AUTUMN MARINE BIRD POPULATIONS IN QUEEN CHARLOTTE STRAIT AND ADJACENT WATERS: A CANDIDATE FOR IBA/KBA STATUS

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ABSTRACT

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Systematic transect surveys of marine birds in eastern Queen Charlotte Strait and the western part of Johnstone Strait, British Columbia, Canada, were made between mid-August and mid-October 2020–2022. All birds within 100-m transect strips were counted and numbers corrected for detectability. Extrapolating within five regions of differing ecological characteristics and seabird densities, our results indicate that the study area supported 1% or more of the North American populations of Pigeon Guillemot *Cepphus columba*, Marbled Murrelet *Brachyramphus marmoratus*, California Gull *Larus californicus,* Glaucous-winged Gull *L. glaucescens*, Iceland Gull *L. glaucoides*, and Short-billed Gull *L. brachyrhynchos*. Our estimation of gull species in our study area would have been even higher if gulls in flight had been included in our survey. Furthermore, maximum estimates of Common Murre *Uria aalge* exceed the total population breeding in British Columbia. Only Pigeon Guillemot, Marbled Murrelet, and Glaucous-winged Gull breed in Queen Charlotte Strait, and only Marbled Murrelet is considered to be "at risk." However, based on current criteria, it seems that the area would be a prime candidate for nomination as an International Union for Conservation of Nature (IUCN) Key Biodiversity Area.

Key words: conservation, distribution, migration, Important Bird and Biodiversity Area, Key Biodiversity Area, *Uria aalge*, *Cepphus columba*, *Brachyramphus marmoratus*, *Larus californicus*, *Larus glaucescens*, *Larus glaucoides*, *Larus brachyrhynchos*

INTRODUCTION

Key Biodiversity Areas (KBAs) have been adopted by a network of international organizations as a framework for identifying important biotic areas (IUCN 2016). As part of this global initiative, Birdlife International has developed a database of internationally important bird conservation areas based on their previous identification of Important Bird and Biodiversity Areas (IBAs), which are now transitioning to Key Biodiversity Areas (http://datazone.birdlife.org/site/ibacriteria). The main aim of the KBA program is to secure the long-term protection of sites that are of significant importance for biodiversity. To qualify for IBA/KBA status, a site designation must be based on robust data and the application of scientific criteria, such as the proportion of the global or regional population of each species using the site (Handley *et al*. 2022).

The waters of Queen Charlotte Strait (QC Strait) separate the northern part of Vancouver Island from the mainland of British Columbia (BC), Canada, and form a southward extension of Queen Charlotte Sound (Fig. 1). Anecdotal information from eBird indicates that eastern QC Strait supports a wide diversity of marine birds in winter and during the periods of northward and southward migration (eBird Canada, n.d.). In addition, the area is known to be important for marine mammals, as it is used regularly by northern resident Orcas *Orcinus orca*; Humpback *Megaptera novaeangliae* and Minke *Balaenoptera acutorostrata* whales; Dall's *Phocoenoides dalli* and Harbour *Phocoena phocoena* porpoises; Pacific White-sided Dolphins *Lagenorhynchus obliquidens*; and Sea Otters *Enhydra lutris*. The area also supports several permanent haul-outs of Steller Sea Lions *Eumetopias jubatus* (Ford 2014).

Extensive surveys of seabirds in BC waters have been published previously, some covering small areas over limited time periods (e.g., Guzman & Myres 1983, Hay 1992, Burger *et al*. 2002, 2008) and some including 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). However, none of those surveys sampled the inner part of QC Strait, and no systematic surveys of marine birds in QC Strait have been published to date. The surveys of Kenyon *et al*. (2009) covered the area only in spring (15 March–15 June), and Fox *et al*. (2017) included transect counts within QC Strait in spring (April–June) and fall (October–November), but coverage was sparse and did not include some of the most promising areas for marine birds. Widespread and intensive surveys for Marbled Murrelets *Brachyramphus marmoratus*, some of which touched eastern QC Strait, were mostly carried out in July (D.F. Bertram unpubl. data).

The west end of the QC Strait, close to where it widens into QC Sound, is dotted with numerous islands. Some of these islands 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 the Storm Islands (about 250 000 pairs of storm petrels and 72 000 pairs of Rhinoceros Auklets). The western part of QC Strait is estimated to hold 37% of British Columbia's Fork-tailed Storm Petrels *Hydrobates furcata*, 53% of Leach's Storm Petrels *H. leucorhous*, and 45% of Rhinoceros Auklets (Rodway *et al*. 2016). There

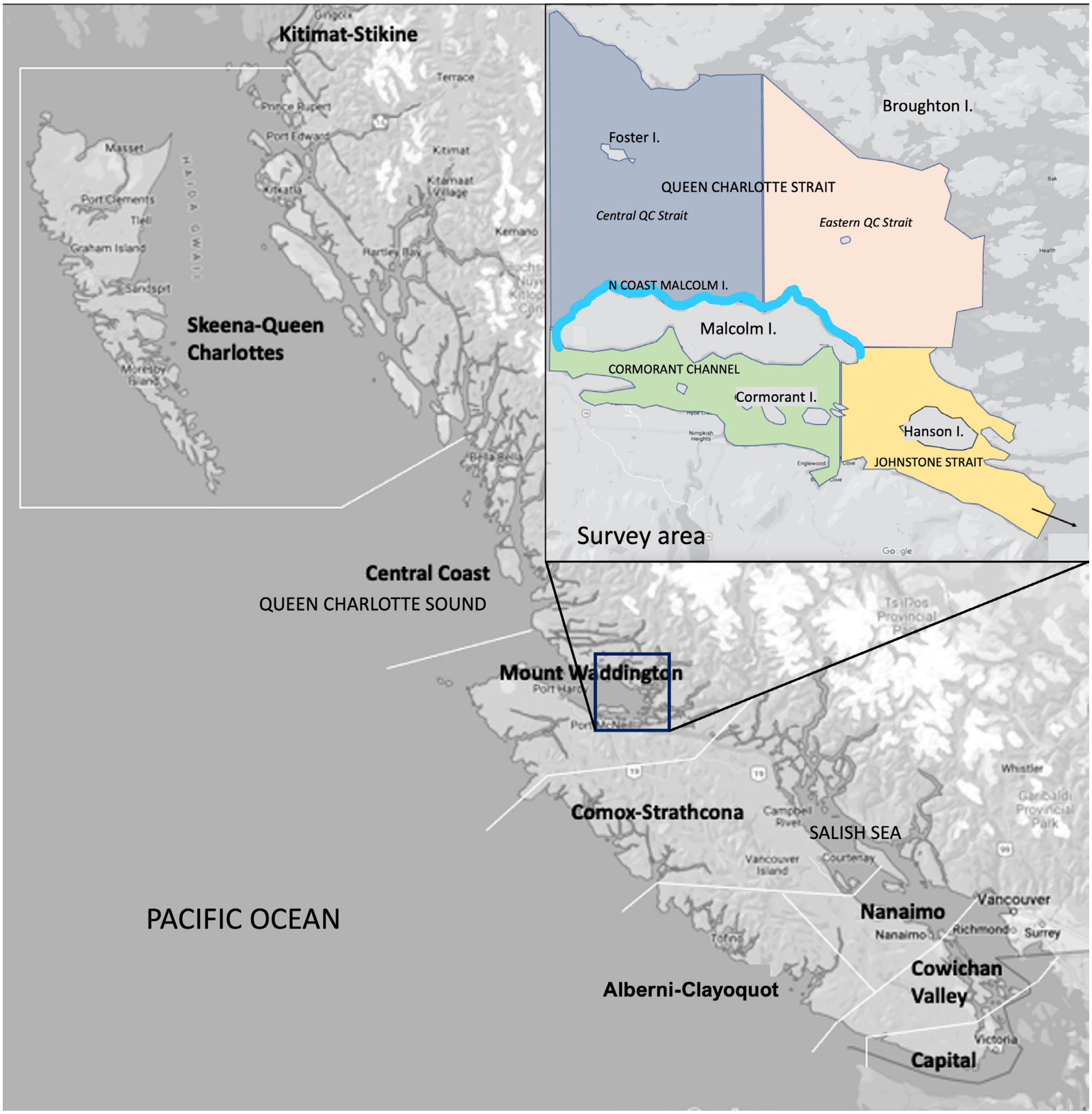

Fig. 1. Coastal British Columbia, Canada, showing the position of the study area (inset) and extent of coastal counties (boldface, used in eBird analyses). The five zones used for population estimation are colour-coded: grey, Central Strait; salmon, Eastern Strait; blue, north coast Malcolm Island; green, Cormorant Channel; yellow, Johnstone Strait (including Blackfish Sound).

is also a colony of several thousand pairs of Cassin's Auklets *Ptychorhamphus aleuticus* on the Buckle Group (listed as a Species of Special Concern under Canada's Species at Risk Act, Rodway *et al*. 2020). However, no burrow-nesting auks, storm petrels, or other colonial seabirds are known to breed east of Numas Island in the central part of the Strait (Rodway & Lemon 1991). There are, however, small numbers of Pigeon Guillemots *Cepphus columba* and Glaucous-winged Gulls *Larus glaucescens* scattered on islets throughout the Strait.

At its eastern end, QC Strait divides into several channels that separate the islands of the Broughton Archipelago and, further east, the Discovery Islands. These channels, the most important of which is Johnstone Strait, connect QC Strait to the partially enclosed waters of the Salish Sea (Fig. 1). Consequently, some species breeding north of Vancouver Island and wintering in the Salish Sea and southwards use QC Strait and associated channels to migrate southwards along the east coast of Vancouver Island.

Preliminary observations in 2016 and 2019 led AJG to conclude that, while the entire QC Strait was not exceptional in its marine bird populations, substantial concentrations of marine birds occurred in the inner part of the QC Strait and at the western end of Johnstone Strait. The high concentration of seabirds in these areas, in addition to the large number of marine mammals present, highlighted the QC Strait and adjacent waters as possible candidates for IBA/KBA status. However, the relevant survey data to establish avian population estimates was lacking. This paper presents the results of systematic surveys carried out in August–September 2020, September–October 2021, and September 2022, with a view to providing suitable seabird population estimates, as well as augmenting information on migration timing for species migrating through the area. The overall goal is to provide data in support of the designation of the QC Strait and adjacent waters as an IBA/KBA.

METHODS

Geographical setting

Most of eastern QS Strait is < 200 m deep, lacking major underwater canyons. To the east of QC Strait is an anastomosing system of sounds and inlets embracing the largely uninhabited Broughton Archipelago and, further east, the Discovery Islands. The narrow channel of Johnstone Strait leads eastwards from the southeastern corner of QC Strait and is considerably deeper than anywhere in QC Strait, reaching > 400 m (Fig. 2, Thompson 1981). It connects to QC Strait via Blackney Passage and Blackfish Sound, to the north and east of Hanson Island, and via Weynton Passage to the west. It also extends westwards via Cormorant Channel to the south of Malcolm Island, which is mostly < 100 m deep. The bathymetry of Weynton Passage is variable, with numerous reefs and sills creating strong currents and extreme turbulence at certain states of tide. According to Thompson (1981, pp. 202–203):

> "As the region is characterized by rapid tidal streams, constricted passages, and numerous shallow sills, the water is in almost constant agitation from top to bottom and never has the opportunity to settle into strongly stratified layers.... Therefore, water temperatures increase very slightly inward [eastward] along Johnstone Strait and remain low throughout the year. At the height of summer heating in late July, for example, temperatures of the surface water are usually colder than 10 °C, which is appreciably colder than the contemporary values of over 20 °C in the central portion of the Strait of Georgia [Salish Sea]. Even the oceanic surface waters of Queen Charlotte Sound are warmer in summer than those in Johnstone Strait. (This cold surface water is a principal reason for the common occurrence of summer fogs in the area.) Particularly vigorous tidal mixing occurs throughout the year in such areas as Seymour Narrows, Race Passage, and Weynton Passage."

Shorelines within our survey area vary from rocky and steep to muddy and gently shelving. For the most part, the shorelines of Johnstone Strait, Broughton Archipelago, and north side of the QC Strait are rocky, with the 50–m isobath within 150 m of the shore (Canadian Hydrographic Service 2005). In Cormorant Channel, large areas of gently sloping intertidal mud and sand surround the mouth of the Nimpkish River, extending up to 1.5 km from the shore. Similarly gently sloping intertidal areas around Malcolm Island are mainly stony and boulder-strewn. The only town in the area is Port McNeill (population 2300).

Field methods

We carried out surveys in August and September 2020, September and October 2021, and September 2022. In each year, surveys were spaced at approximately two-week intervals, starting on 16 August 2020, 13 September 2021, and 14 September 2022. Each survey consisted of a series of parallel transects, running north–south across the major channels, from the western end of Malcolm Island to just west of the Robson Bight Ecological Reserve in Johnstone Strait (Fig. 3). These north–south transects are referred to as "open water" transects. Between the ends of transects, we followed the shoreline approximately 0.2–0.5 km from the water's edge. Observations on these inter-transect journeys were identical to

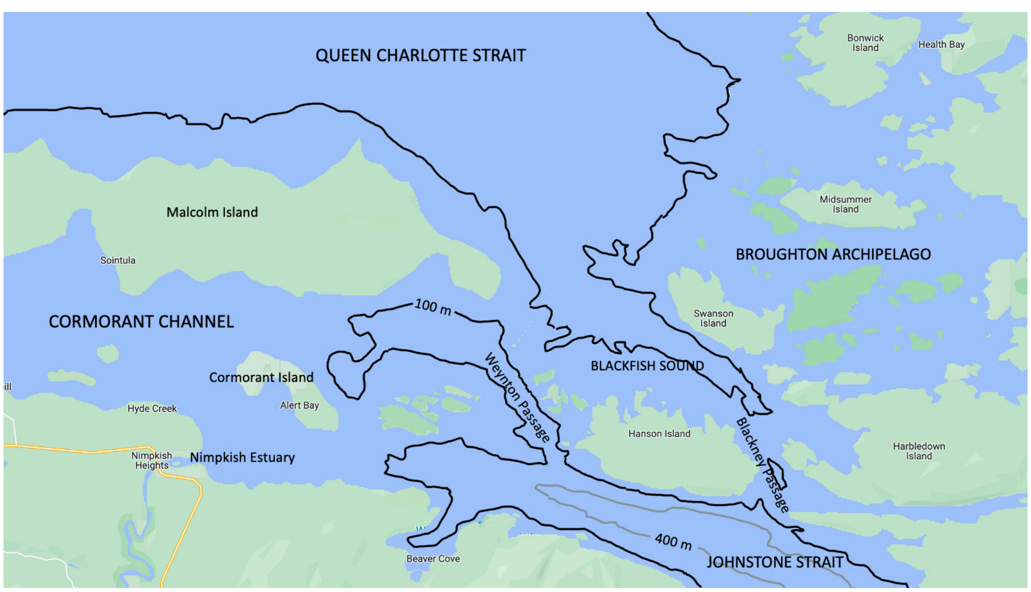

Fig. 2. Bathymetry of the southeastern portion of the study area, including Queen Charlotte Strait, Cormorant Channel, Johnstone Strait, Broughton Archipelago, and Blackfish Sound, in British Columbia, Canada.

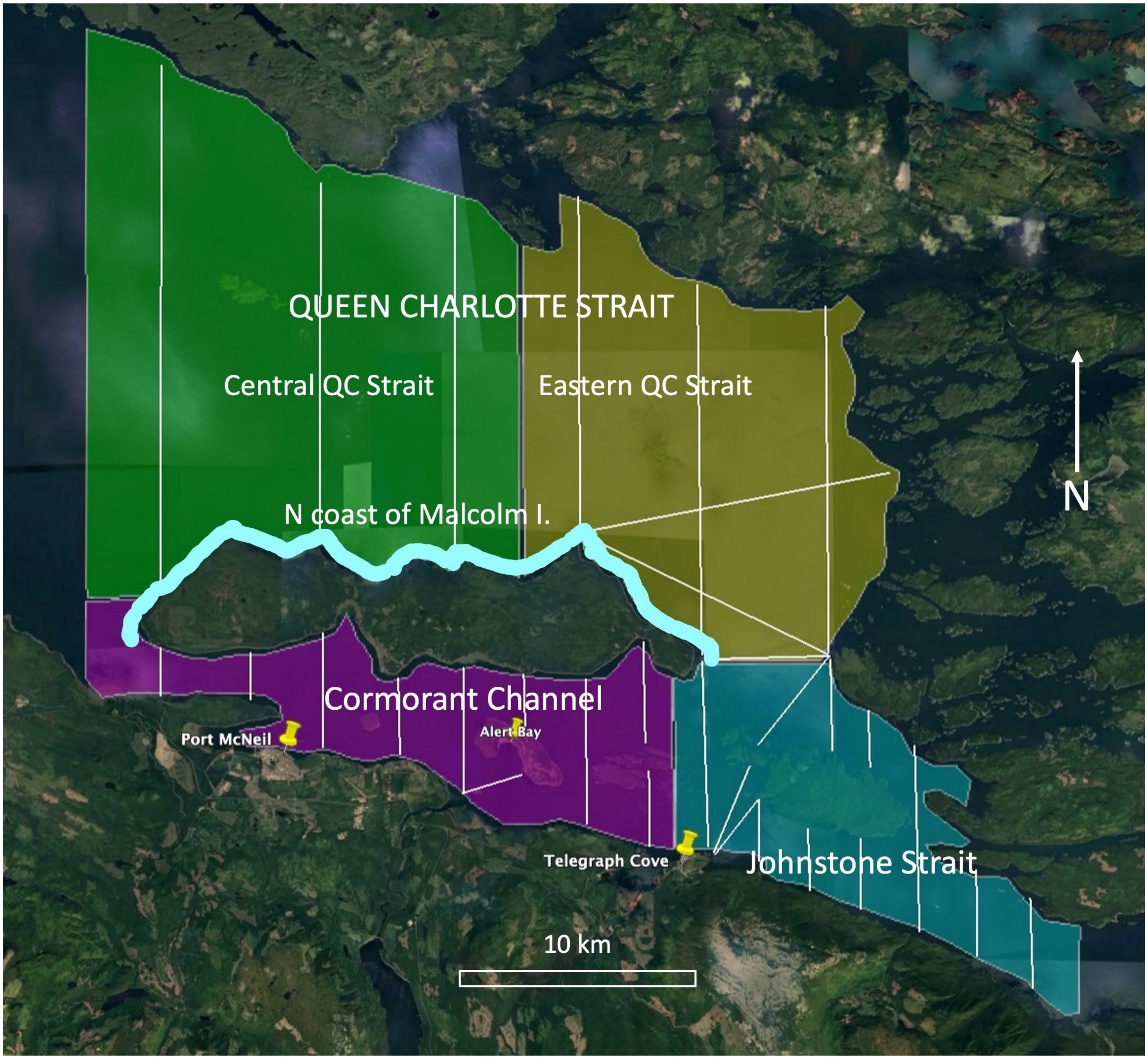

Fig. 3. Position of survey zones (coloured polygons) and open water transects (white lines) in the study area off the coast of British Columbia, Canada.

those on linear transects but were analysed separately to provide a sample of birds using "coastal" habitat. Coastal transects were run throughout Cormorant Channel and Johnstone Strait, and along the north coast of Malcolm Island. However, in the northern part of QC Strait, we travelled from point to point without following the shoreline to conserve time and fuel. These transects, during which birds were counted as on the open-water transects, were not included in analyses of coastal transects. Surveys spanned two or three days, but we allowed four days for each survey assuming that a proportion of days would be unsuitable for surveying, either because of fog, rain, or sea conditions.

We carried out four surveys in 2020, three in 2021, and two in 2022, using an open, 6.4-m, rigid-hull inflatable boat powered by a 150 horsepower outboard motor. Survey speed was determined by the minimum planing speed for the vessel, which was about 14.5 knots (26.9 km/h; range 13.5–16 knots or 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 occasionally to investigate feeding or roosting flocks, restarting the transect at the point where we broke off. The flocks that were investigated were not included in transect results but were reported separately to eBird (eBird Canada, n.d.). Navigation was performed with a global positioning system (GPS) chartplotter in which all transect start/end points had been previously entered and via which we maintained our course.

North of Malcolm Island and east to the Broughton Islands, transects were 5–7 km apart and were adjusted to avoid close approach to islands, with the most westerly transect being 1 km further from the adjacent transect to better incorporate the central reach of QC Strait. In Cormorant Channel south of Malcolm Island, transects were 3 km apart. Within areas east of Malcolm Island, including Weynton Passage, Blackfish Sound, and the western end of Johnstone Strait, transects were 2.5 km apart (Fig. 3). Open water transects began and ended approximately 200 m from shore, except for two transects that terminated in the mouth of large bays. Individual surveys included 170–247 km of open water transects and 48–65 km of shoreline transects, with total transect lengths ranging 227 to 310 km for individual surveys (Appendix 1, available online). When including travel time to and from start and end-points, the total boat time for each survey was 15–20 h.

Two observers, seated in the center of the boat and facing ahead with an unobstructed view both forward and in an arc about 120° to each side, watched continuously throughout the transects, observing a 100-m strip on either side of the route. When seated, observer's heads were about 1.5 m above water level. Observers used 8× or 10× binoculars, or the naked eye, to identify birds. A third observer, who was also the boat driver, contributed birds missed by the primary observers (these instances were few). 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 30–60 min to avoid observer fatigue. All observers were experienced ornithologists with ample prior experience identifying seabirds 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.

Environmental variables recorded at the start of each transect were 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 ~100 m or when the sea state was estimated to be > 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 on the basis of weather and sea conditions to optimize conditions for observations, maximise the transect time, and minimise non-transect travel. Because the order of transects varied, the samples of shorelines surveyed between open-water transects varied among surveys.

Observers reported the species and numbers of birds seen within the transect, noting 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 within transects were also recorded. Each transect was started at the beginning of a 1-min period, and the recorder assigned each observation to a 1-min interval during which the boat covered approximately 450 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). We deemed that, given the densities we expected to encounter, and at the boat speeds we were using, this procedure would be too taxing on the observers and recorder. Likewise, with observers relatively low to the water, it was not considered feasible to use distance sampling, which would have required the estimation of several distance zones (e.g., Ronconi & Burger 2009). In 2020, all *Ardenna* shearwaters seen were identified as Sooty Shearwater *A. grisea* because Short-tailed Shearwater *A. tenuirostris* had not been recorded in the area previously and because all observed birds corresponded to the usual impression of *A. grisea*. Subsequent analysis of photographs taken in 2020 of 110 birds confirmed that many of those seen were *A. grisea* and no definite identifications of *A. tenuirostris* were found. However, in 2021, there was an unprecedented influx of Short-tailed Shearwaters in our study area, as well as in the Salish Sea (Gaston *et al*. 2022). Because we did not seriously consider the presence of *A. tenuirostris* in 2020, we cannot exclude the possibility that some Sooty Shearwaters recorded in 2020 were actually Short-tailed Shearwaters.

Analysis

For analysis, all non-shoreline transects were lumped into five zones (Fig. 3: Central QC Strait, Eastern QC Strait, Cormorant Channel, Johnstone Strait, and north shore of Malcolm Island). For the Cormorant Channel and Johnstone Strait zones, we analysed open-water and shoreline transects separately. When estimating bird densities away from shorelines in all zones, we omitted the first and last 1-min periods of each transect. Therefore, given boat speed, the open-water transects only 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 500 m from shore.

We compared surveys to determine migration timing by summing all birds seen on-transect, including those on the water and in flight. The relationship between the number of birds counted in flight and actual density in the area sampled is a complex function of flight speed and direction relative to boat speed (Gaston *et al*. 1987), and it requires correction to determine the actual number of birds present (Spear *et al*. 1992). However, for this analysis, we assumed that flight speeds and directions were comparable among surveys and that boat speed was constant. Surveys in different years were assigned to one of five time periods: (1) mid-August, (2) late-August, (3) mid-September, (4) late September, and (5) mid-October.

For estimates of the total number of birds present in each zone, we used only birds seen on the water, including those first detected on the water but that later took off, and those that landed within the transect while under observation. We included flying birds in the case of storm petrels, using the rationale of Fox *et al*. (2017) and Ford *et al*. (2021) that storm petrels fly slowly and feed in flight. We did the same for Black-legged Kittiwakes *Rissa tridactyla*, which were also seen mainly in flight. Analysis of inter-year variation was carried out on raw counts of the sum of birds flying and on the water using one-way analysis of variance (ANOVA).

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

$$Dx.z = \sum_{t=1} C \,/\, \sum_{t=1} 0.2L$$

Where $Dx.z$ = density of species x (birds/km^2) in zone z, 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 was estimated by:

$$Dx.z \text{ * the area of the zone (km}^2\text{)}$$

To adjust observed densities for detectability, we also 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), are given in Appendix 2 (available online).

Survey observations were augmented by reference to eBird records for the region (eBird Canada, n.d.; see Sullivan *et al*. 2009 for further details of eBird records). All transect data are archived with the North Pacific Pelagic Seabird Database (Drew *et al*. 2005).

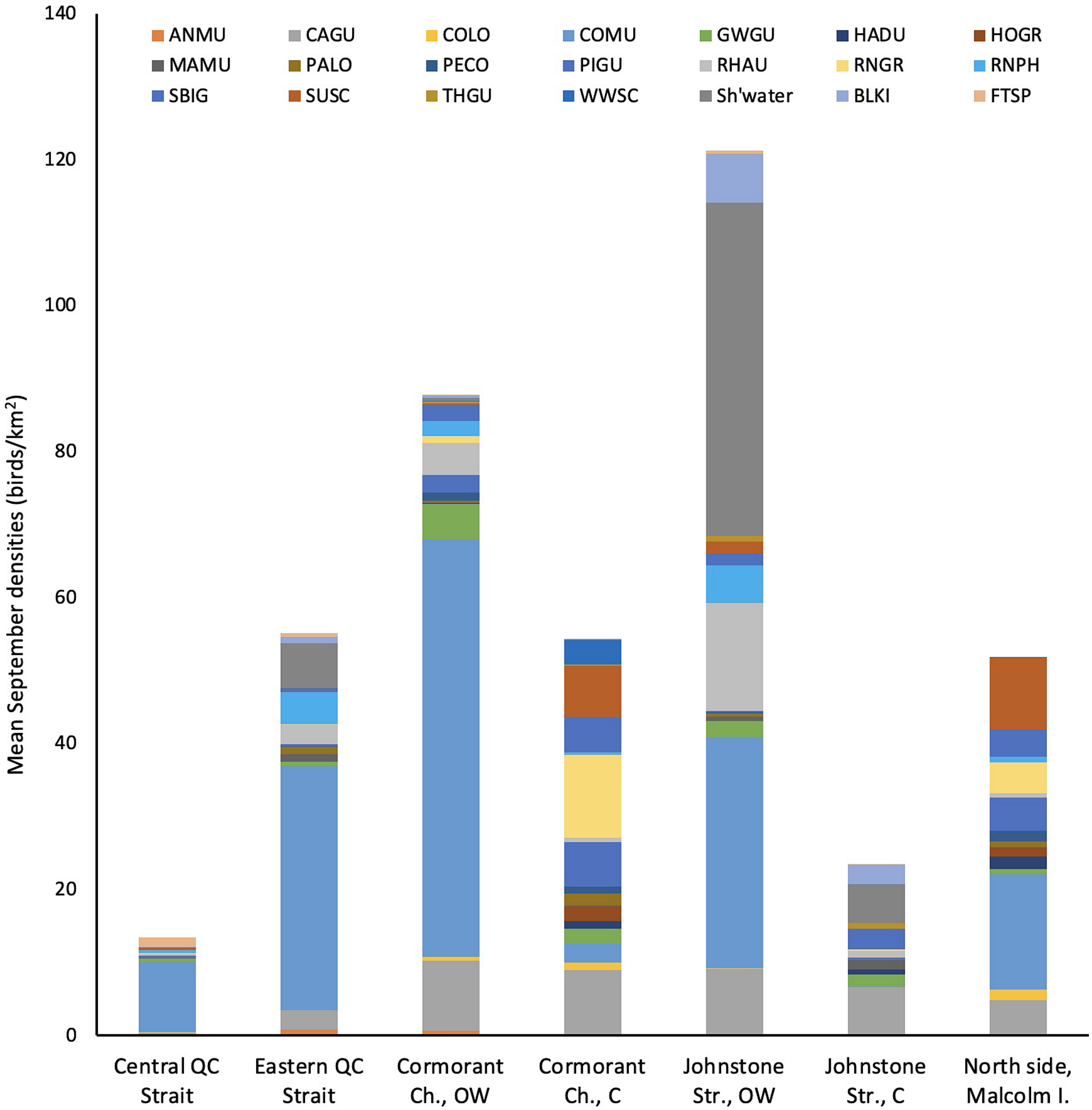

Fig. 4. Densities of the most common species recorded during surveys in the study area by zone, showing the average of September surveys over all three years. Note that "Sh'water" combines all Sooty *Ardenna grisea* and Short-tailed *A. tenuirostris* shearwaters. Densities for Black-legged Kittiwakes *Rissa tridactyla* and Fork-tailed Storm Petrels *Hydrobates furcata* are based on all birds seen, whether flying or on the water. All other species' densities are based only on birds counted on the water. For acronyms, see Table 2. OW = open water; C = coastal.

RESULTS

Fifty-six species of waterbirds were identified, but many were seen infrequently and in small numbers. Twenty-eight species were identified on survey transects in all three years, with > 100 birds counted for all but eight species. On surveys in August (two in 2020), the most common species were California Gull *L. californicus* (mean/survey 990), Red-necked Phalarope *Phalaropus lobatus* (mean 847), and Common Murre *Uria aalge* (mean 460). In September (two surveys in all three years), the most common species were Common Murre (mean 1288), Short-tailed Shearwater (mean 495), and California Gull (mean 364). In contrast, the most common species in the single mid-October survey were Common Murre (790), Surf Scoter *Melanitta perspicillata* (419), and White-winged Scoter *Melanitta deglandi* (345). Only the Short-tailed Shearwater (absent in 2020 and 2022, and the most numerous species recorded in 2021; $F_5 > 50$), Horned Grebe *Podiceps auritus* (very few in 2020; $F_5 = 45.8$), Red-necked Phalarope (scarce in 2022; $F_5 = 11.0$), and Marbled Murrelet (abundant in 2020, scarce in 2021 and 2022; $F_5 = 6.2$) showed significant ($P < 0.05$) inter-year variation in September counts.

Distribution by zones

To compare bird densities among regions, we used data from 13 September–02 October, as two surveys were available for this period in each of the three years of study. Mean densities of all species combined were highest in the open water of Johnstone Strait (121 birds/km^2) and Cormorant Channel (88 birds/km^2), and they were lowest in central QC Strait (14 birds/km^2) and coastal Johnstone Strait 24 birds/km^2). The highest-density species in the two QC Strait zones—the open water of Cormorant Channel and the north side of Malcolm Island—were Common Murres. However, the highest-density species in coastal Cormorant Channel was the Red-necked Grebe *Podiceps grisegena*, whereas the highest-density species in the open waters of Johnstone Strait and the coastal Johnstone Strait were shearwaters and California Gulls, respectively (Fig. 4).

The Fork-tailed Storm Petrel was the only species reaching its highest density in the Central QC Strait zone, while the Ancient Murrelet *Synthliboramphus antiquus* was densest in eastern QC Strait (Table 1). Surf Scoter, Pigeon Guillemot *Cepphus columba,* California Gull, and Glaucous-winged Gull were densest in the coastal strip of Cormorant Channel. The Iceland (Thayer's) Gull *L. glaucoides thayeri* was densest in the coastal strip of Johnstone Strait (Fig. 4). Red-necked Phalarope, Rhinoceros Auklet, Black-legged Kittiwake, and *Ardenna* shearwaters were densest in the open waters of Johnstone Strait. Lastly, Common Murre, Short-billed Gull *Larus brachyrhynchos*, Common Loon *Gavia immer*, and Red-necked Grebe were densest in the open waters of Cormorant Channel.

Total number of birds present

An estimate of the total number of birds present was made separately for each zone. For each estimate, we only included species if they occurred in the zone in more than four 1-min periods during the surveys. Assessments were made for 20 species, all North American breeders, and for one genus (*Ardenn*a), a non-breeding visitor from the southern hemisphere (Table 2).

Common Murre

The most common species recorded on all but two surveys was the Common Murre, with uncorrected estimates for the entire area ranging from 4028 in mid-August 2020 to 26 108 in mid-September 2021, 26 470 in late September 2021, and 28 956 in mid-September 2022. The mean number of Common Murre in September surveys was 20 991 ($n = 6$), with a corrected mean of 39 089 (Table 3). In the August surveys, parent-chick pairs were evident, with juveniles begging actively, but we could not determine what proportion of birds counted were juveniles. We saw very few Common Murres flying during our surveys (< 2% of those counted), suggesting that many adults were in wing moult at the time.

Other auks

Like murres, the other auks were recorded predominantly on the water (> 90%). Maximum corrected estimates for Marbled Murrelet and Pigeon Guillemot exceeded the KBA threshold values (Table 3). Numbers of Pigeon Guillemots greatly exceeded the size of local breeding populations (< 500, Rodway & Lemon 1991, Rodway *et al*. 2016), although this is a notoriously difficult species to census (Rodway *et al*. 2016). However, our corrected estimate (mean 1542, Table 3) strongly indicates that bird movement into inner QS Strait, especially into Cormorant Channel, occurs post-breeding. Some auks may originate from as far away as the Farallon Islands (Johns & Warzybok 2022).

Sea ducks

The highest numbers of sea ducks (Harlequin Duck *Histrionicus histrionicus*, Surf Scoter, and White-winged Scoter) were recorded in the coastal waters of Cormorant Channel and the north coast of Malcolm Island (Fig. 4, Fig. 5). The detection-corrected maximum estimate for White-winged Scoter exceeded the KBA threshold (Table 3). Given that 42% of those seen were in flight and, therefore, did not contribute to our estimates, numbers relative to the KBA threshold must have been substantially higher.

Loons and Grebes

The highest numbers of Common Loon, and Red-necked and Horned grebes, occurred in coastal waters of Cormorant Channel, while the highest numbers of Pacific Loons *Gavia pacifica* occurred in eastern QC Strait. A high proportion of Pacific Loons (52%) were counted in flight, mostly away from coasts. Presumably, most of these birds were on migration. The proportions of other loons and grebes seen in flight were much smaller (9%–15%).

Gulls

California, Glaucous-winged, and Iceland (Thayer's) gulls were the most widely spread species within our study area. Substantial numbers occurred in all zones except central QC Strait and the north coast of Malcolm Island (Fig. 5). Our maximum corrected estimates for all these species, as well as for Short-billed Gull, exceed their KBA thresholds. Between 33%–41% of these species were in flight when recorded, so our estimates are highly conservative. None of the other common species exceeded their KBA thresholds.

Timing of arrival/passage

Among the 18 most numerous species, only two showed no trend in numbers over the dates spanned by the surveys: Pigeon Guillemot and Short-billed Gull (Fig. 6). In contrast, Rhinoceros Auklets fluctuated irregularly among surveys. Numbers of California Gulls and Red-necked Phalaropes were highest during surveys in August 2020, when these two species were the most numerous of all species counted. White-winged Scoter, Pacific Loon, Horned Grebe, Pelagic Cormorant *Urile pelagicus*, Iceland (Thayer's) Gull, and Black-legged Kittiwake were nearly or totally absent in August (Fig. 6). White-winged Scoter, Harlequin Duck, Horned Grebe, and Pelagic Cormorant showed peak numbers in October. All other species peaked in September.

TABLE 1
Zones of highest density for the 17 most widespread species encountered on surveys of Queen Charlotte Strait, British Columbia, Canada, during 13 September–01 October, averaged over 2020–2022, and average recorded maximum species density

Species	Acronym	Zone of highest density	Mean density in highest zone (birds/km^2)
Surf Scoter *Melanitta perspicillata*	SUSC	North side Malcolm Island	9.8
White-winged Scoter *Melanitta deglandi*	WWSC	Cormorant Channel, coastal	3.3
Harlequin Duck *Histrionicus histrionicus*	HADU	North side Malcolm Island	1.7
Common Loon *Gavia immer*	COLO	North side Malcolm Island	1.5
Pacific Loon *Gavia pacifica*	PALO	Cormorant Channel, coastal	1.6
Red-necked Grebe *Podiceps grisegena*	RNGR	Cormorant Channel, coastal	11.4
Horned Grebe *Podiceps auritus*	HOGR	Cormorant Channel, coastal	2.0
Ardenna spp.	Sh'water	Johnstone Strait, open water	45.7
Fork-tailed Storm Petrel *Hydrobates furcata*	FTSP	Central Queen Charlotte Strait	1.3
Pelagic Cormorant *Urile pelagicus*	PECO	North side Malcolm Island	1.4
Red-necked Phalarope *Phalaropus lobatus*	RNPH	Johnstone Strait, open water	5.1
Common Murre *Uria aalge*	COMU	Cormorant Channel, open water	57.2
Pigeon Guillemot *Cepphus columba*	PIGU	Cormorant Channel, coastal	6.1
Marbled Murrelet *Brachyramphus marmoratus*	MAMU	Johnstone Strait, coastal	1.3
Ancient Murrelet *Synthliboramphus antiquus*	ANMU	Eastern Queen Charlotte Strait	0.8
Rhinoceros Auklet *Cerorhinca monocerata*	RHAU	Johnstone Strait, open water	14.8
California Gull *Larus californicus*	CAGU	Cormorant Channel, open water	9.6
Glaucous-winged Gull *Larus glaucescens*	GWGU	Cormorant Channel, open water	4.9
Iceland (Thayer's) Gull *Larus glaucoides thayeri*	THGU	Johnstone Strait, coastal	0.7
Short-billed Gull *Larus brachyrhynchos*	SBIG	Cormorant Channel, coastal	4.8
Black-legged Kittiwake *Rissa tridactyla*	BLKI	Johnstone Strait, open water	6.7

TABLE 2
Estimates of bird numbers within the survey area, corrected for detectability, for the 20 most widespread species encountered on surveys of Queen Charlotte Strait, British Columbia, Canada, during 2020–2022, and maximum corrected estimates of the percentage of the Canadian Key Biodiversity Area (KBA) threshold[a]

Species	Uncorrected estimates		Detection-corrected estimates		Canada KBA threshold
	Mean	Max.	Mean	Max.	(max as % threshold)
Surf Scoter *Melanitta perspicillata*	839	2434	1488	4316	4700 (0.9)
White-winged Scoter *Melanitta deglandi*	**211**	**3035**	**374**	**5381**	**4000 (1.3)**
Harlequin Duck *Histrionicus histrionicus*	148	426	262	755	1700 (0.4)
Common Loon *Gavia immer*	162	253	302	471	11 000 (< 0.1)
Pacific Loon *Gavia pacifica*	431	1242	802	2313	8400 (0.3)
Red-necked Grebe *Podiceps grisegena*	905	1420	1685	2644	7400 (0.4)
Horned Grebe *Podiceps auritus*	135	387	251	721	2500 (0.3)
Fork-tailed Storm Petrel *Hydrobates furcate*	612	1383	1157	2614	> 10 000 (< 0.1)
Pelagic Cormorant *Urile pelagicus*	241	534	270	599	1400 (0.4)
Red-necked Phalarope *Phalaropus lobatus*	1861	7811	3518	14 766	25 000 (0.6)
Common Murre *Uria aalge*	20 991	28 956	39 089	53 922	74 000 (0.7)
Pigeon Guillemot *Cepphus columba*	**928**	**1667**	**1542**	**2769**	**2400 (1.2)**
Marbled Murrelet *Brachyramphus marmoratus*	**396**	**1526**	**749**	**2885**	**2600 (1.1)**
Ancient Murrelet *Synthliboramphus antiquus*	272	689	507	1283	10 000 (0.1)
Rhinoceros Auklet *Cerorhinca monocerata*	2600	3378	5039	6547	9000 (0.7)
California Gull *Larus californicus*	**3684**	**7719**	**6532**	**13 686**	**11 000 (1.2)**
Glaucous-winged Gull *Larus glaucescens*	**1286**	**2696**	**2280**	**4780**	**4400 (1.1)**
Iceland (Thayer's) Gull *Larus glaucoides thayeri*	**167**	**609**	**296**	**1080**	**840 (1.3)**
Short-billed Gull *Larus brachyrhynchos*	**1009**	**2735**	**1789**	**4849**	**3000 (1.6)**
Black-legged Kittiwake *Rissa tridactyla*	1032	2718	1830	4819	16 000 (0.3)

[a] All population estimates and thresholds are from Birds Canada (http://kba-maps.deanrobertevans.ca/Thresholds.html?, accessed 04 April 2023). Estimates for species exceeding the 1% KBA threshold are shown in boldface.

TABLE 3
Comparison of numbers of bird species from three studies involving repeat surveys during the fall migration period off the British Columbia coast[a]

	QC Strait surveys					Vermeer *et al.* 1989[b]					Burger *et al.* 2002[c]		
Species	**mid-Aug**	**late Aug**	**mid-Sept**	**late Sept**	**mid-Oct**	**09–18 Sept**	**22–24 Sept**	**06–08 Oct**	**10-21 Oct**		**Aug**	**Sept**	**Oct**
Surf Scoter *Melanitta perspicillata*	33	44	95	246	419						1	2	3
White-winged Scoter *Melanitta deglandi*	17	5	11	55	345						1	2	3
Common Loon *Gavia immer*	10	13	61	20	16						1	2	4
Pacific Loon *Gavia pacifica*	13	0	15	108	154	12	29	54	8		1	2	3
Red-necked Grebe *Podiceps grisegena*	31	79	124	97	117						1	3	2
Ardenna spp.	0	2	279	0	0	11 241	1202	363	1474		3.5	3.5	1
Fork-tailed Storm Petrel *Hydrobates furcate*	2	50	38	12	20	439	2	6	5		4	3	2
Pelagic Cormorant *Urile pelagicus*	7	7	43	37	82	32	73	93	3	*	1	2	4
Brandt's Cormorant *Urile penicillatus*	0	0	3	4	59						1	2	3
Red-necked Phalarope *Phalaropus lobatus*	789	904	127	211	120	104	15	87	0		4	3	1.5
Common Murre *Uria aalge*	344	576	1326	1250	790	1865	951	1093	543		3	4	1
Pigeon Guillemot *Cepphus columba*	124	131	95	88	41						4	2.5	2.5
Marbled Murrelet *Brachyramphus marmoratus*	149	21	28	58	32						4	2	2
Ancient Murrelet *Synthliboramphus antiquus*	0	4	13	25	52						2	1	3
Rhinoceros Auklet *Cerorhinca monocerata*	395	47	217	225	197	50	6	3	2		3	4	2
California Gull *Larus californicus*	1112	867	432	295	144	32 859	4174	2571	11 552		4	3	1
Glaucous-winged Gull *Larus glaucescens*	5	158	105	230	167	234	490	771	394		1	2	3
Iceland (Thayer's) Gull *Larus glaucoides*	0	0	11	34	25	0	0	357	1816		1.5	1.5	3
Short-billed Gull *Larus brachyrhynchos*	222	147	84	110	195						1.5	1.5	3
Bonaparte's Gull *Chroicocephalus philadelphia*	0	44	2	13	7						3	1.5	1.5
Black-legged Kittiwake *Rissa tridactyla*	0	4	50	75	81	0	6	135	679		2	2	2

[a] The relative density of each species within each survey period is represented by shade intensity.

[b] Vermeer *et al*. (1989) carried out surveys in the zone that was 1–60 km from shore off Barkley Sound, southwest Vancouver Island. Cormorant species were not differentiated in this study.

[c] Burger *et al*. (2002) carried out their surveys in an area similar to the current study but included coastal waters around the Deer Islands in Barkley Sound. Burger et al. (2002) did not provide actual numbers, and the ranks shown here are based on their histograms (Figs. 4–14).

Sea ducks

Both scoter species increased in frequency between early and late surveys, reaching their highest numbers in late September and October. At that time, several large flocks were seen off-transect, flying southeast through Johnstone Strait, presumably migrating towards the Salish Sea.

Phalaropes

Only Red-necked Phalaropes were identified during the surveys. However, the possibility that a small number of Red Phalaropes was present and not detected cannot be discounted. Phalaropes were much more abundant during the August surveys in 2020 than on any survey later in the year, suggesting that staging in the QS Strait area occurs mainly in August (Fig. 5).

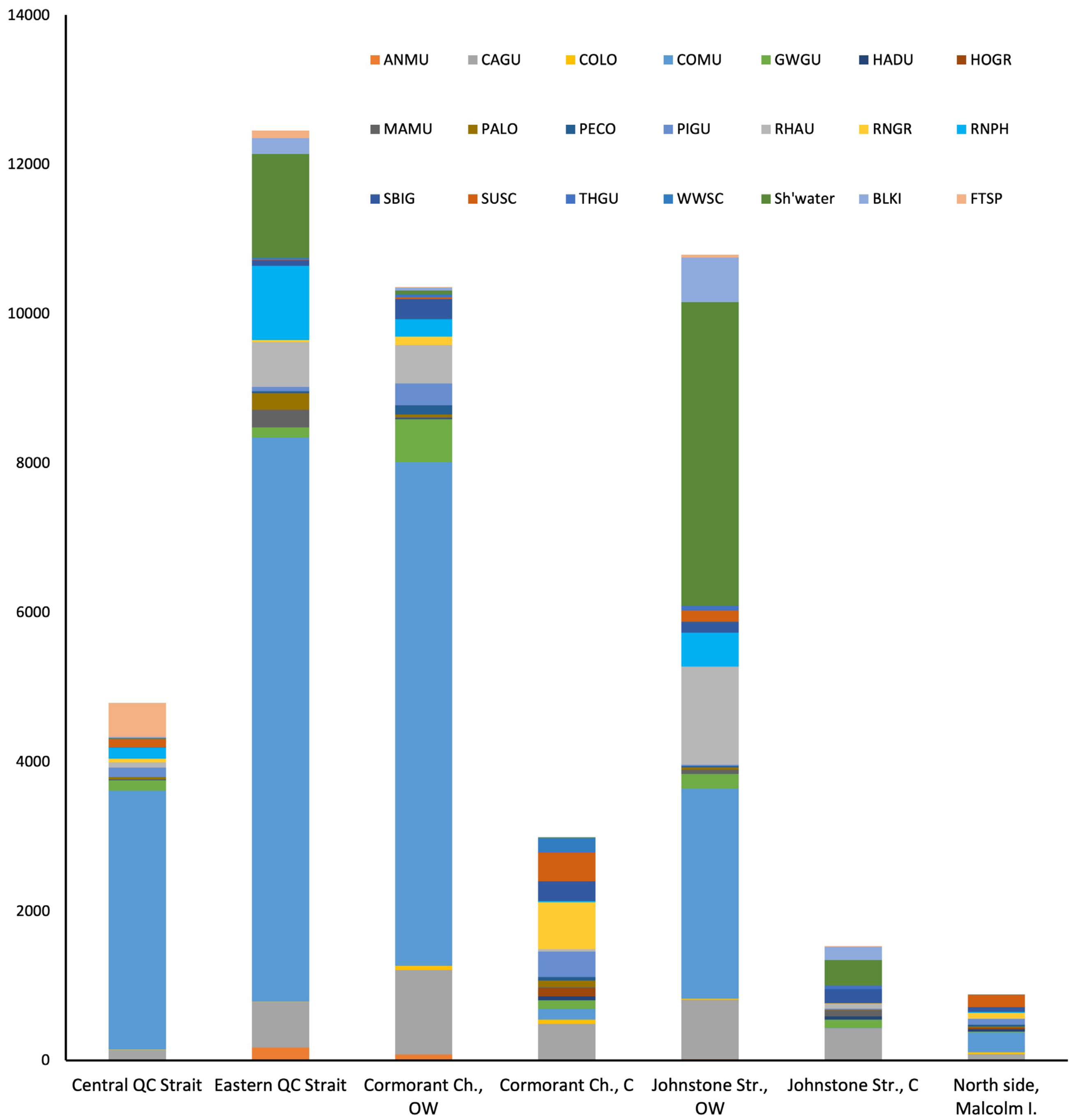

Fig. 5. Estimates of total numbers for the 21 most numerous species in the study area during September, by zone. Note that "Sh'water" combines all Sooty *Ardenna grisea* and Short-tailed *A. tenuirostris* shearwaters. Densities for Black-legged Kittiwakes *Rissa tridactyla* and Fork-tailed Storm Petrels *Hydrobates furcata* are based on all birds seen, whether flying or on the water. All other species' densities are based only on birds counted on the water. For acronyms, see Table 2. OW = open water; C = coastal.

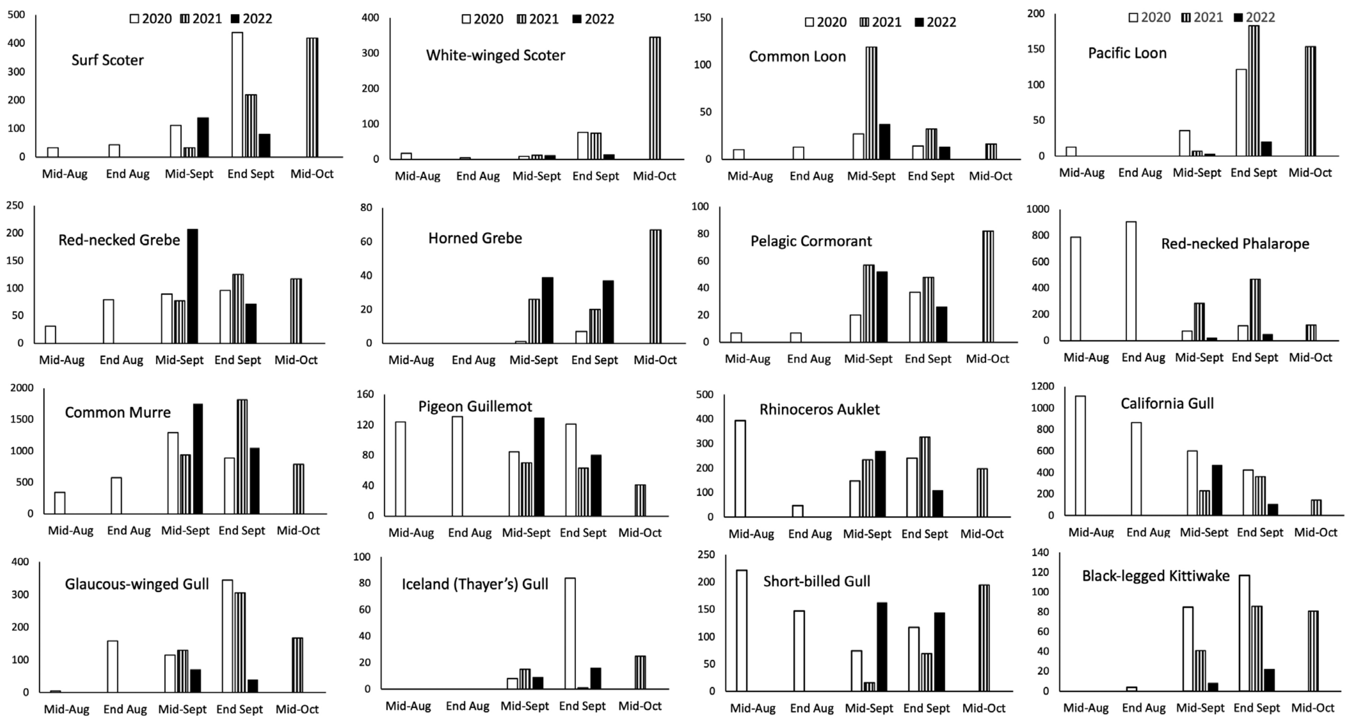

Fig. 6. Total counts, including birds on the water and flying, for surveys in five periods over three years. Note that scales of vertical axes differ among species.

Auks

There was no detectable trend in the number of Pigeon Guillemots, Marbled Murrelets, or Rhinoceros Auklets over the period of the surveys (Fig. 6). Common Murre numbers increased to a peak in mid-September, falling in October but remaining higher than on the August surveys. The number of murres in flight fell from 8.5% on the mid-August survey to < 1% on other surveys. No Common Murres were seen in flight on surveys in mid and late September. 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 a substantial proportion of the population was moulting during September.

Gulls

The number of California Gulls declined steadily between mid-August and mid-October, while the number of Glaucous-winged Gulls peaked in mid-September (Fig. 6). Hundreds of gulls were observed moving south through Johnstone Strait in late September and early October (AJG, pers. obs.), suggesting that a significant migratory movement occurs through the area at that time. The number of Short-billed Gulls decreased from mid-August to late September in 2020, but increased from mid-September to mid-October in 2021 (Fig. 6). No Iceland (Thayer's) Gulls, and only a small number of Black-legged Kittiwakes, were recorded before mid-September. A small number of Herring Gulls *Larus argentatus* occurred on all but one survey, but no trend was evident.

Loons

All four loon species breeding in North America were identified on our transects, but only Common and Pacific loons were seen in all three years. Peak numbers of Common Loons occurred in mid-September in all three years, but numbers were much higher in 2021 than in the other two years. Peak numbers of Pacific Loons occurred after mid-September (Fig. 6). On September surveys, 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, but Western Grebe, with a maximum of 27 recorded on one survey, was too scarce to assess trends in its numbers over time. Sightings of Red-necked and Horned grebes peaked in mid-September and mid-October, respectively. Both species were rarely seen in flight and did not appear to be migrating (flying steadily southwards), so most birds presumably stay in the area for an extended period.

Storm Petrels

Leach's and Fork-tailed storm petrels were both seen, but Leach's Storm Petrel was recorded only in the central QC Strait zone, with a maximum of five birds recorded per survey. Fork-tailed Storm Petrel was seen on all surveys, and in all open-water zones, with a maximum of 50 recorded per survey in late August 2020. Fork-tailed Storm Petrel commonly breeds in outer QS Strait but is generally thought to feed far offshore. It was not recorded in QS Strait by Kenyon *et al*. (2009), but there are numerous records on eBird (eBird Canada, n.d.), especially in Blackfish Sound. Our records included several sightings in Johnstone Strait and Cormorant Channel, which are very enclosed waters for this species. There are a few eBird records further east in Johnstone Strait but only two for the whole of the northern Salish Sea, suggesting that passage through Johnstone Strait must be rare.

Shearwaters

Sooty Shearwater was seen only in 2020 when it was the fourth most abundant species recorded. In addition to 532 Sooty Shearwater seen on-transect, several hundred more were seen off-transect, including a flock of 250 on 16 September. The species is generally most abundant in BC waters in April–August (Guzman & Myres 1983, Kenyon *et al*. 2009). Outside of our study, all the high counts from inner QS Strait occurred in mid-September: 500 on 12 September 1993, 645 on 12 September 1997, 600 on 23 September 2012, 300 on 28 September 2015 (eBird, https://ebird.org/canada/explore, accessed 25 November 2022). Hence, it appears that mid-September may be a time when a large number of Sooty Shearwaters enter QS Strait. The presence of a large number of Short-tailed Shearwaters in our study area in 2021 was very unusual and was discussed in detail by Gaston *et al*. (2022).

Cormorants

Our surveys recorded all three cormorant species breeding on the BC coast, but numbers were generally low. Only Pelagic Cormorant is known to breed in QS 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 Cormorants were recorded only off-transect on one survey), and Brandt's Cormorant *Urile penicillatus* was absent only on August surveys. All three species were present in the highest numbers in September and October. In our study area, most records of all three species occur in September–November (eBird Canada, n.d., accessed 25 November 2022), despite many birders visiting the area in August. Our records suggest that the main build-up of this species occurs after mid-September.

DISCUSSION

Carrying out our surveys was a compromise between the planing capability of the boat and its fuel consumption, and the area we planned to cover. Our routes were also adjusted from survey to survey based on weather and sea state. These constraints resulted in some routes not being identical on every survey, and some small portions of the planned survey area 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 27 km/h was higher than is typical on comparable surveys (usually in the 15–20 km/h range), this had the 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 the acquisition of data that is fully comparable with other boat-based surveys carried out in coastal BC.

Total numbers of birds

Our estimates of total numbers of birds are conservative for several reasons: (1) the northern shoreline transects in the central and eastern QC Strait zones were omitted because the distance from shore was not uniformly maintained. Densities of gulls on these transects were higher than on the open water transects in the same zones, so the omission of these transects will contribute to underestimation for those species. (2) Birds in flight were not estimated except for storm petrels and Black-legged Kittiwakes. Flying birds amounted to > 25% of those counted for Red-necked Phalarope, Pacific Loon, and all gulls and shearwaters. Hence, the estimates of total numbers for all these species are considerably lower than the actual numbers present, but we have no way to quantify the difference. For auks, grebes, and Common Loons, the proportion of birds in flight was < 10%, so our estimates for those species should be less biased. It is likely that our estimate of the number of Common Murres is most accurate because they were rarely in flight and, on most transects, they did not appear to be actively feeding.

The detection-corrected estimates of species numbers (Table 3) indicate that, at birds' peak presence, our study area supported 1% or more of the North American population of Pigeon Guillemot, Marbled Murrelet, California Gull, Glaucous-winged Gull, Iceland (Thayer's) Gull, and Short-billed Gull. If gulls in flight had been included, percentages would be higher. Of these species, only Pigeon Guillemot, Marbled Murrelet, and Glaucous-winged Gull breed in QC Strait. Neither Pigeon Guillemot nor Glaucous-winged Gull breeds in sufficient numbers to account for the total numbers we obtained (Rodway & Lemon 1991). No estimate of the Marbled Murrelet population breeding in the area is available (see Piatt *et al*. 2007). Only Marbled Murrelet is listed by the Committee on the Status of Endangered Wildlife in Canada (as Threatened) and by IUCN (Endangered) (Environment and Climate Change Canada, 2019).

Our estimates of the total number of Common Murre present greatly exceed the known population of British Columbia (< 10 000 birds; Hipfner 2005, Hipfner & Greenwood 2008). Therefore, it seems likely that some birds originated from Washington or Oregon to the south, where the nearest colony is at White Rock, Washington, 310 km south-southwest of the study area (Thomas & Lyons 2017). Alternatively, some could have originated from the Gulf of Alaska (nearest colony Forrester Island, 630 km northwest; Seabird Information Network, n.d.). If a large proportion of murres were moulting in September–October, as the lack of birds in flight suggests, then QC Strait, especially the inner part and Cormorant Channel, is an important moulting area for Common Murres. Hence, it is likely that a substantial number of birds from colonies in the US shift to QC Strait to moult.

Timing of arrival/migration

Although our surveys covered the best part of two months, we may have missed the main arrival/migration period for some species. Red-necked Phalaropes, California Gulls, and Short-billed Gulls were present in substantial numbers on our earliest survey. In contrast, Scoters, Glaucous-winged Gulls, Iceland (Thayer's) Gulls, Herring Gulls, Black-legged Kittiwakes, Pacific Loons, and all three cormorant species reached their highest numbers in late September or October, so their numbers might continue to increase through October. Records from eBird (eBird Canada, n.d.) correspond very closely with our data, suggesting an early peak for California Gull and Red-necked Phalarope and a passage extending into October for most other species. It is also possible that some species occur for only brief periods, during which significant numbers accumulate and subsequently dissipate on a timescale that our survey schedule failed to accurately detect.

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 *et al*. 2020). Hence, many of the birds we saw could have arrived directly from their eastern and high-Arctic breeding grounds. Kenyon *et al*. (2009) did not record Black-legged Kittiwake in QS 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. All but two records of Iceland (Thayer's) Gulls are in September or later (eBird Canada, n.d., accessed 25 November 2022). Off-transect, we estimated 300 Black-legged Kittiwakes roosting on a small islet in Johnstone Strait on 16 September 2020. This appears to be the largest aggregation reported from the area to date. The group included a colour-banded bird that almost certainly originated from the breeding colony at Middleton Island, 1500 km to the northwest. It was probably an individual that had not bred in 2020 (KH Elliott, pers. comm.).

Comparison with other studies

Our data confirm, for QS Strait, many of the trends observed on the west coast of Vancouver Island. Two studies are particularly suitable for comparison with ours: 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 declined from August through October (Table 3). 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 discrepancy among studies arose for (1) Black-legged Kittiwakes, which increased over time in our study and that of Vermeer *et al*. (1989), but were absent in the studies of Burger *et al*. (2002, 2008), appearing in Barkley Sound only in November; and (2) Short-billed Gulls, which peaked in August in QC Strait, but were rare until October off Barkley Sound (Burger *et al*. 2002, not included by Vermeer *et al*. 1989).

A few species of marine birds seen in large numbers off the west coast of Vancouver were uncommon or absent in QS Strait over the same period during our surveys. This is primarily true for 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 numbering in the thousands. In contrast, we saw one Northern Fulmar (off-transect) and one Sabine's Gull. Presumably, neither of these species likes to enter partially enclosed waters such as those found in QS Strait.

Summary

Our observations confirm that the area we surveyed is an outstanding one for dense concentrations of many species of marine birds during autumn, which constitutes the migration period for many species. Given the high number of Marbled Murrelets present (representing > 1% of the North American population), and the large aggregations of Common Murre, California Gull, and Red-necked Phalarope (the latter is considered a Species of Special Concern by the Committee on the Status of Endangered Wildlife in Canada [COSEWIC]), the area could well have qualified as an Important Bird and Biodiversity Area (www.ibacanada.com) when they were designated (1996–2001). We suggest consideration be given to inner QS Strait and associated channels as a KBA. In particular, consideration should be given to the core of the study area, which constitutes the east end of QS Strait, the eastern part of Cormorant Channel, and the western parts of Blackfish Sound and Johnstone Strait. Of note, we also encountered the majority of marine mammals that we saw in that area.

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