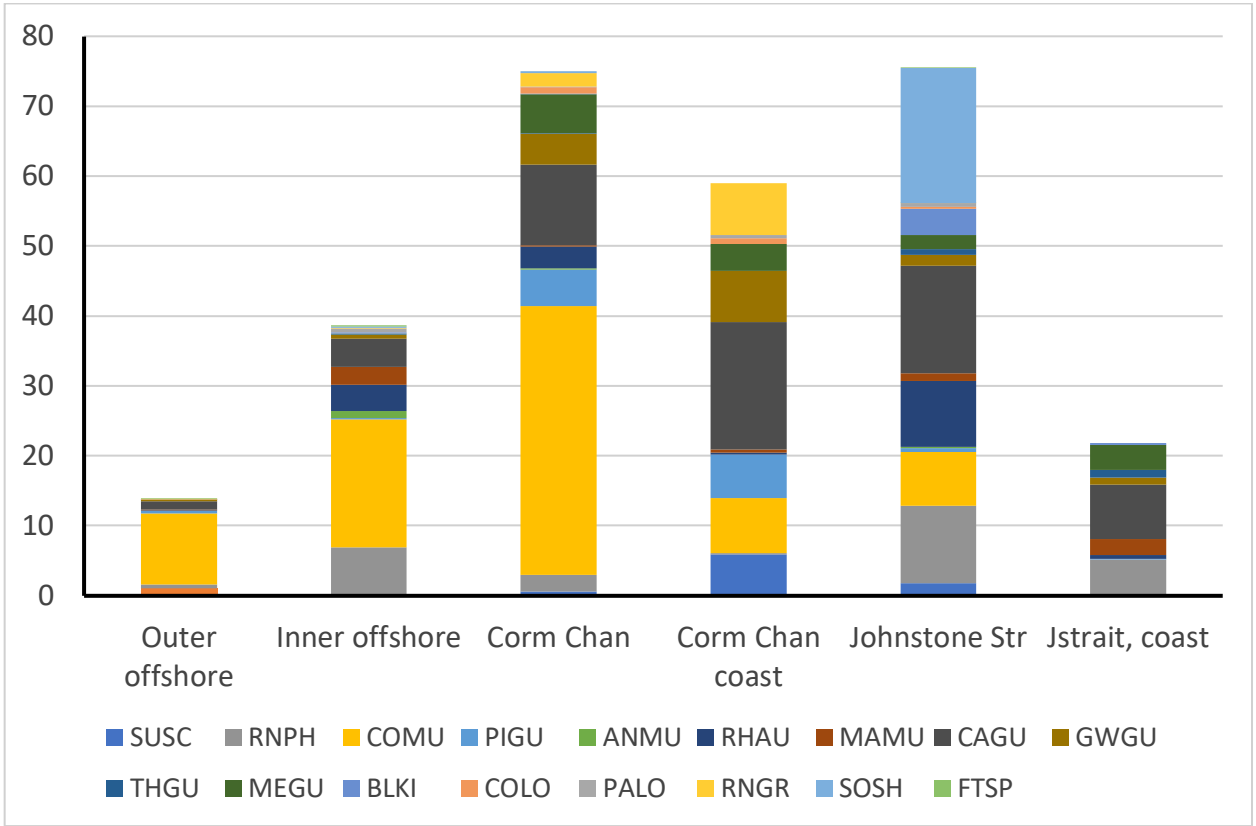

Figure 4. Densities of the commonest species recorded during surveys in Inner Queen Charlotte Strait, by zone: averages of all four surveys. For acronyms, see Table 2.

Table 3. Zones of highest density for the 17 most widespread species encountered on surveys of Queen Charlotte Strait during 16 August – 1 October 2020 and average density recorded in the highest zone.

Species	Zone of highest density	Mean density in highest zone (birds/km^2)
Surf Scoter	Cormorant Channel, coastal	5.9
Red-necked Phalarope	Johnstone Strait	11.1
Common Murre	Cormorant Channel	38.5
Pigeon Guillemot	Cormorant Channel, coastal	6.2
Ancient Murrelet	Inner offshore	1.0
Rhinoceros Auklet	Johnstone Strait	12.6
Marbled Murrelet	Inner offshore	2.5
California Gull	Cormorant Channel, coastal	18.2
Glaucous-winged Gull	Cormorant Channel, coastal	7.3
Iceland (Thayer's) Gull	Johnstone Strait, coastal	1.0
Mew Gull	Cormorant Channel	5.6
Black-legged Kittiwake	Johnstone Strait	3.8
Common Loon	Cormorant Channel	1.0
Pacific Loon	Inner offshore	0.6
Red-necked Grebe	Cormorant Channel	7.4
Sooty Shearwater	Johnstone Strait	19.3
Fork-tailed Storm Petrel	Outer offshore	0.2

Total numbers of birds present

Forty-six species of waterbirds were identified during the transects, but many were seen very infrequently and in small numbers. Totals of all birds seen are given in Appendices 1-4. Estimates of total numbers present were made separately for each zone and for this purpose species were included only if they occurred in the zone in more than four 1-min periods during the survey. Estimates were made for 18 species in one or more zones/surveys: 17 North American breeders (Table 3) and one southern hemisphere visitor (Sooty Shearwater). Raw estimates, uncorrected for detectability, are given in Appendix 5.

Table 4. Highest estimates of numbers within the survey area, corrected for detectability, for the 17 most widespread North American (NA) breeding species encountered on surveys of Queen Charlotte Strait during 16 August – 1 October 2020 and estimates of the % of the North American population represented (based on mean estimates). All population estimates from Birds of the World (2020)

Species	P_a		Detection-corrected estimates		NA population	% NA population
	Mean	95% CI	Mean	Minimum		
Surf Scoter	0.564	0.345-0.921	2206	1351	700000	<1
American Wigeon	0.564	0.345-0.921	2048	1254	2.2 million	<1
Red-necked Phalarope	0.529	0.519-0.540	10624	10407	2.5 million	<1
Common Murre	0.537	0.478-0.604	46259	41127	>4 million	~1
Pigeon Guillemot	0.602	0.541-0.671	2643	2371	69000	3.8
Ancient Murrelet	0.537	0.478-0.604	1076	957	1.3 million	<1
Rhinoceros Auklet	0.516	0.401-0.665	6176	4792	922000	<1
Marbled Murrelet*	0.529	0.519-0.540	2885	2826	552000	<1
California Gull	0.564	0.345-0.921	13589	8321	621000	2.2
Glaucous-winged Gull	0.564	0.345-0.921	4755	2912	570000	<1
Iceland (Thayer's) Gull†	0.564	0.345-0.921	844	517	25000	2.1
Mew Gull	0.564	0.345-0.921	4138	2534	300000	1.4
Black-legged Kittiwake	0.564	0.345-0.921	4507	2760	2.1 million	<1
Common Loon	0.537	0.478-0.604	315	280	620000	<1
Pacific Loon	0.537	0.478-0.604	1128	1003	800000	<1
Red-necked Grebe	0.537	0.478-0.604	1311	1166	45000	2.9
Fork-tailed Storm Petrel	0.529	0.519-0.540	2565	2513	5.5 million	<1

* Bertram et al (2015) estimated 100,000 in BC alone, so the proportion in Queen Charlotte Strait could be just over 1% of Canadian population

† The Canadian IBA thresholds list gives the N American population as 100,000, but this includes the *kumlieni* race that winters on the Atlantic coast. Colony counts suggest a much lower number for *thayeri*, which is confined to the eastern high Arctic (Gaston et al. 2012)

Timing of arrival/migration

Sea ducks

Among the ducks, American Wigeon, Northern Shoveler, Mallard, Green-winged Teal, Harlequin, Common and Red-breasted Merganser, and the three species of Scoter were all patchily abundant in suitable inshore waters, especially at the mouth of the Nimkish River. However, our transects did not sample their habitat adequately and only data for Surf Scoter and White-winged Scoter are analysed here (Fig. 5). Both scoter species increased in frequency between early and late surveys, reaching highest numbers on survey 4. At that time, flocks of both species were seen passing south through Johnstone Strait, clearly on migration.

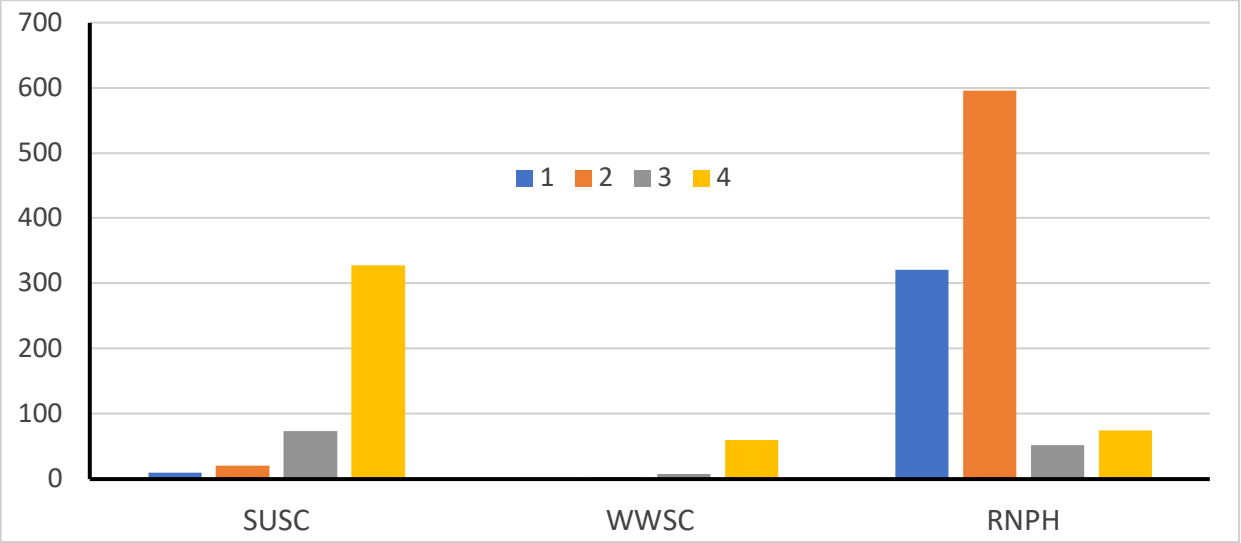

Figure 5. Numbers of sea-ducks and phalaropes counted on all transects, including birds on the water and in flight, by survey

Phalaropes

Only Red-necked Phalaropes were identified during the surveys. The possibility that small numbers of Red Phalaropes could have been present and not detected cannot be discounted, but the vast majority were certainly Red-necked Phalaropes. They were much more abundant on the first two surveys than on surveys 3 and 4, suggesting that staging in the Queen Charlotte Strait area occurs mainly in August (Fig. 5). Anecdotal observations by M. Maftei in mid August of 2020 indicated that densities of this species roughly similar to those we encountered during peak counts were present in waters to the west of our main survey area, between Port Hardy and Storm Island.

Auks

No trend in numbers over the period of the surveys was detectable for Pigeon Guillemots, Marbled Murrelets or Rhinoceros Auklets, all of which breed locally (Fig. 6). Common Murres numbers increased to a peak in survey 3, falling in survey 4, although still higher than on the August surveys. Numbers of murres in flight fell from 8.5% on survey 1 to <1% on survey 3. None was seen in flight on survey 4. Common Murres become flightless during moult, as they drop their primary feathers more or less synchronously. The reduction in flight activity during our study strongly suggests that the population entered, but did not complete, moult during the study period. If so, it suggests that Queen Charlotte Strait, especially the inner part and Cormorant Channel, is an important moulting area for Common Murres. The origin of the murres using the area is unknown. Our estimates of total numbers present greatly exceed the known breeding population of British Columbia (<10,000 birds; Hipfner 2005, Hipfner and Greenwood 2008). Hence a substantial number of birds from colonies in the US probably come to Queen Charlotte Strait to moult.

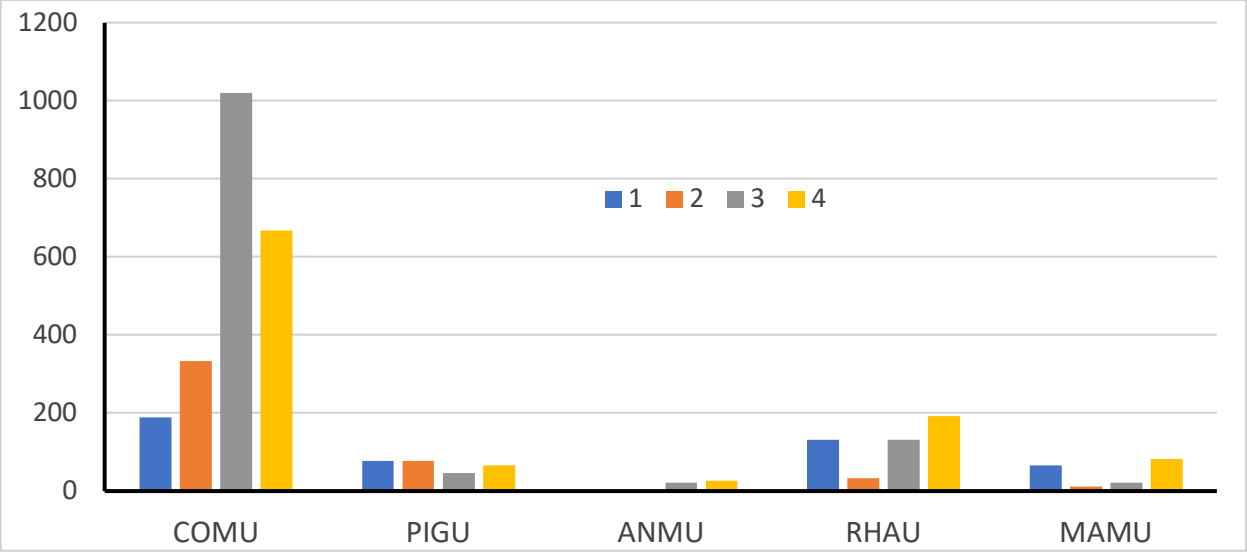

Figure 6. Numbers of auks counted on all transects, including birds on the water and in flight, by survey

Gulls

Numbers of California Gulls fell by about 70% over the period of the study and numbers of Mew Gulls also fell (Fig. 7). Bonaparte's Gull were present only during survey 2. All other species increased: Glaucous-winged Gulls were not recorded on transect at all on survey 1, but >200 were seen on survey 4. Hundreds were observed moving south through Johnstone Strait in late September and early October (incidental obs.), suggesting that a strong migratory movement occurs through the area at that time.

Herring and Iceland (Thayer's) gulls and Black-legged Kittiwakes were recorded only on surveys 3 and 4, presumably arriving from breeding areas farther north.

Kenyon et al. (2009) did not record Black-legged Kittiwake in Queen Charlotte Strait at any time of year. However, they have been frequently reported in our study area in recent years, although most records involve counts of <10 birds (eBird, accessed 20 November 2020). Off transect, we estimated 300 roosting on a small islet in Johnstone Strait on 16 September. This appears to be the largest aggregation so far reported from Queen Charlotte Strait. The group included a colour-banded bird that almost certainly originated from the breeding colony at Middleton Island, 1500 km NW of our observation. Based on the colour bands it was probably an individual that had not bred in 2020 (KH Elliott, pers. comm.).

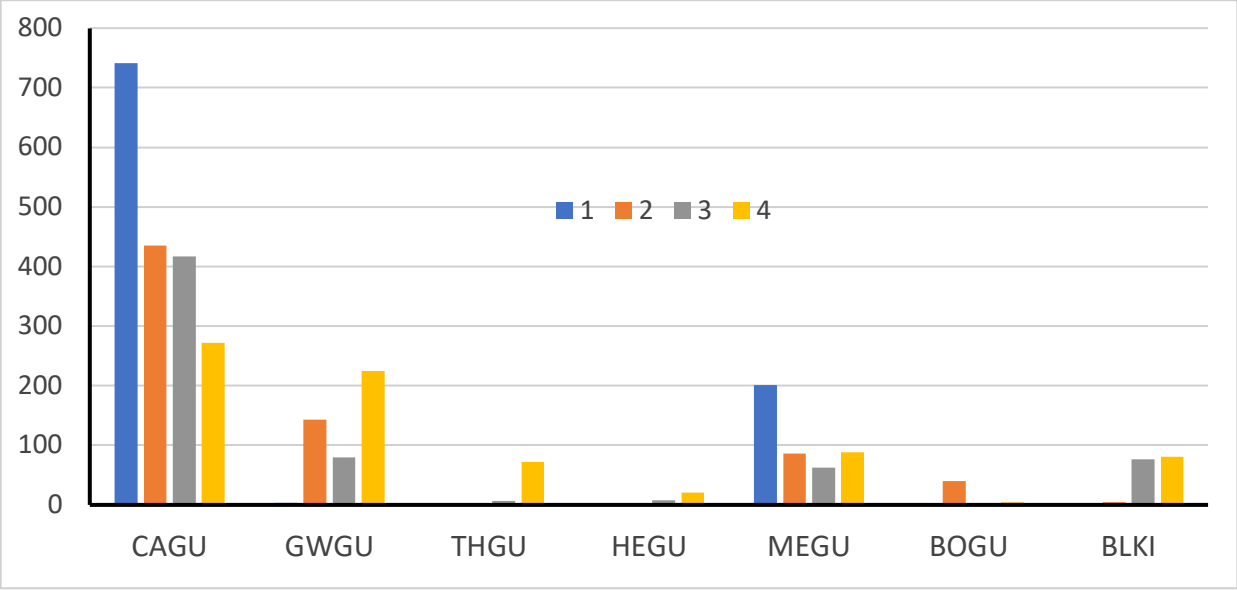

Figure 7. Numbers of gulls counted on all transects, including birds on the water and in flight, by survey

Loons

All four loon species breeding in North America were identified on our transects but only Common and Pacific loons were seen on more than one survey. Numbers of Common Loons increased slightly over the study period, while Pacific Loons were recorded only on surveys 3 and 4 (Fig. 8). On survey 4 many were seen flying south off-transect and it appears that the main movement of Pacific Loons through the study area takes place from the middle of September onwards.

Grebes

Red-necked, Horned and Western grebes were recorded on our transects, but only Red-necked Grebe was considered abundant enough to be worth discussing. Numbers doubled between surveys 1 and 2 but remained stable thereafter, suggesting that either most birds arrived in the area during August, or that movement through the area remained steady from late August through September.

Petrels

We recorded Sooty Shearwater and Leach's and Fork-tailed Storm-Petrels. Leach's Storm-Petrel was recorded only on the outer strait transects and less than ten were seen. Fork-Tailed Storm-Petrel was seen on all four surveys but only one was seen on survey 1 and five on survey 4, with much larger numbers on surveys 2 and 3 (Fig. 8). The species breeds commonly in Queen Charlotte Strait, but is generally thought to feed far offshore. It was not recorded in Queen Charlotte Strait by Kenyon et al. (2009) but there are numerous records on eBird. Our records included one in Johnstone Strait and several in Cormorant Channel, although the bulk were seen on the outer strait transects. They were most commonly encountered on foggy days with limited visibility.

Sooty Shearwater was seen only on survey 3, when it was the third most abundant species recorded. In addition to the 279 seen on transect, several hundred more were seen off-transect, including a flock of 250 on 16 September. Although the species is generally most abundant in BC waters in April-August (Guzman and Myres 1983, Kenyon et al. 2009), many observations of >100 birds have been reported from Queen Charlotte Strait in September (eBird, accessed 20 November 2020). Because the species is highly mobile, it is hard to know if our observations in mid-September represent a typical peak for the area, or simply a brief visit by a small proportion of the coast's population, perhaps caused by local weather conditions. However, outside of our study, all the high counts from inner Queen Charlotte Strait occurred in mid-September: 500 on 12 Sept. 1993, 645 on 12 Sept. 1997, 600 on 23 Sept. 2012, 300 on 28 Sept 2015 (eBird, accessed 20 Nov 2020). It does appear that mid-September may be a time when large numbers of Sooty Shearwaters enter Queen Charlotte Strait. A report from a local fisherman suggested that numbers of this species in 2020 were notably lower than usual.

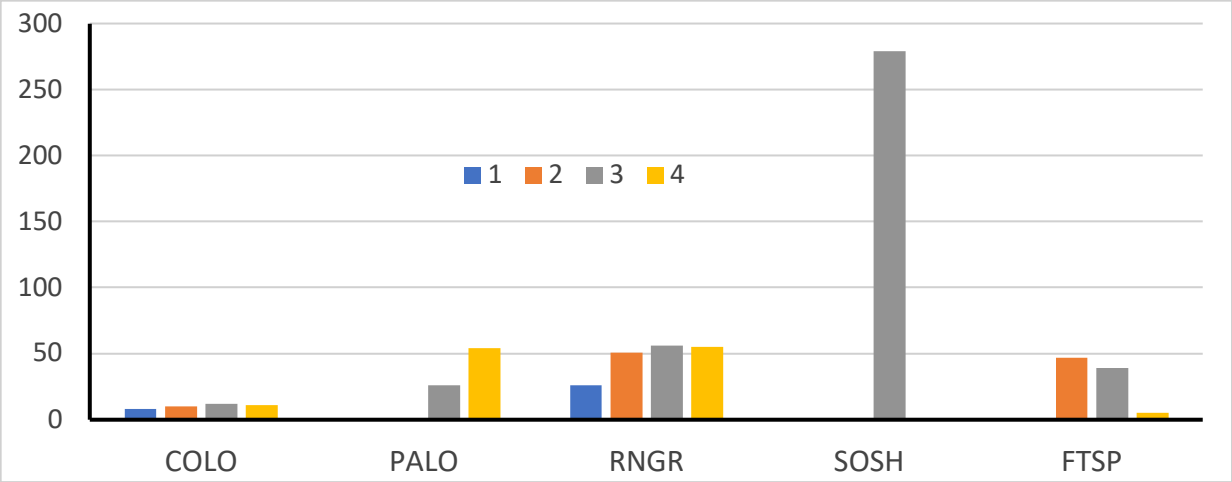

Figure 8. Numbers of loons, grebes and petrels counted on all transects, including birds on the water and in flight, by survey

Cormorants

We recorded all three cormorants present on the BC coast during our surveys, but numbers were generally small. Only Pelagic Cormorant is known to breed in Queen Charlotte Strait in a few small colonies at the western end (Rodway and Lemon 1991). Double-crested and Pelagic cormorants were recorded on all surveys (Double-crested only off-transect, Fig. 9), but Brandt's Cormorant was identified only on surveys 3 and 4. Numbers of all three species were highest on survey 4. Most records of all three species in our study area occur in September-November (eBird, accessed 21 November 2020), despite the fact that many birders visit the area in August. From our sightings, the main build-up occurs after mid-September.

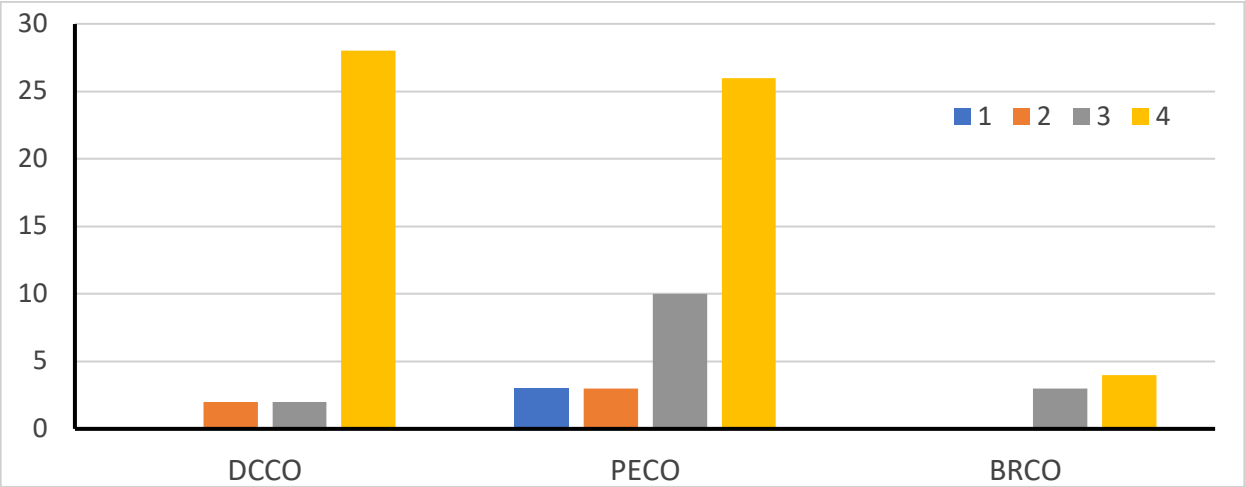

Figure 8. Numbers of cormorants counted on all transects, including birds on the water and in flight, by survey

Comparison with other studies

Our data confirm for Queen Charlotte Strait many of the trends observed on the west coast of Vancouver Island. Two studies are particularly suitable for comparison: surveys year round in and offshore from the mouth of Barkley Sound (Burger et al. 2002, 2008) and surveys during August-October in the same area but extending farther to the west (Vermeer et al. 1989). On all three surveys numbers of Common Murres and Sooty Shearwaters peaked in September, while numbers of Fork-tailed Storm-Petrels, California Gulls and Red-necked Phalaropes diminished from August through October (Table 5). Scoters and Ancient Murrelets (not included by Vermeer et al. (1989)), Cormorants, Loons, and Glaucous-winged, Herring and Iceland (Thayer's) gulls all increased over the same period. The only variation among studies came for (1) Black-legged Kittiwakes, which increased over time in our study and that of Vermeer et al, but were absent in the study of Burger et al. appearing in the area only in November; (2) Mew Gulls, which peaked in August in Queen Charlotte Strait, but were rare until October off Barkley Sound (Burger et al. 2002, not included by Vermeer et al.).

Table 5. Comparison among studies relating to the timing of seabird passage through BC waters.

	2020 surveys				Vermeer et al 1989					Burger et al 2002		
Species	16-19 Aug	30 Aug-3 Sep	16-18 Sep	29 Sep-1 Oct	9-18 Sept	22-24 Sept	6-8 Oct	10-21 Oct		Aug	Sept	Oct
SUSC	10	21	74	328						1	2	3
WWSC	2	3	8	60						1	2	3
RNPH	321	596	52	75	104	15	87	0		3	2	1
COMU	188	333	1020	668	1865	951	1093	543		2	3	1
PIGU	77	78	46	65						3	1.5	1.5
ANMU	0	2	22	26						2	1	3
RHAU	131	33	131	192	50	6	3	2		2	3	1
MAMU	66	11	21	82						3	1.5	1.5
CAGU	741	435	417	272	32859	4174	2571	11552		3	2	1
GWGU	3	143	80	225	234	490	771	394		1	2	3
THGU	0	0	7	72	0	0	357	1816		1.5	1.5	3
HEGU	1	2	8	21	45	47	71	398		1	2	3
MEGU	201	86	63	88						1.5	1.5	3
BOGU	0	40	2	5						3	1.5	1.5
BLKI	0	4	77	81	0	6	135	679		2	2	2
COLO	8	10	12	11						1	2	3
PALO	0	0	26	54	12	29	54	8		1	2	3
RNGR	26	51	56	55						1	3	2
SOSH	0	0	279	0	11241	1202	363	1474		2.5	2.5	1
FTSP	1	47	39	5	439	2	6	5		3	2	1
DCCO	0	2	2	28						1	2	3
PECO	3	3	10	26	32	73	93	3	*	1	2	3
BRCO	0	0	3	4						1	2	3

* Cormorant species were not differentiated in Vermeer et al.

Marine Mammals

We counted all marine mammals observed on transect, identifying eight species (Table 6), with a ninth, Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*), recorded off-transect.

Table 6. Total numbers of marine mammals recorded on transects

Common name	Scientific name	Acronym	Survey 1	Survey 2	Survey 3	Survey 4
Minke Whale	*Balaenoptera acutorostrata*	MIWH				1
Humpback Whale	*Megaptera novaeangliae*	HUWH	5	5	5	
Orca	*Orcinus orca*	ORCA		3		
Harbour Porpoise	*Phocoena phocoena*	HAPO	12	7	4	
Dall's Porpoise	*Phocenoides dalli*	DAPO	2	4	5	3
Steller Sea Lion	*Eumetopias jubatus*	STSL	7	1	10	4
Harbour Seal	*Phoca vitulina*	HASE	5	2	5	8
Sea Otter	*Enhydra lutris*	SEOT	2	1		4

Because observers were concentrating mainly on birds and because most marine mammals spend substantial amounts of time underwater, density estimates, especially for the whales, must be strongly biased downwards. However, comparisons among zones probably remain valid. Sea otters and orcas were seen only on the outer strait transects, but another pod of Orcas was seen off-transect in Blackfish Sound (Figure 9). Orcas are known to be regularly present in the area, which includes two well-known rubbing beaches. Humpback Whales were seen only in the inner strait and in Johnstone Strait, while Steller's Sea lions were not recorded in Cormorant Channel. Both Harbour and Dall's porpoises were seen in all four zones. Only 3 records of Sea Otters in Queen Charlotte Strait are shown by Ford (2014). All our sightings were in our westernmost zone, an area probably less frequented by whale-watchers than the inner strait and Johnstone Strait. They suggest that sea otters currently may be colonizing Queen Charlotte Strait. Otherwise, all marine mammals that we observed are known to be common in the area, according to Ford (2014).

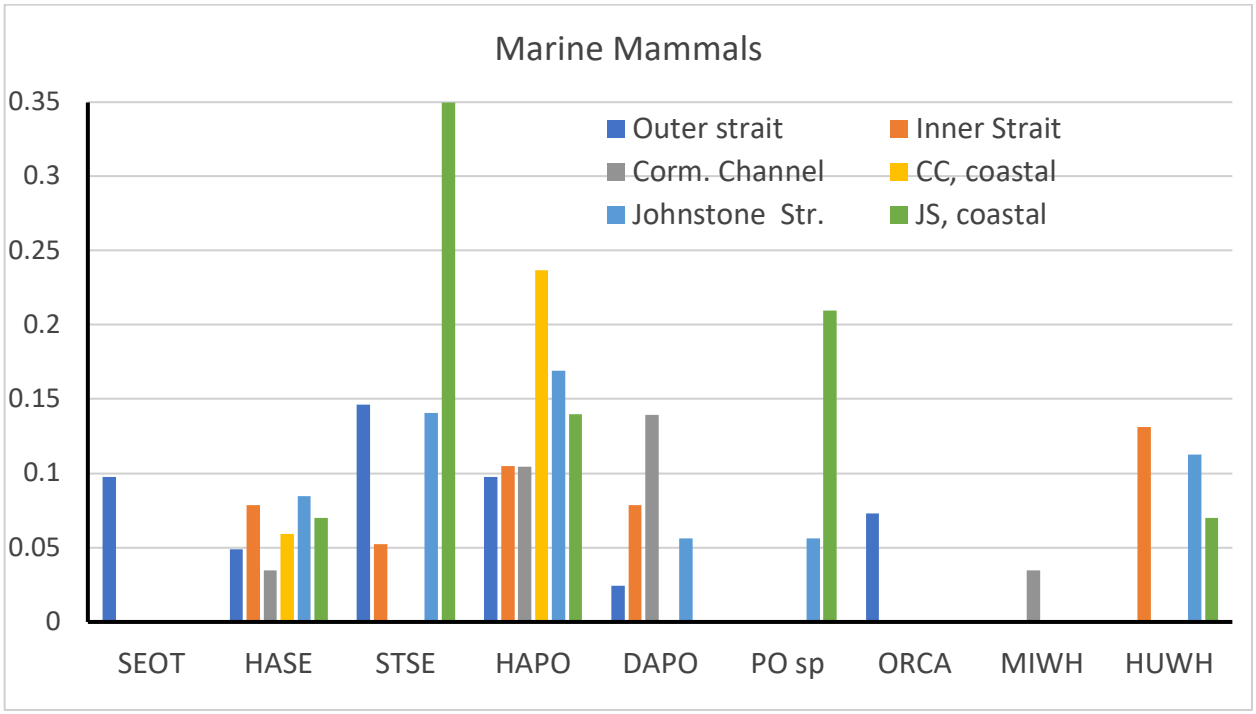

Figure 9. Densities of marine mammals based on the maximum count for each zone over the four surveys. Acronyms are given in Table 6

DISCUSSION

The design of our surveys was constrained by the CoVid-19 pandemic which made our first choice of survey vessel unavailable. The surveys were designed as a compromise between the planing capability of the boat, the fuel consumption and the area to be covered. On top of this, schedules needed to be adjusted to take account of local weather conditions, especially visibility which was much reduced by fog on several days. These constraints resulted in routes not being identical on every survey and some small portions of planned transects being omitted on some surveys. However, we were blessed with very little wind and with sea conditions >1 prevailing for only short periods. Although the realised mean speed of 14.5 kn, imposed by the minimum planing speed of the laden boat was higher than is normal on comparable surveys (usually in the 5.5-11 kn range), the sea conditions we surveyed in were essentially flat water, and thus observations were unimpeded. Our speed had the further advantage of allowing us to cover a greater distance than would otherwise have been possible. By slowing down for dense aggregations of birds, we believe that our methods resulted in data fully comparable with other boat-based surveys carried out in coastal BC.

Total numbers of birds

Our estimates of total numbers are conservative for several reasons: the shoreline transects in the inner and outer strait zones were not included because the distance from shore was not uniformly maintained, and, for all species except storm-petrels, birds in flight were not included. These amounted to >25% of birds counted for Red-necked Phalarope, all gulls, Pacific Loon and Sooty Shearwater. Hence, all these species were considerably more abundant than our figures suggest, but we have no way to quantify this. However, for all auks and grebes and for Common Loons, the proportion in flight was <10%, so our estimates should be more accurate for those species.

The detection-corrected estimates (Table 4) suggest that, at their peak presence, our study area supported 1% or more of the North American Population of Pigeon Guillemot, Mew Gull, California Gull, Iceland (Thayer's) Gull and Red-necked Grebe. Marbled Murrelet numbers exceeded 1% of the Canadian population. For the gulls, percentages would be higher if birds in flight were included. Among these species, only Pigeon Guillemot and Marbled Murrelet breed in Queen Charlotte Strait and Pigeon Guillemot does not do so in sufficient numbers to account for the totals we obtained (Rodway and Lemon 1991). No estimate of the Marbled Murrelet population breeding in the area is available (Piatt et al. 2007). Among the species where >1% of the North American population was present at some point, only the Marbled Murrelet is listed by the Committee on the Status of Endangered Wildlife in Canada (as

Threatened), and by IUCN (Endangered) (https://wildlife-species.canada.ca/bird-status, accessed 22 November 2020).

A few species of marine birds seen in large numbers off the west coast of Vancouver at the same season were uncommon or absent in Queen Charlotte Strait during our surveys. This applies especially to Northern Fulmar (*Fulmarus glacialis*) and Sabine's Gull (*Xema sabini*), both of which occurred on >30% of surveys off Barkley Sound (Burger et al. 2002), sometimes being seen in hundreds. In contrast, we saw one Northern Fulmar (off-transect) and no Sabine's Gulls. Presumably, neither of these species is inclined to enter the partially enclosed waters of Queen Charlotte Strait.

Timing of arrival/migration

Although our surveys covered the best part of two months, it is clear that we did not, or may not have, intersected the main arrival/migration period for many species. Red-necked Phalaropes, California and Mew gulls had clearly begun to arrive before our surveys, while Scoters, Glaucous-winged, Iceland (Thayer's) and Herring gulls, Black-legged Kittiwakes, Pacific Loons and all three cormorant species all reached their highest numbers on the final survey, suggesting that numbers might continue to increase in October. The same applied to all these species on the west coast of Vancouver Island (Burger et al. 2002).

The appearance of high numbers of Iceland (Thayer's) Gulls in the second half of September corresponds closely to the date of arrival on the west coast of four high-Arctic breeders tracked by satellite (23 September – 12 October, Gutowski 2020). This suggests that many of the birds we saw would have arrived direct from their eastern and high-Arctic breeding grounds. The very brief appearance of large numbers of Sooty Shearwaters in mid-September, supported by eBird observations, is puzzling, given that large numbers occur throughout the summer off the west coast of Vancouver Island (Burger et al. 2004). It suggests that either (a) there is a brief flush of very suitable food resources in the area, or (b) there is a regular movement into Queen Charlotte Strait by a segment of the population originating elsewhere in the North Pacific.

Summary

Our observations confirm that the area we surveyed is notable for dense concentrations of many species of marine birds during the autumn migration period. Given the numbers of Marbled Murrelets present, which represent >1% of the North American population and the large aggregations of Common Murre, California Gull and Red-necked Phalarope (considered a Species of Special Concern by COSEWIC) the area could well have qualified as an Important Bird and Biodiversity area (https://www.ibacanada.com)

when those were being designated (1996-2001). We suggest that, given the large number of seabirds and marine mammals it hosts, inner Queen Charlotte Strait and its associated channels would be a strong candidates for inclusion as a Key Biodiversity Area (http://www.kbacanada.org/).

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REFERENCES

Bertram DF, MC Drever, MK McAllister, BK Schroeder, DJ Lindsay and DA Faust. 2015. Estimation of Coast-Wide Population Trends of Marbled Murrelets in Canada Using a Bayesian Hierarchical Model. PLoS ONE 10(8): e0134891. https://doi.org/10.1371/journal.pone.0134891

Burger AE, AD Lawrence and EA Stewart. 2002. Seasonal and spatial variations in densities and composition of seabird communities off southwest Vancouver Island, 1993-1995. In: Burger, A. E. (editor). 2002. Distribution and abundance of seabirds off southwest Vancouver Island: a year-round study in relation to the risks of oil spills. Report to Nestucca Trust Fund and BC Ministry of Water, Land, and Air Protection, Victoria, BC.

Burger AE, CL Hitchcock, and GK Davoren. 2004. Spatial aggregations of seabirds and their prey on the continental shelf off SW Vancouver Island. Marine Ecology Progress Series 283: 279-292.

Burger AE, CL Hitchcock, EA Stewart and GK Davoren. 2008. Coexistence ands spatial distributions of Marbled Murrelets (*Brachyramphus marmoratus*) and other alcids off SW Vancouver Island, BC. Auk 125: 192-204.

Birds of the World (S. M. Billerman, B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, Editors). 2020. Cornell Laboratory of Ornithology, Ithaca, NY, USA. https://birdsoftheworld.org/bow/home

Ford JKB. 2014. Marine Mammals of British Columbia. Royal BC Museum: Victoria, BC.

Fox CH, FH Huettmann, GKA Harvey, KH Morgan, J Robinson, R Williams, PC Paquet. 2017. Predictions from machine learning ensembles: marine bird distribution and density on Canada's Pacific coast. Marine Ecology Progress Series 566: 199–216.

Gaston AJ, BL Collins and AW Diamond. 1987. The "snapshot" count for estimating densities of flying seabirds during boat transects: A cautionary comment. Auk 104: 336-338.

Gaston AJ, BT Collins and AW Diamond. 1987. Estimating densities of birds at sea and the proportion in flight from counts made on transects of indefinite width. C.W.S. Occasional Paper no. 59. Canadian Wildlife Service. Ottawa ON, 16 pp.

Gaston AJ, ML Mallory and HG Gilchrist. 2012. Populations and trends of Canadian Arctic seabirds. Polar Biology 35: 1221-1232.

Gutowski SE, JM Hipfner, M Maftei, S Boyd, MT Auger, DJ Yurkowski and ML Mallory. 2020. First insights into Thayer's Gull *Larus glaucoides thayeri* migratory and overwinter patterns along the Northeast Pacific coast. Marine Ornithology 48: 9–16.

Guzman JR and MT Myres. 1983. The occurrence of shearwaters (*Puffinus* spp.) off the west coast of Canada. Canadian Journal of Zoology 60: 2064-2077.

Hay R. 1992. The Oceanic Habitats of Seabirds: Their Zonal Distribution Off Vancouver Island, British Columbia, Canada. Journal of Biogeography, 19(1), 67-85. doi:10.2307/2845621

Hipfner JM. 2005. Population status of the Common Murre *Uria aalge* in British Columbia, Canada. Marine Ornithology 33: 67–69.

Hipfner JM and JL Greenwood. 2008. Breeding biology of the Common Murre at Triangle Island, British Columbia, Canada, 2002-2007. Northwestern Naturalist 89: 76-84.

Kenyon JK, KH Morgan, MD Bentley, LA McFarlane Tranquilla and K E Moore. 2009. Atlas of Pelagic Seabirds off the West Coast of Canada and Adjacent Areas. Technical Report Series No. 499. Canadian Wildlife Service, Pacific and Yukon Region, BC.

Morgan KH, K Vermeer and RW McKelvey. 1991. Atlas of pelagic birds of western Canada. Occasional Paper Number 72, Canadian Wildlife Service, Ottawa, ON.

Piatt JF, KJ Kuletz, AE Burger, SA Hatch, VL Friesen, TP Birt, ML Arimitsu, GS Drew, AMA Harding, and KS Bixler. 2007, Status review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia: U.S. Geological Survey Open-File Report 2006-1387, 258 p.

Rodway MS and MJF Lemon. 1991. British Columbia seabird colony inventory: Report #8: Queen Charlotte Strait and Johnstone Strait. Technical Report Series No. 123. Canadian Wildlife Service, Pacific and Yukon Region, BC.

Ronconi RA and AE Burger. 2009. Estimating seabird densities from vessel transects: distance sampling and implications for strip transects. Aquatic Biology 4: 297–309.

Tasker ML, PH Jones, T Dixon and BF Blake. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101: 567−577.

APPENDICES

Appendix 1. All counts on transect in Survey 1, by zone, and proportions (%) in flight (based on survey totals)

Species	Water/ Flight	Zone						Totals	% in flight
		Outer off	Inner off	Corm Chan	CC, coast	John Str	JC, coast		
Canada Goose	Water	0	0	0	0	3	0	3	
	Flight	0	0	0	0	0	0	0	0
Greater WF Goose	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Goose sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Harlequin Duck	Water	0	0	1	10	0	0	11	
	Flight	0	0	0	0	0	0	0	0
Barrow's Goldeneye	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Surf Scoter	Water	0	0	3	0	1	0	4	
	Flight	0	0	0	2	3	0	5	56
White-winged Scoter	Water	0	0	0	0	0	0	0	
	Flight	0	0	5	0	0	0	5	100
Black Scoter	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Scoter sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Common Merganser	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Red-breasted Merganser	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Northern Pintail	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Northern Shoveler	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
American Wigeon	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Dabbling duck'	Water	0	0	0	0	0	0	0	
	Flight	35	0	0	0	0	0	35	100
Black Oystercatcher	Water	0	0	0	0	0	0	0	

	Flight	0	0	0	0	0	0	0	
Red-necked Phalarope	Water	0	65	0	0	137	3	205	
	Flight	8	10	0	0	63	0	81	28
Common Murre	Water	24	47	221	0	5	0	297	
	Flight	3	4	0	0	9	0	16	5
Pigeon Guillemot	Water	7	4	19	18	9	0	57	
	Flight	3	3	0	3	3	0	12	17
Ancient Murrelet	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Rhinoceros Auklet	Water	1	83	0	1	16	4	105	
	Flight	2	7	0	0	4	0	13	11
Marbled Murrelet	Water	0	37	0	5	8	9	59	
	Flight	0	1	0	0	3	0	4	6
Cassin's Auklet	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Alcid sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	1	2	3	100
Parasitic Jaeger	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Jaeger sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
California Gull	Water	21	6	12	116	223	21	399	
	Flight	9	20	18	57	55	5	164	29
Glaucous-winged Gull	Water	0	0	74	0	1	1	76	
	Flight	0	0	7	0	1	0	8	10
Thayer's (Iceland) Gull	Water	0	0	2	0	0	0	2	
	Flight	0	0	1	0	0	0	1	33
Ring-billed Gull	Water	0	0	0	0	0	0	0	
	Flight	0	0	1	0	0	0	1	100
Herring Gull	Water	0	0	1	0	0	0	1	
	Flight	0	0	1	0	0	0	1	50
Mew Gull	Water	0	0	0	41	12	10	63	
	Flight	0	0	3	19	0	1	23	27
Bonaparte's Gull	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Black-legged Kittiwake	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Gull sp.	Water	0	0	14	0	2	0	16	
	Flight	0	0	10	2	6	0	18	53
Common Loon	Water	2	0	7	1	0	0	10	

	Flight	0	0	0	0	0	0	0	0
Pacific Loon	Water	0	0	2	0	0	0	2	
	Flight	0	0	1	0	0	0	1	33
Red-throated Loon	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Yellow-billed Loon	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Loon sp.	Water	0	0	0	0	0	0	0	
	Flight	0	0	2	0	0	0	2	100
Red-necked Grebe	Water	1	1	11	20	0	0	33	
	Flight	0	0	0	0	0	0	0	0
Western Grebe	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Horned Grebe	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Sooty Shearwater	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Fork-tailed Storm-Petrel	Water	0	0	0	0	0	0	0	
	Flight	1	0	0	0	0	0	1	100
Leach's Storm-Petrel	Water	0	0	0	0	0	0	0	
	Flight	1	0	0	0	0	0	1	100
Storm-Petrel sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Double-crested Cormorant	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Pelagic Cormorant	Water	0	0	15	0	0	0	15	
	Flight	0	0	2	0	0	0	2	12
Brandt's Cormorant	Water	0	0	0	0	0	0	0	
	Flight	0	0	1	0	0	0	1	100
Comorant sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Great Blue Heron	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Bald Eagle	Water	0	0	0	0	0	0	0	
	Perched	0	0	0	0	1	0	1	100
Sandhill Crane		0	0	0	0	0	0	0	
Belted Kingfisher		0	0	0	0	0	0	0	
Totals		118	288	434	295	566	56	1757	

Marine Mammals							
Sea Otter	2	0	0	0	0	0	2
Harbour Seal	2	1	1	0	2	0	6
Steller Sealion	6	0	0	0	0	1	7
Harbour Porpoise	0	0	0	4	6	2	12
Dall's Porpoise	1	0	0	0	1	0	2
Porpoise sp	0	0	0	0	0	0	0
Orca	0	0	0	0	0	0	0
Minke Whale	0	0	1	0	0	0	1
Humpback Whale	0	2	0	0	2	1	5

Appendix 2. All counts on transect in Survey 2, by zone, and proportions (%) in flight (based on survey totals)

Species	Water/ Flight	Zone						Totals	% in flight
		Outer off	Inner off	Corm Chan	CC, coast	John Str	JC, coast		
Canada Goose	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Greater WF Goose	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Goose sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Harlequin Duck	Water	0	0	0	1	0	0	1	
	Flight	0	0	0	0	0	0	0	0
Barrow's Goldeneye	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Surf Scoter	Water	0	0	5	3	4	0	12	
	Flight	1	2	5	1	0	0	9	43
White-winged Scoter	Water	0	0	2	1	0	0	3	
	Flight	0	0	0	0	0	0	0	0
Black Scoter	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Scoter sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Common Merganser	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Red-breasted Merganser	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Northern Pintail	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Northern Shoveler	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
American Wigeon	Water	0	0	0	0	0	0	0	
	Flight	12	0	0	0	0	0	12	100
Dabbling duck'	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Black Oystercatcher	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Red-necked Phalarope	Water	6	151	30	3	157	77	424	
	Flight	7	46	0	0	118	1	172	29

Common Murre	Water	81	96	72	76	0	0	325	
	Flight	6	0	0	2	0	0	8	2
Pigeon Guillemot	Water	3	0	49	23	0	0	75	
	Flight	1	0	1	1	0	0	3	4
Ancient Murrelet	Water	0	2	0	0	0	0	2	
	Flight	0	0	0	0	0	0	0	0
Rhinoceros Auklet	Water	3	20	4	0	2	0	29	
	Flight	4	0	0	0	0	0	4	12
Marbled Murrelet	Water	3	2	1	2	2	0	10	
	Flight	0	1	0	0	0	0	1	9
Cassin's Auklet	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Alcid sp	Water	0	1	0	0	0	0	1	
	Flight	0	1	0	0	0	0	1	50
Parasitic Jaeger	Water	0	1	1	0	0	0	2	
	Flight	0	0	0	0	0	0	0	0
Jaeger sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
California Gull	Water	15	40	94	103	12	20	284	
	Flight	30	36	13	22	36	14	151	35
Glaucous-winged Gull	Water	1	5	3	112	0	0	121	
	Flight	3	5	8	2	4	0	22	15
Thayer's (Iceland) Gull	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Ring-billed Gull	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	2	0	0	2	100
Herring Gull	Water	0	0	0	1	0	0	1	
	Flight	0	0	0	1	0	0	1	50
Mew Gull	Water	0	1	32	18	0	13	64	
	Flight	0	0	16	4	2	0	22	26
Bonaparte's Gull	Water	0	0	0	22	0	0	22	
	Flight	0	0	0	3	15	0	18	45
Black-legged Kittiwake	Water	0	1	0	0	1	0	2	
	Flight	0	1	0	0	1	0	2	50
Gull sp.	Water	1	1	3	3	1	1	10	
	Flight	5	12	4	5	0	0	26	72
Common Loon	Water	0	0	5	4	0	0	9	
	Flight	0	0	0	1	0	0	1	10
Pacific Loon	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	

Red-throated Loon	Water	1	0	0	0	0	0	1	
	Flight	0	0	0	0	0	0	0	0
Yellow-billed Loon	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Loon sp.	Water	0	1	1	0	0	0	2	
	Flight	0	0	0	0	5	0	5	71
Red-necked Grebe	Water	0	0	22	13	0	0	35	
	Flight	0	0	0	16	0	0	16	31
Western Grebe	Water	0	5	6	0	0	0	11	
	Flight	0	0	0	0	0	0	0	0
Horned Grebe	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Sooty Shearwater	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Fork-tailed Storm-Petrel	Water	2	3	0	0	1	0	6	
	Flight	26	14	0	0	1	0	41	87
Leach's Storm-Petrel	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Storm-Petrel sp	Water	0	0	0	0	0	0	0	
	Flight	0	1	0	0	0	0	1	100
Double-crested Cormorant	Water	0	0	2	0	0	0	2	
	Flight	0	0	0	0	0	0	0	0
Pelagic Cormorant	Water	0	0	3	0	0	0	3	
	Flight	0	0	0	0	0	0	0	0
Brandt's Cormorant	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Comorant sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Great Blue Heron	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Bald Eagle	Water	0	0	0	0	0	0	0	
	Perched	0	0	0	0	0	0	0	
Sandhill Crane		0	0	0	0	0	0	0	
Belted Kingfisher		0	0	0	0	0	0	0	
Totals		211	449	382	445	362	126	1975	

Marine Mammals							
Sea Otter	1	0	0	0	0	0	1
Harbour Seal	0	1	0	0	0	1	2
Steller Sealion	1	0	0	0	0	0	1
Harbour Porpoise	0	4	3	0	0	0	7
Dall's Porpoise	0	0	4	0	0	0	4
Porpoise sp	0	0	0	0	0	3	3
Orca	3	0	0	0	0	0	3
Minke Whale	0	0	0	0	0	0	0
Humpback Whale	0	5	0	0	0	0	5

Appendix 3. All counts on transect in Survey 3, by zone, and proportions (%) in flight (based on survey totals)

Species	Water/Flight	Zone						Totals	% in flight
		Outer off	Inner off	Corm Chan	CC, coast	John Str	JC, coast		
Canada Goose	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	1	1	100
Greater WF Goose	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Goose sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Harlequin Duck	Water	0	0	1	1	0	0	2	
	Flight	0	0	2	4	0	0	6	75
Barrow's Goldeneye	Water	0	0	0	0	1	0	1	
	Flight	0	0	0	0	0	0	0	0
Surf Scoter	Water	2	0	0	1	0	0	3	
	Flight	18	0	12	6	35	0	71	96
White-winged Scoter	Water	0	0	2	2	0	0	4	
	Flight	0	0	3	1	0	0	4	50
Black Scoter	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Scoter sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Common Merganser	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	19	0	19	100
Red-breasted Merganser	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Northern Pintail	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Northern Shoveler	Water	0	0	0	0	0	0	0	
	Flight	0	11	0	0	0	0	11	100
American Wigeon	Water	0	46	0	0	0	0	46	
	Flight	0	0	0	0	0	0	0	0
Dabbling duck'	Water	0	0	0	0	15	0	15	
	Flight	0	0	5	0	0	0	5	25
Black Oystercatcher	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	2	0	2	100
Red-necked Phalarope	Water	1	3	20	0	15	0	39	
	Flight	7	0	6	0	0	0	13	25

Common Murre	Water	234	205	459	53	65	0	1016	
	Flight	1	3	0	0	0	0	4	0
Pigeon Guillemot	Water	1	0	12	30	2	1	46	
	Flight	0	0	0	0	0	0	0	0
Ancient Murrelet	Water	0	13	5	0	1	0	19	
	Flight	0	3	0	0	0	0	3	14
Rhinoceros Auklet	Water	0	18	55	4	43	3	123	
	Flight	1	3	1	0	3	0	8	6
Marbled Murrelet	Water	0	16	0	1	2	0	19	
	Flight	0	2	0	0	0	0	2	10
Cassin's Auklet	Water	0	2	1	0	0	0	3	
	Flight	0	4	0	1	0	0	5	63
Alcid sp	Water	0	1	0	1	0	0	2	
	Flight	1	1	0	0	0	0	2	50
Parasitic Jaeger	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	2	0	2	100
Jaeger sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
California Gull	Water	4	80	21	75	67	43	290	
	Flight	10	31	24	8	47	7	127	30
Glaucous-winged Gull	Water	1	4	10	5	8	3	31	
	Flight	17	5	5	0	18	4	49	61
Thayer's (Iceland) Gull	Water	0	1	0	0	1	3	5	
	Flight	0	0	0	0	1	1	2	29
Ring-billed Gull	Water	0	0	0	0	0	0	0	
	Flight	0	2	0	0	0	0	2	100
Herring Gull	Water	2	1	0	0	0	0	3	
	Flight	0	5	0	0	0	0	5	63
Mew Gull	Water	0	2	4	24	9	1	40	
	Flight	0	0	14	6	3	0	23	37
Bonaparte's Gull	Water	0	0	0	0	1	0	1	
	Flight	0	1	0	0	0	0	1	50
Black-legged Kittiwake	Water	0	2	1	0	31	0	34	
	Flight	1	3	3	0	32	4	43	56
Gull sp.	Water	0	0	0	0	1	0	1	
	Flight	16	1	14	6	13	5	55	98
Common Loon	Water	0	0	3	7	2	0	12	
	Flight	0	0	0	0	0	0	0	0
Pacific Loon	Water	0	2	0	8	5	0	15	
	Flight	2	8	1	0	0	0	11	42

Red-throated Loon	Water	0	0	0	0	0	1	1	
	Flight	0	0	0	0	1	0	1	50
Yellow-billed Loon	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Loon sp.	Water	0	0	0	1	0	0	1	
	Flight	0	0	0	0	0	0	0	0
Red-necked Grebe	Water	0	0	2	52	0	0	54	
	Flight	0	2	0	0	0	0	2	4
Western Grebe	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Horned Grebe	Water	0	0	0	1	0	0	1	
	Flight	0	0	0	0	0	0	0	0
Sooty Shearwater	Water	0	7	5	0	179	0	191	
	Flight	2	7	11	0	68	0	88	32
Fork-tailed Storm-Petrel	Water	3	0	0	0	0	0	3	
	Flight	29	2	1	0	3	1	36	92
Leach's Storm-Petrel	Water	2	0	0	0	0	0	2	
	Flight	3	0	0	0	0	0	3	60
Storm-Petrel sp	Water	0	0	0	0	0	0	0	
	Flight	2	0	0	0	0	0	2	100
Double-crested Cormorant	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	2	0	0	2	100
Pelagic Cormorant	Water	0	1	3	0	1	0	5	
	Flight	1	2	2	0	0	0	5	50
Brandt's Cormorant	Water	0	0	0	0	1	0	1	
	Flight	0	0	0	0	2	0	2	67
Comorant sp	Water	0	0	5	0	0	2	7	
	Flight	0	0	1	0	0	0	1	13
Great Blue Heron	Water	0	0	0	1	1	0	2	
	Flight	0	0	1	0	0	0	1	33
Bald Eagle	Water	0	0	0	0	1	0	1	
	Perched	0	0	0	1	2	1	4	
Sandhill Crane		0	0	0	0	0	0	0	
Belted Kingfisher		0	0	0	0	0	1	1	
Totals		361	500	715	302	703	82	2663	

Marine Mammals							
Sea Otter	0	0	0	0	0	0	0
Harbour Seal	1	1	0	0	3	0	5
Steller Sealion	0	0	0	0	5	5	10
Harbour Porpoise	4	0	0	0	0	0	4
Dall's Porpoise	0	3	0	0	2	0	5
Porpoise sp	0	0	0	0	0	0	0
Orca	0	0	0	0	0	0	0
Minke Whale	0	0	0	0	0	0	0
Humpback Whale	0	1	0	0	4	0	5

Appendix 4. All counts on transect in Survey 4, by zone, and proportions (%) in flight (based on survey totals)

Species	Water/Flight	Zone						Totals	% in flight
		Outer off	Inner off	Corm Chan	CC, coast	John Str	JC, coast		
Canada Goose	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Greater WF Goose	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Goose sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Harlequin Duck	Water	0	0	1	0	0	5	6	
	Flight	1	1	0	5	0	2	9	60
Barrow's Goldeneye	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Surf Scoter	Water	0	0	3	100	60	0	163	
	Flight	1	12	0	4	143	5	165	50
White-winged Scoter	Water	0	0	0	35	0	0	35	
	Flight	0	16	5	1	3	0	25	42
Black Scoter	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Scoter sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Common Merganser	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Red-breasted Merganser	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Northern Pintail	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Northern Shoveler	Water	0	0	0	0	1	0	1	
	Flight	0	0	0	0	10	0	10	91
American Wigeon	Water	0	0	0	0	0	0	0	
	Flight	35	0	0	0	0	0	35	100
Dabbling duck'	Water	2	0	0	0	0	0	2	
	Flight	0	0	0	0	0	0	0	0
Black Oystercatcher	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Red-necked Phalarope	Water	7	53	0	0	0	0	60	

	Flight	0	14	0	0	1	0	15	20
Common Murre	Water	102	326	221	1	18	0	668	
	Flight	0	0	0	0	0	0	0	0
Pigeon Guillemot	Water	5	3	19	34	2	0	63	
	Flight	0	0	0	0	2	0	2	3
Ancient Murrelet	Water	0	23	0	0	3	0	26	
	Flight	0	0	0	0	0	0	0	0
Rhinoceros Auklet	Water	3	24	0	0	157	0	184	
	Flight	2	6	0	0	0	0	8	4
Marbled Murrelet	Water	0	39	0	0	21	20	80	
	Flight	0	2	0	0	0	0	2	2
Cassin's Auklet	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Alcid sp	Water	1	0	0	0	0	0	1	
	Flight	0	0	0	0	0	0	0	0
Parasitic Jaeger	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	2	0	2	100
Jaeger sp	Water	0	0	0	0	0	1	1	
	Flight	0	0	0	0	0	0	0	0
California Gull	Water	7	26	12	10	55	26	136	
	Flight	21	21	18	9	42	15	126	48
Glaucous-winged Gull	Water	5	11	74	4	21	11	126	
	Flight	12	11	7	4	60	5	99	44
Thayer's (Iceland) Gull	Water	0	2	2	0	26	13	43	
	Flight	1	1	1	2	21	3	29	40
Ring-billed Gull	Water	0	0	0	0	0	0	0	
	Flight	0	0	1	0	0	0	1	100
Herring Gull	Water	3	0	1	3	2	0	9	
	Flight	2	1	1	0	8	0	12	57
Mew Gull	Water	1	0	0	0	28	26	55	
	Flight	0	0	3	3	11	8	25	31
Bonaparte's Gull	Water	0	0	0	0	4	1	5	
	Flight	0	0	0	0	0	0	0	0
Black-legged Kittiwake	Water	0	3	0	0	14	3	20	
	Flight	0	15	0	0	39	7	61	75
Gull sp.	Water	0	3	14	0	27	0	44	
	Flight	7	5	10	1	10	5	38	46
Common Loon	Water	0	0	7	2	0	0	9	
	Flight	0	2	0	0	0	0	2	18
Pacific Loon	Water	3	20	2	0	0	0	25	

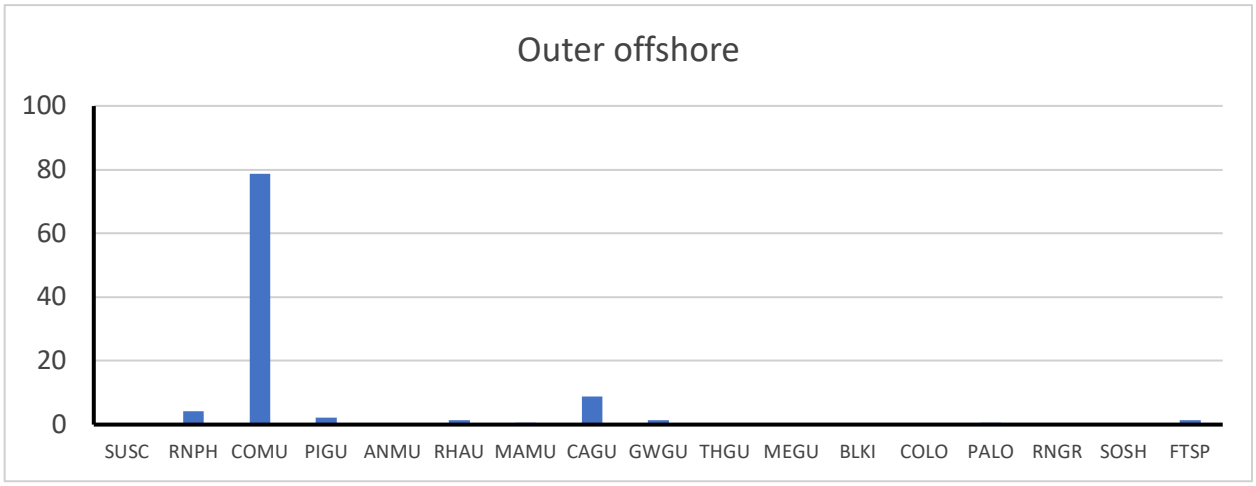
	Flight	13	8	1	2	5	0	29	54
Red-throated Loon	Water	0	2	0	0	0	0	2	
	Flight	0	0	0	0	1	0	1	33
Yellow-billed Loon	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Loon sp.	Water	1	0	0	0	0	0	1	
	Flight	1	2	2	0	2	0	7	88
Red-necked Grebe	Water	0	2	11	40	1	0	54	
	Flight	0	0	0	0	0	1	1	2
Western Grebe	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Horned Grebe	Water	0	0	0	7	0	0	7	
	Flight	0	0	0	0	0	0	0	0
Sooty Shearwater	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Fork-tailed Storm-Petrel	Water	2	1	0	0	0	0	3	
	Flight	1	0	0	0	1	0	2	40
Leach's Storm-Petrel	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Storm-Petrel sp	Water	0	0	0	0	0	0	0	
	Flight	0	0	0	0	0	0	0	
Double-crested Cormorant	Water	0	0	0	17	0	0	17	
	Flight	6	2	0	1	1	1	11	39
Pelagic Cormorant	Water	0	0	15	6	0	0	21	
	Flight	0	1	2	1	0	1	5	19
Brandt's Cormorant	Water	0	0	0	0	0	0	0	
	Flight	0	0	1	0	2	1	4	100
Comorant sp	Water	0	0	0	0	0	0	0	
	Flight	3	0	0	0	0	0	3	100
Great Blue Heron	Water	0	0	0	0	1	0	1	
	Flight	0	0	0	0	0	0	0	0
Bald Eagle	Water	0	0	0	0	0	0	0	
	Perched	0	1	0	0	0	0	1	
Sandhill Crane		0	0	0	0	0	0	0	
Belted Kingfisher		0	0	0	0	0	0	0	
Totals		248	659	434	292	805	160	2598	

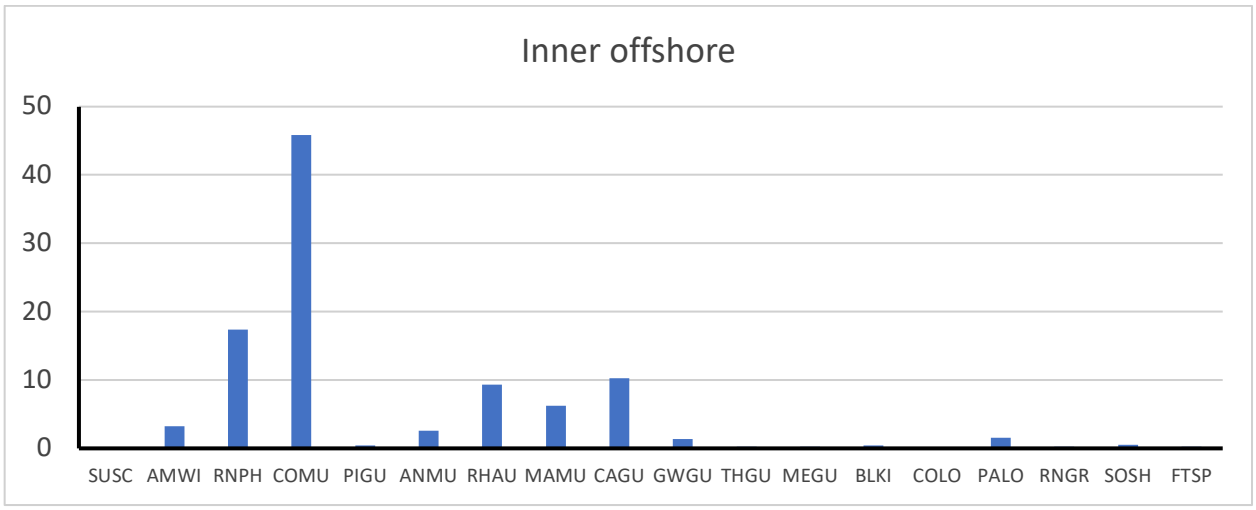
Marine Mammals							
Sea Otter	4	0	0	0	0	0	4
Harbour Seal	0	3	1	1	3	0	8
Steller Sealion	0	2	0	0	2	0	4
Harbour Porpoise	0	0	0	0	0	0	0
Dall's Porpoise	0	3	0	0	0	0	3
Porpoise sp	0	0	0	0	2	0	2
Orca	0	0	0	0	0	0	0
Minke Whale	0	0	1	0	0	0	1
Humpback Whale	0	0	0	0	0	0	0

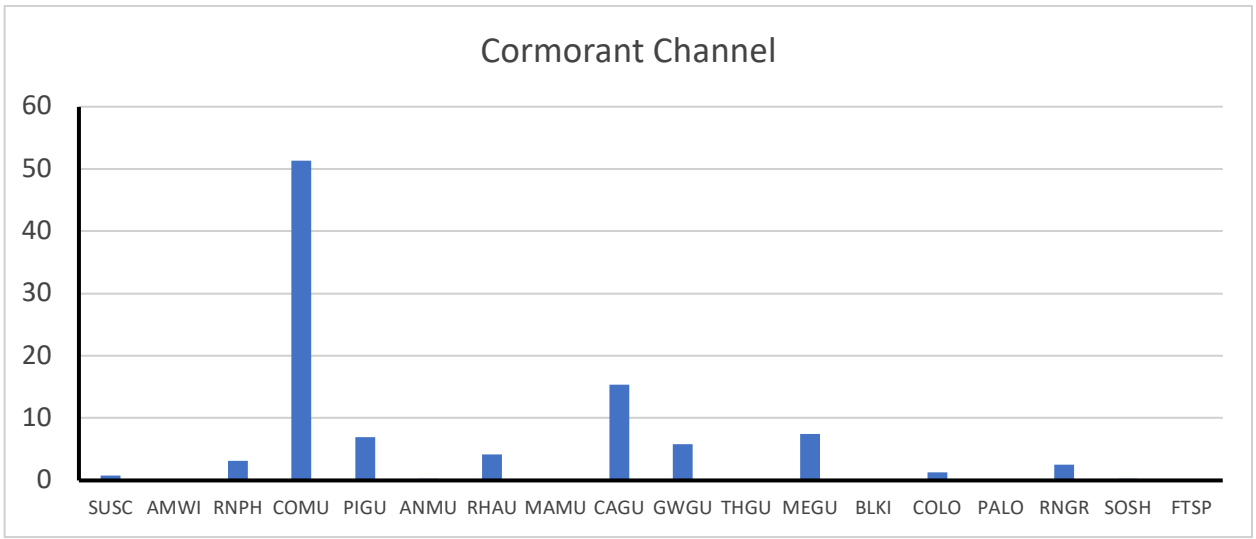
Appendix 5. Uncorrected estimates of total numbers present, by survey

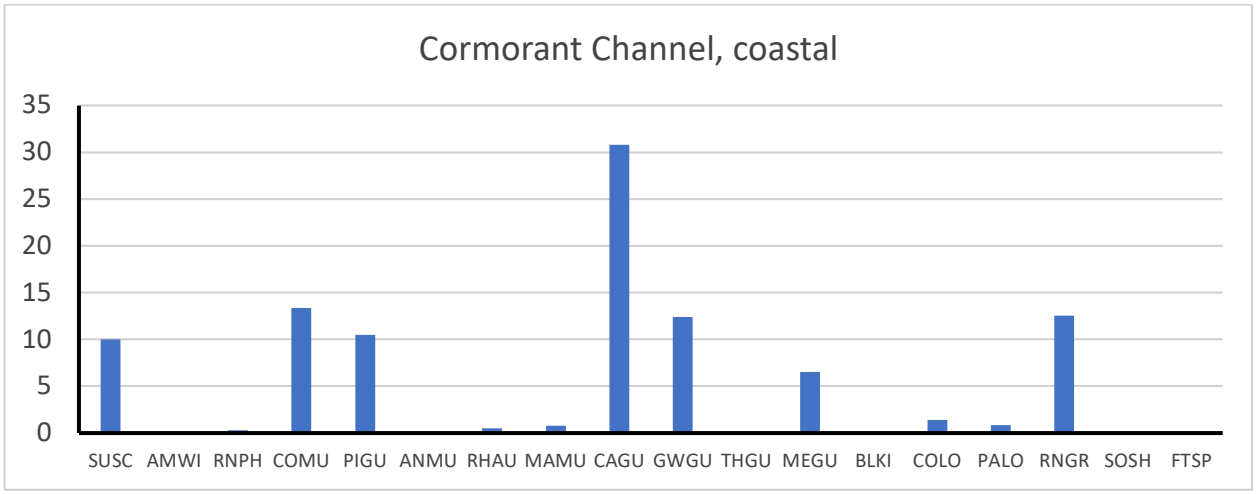
Species	Survey			
	1	2	3	4
Surf Scoter	0	0	0	1244
American Wigeon	0	0	1155	0
Red-necked Phalarope	2827	5620	0	1575
Common Murre	3968	7724	24841	17079
Pigeon Guillemot	984	1591	637	1131
Ancient Murrelet	0	0	326	578
Rhinoceros Auklet	2313	553	3187	2246
Marbled Murrelet	1087	149	402	1526
California Gull	7664	5544	6809	2293
Glaucous-winged Gull	0	1607	639	2682
Iceland (Thayer's) Gull	0	0	0	476
Mew Gull	2334	1226	744	1255
Black-legged Kittiwake	0	0	2542	971
Common Loon	0	0	93	169
Pacific Loon	0	0	50	606
Red-necked Grebe	373	704	694	498
Sooty Shearwater	0	0	7043	0
Fork-tailed Storm Petrel	32	1357	1163	0

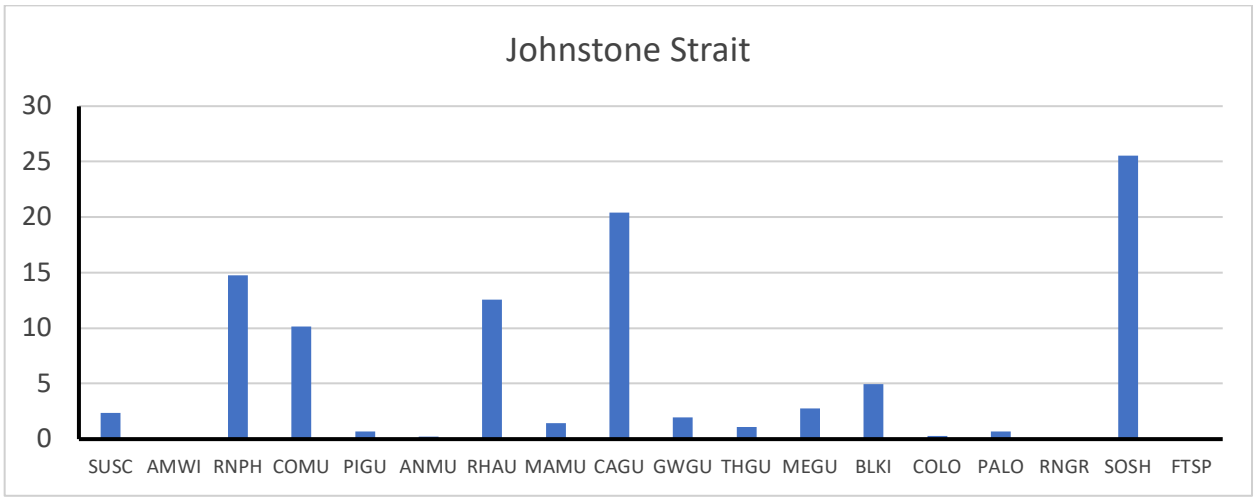
Appendix 6. Densities (birds/km^2) by zone for the 18 most abundant species on transects

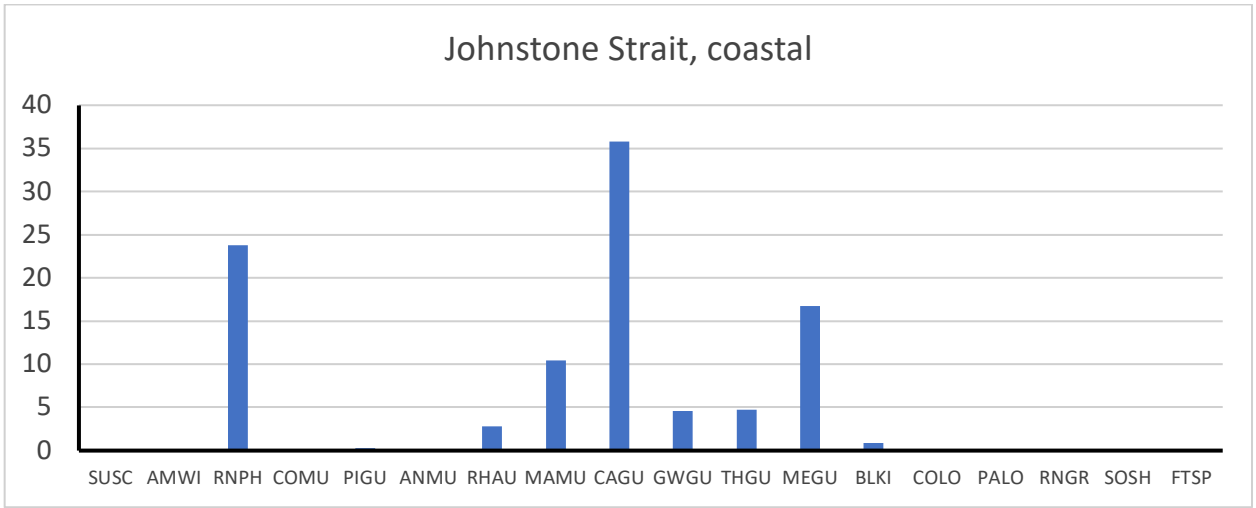







Cormorant Channel, coastal
35
30
25
20
15
10
5
0
SUSC AMWI RNPH COMU PIGU ANMU RHAU MAMU CAGU GWGU THGU MEGU BLKI COLO PALO RNGR SOSH FTSP


Johnstone Strait
30
25
20
15
10
5
0
SUSC AMWI RNPH COMU PIGU ANMU RHAU MAMU CAGU GWGU THGU MEGU BLKI COLO PALO RNGR SOSH FTSP


Johnstone Strait, coastal
40
35
30
25
20
15
10
5
0
SUSC AMWI RNPH COMU PIGU ANMU RHAU MAMU CAGU GWGU THGU MEGU BLKI COLO PALO RNGR SOSH FTSP