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Evaluating UAV-based techniques to census an urban-nesting gull population on Canada's Pacific coast

Louise K. Blight\textsuperscript{1,2}, Douglas F. Bertram\textsuperscript{3}, and Edward Kroc\textsuperscript{4}.

\textsuperscript{1}Procellaria Research & Consulting, 944 Dunsmuir Road, Victoria, BC Canada V9A 5C3, \textsuperscript{2}School of Environmental Studies, University of Victoria, Victoria, BC Canada V8W 2Y2, \textsuperscript{3}Environment and Climate Change Canada, Wildlife Research Division, Institute of Ocean Sciences, 9860 West Saanich Rd, P.O. Box 6000, Sidney, BC, Canada V8L 4B2, \textsuperscript{4}Department of Educational and Counselling Psychology, and Special Education, University of British Columbia, Vancouver BC Canada V6T 1Z4.

Abstract. The use of Unmanned Aerial Vehicles, or drones, in wildlife monitoring has increased in recent years, particularly in hard-to-access habitats. We used fixed-wing and quadcopter drones to census an urban-nesting population of Glaucous-winged Gulls in Victoria, Canada. We conducted our study over two years and asked whether (a) drones represent a suitable survey method for rooftop-nesting gulls in our study region; and (b) Victoria’s urban gull population had increased since the last survey \textgreater{}30 years earlier. Using orthomosaic imagery derived from drone overflights, we estimated at least a threefold increase over the 1986 count reported for the entire city (from 114 to 346 pairs), and an approximate 10-fold increase in the number of gulls nesting in the downtown core. Drones proved to be an excellent platform from which to census rooftop-nesting birds: occupied nests were readily discernible in our digital imagery, and incubating birds were undisturbed by drones. This lack of disturbance may be due to Victoria’s location in an aerodrome; gulls experience dozens of floatplane and helicopter flights per day and are likely habituated to air traffic. Glaucous-winged Gulls have declined considerably at their natural island colonies in the region since the 1980s. Our results indicate that although urban roofs provide replacement nesting habitat for this species, local gull populations have not simply relocated from islands to rooftops in the region.
Key words: Drones; UAS; Glaucous-winged Gull; Larus glaucescens; urban ecology, Salish Sea.

Introduction

The use of Unmanned Aerial Vehicles (UAVs, or drones) in wildlife monitoring has grown rapidly in recent years (Chabot 2018). This increase has been driven in part by the ease with which drone-mounted instrumentation can survey wildlife populations and document aspects of their habitat and behaviour, with utility of UAVs being particularly evident in environments that are hazardous or otherwise problematic for researchers to access. One example of this is provided by field studies of colonial marine birds, where traditional access methods such as rappelling down cliffs or using small boats to land on remote offshore islands pose a distinct human safety risk. Drones can also minimize disturbance in animal studies — another important consideration for marine bird research, where humans entering a breeding colony may cause temporary flushing of nesting adults, exposure of eggs and young to predators, or even nest desertion (Robert and Ralph 1975; Carney and Sydeman 1999; Rush et al. 2018).

Such observer disturbance is a known problem for studies of urban-nesting gulls (Laridae); in the open environment of a rooftop, nests are more vulnerable to researcher disturbance because chicks have few places to hide and instead flee into neighbouring territories, where they may be killed (Vermeer et al. 1988). For studies of gulls nesting in urban areas, even gaining access to nest sites (or vantage points from which to view them) is problematic, because these populations tend to breed in dispersed locations across a cityscape, with nests generally built on rooftops or similarly inaccessible sites such as bridge spans (Hooper 1988; Vermeer et al. 1988; Kroc 2018). Some censuses of urban-nesting gulls have addressed these issues by using aerial photographs taken from fixed-wing aircraft (Cyra et al. 2007; Roby et al. 2007). However, hiring planes and pilots can be expensive; in these circumstances drones also provide an advantage by being potentially more cost-effective (Christie et al. 2016).
Glaucous-winged Gulls (*Larus glaucescens*) nest at numerous island colonies in the Canadian portion of the Salish Sea, a coastal body of water adjacent to south-east Vancouver Island and extending over the Canada—US border into Washington State (BC Geographical Names undated). Censuses have shown that the Canadian portion of this population has undergone long-term declines, with numbers of breeding birds at these ‘natural’ colonies now fewer than 50% of those in the 1980s (Vermeer and Devito 1989; Blight et al. 2015). Glaucous-winged Gulls have also long been known to nest in low numbers on the region’s city rooftops, with this behaviour first documented in the 1940s (Oldaker 1963; Sanford 1974; Hooper 1988). However, the region’s urban-nesting gulls have not been censused for over 30 years (Hooper 1987; Hooper 1988; Vermeer et al. 1988), meaning it has been unknown whether this population has also been decreasing, or has instead been increasing, as is the case with gulls breeding in cities nearby in the coastal U.S. (Roby et al. 2007) and elsewhere in the world (e.g., Raven and Coulsen 1997; Soldatini et al. 2008). As recent unpublished observations suggest nesting populations of Glaucous-winged Gulls have increased in the region’s urban centres of Vancouver, Greater Victoria, and Nanaimo (LKB and EK, unpublished data; T. Chatwin, personal communication), our study’s first objective was to use UAVs to census a local sub-population to ask whether breeding declines in this species’ natural habitats could be explained in part by their relocation to urban areas.

Of equal importance was our second objective: to test how well drones performed as a platform for surveying local urban-nesting gulls in general, with our criteria for usability including functionality (i.e., whether drone-based flights can generate imagery of suitable resolution to census roof-top gull nests under local conditions), and minimizing disturbance to nesting birds (Vas et al. 2015; Brisson-Curadeau et al. 2017). As North America’s city centres densify, understanding population patterns and trends of urban gulls is relevant to managing human-gull
conflicts. Thus, our third objective was to improve our understanding of urban gull colonies in Pacific Canada. Both urban- and island-nesting gulls in the study region nest within or adjacent to marine and terrestrial areas with conservation designations (Figure 1). If Glaucous-winged Gulls continue to decline at their natural colonies in the Salish Sea, greater understanding of the population’s urban-nesting component may be of conservation benefit to the species itself.

**Materials and Methods**

*Study area and timing*

We conducted our study in the downtown core and immediately adjacent areas of the City of Victoria, British Columbia, Canada (48.42°N, 123.36°W; Figure 1), a city situated in approximately the centre of the Salish Sea. We extended our survey flights over two years for budgetary reasons: in 2017, we surveyed the mixed-use (heavy industrial, light industrial, commercial, multi-family and single family residential) districts immediately north and west of downtown (hereafter “Victoria Northwest”), while in 2018 we surveyed the downtown core (“Downtown”), an area primarily comprised of mixed-use commercial and multi-unit residential buildings ranging in age from newly-constructed to heritage structures built in the latter half of the 1800s. Specific delineation of our study area was based on nesting concentrations known from previous ground- and rooftop-based surveys undertaken to assess historical and current concentrations of nesting Glaucous-winged Gulls within the City of Victoria (Hooper 1987; Hooper 1988; Kroc et al. 2018). We did not survey areas found by Hooper (1987) to have low nest density or no nesting gulls. Nor, due to permitting restrictions, did we follow Hooper (1987) in surveying the vicinity of the dockyard buildings at the Canadian Forces Base facility, located approximately 5 km from the downtown core in the adjacent municipality of Esquimalt.

Rooftop images for our remote census were collected via overflights using UAV-mounted cameras. Surveys were flown on 25 June 2017 and 14 June 2018. Dates differed between
study years due to weather conditions and flight permit requirements. We timed UAV flights for mid- to late June based on our previous knowledge of local breeding phenology for this species, so that survey dates were as close as possible to commencement of the hatch period (estimated as 21-25 June over four recent years; LKB unpublished data; Blight 2011; Blight et al. 2015; Kroc 2018). This is the period when the maximum number of nests are occupied by breeding birds, with adults either incubating eggs or brooding newly-hatched chicks.

**UAV specifications, operation, and orthomosaics**

We used two UAV types over the two years of our study. In 2017, survey flights were performed using two multi-rotor UAVs: a DJI Phantom 4 Pro and DJI Inspire 1. In 2018, we used a fixed-wing Sensefly eBee Plus. Because Victoria’s downtown core is part of an aerodrome (i.e., a designated location where aircraft flights occur — here, commercial floatplane and helicopter operations), we contracted flights to commercial drone operators experienced with operating in compliance with federal aviation regulations. (These in essence require that operators pass knowledge tests to earn certification, with highly advanced levels of training required for permissions to fly a drone in controlled airspace.) Over both years, pre-programmed autonomous flights were performed in a grid pattern over our study area, at a ground speed of approximately 15–20 m/sec. Flight height in 2017 was 76–90 m (250–295 ft), and in 2018, 99 m (325 ft) and 122 m (400 ft) above ground level. The minimum elevation flown was greater than that in other studies (e.g., Drever et al. 2015; Rush et al. 2018) due to aviation requirements in this urban area. For image capture, the quadcopters (2017) carried built-in gimballed (over three axes), GPS-enabled DSLR 12–20 megapixel cameras using a 20 mm lens with a rolling shutter, and set to shoot continuously in auto-exposure mode at intervals of 1–2 s. In 2018, the fixed-wing UAV carried its stock (non-gimballed) 20 megapixel camera using a 28 mm lens with a global shutter, set to shoot in auto-exposure mode; picture interval was set to 1.9 s. The
georeferenced overflight images were then stitched into orthomosaics of the study area using photogrammetry software.

*Image interpretation and characterization of nest distribution*

Orthomosaic images were interpreted by scrutinizing them manually for gull nest ‘targets’, using variable zoom levels as required to locate and count rooftop nests. To account for individual-observer error in nest counts, two of us (LKB and EK) independently counted total number of nest targets. Gull nest density for natural colonies has been calculated at various colony and sub-colony scales (e.g., Haycock and Threlfall 1975; Jehl 1994), so to increase comparability with other studies we calculated nest density in two different ways: (1) as number of nests over our entire area of study (i.e., including area of streets, alleys and other large-scale features not inhabited by gulls; “Density1”); and (2) as number of nests per rooftop area alone, with rooftop area estimated using spatial data from the City of Victoria’s Open Data Portal (opendata.victoria.ca; “Density2”). To further characterize gull nesting distribution, we also calculated number of nests per occupied roof, with ‘roof’ roughly defined as a single contiguous surface covering one or more buildings. This imprecise definition captured the fact that the buildings in Victoria’s city blocks might be covered by one or multiple roofs — depending on construction style, heterogeneity of building heights over a block, and so on. For Downtown, we additionally counted number of nests per city block. We did not do this for Victoria Northwest as ‘block’ was a non-standardized size in this structurally heterogeneous zone.

To compare current nest distribution (density) with that of previous studies in the region (Hooper 1988; Vermeer et al. 1988), we estimated inter-nest distances. These were the distances (in meters) from a given nest to its nearest neighbour, with means reported ± SD. Kolmogorov-Smirnov tests were performed to determine if the distribution of inter-nest distances for our study area were different than the earlier distribution reported by Vermeer et al. (1988) for the
nearby city of Vancouver. As those authors only calculated inter-nest distances for pairs that
nested on rooftops with at least one other nesting pair, we made the same exclusions for this
comparison. Spatial data were prepared for analysis using QGIS (QGIS Development Team
2018), and all statistical analyses were performed using base R (R Core Team 2018).

**Results**

In 2017, our UAV overflights surveyed approximately 250 ha of built urban environment (Figure
1). In 2018 our downtown site was 70 ha in area. The study area’s maximum distance from the
ocean was ~970 m. Virtually all the surveyed buildings had roofs that were flat or of a low pitch,
although Victoria Northwest also incorporated about 20 city blocks of adjacent single-family
residential houses, with standard gabled roofs.

Image resolution for both years, measured as ground sample distance (GSD), was 2.8–2.9
cm/pixel. Our orthomosaic imagery was of sufficient resolution to distinguish gulls on nests from
other rooftop features (Figure 2), with occupied nests being readily observable. Both drone
types — multi-rotor and fixed wing, with their respective camera configurations and flight
altitudes — produced qualitatively similar imagery, with orthophoto resolution the same over
both years and both products of equal utility for censusing roof-nesting gulls.

Inter-rater agreement of nest counts was high for both years of our study (Victoria Northwest
2017: 95%, counts of 119 (EK) and 113 (LKB) nests; Downtown 2018: 94%, counts of 237 (EK)
and 223 (LKB) nests). Thus, we estimate a total of 336–356 (mean count 346) occupied
Glaucous-winged Gull nests in our study area. Nests were present on the rooftops of buildings
throughout the areas we surveyed, from buildings along the shoreline to those at the edge of the
study zone, nearly 1 km inland. In Victoria Northwest, gulls nested at a density of 0.005
nests/100m² while Downtown nest density was 0.032 nests/100m² (Density1); Density2
was 0.044 nests/100m² (Victoria Northwest), and 0.085 nests/100m² (Downtown). Of the 157
roofs we identified as having nests present, 127 (81%) of these were occupied by only 1 or 2 pairs of nesting birds. Only 14 of 157 (9%) were occupied by ≥5 pairs (Figure 3). At the city block scale (Downtown only), 15 of the 55 blocks we surveyed (27%) appeared unused by nesting gulls; of the 40 city blocks occupied by nesting gulls, 26 of these (65%, or 47% of all downtown blocks surveyed) were occupied by fewer than five pairs of birds (Figure 4).

Average inter-nest distances between Victoria Northwest (22.86 ± 30.80 m) and Downtown (24.57 ± 22.27 m) sites were not significantly different (Welch’s robust two-sample t-test, \( p = 0.59 \)). However, nests at Victoria Northwest were generally closer together (median = 11.29 m and interquartile range (IQR): 4.73, 26.14) than at the Downtown site (median = 16.75 m, IQR = 9.61, 31.89; Figure 5). This difference reflects the fact that two relatively large colonies (size 20 and 16 nests, 16% and 14% of total respectively) existed on a pair of industrial rooftops at the Victoria Northwest site, whereas no rooftop at the Downtown site housed more than 11 nests (5% of total). Simultaneously, Victoria Northwest contained relatively more nests at a greater distance from their nearest neighbour (90th percentile = 71.80 m, 95th percentile = 90.34 m) compared to Downtown (90th percentile = 63.36 m, 95th percentile = 71.00 m).

There was no evidence of a difference in distribution (i.e., inter-nest distance) between our Victoria Northwest site and earlier values found by Vermeer et al. (1988) for nearby Vancouver (Kolmogorov-Smirnov test, \( p = 0.102 \)), while there was weak evidence of a difference in distribution between our Downtown site and the results of Vermeer et al. (1988; \( p = 0.018 \)). This second \( p \)-value is likely artificially deflated due to the relatively large sample size (i.e., high statistical power) for our Downtown site (170 nests sharing a rooftop with at least one other nest, compared to 79 for the Victoria Northwest site and only 39 in Vermeer et al. 1988). Nor was there evidence of a difference between our mean Downtown inter-nest distance and that found for Victoria by Hooper (1988; Welch’s t-test, \( t(6.46) = 1.57, p = 0.12 \)).
Individual gull nests in our study were generally situated in the lee of a sheltering or shading object, such as roof vents, rooftop parapets and overhangs, but were also built in open areas with only minimal shading. Orientation of gull nests and incubating adults to shading objects was variable. Only 6 nests (2%) were built on pitched — rather than flat or low slope — roofs, usually in an angle such as that formed by roof and chimney. Rooftop nesting substrates included gravel, tar paper, and tiles, but did not include any of the roof surfaces with visible vegetation (moss, grass, etc.) that were present in our images.

Shutter speed was fast enough to capture gull movement such as birds launching into flight — the few flying gulls we photographed were clearly captured as an overlapping series of ‘bird-in-flight’ images — with our orthomosaic imagery indicating that gulls did not flush from their nests during drone overflights.

**Discussion**

Our UAV-based survey estimated 346 nesting pairs of Glaucous-winged Gulls in downtown Victoria and its adjacent mixed-use neighbourhoods, with the majority found in Victoria’s downtown core. Hooper (1987; 1988) estimated there were 114 nests throughout the city in 1986, with about half of these at or near the Canadian Forces Base dockyards, an area not surveyed by us, and about 30-40 pairs in and around downtown. Thus, the current population we found nesting in Victoria’s Downtown and Victoria Northwest alone represents about a threefold increase over the numbers reported for the entire city 30 years before, and an approximate tenfold increase for the downtown core itself.

Our count is undoubtedly an underestimate of the city’s current gull population as some nests may have been obscured by shading or features of roof topography, and because we only
counted nests with incubating adults we were unable to account for nests that failed prior to our survey. Nor did we cover all of Greater Victoria with this pilot study, and recent ground-based observations have shown that gulls nest on city roofs outside our survey area, albeit usually at lower apparent densities than those we report here (Kroc et al. 2018; LKB unpublished data). During the course of this study, however, we did become aware of one larger sub-colony of nesting Glaucous-winged Gulls at the main building of the cruise ship terminal, approximately 1.7 km outside of downtown, occupied by 102 pairs in 2018 (and by only about 30 pairs in 2019 due to deterrence netting placed over the terminal roof; J. Sirois personal communication; Hooper (1987) found 0 pairs there in 1986). We are unaware of any other sub-colonies of this size in or around Victoria.

Although we surveyed Downtown and Victoria Northwest separately over two years, we suggest that our population estimate is a representative total for the surveyed area. Large gulls, including L. glaucescens, are known to exhibit strong nest site fidelity (Kovacs and Ryder 1981; Hooper 1988) so we consider it unlikely that there was appreciable inter-annual movement — a potential source of missed or doubly-counted nests — between the two sub-areas of our study. In a similar study using fixed-wing aircraft, Roby et al. (2007) reported considerable inter-annual variation in numbers of Glaucous-winged and Western Gulls (L. occidentalis) nesting on buildings in Puget Sound ports, but associated this with gull control programs; we are unaware of similar large-scale control efforts in Downtown or Victoria Northwest during the two years of our study.

In addition to increasing in number, Victoria’s urban gull population has also increased its area of occupancy. In 1986, Hooper (1988) found no birds nesting further than 500 m horizontal distance from salt water. In contrast, our overflights extended as far as 970 m inland and showed gull nests occurring to the edge of this zone. In an earlier study Eddy (1982) reported a
similar pattern of expansion in the southern portion of the Salish Sea in the USA: in 1962, Seattle’s small urban population of Glaucous-winged Gulls nested no further from the ocean than 320 m, but by 1981 the population had grown and nest sites were found as far inland as 1 km. Virtually all (98%) of the nests we located were on flat or low-pitch roofs, a pattern also seen in Pacific Canada’s largest city, Vancouver, where gulls have yet to be observed nesting on pitched roofs (Kroc 2018). Interestingly, nesting gulls appeared to avoid flat rooftops with the occurrence of vegetation such as incidental mossy overgrowth and ‘living roof’ plantings. It is worth noting that the five largest nesting aggregations (all >10 pairs) we located occurred on the flat roofs of old commercial buildings or warehouses, a building type which is slowly being converted to new or renovated residential properties.

Because the two-dimensional nature of our images made it difficult to define individual roofs, our estimates of number of gull nests per ‘roof’ are necessarily tentative. Nonetheless, it is clear that the urban Glaucous-winged Gulls we studied are more isolated in their nesting habits than are their conspecifics at island colonies, with most (81%) of the nests we located distributed as 1–2 pairs per roof (Figure 3). On Victoria’s rooftops, gulls nested at a maximum density of 0.032 nests/100 m² (Downtown, Density1; or Density2 of 0.085 nests/100m²). In contrast, for Larus gulls breeding at natural island colonies, nest densities have been recorded as 2.1–8.0 nests/100 m² (Haycock and Threlfall 1975), or as high as 81.3 nests/100 m² at a particularly dense colony (Jehl 1994). At the scale of downtown city blocks Glaucous-winged Gulls in our study showed the same tendency toward isolated nesting, with two-thirds of occupied blocks used by <5 pairs of nesting gulls (Figure 4). This low nesting density is also presently exhibited by urban-nesting gulls in the nearby city of Vancouver, where a recent study showed that 73 of 102 nests were “situated as solitary nests on isolated rooftops or structures” (Kroc 2018). For Victoria, the variable inter-nest distances we observed between Downtown and Victoria Northwest (Figure 5) may simply reflect the lower density of structures at the Northwest site.
Overall, our observed distribution of nests suggested that the density of nesters in the vicinity of Victoria’s downtown has not appreciably increased over 30 years despite the number of nesting birds having grown, and indicated that rooftops and city blocks with large aggregations of nesting gulls are currently uncommon: gulls are electing to colonize new areas rather than increase nesting density.

In contrast, for the population of Glaucous-winged Gulls breeding in natural habitat in the region, only 0.1% or fewer nest as single pairs on spatially isolated structures such as small rocky islets, rather than nesting colonially (Vermeer and Devito 1989; Blight 2014; Blight et al. 2015). Such birds are described as solitary nesters. However, we deliberately avoided use of that term to characterize single pairs of urban gulls we found nesting on isolated structures. Colony-nesting in birds is hypothesized to have evolved in part as a response to predation risk (with coloniality facilitating detection and mobbing of predators), and at a birds’-eye view the downtown core essentially functions as a mid-sized colony, with lines of sight in relation to predator detection similar to that of a natural colony of birds, albeit one of individuals nesting at low densities. Indeed, we have regularly observed flocks of urban gulls in Victoria mobbing Bald Eagles (*Haliaeetus leucocephalus*), an important gull predator in the region (Blight et al. 2015). Other suggested benefits of coloniality include information transfer (e.g., on location of ephemeral food resources) and facilitation of synchronized nesting (Parsons 1976; Wittenberger and Hunt 1985; Siegel-Causey and Kharitonov 1990). Gulls nesting in our survey area likely also receive visual cues from conspecifics on food location. Whether egg-laying is less synchronous in urban environments is a topic worthy of future study, although the breeding success of urban-nesting Glaucous-winged Gulls is similar to or greater than that reported for birds nesting in natural habitats in the region (Hooper 1988; Kroc 2018).
Our results indicate that UAVs provide a viable approach for surveying urban-nesting populations of gulls in our region, despite the limitations posed by operating drones in an urban area, and, in our study area's case, the strict flight restrictions imposed on operating within an aerodrome. We found our images provided good visibility of gulls on roofs, with white birds on darker backgrounds showing high detectability in general in non-vegetated habitats (Barr et al. 2018). The imagery we obtained was consistently useable for gull nest counts, with our drone-derived photogrammetry of better apparent quality (higher resolution, consistent sharp focus) and greater utility for population estimates than images obtained via human photographers on fixed-wing aircraft (cf. Roby et al. 2007, where some photos were reported to be of “poor quality”). We also obtained coverage of our entire study area, something that is not possible from the ground or from vantage points on downtown buildings (LKB and EK, personal observation; Kroc 2018). The resolution we obtained (~2.8 cm/pixel) was lower than the ~1 cm/pixel identified by Drever et al. (2015) as required to identify waterbirds to species, but we had only to identify Glaucous-winged Gulls (the only waterbird species nesting on rooftops in our region) sitting on nests, rather than distinguish one gull species from another in mixed-species flocks.

We saw no evidence of gulls being disturbed during drone overflights. Lack of apparent movement by birds on nests indicated that they continued incubating throughout image capture. Some studies surveying gull species with UASs found that gulls flushed from nest or roost sites in response to drones while others reported little or no apparent disturbance (Sardà-Palomera et al. 2012; Drever et al. 2015). In a drone-based survey of colonies of four Arctic seabird species, Brisson-Curadeau et al. (2017) reported flushing by one species of gull (Icelandic L. glaucoides) but not another (Glaucous L. hyperboreus). Roof-nesting Glaucous-winged Gulls in Victoria are within a busy aerodrome that experiences thousands of floatplane and helicopter flights per year, a situation that has likely resulted in a gull population that is habituated to air traffic. It is
possible that the novel flight characteristics of a UAS could still disturb nesting gulls, and the potential for subtle disturbance responses by animals, even in busy urban environments, should not be dismissed. However, even if we presume a sub-visible response by gulls, such as increased vigilance, there is no doubt that our drone-based survey resulted in a lower level of disturbance to rooftop-nesting birds than one carried out by researchers physically accessing the colony, an approach that is known to cause chick mortality through disturbance (Vermeer et al. 1988).

Our count of urban-nesting Glaucous-winged Gulls in the vicinity of downtown Victoria represents only about 3% of the number censused as breeding in the Canadian portion of the Salish Sea at the population’s peak in the mid-1980s (13,002 pairs; Vermeer and Devito 1989). The most recent estimate for that same population is ~5600 pairs, less than half the count of the mid-'80s peak (Blight et al. 2015). Although our survey certainly resulted in an underestimate of the number of gull pairs nesting in Victoria, if the urban population increase we documented here represents that of urban areas in the wider region, it is clear that Salish Sea Glaucous-Winged Gulls have not simply relocated en masse from natural colonies to rooftop sites. At-sea counts support this interpretation: regional surveys of gulls in their marine habitat, presumably representing birds from both urban and natural colonies, have also documented declining trends (Bower 2009; Crewe et al. 2010). It is not known whether Victoria’s present-day urban gull population consists solely of descendants of the city’s original gull colonists or whether population growth is due to immigration. As urban-nesting gulls in the region appear to enjoy higher reproductive success than their counterparts nesting in natural colonies (Kroc 2018), this is a topic worthy of further research.

Nevertheless, it is also clear that more gulls are nesting on Victoria’s city roofs now than at the time of Hooper’s 1986 census. Like their conspecifics nesting at natural colonies in the vicinity
of our study area, urban gulls are an important component of the avifauna using the Victoria Harbour Migratory Bird Sanctuary (Pacific Canada’s first such designation, in 1923) and adjacent protected areas (Figure 1). As urban-nesting gulls increase in number in Victoria and in Canada’s other urban centres, so too does the potential for human conflict, making it important to develop approaches to studying these populations. Although nearly three-quarters of the city blocks in the downtown core are used by Victoria’s growing population of nesting gulls, most blocks are occupied by only one or two pairs of these birds. This suggests that long-standing concerns about a growing “invasion” by gulls (Vermeer et al. 1988) of Pacific Canada’s urban environments may be overstated, and manageable. As human population centres increase in extent and density, the presence of wild birds such as gulls provide both a potential source of conflict, and an opportunity for city-dwelling humans to experience an element of nature — a nesting wild bird — that is often not readily accessible to us. Urban-nesting gulls have innate value as a component of coastal biodiversity, and rooftop habitat may be of increasing importance to the region’s Glaucous-winged Gull population if urban colonies continue to grow. Drones will be an important tool to document whether these colonies continue increasing in size, and for further defining the microhabitats preferred by urban-nesting gulls.

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Figure captions

Figure 1. Map of survey area within the context of the city of Victoria, British Columbia, Canada, and adjacent marine areas. Basemap attribution: ESRI’s World Imagery file (Sources: Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Aerogrid, IGN, IGP, and the GIS User Community; downloaded from https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9). Aerial photography attribution (bottom panel, shot in May 2017): BC Capital Regional District Map Services, downloaded from https://www.crd.bc.ca/about/data/geospatial-data. Used with permission from the Capital Regional District.

Figure 2. UAS-derived image of Glaucous-winged Gulls nesting on the rooftop of an industrial building in Victoria Northwest study area, June 2017. Five nests are circled; others are also visible in this image.

Figure 3. Frequency distribution of nest count per occupied roof for Glaucous-winged Gulls nesting in Victoria, BC, Canada.

Figure 4. Frequency distribution of nest count per downtown city block occupied by urban-nesting Glaucous-winged Gulls (Victoria, BC, Canada).

Figure 5. Distribution of Glaucous-winged Gull inter-nest distances (in metres) for Victoria Northwest (A) and Victoria Downtown (B). Average internest distance between sites were not significantly different. However, nests at the Northwest site were generally closer together than at the Downtown site. This difference reflects the fact that two relatively large colonies (20 and 16 nests) existed on a pair of industrial rooftops at the Northwest site, whereas no rooftop at the Downtown site housed more than 11 nests. Simultaneously, the Northwest site contained relatively more
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